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BIBLIOMETRIC ANALYSIS OF WATER FOOTPRINT

SU AYAK İZİNİN BİBLİYOMETRİK ANALİZİ

Elif ÇALOĞLU BÜYÜKSELÇUK *

ABSTRACT

With the effect of industrialization and globalization, a rapid increase has occurred in the use of water resources in parallel with the rapid increase in the welfare levels of societies and population increase in the last century. People consume water directly or indirectly during the day. Protection of water resources has become an important and current issue for the sustainability of future generations. In this study, studies on water footprint around the world are discussed and summarized. With the detailed analysis of 2138 publications (access date to WOS: February 1, 2021) in the "water footprint" or “green water footprint” or “blue water footprint” or “grey water footprint” topics between 2006 and 2021 in the Web of Science database, it is aimed to shed light on researchers who plan to work in this field. With bibliometric analysis, issue trends were analysed with the number of publications, publication year, country, institutions and universities, publication language, type of publication, cited references information and keywords. In this study, visual contents were prepared using VOSviewer.

Keywords: Water footprint, VOSviewer, Bibliometric analysis, Web of Science

ÖZET

Son yüzyılda, sanayileşme ve küreselleşmenin etkisiyle birlikte, toplumların refah düzeyleri ve nüfusun yükselişine paralel olarak su kaynaklarının kullanımında hızlı bir artış meydana gelmiştir. İnsanlar gün içinde doğrudan veya dolaylı olarak su tüketirler. Su kaynaklarının korunması, gelecek nesillerin sürdürülebilirliği için önemli ve güncel bir konu haline gelmiştir. Bu çalışmada, dünya genelindeki su ayak izi ile ilgili çalışmalar tartışılmış ve özetlenmiştir. 2006 ile 2021 yılları arasında Web of Science veri tabanında "su ayak izi" veya "yeşil su ayak izi" veya "mavi su ayak izi" veya "gri su ayak izi" konularında 2138 yayının (WoS'a erişim tarihi: 1 Şubat 2021) detaylı analizi ile bu alanda çalışma yapmayı planlayan araştırmacılara ışık tutması amaçlanmıştır. Bibliyometrik analiz ile yayın sayısı, yayın yılı, ülke, kurum ve üniversiteler, yayın dili, yayın türü, atıfta bulunulan kaynak bilgileri ve anahtar kelimeler ile konu trendleri analiz edilmiştir. Bu çalışmada görsel içerikler VOSviewer kullanılarak hazırlanmıştır.

Anahtar Kelimeler: Su ayak izi, VOSviewer, Bibliyometrik analiz, Web of Science

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Endüstri Mühendisliği Bölümü,
Fenerbahçe Üniversitesi, İstanbul / Türkiye

Department of Industrial Engineering,
Fenerbahçe University, Istanbul / Turkey

ORCID: 0000-0002-5976-6727

1. INTRODUCTION

Water is a crucial element for industrial, agricultural and livestock areas and people's domestic activities (Hoekstra & Chapagain, 2006). The water consumed in the course of the production process of any product, regardless of its type, is actually related to this product and this used water is defined as "virtual water". Economic activities such as import and export between countries are actually activities carried out for virtual water in this context. Water footprint is defined as the volume of fresh water people use as a result of their activities in order to survive (Hoekstra & Hung, 2002).

The water footprint is an indicator of the amount of used and polluted of the water for an industry, an individual, a country or an organization. Water can be used directly or indirectly in daily life. While people use the water that is defined direct water for their daily activities such as eating, drinking and bathing, for example the water used in the process of a bread from the field to the final consumer is also defined as indirect water (Figure 1).

Figure 1. Direct and Indirect Water Use

The water footprint consists of three components coded according to their color. These are green, blue, and gray water footprints. The green water footprint is the water that results from precipitation. This water is stored by the soil, evaporates or takes place in the plants. Especially it concerns agricultural, forestry and gardening. The blue water footprint refers to groundwater and surface water. This water can be evaporated, used during the manufacture of a product, or taken from one body of water, immediately or later added to another body of water. Domestic water or water used for industrial activities can be evaluated under the group. Grey water footprint refers to the fresh water used to bring the polluted water to the specified standards. The water footprint components are represented in Figure 2. There are global scale calculation standards put forward by various researchers to calculate the water footprint (Mesfin M. Mekonnen & Hoekstra, 2012).

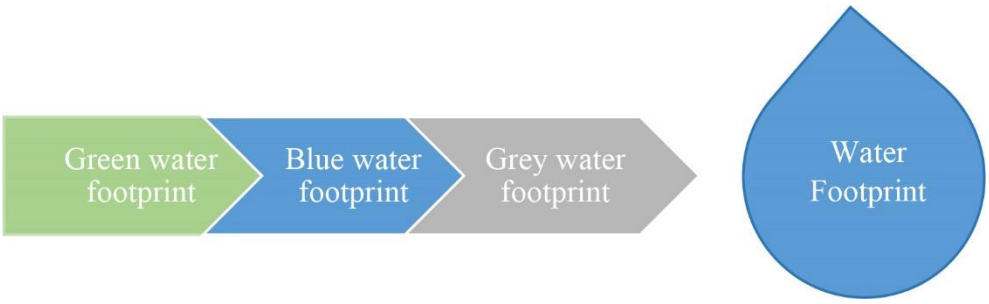

Figure 2. Water Footprint Components

Water consumption is increasing rapidly all over the world in parallel with the rapid rise in human population and industrialization. However, the key point here is that usable clean water resources are not infinite resources, and it is explicit that human beings will experience water scarcity by the 2050s as a result of unconscious consumption of these resources. When considered globally, 70 percent of fresh water resources are used for agricultural activities and also fertilizers or drugs used for agricultural activities negatively affect fresh water resources (Adetoro et al., 2020; Dai et al., 2021). In fact, not only these factors but also human beings will face the impoverishment and destruction of water resources due to global climate change.

Humanity, facing such a serious problem, should urgently offer effective solutions to this problem. Researchers first addressed this issue since 2006 and tried to evaluate the situation with different perspectives. The increasing use of fresh water for agricultural, industrial, live-stock or domestic usages has revealed the importance of applying a controlled water management. Recognizing the importance of the issue, governments have accelerated their efforts to ensure the sustainability of life. As a result of the review of the literature, the Chinese government have promoted the use of new irrigation techniques in agricultural areas, ensuring the protection of water resources, and also aimed to identify key sectors for water resources (Deng et al., 2020). In a study conducted in Iran, the researchers, as a result of their examination of 45 buildings, actually aimed to contribute to reducing the water footprint in the construction sector (Hosseinian & Ghahari, 2021). In South Africa, which is among the regions suffering from water scarcity, development of irrigation techniques and similar measures have been discussed in order to reduce the water footprint required for sugar cane production. The economic consequences of reducing the water footprint are also evaluated (Adetoro et al., 2020). Researches are carried out in different parts of the world for the effective and efficient management of water resources, measures to be taken to prevent water scarcity, the duties of governments and actions to be taken regarding water footprint (Hogeboom, 2020). A study conducted in various parts of the world, for example in India, aimed to calculate and evaluate the water footprint for food and cooking activities for rural areas (Das et al., 2021).

2. MATERIALS AND METHODS

Bibliometry can be expressed as the whole of mathematical and statistical methods applied to publishing tools as books, magazines, etc. or to documents published there (Pritchard, 1969). Bibliometry consists of three concepts. Informetrics examines the numerical state of information in all forms. Scientometrics is the mathematical analysis of science. In

webometrics, content analysis of web pages, analysis of web links, web usage analysis and web technology analysis are performed (Price, 1976).

Bibliometric laws include Bradford's, Lotka's, Zipf's, Price, and Pareto Laws. According to Bradford's Law, when journals are ranked from best to worst according to their efficiency, there is a nucleous group of journals that are more relevant to a particular topic. On the other hand, there are other field groups that contain the same number of articles as the core journal group in the nucleous group (Alabi, 1979). Lotka's Law measures the productivity of scientists. It is also defined as the inverse square law of efficiency (Adigwe, 2016). Zipf's Law states that the length of a word is closely related to the frequency of use of that word. The fewer letters a word consists of, the more frequent it is used (Saichev et al., 2010). The Price Law says that half of all scientific research papers are written by the number of authors equal to the square root of the total scientists writing on that subject. The Price Law says that half of all scientific research papers are written by the number of authors equal to the square root of the total scientists writing on that subject (Dehdarirad, 2016). Pareto's Law is also known as the 80/20 rule. It is said that an estimated 80 percent of the publications were made by 20 percent of the sources (author, journal, ...) (Bailón-Moreno et al., 2005).

In this study, it is aimed to that bibliometric analysis has been used to research and analyze the water footprint, which is one of the hot topic topics of recent years, and to create a detailed report of the studies in the literature. Bibliometric analysis is aimed at analyzing scientifically published books, articles, book chapters statistically and shedding light on other researchers with this reporting (Lee et al., 2020). In 1926, Alfred Lotka investigated the efficiency of researchers and authors and formed the basis of the Bibliometric analysis defined as Lotka's law. In the years that followed, Samuel Bradford analyzed the frequency distribution of articles published in a specific area. In fact, the laws put forward by these two researchers formed the basis of Bibliometric Analysis. Actually, it gives mathematical and statistical meanings to published papers such as articles, books, book chapters. Web of Science (WoS), Scopus and Google Scholar databases are widely used in bibliometric analysis, however, among of them, the most valuable database is WoS (Thompson & Walker, 2015).

There are researchers in the literature who use this analysis to examine many different topics. Bibliometric analysis was used to evaluate universities for innovative research and it was concluded that universities in the United States of America and United Kingdom are pioneers in innovative activities (Cancino et al., 2017). Cebrino and Cruz, on the other hand, analyzed the researches on violence against healthcare personnel in the work environment using the same technique and concluded that since 1992, studies have been concentrated especially in the United States of America (Cebrino & Portero de la Cruz, 2020). It has been determined that bibliometric analysis is used in researches conducted in many different sectors. Studies conducted for gastric disease since 1965 were examined and the most cited ones among them were analyzed in detail (Yuan et al., 2020). Recently, scientific studies on COVID-19, the world's biggest problem, have been scanned in both British and Chinese databases and bibliometric analyzes of these studies have been made. It can be said that the publications published in English shed light on the world of medicine and science and are important sources of exchange of ideas. It has been concluded that publications in Chinese may actually be more useful resources for local researchers (Fan et al., 2020). Thanks to this technique, which is also applied on Medical Big Data, detailed and guiding information flow is provided to researchers (Liao et al., 2018).

There are many studies in the literature that use bibliometric analysis. A number of analyzes and evaluations have been made in order to guide the researchers about the water footprint, which is the key point in this study.

3. APPLICATION OF BIBLIOMETRIC ANALYSIS

Within the scope of this study, firstly, "Web of Science Core Collection"(indexes: SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI) was used as a database. This may be a limiting factor for the study, but it was widely preferred to use the most preferred database. While researching studies published between 2006-2021 in the

database, the keywords "water footprint" or "blue water footprint" or "green footprint" or "grey footprint" were used as "topics". As a result of this search, 2138 published articles, boks or book chapters on the subject were reached. Then, the information of these articles was analyzed with bibliometric analysis according to the publication year, types of publications, language, number of publications, and subject. The results obtained using the Web of Science database are presented below. In the course of the data collection in the study, the answers to the following questions were sought:

- In which years have studies on "water footprint" been conducted?
- What is the distribution of the types of publication of the studies on "water footprint" in the literature?
- What are the number of authors in a study on "water footprint"? (Single author, double author, three authors etc.)
- In which journals are the studies on "water footprint" in the literature generally published?
- What is the language for the studies on "water footprint" in the literature?
- In which countries have studies on "water footprint" been conducted?
- In which organizations have studies on "water footprint" been conducted?
- Among the studies on "water footprint" and the authors who made studies on this subject, which were the most cited?
- What are the frequently used keywords related to the subject in the literature?

3.1. Publication Year

Since water footprint is a concept introduced by Hoekstra for the first time in 2002 (Vanham & Mekonnen, 2021), the period from 2002 to nowadays has been evaluated in this study as a date range. In Figure 3, the numbers of the publications within the scope of the water footprint related subject by years is given.

Various researchers have conducted studies on water footprint since 2006 and the number of studies on this issue has gradually increased. 48 studies were conducted in the first month of 2021 and this number is expected to increase by the end of this year. Because all countries of the world will start to face water shortage due to various reasons. Countries, governments, industries, or individuals should work together to take necessary action.

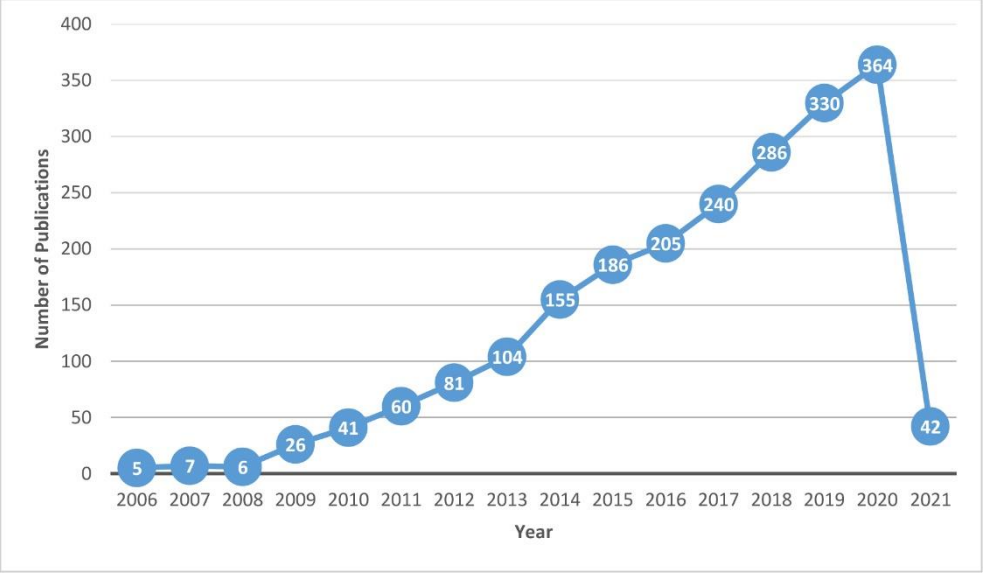

Figure 3. Number of Publications Between 2006-2021

3.2. Document Types of Publications

Based on the analysis result given by Web of Science, the number of the published publications according to the document type is given in Figure 4.

When the publications are examined according to the document type, it is seen that the most publication type is articles. (number of 1772). 181 of the publications are the proceeding papers due to document type. There are only two books printed about water footprint.

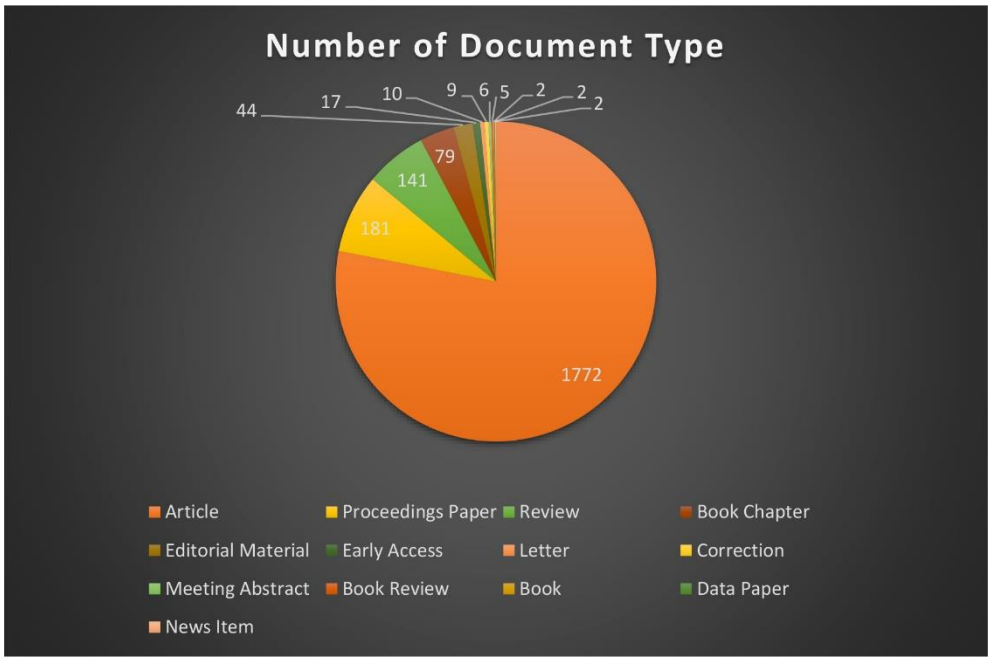

Figure 4. Number of Publications due to Document Type

3.3. Author Analysis

When the relationship between the number of authors and publications is examined, according to the Pareto Law, half of the 2138 publications is equal to 1069 publications. The square root of 5713 authors is equal to 76. As a result, 1069 publications have published by 76 authors. When ranking in terms of productivity, it was determined that the first 76 authors made a total of 1103 publications.

For the author analysis, articles, proceeding papers, reviews, book chapter and editorial materials were analyzed. The results of the analysis made according to the number of authors of the publications are given in Table 1.

Number of Authors	Number of Publications	Number of Authors	Number of Publications
1	194	6	176
2	376	7	117
3	473	8	64
4	416	9	31
5	313	10	12

Table 1. Number of Articles by Number of Authors

When the table is examined, it is seen that the number of publications written with a single author is 194; The number of publications written by 10 or more authors was determined as 45, but these values are not given in the table. It is clear from the table that more publications have emerged as a result of teamwork of 3 or 4 people.

When all publications are examined, 3 of the 5713 authors have 34 publications. 1203 authors have at least two publications. 9.9 percent of the authors have at least 3 publications.

3.4. Distribution of Publications by Journal

Analysis according to the journals in which the publications were published was analyzed by the free VOSviewer and the network graph has been represented shown in Figure 5. While 10.945% of the publications on the subject were published in the Journal of Cleaner Production, 6.034% were published in Science of The Total Environment.

When Figure 5 is examined, the size of the circle where the name of the journal is written indicates that it is the journal with a large number of publications related to the subject. In addition, the thickness of the links between the circles shows the density of the relations between the journals.

Figure 6 gives the results of the Pareto Analysis for the journals published on "water footprint" and the total number of publications. 20 percent of 607 journals is 121. 121 of the most productive journals have a total of 1640 publications on the subject. In this value, it corresponds to 77 percent of the total number of publications.

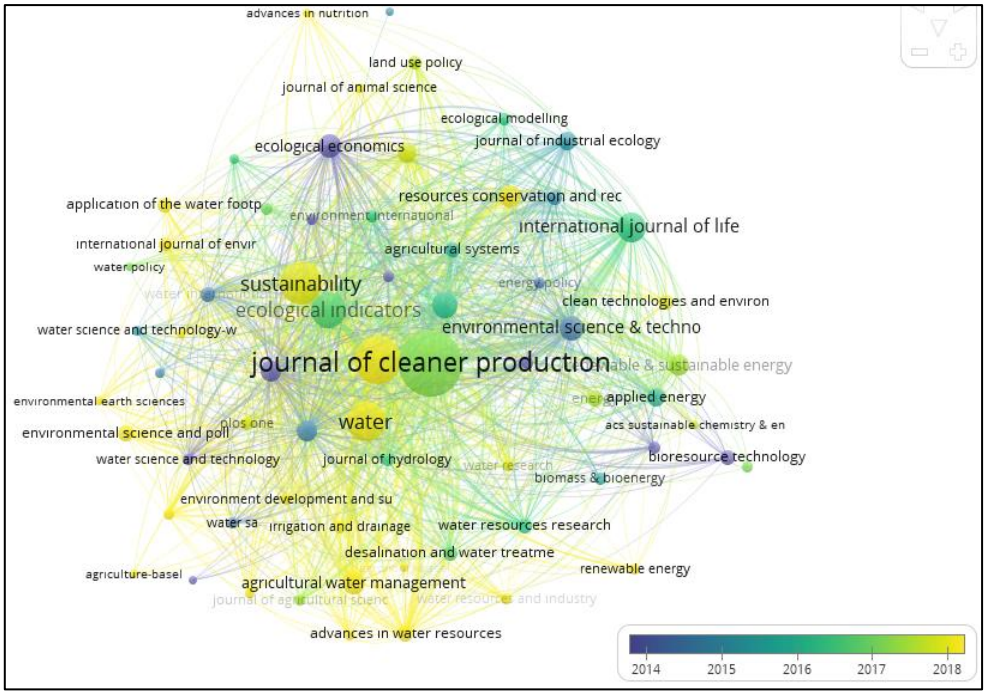

Figure 5. Network Graph of Publications by Journals (Source: VOSviewer)

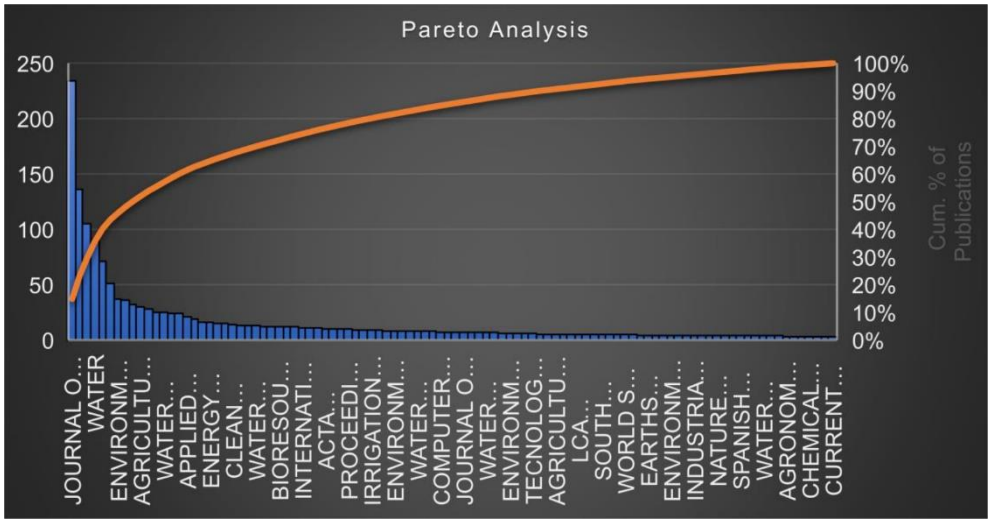

Figure 6. Pareto Analysis for Journal and Publications

3.5. Publication Language

It is clearly recognized that English, which is used as a universal language all over the world, is the common language. Of the 2138 publications, 2092 were written in English. Figure 7 shows the distribution of publications according to the publication language. Turkey published 29 publications written in Turkish, only one of them, and the rest were written in English. After English, 23 publications were written in Spanish.

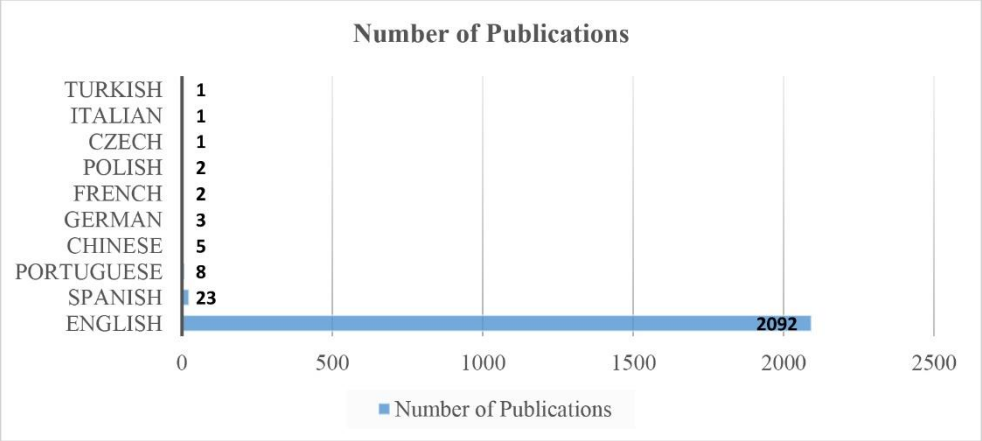

Figure 7. Distribution of Language in Publications

3.6. Distribution of Publications by Country

In Figure 8, the distribution of the publications in the literature about water footprint by country is given. When the graph is examined, it is clear that the country with the most research on this subject is the People Republic of China. In some European countries, it is seen that this issue is taken seriously and studied.

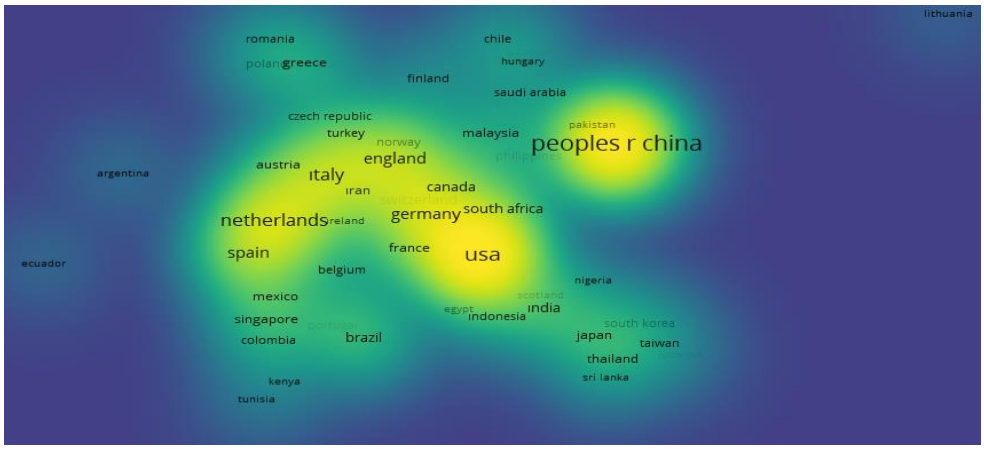

Figure 8. Density Map of Publication Performance of Countries (Source: VOSviewer)

3.7. Distribution of Publications by Organizations

When the organizations carried out the studies on water footprint were examined, the network graph in Figure 9 was obtained.

While creating this chart, the selection of those with at least five publications among a total of 2014 organizations was taken as a basis. Relationships of only 203 organizations that meet this threshold are specified. 20.6 percent of 2014 organizations have at least three publications.

Among these organizations, the University of Twente, located at the center, is the organization that conducts the most studies and research on this subject. This organization is followed by the Chinese Academy of Sciences. Beijing Normal University is among the organizations that carry out detailed research and studies on this subject.

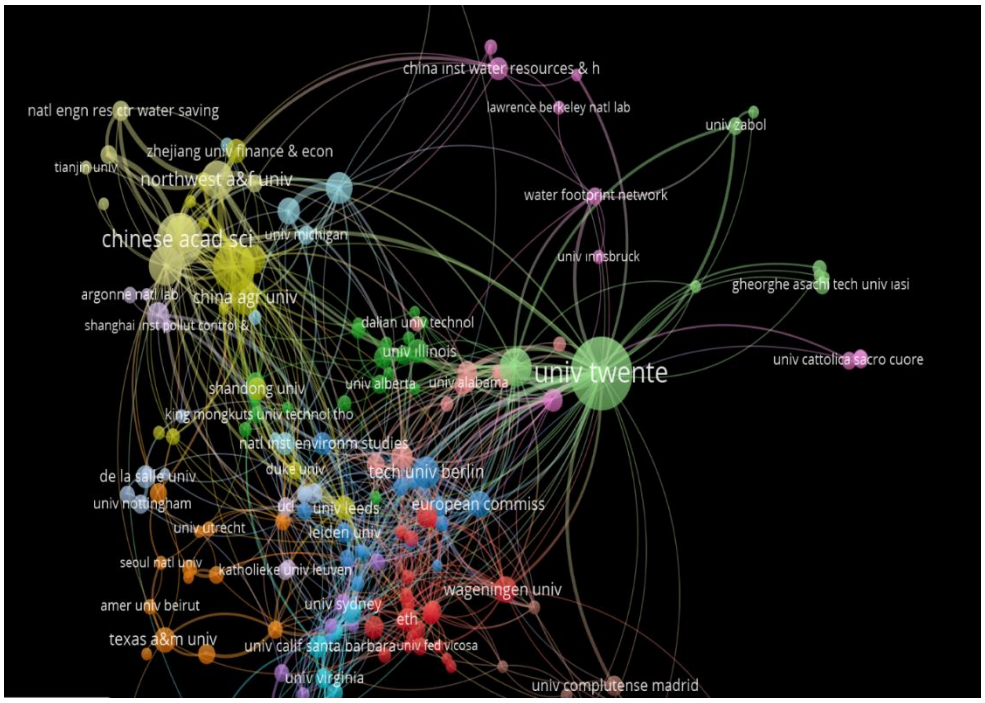

Figure 9. Network Map of Publications by Organizations (Source: VOSviewer)

3.8. Publications and Number of Cited

In Figure 10, the network graph of the total number of citations received by the publications on this subject by years is shown. The threshold for a publication to receive a minimum of 5 citations has been set. There are 1221 publications that meet this threshold. Detailed information on the most cited publications in the literature is given in Table 2.

Table 2 contains detailed information of the 10 most cited publications. Here the authors' references to them are taken into account. Hoekstra, the researcher who caused the emergence of water footprint in the world, was the most cited researcher and the researcher who published the most on this subject. Mekonnen is also one of the most published and cited researchers on this subject.

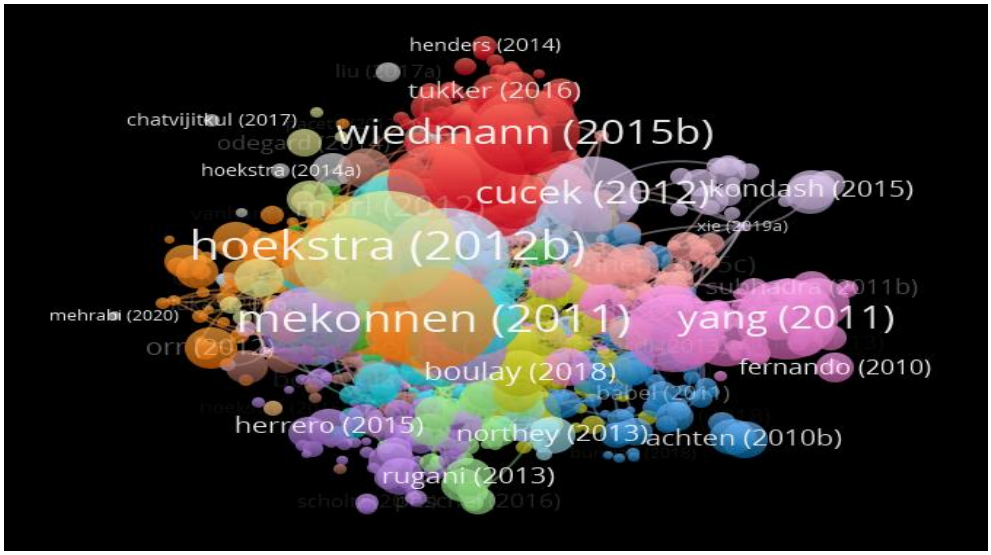

Figure 10. Most Cited Authors and Publications (Source: VOSviewer)

Title	Authors	Year	Keywords	Source Title	Total Citations
The water footprint of humanity	Hoekstra & Mekonnen	2012	Globalization, sustainable consumption, virtual water trade, water pollution	Proceedings of The National Academy of Sciences of The United States of America	895
The green, blue and grey water footprint of crops and derived crop products	M. M. Mekonnen & Hoekstra	2011	High-resolution assessment, resources, consumption, irrigation, world, flows, model	Hydrology and Earth System Sciences	746
Water footprints of nations: Water use by people as a function of their consumption pattern	Hoekstra & Chapagain	2006	Virtual water consumption, water footprint, indicators, water use efficiency, external water dependency	Water Resources Management	704
The material footprint of nations	Wiedmann et al.	2015	Raw material consumption, multiregion input–output analysis, sustainable resource management	Proceedings of The National Academy of Sciences of The United States of America	531
Water balance of global aquifers revealed by groundwater footprint	Gleeson et al.	2012	Human appropriation, resources	Nature	520
Life-cycle analysis on biodiesel production from microalgae: Water footprint and nutrients balance	Yang et al.	2011	Water footprint, life-cycle assessment, microalgae, biodiesel	Bioresource Technology	462
A Global Assessment of the Water Footprint of Farm Animal Products	Mesfin M. Mekonnen & Hoekstra	2012	Meat consumption, livestock production, animal feed, water consumption, water pollution, sustainable consumption	Ecosystems	445
The water footprint of bioenergy	Gerbens-Leenes et al.	2009	Sustainability, climate change, energy, biomass, natural resource use	Proceedings of The National Academy of Sciences of The United States of America	444
A Review of Footprint analysis tools for monitoring impacts on sustainability	Čuček et al.	2012	Sustainable development, life cycle assessment, environmental, social and economic footprints, footprint evaluation tools	Journal of Cleaner Production	419
Humanity's unsustainable environmental footprint	Hoekstra & Wiedmann	2014	Water footprint, ecological footprint, carbon footprint, international-trade, land, nitrogen, energy, sustainability, exploration, consumption	Science	406

Table 2. Most Cited Publications

According to Figure 10, Hoekstra and Mekonnen are at the center of the studies on the water footprint. Together with other researchers or alone, they have contributed to splendid publications on one of the most important issues of our day, water use and management.

3.9. Keyword Analysis in Publications

In studies on water footprint, it was investigated which keywords the authors used the most. Details of the keywords that are repeated at least 10 times among 4249 keywords are given in Figure 11.

According to the threshold value given, only 105 keywords have been used at least 10 times. In the light of the information obtained from Figure 11, the most crucial keyword among all keywords is "water footprint". The "water footprint" keyword, which is repeated 910 times in publications, also has a strong link with other keywords. Among the keywords frequently in the literature, concepts such as "Life cycle assessment", “carbon footprint”, "water scarcity", "sustainability", "climate change", "virtual water" have been included.

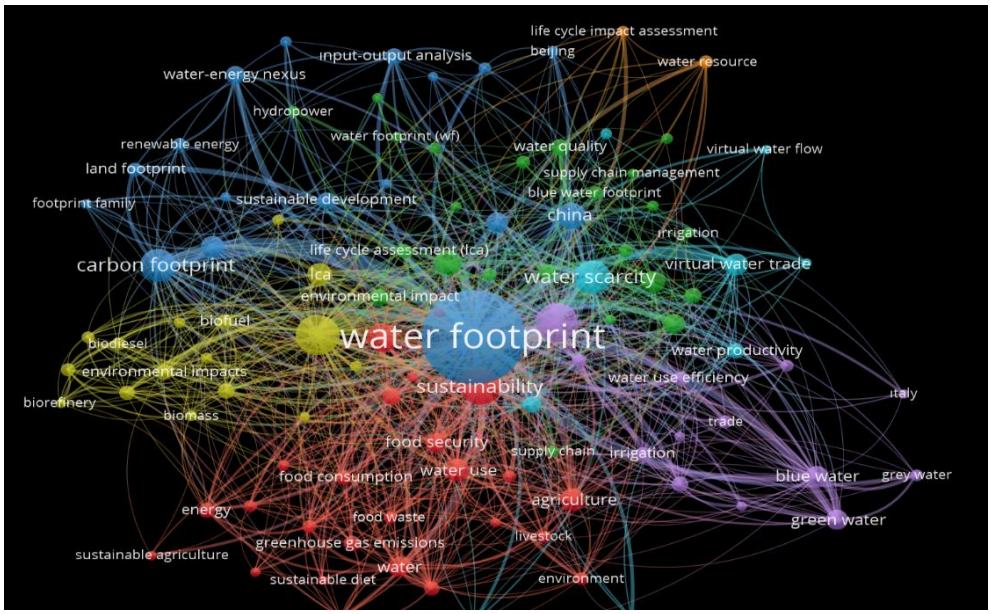

Figure 11. Keywords Analysis in Publications (Source: VOSviewer)

4. CONCLUSION

Soon, people's need for fresh water will become the biggest problem of all over the world. Due to climate changes, various activities of people, industrialization and urbanization and many other reasons, there will have negative effects dramatically on the water resources. In addition, it is not possible for humanity not to suffer from this problem because of unconscious consumption and pollution of water resources. In this study, a bibliometric analysis of the studies conducted in the literature on such an important issue was made.

With water consumption gaining a critical importance, researchers have begun to focus on this issue. Mathematical and statistical analysis of the concept of "water footprint", which is closely related to water use, has conducted in this study. According to the results of the analysis, it is a natural process that the number of publications on this subject increases gradually. This subject, which was first noticed and started to be studied in 2006, will be one of the most important research topics in the coming years. In the meantime, this issue will become even more notable with the new laws and sanctions to be taken by governments and local governments, as well as incentives.

According to the results of the literature review, it is seen that the publications made are generally articles and they are written using the English language, which is a universal language. It is seen that 18% of the publications were two-author publications, while 22% of them had 3 authors. Approximately 9% of them are publications with a single author. It is seen that approximately 11 % of the publications are published in Journal of Cleaner Production. The impact factor of this journal, in which publications on environmental problems are published, is 7.246.

It is surprising that China has the highest number of publications on "water footprint". In fact, China's average water footprint is 700 m3 / cap / yr. The United States is the country with the largest water footprint and is 2480 m3 / cap / yr at this value. The fact that the most publications on the subject are made in China, one of the countries with low water footprint, may be a proof of the importance the country attaches to this issue. It has been determined that Hoekstra, which has made the concept of water footprint into the literature and made the most publications on this subject, has the most publications and these publications are the most cited publications. Again, it was determined that journals with the highest number of citations were found in journals with the highest number of publications. The Netherlands and the University of Twente are among the most cited institutions and countries due to Hoekstra. Keywords that are most frequently used in studies on the subject include "water footprint", "water scarcity", "climate change" and "sustainability".

Based on these data, it is obvious that this issue will have an important place in science in the coming years. With this study, it is possible to follow closely which authors, which institutions, which journals, which countries have done on this subject. In addition, it is seen that there are not many publications on this subject in our country.

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