Journal of Urban and Environmental Engineering, v.18, n.2 , p.71-77

ISSN 1982-3932
doi: 10.4090/juee.2024.v18n2.071077

Journal of Urban and Environmental Engineering

www.journal-uee.org

WATER FOOTPRINT RESEARCH IN BRAZIL – SCOPING REVIEW

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Received 25 January 2024; received in revised form 12 July 2024; accepted 15 July 2024

Abstract: Freshwater plays a crucial role in human life and is also necessary for economic and ecosystem stability. Freshwater resources around the globe are under significant pressure because of increasing consumption and pollution of water by society, and decreasing water availability due to climate change. Therefore, many tools for sustainability assessment of water use have been developed in the last several decades. One of the popular methodologies is water footprinting. The intensity of water footprint research can show the importance of water-related issues in individual communities. This paper aims to make a review of water footprint research in Brazil, its influence, and internationality. The main research methods for scoping review described in this article include bibliometric analysis. Scopus database was used for the data aquisition. The term "water footprint" and affiliation to the institution in Brazil were used as eligible criteria. The number of publications, its citations and co-authorship analysis were used for the analysis of research groups and influence of its research outputs. Co-authorship analysis was used for the description of international collaboration of Brazilian researchers. Keyword analysis was used for the identification of main topics in the water footprint research in Brazil. The analyses showed the high intensity of water footprint research in Brazil and its importance for the scientific community. International collaboration of Brazilian research is on the level of 30%. The main topics of water footprint research in Brazil are sustainability, life cycle assessment, and water resources. This scoping review will be conducted according to the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Statement.

Keywords: Water footprint, Brazil, scoping review, bibliometric analysis

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INTRODUCTION

Freshwater resources around the globe are under significant pressure because of increasing consumption by the growing population and increasing living standards. The amount of pollution discharged into the water by society led to ecological problems in many places on the globe. Also decreasing water availability due to climate change and changes in the hydrological cycle led to an increase in water scarcity. Is it expected that 87 out of 180 countries will be affected by water scarcity by 2050 (Baggio et al., 2021). Brazil has the highest volume of renewable freshwater resources, accounting for approximately 12% of the world's supply, but water resources are becoming scarce because of high consumption, extended droughts, the national precarious distribution infrastructure, and water quality degradation (Val et al., 2019).

Water footprint was proposed as an indicator to evaluate water resources utilization relative to human consumption (Hoekstra and Hung, 2002). In general, footprints could be used as an indicator of sustainability (Čuček et al., 2012). The water footprint can be an effective steering instrument to support achieving United Nations Sustainable Development Goals (SDGs) (Hoekstra et al., 2017; Berger et al., 2021). On the other hand, the water footprint is still a relatively young tool and the number of research papers increasing every year (Ansorge et al., 2019). Descriptive analyses based on bibliometric data are used very often for the mapping progress of research in field subject or concept. In the field of water footprint research. Zhang et al. (2017) mapped water footprint research between 2006 and 2015. Mubako (2018) provides an overview of recent blue, green, and grey water quantification approaches between the years 2000 and 2018. Çaloğlu Büyükselçuk (2021) covered period between 2006 and 2021. Analyses of papers produced by authors from individual countries were analysed for China (Zhu et al., 2019; Zhuo et al., 2020), the Czech Republic (Ansorge et al., 2019), and states of former Yugoslavia (Ansorge et al., 2021). Adetoro et al. (2021) published a bibliometric study focused on the global trends in water footprint, water sustainability, and water productivity research. Ma et al. (2020) published a bibliometric study focused on virtual water and water footprint.

The main objective of the study presented in this paper is mapping water footprint research in Brazil. The main review questions are:

- What research institutions in Brazil are leaders in water footprint research?
- Which research areas are focused on water footprint research in Brazil?
- How intensive is international collaboration in the water footprint research in Brazil?

MATERIALS AND METHODS

This scoping review is conducted according to the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Statement. As a review protocol, the PRISMA-ScR extension checklist was used (Tricco et al., 2018). The checklist contains 20 essential reporting items and 2 optional items to include when completing a scoping review. The checklist can be provided on demand by email to the correspondent author.

Information about the research can be found in several data sources such as specialized bibliometric databases (e.g. Web of Science, Scopus) or scientific search/indexing services (e.g. Google Scholar, Microsoft Academic, Semantic Scholar, etc.). Bibliometric databases are more suitable for this study because provide metadata about authors' affiliation. Web of Science covers over 75 million records in its Core Collection, from around 20,900 serial titles plus books and conference proceedings (Birkle et al., 2020). When other regional and subject-specific citation indexes are included, Web of Science covers up to 155 million records from more than 34,200 serial titles, books, and proceedings (Birkle et al., 2020). Scopus cover over 76 million records from 39,100 serial titles, 120,000 conferences, and 206,000 books (Baas et al., 2020).

The query "water footprint" (topic) AND Brazil (address) were used for search in all databases of Web of Science. This query provided 116 results on January 15th, 2022. The query TITLE-ABS-KEY("water footprint") AND AFFILCOUNTRY(Brazil) was used for search in the Scopus database. This query provided 126 results on January 15th, 2022. For a deeper analysis, the outputs from the Scopus database were used. Microsft Excel was used for the statistical analysis of data from Scopus. VOSviewer in version 1.6.17 (van Eck and Waltman, 2010) was used for cluster analysis. The fractionalization method implemented in VOSviewer was used for normalizing the strength of the links between items. Apart from a multiplicative constant, this method is identical to Eq. (13) in Van Eck and Waltman (2009).

RESULTS AND DISCUSSIONS

Paper production

The first article focused on the water footprint authored by Brazilian researchers was published in 2011. It is 9 years after the water footprint concept was introduced (Hoekstra and Hung, 2002). Since that year, the number of published articles has been increasing, as in the whole world (**Fig. 1**).

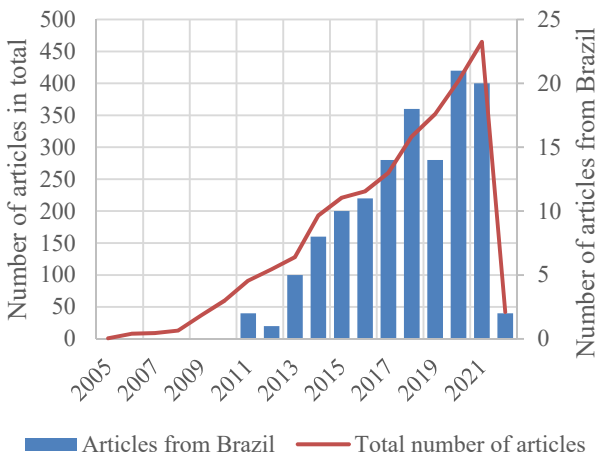

Fig. 1. The annual number of articles about water footprint in Scopus

From 126 papers covered by the analysis, there were 108 articles, 9 reviews, 5 conference papers, and 3 books. 1 paper was retracted due to duplication of another article (Batista, 2016). 38 papers were prepared in international collaboration with researchers from 28 countries. Most of them (23 papers) were prepared in cooperation with researchers from the US. The second country is the Netherlands (7 papers). 5 papers were prepared with cooperation with researchers from Canada and Sweden. **Fig. 2** shows a map of international collaboration. 38 internationally collaborative papers represent 30.15% of total production by Brazilian authors, which is very close to the global average 31.9 % (Zhang et al., 2017). Most papers were published in the Journal of Cleaner Production, 2 and more papers were published in 21 journals (**Table 1**). Of the Brazilian journals, most articles were published in Revista Ambiente & Água (8 papers). 25 articles were published in Portuguese, the others in English.

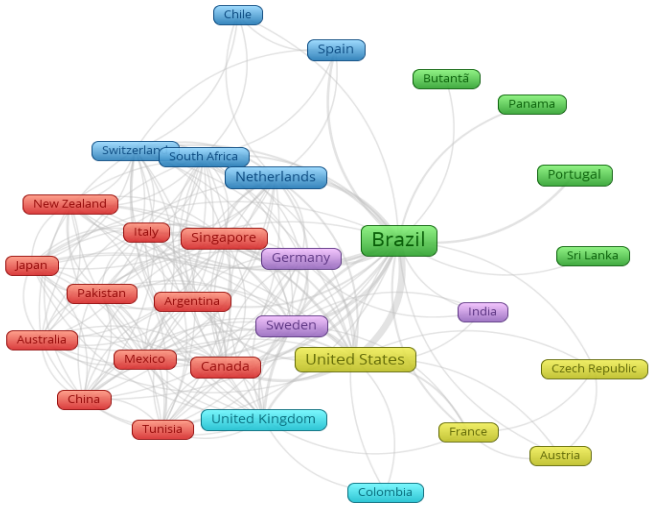

Fig. 2. Map of international collaboration – individual colours represent close collaboration

Table 1. Journals, where Brazilian authors published results of water footprint research

Source title	Number
Journal of Cleaner Production	12
Revista Ambiente & Água	8
International Journal of Life Cycle Assessment	5
Revista em Agronegócio e Meio Ambiente	4
Science of The Total Environment	4
Revista Brasileira de Engenharia Agrícola e Ambiental	3
Sustainability (MDPI)	3
Agricultural Systems	2
Ambiente e Sociedade	2
Australian Journal of Crop Science	2
Biofuels Bioproducts and Biorefining	2
Biomass and Bioenergy	2
Engenharia Sanitária e Ambiental	2
Environmental Research Letters	2
Espacios	2
Foods	2
Fronteiras	2
Irriga	2
Revista Brasileira de Recursos Hídricos	2
Spanish Journal of Agricultural Research	2
Water (MDPI)	2
Others	59

Water footprint research performances

Brazilian authors account for 4-5% of worldwide article production in the field of water footprint research. The influence of the research can be described by the citations of published papers (Moed, 2005). English is the *lingua franca* of international science, and non-English articles get fewer citations in general (Tahamtan et al., 2016). 98 papers received one or more citations according to Scopus on January 15th, 2022. It is 78 % of all articles, but only 12 articles published in Portuguese received any citations (48%).

The most cited article by Bordonal et al. (2018) received 137 citations. The second most cited article is the article by Albert et al. (2021) with 87 citations and the article in third place by Rodrigues et al. (2014) received 56 citations. The most cited article published in Portuguese by Palhares (2011) received only 16 citations, which ranks them 25th most cited. Publications received 90.5% of citations within the first 5 years from publication (**Fig. 3**), which confirms the general findings (Mendoza, 2021) although some sectors of science have a little bit different citation behavior (Galiani and Gálvez, 2019). However, this statistic is skewed because only 30% of the publications included in the analysis are over 5 years old.

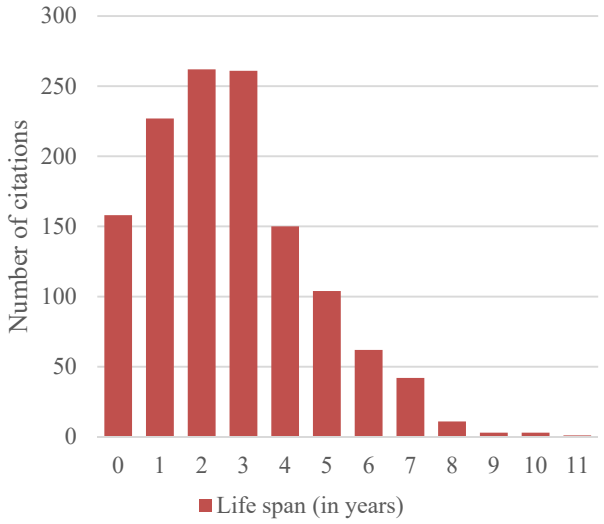

Fig. 3. Life span of papers (citations)

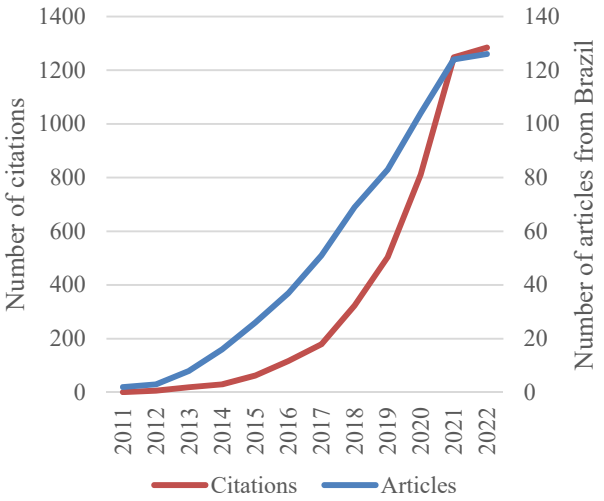

Fig. 4. Trends in paper production and its citations

Figure 4 shows cumulative values of published articles and their citations. The growth in the number of citations is higher than the growth in the number of publications, which is proof of the quality of water footprint research in Brazil, although the clean number of citations does not describe the influence of individual citation (Zhu et al., 2015).

Authors' and institutions' performances

155 authors affiliated with 160 institutions participated in the publications included in the analysis. The number of articles from the top 12 most productive institutions (with 5 and more papers) is shown in **Table 2**. Ten of them are universities. The most active author is Júlio César Pascale Palhares from Embrapa with 8 papers and 96 citations. **Table 3** shows the most active authors and the number of citations which received their articles involved in the analysis. **Fig. 4** shows the co-authorship network.

Table 2. Institutions with a higher number of papers

Institution	Number
Universidade de São Paulo	30
Empresa Brasileira de Pesquisa Agropecuária - Embrapa	18
Universidade Federal do Rio Grande do Sul	10
Universidade Federal de Campina Grande	9
Universidade Federal de Vicosa	8
Universidade Estadual de Campinas	8
Universidade Federal de Santa Maria	8
Universidade Estadual Paulista Júlio de Mesquita Filho	7
Universidade Federal da Paraíba	7
Universidade Federal Rural de Pernambuco	5
Universidade Federal de Minas Gerais	5
Laboratório Nacional de Biorrenováveis	5

Table 3. Authors with a higher number of papers and their citations

Name	Articles	Citations
Palhares, J.C.P.	8	96
Mendiondo, E.M.	5	84
(de) Araújo, L.E.	5	65
Neto, J.D.	5	56
Deprá, M.C.	5	44
Jacob-Lopes, E.	5	44
Strasburg, V.J.	5	31
Hernandes, T.A.D.	4	117
Lathuillière, M.J.	4	66
da Silva, V.d.P.R.	4	65
Zepka, L.Q.	4	43

Keyword analysis

360 keywords were used in the published papers. The most often used keyword was "water footprint" (36x). More than 10 times was used "sustainability" 16x), "life cycle assessment" (13), and "water resources" (12x). **Fig. 5** shows 29 keywords, that have been used 3 or more times and their connection. Keyword analysis shows the main topics of the research. The size of the nodes in **Fig. 5** is proportional to the number of occurrences of the keywords. The distance between the nodes reflects the strength of the relation between them. The color of the nodes is determined by the ages of the keywords, with colors ranging from blue (the oldest papers) through green to yellow (the youngest papers). The most frequently used keywords were from 2016 and 2019.

Limitation of the study

Bibliometric data from the Scopus database were used for the study. It leads to these limitations:

1. Scopus contains more than 90% of papers in English (Vera-Baceta et al., 2019) and language biases play an important role in the comparison and evaluation of research on a national level (Leeuwen et al., 2004).

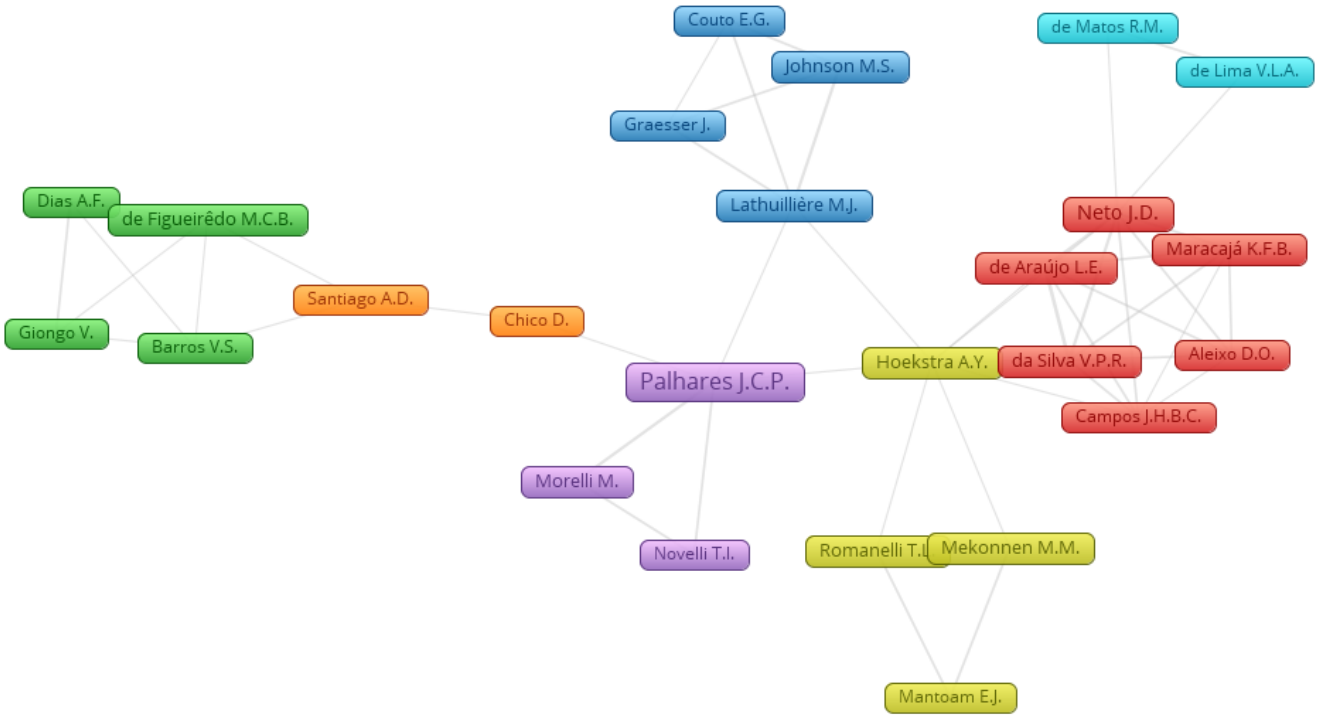

Fig. 4. Network of main co-authorship clusters

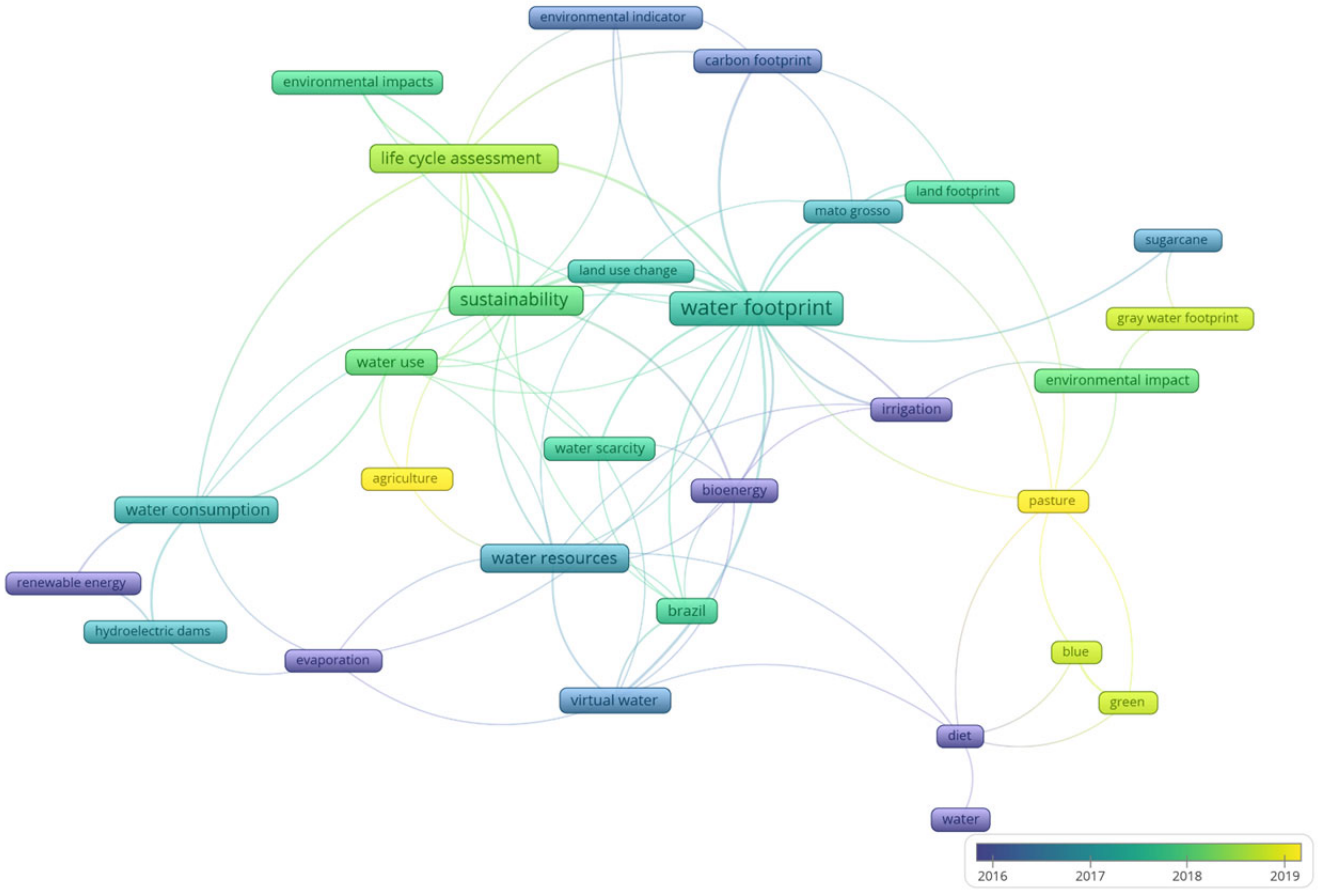

Fig. 5. Network of main keywords

2. This study uses descriptive metadata obtained from the Scopus database and does not conduct a content analysis of published texts. The content analysis could lead to a more precise definition of the content of water footprint research in Brazil and the main research problems, challenges, and future directions.

CONCLUSIONS

This article is scoping review of the water footprint research in Brazil. The review has shown that water footprint research in Brasil has the same progress as research in the world (in terms of the number of papers). Brazilian authors participate by 4 - 5% in the world production of articles focused on the water footprint. The high influence of water footprint research in Brazil is proven by the number of citations. Water footprint research is carried out by a number of institutions in Brazil, the most important of which are mainly universities. 10 universities are in the group of 12 most active research institutions. Most papers were published by authors affiliated with Universidade de São Paulo. In the second place, there are authors affiliated with Empresa Brasileira de Pesquisa Agropecuária (Brazilian Agricultural Research Corporation) which is a governmental research institution.

International collaboration on the papers is on the level of 30%, which is a similar level as collaboration in the world´s research of water footprint. The Journal of Cleaner Production is the most widely used journal for Brazilian researchers publishing results in the field of water footprint, 10 % of analyzed papers were published there. The second most widely used journal is Revista Ambiente & Água in Brazil.

According to the keywords, the water footprint research in Brazil is focused mainly on sustainability, life cycle assessment, and water resources. Furthermore, opportunities are there for the content analysis of highly cited articles to identify research problems, challenges, and future directions.

Acknowledgment This study was funded by internal grant from Výzkumný ústav vodohospodářský T. G. Masaryka, Prague, Czech Republic.

REFERENCES

Adetoro, A.A.; Ngidi, M.; Nyam, Y.S. and Orimoloye, I.R. 2021. Temporal evaluation of global trends in water footprint, water sustainability and water productivity research. *Scientific African* 12: e00732, https://doi.org/10.1016/j.sciaf.2021.e00732

Albert, J.S.; Destouni, G.; Duke-Sylvester, S.M.; Magurran, A.E.; Oberdorff, T.; Reis, R.E.; Winemiller, K.O. and Ripple, W.J. 2021. Scientists' warning to humanity on the freshwater biodiversity crisis. *Ambio* 50(1): 85–94, https://doi.org/10.1007/s13280-020-01318-8

Ansorge, L.; Stejskalová, L. and Vološinová, D. 2019. Comparison of water footprint research in the Czech Republic and in abroad – bibliometric analysis. *Vodohospodářské technicko-ekonomické informace* 61(6): 60–62, https://www.vtei.cz/en/2019/12/comparison-of-water-footprint-research-in-the-czech-republic-and-in-abroad-bibliometric-analysis/

Ansorge, L.; Stejskalová, L. and Vološinová, D. 2021. Bibliometric analysis of water footprint research in countries of former Yugoslavia. *Acta hydrotechnica* 34(61): 93–102, https://doi.org/10.15292/acta.hydro.2021.07

Baas, J.; Schotten, M.; Plume, A.; Côté, G. and Karimi, R. 2020. Scopus as a curated, high-quality bibliometric data source for academic research in quantitative science studies. *Quantitative Science Studies* 1(1): 377–386, https://doi.org/10.1162/qss_a_00019

Baggio, G.; Qadir, M. and Smakhtin, V. 2021. Freshwater availability status across countries for human and ecosystem needs. *Science of The Total Environment* 792: 148230, https://doi.org/10.1016/j.scitotenv.2021.148230

Batista, G.T. 2016. [Artigo Retratado]:Pegada hídrica de indivíduos com diferentes hábitos alimentares. *Revista Ambiente & Água* 11: 1022–1022, https://doi.org/10.4136/ambi-agua.1874

Berger, M.; Campos, J.; Carolli, M.; Dantas, I.; Forin, S.; Kosatica, E.; Kramer, A.; Mikosch, N.; Nouri, H.; Schlattmann, A.; Schmidt, F.; Schomberg, A. and Semmling, E. 2021. Advancing the Water Footprint into an instrument to support achieving the SDGs – Recommendations from the "Water as a Global Resources" Research Initiative (GRoW). *Water Resources Management*, https://doi.org/10.1007/s11269-021-02784-9

Birkle, C.; Pendlebury, D.A.; Schnell, J. and Adams, J. 2020. Web of Science as a data source for research on scientific and scholarly activity. *Quantitative Science Studies* 1(1): 363–376, https://doi.org/10.1162/qss_a_00018

Bordonal, R. de O.; Carvalho, J.L.N.; Lal, R.; de Figueiredo, E.B.; de Oliveira, B.G. and La Scala, N. 2018. Sustainability of sugarcane production in Brazil. A review. *Agronomy for Sustainable Development* 38(2): 13, https://doi.org/10.1007/s13593-018-0490-x

Çaloğlu Büyükselçuk, E. 2021. Bibliometric analysis of water footprint. *Tasarım Mimarlık ve Mühendislik Dergisi* 1(1): 42–53, https://dergipark.org.tr/en/pub/dae/issue/65804/1024124

Čuček, L.; Klemeš, J.J. and Kravanja, Z. 2012. A review of footprint analysis tools for monitoring impacts on sustainability. *Journal of Cleaner Production* 34: 9–20, https://doi.org/10.1016/j.jclepro.2012.02.036

van Eck, N.J. and Waltman, L. 2009. How to normalize cooccurrence data? An analysis of some well-known similarity measures. *Journal of the American Society for Information Science and Technology* 60(8): 1635–1651, https://doi.org/10.1002/asi.21075

van Eck, N.J. and Waltman, L. 2010. Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics* 84(2): 523–538, https://doi.org/10.1007/s11192-009-0146-3

Galiani, S. and Gálvez, R.H. 2019. An empirical approach based on quantile regression for estimating citation ageing. *Journal of Informetrics* 13(2): 738–750, https://doi.org/10.1016/j.joi.2019.03.014

Hoekstra, A.Y.; Chapagain, A.K. and van Oel, P.R. 2017. Advancing Water Footprint Assessment Research: Challenges in Monitoring Progress towards Sustainable Development Goal 6. *Water* 9(6): 438, https://doi.org/10.3390/w9060438

Hoekstra, A.Y. and Hung, P.Q. 2002. Virtual water trade - A quantification of virtual water flows between nations in relation to international crop trade. 12. Value of Water Research Report Series. Delft, The Netherlands: UNESCO-IHE Institute for Water Education,

https://waterfootprint.org/media/downloads/Report11_1.pdf (accessed 16 January 2019)

Leeuwen, T.V.; Moed, H.; Tijssen, R.; Visser, M. and Raan, A.V. 2004. Language biases in the coverage of the Science Citation Index and its consequencesfor international comparisons of national research performance. *Scientometrics* 51(1): 335–346, https://doi.org/10.1023/a:1010549719484

Ma, W.; Opp, C. and Yang, D. 2020. Past, Present, and Future of Virtual Water and Water Footprint. *Water* 12(11): 3068, https://doi.org/10.3390/w12113068

Mendoza, M. 2021. Differences in Citation Patterns across Areas, Article Types and Age Groups of Researchers. *Publications* 9(4): 47, https://doi.org/10.3390/publications9040047

Moed, H.F. 2005. *Citation Analysis in Research Evaluation*. Information Science and Knowledge Management 9. Berlin/Heidelberg: Springer-Verlag, https://doi.org/10.1007/1-4020-3714-7

Mubako, S.T. 2018. Blue, green, and grey water quantification approaches: a bibliometric and literature review. *Journal of Contemporary Water Research & Education* 165(1): 4–19, https://doi.org/10.1111/j.1936-704X.2018.03289.x

Palhares, J.C.P. 2011. Pegada hídrica dos suínos abatidos nos Estados da Região Centro-Sul do Brasil. *Acta Scientiarum. Animal Sciences* 33(3): 309–314, https://doi.org/10.4025/actascianimsci.v33i3.9924

Rodrigues, D.B.B.; Gupta, H.V. and Mendiondo, E.M. 2014. A blue/green water-based accounting framework for assessment of water security. *Water Resources Research* 50(9): 7187–7205, https://doi.org/10.1002/2013WR014274

Tahamtan, I.; Safipour Afshar, A. and Ahamdzadeh, K. 2016. Factors affecting number of citations: a comprehensive review of the literature. *Scientometrics* 107(3): 1195–1225, https://doi.org/10.1007/s11192-016-1889-2

Tricco, A.C.; Lillie, E.; Zarin, W.; O'Brien, K.K.; Colquhoun, H.; Levac, D.; Moher, D.; Peters, M.D.J.; Horsley, T.; Weeks, L.; Hempel, S.; Akl, E.A.; Chang, C.; McGowan, J.; Stewart, L.; Hartling, L.; Aldcroft, A.; Wilson, M.G.; Garritty, C.; Lewin, S.; Godfrey, C.M.; Macdonald, M.T.; Langlois, E.V.; Soares-Weiser, K.; Moriarty, J.; Clifford, T.; Tunçalp, Ö. and Straus, S.E. 2018. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. *Annals of Internal Medicine* 169(7): 467–473, https://doi.org/10.7326/M18-0850

Val, A.L.; Bicudo, C.E. de M.; Bicudo, D. de C.; Pujoni, D.G.F.; Spilki, F.R.; Nogueira, I. de S.; Hespanhol, I.; Cirilo, J.A.; Tundisi, J.G.; Pedro Val; Hirata, R.; Azevedo, S.M.F. de O. e; Crestana, S. and Ciminelli, V.S.T. 2019. Water Quality In Brazil. In Vammen, K.; Vaux, H. and Molina, A. de la C. (Eds), *Water Quality in the Americas: Risks and Opportunities*, pp. 102–126. Mexico: The Inter-American Network of Academies of Sciences (IANAS-IAP), https://ianas.org/wp-content/uploads/2020/07/02-Water-quality-INGLES.pdf

Vera-Baceta, M.-A.; Thelwall, M. and Kousha, K. 2019. Web of Science and Scopus language coverage. *Scientometrics* 121(3): 1803–1813, https://doi.org/10.1007/s11192-019-03264-z

Zhang, Y.; Huang, K.; Yu, Y. and Yang, B. 2017. Mapping of water footprint research: A bibliometric analysis during 2006–2015. *Journal of Cleaner Production* 149: 70–79, https://doi.org/10.1016/j.jclepro.2017.02.067

Zhu, X.; Turney, P.; Lemire, D. and Vellino, A. 2015. Measuring academic influence: Not all citations are equal. *Journal of the Association for Information Science and Technology* 66(2): 408–427, https://doi.org/10.1002/asi.23179

Zhu, Y.; Jiang, S.; Han, X.; Gao, X.; He, G.; Zhao, Y. and Li, H. 2019. A Bibliometrics Review of Water Footprint Research in China: 2003–2018. *Sustainability* 11(18): 5082, https://doi.org/10.3390/su11185082

Zhuo, L.; Feng, B. and Wu, P. 2020. Water footprint study review for understanding and resolving water issues in China. *Water* 12(11): 2988, https://doi.org/10.3390/w12112988