PAPER • OPEN ACCESS

Grey water footprint of crop in Riau Province

To cite this article: P W Titisari *et al* 2024 *IOP Conf. Ser.: Earth Environ. Sci.* **1297** 012024

Grey water footprint of crop in Riau Province

P W Titisari*[1], Elfis[1], A Maryanti[1], I Chahyana[2], T Permatasari[3], F Dalilla[4]

[1]Department of Agrotechnology, Faculty of Agriculture, Universitas Islam Riau, Jalan Kaharuddin Nasution No 113, Pekanbaru, Riau 28284, Indonesia
[2]Biomanagment, School of Life Sciences and Technology, Institut Teknologi Bandung, Jl. Ganesha No 10, Bandung, Jawa Barat 40132, Indonesia
[3]Department of Biology Education, Faculty of Education, Universitas Islam Riau, Jalan Kaharuddin Nasution No 113, Pekanbaru, Riau 28284, Indonesia
[4]Department of Urban Regional Planning, faculty of Engineering, Universitas Islam Riau, Jalan Kaharuddin Nasution No 113, Pekanbaru, Riau 28284, Indonesia

*Email: pw.titisari@edu.uir.ac.id

Abstract. The escalating severity of the water problem poses a potential threat to the prospects of sustainable development in the future. The grey water footprint is an indicator of the need for fresh water to mix and dilute pollutants and maintain air quality according to water quality standards. The evaluation of the grey water footprint (GWF) serves as a valuable measure in the mitigation and management of water contamination. The main objective of this study is to determine the grey water footprint associated with crop production along the Kampar Watershed and develop strategies to mitigate pollution levels. The grey water footprint is calculated using a water footprint assessment method. The finding show that the grey water footprint of rice farming (17.01 m^3/ton) is larger than the maize (9.51 m^3/ton), this indicate that necessary to improve water management on rice and maize agriculture. The water footprint performance scores of rice and corn plants are both in the poor category with scores of 11.93 and 45 respectively. To improve grey water performance and reduce air pollution, it can be done by using fertilizer according to plant needs, replacing inorganic fertilizer with organic fertilizer, implementing practices conventional tillage and maintain soil moisture.

1. Introduction

The notion of water footprint is a constituent of a broader set of footprint concepts that has been formulated within the field of environmental studies in recent decades. The water footprint divided in to three components, namely green water footprint, blue water footprint, and grey water footprint. The term "grey water footprint" (GWF) component pertains to the number of contaminated waters linked to the production of goods and services. It is measured as the volume of water needed to decrease pollutants to a level where the condition of the surrounding water remains higher than the established water quality standards [1,2]. The agricultural industry is among the five largest sectors that contribute grey water globally [3]. In the context of crop production, grey water is necessary to determine the appropriate degree of dilution required to lower nitrate and phosphate (fertiliser) levels, as well as pesticide levels, in order to meet the agreed-upon requirements and prevent their leaching from soils.

The calculation of the grey water footprint may be derived by dividing the pollutant content of the disparity between the maximum allowable concentration and the natural background concentration [1]. A limited number of studies have been conducted to assess measurements of the grey water footprint.

In some study, the impact of nitrogen application on the grey water footprint in irrigated agricultural production [4]. Qin [5] examined The assessment of the Grey Water Footprint from a perspective of water pollution sources in China. In their study, Ariyani [6] conducted an analysis of the grey water footprint associated with rice-straw pulp. The study conducted by Meng [2] focuses on the quantification and evaluation of the grey water footprint in the region of Yantai.

The decrease of the grey water footprint (GWF) is imperative because to the escalating water pollution linked to crop production and the constrained capacity of fresh water assimilation. The application of fertiliser can have a substantial impact on the water footprint of agriculture due to the leaching of nutrients into groundwater and the discharge of these nutrients into streams. The Grey Water Footprint Score (GWFS) evaluates the water performance of a crop in water management for fertilisation practices. It is determined by comparing the actual water footprint of the crop to the yearly reference level of water footprint (WF').

2. Materials and methods

2.1. Study area
The present study was carried out inside the Kampar watershed, located in Riau Province, encompassing two administrative districts, namely Kampar and Pelalawan Regencies. The Kampar Regency comprises four sub-districts, specifically XIII Koto Kampar, East Kampar, Kampar Kiri, and Kampar Kiri Hilir. Pelalawan Regency encompasses four sub-districts, specifically Langgam, Pelalawan, Teluk Meranti, and Kuala Kampar. The Kampar Watershed is home to eight districts that serve as prominent hubs for the cultivation of agricultural crops, including paddy and maize.

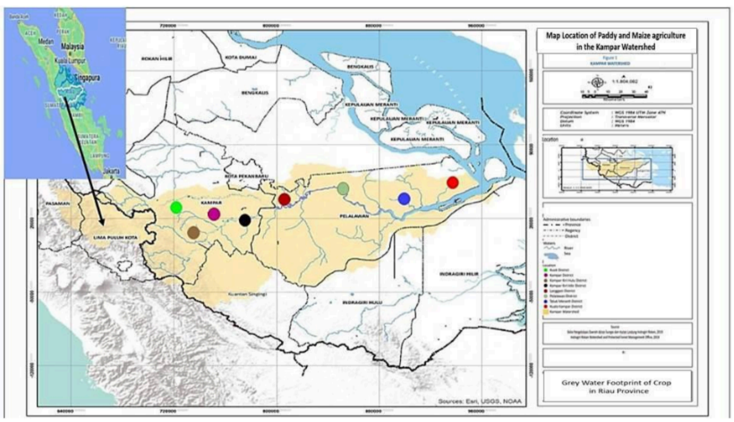

Figure 1. Research location of Kampar watershed

2.2. *Analysis method*
The grey water footprint (GWF) in the field of agriculture can be determined through a calculation that involves quantifying the volume of water required for assimilating fertilizers that enter ground or surface water. This calculation is achieved by multiplying the leaching-

IOP Conf. Series: Earth and Environmental Science 1297 (2024) 012024 doi:10.1088/1755-1315/1297/1/012024

runoff fraction (α, %) by the rate at which chemicals are applied (Appl, kg/m^3). The result is then divided by the difference between the maximum acceptable concentration of nitrogen (cnat, kg/m^3) and the natural concentration of nitrogen in the receiving water body (cnat, kg/m^3). Finally, this value is divided by the actual yield (Y, t/ha), as presented in Equation (1) by Hoekstra [7]. The primary contributor to non-point source pollution of surface and subterranean water bodies is the leaching or runoff of nutrients from agricultural fields [8].

$$WFgrey = \frac{(\alpha \; x \; AR) \, / \, (Cmax - Cnat)}{Y} \; [volume/mass] \qquad (1)$$

When considering instances of water pollution caused by point sources, it is observed that chemicals are directly released into a surface water body as wastewater discharge. In such cases, the water footprint of the pollutant (GWF) can be approximated by dividing the pollutant load (L, in mass/time) by the difference between the ambient water quality standard for that specific pollutant (cmax, measured in mass per unit volume) and its natural concentration in the receiving water body (cnat, measured in mass per unit volume) as represented by Equation (2).

$$WFgrey = \frac{L}{Cmax - Cnat} \qquad (2)$$

$$GWFS = 100\% \; x \; \frac{WF'grey}{WFgrey} \qquad (3)$$

The grey water footprint score (GWFS) data conducted from equation (3) are subsequently categorised into three distinct groups in order to assess the effectiveness of the GWFS [9].

Poor	Medium	Excellent
0-29	30-69	70-100

Figure 2. Water footprint score performance category.
Source: Fotia and Tsirogiannis (2023).

Results and discussion

The grey water footprint refers to the amount of freshwater that is utilised for the purpose of absorbing and assimilating a specific load of pollutants. The utilisation of pesticides and artificial fertilisers leads to the occurrence of agricultural contamination. The primary reason for nitrogen fertiliser being the predominant contributor to water pollution is its high solubility, facilitating its entry into aquatic ecosystems. Additionally, the sheer quantity of nitrogen fertiliser applied further exacerbates its impact, rendering it the principal pollutant in water bodies. Hence, nitrogen fertiliser emerged as the primary source of pollution. It is important to note that the grey water calculation in this study only considers water pollution caused by fertiliser usage, disregarding the impacts of agricultural methods and climatic conditions. In addition, the impact of pesticides on water quality is also disregarded.

3.1. Fertiliser used in rice and maize farming

Nutrients, namely nitrogen (N), phosphorus (P), and potassium (K), are essential for optimal plant growth. Consequently, it is crucial to carefully consider the availability and requirement of fertilisers in plants. The cultivation of rice and corn within the Kampar watershed involves the application of urea and NPK (Phonska) fertilisers. The data indicates that around 15% of fertiliser residue is generated at the research site. The amount of residue in rice and corn farming in Kampar and Pelalawan Regencies is obtained from the multiplication of harvest area, harvest frequency, and fertilizer requirements. Harvest area data was obtained from the Riau Province Central Statistics Agency (2018) [10]. Harvest frequency was obtained from survey results, while data on fertilizer use was obtained from the provisions of the National Standardization Agency. Table 1 presents the data regarding the quantity of residue that is discarded during rice and corn planting at the research site.

Table 1. The amount of residue wasted from rice and maize farming in Kampar and Pelalawan Regencies

Cultivated Plants	**Residue wasted in Kampar District**		**Residue wasted in Pelalawan District**	
	Urea (Kg)	NPK (Kg)	Urea (Kg)	NPK (Kg)
Paddy	2615	1743	448,65	299,10
Maize	329,25	655,80	747 kg	1122

According to Table 1, the quantity of residue generated in the rice growing technique surpasses that of maize in both districts. The resultant residue will exert an influence on both flora and the surrounding ecosystem. The application of fertiliser should be tailored to meet the specific requirements of the plant. In accordance with the findings of Rosadi [11], the provision of fertiliser tailored to the specific requirements of plants has been shown to promote enhanced agricultural productivity, hence exerting a direct influence on the availability of food resources.

3.2. Total grey water footprint for crop production in Kampar and Pelalawan District

The present study revealed that the grey water footprint in the Pelalawan district had a higher magnitude in relation to maize farming, but in the Kampar district, it was observed to be more significant in the context of rice cultivation (Figure 3).

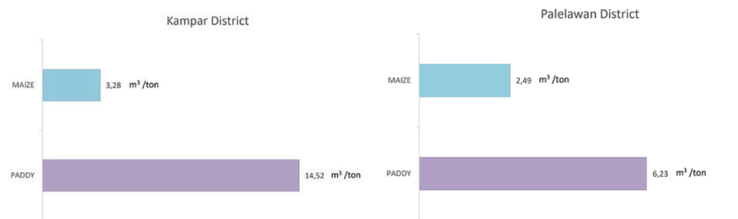

Figure 3. Total grey water footprint for crop production in Kampar and Pelalawan District

According to Figure 3, the water footprint (WF) of grey water in maize farming in Pelalawan district is measured at 6.23 m^3/ton, which surpasses the WF of grey water in maize farming in Kampar district, recorded at 3.28 m^3/ton. In comparison, the water footprint (WF) of rice cultivation in Pelalawan district is 2.49 m^3/ton, which is lower than the water footprint of rice farming in Kampar district, which is 14.52 m^3/ton. The variation seen can be attributed to the influence exerted by the implementation of a specific agricultural system. A decrease in output levels is associated with an increase in the grey water footprint [12, 13]. Conversely, increased production yields have the potential to diminish the significance of the grey water footprint. The high agricultural output outcomes can be attributed to either the high WF blue value or the presence of efficient irrigation facilities [14].

[illegible]. Total grey water footprint for crop production in Kampar Watershed

Based on the results of the analysis, it was found that the total value of the gray water footprint in rice and corn farming in the Kampar watershed (Figure 4).

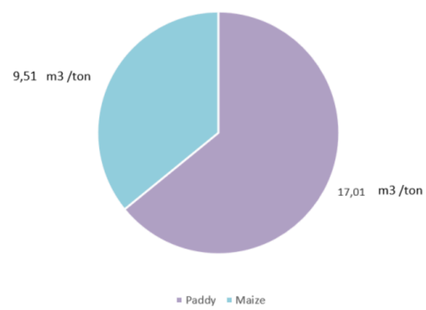

Figure 4. Total grey water footprint for crop production in Kampar Watershed

According to the data presented in Figure 4, the total grey water footprint (WF) in rice cultivation amounts to 17.01 m^3 per ton, surpassing the corresponding value of 9.51 m^3 per ton observed in maize cultivation. According to the research conducted by Rao [15], it has been shown that the utilisation of grey water in rice production, at a rate of 39 m^3 per ton, surpasses that of maize cultivation, which stands at 36 m^3 per ton. Furthermore, the water footprint (WF) value associated with this practice significantly exceeds the average national WF value of India. Deng [16] observed a similar phenomenon, wherein rice plants have a comparatively higher water footprint (WF) in grey terms when compared to other plant species. Rice is identified as one of the primary agricultural products that significantly contribute to pollution. The consumption of grey water is contingent upon the quantity of residue, specifically fertiliser, utilised [3]. The utilisation of fertilisers has the potential to make a substantial contribution to grey water footprint (WF) due to the process of nutrient leaching into groundwater and subsequent runoff into rivers.

3.4. Grey Water Footprint Score (GWFS) and Performance production in Kampar Watershed

Grey water footprint is not enough to describe the application performance of water use for fertilisation in agricultural systems, for this reason it is necessary to calculate WFS. The WFS and the performance of each plant found in this study are presented in Figure 5.

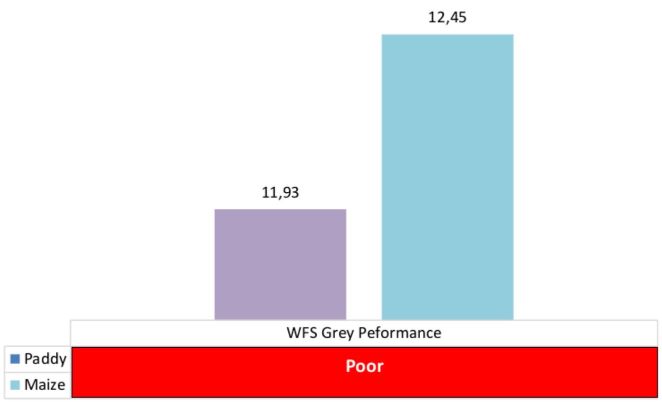

Figure 5. Grey water footprint score performance on paddy and maize in Kampar watershed

According to Figure 5, the water consumption technique employed by farmers in the Kampar watershed for fertilisation in rice and maize farming is categorised as inadequate, as evidenced by respective scores of 11.93 for rice and 12.45 for maize. The suboptimal score and performance of the grey water footprint seen in this investigation can be attributed to the utilisation of rather substantial leftovers. This disease is expected to exert a detrimental influence on the environment. The utilisation of inefficient fertilisation application techniques can result in the wastage of fertilisers into water bodies, hence diminishing the water quality in the surrounding areas and downstream regions. The primary source of river water pollution and land degradation stems from residues resulting from agricultural activities [4,17,18].

The transportation of nutrient residues resulting from fertilisation practices, including the application of urea fertiliser, will be facilitated through irrigation systems. Urea ($CO(NH_2)_2$) undergoes hydrolysis to yield ammonium nitrate, which is then absorbed by plants in the form of ammonium (NH_4^+) and nitrate (NO_3^-) [19–21]. In the event that these nutrients are not taken up by plants, they may be carried into irrigation canals and water bodies, such as rivers. There exists a correlation between the residual nitrogen present in the discharge channel and the irrigation practices in the upper Kampar Watershed. Urea cocrystal has a beneficial function in delivering a well-balanced nitrogen supply and enhancing crop productivity in a manner that is more ecologically sustainable compared to the use of urea alone. The utilisation of alternative fertilisers has the potential to effectively mitigate nitrogen (N) loss, particularly in the form of nitrous oxide (N_2O) emissions, while also substantially enhancing nitrogen usage efficiency in sorghum cultivation [22].

Due to incomplete uptake by crops, a portion of the nutrients present in artificial fertilisers ultimately finds its way into both groundwater and surface water sources. The leaching of nitrates from agricultural land can result in both the eutrophication of surface water and the contamination of drinking water sources derived from surface and groundwater. Quantifying the precise contribution of nitrogen fertilisers to the contamination of surface water is a challenging task due to the presence of several nitrogen sources in most water bodies. Furthermore, the transformation of nitrogen in soil into gaseous or immobile forms might vary depending on climatic conditions [23]. Achieving optimal utilisation of nitrogen fertiliser can be accomplished through the modification of cultivation techniques, with a primary focus on cultivating varieties that possess superior nitrogen absorption efficiency. This approach enables the attainment of high crop yields while minimising input requirements [24–26]. The utilisation of fertilisers has been found to have detrimental effects on local surface water resources, resulting in pollution. However, these impacts can be mitigated by the implementation of a targeted fertiliser application management strategy. The potential for leaching-induced nitrates loss can be mitigated by ensuring that the nitrogen levels provided are either smaller than or equivalent to the crop's absorption capacity [27,28].

In addition, the substitution of inorganic fertilisers utilised in agricultural systems with organic alternatives, such as manure, can enhance the efficacy of grey water and mitigate the consequent water pollution. The implementation of conventional tillage, can be utilised as a method to mitigate water pollution per unit of agricultural output [4]. This approach involves the monitoring of soil moisture levels, with the aim of reducing leaching of pollutants into water bodies [9].

4. Conclusions

The research revealed that maize growing exhibited the highest grey water impact within the Pelalawan District. In contrast to the Kampar district, rice emerges as the primary source responsible for the substantial grey water footprint. In the Kampar watershed, the grey water footprint scores for rice and maize were found to exhibit suboptimal performance, as indicated by respective scores of 11.93 and 12.45.

In order to enhance future research endeavours, it is recommended that the methodology employed for the computation of GWF, as presented in this study, be subject to further refinement. The range of criteria considered for the determination of water quality in the context of GWF analysis could be expanded to incorporate more pollutants. The impact on GWF extends beyond the influence of nitrate-nitrogen and COD, encompassing nitrogen and phosphorus as well. In future research, it is recommended to utilise these supplementary factors as multiple proxies for the calculation of the Global Water Footprint (GWF). Hence, it is imperative to assess the effectiveness of the grey WF strategy and its utilisation in policymaking.

References

[1] Hoekstra A Y, Chapagain A K, Aldaya M M and Mekonnen M M 2009 *Water footprint manual* (Enchede: Water Footprint Network)
[2] Meng X, Lu J, Wu J, Zhang Z and Chen L 2022 Quantification and Evaluation of Grey Water Footprint in Yantai *Water* **14** 1893
[3] Zhao X, Liao X, Chen B, Tillotson M R, Guo W and Li Y 2019 Accounting global grey water footprint from both consumption and production perspectives *J. Clean. Prod.* **225** 963–71
[4] Chukalla A D, Krol M S and Hoekstra A Y 2018 Grey water footprint reduction in irrigated crop production: effect of nitrogen application rate, nitrogen form, tillage practice and irrigation strategy *Hydrol. Earth Syst. Sci.* **22** 3245–59
[5] Xionghe Qin, Sun C, Han Q and Zou W 2019 Grey Water Footprint Assessment from the Perspective of Water Pollution Sources: A Case Study of China *Water Resour.* **46** 454–65
[6] Ariyani M, Asdak C and Herwanto T 2021 Grey water footprint analysis of rice-straw pulp toward an adaptive strategy to climate change *Ecodevelopment J.* **4** 43–6
[7] Hoekstra A Y, Chapagain A K, Aldaya M M and Mekonnen M M 2009 *Water footprint manual* (Enchede: Water Footprint network)
[8] Mekonnen M M and Hoekstra A Y 2020 Sustainability of the blue water footprint of crops *Adv. Water Resour.* **143** 103679
[9] Fotia K and Tsirogiannis I 2023 Water Footprint Score: A Practical Method for Wider Communication and Assessment of Water Footprint Performance *ECWS-7 2023* (Basel Switzerland: MDPI) p 71
[10] Badan Pusat Statistik Provinsi Riau 2018 *Luas Panen dan Produksi Padi* (Badan Pusat Statistik (BPS) Provinsi Riau)
[11] Rosadi A H 2015 Kebijakan Pemupukan Berimbang untuk Meningkatkan Ketersediaan Pangan Nasional Balanced Fertilization Policy to Improve Availability of National Food *J. Pangan* **24** 1–14
[12] Ibrahim M and Khalil A 2021 The Water Footprint of Sugar Cane And Sugar Beet Cultivated in Egypt *J. Soil Sci. Agric. Eng.* **12** 647–55
[13] Wu M, Cao X, Guo X, Xiao J and Ren J 2021 Assessment of grey water footprint in paddy rice cultivation: Effects of field water management policies *J. Clean. Prod.* **313** 127876
[14] Kamble D C and Mane S P 2018 Agriculture Productivity In Malshiras Tahsil: A Geographical Analysis *Interdisciplinary International Seminar on Agriculture and Rural Development: Spatial Issues, Challenges and Approaches*
[15] Rao J H, Hardaha M K and Vora H M 2019 The Water Footprint Assessment of Agriculture in Banjar River Watershed *Curr. World Environ.* **14** 476–88
[16] Deng S, Mou S and Liu H 2020 Research on water footprint of main crops production in Baoding, China *IOP Conf. Ser. Earth Environ. Sci.* **545** 012029
[17] Lawniczak A E, Zbierska J, Nowak B, Achtenberg K, Grześkowiak A and Kanas K 2016 Impact of agriculture and land use on nitrate contamination in groundwater and running waters in central-west Poland *Environ. Monit. Assess.* **188** 172
[18] Taylor S D, He Y and Hiscock K M 2016 Modelling the impacts of agricultural management practices on river water quality in Eastern England *J. Environ. Manage.* **180** 147–63
[19] Kirk E R, van Kessel C, Horwath W R and Linquist B A 2015 Estimating Annual Soil

Carbon Loss in Agricultural Peatland Soils Using a Nitrogen Budget Approach ed X Wang *PLoS One* **10** e0121432
[20] Wijayanti F, Kurniawan S and Suprayogo D 2019 Impact of maize conservation agricultural system on nitrogen losses through surface runoff and soil erosion in dryland *J. Degrad. Min. Lands Manag.* **7** 1965–76
[21] Wantasen S, Luntungan J N, Tarore A E and Ogie T B 2020 The impact of nitrogen fertilizer on the aquatic environment in the Upper Tondano watershed, North Sulawesi Province *J. Phys. Conf. Ser.* **1434** 012031
[22] Bista P, Eisa M, Ragauskaitė D, Sapkota S, Baltrusaitis J and Ghimire R 2023 Effect of Urea-Calcium Sulfate Cocrystal Nitrogen Fertilizer on Sorghum Productivity and Soil N2O Emissions *Sustainability* **15** 8010
[23] Grzyb A, Wolna-Maruwka A and Niewiadomska A 2021 The Significance of Microbial Transformation of Nitrogen Compounds in the Light of Integrated Crop Management *Agronomy* **11** 1415
[24] Cao X, Qin B, Ma Q, Zhu L, Zhu C, Kong Y, Tian W, Jin Q, Zhang J and Yu Y 2023 Predicting the Nitrogen Quota Application Rate in a Double Rice Cropping System Based on Rice–Soil Nitrogen Balance and 15N Labelling Analysis *Agriculture* **13** 612
[25] Jahangir M M R, Kamruzzaman M, Ferdous J, Rahman M S and Islam K R 2023 *Integrating nitrogen fertilization with crop residue management to improve nitrogen-use efficiency of crops*
[26] Park J-R, Jang Y-H, Kim E-G, Lee G-S and Kim K-M 2023 Nitrogen Fertilization Causes Changes in Agricultural Characteristics and Gas Emissions in Rice Field *Sustainability* **15** 3336
[27] Bijay-Singh and Craswell E 2021 Fertilizers and nitrate pollution of surface and ground water: an increasingly pervasive global problem *SN Appl. Sci.* **3** 518
[28] Lyu Y, Yang X, Pan H, Zhang X, Cao H, Ulgiati S, Wu J, Zhang Y, Wang G and Xiao Y 2021 Impact of fertilization schemes with different ratios of urea to controlled release nitrogen fertilizer on environmental sustainability, nitrogen use efficiency and economic benefit of rice production: A study case from Southwest China *J. Clean. Prod.* **293** 126198

2024_Grey_water_footprint_of_crop_in_Riau_Province.pdf

ORIGINALITY REPORT

17%	12%	16%	%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	www.cuj.ac.in Internet Source	2%
2	Zhichen Liu, Ying Li. "Lithium Battery Thermal-Runaway Monitoring Based on Whole-Feature Neural Networks", Journal of The Electrochemical Society, 2024 Publication	1%
3	Baizhou Ma, Hui Huang, Hongjian Tang, Qiufang Huang, Xiufang Lin, Shumei Chen, Weiwen Li. "Experiment and analysis of drop-weight damping control of MR semi-active impact resistance-based hydraulic actuator", Smart Materials and Structures, 2023 Publication	1%
4	Prima Wahyu Titisari, Elfis Elfis, Irina Safitri Zen, Indry Chahyana, Tika Permatasari, Adelina Maryanti, Faizan Dalilla. "The role of Kampar watershed in achieving sufficient rice production and sustaining agriculture", Water Supply, 2024 Publication	1%
5	Enoch Owusu-Sekyere, Morné Erwin Scheepers, Henry Jordaan. "Economic Water Productivities Along the Dairy Value Chain in South Africa: Implications for Sustainable and Economically Efficient Water-use Policies in the Dairy Industry", Ecological Economics, 2017 Publication	1%

6	Yuchi Luo, Ye Yuan, Zhiwen Liang, Tianren Cai et al. "Improving the structural performance of low-temperature sputtered AlN on silicon substrate", Semiconductor Science and Technology, 2024 Publication	1 %
7	Yeqiao Wang. "Fresh Water and Watersheds", CRC Press, 2020 Publication	1 %
8	keep.eu Internet Source	1 %
9	Chapagain, A.K.. "The blue, green and grey water footprint of rice from production and consumption perspectives", Ecological Economics, 20110215 Publication	1 %
10	pure.rug.nl Internet Source	1 %
11	www.hydrol-earth-syst-sci.net Internet Source	1 %
12	discovery.researcher.life Internet Source	<1 %
13	moam.info Internet Source	<1 %
14	www.certex.ro Internet Source	<1 %
15	juniperpublishers.com Internet Source	<1 %
16	Christopher M. Chini, Lauren H. Logan, Ashlynn S. Stillwell. "Grey water footprints of U.S. thermoelectric power plants from 2010–2016", Advances in Water Resources, 2020 Publication	<1 %

17	Qian Wang, Kai Huang, Hui Liu, Yajuan Yu. "Factors affecting crop production water footprint: A review and meta-analysis", Sustainable Production and Consumption, 2023 Publication	<1 %
18	Shikun Sun, Jing Liu, Pute Wu, Yubao Wang, Xining Zhao, Xiaohong Zhang. "Comprehensive evaluation of water use in agricultural production: a case study in Hetao Irrigation District, China", Journal of Cleaner Production, 2016 Publication	<1 %
19	ejournal.uniks.ac.id Internet Source	<1 %
20	gardentabs.com Internet Source	<1 %
21	Seung-Hwan Yoo, , Jin-Yong Choi, Sang-Hyun Lee, and Taegon Kim. "Estimating Blue, Green and Grey Water of Paddy Rice in Korea", 2011 Louisville Kentucky August 7 - August 10 2011, 2011. Publication	<1 %
22	www.fao.org Internet Source	<1 %
23	Miguel Ayala, Laura, Michiel van Eupen, Guoping Zhang, Marta Pérez-Soba, Lucieta G. Martorano, Leila S. Lisboa, and Norma E. Beltrao. "Impact of agricultural expansion on water footprint in the Amazon under climate change scenarios", The Science of The Total Environment, 2016. Publication	<1 %
24	Xiaomin Xie, Tingting Zhang, Liming Wang, Zhen Huang. "Regional water footprints of	<1 %

potential biofuel production in China", Biotechnology for Biofuels, 2017
Publication

25	Yun Wang, Zhaoxian Su, Qingqing Zhang. "A Study on Spatial-Temporal Differentiation and Influencing Factors of Agricultural Water Footprint in the Main Grain-Producing Areas in China", Processes, 2022 Publication	<1 %
26	s3.eu-west-2.amazonaws.com Internet Source	<1 %
27	worldwidescience.org Internet Source	<1 %
28	www.ucviden.dk Internet Source	<1 %
29	Pejman AliGhaleh, Abbas Rohani, Mohammad Hossein Aghkhani, Armaghan Kosari Moghaddam. "How Production System Would Affect the Environmental Impacts of Sugar Beet Production?", Sugar Tech, 2024 Publication	<1 %
30	aiirjournal.com Internet Source	<1 %
31	Diana J. Fuerte-Velázquez, Luis Seguí-Amórtegui, Alberto Gómez-Tagle, Hilda Guerrero-García-Rojas. "Avocado Water Footprint for Two Municipalities in Michoacán, Mexico: A Research of the Blue and Green WF", Agriculture, 2024 Publication	<1 %
32	Francesca Serio, Pier Paolo Miglietta, Lucrezia Lamastra, Salvatore Ficocelli et al. "Groundwater nitrate contamination and agricultural land use: A grey water footprint perspective in Southern Apulia Region (Italy)", Science of The Total Environment, 2018	<1 %

Publication

33	Maziyar Vaez Roudbari, Ali Dehnavi, Shervin Jamshidi, Mohamadreza Yazdani. "A multi-pollutant pilot study to evaluate the grey water footprint of irrigated paddy rice", Agricultural Water Management, 2023 Publication	<1 %
34	Raul Munoz Castillo, Kuishuang Feng, Klaus Hubacek, Laixiang Sun, Joaquim Guilhoto, Fernando Miralles-Wilhelm. "Uncovering the Green, Blue, and Grey Water Footprint and Virtual Water of Biofuel Production in Brazil: A Nexus Perspective", Sustainability, 2017 Publication	<1 %
35	Abebe D. Chukalla, Maarten S. Krol, Arjen Y. Hoekstra. "Grey water footprint reduction in irrigated crop production: effect of nitrogen application rate, nitrogen form, tillage practice and irrigation strategy", Hydrology and Earth System Sciences Discussions, 2017 Publication	<1 %
36	Kongboon, Rattikarn, and Sate Sampattagul. "The water footprint of sugarcane and cassava in northern Thailand", Procedia - Social and Behavioral Sciences, 2012. Publication	<1 %
37	Wenfeng Liu, Marta Antonelli, Xingcai Liu, Hong Yang. "Towards improvement of grey water footprint assessment: With an illustration for global maize cultivation", Journal of Cleaner Production, 2017 Publication	<1 %

Exclude quotes	On	Exclude matches	Off
Exclude bibliography	On		