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Evapotranspiration: A scientometric analysis

Evapotranspiração: uma análise cienciométrica

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Abstract

This study shows how the advent of technologies and the increase of study centers have influenced evapotranspiration estimation methods in different regions of Brazil and worldwide. Therefore, a search was performed, based on Scopus database, on papers containing the word “evapotranspiration” in the title, abstract, and/or keywords. We evaluated the first year of publication available on the platform, the authors of the first publications, the name of the journal in which the work was published, and the country of publication. Then, a new search was performed on papers containing the words “evapotranspiration” AND “estimate” *OR “method” in the title, abstract, and/or keywords. The following were evaluated in each article: i) year of publication; ii) type of study; iii) name of the journal in which the study was published; iv) Qualis CAPES of journals; v) concentration area; vi) keywords; vii) language of origin; viii) country of publication; and ix) estimation method used in Brazil. The FAO-56 standard method is the most widely used, however, remote sensing has been increasingly used in studies.

Additional keywords: bibliographic measuring; loss of water; remote sensing; vegetated surface.

Resumo

O objetivo foi mostrar como o advento das tecnologias e o aumento dos centros de estudos têm influenciado os métodos de estimativa da evapotranspiração nas diferentes regiões brasileiras e no mundo. Assim, fez-se uma busca na base Scopus em trabalhos que continham, no título, resumo e/ou palavras-chave, a palavra: *evapotranspiration.* Avaliaram-se o primeiro ano de publicação disponível na plataforma, os autores das primeiras publicações, o nome do periódico em que o trabalho foi publicado e o país de publicação. Uma nova busca foi realizada em trabalhos que possuíam, no título, resumo e/ou palavra-chave: *evapotranspiration* AND *estimate** OR *method*. Foram avaliados em cada artigo: i) ano de publicação; ii) tipo de trabalho; iii) nome do periódico em que o trabalho foi publicado; iv) Qualis CAPES dos periódicos; v) área de concentração; vi) palavras-chave; vii) idioma; viii) país de publicação, e ix) método de estimativa utilizado no Brasil. O método padrão da FAO-56 é o mais utilizado; no entanto, os trabalhos estão cada vez mais utilizando o sensoriamento remoto.

Palavras-chave adicionais: perda de água; quantificação bibliográfica; sensoriamento remoto; superfície vegetada.

Introduction

Evapotranspiration is a process studied both in hydrology and in climatology, being one of the main elements of the hydrological cycle. Its estimation is important for studies and management of water resources and in the design of irrigation projects (Keskin et al., 2004; Harmsen et al., 2009; Falamarzia et al., 2014). Evapotranspiration includes all processes (transpiration and evaporation) to convert surface water to water vapor (Allen et al., 1998; Verstraeten et al., 2005).

The direct method consists of the use of lysimeters (Jia et al., 2006; Benli et al., 2006; Valipour, 2015). However, it is an expensive technique, making studies often unfeasible. The indirect form can be made from empirical equations that use meteorological elements as input variables. The literature comprises the different methods proposed, as well as their accuracies and limitations (Allen et al., 1989; Rojas & Sheffield, 2013; Jia et al., 2013; Valiantzas, 2013; Kisi, 2013; Dimitrios et al. 2014; Bogawski & Bednorz, 2014; Valipour, 2015; Djaman et al., 2016).

Scientometric studies have been used to evaluate the importance of a subject, author or article, as well as to emphasize future directions and the contri-

butions of a discipline, scientist or research group, institution or country on scientific and technological advances (Carneiro et al., 2008; Nabout et al., 2012).

This study shows show how the advent of technologies (computers, electronic sensors, satellites) and the increase of study centers (colleges, universities, institutes, researchers) have influenced evapotranspiration estimation methods in different regions of Brazil and worldwide.

Materials and methods

The scientometric survey was carried out using the database "SciVerseScopus" (http://www.scopus.com/scopus/home.url). According to the publisher, Elsevier (2014), this database has the largest number of indexed journals.

The search was carried out until the year 2016 on papers containing the word “evapotranspiration” in the title, abstract, and/or keywords. We evaluated the first year of publication available on the platform, the authors of the first publications, the name of the journal in which the study was published, and the country of publication.

In addition, a new search was performed on papers containing the words “evapotranspiration” AND “estimate” *OR “method” in the title, abstract, and/or keywords. Data were collected on November 3, 2017. The following were evaluated in each article: i) year of publication; ii) type of study; iii) name of the journal in which the study was published; iv) Qualis CAPES of journals; vi) concentration area; vi) keywords; vii) language of origin; viii) country of publication; and ix) estimation method used in Brazil.

Results and discussion

According to the survey using the term evapotranspiration, 26,432 studies were found. The first studies that used this term were published in 1944 (n = 3), the first authors being Blaney (1944a; 1944b), with two papers, and Musgrave (1944), with one paper. These studies were published in the form of articles in the journals ‘Soil Conservation Service’ and ‘United States Department of Agriculture’, both edited in the United States.

The term evapotranspiration - ET was introduced by Thornthwaite & Wilm (1944), describing the simultaneous occurrence of evaporation and transpiration processes on a vegetated surface (Camargo, 1962).

The year 1948 is considered by many researchers as a landmark in the study of evapotranspiration, since two important scientific contributions have arisen in the fiedls of agriculture, climatology, and hydrology. The first was Warren Thornthwaite's "An approach towards a rational classification of climate" (1948), and the second was Howard Penman's "Natural evaporation from open water, bare soils and grass" (1948).

According to Sediyama (1996), Thornthwaite wanted to explain the seasonal variations of the soil water balance and tried to define regional climate differences. Penman, on the other hand, was concerned with the physical processes involved in evaporation and with the search for an equation estimating the evaporation rate of free water and soil water from relevant climatic elements: radiant energy, temperature, humidity, and wind speed.

These articles do not appear in the search, due to title, abstract, and/or keyword limitation. Both articles do not have abstract and keywords, and the title does not have the word “evapotranspiration”.

The search for studies containing the words “evapotranspiration” AND “estimate” *OR “method” in the title, abstract, and/or keywords identified 11,976 publications. Figure 1 shows an exponential adjustment between the number of published works as a function of the year of publication ($R^2 = 0.961$). There were no publications in the years 1945-1947, 1949, and 1954.

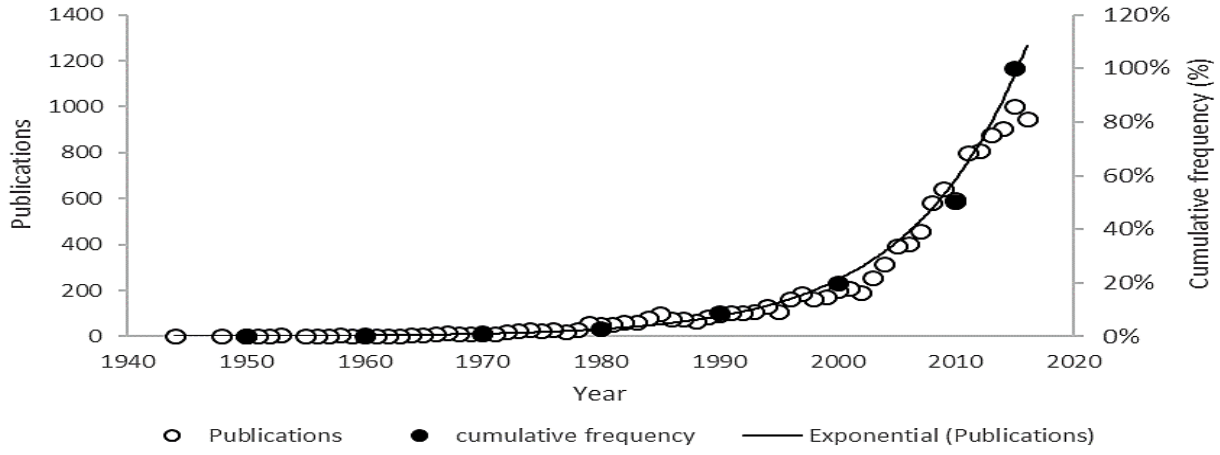

Figure 1 - Number of papers published according to the years after the first publication (n = 11976). Publications from 1944 to 2016.

The study showed an annual increase in scientific production from 1998, the same year of publication of the FAO-56 Bulletin. Until 1998, ETo was estimated using mathematical models; however, precision problems arose, mainly due to the lack of fit of their respective coefficients, reading errors, sensor accuracy, and because they were developed for specific climatic and agronomic conditions (Barros et al., 2009).

For this reason, the FAO (United Nations Food and Agriculture Organization) and the International Commission on Irrigation and Drainage (ICID) standardized the Penman-Monteith method in Bulletin 56, recommending it as the standard method for ETo estimation. It is noteworthy that climatic and physiological data are necessary for its application, (Allen et al., 1998) and that, under special climatic conditions, errors close to 30% may occur (Widmoser, 2009).

Most studies (n = 10,048; 84%) were published as scientific papers. Publications such as conferences (n = 1,570; 13%) and reviews (n = 203; 2%) were also highlighted. Notwithstanding, other types of publications accounted for less than 1.0% of the total. According to Pinto & Grelle (2009), scientific studies are mostly published in the form of articles in the different areas of knowledge, being a generalization of studies and research.

The papers analyzed were published in 145 different journals. In 75.9% (110) of the journals, we observed a number less than 50 published papers per journal. Forty point eight percent (40.8%) of the publications (4,883 publications) were concentrated in 31 journals (Figure 2), and the 'Journal of Hydrology' was the journal that most published scientific research on this theme (5.1% of articles).

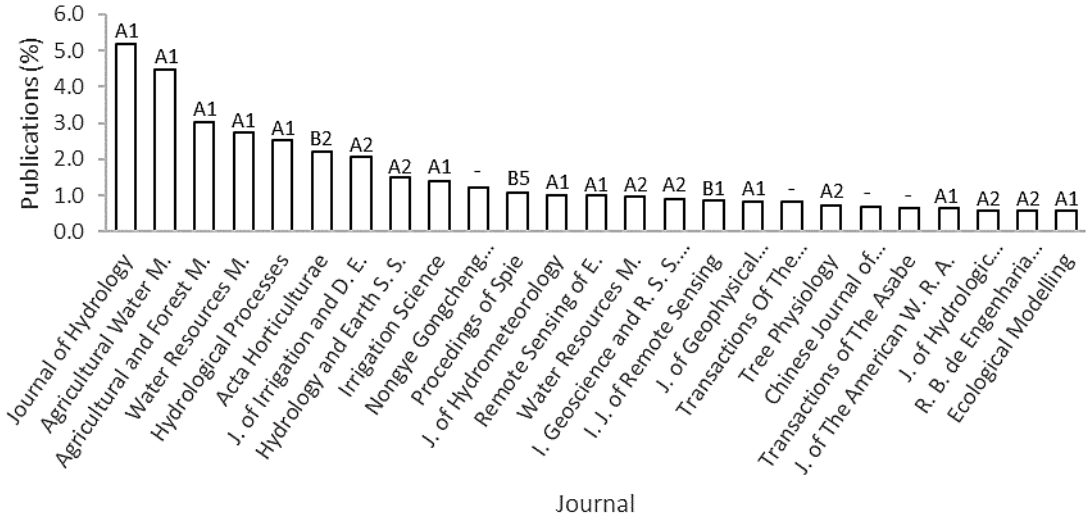

Figure 2 - Percentage of publications of the main journals published in the analyzed papers and the QUALIS of each journal.

Another relevant fact is that most of the studies are within the scope of "Environmental Sciences" (n = 6116), preceding "Agrarian and Biological Sciences" (n = 5324). Next, we find "Earth and Planetary Sciences" (n = 4457) and "Engineering" (n = 1747) (Figure 3).

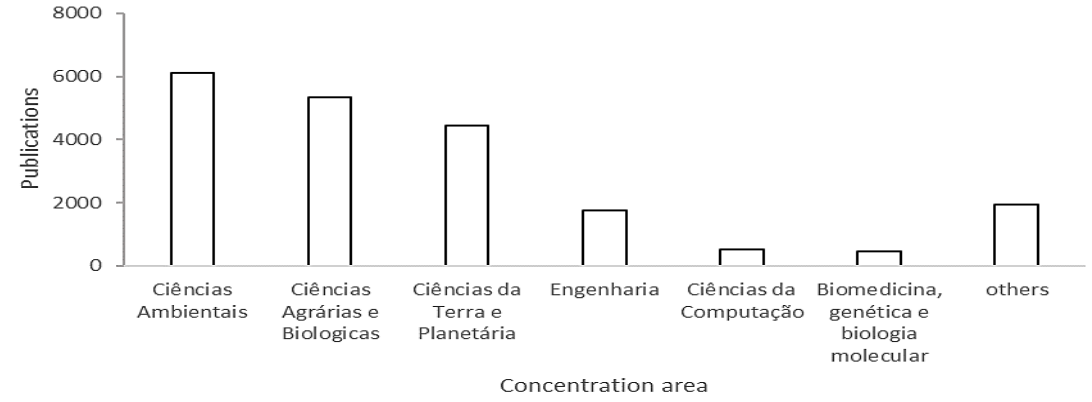

Figure 3 - Main areas of papers published according SCOPUS platform.

As for keywords, only words with a number of citations above 880 (Figure 4) were described. The most cited word was "Evapotranspiration" (7727 studies), which may have occurred because this word was part of the search, followed by "Water Supply" (n = 2882) (Figure 4).

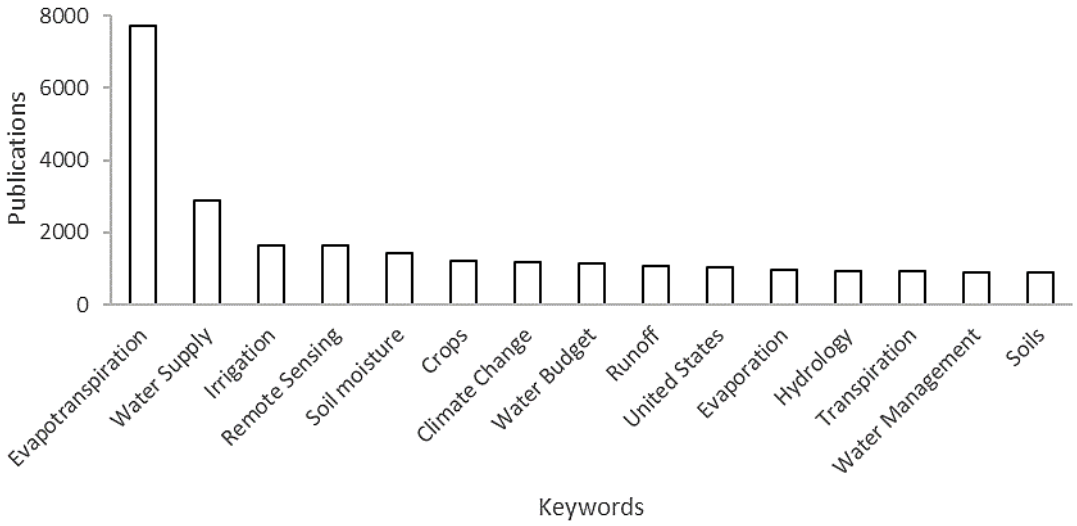

Figure 4 - Most frequent keywords in the analyzed papers.

Most studies were written in English (n = 9906; 90.7%), followed by Chinese (n = 493; 4.5%), Portuguese (n = 267; 2.5%), Spanish (n = 100; 0.91%), and French (n = 99; 0.91%). Thus, the United States obtained the largest number of publications (n = 3805), second to China (n = 1965). Brazil ranked 4th in terms of number of publications (n = 565) (Figure 5).

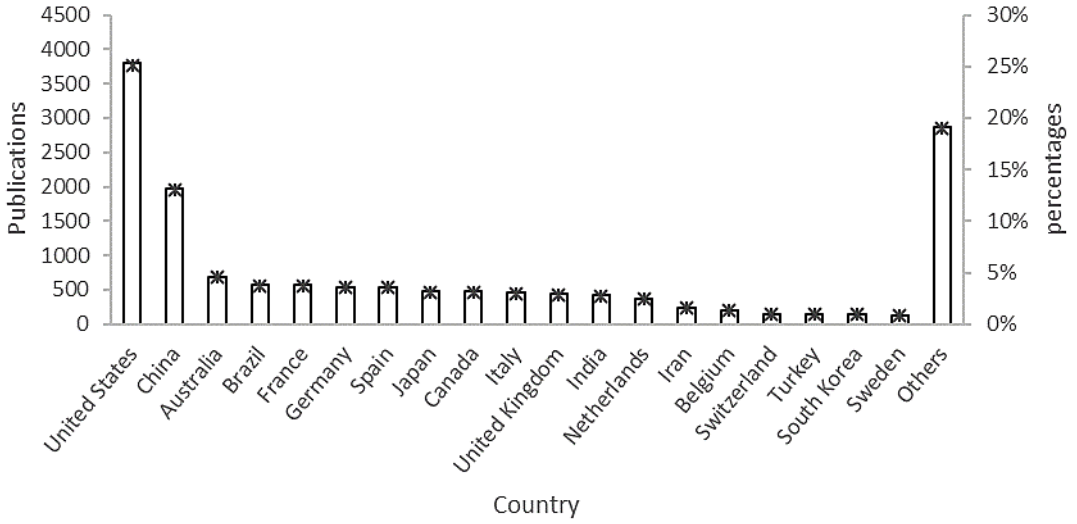

Figure 5 - Number of papers published in each country (columns), and their respective percentages (*).

Brazil has published 1128 papers (Figure 6), which represent 9.4% of the total. According to the search, the first Brazilian study was published in 1978, by Mota (1978), from the University of Pelotas, Rio Grande do Sul. However, the study of Camargo (1962) was recognized as a pioneer, being published as a technical bulletin of the Agronomic Institute of São Paulo; followed by Camargo and Pereira (1981), Camargo and Camargo (1983), and Camargo and Sentelhas (1997). An important fact to be mentioned is that in 1960 began the establishment of several post-graduate courses in agriculture in Brazil, favoring the beginning of publications.

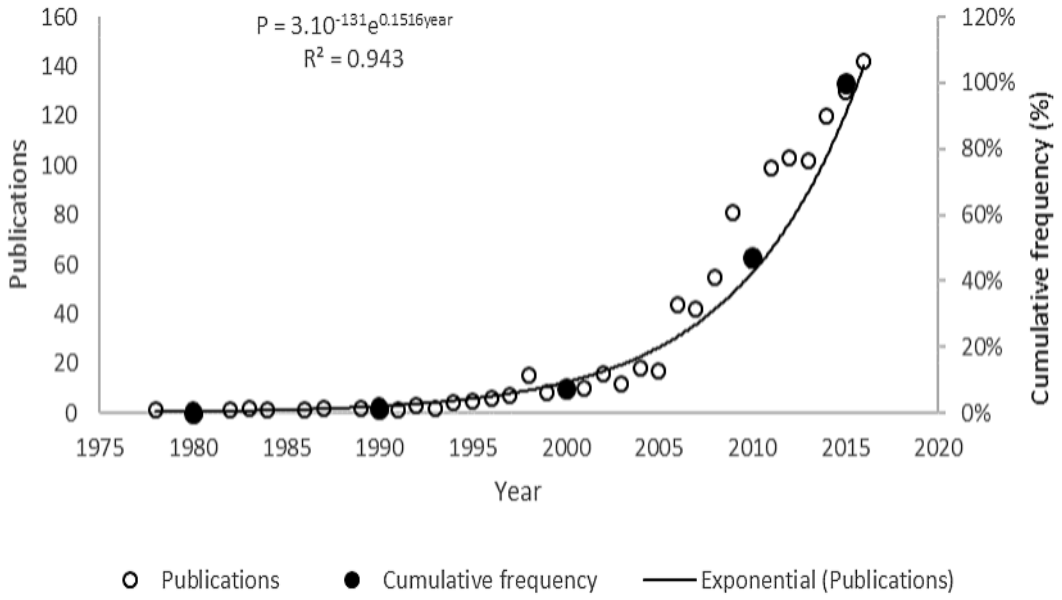

Figure 6 - Number of Brazilian papers published (n = 1128) according to the years after the first publication.

The Brazilian journal 'Irriga' published most of the scientific papers with the subject (n = 118; 12%). Figure 7 shows the journals with number of publications equal or superior to 10 publications. The authors who published the most, respectively, are Gilberto Chohaku Sediyama, Bernardo Barbosa da Silva, Janice Freitas Leivas, Everardo Chartuni Mantovani, and Antônio Heriberto de Castro Teixeira.

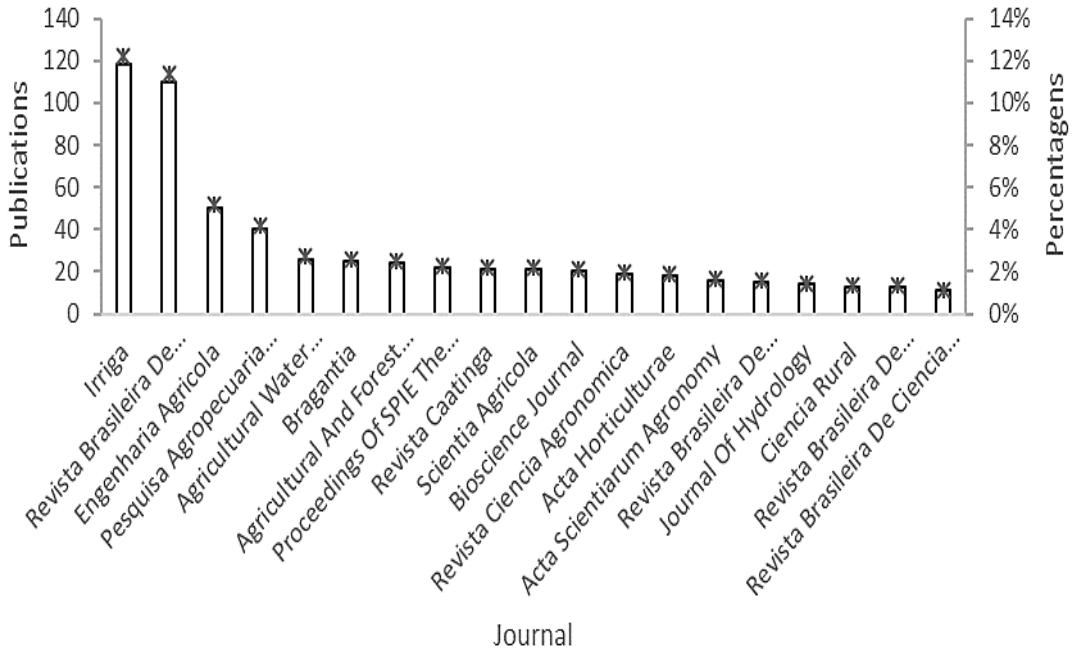

Figure 7 - Main Periodicals of publication of the analyzed papers.

Institutions with the highest number of publications were also evaluated (Figure 8). It should be noted that only institutions with more than 25 publications were analyzed, the most outstanding being the University of São Paulo (USP), with n = 199 publications.

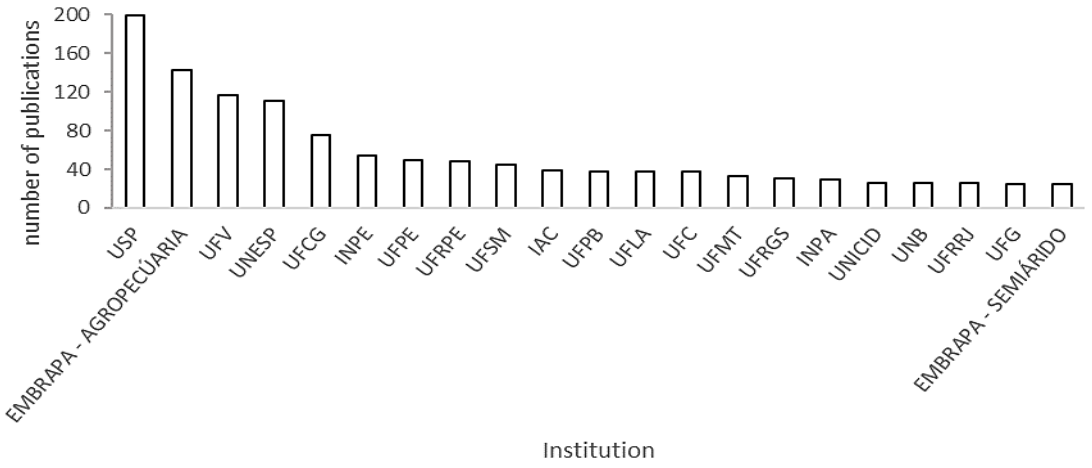

Figure 8 - Main Institutions that published evapotranspiration papers.

Regarding evapotranspiration estimation methods, the most used method for the determination of evapotranspiration in Brazil is the FAO Penman-Monteith standard method, followed by the Thornthwaite method. Moreover, evapotranspiration estimation from algorithms that have orbital images as input data has increased (approximately 6%).

Conclusions

Research has shown that scientific production on evapotranspiration has been increasing worldwide, showing the importance of the topic.

The most commonly used method for estimating evapotranspiration is the FAO-56 standard method. Notwithstanding, research shows interest in optimizing estimation methods; thus, studies are increasingly using satellite imagery (remote sensing).

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