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Measuring Water-Related Environmental Impacts of Organizations: Existing Methods and Research Gaps

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Water scarcity is one of the most threatening challenges of the twenty-first century. Production processes have impacts on local water resources throughout their entire (often transboundary) value chain. This has been addressed in the last decade at the corporate level by developing and applying a broad set of approaches with different focuses and scopes. This paper reviews and evaluates existing approaches with the following aims: i) providing guidance for practitioners concerning the suitability of available methods and tools for different applications; ii) providing a scientifically robust criteria-based comparison identifying the strengths and weaknesses of existing approaches to stimulate future method development. Eight literature-based criteria for a suitable method for organizations are identified: documentation and transparency, scientific soundness, environmental relevance, organizational system boundaries, broadness of application, ease of application, stakeholder's acceptance, and transformative potential, specified by a total of 22 subcriteria. Nine existing approaches for measuring water-related impacts of organizations are evaluated accordingly. These show diverging performance. Based on the overall evaluation results, taking Water Footprint (ISO 14046) as a global information tool is recommended, in combination with the Water Stewardship approach, to link assessment results to concrete mitigation measures.

1. Introduction

Universal access to safe and affordable freshwater is a fundamental target for the international community, as stated by the United Nations sustainable development goal 6 Ensure access to water and sanitation for all by 2030. Among the targets related to goal 6, the improvement of water quality and the substantial increase of water use efficiency to face freshwater scarcity are mentioned.[1]

Regional differences in production patterns reveal that water withdrawn in basins subjected to scarcity, often situated in the Global South, is used in core production processes in industrialized countries—thus contributing to the developed world's welfare increase. Virtual water trade analysis shows for example that scarce water associated to production from Pakistan's agriculture (mainly cotton) is used in the Italian and Hong Kong's textile industry and the Iraqi mining and drilling sector,[2] operating in a water scarce region, supplies to the US petroleum refineries and Singapore's petroleum products. At a larger scale, the volumetric blue Water Footprint analysis (i.e., including surface and groundwater) highlights that the European Union, where 7% of global territorial water extraction takes place, consumes almost the double amount of embodied water, mostly coming from the Asian continent.[3] In contrast to the transboundary character of value chains, putting into place programs for integrated water resources management (IWRM) falls under the jurisdiction of national or local authorities. However, most developing countries, in general more vulnerable to water scarcity, have not implemented IWRM policies so far.[4]

Not only geography plays a role in the uneven distribution of water use and the related impacts. Product-related case studies from a wide variety of sectors reveal that different stages of the value chain contribute differently to the overall effects of production on water resources. For example, the first Water Footprint study for the automotive sector shows that the main impacts of a car's life cycle are located in the upstream value chain (materials and energy production).[5] Differently, a soap bar affects water resources during the use and end-of-life phase.[6] Though delivering relevant information on water-related impacts throughout specific life cycles, the mentioned studies are limited to single products and do not depict the impacts of all production lines and further activities of an organization. This makes them in general unsuitable for supporting decision making at strategic corporate level and motivating changes in a company' s supply strategy.

As most studies focus on a product or country level, we focus here on organizations (e.g., companies, public bodies, NGOs) as another relevant level of analysis for including the responsibility for production processes and for their transboundary effects. Organizations have to consider the entire value chain if their assessment is intended to put into place proper mitigation measures.

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So far, several approaches to assess companies' impacts on and risks related to water have been developed:

- the Water Stewardship framework by the Alliance for Water Stewardship (AWS),[7]
- the Water Program (CDP),[8]
- Corporate Water Gauge by the Center for Sustainable Organizations (CSO),[9]
- the Local Water Tool,[10] and Connecting the Drops by the Global Environmental Management Initiative (GEMI),[11]
- Water Footprint according to the standard ISO 14046,[12]
- the Global Water Tool by the World Business Council for Sustainable Development (WBCSD),[13]
- Water Footprint according to the Water Footprint Network (WFN),[14] and
- the Water Risk Filter by the World Wide Fund for Nature (WWF) and the Deutsche Investitions- und Entwicklungsgesellschaft (DEG).[15]

These approaches are of diverse nature and include templates for environmental reporting and transparency purposes, online calculation tools, standardized scientific methods, and impact mitigation oriented frameworks. They differ in terms of context of their method development, the main aims of the approach, the part of the value chain addressed, if and how impacts on the environment are measured, and other characteristics. Such methodological variety on the one hand bears witness to the demand for a structured organizational approach and the urgency of efforts for water-related mitigation measures. On the other hand, the risk of method proliferation emerges, with the related drawbacks of perceived arbitrariness, lower recognition value, and disorientation for practitioners and stakeholders.

Previous comparisons between a set of existing methods are available. Morrison and Schulte evaluate four approaches (WFN Water Footprint, ISO Water Footprint, GEMI Sustainability Tool, WBCSD Water Footprint tool) and propose the harmonization of assessment methods and reporting standards, which has not occurred so far.[16] The Water Risk Filter provides a short qualitative overview of several tools with a strong focus on organizational risks. However, the criteria selection is not made explicit and no specific conclusions are drawn.[17] Mueller et al. compare risk assessment tool functionalities (WBCSD Global Water Tool, WBCSD India Water Tool, Aqueduct Water Risk Atlas Tool, WWF Water Risk Filter) and highlight specific data and tool requirements from the automotive industry perspective.[18] These comparative studies offer a first overview on the approaches and their characteristics, but either have a limited coverage,[16,18] or lack some explicit guidance to inform practitioners' choices.[17] In addition, the main object of the methods and tools analyzed is company-related risk. However, the environmental and societal impacts of water use and the related mitigation goals stated in the SDGs suggest that effects on humans and the environment should play a central role in the analysis of water-related impacts of companies in order to reflect the priorities of the international community and address global environmental challenges.

The aim of this paper is to assess a comprehensive set of existing methods, frameworks, and tools analyzing the water-related impacts of companies. The results support two main applications: i) helping practitioners in selecting the most suit-

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able method for their specific needs; ii) identifying gaps to stimulate method refinement. First, the criteria to be applied in the evaluation of the approaches analyzed are developed (Section 2). Further, the existing methods are assessed accordingly (Section 3). The results are discussed in Section 4. The conclusions drawn from the study are presented in Section 5.

2. Evaluation Scheme

In this section, the evaluation scheme applied to existing methods for the assessment of water-related environmental impacts of organizations is developed. According to the overall aim of the paper eight overarching evaluation criteria were identified: 1) documentation and transparency, 2) scientific soundness, 3) environmental relevance, 4) organizational system boundaries, 5) broadness of application, 6) ease of application, 7) stakeholder acceptance, and 8) transformative potential. Each criterion is specified by one or more subcriteria, partly inspired by and adapted from previous frameworks developed for evaluating impact assessment methods.[19–22] The remaining criteria address specificities of organizational methods and are motivated in the following.

To provide a clear overview of methods' performance, each subcriterion is attributed a score (from 0: criterion not met to 4: criterion met). Precise indications on rating the approaches in relation to each subcriterion are delivered in **Table 1**.

No absolute comparison between the approaches nor prioritization of certain criteria via weighting is performed, due to the diversity of the approaches' scope and the informative character of the results. The aim of the scores is to analyze main patterns according to the given criteria and to draw conclusions for further improvement.

2.1. Documentation and Transparency

This criterion consists in the public availability and accessibility of a complete guidance for method application. A document qualifies as guidance if it contains "unanimous instructions for the application by providing a widely-accepted set of rules defining how the specific[...] method is to be conducted."[20] Easy accessibility of the documents is crucial for quality assurance because it allows uniform application by practitioners, third party reviews and scientific work. The availability and accessibility of methodological guidelines are evaluated based on web search. A document is rated as available if it is referred to in the promoting organization's or tool's website; a document is rated as accessible if available online.

Guidelines on both organization modelling and the assessment of water-related environmental aspects are crucial and thus defined as subcriteria. Defining the organization to be analyzed allows attributing the responsibilities for environmental impacts. Moreover, being aware of all organization's components raises practitioners' awareness of all potential sources of water use and existing water sinks. Guidelines for assessing water-related environmental aspects represent a quality assurance for final results. The availability of a standard guarantees methodological transparency and is therefore considered as third subcriterion.

2.2. Scientific Soundness

This criterion includes the recognition by the scientific community through the publication in a peer-reviewed journal. This ensures "that the recommended indicator follows current knowledge and evidence rather than opinions, subjective or arbitrary choices, and normative assumptions."[22] To assess scientific recognition, the availability of peer-reviewed publications illustrating the whole method and the availability of method-related publications (e.g., on specific aspects of the method or method application) are considered as subcriteria. The first 100 Google Scholar results delivered when entering the name of the approach and the name of the approach "+ case study" are taken into account. Moreover, the reproducibility of results and the assessment of uncertainties are considered as further subcriteria. Results are considered reproducible if the method used and the underlying equations are made explicit in the method documentation, so that, given the same inventory data, the same results can be obtained. To evaluate the ability of the method to assess uncertainties, it is considered whether the guidance foresees that data quality and underlying assumptions of the model are made explicit and assessed. The rationale behind this subcriterion is to facilitate the interpretation of the assessment results and to guarantee its quality.[19] In addition, carrying out comprehensive uncertainties assessments encourages organizations to commit to sound scientific practice and to increase the quality of results in following versions of the assessment.

2.3. Environmental Relevance

In current environmental research, the effects of water consumption on the environment are assessed using different methods, volumetric and impact oriented approaches being the two overarching categories.[23] Volumetric approaches account for the overall water consumption of an organization on an inventory level and often categorize it into blue, green, and gray water footprint. Blue water refers to surface and groundwater, green water refers to precipitation water, and gray water is the amount of fresh water needed to dissolve pollutants according to specific water quality standards.[24] Impact-based methods consider the effects of water consumption on human health and the environment on the basis of a cause–effect relationship, by taking water consumption volumes as a starting point.[25,26]

The criterion environmental relevance considers the method used to measure the impacts of the organization's activities on the environment. For the case of water, ensuring the environmental relevance of the assessment means accounting for the local consequences caused by both water withdrawal and water discharge (quantity and quality) and considering relevant variables such as the regional water scarcity and overall resource availability at the local level or the vulnerability of population and ecosystem, etc.[22] Due to the broad range of possible impacts related to water,[25] four subcriteria were identified: water scarcity, water-related effects on humans, water-related effects on ecosystems, and water-related effects on resources. In this context, it is evaluated whether the approach requires considering such effects and whether calculation methods are provided.

Table 1. Evaluation scheme and scoring criteria.

Criteria	Subcriteria	Aspects to be considered	Score (0–4)
Documentation and transparency			
	Guidelines for modeling the organization	Available accessible understandable detailed	Each aspect = 1 point partly available/accessible: 0.5 point
	Guidelines to assess water-related environmental aspects	Available accessible understandable detailed	Each aspect = 1 point partly available/accessible: 0.5 point
	Availability of a standard for the method	Type of standard and status	International standard: 4 national or sectoral standard: 3 standard (others, multistakeholder): 2 standard in preparation: 1
Scientific soundness			
	Method is object of scientific work	Peer-reviewed publications	The method is entirely published: 2 points method-related publications are available: 1 point (if ≥3 publications: +1 point)
	Method allows for reproducibility of results	Calculation methods and equations are made explicit	Each aspect: 2 points
	The analysis of uncertainties is foreseen	Parameter, scenario and model uncertainties: data quality assessment, sensitivity analysis, consistency analysis, analysis of the influence of assumptions are included in the method	Each aspect (or additional aspects considered): 1 point, max. 4 points
Environmental relevance			
	Comprehensive approach	Water consumption and water quality are considered	Inputs considered (quantity): 1 point (also quality: +1 point) outputs considered (quantity): 1 point (also quality: +1 point)
	The method(s) accounts for relevant temporal and geographical resolution	Country or basin level monthly/yearly resolution	country level: 1 point/basin level: 2 points yearly resolution: 1 point/monthly resolution: 2 points geographical variables: 1–2 points
	The method accounts comprehensively for water scarcity	Causal relationship included in the method Model developed	Mentioned as evaluation criterion: 2 points Calculation method included: 2 points
	The method accounts comprehensively for water-related effects on humans	Causal relationship included in the method model developed	Mentioned as evaluation criterion: 2 points Calculation method included: 2 points
	The method accounts comprehensively for water-related effects on ecosystems	Causal relationship included in the method model developed	Mentioned as evaluation criterion: 2 points Calculation method included: 2 points
	The method accounts comprehensively for water-related effects on resources	Causal relationship included in the method model developed	Mentioned as evaluation criterion: 2 points Calculation method included: 2 points
Organizational system boundaries			
	Suppliers are included in the model	No exclusion voluntary/compulsory guidance available	Not excluded: 1 point inclusion is encouraged: 2 points integral part of the method: 3 points detailed guidance provided: +1
	The use phase of sold products/services is included in the model	No exclusion voluntary/compulsory guidance available	Not excluded: 1 point inclusion is encouraged: 2 points integral part of the method: 3 points detailed guidance provided: +1
	The end-of-life phase of products/services is included in the model	No exclusion voluntary/compulsory guidance available	Not excluded: 1 point inclusion is encouraged: 2 points integral part of the method: 3 points detailed guidance provided: +1

Table 1. Continued.

Criteria	Subcriteria	Aspects to be considered	Score (0–4)
	Elements of the organization not directly linked to production (e.g., administration, canteens, gardens, capital equipment) are included in the model	No exclusion voluntary/compulsory guidance available	Not excluded: 1 point inclusion is encouraged: 2 points integral part of the method: 3 points detailed guidance provided: +1
Broadness of application			
	Flexibility of application to different sectors (technological scope)	No exclusion: the method is not developed for a specific sector challenges recognized solutions proposed	Not sector-specific: 1 point challenges for different sectors analyzed: 2 points solutions provided: +1 examples/case studies provided: +1
	Flexibility of application to different organization sizes	No exclusion: the method is not developed for a specific organization size challenges recognized solutions proposed	Not size-specific: 1 point challenges for different sizes analyzed: 2 points solution provided: +1 examples/case studies provided: +1
	Flexibility of method to system definition (e.g., for assessing one part of the organization)	No exclusion challenges recognized solutions proposed	Not fixed: 1 point challenges for different system definitions analyzed: 2 points solution provided: +1 examples/case studies provided: +1
Ease of application			
	Data availability	Is the data required by the method available?	Partially available: 1 point fully available: 2 points high granularity (processes/sectors): +1 High granularity (spatial/temporal): +1
	Software tools	Are software tools for the method available? Are they method-specific and functional??	1 tool exists: 1 point method-specific tool exists: +1 direct linkage to relevant datasets: +1 suitable for all kinds of organizations: +1
Stakeholders acceptance			
	Case studies	Case studies available case studies from diverse organizations available (size, sectors, geographical diversity)	Case studies exist: 1 point case studies different sizes, sectors, countries = 1 point each
	Diversity of stakeholders involved in method development	Applications by industry by NGOs/consumer organizations by research institutes by public sector/policy	1 point each
Transformative potential			
	The approach is linked to concrete measures	Possibility to use assessment results as basis to develop environmental measures; linkage to measures mentioned in documentation (different degrees); measures integral part of the method	Possibility of using the method for planning measures is given, but up to the organizations: 1 point possibility of using the method for planning measures is highlighted in method documents, no specific guidance is given: 2 points specific guidance on measures is given in documentation, carrying out measures is up to the organization: 3 points specific guidance on measures is given in documentation and measures are integral part of the method: 4 points

2.4. Organizational System Boundaries

In the past, widespread environmental tools such as environmental management systems took a gate-to-gate perspective. However, product-related studies show that, in some cases, only a small share of water-related burdens can be attributed to the direct activities of an organization.[5,27] Therefore, to fully account for an organization's impacts, it is necessary to consider whether the approach targets the whole value chain. This means that upstream processes, i.e., suppliers, are included in the assessment, and the analysis is not limited to the direct suppliers of the organization (first tier) but traces back the suppliers' suppliers (second tier, third tier, and so on) until the resource extraction stage. To fulfill the requirement of holistically assessing the organization, it is evaluated whether downstream processes (further production stages, use phase and end-of-life phase) and additional activities of the organization (e.g., administration, canteens, gardens, and capital equipment such as buildings and machines) are integrated in the model too.

2.5. Broadness of Application

In line with the criterion "applicability to a broad range of goods and services" established for product LCA methods,[20] we consider whether the approach can be applied to different types of organizations. This criterion addresses the universality of the assessment method, i.e., the possibility to be adapted to organizations active in different sectors (e.g., production as well as services, both public and private), with different structure, size, and geographical scope. High flexibility is guaranteed if the instructions of the guidelines are general enough not to exclude some types of organizations and if examples and specific options, e.g., for internationally acting organizations, for small organizations, for organizations acting in the service sector, are provided, or a broad range of case studies is made available to practitioners.

2.6. Ease of Application

The goal of an assessment method is being easily applicable by practitioners to identify the water-related impacts of an organization. This is taken into account in the criterion "ease of application." This means that the data needed and software support are available. Data is needed in the granularity foreseen by the method for geographical specificity, temporal variability, and the level of detail in which processes are depicted. Further, a calculation tool (software) facilitates generating the assessment results, since it (potentially) guides the practitioner through the different steps of method application and allows directly retrieving relevant datasets.

2.7. Stakeholders Acceptance

This criterion evaluates whether the method is accepted by relevant stakeholders. The acceptance of a method is conceived as its perception as adequate. The first subcriterion refers to the availability of case studies on the tool or method website or in related websites, plus case studies published in peer-reviewed journals. It considers both the number of studies and the diversity of the organizations included (size, sector, country). Moreover, stakeholder acceptance increases if different parties are included in the development of the method and in the related decision making processes.[20] To reflect the position of a broad range of stakeholders, the diversity of organizations and companies involved in method development, diffusion, and application is considered as a subcriterion. In this case, not only published reports are considered, but also organizations appearing as supporters or promoters.

2.8. Transformative Potential

Assessment methods primarily aim at measuring impacts, thus delivering information for decision making in the organizational context. However, the object of analysis corresponds to the level at which decisions are taken, which facilitates a direct linkage between assessment results and concrete action. This is even more relevant for assessments focused on one environmental compartment, since the room for intervention is more limited than for overarching multi-impact assessment methods.

Transformative potential refers to the existence of a direct linkage between the results of the measurement or assessment and policies or instruments allowing a concrete relief for the environment. The transformative potential can be determined by measures that are foreseen or encouraged in the case specific damages are identified or a threshold is exceeded. To reach this aim, the method may include an action plan with specific routines and measures to be taken. Table 1 summarizes the evaluation scheme and the related scoring criteria.

3. Results

In this section, the approaches for the assessment of water-related impacts illustrated in Section 1 are evaluated according to the criteria developed in Section 2. In a first overview, following approaches were reviewed: CERES Water Gauge; CPD water program; CSO Corporate Water Gauge; GEMI Collecting the Drops; GEMI Connecting the Drops; GEMI Local Water Tool; ISO Water Footprint; Veolia Water Impact Index; WBCSD Global Water Tool; WNF Water Footprint; WRI Water Aqueduct Tool; WWF Water Risk Filter. Each approach is described in the Supporting Information. After a first screening, four methods were excluded from further analysis: Collecting the Drops, because of its focus on processes instead of organizations; CERES Aqua Gauge, as it is mainly devoted to assessing companies' water management measures; WRI Aqueduct Water Risk Atlas, because it focuses on local risks and does not refer to organizations; Veolia Water Impact Index, because the related tool went offline during the preparation of this paper and the index alone is a specific application of the ISO Water Footprint approach. The remaining approaches explicitly address companies or organizations and their water-related impacts. They however embrace different aims (e.g., such as assessing company's risks and opportunities), and formats. Some approaches are available as tool, some as questionnaire, others as a collection of guidelines.

It should be noted that two different approaches are known under the same name: Water Footprint. In this paper, the qualifiers "ISO" and "WFN" are used to differentiate between them. ISO Water Footprint refers to the method standardized by the International Organization for Standardization (ISO);[28] WFN Water Footprint refers to the method developed by the Water Footprint Network (WFN).[24]

The scores obtained for each subcriterion are summarized in **Table 2**. Tables S1–S9 (Supporting Information) include

Table 2. Evaluation results.

Criteria	Subcriteria	AWS Water Stewardship	CDP Water Program	CSO Corporate Water Gauge	GEMI Connecting the Drops	GEMI Local Water Tool	ISO Water Footprint	WBCSD Global Water Tool	WFN Water Footprint	WWF Water Risk Filter
Documentation and transparency										
	Guidelines for modelling the organization	3	3	1	3	0	3	1	4	2
	Guidelines to assess water-related environmental aspects	3	3	2	3	2	3	3	4	3
	Availability of a standard for the method	2	0	0	0	0	4	0	2	0
Scientific soundness										
	Method is object of scientific work	0	0	0	0	0	2	0	2	0
	Method allows for reproducibility of results	1	4	3	0	4	4	4	4	2
	The analysis of uncertainties is foreseen	0	1	0	0	0	4	0	1	0
Environmental relevance										
	Comprehensive approach	3	4	2	4	3	4	2	3	4
	The method(s) accounts for relevant temporal and geographical resolution	2	2	2	4	2	4	4	4	4
	The method accounts comprehensively for water scarcity	2	0	2	2	2	2	2	4	4
	The method accounts comprehensively for water-related effects on humans	2	0	0	2	0	2	0	0	4
	The method accounts comprehensively for water-related effects on ecosystems	2	0	0	2	0	2	0	0	4
	The method accounts comprehensively for water-related effects on resources	0	0	0	0	0	2	0	0	0
Organizational system boundaries										
	Suppliers are included in the model	2	3	0	3	0	4	3	3	3

Table 2. Continued.

Criteria	Subcriteria	AWS Water Stewardship	CDP Water Program	CSO Corporate Water Gauge	GEMI Connecting the Drops	GEMI Local Water Tool	ISO Water Footprint	WBCSD Global Water Tool	WFN Water Footprint	WWF Water Risk Filter
	The use phase of sold products/services is included in the model	0	0	0	3	0	4	0	0	0
	The end-of-life phase of products/services is included in the model	0	0	0	3	0	4	0	2	0
	Elements of the organization not directly linked to production (e.g., administration, canteens, gardens, capital equipment) are included in the model	1	1	1	3	1	3	1	3	1
Broadness of application										
	Flexibility of application to different sectors (technological scope)	4	3	1	3	2	4	3	3	2
	Flexibility of application to different organization sizes	3	1	1	1	0	3	1	4	1
	Flexibility of method to system definition (e.g., for assessing one part of the organization)	0	3	1	2	0	4	1	2	1
Ease of application										
	Data availability	n.a.	4	4	1	4	4	4	3	4
	Software tools	0	1	4	1	3	3	4	4	4
Stakeholders acceptance										
	Case studies	1	4	3	3	2	0	3	3	3
	Diversity of stakeholders in method development	3	2	1	2	4	3	3	4	3
Transformative potential										
	The approach is linked to concrete measures	4	2	1	3	1	1	2	2	3

keywords and literature motivating the score in order to reflect the scope and flexibility of each approach.

3.1. Documentation and Transparency

Guidance on organization modeling is provided at different levels. While ISO Water Footprint and WFN Water Footprint offer detailed information on how to define the external organizational boundaries as well as the internal demarcation between different parts of the organization or organization's activities, other (mostly tool based) approaches lack these explanations. The remaining approaches provide partial guidelines, e.g., refer only to the organization's activities (e.g., GEMI Connecting the Drops) or only to the site's boundary (e.g., AWS Water Stewardship: the standard mentions the possibility to assess the supply chain but does not deliver information on how to model it).

Guidelines to assess water-related environmental aspects are delivered in a detailed way only by WFN Water Footprint, whereas other approaches only mention the methods to be used.

An international standard is available for ISO Water Footprint. AWS Water Stewardship and WFN Water Footprint were standardized in a multistakeholder process.

3.2. Scientific Soundness

None of the approaches has been so far object of a purely methodological peer-reviewed publication. For ISO Water Footprint and WFN Water Footprint, publications on specific methodological aspects and case studies are available.

Reproducibility of results is given for the CDP water program, GEMI Local Water Tool, ISO Water Footprint, WBCSD Water Tool, WFN Water Footprint, WWF Water Risk Filter, and partly for CSO Corporate Water Gauge and GEMI Connecting the Drops. AWS Water Stewardship includes a list of different methods and links, without allowing for immediate overview and replicability.

Model and data uncertainties are included as a core element of the method only in ISO Water Footprint. Uncertainty analysis is optional WFN Water Footprint and mentioned in CDP Water Program. Other tools and methods do not account explicitly for uncertainties.

3.3. Environmental Relevance

All approaches account for both water inputs and outputs. CSO Corporate Water Gauge and WBCSD Global Water Tool leave water quality unconsidered. Most approaches consider the effects of water consumption on water scarcity, although only WWF Water Risk Filter and WFN Water Footprint directly indicate the calculation method to be used. Water-related effects on humans and the ecosystems are taken into account in AWS Water Stewardship, GEMI Connecting the Drops, ISO Water Footprint and WWF Water Risk Filter. Considering the effects on resources is only required by ISO Water Footprint. Except for WFN Water Footprint and WWF Water Risk Filter, which indicate how to calculate the water-related effects in certain categories, no calculation methods are included in the approaches. The absence of specific indicators is in some cases related to the nature of the approach. In the context of AWS Water Stewardship, for example, the choice of indicators is performed by stakeholders (which leads to a heterogeneous set of indicators chosen); for CDP Water Program the focus is on business-related risks. All methods acknowledge and include the importance of considering the watershed/catchment level. ISO Water Footprint, WBCSD Global Water Tool, WFN Water Footprint and WWF Water Risk Filter consider also seasonal variability.

3.4. Organizational System Boundary

Some methods (mostly tool related) refer to a specific facility and do not include indirect impacts (CSO Corporate Water Gauge, GEMI Local Water Tool). In other cases, only suppliers are included, not the use and end-of-life phases (AWS Water Stewardship, CDP Water Program, WBCSD Water Tool, WWF Water Risk Filter). Only GEMI Connecting the Drops and ISO Water Footprint consider also the use and end-of-life phases as an integral part of the model. In the WFN Water Footprint the use phase is excluded from the organization's Water Footprint because included in the Water Footprint model for consumers. Elements of the organization not directly linked to production are in almost all cases not explicitly included in the system boundary. This means in most cases that, if the data for administrations' water use is available at a facility level (e.g., because the factory and offices are in the same building), also the administration's impacts are considered; otherwise they are not. Only ISO Water Footprint makes this further source of impacts explicit ("other activities" or "supporting activities").

3.5. Broadness of Application

The approaches are not sector-specific and in some cases specific guidelines, modules or customized tools for different production sectors are available. For example, the WBCSD provides specific tools for the oil and gas sector and for the cement sector, and GEMI Connecting the Drops offers rector-specific guidelines regarding the value chain. The service sector (incl. public sector) is seldom addressed or included in case studied (e.g., WFN Water Footprint: country studies, WWF Water Risk Filter: country studies, CDP Water Program: module for cities).

The approaches analyzed do not exclude organizations according to their size. However, most of them do not provide guidance on how to cope with the challenges posed, e.g., by very large organizations, with different sizes and facilities, or on simplification options for SMEs. Latter is addressed only by WFN Water Footprint that offers a simplified tool for SMEs. Other approaches refer either to single sites (GEMI Local Water Tool) or have multinational companies as main target users (CDP Water Program).

The flexibility of application to different system definitions depends on the nature of the method. The tool-based approaches CSO Corporate Water Gauge, WBCSD Water Tool, and WWF Water Risk Filter allow entering facility-level data in the tool, so both considering a more complex organization and disaggregation of the facility's activities is not possible within the framework of one analysis (i.e., by using the tool once). Only GEMI Connecting the Drops, WFN Water Footprint, and ISO Water Footprint present case studies assessing only one part of an organization.

3.6. Ease of Application

Data availability cannot be assessed for the case of AWS Water Stewardship, because no precise indications on the method used (and therefore on the data needed) is given. In the other cases, data is available within the scope of the method. For example, GEMI Local Water Tool and WBCSD Global Water Tool provide a database linked to the tool, however, no data for the value chain is available, since it is out of scope; WFN is linked to the WaterStat database, whose granularity for nonagricultural sectors is very limited; ISO Water Footprint is carried out with high product granularity and value chain data and different databases are available.

Depending on the method, diverse tools are available. Simple tools are delivered by the CDP Water Program and Connecting the Drops, including only questionnaires for reporting. AWS Water Stewardship provides no tools at all. Other approaches offer simple tools which exclude the value chain (CSO Corporate Water Gauge, GEMI Water Local Tool) or include it only for certain sectors (WFN Water Footprint). Advanced tools are available for ISO Water Footprint, WWF Water Risk Filter, and WFN Water Footprint.

3.7. Stakeholders Acceptance

Case studies for diverse organizations are available for several approaches: AWS Water Stewardship, CDP Water Program, GEMI Connecting the Drops, WBCSD Water Tool, WFN Water Footprint, WWF Water Risk Filter, and CSO Corporate Water Gauge. For ISO Water Footprint only product-related case studies are available so far. However, first case studies on the organizational life cycle assessment method include also water-related indicators, thus delivering fist insights on value-chain related environmental burdens of companies from a life cycle thinking perspective.[29] For GEMI Local Water Tool only examples for the oil sector are publicly available. Most methods were developed by a diverse stakeholder group. Only CSO Corporate Water Gauge was not developed in a multistakeholder process.

3.8. Transformative Potential

All approaches can be used as a basis for developing mitigation measures. However, the direct linkage between approach and measures as well as the level of prescriptiveness in relation to the measures strongly diverge. For example, for AWS Water Stewardship carrying out mitigation measures represents the focus of the approach and for GEMI Connecting the Drops a fundamental part of it; WWF includes Water Stewardship as a solution to the risks highlighted by the Water Risk Filter; CDP Water Program and WFN Water Footprint encourage developing action plans through links to related initiatives (WFN) or higher scores (CDP). The remaining approaches do not provide specific information in this sense, but the information gained can be used as a basis for organizational decisions and concrete measures.

3.9. Overall Results

Sections 3.1–3.8 show that the approaches studied in this paper are heterogeneous according to the chosen criteria, as shown in **Figure 1**. Although no explicit weighting of criteria and subcriteria is performed, it should be noticed that criteria with several subcriteria are implicitly attributed a higher weight. This should be borne in mind when taking the following results as starting point for choosing the most suitable approach.

The overall highest score was obtained by ISO Water Footprint, primarily due to high performance in the criteria documentation and transparency, scientific soundness, organizational system boundaries, and ease of application. Also WFN Water Footprint and WWF Water Risk Filter reached high overall scores, the former with high performance in the criteria documentation and transparency and acceptance, the latter through high scores in environmental relevance. Other approaches show above-average scores in relation to specific criteria. For example, AWS Water Stewardship has the highest transformative potential and GEMI Connecting the Drops has above-average environmental relevance. This is linked to the different aims and scopes of the approaches analyzed in this paper.

4. Discussion

4.1. Methodological Limitations

Any comparison depends on the criteria chosen. The evaluation scheme developed in this paper is comprehensive and detailed, corroborated by a list of aspects to be considered and related scores. To increase transparency for the reader, Tables S1–S9 (Supporting Information) briefly motivate the scores assigned to each approach.

It is important that the criteria are independent, but overlaps in the evaluation cannot be totally excluded.

This applies for the criterion "documentation and transparency," subcriteria "guidelines for modelling the organization" and "guidelines to assess water-related environmental aspects." The former overlaps with the criterion "organizational system boundaries." In fact, if the supply chain is not or only partly considered, indications on how to model it are obviously not included in the guidelines. However, the supply chain might be included in a tool but not explained in a guidance document or in the tool itself, which reduces the method transparency. At the same time, the criterion "organizational system boundaries," through its detailed subcriteria, delivers deeper insights on the scope of the method, which could not be covered by the sole subcriterion "guidelines for modelling the organization." The same rationale applies for water-related environmental aspects, assessed in the criterion "environmental relevance" and partly influencing the subcriterion "guidelines to assess water-related environmental impacts."

Considering the number of publications in different subcriteria possibly leads to further overlaps. However, different characteristics of publications are considered. "Scientific soundness" considers only method-related peer-reviewed publications, while in the criteria "acceptance" and "broadness of application" all kinds of publications (also company-own reports) or documents that prove method application are taken into account. It should be noticed that in "broadness of application" and "acceptance" different case studies characteristics are included: While in "broadness of application" the subject of the study is considered (the kind of organization analyzed), "acceptance" includes all the organization types involved in method application.

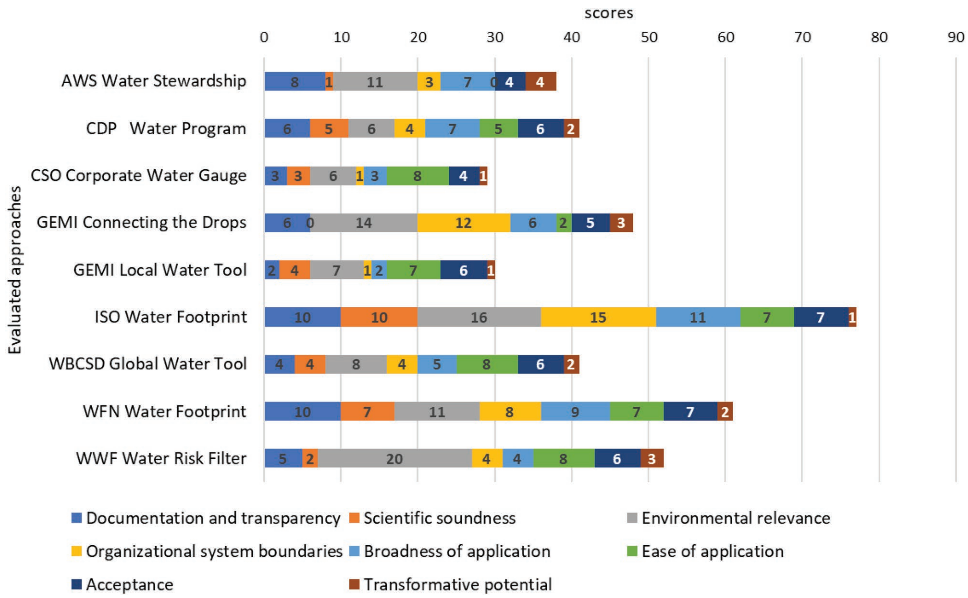

Figure 1. Scores attributed to the evaluated approaches.

Some criteria are not straightforward to interpret, for example "broadness of application" as a criterion. One could argue that, e.g., company-own tools, adapted and customized for the needs of a specific organization, might be the best solution to carry out an assessment. In this evaluation scheme, a tool of this type would obtain a low score according to the evaluation. According to the motivation of this paper, i.e., providing practitioners information to choose the most suitable tool for their specific task, the perspective of universally applicable tools was chosen. This is not related to the (assumed) quality of customized solutions, but to the broader target audience envisaged by this evaluation.

To conclude, even though the evaluation has been conducted transparently and documented through the comments available in the Supporting Information, some points, e.g., the understandability of guidelines, is subject to personal judgment. To alleviate individual biases, consultations between the authors have been conducted.

4.2. Results

The approaches analyzed in this paper differ according to the overarching aim and the context in which they were developed, the format, and the scientific standards. For these reasons, the evaluation of the methods' performance is contextualized and the focus of the result analysis is set on highlighting the differences between the approaches under study.

According to the aim and the context, it can be differentiated between methods primarily developed to measure companies' risks (CDP Water Program, WBCSD Global Water Tool, WWF Water Risk Filter) and those intended for environmental assessment (ISO Water Footprint, WFN Water Footprint). The latter have a stronger environmental focus and account more comprehensively for the entire value chain.

Some approaches are developed primarily to be applied in a specific tool, so that the characteristics of the tool and those of the method overlap. In fact, in order to increase user-friendliness by integrating guidelines into the tool, detailed guidance and explanation risk being sacrificed due to lack of background documents. In the case of advanced tools, one could argue that the nature of the approach justifies the absence of detailed guidelines. In fact, different tools allow inserting data related to individual facilities, and automatically calculate assessment results. However, none of these tools foresees a preliminary modeling of the organization under study. This poses the problem of organizational boundaries: Which facilities is the organization under study responsible for and to which extent? If the organization's performance in two different years is compared, how can be verified whether the amount and type of goods produced in the facility remains unchanged? Moreover, the results of tool-based methods do not make clear which organizational activities are included in the facilities and whether high-impact activities were excluded.

Although the influence of an organization and its water-related impacts reach out beyond the organizational boundary, most approaches include only a limited segment of the value chain. Upstream suppliers are considered in several approaches, though to different degrees, e.g., their inclusion is only suggested or encouraged for large companies (see CDP Water Program and AWS respectively). Differently, the inclusion of all downstream activities (use and end-of-life) is foreseen only by GEMI Connecting the Drops and ISO Water Footprint. However, the company often has the possibility to influence the environmental performance during its use and end-of-life phase, e.g., through use instructions, product design and recycling strategies. To make full use of their influence on environmental impacts, it is crucial for organizations to develop a data and analysis basis on the impacts their products have after leaving the factory's gate.

Except for ISO and WFN Water Footprint, elements of the organization unrelated to production are not consciously integrated in the analysis. Only if located within the borders of the site, activities linked to the organization like administrative offices and canteens might be automatically included in water use and water discharge accounts. However, external parts of the organization need to be included too (common garden with other sites, common canteen, external administration, outsourced IT) to have a complete picture of hotspots and avoid burden shifting. This is of particular relevance for the service sector, whose main sources of water consumption might be related to supporting activities, and for large companies, with complex structures including external services.

One of the most diverging figures that emerge in the assessment is the availability of scientific publications and the often-lacking involvement of academia in method development and application. It is worth highlighting that none of the approaches evaluated in this paper has been validated through a scientific peer review of the method itself. While several publications related to ISO Water Footprint and WFN Water Footprint are available, the other methods lack the external check guaranteed by peer-review. This is the case for most tool-based approaches, which probably obtain practitioners' feedback due to their increased applicability. However, this might lead to qualitative drawbacks. In fact, leaving uncertainties unconsidered represents a risk for tool users and customers who might tend to consider the results as absolute, thus neglecting the room for improvement of data quality and assumptions, and the possibility to calculate different scenarios. On the other hand, the availability of an approach-related tool in combination with a linked database represents a great advantage for practitioners, who do not have to search data and connect it separately, or create an own tool.

Finally, the transformative potential of most assessed methods is limited, since it is mostly out of their scope. In fact, most approaches are of informative nature, and their task ends as soon as the organizations are informed about the environmental performance or risk. However, in the last years a trend toward linking assessment results to mitigation measures, e.g., water stewardship, can be observed (WWF Water Risk Filter, WFN Water Footprint). This shows an ongoing conceptual shift from pure environmental assessment toward actively shaping environmental protection.

4.3. Recommendations

Considering the evaluation results and discussion, we suggest taking ISO Water Footprint as a starting point. The approach is object of an international standard and scientific papers, allows for reproducibility and uncertainty analysis, ensures environmental relevance and considers the whole value chain. Room for improvement is given also in these fields. In fact, although guidelines for both organization modelling and literature on impact assessment are available, a comprehensive guidance document including both aspects would be helpful for both practitioners and method developers. The former could obtain complete guidance and thus apply the method more efficiently; the latter would have the opportunity to reflect both water-specific challenges of organization modelling (e.g., provide guidance on which activities and parts of the value chain not to overlook) and adapt water-related impact assessment methods to organizations. For the organization-related elements of the approach, the organizational life cycle assessment method seems appropriate as main source. A guidance document on Organizational Life Cycle Assessment,[30] compliant with the related ISO standard,[31] and object of scientific research,[32] is already available. It provides specific advice for different kinds of organizations, and was tested in case studies.[29] This document, combined with ISO 14046, could represent the basis for developing scientifically founded, useful and applicable guidelines for determining the Water Footprint of organizations.

Producing specific guidelines for organizational Water Footprint might unfold further positive effects, like spreading an organizational Water Footprint method and encouraging its application. To validate the method and increase its credibility within the experts' community, the method itself and the underlying theoretical background should be validated through peer-reviewed publications. Further, room for improvement is given for the ease of application. Although databases and tools for product Water Footprint are available, these are originally developed for product modelling, so that practitioners are required additional efforts for creating an organizational model. A software tool able to guide practitioners through the organizational structure and the possible sources of water consumption is expected to increase and facilitate applications. Additionally, different databases for Life Cycle Assessment provide water data, therefore case-specific guidance for practitioners on which database is most suitable for different situations should be provided.

Last, the transformative potential of ISO Water Footprint needs to be unfolded. In fact, the approach ends in its actual form with the identification of hotspots in the supply chain, but no direct support of corporate decisions and mitigation actions follow. Taking example from mitigation oriented approaches such as the Water Stewardship concept, a direct linkage between impacts and action can be established. Thus, combining the global perspective of the Water Footprint and local mitigation measures at hotspots in the supply chain is recommended in the methodological development of organizational Water Footprint.

5. Conclusions

This paper provides an evaluation of 9 approaches to assess water-related impacts of organizations. Eight evaluation criteria, specified by 22 subcriteria, are developed based on scientific literature. The approaches diverge according to their main aim (assessing the risks for the company or those originated by the company) and main product (a calculation tool or a guidance for method application). They include different parts of the organization's value chain, often excluding downstream processes and activities not directly linked to production. Only a few approaches include concrete mitigation measures among their core tasks. Due to the overall scores, the authors recommend basing future method development on the ISO Water Footprint method, and combine it with the organization-related elements and application experience available for Organizational Life Cycle Assessment. Further, the transformative potential of the method should be increased by combining local Water Stewardship activities at hotspots identified in the value chain.

Supporting Information

Supporting Information is available from the Wiley Online Library or from the author.

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Conflict of Interest

The authors declare no conflict of interest.

Keywords

corporate water management, organizational Water Footprint, water assessment, water risk, Water Stewardship

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