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Understanding trends and gaps in global research of crop evapotranspiration: a bibliometric and thematic review

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Abstract. Estimating crop evapotranspiration (ET_c) is crucial for ensuring sustainable and efficient agricultural water management. Although this subject has garnered significant attention from the global scientific community, a comprehensive study encompassing the diversity, trends, and dynamics of research themes is currently lacking. To address this knowledge gap, this review employed a combined bibliometric and thematic approach to analyze bibliographic data from 1872 documents retrieved from the Web of Science™ core collection, spanning the period 1987–2022. The main findings of this review are as follows: (1) the scientific landscape is predominantly shaped by institutions from the USA and China; (2) the journal Agricultural Water Management emerged as the most prolific, with the highest number of publications and total citations; (3) a broad range of topics within ET_c research were identified, with a notable emphasis on remote sensing-related subjects; (4) strategic coordination mapping revealed that ET_c and reference evapotranspiration (ET_o) remains an underdeveloped area of study; (5) climate change and machine learning emerged as key topics of significant scientific concern. The results suggest a need for enhanced institutional collaborations and expanded research investigations, particularly in regions grappling with agricultural water scarcity. Furthermore, research investigations should focus on ET_c and ET_o to fill existing knowledge gaps and advance both theoretical understanding and practical applications. Future studies should aim to contribute to the understanding of the impacts of climate change on ET_c by leveraging machine learning techniques and enhancing our understanding of crop water requirements and their application in irrigation management, while also ensuring continuous updates to the existing body of knowledge to meet future challenges.

Keywords: bibliographic coupling, co-authorship and citation networks, crop water requirements, crop evapotranspiration, Web of Science.

INTRODUCTION

Evapotranspiration is the sum of all processes by which water moves from the land surface to the atmosphere via evaporation and transpiration

(United States Geological Survey, 2018). In agroecosystems, it includes transpiration which represents the major use of irrigation and rainfall water by plants and evaporation from the soil (Gowda et al., 2008). Hence, it is crucial to accurately evaluate evapotranspiration in order to avoid excess or deficit irrigation. This can be accomplished through the utilization of models that assess and forecast evapotranspiration rates (Ghiat et al., 2021), or by conducting direct measurements using *in situ* sensors.

Potential evapotranspiration (ET_p) is defined by Jensen (1968) as the rate of evapotranspiration from a well-watered crop having an aerodynamically rough surface like alfalfa with 0.3–0.5 m of top growth. However, the concept of ET_p evolved into that of reference evapotranspiration (ET_{ref}) which was introduced by irrigation engineers and researchers to avoid the confusions that existed in the definition of ET_p (Pokorny, 2019). Reference evapotranspiration is best suited for crop assessments because it is more precise and accounts for crop-related changes (Ghiat et al., 2021). By adopting ET_{ref} (grass [ET_o] or alfalfa [ET_r]), it became easier and more practical to select consistent crop coefficient (K_c) and to make reliable actual crop evapotranspiration (ET_c) estimates in new areas (Pereira et al., 2015; Pokorny, 2019). However, the grass is more often used as a reference crop than alfalfa. ET_o is defined by Allen et al. (1998) as the rate of evapotranspiration from a hypothetical reference crop with an extensive surface of green grass of uniform height, actively growing, well-watered, and completely shading the ground. In this definition, grass is particularly defined as the reference crop and is expected to be free of water shortage and diseases. The reference evapotranspiration can be calculated using the standardized Penman-Monteith ET_o (PM-ET_o) equation which remains the commonly used method at present (Pereira et al., 2015; Pereira et al., 2021a).

Crop evapotranspiration is defined by Pereira and Alves (2005, 2013) as the rate of evapotranspiration [mm d^{-1}] of a given crop as influenced by its growth stages, environmental conditions, and crop management to achieve the potential crop production. Thus, the crop water requirements is the sum of ET_c for the entire crop growth period which is defined as the depth of water [mm] needed to meet the water consumed through ET_c by a disease-free crop, growing in large fields under non-restricting soil conditions including soil water and fertility, and achieving full production potential under the given growing environment.

There are many direct and indirect methods of determining ET_c [mm] but the most commonly used method of estimation known as the two-step approach (Eq. 1) requires first calculating ET_o [mm d^{-1}] and then multiplying it with K_c (Paredes et al., 2020; Pereira et al., 2021b; Pokorny, 2019; Todorovic, 2005).

$$ET_c = K_c * ET_o \quad (1)$$

$$K_c = \frac{ET_c}{ET_o} \quad (2)$$

The K_c (Eq. 2) is the crop coefficient for a given crop which is usually determined experimentally and then calculated and inferred from the observed evapotranspiration flux under changing environmental conditions using empirical approaches. The K_c values represent the integrated effects of changes in leaf area, plant height, crop characteristics, irrigation method and water availability, rate of crop development, crop planting date, degree of canopy cover, canopy resistance, soil and climate conditions, and management practices (Ghiat et al., 2021; Pokorny, 2019). Thus, each crop will have a set of K_c for different growth stages: initial, crop development, mid-season, and late season (Pereira et al., 2015; Pokorny, 2019).

To revise the guidelines for computing crop water requirements, the Food and Agriculture Organization (FAO) of the United Nations (UN) introduced the Irrigation and Drainage Paper No. 56 "Crop Evapotranspiration" in 1998 (Allen et al., 1998; Pereira et al., 2015). There are two K_c approaches considered in FAO56. The first is the time-averaged single K_c which includes multi-day effects of soil evaporation in addition to plant transpiration. While the second is the dual K_c (Eq. 3) consisting of a basal crop coefficient (K_{cb}) (Eq. 4) and an evaporation coefficient (K_e) (Eq. 5), where T_c is the crop transpiration and E_s is the soil evaporation (Pereira et al., 2021c; Rallo et al., 2021).

$$K_c = K_{cb} + K_e \quad (3)$$

$$K_{cb} = \frac{T_c}{ET_o} \quad (4)$$

$$K_e = \frac{E_S}{ET_o} \quad (5)$$

The crop coefficient is a key link between ET_c and ET_o which is important for agricultural water management, particularly in determining crop water and irrigation requirements (Paredes et al., 2020; Wang et al., 2023).

Bibliometrics is considered one of the key research tools widely extended to all scientific areas, particularly applicable to fields with large bodies of literature that are difficult to summarize by traditional review methods (Chàfer et al., 2021). This method can demonstrate the current status and developing trends of knowledge

through visual network mapping (Chen et al., 2022). Currently, the bibliometric approach has already been used to study trends, gaps, and thematic dynamics of different topics in agriculture and related disciplines including sustainable use of water in agriculture (Abafe et al., 2022), water-use efficiency (Aleixandre-Tudó et al., 2019), agriculture 4.0 (Mühl and Oliveira, 2022), biodynamic agriculture (Santoni et al., 2022), sustainable agriculture (Sarkar et al., 2022), greenery systems (Chàfer et al., 2021), forest ecosystem services (Chen et al., 2022), and application of remote sensing in crop spatial patterns (Xiao et al., 2022). Along with the bibliometric analysis, strategic coordination mapping provides a robust analysis of research topics which allows the researchers to identify interconnections between research frameworks and potential topics for future investigations and evaluate the changes and development of research themes. This approach has also been used by several authors to study thematic evolution and identify research hotspots, topic trends, and knowledge gaps (Abafe et al., 2022; Janik et al., 2021; Mühl and Oliveira, 2022; Sarkar et al., 2022; Zhu et al., 2022). Given these wide and flexible applications, bibliometrics and thematic approaches offer a robust methodology to explore the topic of ET_c estimation.

Many studies on the technical development of the available methodologies and advanced techniques in the estimation of ET_c for agricultural water management have been done. Recent reviews and investigations focused on different aspects of ET_c such as progress and development in FAO56 (Pereira et al., 2015; Pereira et al., 2021a), FAO56 framework for coping with the effects of soil salinity on ET_c and yields (Minhas et al., 2020), assessment of model-estimated crop transpiration and ET_c using satellite-based normalized difference vegetation index (NDVI) (French et al., 2020), machine learning techniques with different meteorological input variables (Yamaç and Todorovic, 2020), updates on the various approaches to determine K_c in its single and dual versions for vegetable crops (Pereira et al., 2021b), field crops (Pereira et al., 2021c), and tree and vine fruit crops (Rallo et al., 2021), determination of ET_c and crop coefficients of sprinkler irrigated canola from lysimeter (López-Urrea et al., 2020) and almond and pistachio orchard using remote sensing (Bellvert et al., 2018), evaluation of the accuracy of a vegetation index-based approach for calculation of ET_c using a well instrumented, drip irrigated sugar beet (Wang et al., 2021), mechanistic and empirical models for open and closed agricultural field applications (Ghiat et al., 2021), and internet of things (IoT) approach to crop water use modeling and prediction for soilless cultivations (Kocian et al., 2023).

After the publication of FAO56 in 1998, ET_c research gained a lot of interest in the scientific community which led to a huge amount of literature in many publication databases. However, there is no comprehensive and exhaustive bibliographic review that has been conducted yet to understand the trends and thematic dynamics of ET_c research at the global scale. Thus, this review intends to fill those knowledge gaps by critically exploring ET_c estimation research using different types of documents in the Web of Science™ (WoS) core collection through a combined bibliometric and thematic approach. The novel findings of this review would provide a synopsis of the current status of research on ET_c estimation globally, identify knowledge gaps and research themes for future research directions, and accentuate the existing collaborations and networks among researchers and institutions in different geographical regions of the world which could be beneficial for future collaborative plans and actions. Specifically, this review aimed to: (1) discuss the *status quo* of research on ET_c estimation and identify geographical-temporal patterns within the literature; (2) analyze the dynamics of major research themes and topics and identify knowledge gaps that could serve as the foundation for future research directions; and (3) infer global relationships between researchers and countries through the analysis of co-authorship, co-occurrence, citation, and bibliographic coupling.

CHARACTERISTICS OF THE BIBLIOGRAPHIC DATA

The WoS™ is one of the world's largest comprehensive and multidisciplinary academic retrieval platforms for citation data and is preferable compared to other databases in terms of data quality (Aleixandre-Tudó et al., 2019; Chen et al., 2022; Sarkar et al., 2022). Only one database was used to reduce the possibility of errors and ease the integration and analysis of data with different software. The academic publications relating to ET_c were retrieved from the WoS™ core collection database using the search pattern TS=(crop evapotranspiration estimation). This query searched the title, abstract, author keywords, and keywords plus of the documents present in the database regardless of the year of publication and subject area. After the search query, the results were exported in plain text (.txt) and binary file (.xls) formats.

The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol was adopted as a strategy for the selection of documents for the analysis as it is a well-established method for carrying out systematic reviews and meta-analyses (Haddaway

et al., 2022). There were 1879 results in the WoS™ core collection. All of the documents were unique and has no duplication. A total of three unverifiable documents, one retracted paper, one editorial material, one letter, and one meeting abstract were removed from the data set (Appendix Fig. 1). All the bibliographic data with double entries for document type and missing entries for the year of publication were verified manually online. The processed bibliographic data set has 1872 entries and was imported to Biblioshiny and VOSviewer interface for subsequent analyses.

METHODOLOGICAL CONSIDERATIONS FOR BIBLIOMETRIC AND THEMATIC ANALYSES

The documents were assessed in terms of typology of publication, distribution of publications by country and year, categories of distribution topics as well as the frequency of the keyword occurrence, and analysis of citations and collaborations. The annual scientific production was generated by plotting the number of published articles per year using the library(ggplot2) in RStudio to create graphs and density plots. The data were visually represented and analyzed using the VOSviewer and Bibliometrix software package. The Bibliometrix package is an open-source tool programmed in the R language which is capable of performing a comprehensive scientific mapping analysis of scientific literature. In the bibliometrix package, Biblioshiny was utilized which combines the functionality of the bibliometrix package with the ease of use of web apps using the Shiny package environment (Aria and Cuccurullo, 2017). Similarly, VOSviewer is a freely available computer program that collects bibliographic data and builds graphical maps based on co-authorship, co-occurrence of keywords, citation, and bibliographic coupling (van Eck and Waltman, 2017).

Bibliometric analysis was conducted using the visualization of similarity algorithm feature of VOSviewer. For better visualization, a minimum link strength was set for each analysis. The documents or keyword occurrences were used as weights and average publications or average citations as scores to create VOSviewer maps. On the other hand, the trend of the topics was analyzed using the feature of Biblioshiny. In this analysis, the author keywords were used as field of analysis with parameters set to five for word minimum frequency and two for the number of words per year.

The strategic mapping feature of Bibliometrix was used to detect and visualize conceptual subdomains and thematic evolution using the author keywords as field analysis. No text editing was done and parameters were set to 100 for the number of words, five for minimum cluster frequency per 1000 documents, two keywords per cluster, weight index according to inclusion index weighted by word occurrences, minimum weight index to 0.1, and WalkTrap as the clustering algorithm. The number of cutting points was set to three: 1997, 2007, and 2017. This resulted in four time periods namely: 1987–1997, 1998–2007, 2008–2017, and 2018–2022. The same procedure was done to generate the overall thematic evolution map except that no cutting points, five keywords per cluster, and 250 number of words were used for more inclusive analysis.

GEOGRAPHICAL-TEMPORAL PATTERNS OF SCIENTIFIC PUBLICATIONS IN CROP EVAPOTRANSPIRATION

The publication record spans from 1987–2022. The earliest record was a paper by Shih S.F. entitled "Using crop yield and evapotranspiration relations for regional water requirement estimation" which is published in the journal Water Resources Bulletin in 1987. Over the last three decades, the publications increased exponentially with an annual growth rate of 16.19% (Appendix Table 1), indicating strong awareness and engagement of the scientific community in ET_c research. The highest record was in 2021 having 193 documents while the lowest was in 1988 with no recorded document (Fig. 1a). The documents were mostly articles (1596) representing 85.25% of the total publications while only 2 (0.11%) were book chapters. The other documents were conference papers with 230 documents (12.29%) and review papers with 44 documents (2.35%) (Fig. 1b; Appendix Table 1).

The number of articles published by authors in various countries and institutions could be a proxy indicator of research progress and development and to a certain extent, the popularity of the topic. The ET_c research has gained interest among scientific communities from different parts of the world though some counties in Latin America, Asia, and Africa are underrepresented (Fig. 1c). In terms of country production, the documents were dominated by publications from the USA (991), China (973), and India (357). The countries such as Spain (348), Italy (201), France (149), and Germany (126) dominated the European region while Brazil (278), Iran (192), and Australia (134) dominated the regions of Latin America, Middle East, and Oceania, respectively. This geographical pattern was also observed in the bibliometric analysis of research in sustainable agriculture, sustainable water use in agriculture, and water-use efficiency where-

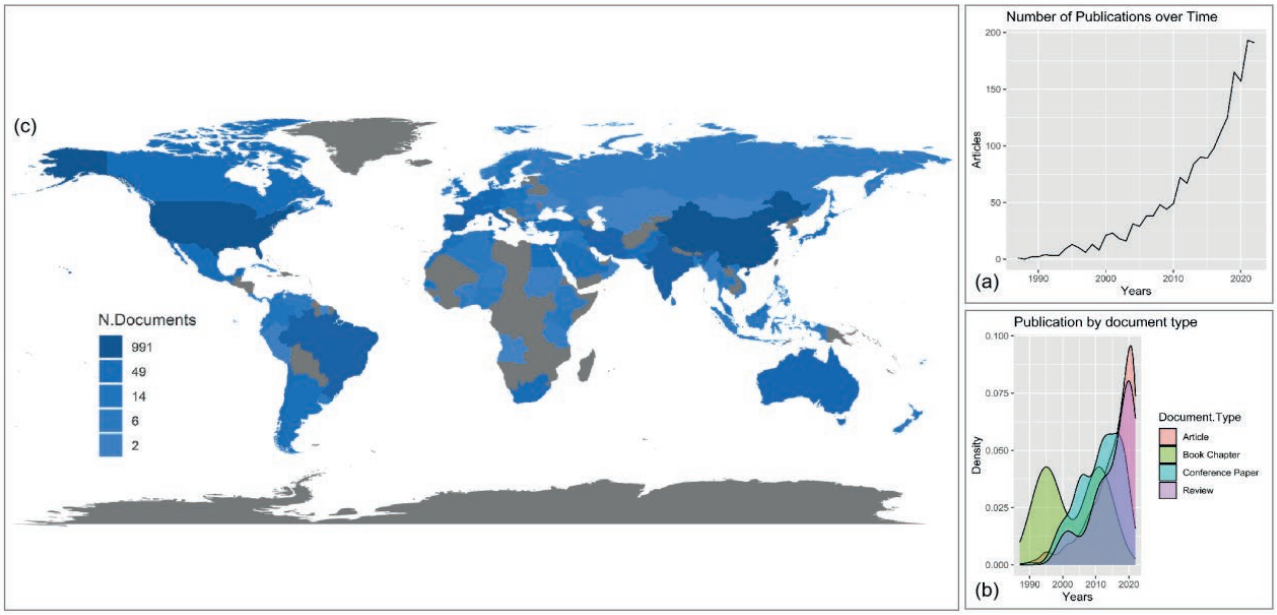

Figure 1. Geographical-temporal patterns of research publications in crop evapotranspiration estimation from 1987-2022 (a) number of publications over time; (b) density plot of document type; (c) worldwide distribution of documents.

in authors reported that the USA, China, Australia, and some European countries have the highest contribution (Abafe et al., 2022; Aleixandre-Tudó et al., 2019; Sarkar et al., 2022).

Co-authorship networks of countries and institutions

International cooperation and exchange play a crucial role in enhancing the research capabilities and academic influence of countries and institutions (Chen et al., 2022). Thus, the co-authorship networks of countries and institutions were analyzed to gain insights into the social networks formed by authors through scientific collaboration. The threshold for the minimum number of documents was set at five for countries and ten for institutions (Janik et al., 2021). Out of the 103 countries and 1967 institutions analyzed, 61 successfully met the threshold criteria. In the network visualization, larger circles indicate a higher number of associated documents, while thicker lines represent greater co-authorship. The colors in the network indicate clustering. Nine co-authorship networks were identified for countries (Fig. 2a), revealing strong collaborative ties and global partnerships among authors from the USA, China, Australia, Iran, India, and various European countries such as Spain, Germany, Italy, The Netherlands, and France. Further analysis highlighted the emergence of newer contributors including Sweden, Georgia, Ethiopia, Egypt, Lebanon, Iraq, Vietnam, and Thailand, while the oldest contributors were France, Belgium, The Netherlands, England, Scotland, New Zealand, Taiwan, Japan, Jordan, Sri Lanka, and Venezuela (Fig. 2b).

The co-authorship network of institutions is composed of six clusters (Fig. 2c) with a strong tendency for collaborations to occur among authors of the same country and institution. This was also observed by Abafe et al. (2022) when they did the same analysis on the topic of sustainable water use in agriculture. The highest total link strengths were observed among academic and research institutions in the USA and China. These institutions include the US Department of Agriculture (USDA) Agricultural Research Service (ARS), Utah State University, Chinese Academy of Sciences, Chinese Academy of Agricultural Sciences, and China Agricultural University. This could mean that both countries place nearly equal emphasis on international cooperation. Despite having relatively high publications, the University of Nebraska, the University of California Davis, Hohai University, the University of Castilla-La Mancha, and the University of Lisbon showed low total link strength, suggesting limited collaborations at the institutional level. On the other hand, Sichuan University, the University of Maryland, and Wuhan University demonstrated high total link strength despite having low publications, indicating good institutional collaboration initiatives. Moreover, the analysis revealed the emergence of several recent institutions conducting research on the

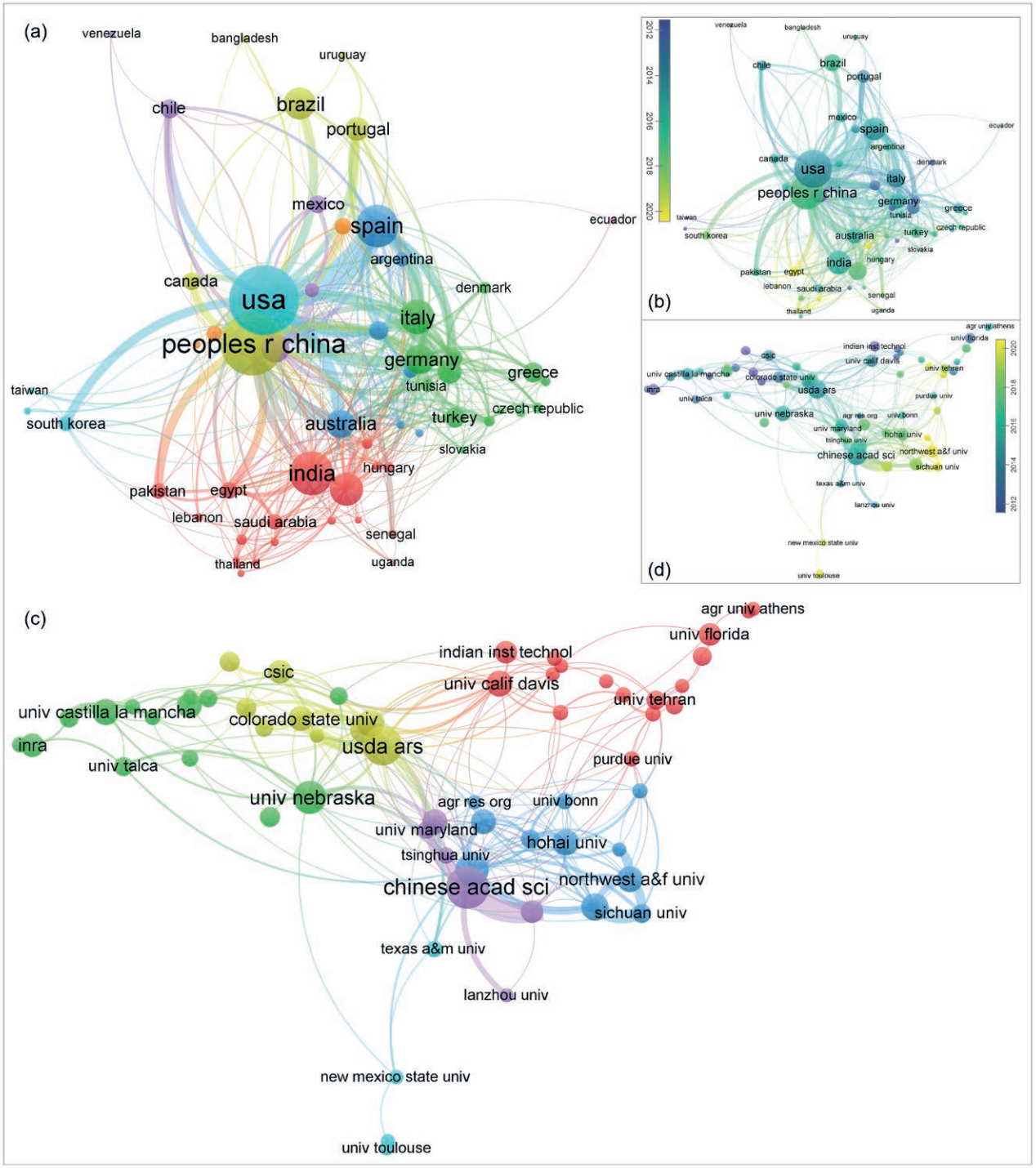

Figure 2. Co-authorship networks of (a-b) countries and (c-d) institutions [minimum link strength: 1].

topic. These include the University of Montpellier and the University of Toulouse in France, New Mexico State University in the USA, University of Chinese Academy of Sciences, Northwest A&F University, Sichuan University, Nanchang Institute of Technology, Nanjing University of Information Science and Technology, and Jiangsu University in China, as well as Mansoura University in Egypt (Fig. 2d).

TREND AND CO-OCCURRENCE NETWORK OF AUTHORS' KEYWORD

There are highly variable keywords in the analyzed documents which highlights the multidimensional and contemporary nature of ET_c research. The keyword with the highest number of occurrences was evapotranspiration (564) followed by remote sensing (219), crop coefficient (119), reference evapotranspiration (118), irrigation (96), eddy covariance (64), energy balance (55), moderate resolution imaging spectroradiometer (MODIS) (46), Penman-Monteith (45), and crop evapotranspiration (44) (Fig. 3a), suggesting that these are among the most commonly discussed areas in ET_c research. Most of these keywords appeared simultaneously three years after the publication of the FAO56 Penman-Monteith ET_o method in 1998. Other authors who conducted bibliometric analysis on related topics such as sustainable water use in agriculture and water-use efficiency also reported a high frequency of the keywords evapotranspiration and irrigation (Abafe et al., 2022; Aleixandre-Tudó et al., 2019). Trend analysis further showed that keywords such as stomatal resistance and irrigation requirements were commonly used by researchers since the early 2000s and remain relevant to the present day. These two keywords are interconnected, with stomatal resistance playing a crucial role in assessing crop water status and estimating transpiration, which are essential for effective irrigation management (Cannavo et al., 2016). The period between 2008 and 2018 exhibited the maximum diversification of authors' keywords, with many terms revolving around soil-plant-atmosphere interactions and decision support systems. Moreover, the term crop modeling paved the way for the emergence of new keywords such as machine learning, random forest, artificial intelligence, and google earth engine which began to gain prominence starting in 2020 (Fig. 3b).

Keywords represent the main contents of existing research and depict the areas studied within the boundaries of a given domain and their co-occurrence highlights the main areas of research (Chàfer et al., 2021). In this context, the co-occurrence network of author keywords was analyzed to gain a better understanding of the main research areas. To ensure a more focused analysis and exclude less significant topics, only keywords with a minimum of 15 occurrences were considered (Janik et al., 2021). Out of the 3739 keywords initially identified, only 59 met this threshold (Fig. 3c). In the co-occurrence network, larger circles and thicker lines represent higher occurrences and co-occurrences in publications, respectively, while colors indicate clustering. The analysis revealed six distinct clusters that represent the primary sub-areas of research in ET_c. Apart from Landsat—a keyword related to space-based moderate-resolution land remote sensing data, the top ten keywords with the highest occurrence also showed the highest total link strength with one another. Recent approaches to estimating ET_c primarily focus on utilizing remotely sensed data (Pereira et al., 2015) and all of these keywords are somehow related to remote sensing. Therefore, it is highly likely that these keywords will continue to exist and co-occur in future publications.

CENTRAL THEMES OF CROP EVAPOTRANSPIRATION RESEARCH

Thematic maps were generated based on the relationship that a network of topics establishes with other networks of topics. The algorithm grouped the topics according to subject areas and distributed them according to different themes based on centrality and density. These themes were classified as follows:

1. Motor - This theme represents well-developed and significant research areas that serve as the foundation for the field. They play a crucial role in structuring the overall research landscape.
2. Niche - The niche theme consists of highly specialized and peripheral topics that cater to specific areas within the field. They address specific, focused aspects that may not receive widespread attention.
3. Emerging or Declining - This theme encompasses topics that are either emerging or declining in importance within the research field. These topics are characterized by evolving trends and changes in relevance.
4. Basic - The basic theme comprises topics that hold importance but are not yet fully developed within the research field. These areas show potential for growth and further exploration.

Centrality is a measure of the extent to which a topic network interacts with other networks within the same discipline. It reflects the interconnectedness and influence of a particular topic grouping. On the other hand, density indicates the internal strength of a network, revealing how closely related the topics within it are. A higher density suggests strong connections between topics, indicating their potential for resilience and improvement (Janik et al., 2021; Mühl and Oliveira, 2022; Sarkar et al., 2022).

A total of four clusters were identified in the overall thematic map (Fig. 4a). Two clusters focused on motor themes, with the first cluster pertaining to crop ecophysiological processes, such as transpiration, soil water bal-

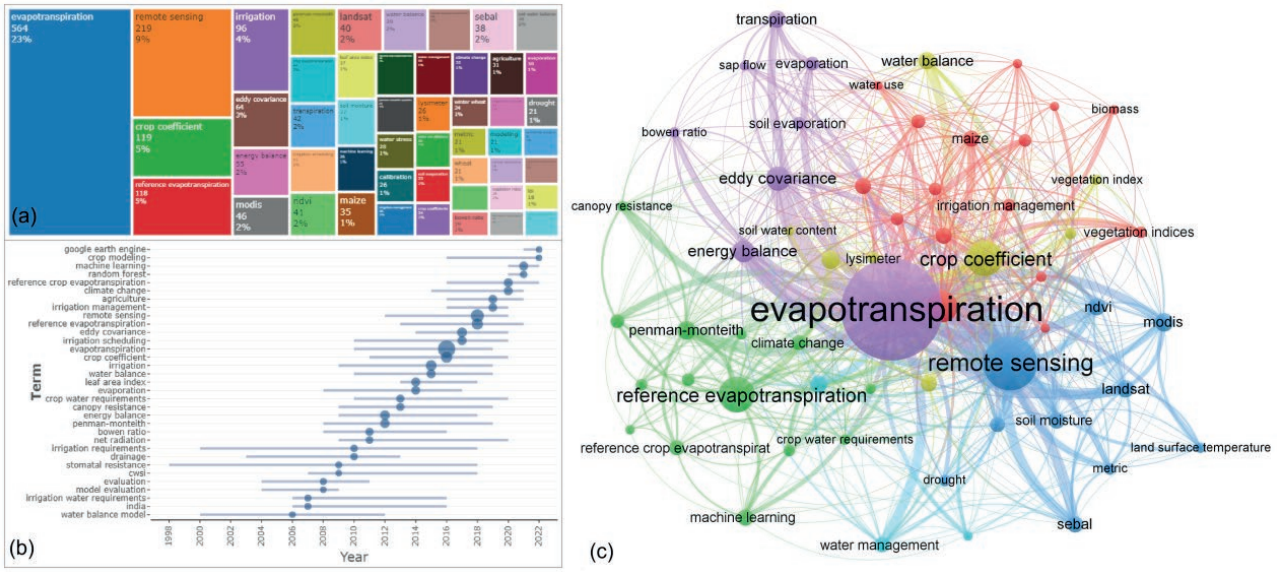

Figure 3. (a-b) Trend analysis and (c) co-occurrence network of author keywords [minimum link strength: 1].

ance, leaf area index, and water stress. The second cluster centered around methods and approaches for estimating ET_c, including remote sensing, crop coefficient, and eddy covariance. Similarly, two clusters were identified as emerging or declining themes. These clusters encompassed a range of conventional and modern methodologies for estimating ET_c, which could signify either sustained relevance or the replacement of conventional methods by modern tools such as machine learning or deep learning techniques. Pereira et al. (2015) emphasized the importance of continuing to use primary data collection systems such as lysimeters, eddy covariance, Bowen ratio, and soil water balance for determining K_c using ET measurements. While the FAO56 method does not explicitly mention the application of remote sensing, there have been significant developments in the past three decades regarding the inclusion of remote sensing data for estimating K_c, K_{cb}, and evapotranspiration, which can greatly support irrigation management (Pôças et al., 2020). In addition, future improvements to the FAO56 K_c-ET_o method for estimating ET_c should take into account the availability of remote sensing observations, particularly in defining crop growth stages at specific locations (Pereira et al., 2021c). Therefore, it is highly likely that the scientific community will continue to investigate these topics in the future.

A comprehensive analysis was conducted to depict the thematic evolution of ET_c research sub-areas over four distinct time spans (Fig. 4b). The initial phase (1987–1997) primarily concentrated on irrigation and transpiration as the main research domains. Subsequently, during the second period (1998–2007), the concept of transpiration underwent significant advancements and expansions. Key developments during this time included the Penman-Monteith equation, reference evapotranspiration, crop coefficients, and water balance. The majority of investigations focused on two prominent crop species, maize and wheat, while new concepts such as climate change also emerged during this period. It is notable that during this period, researchers recognized the importance of *in-situ* sensors in estimating ET_c as marked by the emergence of the term lysimeter. Weighing lysimeters directly measure evapotranspiration by assessing changes in soil and crop mass. These lysimeters are renowned for providing the most precise and dependable measurements of ET_c, making them the standard for evaluating energy and water balance models and calibrating crop coefficients, as outlined in the FAO56 methodology (Ghiat et al., 2021; López-Urrea et al., 2020). The majority of the topics addressed in the second period remained pertinent during the third period (2008–2017), with a particular focus on investigating crop responses to water, such as water stress and crop water requirements. Furthermore, novel concepts emerged, including modeling, MODIS, and latent heat flux, all of which are associated with various approaches for estimating ET_c. Current research (2018–2022) has maintained a strong focus on evapotranspiration, specifically reference and crop evapotranspiration. Pereira et al. (2015) noted that ET_{ref} remains widely used and accepted for practical estimation of ET_c, indicating that these terms

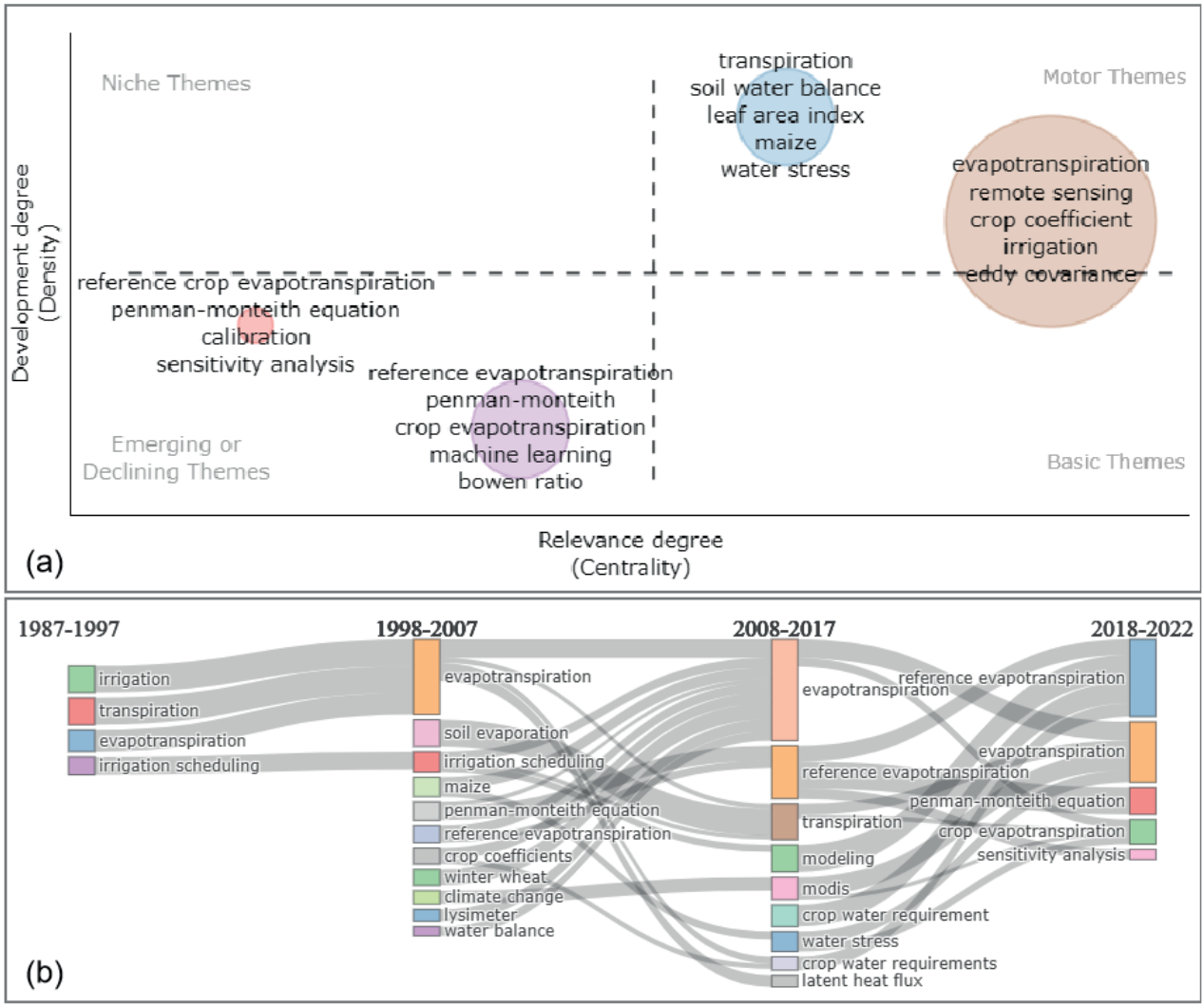

Figure 4. Overall (a) thematic map and (b) evolution of topics over time.

will continue to coexist until new estimation methods for ET_c are developed. Notably, ongoing research in ET_c aligns with advancements in digital tools, such as machine learning, and addresses pressing environmental challenges like climate change. Studies suggest that climate change will negatively impact vegetation water availability, particularly crop water requirements and net irrigation needs (Saadi et al., 2015). Consequently, integrated and sustainable water management becomes crucial to mitigate the vulnerability of agriculture to climate change and its associated environmental consequences (Pereira et al., 2020; Pereira et al., 2021b). Therefore, it is imperative to address these issues concerning ET_c, quantify their impacts, and develop appropriate mitigation and adaptation strategies.

Thematic evolution of topics in crop evapotranspiration research

An in-depth analysis of the evolution of the thematic maps was conducted dividing the studied topics into four categories of themes and time periods previously mentioned. Three themes were identified for the initial period, 1987–1997 (Fig. 5a). The motor themes encompassed studies on evapotranspiration and crop coefficient. The niche themes focused on irrigation scheduling and the crop potato, whereas, emerging or declining themes centered around the concept of transpiration. Notably, during this particular time frame, the diversity of topics was limited due to the nascent stage of ET_c research, which had only begun to capture the attention of the scientific community.

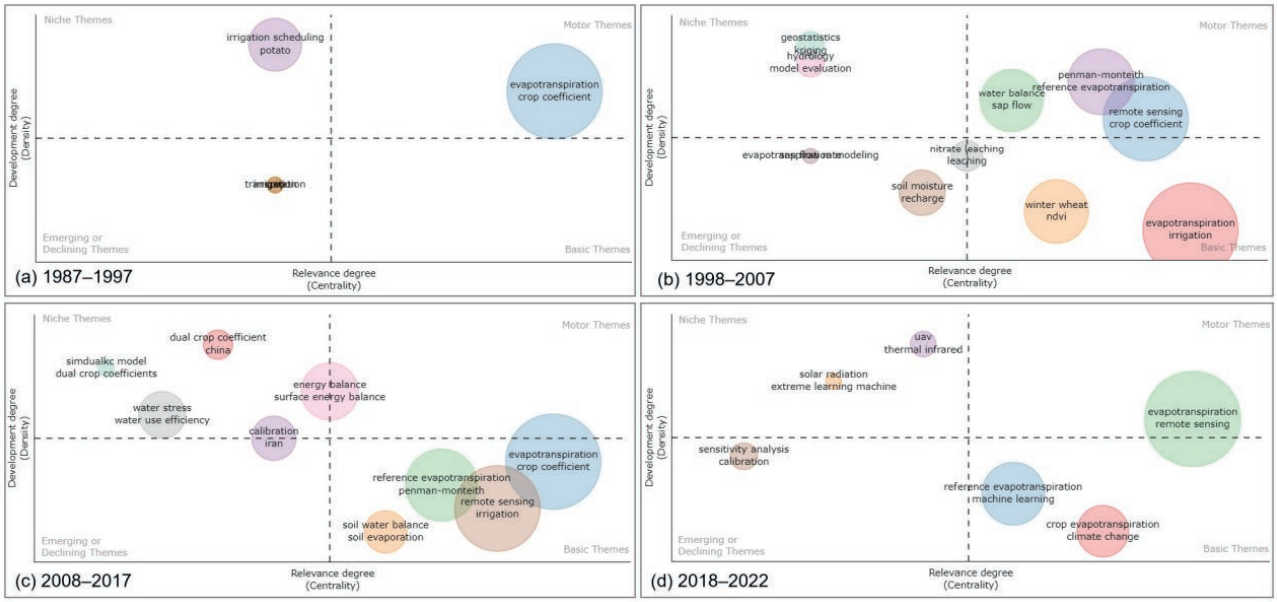

Figure 5. Thematic analysis of topics in four different time periods from 1987–2022: (a) 1987–1997; (b) 1998–2007; (c) 2008–2017; and (d) 2018–2022.

During the second period, 1998–2007 (Fig. 5b), the analysis revealed four main themes, consisting of ten clusters. The motor themes encompassed three clusters that focused on various aspects such as remote sensing, crop coefficient, Penman-Monteith, reference evapotranspiration, water balance, and sap flow. Of these topics, sap flow is of particular interest. It is a method developed to measure transpiration at the individual plant level, and currently, heat tracer-based sap flow techniques are the predominant method of estimation (Wang et al., 2022). The niche themes comprised two clusters that delved into specialized topics related to the prediction and analysis of data associated with spatial or spatiotemporal phenomena, specifically geostatistics and kriging. Two additional clusters were identified as emerging or declining themes, which encompassed topics like evapotranspiration, modeling, soil moisture, and recharge. Similarly, the topic of evapotranspiration, along with irrigation, winter wheat, and NDVI, was classified as a basic theme. Notably, during this period, researchers dedicated significant efforts to exploring the application of remote sensing for indirect measurement of leaf area index, as evident from the co-occurrence of the topics NDVI and remote sensing. Reyes-González et al. (2019) suggested that image-based remote sensing techniques could be employed to estimate leaf area index based on empirical relations with vegetative indices. These vegetative indices could then be incorporated in the surface resistance estimation within the Penman-Monteith model (Ghiat et al., 2021). More recently, French et al. (2020) found that, in most cases, remote sensing of NDVI and modeled K_{cb} accurately estimated K_c and ET_c during the mid-season through senescence. Furthermore, Pereira et al. (2020) provided a comprehensive review on the relationships between single K_c and basal K_{cb} and various parameters, including the fraction of ground cover and height.

In the third period, 2008–2017 (Fig. 5c), the topics energy balance and surface energy balance are located at the center of the strategic diagram which implies that they can be both motor and niche themes. The presence of these topics alongside remote sensing indicates substantial advancements in remote sensing of evapotranspiration, providing a reliable foundation for determining evapotranspiration through surface energy balance (Pereira et al., 2015). China and Iran emerge as niche themes in this period, signifying extensive research efforts related to ET_c in these countries. The topic crop coefficient or single K_c in 1987–2007 evolved to dual crop coefficient as a niche theme in this period. The single K_c only represents typical conditions that can vary with wetting frequency by precipitation and irrigation and with the type of irrigation practiced. This concept was extended by introducing the dual crop coefficient that integrates K_{cb} which is the basal crop coefficient representing primarily plant transpiration and K_e which is the evaporation coefficient that represents the contribution of evaporation from soil to total evapotranspira-

tion (Pereira and Alves, 2013). Over the years, the dual approach significantly improved the accuracy of the evapotranspiration estimate and enabled several entities to update and revise guidelines on evapotranspiration and irrigation water requirements. However, quantifying seasonal variations in the single and dual crop coefficients remains a challenge even today (Pereira et al., 2015; Wang et al., 2023). Pôças et al. (2020) provide a comprehensive review on the application of remote sensing data for assessing K_c and K_{cb} coefficients, particularly focusing on the use of spectral vegetation indices. The other topics under niche themes include the SIMDualKc model, water stress, water-use efficiency, and calibration. Among these topics, the SIMDualKc model is particularly important. It is a model that performs a daily soil water balance at the field scale adopting the dual K_c approach to compute and partition ET_c into T_c and E_s. A recent review by Pereira et al. (2021b) has shown that a well-calibrated and validated SIMDualKc model made it possible to overcome problems related to stress and achieve K_c standardized values. Similarly, Rosa et al. (2016) utilized this model to estimate transpiration rates of maize and sweet sorghum considering the effect of transient salinity stress. Under the basic theme category, one significant topic is the soil water balance, which evolved from the water balance topic in the 1998–2007 period. Extensive research has been conducted on this topic over the years, and it is likely that field and crop-focused soil water balance models will continue to be utilized by farmers and agricultural advisors. Pereira et al. (2020) provide a comprehensive discussion of different approaches to soil water balance modeling. Furthermore, trends in this topic are expected to shift, with traditional models predominantly used for research purposes, while new, fast-responding, and multi-user models based on cloud and Internet of Things (IoT) technologies will be developed for practical farm applications. Kocian et al. (2023) recently employed an IoT approach to predict ET_c of sweet basil in soilless cultivations. Lastly, the other topics falling under the basic themes category include soil evaporation, irrigation, Penman-Monteith, reference evapotranspiration, and evapotranspiration.

In the current period, 2018–2022 (Fig. 5d), topics such as evapotranspiration and remote sensing have become well-developed and are recognized as motor themes. These topics have also been present in previous periods (1998–2017) either as motor or basic themes. One prevalent approach for estimating evapotranspiration using remote sensing involves the utilization of vegetation indices or surface energy balance models based on thermal infrared data (Pereira et al., 2015). This explains the presence of the topic thermal infrared alongside remote sensing. Further analysis showed that researchers exhibit a strong inclination towards topics related to digital agriculture and new technologies in computer science and data analytics. Mühl and Oliveira (2022) observed a similar trend when investigating the dynamics of research topics in agriculture 4.0. Apart from thermal infrared, the niche themes were composed of two clusters which include the topics unmanned aerial vehicle (UAV), solar radiation, and extreme learning machine. One cluster was identified as emerging or declining themes, which include sensitivity analysis and calibration. These topics likely represent emerging themes that highlight the need for fine-tuning and evaluating the robustness of different models available for estimating ET_c. Recent reviews have indicated that many papers fail to satisfy the adopted K_c requirements for various crops, such as vegetable crops, field crops, and fruit trees and vines, in terms of the ET_o computation method or provide solid evidence of measurement accuracy for ET_c. Therefore, future research should prioritize adopting improved accuracy and quality control measures to determine K_c data comparable to currently recognized standard values. This will provide more transferable data to other regions (Pereira et al., 2021b, 2021c; Rallo et al., 2021).

Lastly, the basic themes include interrelated topics such as crop evapotranspiration, climate change, reference evapotranspiration, and machine learning. Despite the substantial amount of research conducted in the past 35 years, it is interesting to note that based on the analysis, these topics are still underdeveloped. Pereira et al. (2015) emphasized that the use of the crop coefficient curve and reference evapotranspiration will live on into the future taking advantage of sophisticated computer language. Future applications of K_c will include the use of thermal-time units such as growing-degree days to establish lengths of periods which is important for assessing the impacts of climate change on future crop water use. Therefore, the scientific community should prioritize future research investigations related to these topics to gain a deeper understanding of the concepts, principles, methodologies, and applications of crop evapotranspiration.

CITATION NETWORK ANALYSIS

The dynamics of citation among authors involved in ET_c research were examined by analyzing the citation networks of countries, institutions, sources, and documents.

Citation network of countries and institutions

In the citation network analysis, the minimum number of documents of a country was set to ten while to 15 for the institution. Among the 103 countries and 1967 institutions considered, 35 met the specified thresholds. The size of the circles in the visual representation indicates the volume of publications, with larger circles representing higher publication numbers. Similarly, the thickness of the lines connecting the circles represents the frequency of mutual citations between the entities.

A total of four citation network groups for countries were identified, with the highest total link observed between USA and China, Spain, Portugal, and Italy. Other countries also showed links with these five countries (Fig. 6a). The analysis further revealed that papers from the USA, Israel, Denmark, Austria, France, Italy, Belgium, and Portugal received the highest average number citations (Fig. 6b). It is worth noting that the first three countries also received a significant number of citations in a previous bibliometric study on water-use efficiency research (Aleixandre-Tudó et al., 2019). The number of citations serves as a metric for assessing the impact of articles on the advancement of the field (Wang et al., 2019). Based on this criterion, papers from these countries can be regarded as highly impactful.

In the citation network of institutions, a total of four clusters were identified, with a strong tendency for institutions of the same country to cite one another (Fig. 6c). In China, the highest links were observed between Northwest A&F University, Chinese Academy of Agricultural Sciences, and Sichuan University. In Portugal, the University of Lisbon showed strong links with the Technical University of Lisbon and the University of Idaho. In the USA, the USDA-ARS displayed strong connections with the Agricultural Research Service (ARS), Utah State University, Colorado State University, and the University of Nebraska. In Spain, the University of Castilla-La Mancha demonstrated a strong link with the University of Valencia. Lastly, in Italy, the University of Palermo showed citation connections with institutions such as the University of Lisbon, Technical University of Lisbon, University of Idaho, University of Nebraska, and ARS. Further analysis revealed that the Technical University of Lisbon and the University of Idaho had the highest average citations thus, making them the most impactful institutions (Fig. 6d). This finding is further supported by the fact that most influential authors in the field are affiliated with these institutions (Appendix Table 2).

Citation networks of sources and documents

The importance of ET_c research is reflected in the type and quality of the sources and documents. Thus, the citation networks were analyzed as a proxy measure of impact and knowledge generation. For this analysis, the minimum number of documents of a source was set to eight while the minimum number of citations of a document was set to 100. Out of 496 sources, 36 met the threshold while out of 1872 documents, 56 met the threshold. However, only 33 documents demonstrated connections within the network.

A total of seven citation networks for sources were identified. The trans- and multidisciplinary nature and diverse subject areas of ET_c has resulted in research findings being published in a wide variety of journals with various aims and scopes. The journal Agricultural Water Management exhibited strong connections with journals specializing in water, irrigation, and remote sensing technologies applications, such as Remote Sensing, Journal of Hydrology, Journal of Irrigation and Drainage Engineering, Agricultural and Forest Meteorology, Water, Irrigation Science, Theoretical and Applied Climatology, Hydrological Processes, and Computers and Electronics in Agriculture (Fig. 7a). These journals also had the highest number of publications and citations highlighting their importance in disseminating research results related to ET_c (Appendix Table 3). Abafe et al. (2022) identified Agricultural Water Management, Water, and Journal of Hydrology as leading journals in advancing research on sustainable water use in agriculture. In addition, Aleixandre-Tudó et al. (2019) identified Agricultural Water Management as the most prolific journal in water-use efficiency research. Further analysis revealed that despite their lower number of publications, the journals Remote Sensing of Environment, Water Resources Research, Ecological Modelling, and Hydrology and Earth System Sciences had the highest average citations, indicating their high credibility (Fig. 7b). Moreover, these journals have high impact factor and are managed by reputable publishers and scientific societies like Elsevier, Springer Nature, Wiley, MDPI, American Society of Civil Engineers, and European Geosciences Union (Appendix Table 3).

Out of the analyzed documents, only 74 were single-authored, with international co-authorship accounting for 30.77% (Appendix Table 1). A total of eight citation networks for the documents (Fig. 7c–d) were identified, with four papers receiving the highest number of citations. The other most cited documents with at least 200 citations can be found in Appendix Table 4. According to Mühl and Oliveira (2022), a highly cited paper is

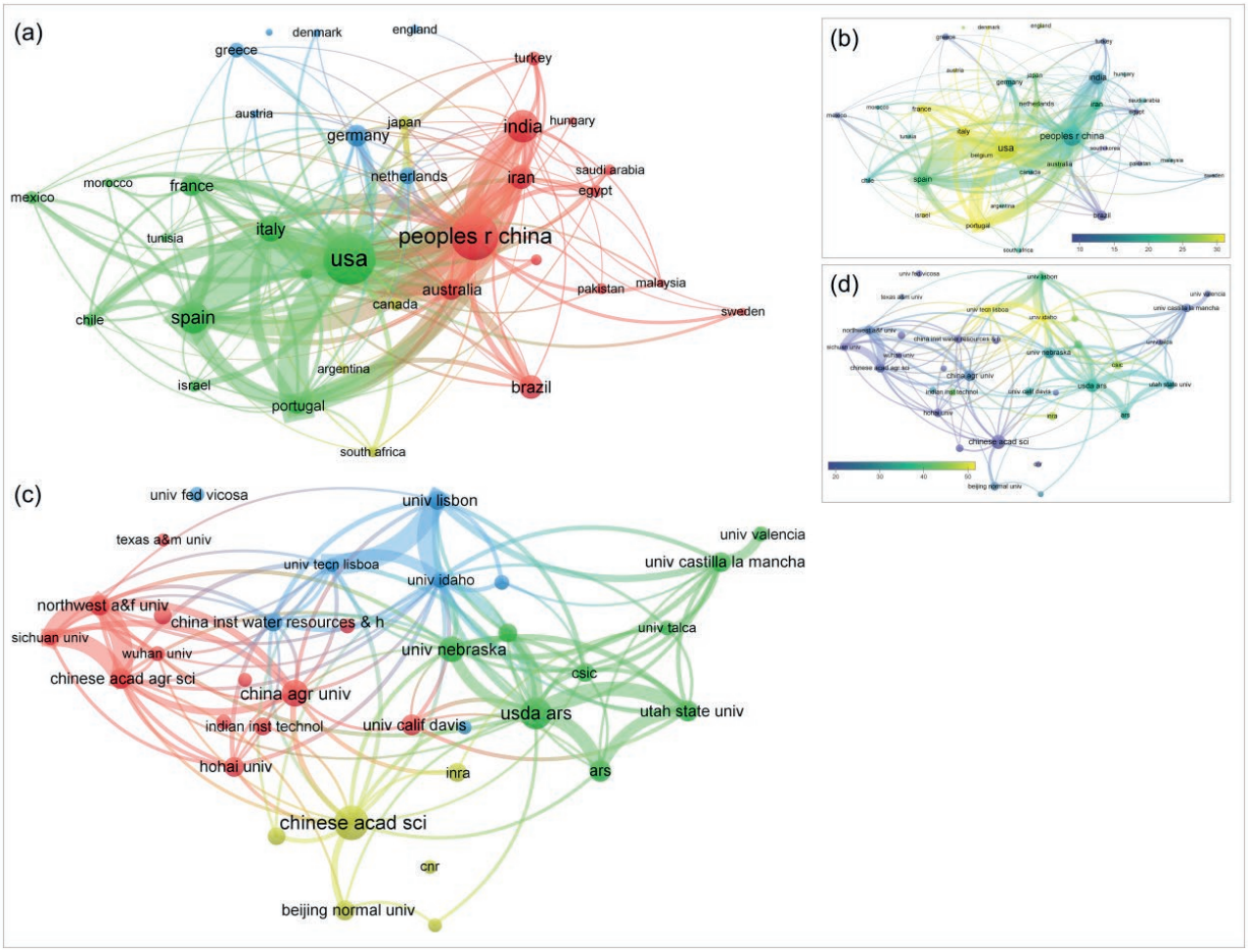

Figure 6. Citation networks of (a-b) countries and (c-d) institutions [minimum link strength: 10].

considered impactful, although impact could also be measured in terms of the number of published papers by authors. The first document is "Evapotranspiration information reporting: I. Factors governing measurement accuracy" by Allen et al. (2011b), published in the Agricultural Water Management journal. This review article discusses the fundamental principles of evapotranspiration measuring systems, common errors, and biases associated with these systems. The second document is also a review paper entitled "Measurement and estimation of actual evapotranspiration in the field under Mediterranean climate: a review" by Rana and Katerji (2000), published in the European Journal of Agronomy. This paper focuses on comparing different methods for estimating evapotranspiration and assessing their accuracy and suitability for arid and semi-arid environments. The third paper is "Crop evapotranspiration estimation with FAO56: Past and future" by Pereira et al. (2015) which is also published in the journal Agricultural Water Management. This review paper provides updated definitions and procedures for computing reference evapotranspiration, discusses the adoption of the dual K_c method for separate estimation of crop transpiration and soil evaporation, and presents improved estimations of ET_c under water, salt stress, and non-standard conditions. The last paper is entitled "Estimating actual, potential, reference crop and pan evaporation using standard meteorological data: a pragmatic synthesis" by McMahon et al. (2013) published in Hydrology and Earth System Sciences. This article serves as a comprehensive guide for estimating actual evaporation from deep lakes and farm dams, potential evaporation for rainfall-runoff models, and reference crop evapotranspiration for small irrigation areas and large irrigation districts. The citation behavior of these four highly cited papers suggests the flow of knowledge between articles. When an article is cited by a large

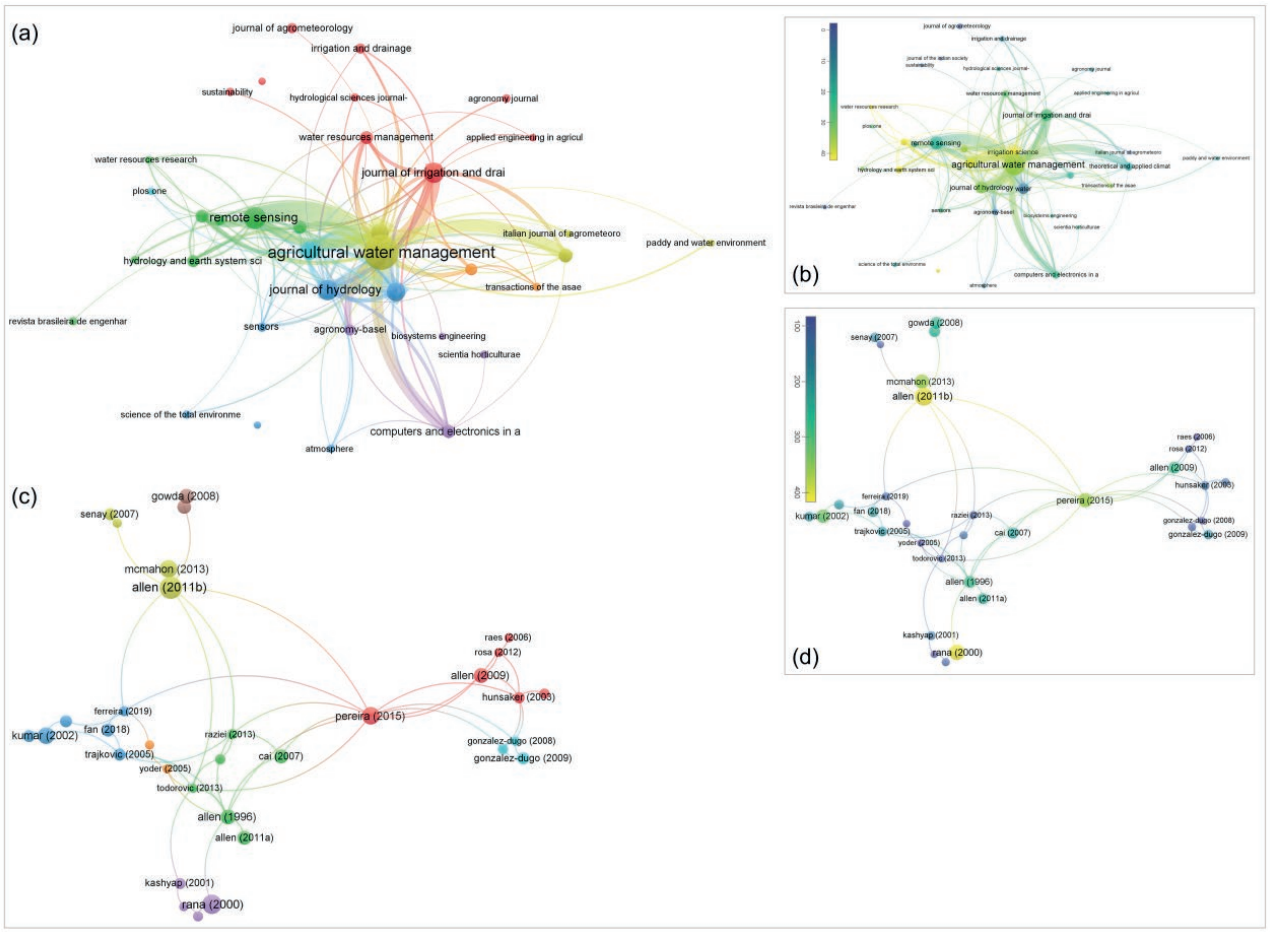

Figure 7. Citation networks of (a-b) sources [minimum link strength: 4] and (c-d) documents [minimum link strength: 6]. For the documents, only the first author is shown by VOSviewer.

number of authors from different countries, institutions, disciplines, and journals, it indicates that the knowledge presented in the article has a significant impact on scientific research conducted by multiple academic entities (Wang et al., 2019).

BIBLIOGRAPHIC COUPLING ANALYSIS

Bibliographic couplings of countries, institutions, sources, and documents were also examined using the same parameters employed in the citation network analysis. Bibliographic coupling refers to the number of shared cited references between two publications, allowing for the identification of publications that are most closely related in terms of their topics (Janik et al., 2021). In general, the findings from the bibliographic coupling analysis complement those obtained from the citation network analysis.

Bibliographic coupling of countries and institutions

Five bibliographic coupling groups for countries were identified (Fig. 8a). Among these groups, the countries that showed strong links with each other were USA, China, Spain, Italy, Portugal, France, Brazil, India, Iran, Australia, Germany, and The Netherlands. The highest link was observed between USA and China, indicating a significant level of collaboration and knowledge exchange between these two countries.

Three bibliographic coupling groups were identified for institutions (Fig. 8b). Chinese institutions, including Northwest A&F University, China Agricultural University, Chinese Academy of Sciences, Chinese Academy of Agricultural Sciences, Sichuan University, as well as US institutions like USDA-ARS, University of Nebraska, Utah State University, University of California Davis, Colorado State University, and University of Idaho, demonstrated strong connections with each other. It is

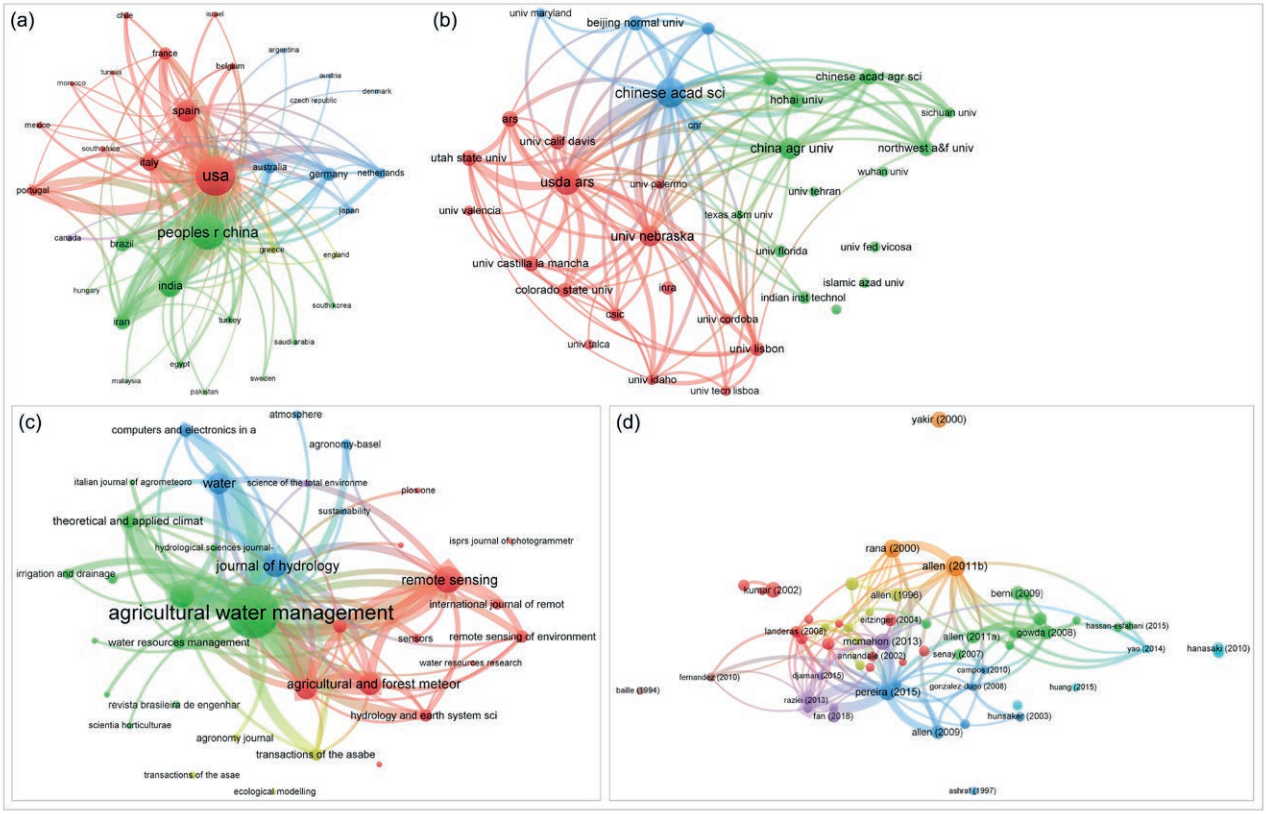

Figure 8. Bibliographic coupling of (a) countries [minimum link strength: 3000], (b) institutions [minimum link strength: 1000], (c) sources [minimum link strength: 1000], and (d) documents [minimum link strength: 5]. For the documents, only the first author is shown by VOSviewer.

worth mentioning that Northwest A&F University and China Agricultural University were also recognized as prominent institutions in producing publications related to sustainable water use in agriculture (Abafe et al., 2022). Lastly, the other institutions that showed strong links were from Spain such as the University Castilla-La Mancha, the University of Valencia, and the University of Cordova, and from Portugal such as the University of Lisbon and the Technical University of Lisbon.

Bibliographic coupling of sources and documents

A total of five bibliographic coupling groups were identified for sources (Fig. 8c). The journal Agricultural Water Management exhibited strong links with the Journal of Water Resources Management and with all the journals identified as impactful in the citation network analysis, except for Hydrological Processes. For documents, a total of eight bibliographic couplings were identified (Fig. 8d). The documents by Rana and Katerji (2000), Allen et al. (2011b), Pereira et al. (2015), McMahon et al. (2013), Gowda et al. (2008), Allen et al. (2011a), Raziei and Pereira (2013), Todorovic et al. (2013), and Rosa et al. (2012) showed strong links with one another but the highest link was found between Raziei and Pereira (2013) and Todorovic et al. (2013). Most of these papers were authored or co-authored by Luis S. Pereira from the University of Lisbon in Portugal, who is also the most locally cited author. However, Rana and Katerji (2000), McMahon et al. (2013), and Gowda et al. (2008) were authored by other researchers. In addition, the first four documents were also identified as the most impactful papers in the citation network analysis.

CONCLUSIONS AND LIMITATIONS

This review provided a comprehensive overview of contemporary research topics in ET_c estimation from 1987 to 2022. The USA and China were the two world-leading countries in ET_c research which could potentially influence future research direction since most of the institutions working on this topic are located in

these countries. There is a wide range of journals for publication of research results on ET_c but the Agricultural Water Management has gained great importance because most authors are publishing and citing papers in this journal. The growth of ET_c research is increasing and the findings demonstrate a widespread collaboration between the authors, institutions, and countries around the world indicating that ET_c is a well-established topic. However, there are some underrepresented countries in the analysis. It is important to note that this review focused only on documents where the term "crop evapotranspiration estimation" appeared in the title, abstract, or keywords, which poses some limitations on the comprehensive representation of the research topic. Despite these limitations, rigorous efforts were made to conduct this research accurately following the PRISMA protocol. Due to the difficulty of merging bibliographic data from different sources, only the WoS™ publication database was utilized which implies that it cannot be assumed as complete. Nevertheless, this review provides a valuable overview of the current state of global research on ET_c. With the inclusion of documents that can be found in other databases like Scopus®, the results could deviate a little bit from what is presented in this review. Moreover, the number of publications and the number of their citations were utilized as proxy measures of the quality and quantity of the analyzed documents regardless of their actual scientific value.

The analysis revealed the complexity and broadness of ET_c research while emphasizing the significance of transdisciplinary and multidisciplinary approaches to investigate related research questions. Over the past 35 years, research themes have diversified, new concepts have emerged, and researchers worldwide have employed various approaches, tools, and methodologies to address research questions in this field. Thematic analysis indicates that topics such as crop evapotranspiration and reference evapotranspiration are still underdeveloped, suggesting the need to focus on these areas to fill existing knowledge gaps and advance both theoretical understanding and practical applications. The findings regarding leading authors, countries, and academic and research organizations can serve as a foundation for establishing meaningful scientific collaborations in the future, fostering further research growth and scientific advancements. Additionally, as the topics of crop evapotranspiration research rapidly evolve, addressing the lack of basic information on crop water requirements becomes crucial for improving water use efficiency and irrigation management. Therefore, future research efforts should contribute to enhancing our understanding of crop water requirements and their application in irrigation management, while also ensuring continuous updates to the existing body of knowledge to meet future challenges.

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AUTHOR CONTRIBUTIONS

Wilfredo B. Barrera Jr.: Conceptualization, Methodology, Formal analysis, Visualization, Writing- Original draft, Writing- Reviewing and Editing.

Anna Dalla Marta: Conceptualization, Supervision, Writing- Reviewing and Editing.

Roberto Ferrise: Conceptualization, Supervision, Writing- Reviewing and Editing.

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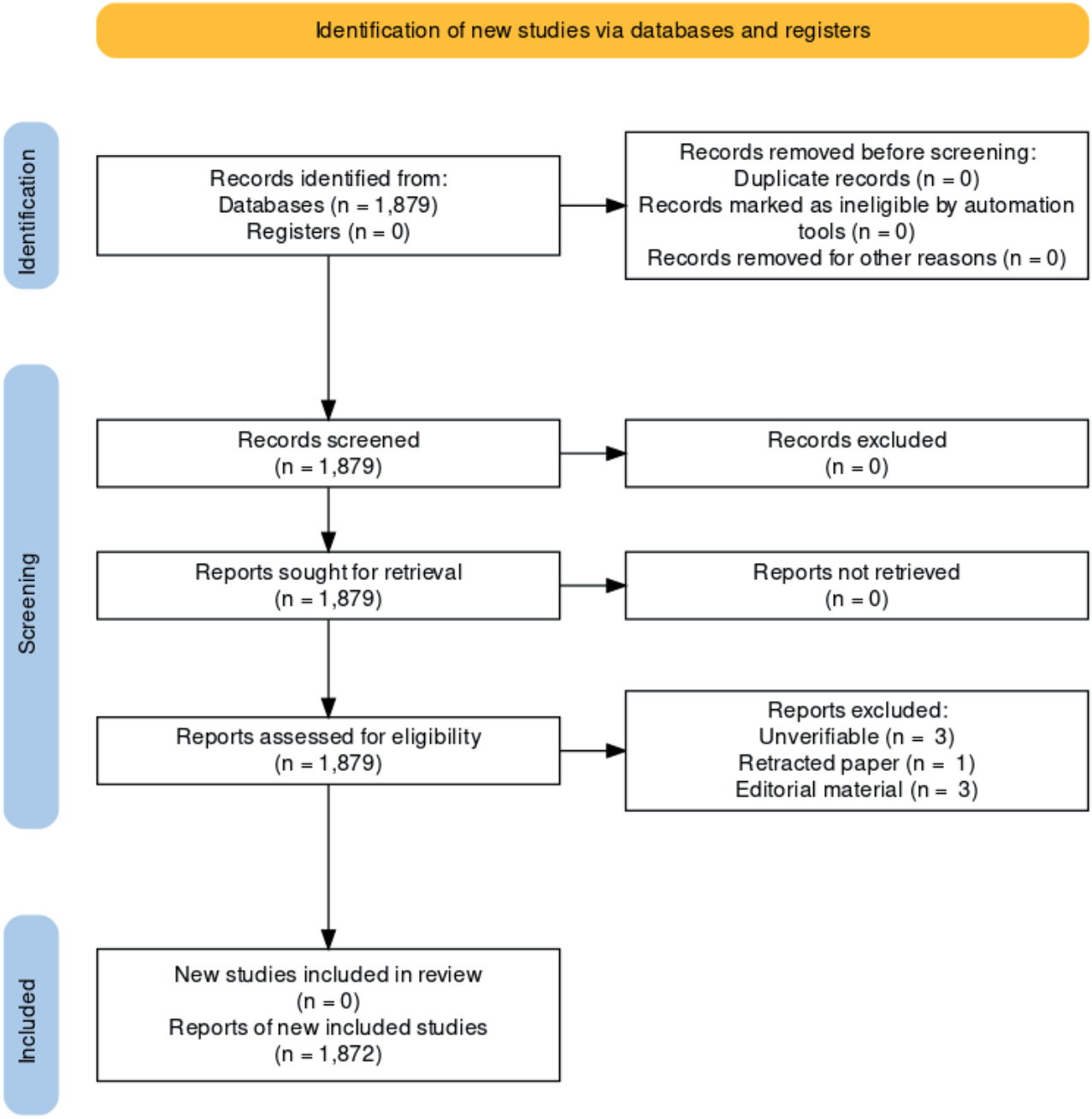

Appendix Figure 1. Procedure applied for document selection for the bibliometric review and thematic analysis (PRISMA protocol).

Appendix Table 1. General information of the bibliographic data.

Description	Results
Timespan	1987-2022
Sources (journals, books, etc.)	496
Documents	1872
Annual growth rate (%)	16.19
Document average age	8.4
Average citations per document	19.97
References	44639
Keywords plus	2389
Author's keywords	3739
Authors	5480
Authors of single-authored documents	70
Single-authored documents	74
Co-authors per document	4.56
International co-authorships (%)	30.77
Article	1596
Book chapter	2
Conference paper	230
Review paper	44

Appendix Table 2. Number of publication and citation metrics of the most influential authors with at least 15 documents. The affiliation of author was retrieved from Scopus database through 'author search'. Legend: TC-total citations; NP-number of publications; SYP-start of the year of publication.

Author	h index	g index	m index	TC	NP	SYP	Affiliation
Pereira LS	25	36	0.9620	2883	36	1998	University of Lisbon
Kustas WP	17	29	0.8100	1063	29	2003	U. S. Department of Agriculture, Agricultural Research Service
Irmak S	11	21	0.5240	466	26	2003	Pennsylvania State University
Neale CMU	12	22	0.5220	741	22	2001	University of Nebraska
Paredes P	19	22	1.5830	1026	22	2012	University of Lisbon
Anderson MC	13	21	0.6190	995	21	2003	U. S. Department of Agriculture, Agricultural Research Service
Allen RG	16	20	0.5710	2243	20	1996	University of Idaho
Gowda PH	13	20	0.7650	697	20	2007	U. S. Department of Agriculture, Agricultural Research Service
Howell TA	14	18	0.5830	1346	18	2000	U. S. Department of Agriculture, Agricultural Research Service
Prueger JH	13	18	0.8130	605	18	2008	U. S. Department of Agriculture, Agricultural Research Service
Chavez JL	11	17	0.6470	658	17	2007	Colorado State University
Cui NB	8	17	1.1430	293	17	2017	Sichuan University
Kang SZ	13	16	0.7650	554	16	2007	China Agricultural University
Nieto H	8	16	0.7270	300	16	2013	Institute of Agricultural Sciences, ICA-CSIC
Olioso A	9	16	0.3100	419	16	1995	Ecologie des Forêts Méditerranéennes (URFM)
Ortega-Farias S	7	16	0.3500	332	16	2004	Universidad de Talca
Calera A	8	15	0.4000	367	15	2004	Universidad de Castilla-La Mancha
Gonzalez-Dugo MP	8	15	0.4440	438	15	2006	Centro IFAPA Almeda del Obispo
Lopez-Urrea R	7	15	0.3890	309	15	2006	Info Instituto Tecnico Agronomico Provincial de Albacete
Raghuwanshi NS	11	15	0.4230	746	15	1998	Indian Institute of Technology Kharagpur

Appendix Table 3. Number of publications and citation metrics of sources with at least eight documents. The impact factor of the journal was retrieved from the 2021 Journal Citation Reports (Clarivate Analytics, 2022). Legend: TC-total citation; NP-number of publication; SYP-start of the year of publication; AC-average citation; IF-impact factor; NR-no record.

Sources	h index	g index	m index	TC	NP	SYP	AC	IF	Publisher
Agricultural Water Management	46	74	1.438	7503	221	1992	33.95	6.611	Elsevier-ScienceDirect
Remote Sensing	20	36	1.429	1498	80	2010	18.73	5.349	Multidisciplinary Digital Publishing Institute (MDPI)
Journal of Hydrology	26	46	0.897	2216	69	1995	32.12	6.708	Elsevier-ScienceDirect
Journal of Irrigation and Drainage Engineering	22	40	0.667	1730	68	1991	25.44	NR	American Society of Civil Engineers
Agricultural and Forest Meteorology	27	46	0.931	2253	59	1995	38.19	6.424	Elsevier-ScienceDirect
Water	12	17	0.857	416	58	2010	7.17	3.530	Multidisciplinary Digital Publishing Institute (MDPI)
Irrigation Science	24	46	0.8	2211	53	1994	41.72	3.519	Springer Nature
Theoretical and Applied Climatology	12	20	0.857	448	31	2010	14.45	3.410	Springer Nature
Hydrological Processes	14	28	0.467	949	28	1994	33.89	3.784	Wiley
Computers and Electronics in Agriculture	14	24	1.167	623	28	2012	22.25	6.757	Elsevier-ScienceDirect
Remote Sensing of Environment	19	26	0.576	1765	26	1991	67.88	13.850	Elsevier-ScienceDirect
Hydrology and Earth System Sciences	16	25	1.067	1003	25	2009	40.12	6.617	European Geosciences Union
Water Resources Research	6	9	0.286	412	9	2003	45.78	6.159	Wiley
Ecological Modelling	7	8	0.269	324	8	1998	40.50	3.512	Elsevier-ScienceDirect

Appendix Table 4. Most cited documents (only documents with at least 200 citations are presented). Legend: TC-total citation; TCY-total citation per year; NTC-normalized total citation.

Authors	Title	DOI	TC	TCY	NTC
Allen et al. (2011)	Evapotranspiration information reporting: I. Factors governing measurement accuracy	10.1016/j.agwat.2010.12.015	561	43.15	19.17
Rana et al. (2000)	Measurement and estimation of actual evapotranspiration in the field under Mediterranean climate: a review	10.1016/S1161-0301(00)00070-8	425	17.71	7.24
Pereira et al. (2015)	Crop evapotranspiration estimation with FAO56: Past and future	10.1016/j.agwat.2014.07.031	351	39.00	14.61
Mcmahon et al. (2013)	Estimating actual, potential, reference crop and pan evaporation using standard meteorological data: a pragmatic synthesis	10.5194/hess-17-1331-2013	350	31.82	10.82
Kumar et al. (2002)	Estimating Evapotranspiration using Artificial Neural Network	10.1061/(ASCE)0733-9437(2002)128:4(224)	317	14.41	5.61
Allen (1996)	Assessing Integrity of Weather Data for Reference Evapotranspiration Estimation	10.1061/(ASCE)0733-9437(1996)122:2(97)	274	9.79	5.85
Allen and Pereira (2009)	Estimating crop coefficients from fraction of ground cover and height	10.1007/s00271-009-0182-z	273	18.20	7.02
Berni et al. (2009)	Mapping canopy conductance and CWSI in olive orchards using high resolution thermal remote sensing imagery	10.1016/j.rse.2009.06.018	266	17.73	6.84
Gowda et al. (2008)	ET mapping for agricultural water management: present status and challenges	10.1007/s00271-007-0088-6	255	15.94	5.63
Drexler et al. (2004)	A review of models and micrometeorological methods used to estimate wetland evapotranspiration	10.1002/hyp.1462	250	12.50	7.28
Norman et al. (2003)	Remote sensing of surface energy fluxes at 10^1-m pixel resolutions	10.1029/2002WR001775	248	11.81	4.90
Allen et al. (2011)	Satellite-based ET estimation in agriculture using SEBAL and METRIC	10.1002/hyp.8408	237	18.23	8.10
Cai et al. (2007)	Estimating reference evapotranspiration with the FAO Penman–Monteith equation using daily weather forecast messages	10.1016/j.agrformet.2007.04.012	221	13.00	6.64
Hanasaki et al. (2010)	An estimation of global virtual water flow and sources of water withdrawal for major crops and livestock products using a global hydrological model	10.1016/j.jhydrol.2009.09.028	215	15.36	6.77
Fan et al. (2018)	Evaluation of SVM, ELM and four tree-based ensemble models for predicting daily reference evapotranspiration using limited meteorological data in different climates of China	10.1016/j.agrformet.2018.08.019	205	34.17	12.05