Research Trends in Water Management by Using Environmental Parameters Derived from Remote Sensing

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Abstract

Water management is one of the most important strategies for sustainability. In many regions, this management is not easy and remote sensing can be useful to have data about the water status, especially from environmental derived indices associated with satellite data. It is important to know the research trends based on water management and remote sensing. Policy decision making in water management could be assisted and improved considering this tool. The aim of this work is to explore remote sensing articles that use environmental indicators in the last twenty years for the study of water resources by using a bibliometric analysis.

Keywords: Evapotranspiration; Soil Moisture; Vegetation index; Water Reservoir

Introduction

Water is an essential resource for social, environmental, economic and technological development [1]. Therefore, protection of the planet's water resources and minimization of the impacts that our activities generate on them is crucial. In fact, guaranteeing the availability of water and its sustainable management is one of the goals of the 2030 Agenda for Sustainable Development [2]. With the rapid population growth, it is necessary to guarantee both access to quality drinking water and food production. For this reason, agriculture is one of the main human activity that generates more pressure, not only on water consumption, but also on groundwater and surface water pollution. Other industrial activities or energy generation also have a direct implication on water quality. It is of great importance for the maintenance of societies and ecosystems to implement efficient policies for water management and promote the development of sustainable technologies, especially taking into account the future climatic conditions of water scarcity under the different scenarios of climate change. Behind the water management and the scarcity of renewable resources, there are severe latent socioeconomic conflicts.

In many regions of the world, water management is complex for several reasons, but accessibility to control and measure the resource is one of the most important. Remote sensing has evidenced to be a multidisciplinary, very useful and effective tool for the study of the Earth environmental processes and resources. Due to the amount of information collected and the data processing capability of time series at different scales, remote sensing allows the development of methodologies in order to improve knowledge about the elements implied and the water dynamics and obtaining models that help in decision-making. Remote sensing is used in a wide variety of studies and in recent decades, a large number of indices have been developed such as those based on measuring vegetation properties. The role of vegetation indices as valuable biophysical data for models have been highlighted by several authors [3]. Reservoirs, among others, are key elements of surface water management thus monitoring their dynamic is essential for policy makers [4]. As well, irrigation is one of the main activities to take into account in water management therefore, knowing the soil moisture content can be influenced by agricultural irrigation practices [5].

Under a global view, it could be helpful to determine the trend of the research on the use of remote sensing and water management. In this case, the study of environmental and biological derived indices used in remote sensing and a bibliometric analysis can be used to know the impact or research potential and science community

contribution. A bibliometric study allows us to perform a statistic and descriptive analysis to evaluate and quantify the evolution of different fields in order to know the scientific community advances, the interest or impact of an issue, the research potential, etcetera [6]. Although there are several scientific and multidisciplinary databases such as Google Scholar or ScienceDirect, Scopus [7] offers a wide peer-reviewed publications and implements for a preliminary literature analysis despite being a subscription citation database. The aim of this work is to explore remote sensing methods that use environmental indicators over the last twenty years to the study of water resources and management by using a bibliometric analysis.

Materials and Methods

A descriptive-retrospective bibliometric study of the last 20 years (2000-2019) of articles indexed in the Scopus database (conference paper, review, books, chapters, etc. were excluded) was performed using the keywords "water management" and "remote sensing" as starting point of search. The advanced search was applied after that with different keywords related to water management and remote sensing. The field code title-abs-key were used with different environmental terms. These terms are associated with biological indicators and were vegetation index, soil moisture and reservoir.

From Each of Them, the Search was Narrowed Down Adding more terms as Follow:

a) To the term "vegetation index", "NDVI" (Normalized Difference Vegetation Index) or "LAI" (Leaf Area Index) were added. Both common indices used in remote sensing.

b) "Soil moisture" was complemented with "Evapotranspiration" or "SWI" (Soil Water Index).

c) The terms "evaporation", "water level", "surface" and "vegetation" were used after searching by using "reservoir".

Results and Discussion

The information analyzed comes from a total number of 1,205 articles obtained searching by using the terms "water management" and "remote sensing", published between 2000 and 2019. Figure 1 shows the number of articles published containing only the terms used. Therefore, 112 documents of the initial 1,205 fit with "vegetation index" as a search term and in this group, 73 results were obtained searching with "NDVI" and only 5 with the term "LAI". After the search by using "soil moisture" (129 articles), the term "evapotranspiration" gave 61 results, and the "SWI" only 3. Moreover, 96 articles of "reservoir" were searched where 48 were associated with "surface", and 10 with "water level", 11 related to "reservoir" plus "vegetation", and 6 articles with "evaporation". One of the most important results is that the publications has been increasing in recent years, mainly since 2004 as Figure 2 shows. This increment may be related with different dry periods over the world

in the last years that concern researchers about the importance of these studies based on a global tool like remote sensing and the sue of satellite images. According to World Resources Institute and FAO, some regions as Northern Africa, Central Asia, Southern and Eastern Asia, Oceania and Southern and Central America are exposed to water stress [8,9]. For instance, in Europe during the years 2004 to 2007 the drought affected mainly to the Iberian Peninsula and it was one of the worst in recent years causing severe socioeconomic impacts [10]. Between 2012 and 2014 the United States experienced one of the most severe drought in which 60% of the territory and the 80% of productive agriculture lands were affected [11]. In this sense, this review wants to point to the need to study water management from the perspective of climate change and the use of remote sensing as a basic tool.
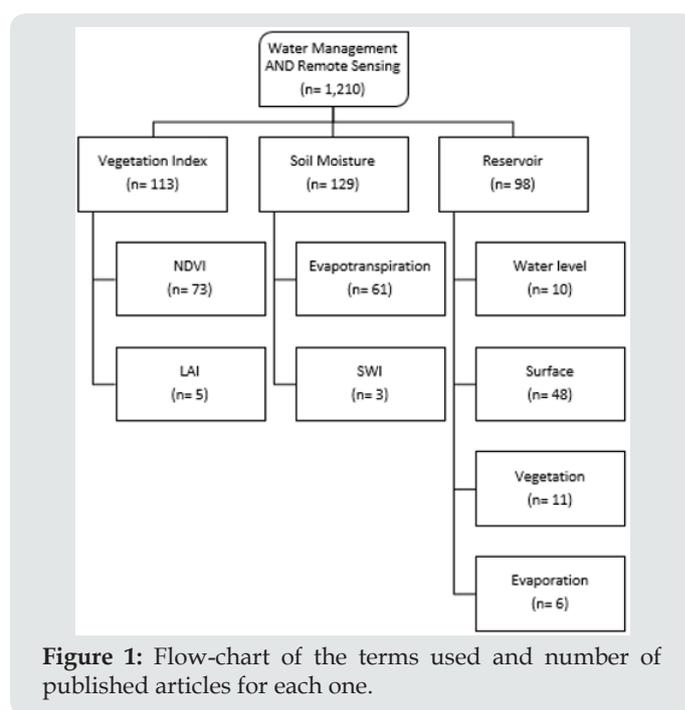

Figure 1: Flow-chart of the terms used and number of published articles for each one.
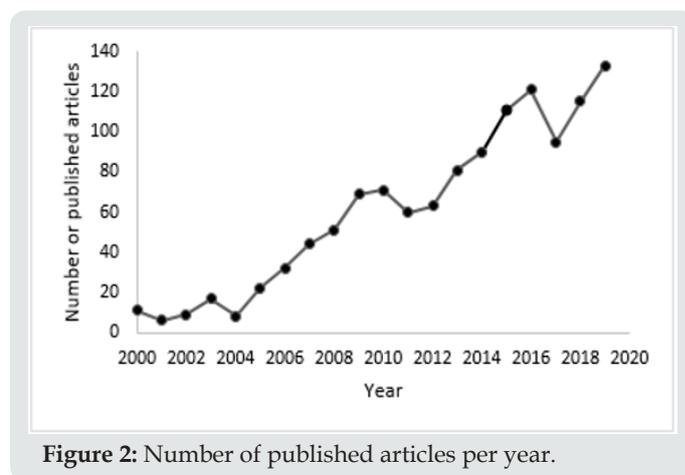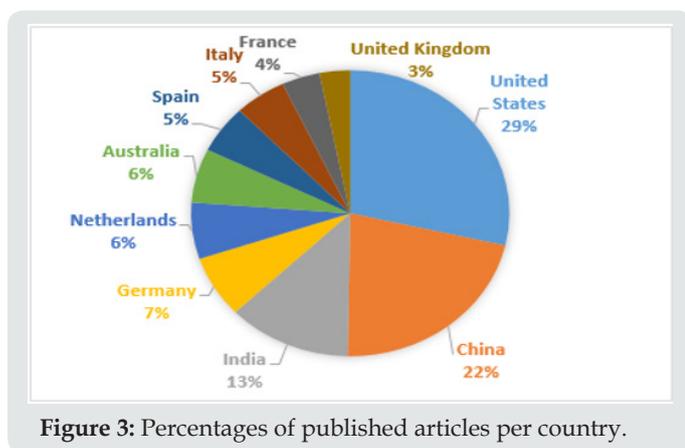

Figure 2: Number of published articles per year.

The countries that have published more articles about "water management" and "remote sensing" topics found in Scopus database are shown in Figure 3. Some of the reasons that could

explain this distribution are the climatic, social and economic conditions of the country, the scientific community concern, the technological facilities or the investment by public and private organizations. It is important to notice that 51% of the articles are from United States of America and China, two countries that cover a large area, present very different climatic patterns and have important satellite programs. In the United States, there is a great interest in research on water resources, especially for irrigation and electricity generation, but in which there are no unify water management plans [12]. China is a country with a great agricultural development. There are arid and semi-arid areas as in northern of China with problems of overexploitation of water resources [13]. Many space and satellite programs depend on the China National Space Agency (CNSA) and others Chinese institutions and, as Table 1 shows, they sponsored many articles about remote sensing and water management. The third country with important research on water management and remote sensing is India. This country has regions with great precipitation patterns fluctuations. There are areas in which, the growing population does not have access to drinking water. Moreover, agriculture is the economic driver and traditional irrigation methods are still used [13,14]. In fact, India is one of the countries more involved in satellite and space programs and has undergone a rapid expansion in recent decades [15].

Table 1: Funding sponsors of articles published on water management and remote sensing.

Funding Sponsors	Articles
National Natural Science Foundation of China	89
National Aeronautics and Space Administration	22
Chinese Academy of Sciences	17
National Science Foundation	16
National Basic Research Program of China (973 Program)	13
Deutscher Akademischer Austauschdienst	11
Fundamental Research Funds for the Central Universities	11
China Scholarship Council	10
Conselho Nacional de Desenvolvimento Científicoe Tecnológico	10
European Commission	10

Figure 3: Percentages of published articles per country.

Table 2: Impact metric in the journals with more published articles about "water management" and "remote sensing".

Journals	JIF (2018)	Total, Cites (2018)	Impact Factor without Journal Self Cites	Quartile (2018)
Remote Sensing	4.118	23,567	2.991	Q1
Agricultural Water Management	3.542	14,058	3.012	Q1
Journal of Hydrology	4.405	54,625	3.763	Q1
Science of the Total Environment	5.589	97,467	4.723	Q1
International Journal of Remote Sensing	2.493	22,212	2.207	Q2
Remote Sensing of Environment	8.218	54,482	7.242	Q1
IEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing	3.392	9,671	3.011	Q2

Table 3: Top ten most cited articles about "water management" and "remote sensing" in the last twenty years.

Articles	Source Title	Cited	Country
Gorelick N et al. [17]	Remote Sensing of Environment	582	Switzerland
Alsdorf DE et al. [18]	Reviews of Geophysics	475	United States
Bastiaanssen WGM et al. [19]	Journal of Irrigation and Drainage Engineering	448	Netherlands
Kim Y et al. [20]	IEEE Transactions on Instrumentation and Measurement	340	United States
Allen RG [21]	Journal of Hydrology	286	United States
Anderson MC et al. [22]	Remote Sensing of Environment	269	United States
Voss KA et al. [23]	Water Resources Research	248	United States
Bastiaanssen WGM et al. [24]	Agricultural Water Management	246	Sri Lanka
Cifre J et al. [25]	Agriculture, Ecosystems and Environment	196	Spain
Jha MK et al. [26]	Water Resources Management	192	India

After this overview, the impacts on Scientific Community are presented in the following tables. Table 2 shows the metric impact of the journals with more published articles about remote sensing and water management in the last 20 years considering the Journal Citation Reports (JCR) [16]. Only two of the journals described in Table 2 are in Q2, the rest of them are in Q1. However, Table 3 shows the 10 most cited articles, and as it can be observed, only 4 of them are published in the journals mentioned in Table 2. Moreover, except for "Journal of Irrigation and Drainage Engineering" which is in Q3, all of the rest articles are published in Q1 journals. Table 3 presents the most cited articles about water management and

remote sensing and, in Table 4, the most cited articles according to the keywords used. Only two articles are in both tables, which means that environmental derived indices (from vegetation and soil) do not have the same consideration for all the scientific community involved in remote sensing plus water management. According to the Figure 3, articles per country, and Tables 3 and 4, United States of America is the country with more publications, even though collaborations between countries are very frequent due to the presence of researchers of several countries as co-authors. The author who most articles has provided in relation with water management and remote sensing is from Netherlands as Table 5 reports, but most of the top ten authors are from the United States of America.

Table 4: Most cited articles according to the terms used in the bibliometric analysis.

Term	Article	Cited	First Author Country
Water management and remote sensing	Gorelick N et al. [17]	582	Switzerland
Vegetation index, NDVI	Senay GB et al. [27]	138	United States
Soil moisture	Fang QX et al. [28]	139	China
Evapotranspiration	Wu B et al. [29]	99	China
SWI	Brocca L et al. [30]	101	Italy
LAI	Alemayehu T et al. [31]	11	Belgium
Reservoir, surface, vegetation	Alsdorf DE et al. [18]	475	United States
Water level	Crétaux J-F, Birkett C [32]	163	France
Evaporation	Oberhänsli H et al. [33]	24	Germany

Table 5: Top ten authors and number of published articles about "water management" and "remote sensing".

Author	Articles	H-Index	Country
Bastiaanssen WGM [24]	18	45	Netherlands
Allen RG [21]	11	51	United States
Kustas WP [22]	11	71	United States
Anderson MC [22]	10	55	United States
Chowdary VM [26]	10	21	India
Gao F	10	31	United States
Jha MK [26]	10	25	India
Alfieri JG	8	18	United States
Simonneaux V	8	13	France
Boulet G	7	27	France

In addition, among the most cited articles are some where the first author is Bastiaanssen, W.G.M., Allen, R.G. or Anderson, M.C. In this sense, these authors are key researchers in the scientific community taking into consideration water management and remote sensing.

Conclusion

According to this search carried out in Scopus database, United States of America, China and India are the countries with more articles published by their researches as first author about remote sensing and water management. They are involved in important space and satellite programs and have a great technological potential. Moreover, their administration supports this type of research and favor the technological progress in remote sensing. The rest of the countries are mainly situated in the European Union and Australia. Vegetation (vegetation and vegetation index) is the biological parameter that appears in the majority of the articles and soil is less considered. In general, vegetation indices are easily to obtain from satellite data (many sensors have the Red and Infrared band to measure this parameter) although new satellite sensors are improving the capability to study soil moisture. The management of renewable resources would be based in the use of sensors and biosensors, and what is desirable is that this technology can be extended to developing countries to help them to sustainable resource management and policymaking.

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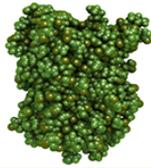
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