water

Editorial

Advances and Challenges in the Water Footprint Assessment Research Field: Towards a More Integrated Understanding of the Water–Energy–Food–Land Nexus in a Changing Climate

Maite M. Aldaya [1,*], Diego Sesma-Martín [2,*] and Joep F. Schyns [3,*]

1 Institute for Sustainability & Food Chain Innovation (IS-FOOD), Public University of Navarra (UPNA), Jerónimo de Ayanz Centre, Arrosadia Campus, 31006 Pamplona, Spain
2 Department of Economics and Business, University of La Rioja, Quintiliano Building, 26004 Logroño, Spain
3 Multidisciplinary Water Management Group, Faculty of Engineering Technology, University of Twente, 7500 AE Enschede, The Netherlands
* Correspondence: maite.aldaya@unavarra.es (M.M.A.); diego.sesmam@unirioja.es (D.S.-M.); j.f.schyns@utwente.nl (J.F.S.)

check for updates

Citation: Aldaya, M.M.; Sesma-Martín, D.; Schyns, J.F. Advances and Challenges in the Water Footprint Assessment Research Field: Towards a More Integrated Understanding of the Water–Energy–Food–Land Nexus in a Changing Climate. *Water* **2022**, *14*, 1488. https://doi.org/10.3390/w14091488

Received: 27 April 2022
Accepted: 2 May 2022
Published: 6 May 2022

1. Introduction

Today, human activities are highly dependent on fossil fuels and industrialized forms of agriculture and have reached a level that could damage the Earth's systems [1,2]. The energy production domain is a major driver of water stress globally, representing about 15 per cent of the world's freshwater withdrawals [3]. Likewise, the energy sector is the dominant contributor to climate change, accounting for about 60 per cent of total global greenhouse gas emissions [4]. However, 13 per cent of the world's population still lacks access to modern electricity [4]. In the domain of water supply, agriculture accounts for around 70 per cent of freshwater withdrawals globally, and more than 1 billion people still do not have access to drinking water [4]. In the food domain, each year, one third of all food produced is wasted or lost, while, paradoxically, nearly 690 million people are living in hunger [4]. According to the latest projections, the global population is expected grow to around 8.5 billion in 2030 and 9.7 billion in 2050 [4]. In the land domain, land use changes have affected almost a third (32%) of the global land area in just six decades (1960–2019) [5].

However, if efforts are just concentrated on one of these domains in isolation, impacts could shift to the other domains. Therefore, integrated research approaches are needed to address the interactions among the different domains in the context of a changing climate [2,6,7]. In terms of decision making, identifying integrated solutions requires analysing the broader context, contextualizing and complementing water information with other indicators [8]. In the face of meeting Sustainable Development Goals (SDGs), integrated assessments covering the water–energy–food–land nexus are needed to ensure that the gains and trade-offs among domains are considered.

Water footprint (WF) assessment has developed into a fundamentally interdisciplinary and integrative research field [9,10]. A WF assessment, when properly detailed and disaggregated, can be a useful tool to address the nexus [7]. However, in the context of climate change, several gaps in our understanding of the feedbacks within the water–energy–food–land nexus remain, which requires advances in the field of WF assessment, as we will argue in this editorial. Section 2 focuses on the water–energy side of the nexus, Section 3 deals with the water–food component, and Section 4 covers the water–land interface. Finally, Section 5 includes a call for action to develop papers that advance the research on WF assessment in the water–energy–food–land nexus in the context of climate change, trying to overcome the silos that prevent a more integrated management of water resources.

2. Towards a Water-Sustainable Energy Transition to Meet Climate Objectives

The energy sector is one of the most water-intensive sectors and the main contributor to greenhouse gas emissions worldwide [3,4]. The success of the energy transition depends both on reducing greenhouse gas emissions to meet climate objectives and on achieving a sustainable energy mix within the limits to freshwater use.

Pioneering research on the WF of energy emerged in 2009. Early work assessed the WFs for bioethanol and biodiesel derived from food or energy crops, so-called first-generation biofuels, as they are relatively water-intensive [11–14]. This literature was subsequently broadened through studies assessing the WFs of wood-energy products [15–17], first-generation biofuels produced in circular systems [18], second-generation biofuels from crop residues [19,20], and third-generation biofuels from algae [21]. In terms of the generation of electricity, the existing literature covers practically all generation technologies (renewable and non-renewable) that use water at some stage [22–27]. Furthermore, the WFs of energy in specific regions of the world have also been investigated [28,29]. Finally, some studies have also recently analyzed virtual water trade from the power grid [30,31].

The energy sector is a major contributor to climate change. Consequently, most efforts have focused on reducing greenhouse gas emissions to achieve the climate targets of the Paris Agreement. Reducing the carbon footprint can be achieved with a transition to a cleaner energy mix. However, new energy scenarios may involve trade-offs in terms of water [32,33] and land. For example, Holmatov et al. [18] assessed the water, land, and carbon footprints of two energy scenarios with large bioenergy contributions and found important trade-offs. Hydropower represents another example of a technology with low emission generation, but with a substantial WF [23,34]. Therefore, considering all footprints is necessary to better understand the impacts of the energy sector and improve decision-making regarding the energy transition [29].

Despite previous efforts, there are some limitations and caveats that require further research. Most research has focused on the consumptive (green and blue) WF of energy. However, the grey WF, a measure of water pollution, of different energy sources is still poorly understood. It is expected that considering grey water will have a significant impact on the WF of some energy sources (e.g., nuclear). Additionally, there is also a lack of studies analysing the WFs of new fossil fuels such as hydrogen gas, whose potential in the transport sector is promising. Finally, WF studies generally ignore climate-related shocks. Including these types of aspects could provide an idea of how resilient possible future electricity mixes are to climate change. Furthermore, one of the main barriers to proper accounting of water use of the energy sector is the lack of data availability [35,36], which calls for efforts to reduce data gaps.

3. Feeding the Growing World Population in a Water-Sustainable Way

WF studies about feeding the world in a water-sustainable way have traditionally focused on how to increase water productivity in crop production and raise livestock in order to mitigate water scarcity [9,37].

More recently, since the publication of the first study on the impact of diet on the WF [38], the WF of diets research has boomed. The WFs of different diets have been analysed in detail, comparing the existing diet versus recommended ones (healthy diet with meat, healthy pescetarian diet, and healthy vegetarian diet) [39,40]. Different aspects such as the nutritional water productivity have also been studied in terms of kilocalories or grams of protein, fat, or carbohydrates per litre of water [41]. Furthermore, the WF studies have opened up the possibility of analysing dietary shifts to mitigate climate change and water crises [42].

However, many studies have focused on diets, providing total WFs per product or category without differentiating between the WFs of different production systems [41–43], which can vary quite substantially. For instance, in the case of livestock production, extensive grassland-based systems generally present lower blue- and nitrogen-related grey WFs compared with intensive landless systems [44]. Another example is the organic crop production versus the conventional production system. Scattered studies comparing both systems also point to significant differences in blue and grey WFs between them [45,46]. Further research is needed to include the green, blue, and grey WFs and related impacts of the different types of livestock production systems and organic versus conventional production systems in diet studies as they vary in terms of water pressure [44–46].

Another focus of research has become the WF of food loss and waste. At the global level, the blue WF related to the production of food waste is about 250 billion m^3, which is 3.6 times the blue WF of the USA's total consumption [9]. The WF of food losses has been applied to different contexts, including China [47], America [48], or Spain [49,50]. According to the USA analysis, the water savings through avoiding food loss and waste is as much as twice as what could be achieved by dietary shifts [48]. Therefore, a combination of both dietary shifts and reductions in food loss and waste are effective for mitigating water scarcity.

Nevertheless, the vast majority of the WF studies on diets and food waste only consider water use or water use coupled with a few environmental aspects, such as greenhouse gas emissions, and hardly any adopt a holistic environmental approach. Therefore, the results obtained from these assessments must be interpreted rigorously, as they may show a reductionist outlook of the whole environmental impact [51]. For instance, when analysing the WF alone, one develops preferred strategies from a water-sustainability perspective, but not preferred in terms of climate change mitigation. Future research could adopt a systems approach to integrate the different environmental domains to build resilient food systems [52].

Finally, in the context of climate change, a greater understanding of different countries' dependencies on the availability of water in other parts of the world for producing the different consumer products is key. For instance, Europe's reliance on soybean imports could disrupt meat and dairy prices, as most soybean producing regions are highly vulnerable to water scarcity [53]. This would help ensure not only food and water security but also economic stability as climate change begins to affect water availability and drought severity.

4. Reconciling the Sustainable Use of Both Water and Land Resources

Water footprint and virtual water trade have connections with sustainable land management and biodiversity conservation. A better understanding of these connections in the context of climate change is needed to reconcile the sustainable water and land use in the future. We illustrate this with three examples.

First, WF reduction in agriculture can be achieved by increasing crop yields, i.e., land productivity, by changing agricultural practices and inputs that increase yield but do not proportionally increase water consumption [54]. Thus, WF reduction comes with trade-offs between sustainable use of water and land resources, which require further exploration. For example, by how much can WFs be reduced through sustainable intensification of agriculture [55]? Further, what trade-offs are there in consumptive (green and blue) and grey water use and the intensity of land use of conventional versus organic farming? Exploring such trade-offs in the context of climate change is especially interesting, since climate change affects both crop water consumption and yields through changes in precipitation and evapotranspiration patterns (including the occurrence of shocks such as droughts and heat waves) and the effects of CO_2 fertilization [56–58].

Second, it has been estimated that significant water savings could be achieved at the regional and global scales through the optimization of cropping and virtual water trade patterns [59,60]. However, land constraints are crucial in determining the potential water savings of such optimization procedures, since they determine to what degree the production of crops can be concentrated in the regions where they have the smallest WF per unit of production. Therefore, it is interesting to explore water saving potentials through cropping pattern optimization under different scenarios of crop area expansion when considering the changes in the agricultural suitability (and hence WFs) of these areas as a result of climate change [61].

Lastly, the link between limits to land and green water use have recently been made explicit. Schyns et al. [62] show that, similar to how environmental flow requirements subtract from the availability of blue water, biodiversity conservation needs (i.e., environmental land requirements) subtract from the availability of green water for human uses. However, many questions still remain on how land-use constraints affect water scarcity. For example, how do alternative scenarios of lands reserved for biodiversity conservation (in terms of total size and spatial configuration) affect green water availability and scarcity patterns? Moreover, how will these patterns be different under climate change, which affects green water resources availability?

5. Call for Action

We have argued that WF assessment has brought many insights to the water–energy–food–land nexus, but also that advances in the field are needed to better understand interaction in this nexus in the context of climate change. For this Special Issue, "Water Footprint and Virtual Water Trade Approaches: Applications to the Water-Energy-Food-Land Nexus in a Context of Climate Change", we invite studies that innovatively apply existing or develop new WFs (green, blue, grey) and virtual water trade approaches to contribute to the advancement of the field in this direction.

Author Contributions: M.M.A.: Conceptualization and writing. D.S.-M.: Conceptualization and writing. J.F.S.: Conceptualization and writing. All authors have read and agreed to the published version of the manuscript.

Funding: The project leading to these results received funding from Fundación La Caixa and Fundación Caja Navarra, under agreement LCF/PR/PR13/51080004. Additionally, this publication has been supported by the grant *HAR2017-860086-R* funded by MCIN/AEI/10.13039/501100011033 and by "ERDF A way of making Europe".

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Persson, L.; Almroth, B.M.C.; Collins, C.D.; Cornell, S.; de Wit, C.A.; Diamond, M.L.; Fantke, P.; Hassellöv, M.; MacLeod, M.; Ryberg, M.W.; et al. Outside the Safe Operating Space of the Planetary Boundary for Novel Entities. *Environ. Sci. Technol.* **2022**, *56*, 1510–1521. [CrossRef] [PubMed]
2. Rockström, J.; Steffen, W.; Noone, K.; Persson, Å.; Chapin, F.S., III; Lambin, E.; Lenton, T.M.; Scheffer, M.; Folke, C.; Schellnhuber, H.J.; et al. Planetary boundaries: Exploring the safe operating space for humanity. *Ecol. Soc.* **2009**, *14*, 32. Available online: http://www.ecologyandsociety.org/vol14/iss2/art32/ (accessed on 15 April 2022). [CrossRef]
3. IEA (International Energy Agency). Water for energy. Is energy becoming a thirstier resource. In *World Energy Outlook 2012*; IEA: Paris, France, 2012.
4. UN (United Nations). United Nations Sustainable Development Goals. United Nations, 2022. Available online: https://www.un.org/sustainabledevelopment/ (accessed on 15 April 2022).
5. Winkler, K.; Fuchs, R.; Rounsevell, M.; Herold, M. Global land use changes are four times greater than previously estimated. *Nat. Commun.* **2021**, *12*, 2501. [CrossRef] [PubMed]
6. Steffen, W.; Richardson, K.; Rockström, J.; Cornell, S.E.; Fetzer, I.; Bennett, E.M.; Biggs, R.; Carpenter, S.R.; de Vries, W.; de Wit, C.A.; et al. Planetary boundaries: Guiding human development on a changing planet. *Science* **2015**, *347*, 1259855. Available online: https://www.science.org/doi/pdf/10.1126/science.1259855 (accessed on 15 April 2022). [CrossRef]
7. Vanham, D. Does the water footprint concept provide relevant information to address the water–food–energy–ecosystem nexus? *Ecosyst. Serv.* **2016**, *17*, 298–307. [CrossRef]
8. Aldaya, M.M.; Garrido, A.; Llamas, R. Water Footprint and Virtual Water Trade: The Birth and Growth of a New Research Field in Spain. *Water* **2020**, *12*, 2641. [CrossRef]
9. Hoekstra, A.Y. Water Footprint Assessment: Evolvement of a New Research Field. *Water Resour. Manag.* **2017**, *31*, 3061–3081. [CrossRef]

10. Zhang, Y.; Huang, K.; Yu, Y.; Yang, B. Mapping of water footprint research: A bibliometric analysis during 2006–2015. *J. Clean. Prod.* **2017**, *149*, 70–79. [CrossRef]
11. Hoekstra, A.Y.; Gerbens-Leenes, W.; Van der Meer, T.H. The water footprint of Jatropha curcas under poor growing conditions. *Proc. Natl. Acad. Sci. USA* **2009**, *106*, E119. [CrossRef]
12. Gerbens-Leenes, W.; Hoekstra, A.Y.; van der Meer, T.H. The water footprint of bioenergy. *Proc. Natl. Acad. Sci. USA* **2009**, *106*, 10219–10223. [CrossRef]
13. Gerbens-Leenes, P.W.; Hoekstra, A.Y.; Van der Meer, T.H. The water footprint of energy from biomass: A quantitative assessment and consequences of an increasing share of bio-energy in energy supply. *Ecol. Econ.* **2009**, *68*, 1052–1060. [CrossRef]
14. Gerbens-Leenes, W.; Hoekstra, A.Y. The water footprint of sweeteners and bio-ethanol. *Environ. Int.* **2012**, *40*, 202–211. [CrossRef]
15. Schyns, J.F.; Booij, M.J.; Hoekstra, A.Y. The water footprint of wood for lumber, pulp, paper, fuel and firewood. *Adv. Water Resour.* **2017**, *107*, 490–501. [CrossRef]
16. Schyns, J.F.; Vanham, D. The water footprint of wood for energy consumed in the European Union. *Water* **2019**, *11*, 206. [CrossRef]
17. Das, K.; Gerbens-Leenes, P.W.; Nonhebel, S. The water footprint of food and cooking fuel: A case study of self-sufficient rural India. *J. Clean. Prod.* **2021**, *281*, 125255. [CrossRef]
18. Holmatov, B.; Hoekstra, A.Y.; Krol, M.S. Land, water and carbon footprints of circular bioenergy production systems. *Renew. Sustain. Energy Rev.* **2019**, *111*, 224–235. [CrossRef]
19. Mathioudakis, V.; Gerbens-Leenes, P.W.; Van der Meer, T.H.; Hoekstra, A.Y. The water footprint of second-generation bioenergy: A comparison of biomass feedstocks and conversion techniques. *J. Clean. Prod.* **2017**, *148*, 571–582. [CrossRef]
20. Holmatov, B.; Schyns, J.F.; Krol, M.S.; Gerbens-Leenes, P.W.; Hoekstra, A.Y. Can crop residues provide fuel for future transport? Limited global residue bioethanol potentials and large associated land, water and carbon footprints. *Renew. Sust. Energ. Rev.* **2021**, *149*, 111417. [CrossRef]
21. Gerbens-Leenes, P.W.; Xu, L.; De Vries, G.J.; Hoekstra, A.Y. The blue water footprint and land use of biofuels from algae. *Water Resour. Res.* **2014**, *50*, 8549–8563. [CrossRef]
22. Mekonnen, M.M.; Hoekstra, A.Y. The blue water footprint of electricity from hydropower. *Hydrol. Earth Syst. Sci.* **2012**, *16*, 179–187. [CrossRef]
23. Mekonnen, M.M.; Gerbens-Leenes, P.W.; Hoekstra, A.Y. The consumptive water footprint of electricity and heat: A global assessment. *Environ. Sci. Water Res. Technol.* **2015**, *1*, 285–297. [CrossRef]
24. Sesma-Martín, D.; Mar Rubio-Varas, M. Freshwater for cooling needs: A long-run approach to the nuclear water footprint in Spain. *Ecol. Econ.* **2017**, *140*, 146–156. [CrossRef]
25. Rosa, L.; Rulli, M.C.; Davis, K.F.; D'Odorico, P. The water-energy nexus of hydraulic fracturing: A global hydrologic analysis for shale oil and gas extraction. *Earth's Future* **2018**, *6*, 745–756. [CrossRef]
26. Sesma-Martín, D. The river's light: Water needs for thermoelectric power generation in the Ebro River Basin, 1969–2015. *Water* **2019**, *11*, 441. [CrossRef]
27. Vaca-Jiménez, S.; Gerbens-Leenes, P.W.; Nonhebel, S. The monthly dynamics of blue water footprints and electricity generation of four types of hydropower plants in Ecuador. *Sci. Total Environ.* **2020**, *713*, 136579. [CrossRef]
28. Fulton, J.; Cooley, H. The water footprint of California's energy system, 1990–2012. *Environ. Sci. Technol.* **2015**, *49*, 3314–3321. [CrossRef]
29. Vanham, D.; Medarac, H.; Schyns, J.F.; Hogeboom, R.J.; Magagna, D. The consumptive water footprint of the European Union energy sector. *Environ. Res. Lett.* **2019**, *14*, 104016. [CrossRef]
30. Chini, C.M.; Djehdian, L.A.; Lubega, W.N.; Stillwell, A.S. Virtual water transfers of the US electric grid. *Nat. Energy* **2018**, *3*, 1115–1123. [CrossRef]
31. Chini, C.M.; Peer, R.A. The traded water footprint of global energy from 2010 to 2018. *Sci. Data* **2021**, *8*, 7. [CrossRef] [PubMed]
32. Cano-Rodríguez, S.; Rubio-Varas, M.; Sesma-Martín, D. At the crossroad between green and thirsty: Carbon emissions and water consumption of Spanish thermoelectricity generation, 1969–2019. *Ecol. Econ.* **2022**, *195*, 107363. [CrossRef]
33. Mekonnen, M.M.; Gerbens-Leenes, P.W.; Hoekstra, A.Y. Future electricity: The challenge of reducing both carbon and water footprint. *Sci. Total Environ.* **2016**, *569*, 1282–1288. [CrossRef]
34. Hogeboom, R.J.; Knook, L.; Hoekstra, A.Y. The blue water footprint of the world's artificial reservoirs for hydroelectricity, irrigation, residential and industrial water supply, flood protection, fishing and recreation. *Adv. Water Resour.* **2018**, *113*, 285–294. [CrossRef]
35. Sesma-Martín, D.; Rubio-Varas, M. The weak data on the water–energy nexus in Spain. *Water Policy* **2019**, *21*, 382–393. [CrossRef]
36. Larsen, M.A.D.; Petrovic, S.; Engström, R.E.; Drews, M.; Liersch, S.; Karlsson, K.B.; Howells, M. Challenges of data availability: Analysing the water-energy nexus in electricity generation. *Energy Strategy Rev.* **2019**, *26*, 100426. [CrossRef]
37. Mekonnen, M.M.; Gerbens-Leenes, W. The Water Footprint of Global Food Production. *Water* **2020**, *12*, 2696. [CrossRef]
38. Hoekstra, A.Y. The water footprint of animal products. In *The Meat Crisis: Developing More Sustainable Production and Consumption*; D'Silva, J., Webster, J., Eds.; Earthscan: London, UK, 2010.
39. Vanham, D.; Hoekstra, A.Y.; Bidoglio, G. Potential water saving through changes in European diets. *Environ. Int.* **2013**, *61*, 45–56. [CrossRef]
40. Vanham, D.; Comero, S.; Gawlik, B.M.; Bidoglio, G. The water footprint of different diets within European sub-national geographical entities. *Nat. Sustain.* **2018**, *1*, 518–525. [CrossRef]

41. Blas, A.; Garrido, A.; Unver, O.; Willaarts, B. A comparison of the Mediterranean diet and current food consumption patterns in Spain from a nutritional and water perspective. *Sci. Total Environ.* **2019**, *664*, 1020–1029. [CrossRef]
42. Kim, B.F.; Santo, R.E.; Scatterday, A.P.; Fry, J.P.; Synk, C.M.; Cebron, S.R.; Mekonnen, M.M.; Hoekstra, A.Y.; de Pee, S.; Bloem, M.W.; et al. Country-specific dietary shifts to mitigate climate and water crises. *Glob. Environ. Chang.* **2020**, *62*, 101926. [CrossRef]
43. Willett, W.; Rockström, J.; Loken, B.; Springmann, M.; Lang, T.; Vermeulen, S.; Garnett, T.; Tilman, D.; DeClerck, F.; Wood, A.; et al. Food in the Anthropocene: The EAT–Lancet Commission on healthy diets from sustainable food systems. *Lancet* **2019**, *393*, 447–492. [CrossRef]
44. Mekonnen, M.M.; Hoekstra, A.Y. *The Green, Blue and Grey Water Footprint of Farm Animals and Animal Products, Volume 2: Appendices*; Value of Water Research Report Series No.48; UNESCO-IHE: Delft, The Netherlands, 2010.
45. Ercin, A.E.; Aldaya, M.M.; Hoekstra, A.Y. The water footprint of soy milk and soy burger and equivalent animal products. *Ecol. Indic.* **2012**, *18*, 392–402. [CrossRef]
46. Johannes, H.P.; Priadi, C.R.; Herdiansyah, H.; Novalia, I. Water footprint saving through organic rice commodity. *AIP Conf. Proc.* **2020**, *2255*, 040002. [CrossRef]
47. Liu, J.; Lundqvist, J.; Weinberg, J.; Gustafsson, J. Food Losses and Waste in China and Their Implication for Water and Land. *Environ. Sci. Technol.* **2013**, *47*, 18, 10137–10144. [CrossRef]
48. Mekonnen, M.M.; Fulton, J. The effect of diet changes and food loss reduction in reducing the water footprint of an average American. *Water Int.* **2018**, *43*, 860–870. [CrossRef]
49. Blas, A.; Garrido, A.; Willaarts, B. Food consumption and waste in Spanish households: Water implications within and beyond national borders. *Ecol. Indic.* **2018**, *89*, 290–300. [CrossRef]
50. Penalver, J.G.; Aldaya, M.M. The Role of the Food Banks in Saving Freshwater Resources through Reducing Food Waste: The Case of the Food Bank of Navarra, Spain. *Foods* **2022**, *11*, 163. [CrossRef]
51. Aldaya, M.M.; Ibañez, F.C.; Domínguez-Lacueva, P.; Murillo-Arbizu, M.T.; Rubio-Varas, M.; Soret, B.; Beriain, M.J. Indicators and Recommendations for Assessing Sustainable Healthy Diets. *Foods* **2021**, *10*, 999. [CrossRef]
52. Rockström, J.; Edenhofer, O.; Gaertner, J.; DeClerck, F. Planet-proofing the global food system. *Nat. Food* **2020**, *1*, 3–5. [CrossRef]
53. Ercin, E.; Chico, D.; Chapagain, A.K. Vulnerabilities of the European Union's Economy to Hydrological Extremes Outside its Borders. *Atmosphere* **2019**, *10*, 593. [CrossRef]
54. Chukalla, A.D.; Krol, M.S.; Hoekstra, A.Y. Green and blue water footprint reduction in irrigated agriculture: Effect of irrigation techniques, irrigation strategies and mulching. *Hydrol. Earth Syst. Sci.* **2015**, *19*, 4877–4891. [CrossRef]
55. Rockström, J.; Williams, J.; Daily, G.; Noble, A.; Matthews, N.; Gordon, L.; Wetterstrand, H.; DeClerck, F.; Shah, M.; Steduto, P.; et al. Sustainable intensification of agriculture for human prosperity and global sustainability. *Ambio* **2017**, *46*, 4–17. [CrossRef] [PubMed]
56. Karandish, F.; Kalanaki, M.; Saberali, S.F. Projected impacts of global warming on cropping calendar and water requirement of maize in a humid climate. *Arch. Agron. Soil Sci.* **2017**, *63*, 1–13. [CrossRef]
57. Masud, M.B.; McAllister, T.; Cordeiro, M.R.C.; Faramarzi, M. Modeling future water footprint of barley production in Alberta, Canada: Implications for water use and yields to 2064. *Sci. Total Environ.* **2018**, *616–617*, 208–222. [CrossRef] [PubMed]
58. Jägermeyr, J.; Müller, C.; Ruane, A.C.; Elliott, J.; Balkovic, J.; Castillo, O.; Faye, B.; Foster, I.; Folberth, C.; Franke, J.A.; et al. Climate impacts on global agriculture emerge earlier in new generation of climate and crop models. *Nat. Food* **2021**, *2*, 873–885. [CrossRef]
59. Davis, K.F.; Rulli, M.C.; Seveso, A.; D'Odorico, P. Increased food production and reduced water use through optimized crop distribution. *Nat. Geosci.* **2017**, *10*, 919–924. [CrossRef]
60. Chouchane, H.; Krol, M.S.; Hoekstra, A.Y. Changing global cropping patterns to minimize national blue water scarcity. *Hydrol. Earth Syst. Sci.* **2020**, *24*, 3015–3031. [CrossRef]
61. Delzeit, R.; Zabel, F.; Meyer, C.; Václavík, T. Addressing future trade-offs between biodiversity and cropland expansion to improve food security. *Reg. Environ. Change* **2017**, *17*, 1429–1441. [CrossRef]
62. Schyns, J.F.; Hoekstra, A.Y.; Booij, M.J.; Hogeboom, R.J.; Mekonnen, M.M. Limits to the world's green water resources for food, feed, fiber, timber, and bioenergy. *Proc. Natl. Acad. Sci. USA* **2019**, *116*, 4893–4898. [CrossRef]