EPiC Series in Computing
Volume 84, 2022, Pages 117–128
Proceedings of the Society 5.0 Conference 2022
- Integrating Digital World and Real World
to Resolve Challenges in Business and Society

Identification and Chaining of Water Accounting Data Stakeholders

Ryan Prater[1] and Barbara Eisenbart[2]

[1] FHNW University of Applied Sciences and Arts Northwestern Switzerland, Windisch, Switzerland
ryanjprater@gmail.com
[2] FHNW University of Applied Sciences and Arts Northwestern Switzerland, Windisch, Switzerland
barbara.eisenbart@fhnw.ch

Abstract

Purpose – Multiple water accounting techniques exist and suffer from data gaps and misaligned stakeholders which creates standardization and consolidation problems in the data of the industry. This study identifies domain-based stakeholders and defines stakeholder data relationships to improve inter-stakeholder data efficiency.

Design/methodology/approach – The research design follows an inductive data collection of qualitative cross-sectional data through semi-structured expert interviews. The recorded interviews were transcribed, thematically coded, and the findings summarized.

Findings – The result is an improved specificity of water accounting data stakeholders which have different data input and output requirements. Our research found that these stakeholders can be chained together based on their data relationships which enables identifying inter-stakeholder relationships and improved data efficiency.

Social Implications – Water is a vital resource for humans and the United Nations Sustainable Development Goals. More precise description of stakeholders and data factors enable more efficient data flow which can improve the efficacy of terminal impact.

Originality/value – The awareness of problem is refined by increasing stakeholder specificity and identifying data input/output requirements. This enables chaining of stakeholders and data to clarify stakeholder data requirements and improve data efficiency for purposes such as collaboration and policy guidance.

Keywords: Sustainable Water Management, Water Accounting, Water Footprinting, Life Cycle Assessment, Data Stakeholders

Type of work: Conceptual Paper

1 Introduction

Water management is explicitly and implicitly present in the 17 United Nations Sustainable Development Goals, "a shared blueprint for peace and prosperity for people and the planet, now and into the future"[1]. To manage water and ensure the survivability of our planet and species, we must first establish aligned and quality accounting standards.

Water accounting literature often points to agriculture as contributing up to 92% of global water use [1], however, significant problems of data quality exist [1; 2; 3; 4, p. 754; 5]which make accounting for, and therefore managing water an inaccurate practice. This problem has been compounded by international trade of water-based goods and services [6; 7], and misalignment of stakeholders [8].

If the United Nations Water Sustainable Development Goals are not properly addressed, negative global consequences may take place, such as:

- Negative shifts in natural resources (climate change) and animal extinctions [9; 10]
- Food insecurity [11]
- Increased human migration [12]
- Exceeding the biological capacity of the earth (this already happened around 1970) [13]
- Water-borne pandemics, hydro-terrorism, and war [14]

This paper is the result of a one-year research process which conducted a two-part literature review on water accounting and water data to answer the question **what is the relationship between stakeholders and data in water accounting?** To answer this, expert interviews were used to produce 14 water accounting data stakeholder roles which build upon models from the literature. The relation of these roles was then analyzed to produce a more granular approach to understanding the differing input/output data requirements of water accounting data stakeholders.

2 Key Concepts

A two-part literature review was conducted which covered (1) water accounting and (2) water data. Both literature reviews used multiple search keyword sets to produce results which were then narrowed down by screening phases. From these reviews, the data stakeholder framework of Lnenicka & Komarkova [15] was used as a foundational resource for the remainder of this study (Section 2.3).

2.1 Water Accounting

Water accounting refers to the quantitative assessment of water data (e.g., rainfall, consumption, etc.) for a desired stakeholder defined and dependent goal. Two core practices exist for water accounting, each with their own perspectives.

The **Water Footprint Assessment (WFA)** measures basin water appropriation in terms of liters of water by using color schemes of water to differentiate between groundwater, rainfall and moisture, and pollution offset. WFA focuses on improved water management and uses benchmarks to compare products and assess sustainability within a response formulation [16].

[1] https://sdgs.un.org/goals

Table 1: A sample of datasets used for water accounting, indicating the complexity and in some cases, redundancy of data. Source: own table, data from Wiedmann et al. [5].

Dataset Name	**Years Covered**	**Data Details**
Asian International Input-Output Table	1985 - 2005 in five-year intervals	Nine Asian countries plus the USA, 76 sectors, including an employment matrix
Eora	1970 – present	∼170 countries, 40-100 sectors, tax info, multiple sustainability indicators
EXIOPOL	2000 – present	43 countries, 130 sectors, 300+ environmental extensions
Global Analysis Trade Project (GTAP)	2004 – present	113 countries, 57 sectors, environmental extensions
World Input-Output Database (WIOD)	1995 – 2006	40 countries, 35 industries, 59 sectors, labor, and value-added extensions

The **Life-Cycle Assessment (LCA)** practice takes a different perspective by measuring inventories within a product's supply chain, of which water is one part. Whereas WFA compares products and basins directly to assess holistic water consumption and scarcity, LCA considers water as one factor which must be balance against others (e.g., social welfare) to measure impact.

Some attempts have been made to combine such perspectives [16], but there remains no agreed upon central standard for scientifically conceptualizing water use [17; 18].

2.2 Water Data

Within water accounting, there is another problem frequently noted: water data. Because of the difference of accounting methods and reliance on national or sub-national accounts, many studies address the lack of data standardization and consolidation for water accounting [2; 3; 5]. This leads researchers to compare-and-contrast datasets, as seen in Table 1. Further, data issues may include multiple geographic locations which contain data of different spatial resolutions and standardized units of measure, outdated data which prevents extrapolation of trends and small sample sizes, and high variance of results. In this study, *data disorganization* is used to refer to the overall problem of water data.

2.3 Data Stakeholders

A framework was sought which could structure and address the roles and responsibilities of water data stakeholders. For this, the Big Open Linked Data Stakeholders [15] were used to provide a general conceptualization of data-stakeholders relationships.

Lnenicka & Komarkova [15] list the following data stakeholders:

- **Ecosystem Orchestrators** have the responsibilities of "regulation and enforcement" [15, p. 138] of the context's (i.e., water accounting) goals.
- **Data Prosumers** produce and use data, such as aggregating existing data to create combined datasets.
- **Data Users** create value with data and provide feedback about quality and reusability.

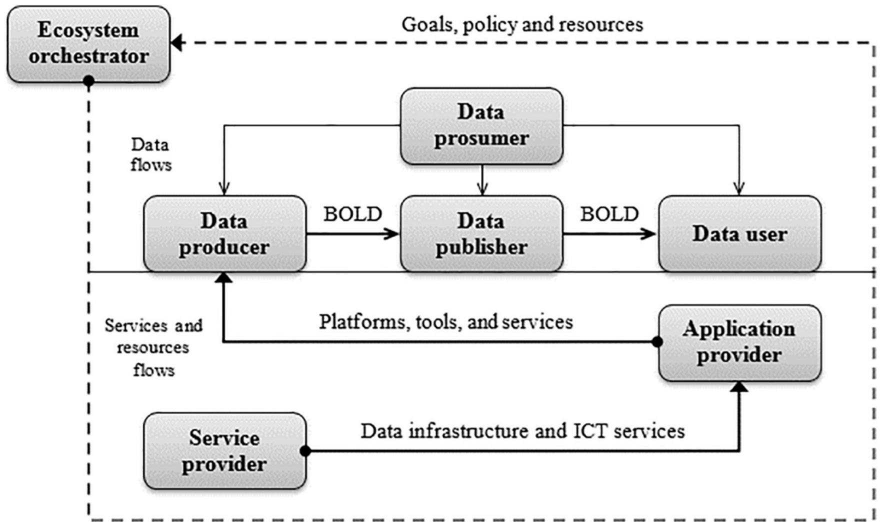

Figure 1: The Big Open Linked Data Stakeholders. Source: Lnenicka & Komarkova [15]

- **Data Publishers** are similar to Data Producers, but include responsibilities of data disclosure, awareness, and delivery.
- **Data Producers** generate and maintain "adequate data quality and compliance with standards" [15, p. 139].
- **Application Providers** deliver platforms, tools, and services which support the further roles.
- **Service Providers** establish and maintain the computing framework in which the data is stored and moved.

For brevity, this study refers to the above roles as *general data stakeholders*.

2.4 Summary

The multiple methods of water accounting have led to a misalignment of stakeholders, e.g., water accounting researchers which fill the Data Prosumer role. Lack of standardization and gaps from these stakeholders results in data organization problems. As seen in Figure 1, this creates a negative feedback loop, i.e., divergence and disconnection of the stakeholders and data. To explore this phenomenon, Section 3 details the stakeholder exploration and objectives of this study.

3 Exploring Stakeholders of Water Accounting Data

The literature highlights a misalignment of stakeholders and data disorganization in water accounting. Lnenicka & Komarkova [15] show a relationship exists between stakeholders and data.

Therefore, this study aims to answer: **what is the relationship between stakeholders and data in water accounting?**

To answer the question of the study, qualitative primary data was obtained through expert interviews and refined through thematic coding. These patterns were then applied to the general data stakeholders to identify matches and gaps in application to this study. This prompted the discovery of 14 *water accounting data stakeholders* and a refinement of water data disorganization.

3.1 Research Design

This study took place under the context of a comprehensive research project of the same research question. 11 experts (`n=11`) were interviewed with varying responsibilities in water accounting (`INT1-INT11`). Discovery of interviewees was mixed between outreach and "opportunistic sampling" [19, p. 32]. 10 interviews were conducted via video call, the remaining interview via phone (`INT1`), each interview lasting between 30-90 minutes. Questions were based on the research question of this study and adapted to "elicit participants' accounts of aspects of their experience" [20]. Only one of the interviews was not recorded (`INT8`). All recorded interviews were transcribed with Sonix[2] and corrected manually. 10 interviews were single-cycle thematically coded (`INT2-INT11`). Seven interviews were further two-cycle coded for further insights into topical patterns (`INT2-INT8`). All coding was done with ATLAS.ti[3]. Details of the interviewees can be found in Table 2.

3.2 Findings of Stakeholders in Water Accounting Data

The interviews indicated interviewees of the same general data stakeholder role had varying perspectives and relationships with data or their assigned role was not accurate in terms of their observed data input/output. Examples include:

- Serving different customer segments (`INT1, INT7`)
- Conceptualizing research in different manners (`INT3, INT7`)
- Producing data without significant connection to other general data stakeholders (`INT10`)

These findings suggested the granularity of the stakeholder assignment was not fine enough to capture differences in stakeholder-data relationships which prevented accurate analysis of the research question. To achieve such granularity, the data roles were subdivided into 14 water accounting data stakeholder roles, each described briefly below.

Policy Creators accept data from Corporations, Outcome Creators, and Impact Creators in the form of reports, aggregated data, lobbying, and the voices of those they govern. Their output is the regulation that is passed to Government Agencies responsible for implementation.

Impact Creators receive data from Data Users, Corporations, and Outcome Creators to identify actions which lead to improved terminal situations for the basins or society (as opposed to corporate outcomes).

Government Agencies were not represented in the interviews but were mentioned frequently by `INT6` and `INT10`. They represent entities of the state which transform policy into practice.

Farming Communities are where individual farm data becomes aggregated and redistributed out again. This "coffee shop" (`INT10`) acts as a self-governing body where information and cultural norms are shared and implicitly communicated.

[2] https://sonix.ai/
[3] https://atlasti.com/

Table 2: Overview of data collection of qualitative interviews. Source: own summary.

Interview	General Data Stakeholder Role	Position, Organization (Country)	Organization Type	Selection Rationale
INT1	Data Prosumer	Sustainability Consultant, Quantis (CH)	Consultancy	Author of ISO 14046
INT2	Data Prosumer	Researcher, FHNW (CH)	Public university	Data Expert
INT3	Data Prosumer	Assistant Professor, University of Twente (NL)	Public university	Data Coordinator, Water Footprint Network
INT4	Application Provider	Researcher, Paul Scherrer Institute (CH)	Research Institute	Author, brighway.dev, bosai.uno
INT5	Data User	Founder, Valuing Impact (CH)	Consultancy	Corporate Sustainability Advocate
INT6	Ecosystem Orchestrator	Global Water Stewardship Lead, WWF (CA)	NGO	Industry Coordinator
INT7	Data Prosumer	Researcher, ETH (CH)	Public university	Scientific author, LCA
INT8	Data Prosumer	Assistant Professor, University of Illinois (US)	Public university	Scientific author, WFA
INT9	Data Publisher	Researcher, Water Footprint Network (NL)	NGO	Maintainers of WFA
INT10	Data Producer	Farmer (US)	Farmer	Hands-on perspective
INT11	Data Prosumer	Managing Director, Water Footprint Implementation (NL)	Consultancy	Corporate Sustainability Advocate

Data Consultants combine the knowledge of policy and data to produce information which aligns their customers with regulation. Output is skewed towards data rather than strategy.

Data Researchers obtain their data via aggregated data sources from Government Agencies or Data Aggregators. Their common responsibility is to transform data insights into research output.

Data Conceptualizers connect studies to purpose. Their output is similar to Data Researchers but includes the relevance and practical applications of Data Disseminators.

Corporations receive purchasing behavior and social pressure from Consumers, regulations from Policy Creators, advice on how to satisfy regulations and pressure from Outcome Creators and Data Consultants, and suggestions for change from Impact Creators.

Outcome Creators deliver strategy to customer in the form of higher-level input to influence the "mindset and process and strategy that is put in place" (`INT5`).

Data Disseminators combine the rigor of Data Researchers with the relevance of Government Agencies to create digestible information which can be used to inform Policy Makers and Impact Creators.

Farmers are the raw product creators and most often produce data without receiving data in return. Although other raw commodity industries can be water intensive, multiple interviews indicated agriculture "is 90 percent of the issue, is vastly engaged and not tracked" (`INT6`).

Data Aggregators focus on aggregating and standardizing multiple streams of data needed for reducing data variance and delivering a clearer message up the chain.

Remote Data Monitors are a deployed field of spatially distributed monitors in water basins which require configuration as input and can deliver raw data to stakeholders such as Farmers and Data Aggregators.

Consumers are included to highlight their lack of data reception. Consumers provide their purchasing behavior and demands to Corporations and their regulatory wishes to Policy Creators. In return, Consumers are generally left without data which presents challenges for making informed decisions.

Each of these 14 stakeholders map to a general data stakeholder. Figure 2 is an own extension of Figure 1 which indicates such mappings to identify differences in relations to data.

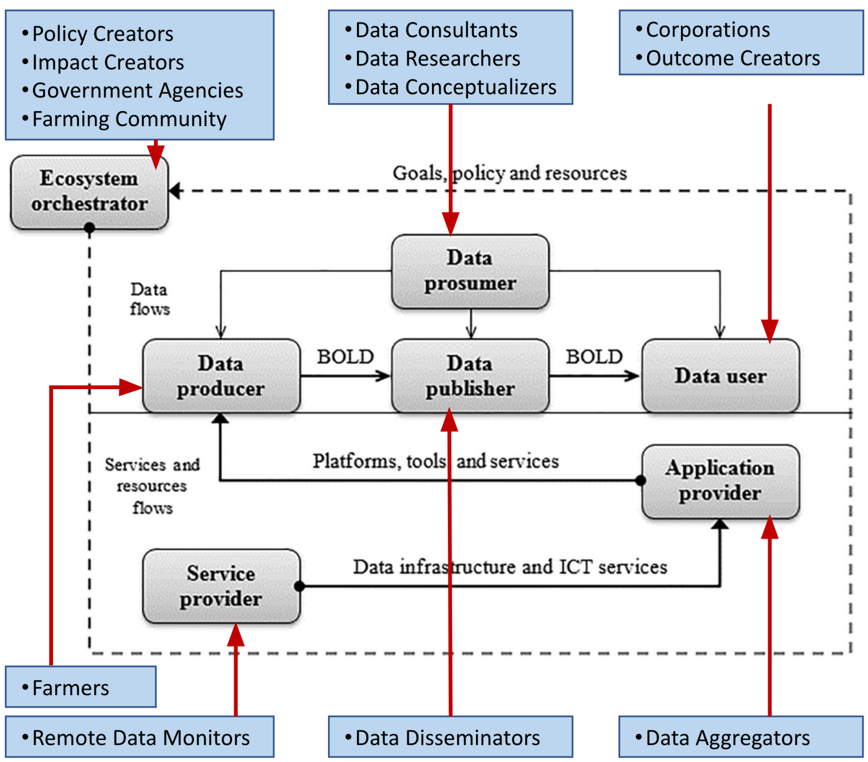

Figure 2: Mapping of general data stakeholders (grey boxes) to water accounting data stakeholders (blue boxes). Source: own illustration, extended from Lnenicka & Komarkova [15].

4 Discussion

Specification of the 14 water accounting data stakeholders enables the discovery of relationships between the water accounting stakeholders and data organization with the goal of answering the research question.

4.1 Mapping the Water Accounting Data Stakeholder Roles

The interviewees were mapped to the 14 water accounting data stakeholders to validate if granularity was refined. Table 3 illustrates this decomposition, where the 11 interviewees previously mapped to the seven general data stakeholders now compose eight out of the 14 water accounting data stakeholder roles. This extraction plays a crucial role in stakeholder data chaining in Section 4.2.

Table 3: Mapping the water accounting data stakeholders to the general data stakeholders. Source: own summary. Legend: * Indicates hypothetical examples.

Water Accounting Data Role	General Data Stakeholder Role	Example
Policy Creators	Ecosystem Orchestrator	European Union*
Impact Creators	Ecosystem Orchestrator	INT6
Government Agencies	Ecosystem Orchestrator	California Water Commission*
Farming Communities	Ecosystem Orchestrator	Local coffee shop*
Data Consultants	Data Prosumer	INT1, INT11
Data Researchers	Data Prosumer	INT3, INT8
Data Conceptualizers	Data Prosumer	INT2, INT7
Corporations	Data User	Nestlé*
Outcome Creators	Data User	INT5
Data Disseminators	Data Publisher	INT9
Farmers	Data Producer	INT10
Data Aggregators	Application Provider	INT4, bonsai.uno*
Remote Data Monitors	Service Provider	Snowpack LoRaWAN sensor*
Consumers	-	Citizen*

4.2 Stakeholder Data Chaining

Section 3.2 introduced the 14 water accounting data stakeholders and their relations to the general data stakeholders (Figure 2). Combining this with Table 3 allows using the interview data of Section 3.1 to identify input/output data requirements for each stakeholder. This schema is described with an example in Figure 3.

The input/output stakeholder schema can then be used to chain multiple stakeholders together based on their data requirements. For example, the data from a Remote Data Monitor may be used to influence the product of a Corporation. An example of this can be seen in Figure 4.

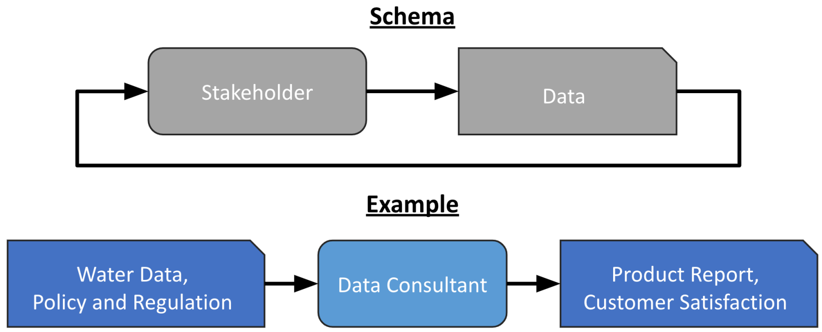

Figure 3: The schema of data input/output for a water accounting data stakeholder, with an example of a Data Consultant. Source: own illustration.

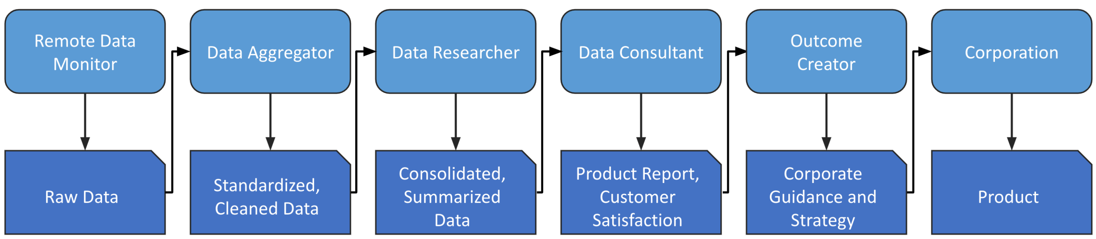

Figure 4: An example of data chaining where a Remote Data Monitor influences the product of a Corporation. Source: own illustration.

This input/output schema may be used to address the three examples of improper data granularity of Section 3.2:

- Serving different customer segments (`INT1` – Data Consultant, `INT7` – Data Conceptualizer). `INT1` and `INT7` will vary their data outputs depending on customer.

- Conceptualizing research in different manners (`INT3` – Data Researcher, `INT7` – Data Conceptualizer). `INT3` can be expected to produce more research-based and detailed reports, whereas `INT7` focuses data output on usefulness and purpose.

- Producing data without significant connection to other stakeholders (`INT10 - Farmer`). Data inputs are not marketed to them and instead are limited to the channels they choose to subscribe to, e.g., weather data, whereas their data outputs are aggregated by other stakeholders, e.g., Data Aggregators.

The implications of water accounting data stakeholder chaining are twofold: first, the research question of stakeholder-data relationships can be answered specifically per-stakeholder by determining their output data requirements and connecting them to other stakeholders which use such inputs, forming an illustrative chain of data flow. Second, the social implications of such a stakeholder chain could assist in stakeholder alignment, i.e., with a clearer understanding of their own role, stakeholders may refine data input requirements and data output artifacts to increase the efficiency of data flow. This improvement of data flow efficiency could have implications for the data organization problems identified in the literature in Section 2.2.

5 Conclusion

This study sought to answer the research question **what is the relationship between stakeholders and data in water accounting?** A summary along with considerations and future research is provided below.

5.1 Overview

This study began by exploring the current literature on water accounting practices and identified two problems: there exists a misalignment of water accounting data stakeholders, and water data suffers multiple problems which result in data disorganization. To frame the relationship of these problems, seven general data stakeholders [15] were used as a basis of comparison.

To answer the research question, 11 industry experts covering 6/7 data stakeholder roles were interviewed and their experiences led to the creation of 14 water accounting data stakeholder roles. These roles are domain-specific, and the 11 interviewees could be mapped back to both the water accounting data stakeholders and general data stakeholders.

Explicating water accounting data stakeholders increased the granularity of stakeholder identification and enabled the chaining of stakeholders, which helps to clarify the flow of water data. This flow of data can be used to improve efficiency of input/output data organization, which was shown to be a problem in the relevant literature. This may help to clarify stakeholder roles and responsibilities for purposes such as collaboration and policy guidance.

5.2 Limitations and Future Research

The limitations of this study were the sample size of interviewees (`n=11`), and not all water accounting stakeholder roles being part of the interview sample (Table 3). The 14 identified roles were qualitatively developed, meaning some redundancies or gaps may be present which presents an opportunity for future development. Future studies may seek to discover specific data qualities or variables which can be mapped to water accounting data stakeholders, or map chains of stakeholders to different actions and outcomes, e.g., which stakeholders are necessary for policy guidance.

5.3 Outlook

These 14 water accounting data stakeholders provide necessary granularity and a multi-faceted contribution for practice. A deeper domain-specific understanding improves the informal communication processes between stakeholders, e.g., easing the understanding of newcomers to the field and improving data organization. Such processes could improve the communication between research, policy, and practitioners by explicating expectations and requirements, e.g., an Outcome Creator can focus their output to cater to Corporations' interest in governance and strategy. By doing so, measurable impacts at the water basin level can be better implemented to align with the United Nations Sustainable Development Goals.

References

[1] Mesfin Mekonnen and Arjen Ysbert Hoekstra. *National water footprint accounts: the green, blue and grey water footprint of production and consumption*. Number 50 in Value of water research report 50. Unesco-IHE Institute for Water Education, 2011. Available at: https://research.utwente.nl/en/publications/national-water-footprint-accounts-the-green-blue-and-grey-water-f.

[2] Adriane Chapman, Elena Simperl, Laura Koesten, George Konstantinidis, Luis-Daniel Ibáñez, Emilia Kacprzak, and Paul Groth. Dataset search: a survey. *The VLDB Journal*, 29(1):251–272, 2020. https://doi.org/10.1007/s00778-019-00564-x.

[3] Landon Marston, Yufei Ao, Megan Konar, Mesfin M Mekonnen, and Arjen Y Hoekstra. High-Resolution Water Footprints of Production of the United States. *Water Resources Research*, 54(3):2288–2316, 2018. https://doi.org/10.1002/2017WR021923.

[4] Esther Velázquez, Cristina Madrid, and María J Beltrán. Rethinking the Concepts of Virtual Water and Water Footprint in Relation to the Production–Consumption Binomial and the Water–Energy Nexus. *Water Resources Management*, 25(2):743–761, 2011. https://doi.org/10.1007/S11269-010-9724-7.

[5] Thomas Wiedmann, Harry C Wilting, Manfred Lenzen, Stephan Lutter, and Viveka Palm. Quo Vadis MRIO? Methodological, data and institutional requirements for multi-region input–output analysis. *Ecological Economics*, 70(11):1937–1945, 2011. https://doi.org/10.1016/j.ecolecon.2011.06.014.

[6] Oliver Taherzadeh, Mike Bithell, and Keith Richards. Water, energy and land insecurity in global supply chains. *Global Environmental Change*, 67:102158, 2021. https://doi.org/10.1016/j.gloenvcha.2020.102158.

[7] Qiang Wang and Shuting Ge. Carbon footprint and water footprint in China: Similarities and differences. *Science of The Total Environment*, 739:140070, 2020. https://doi.org/10.1016/j.scitotenv.2020.140070.

[8] Stephan Pfister, Anne-Marie Boulay, Markus Berger, Michalis Hadjikakou, Masaharu Motoshita, Tim Hess, Brad Ridoutt, Jan Weinzettel, Laura Scherer, Petra Döll, Alessandro Manzardo, Montserrat Núñez, Francesca Verones, Sebastien Humbert, Kurt Buxmann, Kevin Harding, Lorenzo Benini, Taikan Oki, Matthias Finkbeiner, and Andrew Henderson. Understanding the LCA and ISO water footprint: A response to Hoekstra (2016) "A critique on the water-scarcity weighted water footprint in LCA". *Ecological Indicators*, 72:352–359, 2017. https://doi.org/10.1016/j.ecolind.2016.07.051.

[9] Behzad Ahmadi, Ali Ahmadalipour, and Hamid Moradkhani. Hydrological drought persistence and recovery over the CONUS: A multi-stage framework considering water quantity and quality. *Water Research*, 150:97–110, 2019. https://doi.org/10.1016/j.watres.2018.11.052.

[10] Brian D. Richter, Dominique Bartak, Peter Caldwell, Kyle Frankel Davis, Peter Debaere, Arjen Y. Hoekstra, Tianshu Li, Landon Marston, Ryan McManamay, Mesfin M. Mekonnen, Benjamin L. Ruddell, Richard R. Rushforth, and Tara J. Troy. Water scarcity and fish imperilment driven by beef production. *Nature Sustainability*, 3(4):319–328, 2020. https://doi.org/10.1038/s41893-020-0483-z.

[11] Louise Manning. The impact of water quality and availability on food production. *British Food Journal*, 110(8):762–780, 2008. https://doi.org/10.1108/00070700810893304.

[12] Jorge Alejandro Silva Rodríguez de San Miguel, Esteban Martínez Díaz, and Dulce María Monroy Becerril. The relationship between climate change and internal migration in the Americas. *Management of Environmental Quality: An International Journal*, 32(4):822–839, 2021. https://doi.org/10.1108/meq-01-2021-0020.

[13] David Lin, Laurel Hanscom, Adeline Murthy, Alessandro Galli, Mikel Evans, Evan Neill, Maria Serena Mancini, Jon Martindill, Fatime-Zahra Medouar, Shiyu Huang, and Mathis Wackernagel. Ecological Footprint Accounting for Countries: Updates and Results of the National Footprint

Accounts, 2012–2018. *Resources*, 7(3), 2018. https://doi.org/10.3390/resources7030058.

[14] Ozcan Saritas and Liliana N Proskuryakova. Water resources – an analysis of trends, weak signals and wild cards with implications for Russia. *foresight*, 19(2):152–173, 2017. https://doi.org/10.1108/FS-07-2016-0033.

[15] Martin Lnenicka and Jitka Komarkova. Big and open linked data analytics ecosystem: Theoretical background and essential elements. *Government Information Quarterly*, 36(1):129–144, 2019. https://doi.org/10.1016/j.giq.2018.11.004.

[16] Anne-Marie Boulay, Arjen Y Hoekstra, and Samuel Vionnet. Complementarities of Water-Focused Life Cycle Assessment and Water Footprint Assessment. *Environmental Science & Technology*, 47(21):11926–11927, 2013. https://doi.org/10.1021/es403928f.

[17] Kuishuang Feng, Ashok Chapagain, Sangwon Suh, Stephan Pfister, and Klaus Hubacek. COMPARISON OF BOTTOM-UP AND TOP-DOWN APPROACHES TO CALCULATING THE WATER FOOTPRINTS OF NATIONS. *Economic Systems Research*, 23(4):371–385, 2011. https://doi.org/10.1080/09535314.2011.638276.

[18] Arjen Y. Hoekstra. A critique on the water-scarcity weighted water footprint in LCA. *Ecological Indicators*, 66:564–573, 2016. https://doi.org/10.1016/j.ecolind.2016.02.026.

[19] M. Miles, A. Michael Huberman, and Johnny Saldaña. *Qualitative Data Analysis: A Methods Sourcebook. Third Edition.* SAGE, 2014.

[20] Nigel King and Christine Horrocks. *Interviews in Qualitative Research.* SAGE, 2010.