# INTERSESSIONAL PANEL OF THE UNITED NATIONS COMMISSION ON SCIENCE AND TECHNOLOGY FOR DEVELOPMENT (CSTD)

**Geneva, Switzerland**
**25-26 October 2022**

Contribution by UNRISD

to the CSTD 2022-2023 priority theme on “Ensuring safe water and sanitation for all: a solution by science, technology and innovation”

Received: 14 December 2021 | Revised: 4 February 2022 | Accepted: 17 February 2022
DOI: 10.1002/sd.2310

RESEARCH ARTICLE

Sustainable Development WILEY

# Supporting the Sustainable Development Goals: A context sensitive indicator for sustainable use of water at the facility level

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**Funding information**
This research was supported by funds from the United Nations Research Institute for Social Development (UNRISD).

## Abstract

This paper presents a low-cost and scalable method for providing a sustainable water allocation for enterprises based on the hydrological, economic, and demographic contexts of their facilities. Context-based performance indicators are vital for effectively monitoring and achieving the Sustainable Development Goals (SDGs). Currently, the SDGs consist of 17 goals that are associated with 169 targets and 232 indicators. Making valid and objective measurements of the 232 indicators represents a significant challenge for scientists and policy makers. Achieving the SDGs will likely involve significant efforts in developing and sustaining systems for monitoring status and progress, providing incentives, and conducting enforcement. Provision of low-cost Sustainable Development Performance Indicators (SDPIs) of progress at high spatial and temporal resolution is essential for effective management by governments and businesses. The water allocations we produce are based on a facility's total and consumptive use of water, their contribution to gross domestic product (GDP), their number of full-time employees, the population and GDP of several geographic contexts, and the annually specific hydrological balance (i.e., precipitation minus evapotranspiration) of those contexts. The allocations and related sustainability assessments are determined for a range of geographic contexts (circular regions centered on the facility with radii of 10, 50, 100, 200, and 300 km respectively). From the hydrological data we give priority to ‘Water for Nature’ and allocate a proportion of the remaining ‘Water for Economy’ to the facility based on their contribution to GDP and the number of full-time employees they have. This allocation is compared to their actual water withdrawals to provide an indication of the sustainability of their economic activity.

KEYWORDS
context-based SDGs, earth observation data for SDGs, SDPI, water allocation, water for environment

## 1 | INTRODUCTION

The overarching objectives of the Sustainable Development Goals (SDGs) could be summarized as an attempt to guide us to ‘a safe operating space for humanity’ (Rockström et al., 2009) while providing all human individuals with a just, equitable, and dignified suite of societal living conditions (Raworth, 2017). The development of the Millennium Development Goals and the SDGs likely manifested because of our regress rather than progress toward them. There remains considerable dialog and debate regarding the coherence and consistency of the 17 goals and their related indicators with respect to achieving 'a safe operating space for humanity' (Dawes, 2020; Giannetti et al., 2020; Hickel, 2019). Many argue that we have reached or exceeded the 'Limits to Growth' (Meadows et al., 1972) and there is little doubt that there is room for a great deal of progress in terms of sustainable development. If human civilization is coming to grips with learning how to fly what Kenneth Boulding termed 'Spaceship Earth' (Boulding, 1966), then the SDGs can be viewed as the gauges and instrumentation for the cockpit of that 'spaceship'.

The SDGs have established targets and indicators that attempt to characterize, measure, and respond to a suite of planetary civilizational challenges. These indicators must be measured in appropriate ways with sufficient spatio-temporal detail to provide useful and actionable information. Composite aggregate indicators such as gross domestic product (GDP), the ecological footprint, the human development index, and the Genuine Progress Indicator (Kubiszewski et al., 2013) are interesting and often useful; nonetheless, they frequently do not provide enough specificity to be actionable at the level of specific enterprises and local governments nor do they guide management of particular natural resources or impacts (Diaz-Sarachaga et al., 2018). There is undoubtedly a tension between two few indicators and too many (Kubiszewski et al., 2021). Aggregate global and national level measures of our collective failure to achieve the SDGs (e.g., rising $CO_2$ concentrations in the atmosphere, loss of biodiversity, and growing economic inequality) call for the establishment of context-based local monitoring and enforcement of phenomena relevant to the goals so that practical and effective changes can be initiated and sustained.

The Montreal Protocol is a good example of this. The Montreal Protocol is regarded as a successful policy response to the global environmental problem of stratospheric ozone depletion caused by increased concentrations of Chlorofluorocarbons (CFCs) emanating from anthropogenic emissions. The success of the Montreal Protocol as an environmental policy is, significantly, due to enduring environmental monitoring and constant vigilance with respect to enforcement and it explicitly recognized the driver (e.g., CFC emissions) of the environmental damage. The need for sustained monitoring and enforcement is exemplified by two Chinese provinces that have been identified as emitting a significant amount of ozone-depleting chemicals (Cyranoski, 2019). There are many who are calling for more indicators that capture the 'Pressures' and 'Drivers' from DPSIR analyses rather than the 'States' and 'Impacts' indicators for the SDGs (Spangenberg, 2017).

Monitoring and enforcement of laws and regulations are often necessary because a substantial fraction of the population will not obey them unless there is a perceived probability of consequences (e.g. speed limits are pointless if there are no speeding tickets). Sadly, the level and degree of law enforcement for wealthy individuals and large corporations in the United States lags far behind the level and degree of law enforcement for the proletariat (Sarin & Summers, 2019). Achievement of the SDGs will likely be a formidable challenge because a great deal of the monitoring and enforcement will necessarily affect wealthy individuals and large corporations who operate primarily in the developed world. In light of these challenges the gauges and instruments in the cockpit of 'Spaceship Earth' must be regarded as fair and valid measures of appropriate phenomena to engender compliance. If adopted, the context-based water metric we present here would ultimately be just one of a great many gauges on the 'Planetary Dashboard'; nonetheless, it is instructive to explore why it may be essential, useful, valid, and just.

Human appropriation of water for agriculture, industry, and domestic consumption represents a significant set of human-environment interactions that relate to several of the SDGs including but not limited to: SDG 6 'Clean Water and Sanitation', SDG 11 'Sustainable Cities and Communities', SDG 12 'Responsible Consumption and Production', SDG 14 'Life below water', and SDG 15 'Life on Land'. Because the availability and use of fresh water is spatially and temporally variable across the globe it makes sense for our estimates of sustainable use of water to have 'context sensitivity'.

Here we incorporate spatial and temporal context into a SDPI. From a spatial perspective it may be regarded as unreasonable to grow water intensive crops (e.g. cotton) in semi-arid inland Australia while it may make sense to do so in tropical regions. From a temporal perspective it may be appropriate to divert water from streams and rivers to reservoirs in high flow seasons and situations but not appropriate to do so during low flow seasons and droughts. Spatial and temporal context matter as to when and where water is diverted for economic activities. This index could support identification of regions that could benefit from water distribution prioritization schemes as described by Kaghazchi et al. (2021). In addition, facilities that score poorly might benefit from consultation with indigenous populations regarding sustainable water resource management (Gearey, 2018).

Our metric involves a very limited quantity of Earth Observation data (EO data) used in conjunction with location, employment, water use, and gross economic revenue data reported by specific facilities. We contend that EO data can make a useful contribution to the assessment of both the state and dynamics of many of the SDGs (Andries et al., 2019; Ghosh et al., 2020; Kuffer et al., 2018; UNEP, 2019). This analysis explores the use of several EO data derived from spatio-temporally explicit datasets (e.g., rainfall, evapotranspiration, GDP, and population) to develop spatially and temporally context-based water allocations for facilities located at points on the earth's surface.

## 2 | DATA AND METHODS

The water allocation we present here aims to provide a sustainable development performance indicator (SDPI) relevant to a particular facility in a particular location for a particular window of time (M. McElroy, 2008; McElroy & Van Engelen, 2012). In the spirit of the SDGs we seek to ensure that environmental flow requirements (aka 'water for environment' or 'water for nature') are prioritized in addition to avoiding the exceedance of certain thresholds (namely baseline water stress, baseline water stress (BWS) >0.4). BWS is measured as total (gross) annual water withdrawals expressed as a percent of total (net) annual available flow (Hofste et al., 2019).

There is a variety of approaches to calculating this water indicator. In this case the basic premise uses the following reasoning. For a 'facility' that produces a given amount of economic activity ($\mathrm{GDP}_{\mathrm{facility}}$), there is a fair allocation of water ($W_{\mathrm{facility}}$) derived from a geographic context (i.e., areal extent) that provides $W_{\mathrm{econ}}$ (water for economic activity) and produces $\mathrm{GDP}_{\mathrm{region}}$ worth of economic activity. This relationship is summarized in the following equation:

$$\frac{\mathrm{W}_{\mathrm{facility}}}{\mathrm{GDP}_{\mathrm{facility}}}=\frac{W_{\mathrm{econ}}}{GDP_{\mathrm{region}}}. \tag{1}$$

Rearranging we solve for water allocated to the facility:

$$W_{\mathrm{facility}}=W_{\mathrm{econ}}\left(\frac{\mathrm{GDP}_{\mathrm{facility}}}{\mathrm{GDP}_{\mathrm{region}}}\right). \tag{2}$$

In general, water scarcity is analyzed with two fundamental concepts: water shortage (impacts due to low availability per capita) and water stress (impacts due to high consumption relative to availability). The former indicates difficulty in satisfying the needs of a population while the latter concerns overuse of water. The context based SDPI indicator we propose incorporates these two concerns which indicates whether a company uses water in a sustainable manner in the sense that it conforms to their fair, just and proportionate share of available renewable supplies.

We present four 'water allocations' based on 'Gross Withdrawals' (GW), 'Consumptive Use' (C), GDP, and Population (POP) in the geographic context of a facility. Appropriately determining the geographic context of a facility with respect to its 'watershed' is a non-trivial matter we describe in Appendix A (Table A1).

$$W_{\mathrm{facility\,(GW,GDP)}}=W_{\mathrm{econ,GW}}\left(\frac{\mathrm{GDP}_{\mathrm{facility}}}{\mathrm{GDP}_{\mathrm{region}}}\right), \tag{3}$$

$$W_{\mathrm{facility\,(C,GDP)}}=W_{\mathrm{econ,C}}\left(\frac{\mathrm{GDP}_{\mathrm{facility}}}{\mathrm{GDP}_{\mathrm{region}}}\right), \tag{4}$$

$$W_{\mathrm{facility\,(GW,POP)}}=W_{\mathrm{econ,GW}}\left(\frac{\mathrm{POP}_{\mathrm{facility}}}{\mathrm{POP}_{\mathrm{region}}}\right). \tag{5}$$

$$W_{\mathrm{facility\,(C,POP)}}=W_{\mathrm{econ,C}}\left(\frac{\mathrm{POP}_{\mathrm{facility}}}{\mathrm{POP}_{\mathrm{region}}}\right). \tag{6}$$

Most of the EO data we incorporate into this indicator are structured spatially in a raster or cell-based format. In this case cells can be conceived of as square patches of land for which we have measures of annual rainfall (Precip), annual evapotranspiration (Evap), Gross Domestic Product (GDP \$/year), and population (See Appendix B, Table B1 for data sources). The annual GDP data at 1 km$^2$ is developed by combining the rural and urban GDP derived from the nighttime light data (NPP-VIIRS), the population data (GHSL), and national administrative boundaries (GADM).

The input data, data extraction, and output data are summarized in a data processing flowchart (Figure 1). Annual VIIRS nighttime lights are obtained from 2015. Evapotranspiration and precipitation are obtained from 2019. Water withdrawal data (PCRglobeWB) is obtained from 2019. They are the most recent datasets available at the time of study. The monthly evapotranspiration and precipitation are aggregated into the annual products at 1 km$^2$ level. Watershed buffer zones with different radii are created in ArcGIS Pro to extract the sum of precipitation, evapotranspiration, population, and GDP values within the corresponding zones. Therefore, a summary table is produced for summarizing the values used for hydrological assessment.

We consider consumptive flows (water that is removed from the environment without being returned) and non-consumptive flows (water that is removed from the environment and is returned to the environment as wastewater that is presumably sufficiently treated). Consumptive and non-consumptive withdrawals of water can be disaggregated in a variety of ways (e.g., domestic, industrial, livestock, and irrigation); however, data availability of this nature is limited. Water stress and environmental flow calculations are carried out using hydrological models approximating stream flows and human withdrawals (Figure 1).

The gross water available at a point in space (a 'cell') is a function of the precipitation and evapotranspiration, as well as—where relevant—any stream flow coming from upstream cell(s), denoted $Q_{\mathrm{in}}$:

$$Q_{\mathrm{gross}}=\mathrm{Precip}-\mathrm{Evap}+Q_{\mathrm{in}}. \tag{7}$$

We have produced an MS Excel based interactive model (Appendix S1 Figures 2 and 3) to illustrate the way consumptive and non-consumptive withdrawals are apportioned, and how they affect the criteria that are derived below.

Gross withdrawals by humans are denoted $Q_{\mathrm{GW}}$ and consist of a consumptive flow ($Q_{\mathrm{C}}$) that is removed from the system for domestic use as well as various economic purposes (industrial, livestock and irrigation):

$$Q_{\mathrm{C}}=Q_{\mathrm{dom,C}}+Q_{\mathrm{econ,C}}. \tag{8}$$

The consumptive use is a fraction of overall or gross withdrawals ($Q_{\mathrm{GW}}$). $Q_{\mathrm{GW}}$ includes water used for the same sectors, some of which is non-consumptive and eventually returns to the ecosystem.

The net water available ($Q_{\mathrm{net}}$) is thus the gross water available minus the gross withdrawals, plus the return flows from non-consumptive use:

$$Q_{\mathrm{net}}=Q_{\mathrm{gross}}-Q_{\mathrm{dom,C}}-Q_{\mathrm{econ,C}}=\mathrm{Precip}-\mathrm{Evap}+Q_{\mathrm{in}}-Q_{\mathrm{C}}, \tag{9}$$

where $Q_{\mathrm{C}}$ is the sum of consumptive uses for domestic ($Q_{\mathrm{dom,C}}$) and economic ($Q_{\mathrm{econ,C}}$) activities. The outflowing water from one cell to the next ($Q_{\mathrm{out}}$) is equal to $Q_{\mathrm{net}}$.

Our indicator uses two distinct hydrological concepts. The first, environmental flow requirements (EFR) (aka 'water for nature'), can be interpreted as limiting consumptive human withdrawals ($Q_C$) so as to preserve the outflow ($Q_{out}$) above a minimum level deemed necessary for ecosystem function. The second, BWS, is conceptually different from EFR, as it relates to the gross withdrawals ($Q_{GW}$) at a certain point, relative to the net water available ($Q_{net}$) in a cell:

$$\mathrm{BWS} = \frac{Q_{GW}}{Q_{net}}, \tag{10}$$

BWS recognizes that even though non-consumptive withdrawals are, by definition, returned to the ecosystem, they may be discharged some way downstream and therefore local stress may still be incurred on water resources.

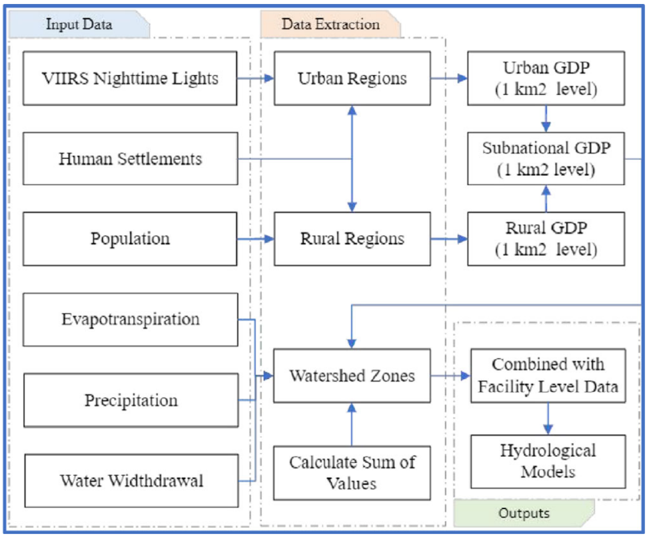

FIGURE 1 Flow chart of data processing [Colour figure can be viewed at wileyonlinelibrary.com]

## 2.1 | Two criteria for sustainable allocation of water resources

For sustainable allocation of water resources, we consider two criteria:

1. EFR needs to be a minimum of 50% of river flows (Revenga et al., 2004).
2. BWS should be <0.4 to ensure the risk classification is no higher than 'medium' (Hofste et al., 2019).

The inclusion of both EFR and BWS, with the latter considering both consumptive and non-consumptive withdrawals, is broadly in line with the recommendations of Vanham et al. (2018) for the creation of comprehensive water scarcity metrics in the context of the Sustainable Development Goals. The interpretations of these different criteria are described below in relation to the SDPI water indicator, which should be a simple, replicable water allocation metric.

### 2.1.1 | Interpretation of criterion 1 (environmental flow requirements)

We assume that the correct way to interpret this is that 50% of undisturbed river flows (i.e. flows that would occur in the absence of human withdrawals) should be left for nature, following Shakthi et al. (2004).

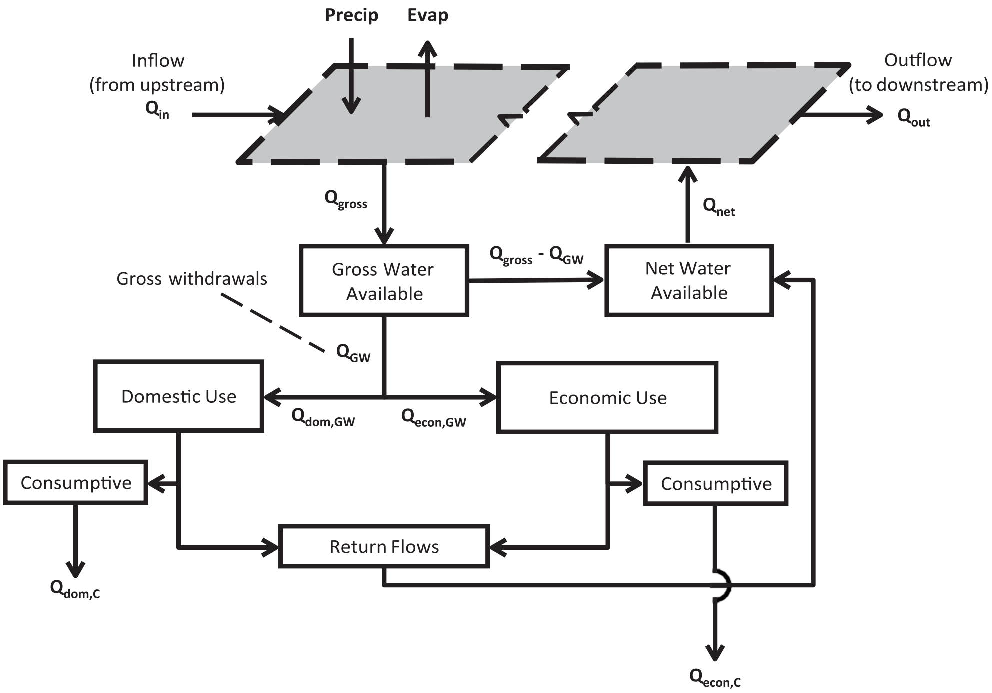

FIGURE 2 Conceptual model of natural flows, consumptive, and non-consumptive withdrawals

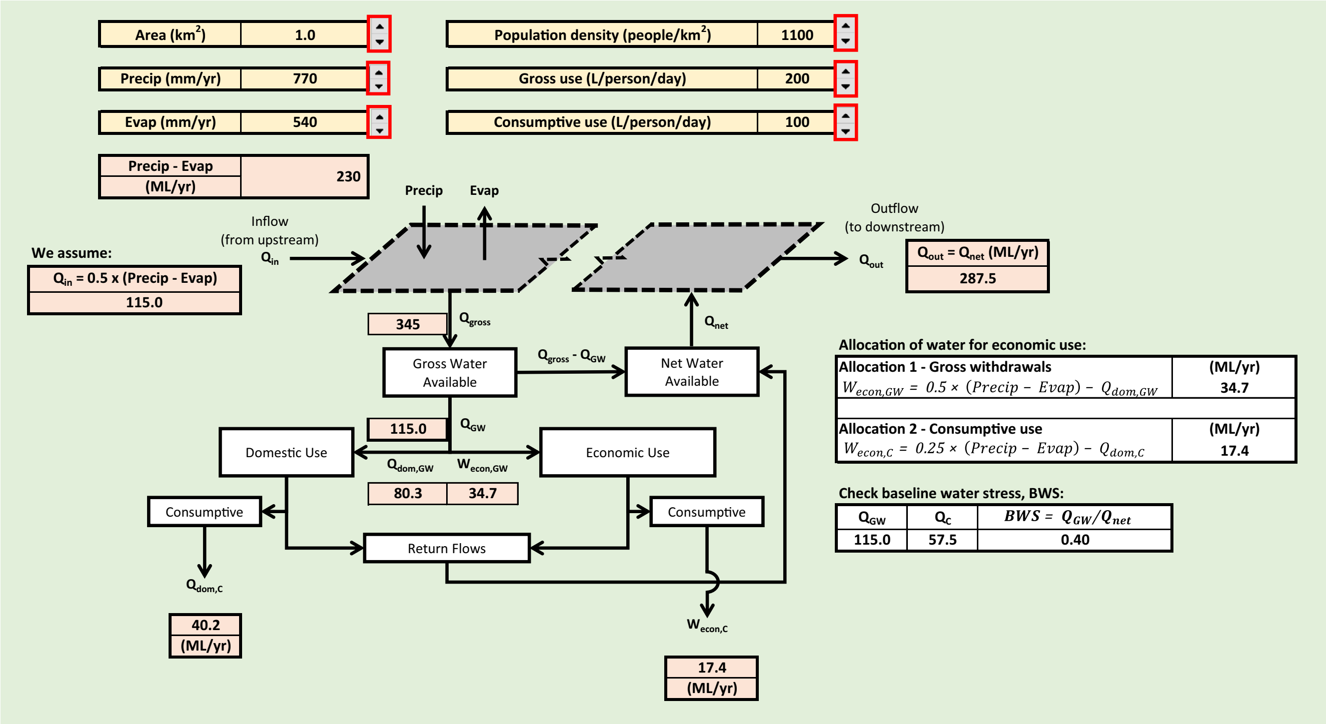

**FIGURE 3** Graphical representation of the excel based interactive model (see Appendix S1) [Colour figure can be viewed at wileyonlinelibrary.com]

In the interests of rapid replicability of the indicator, we are avoiding modeling the hydrology of actual watersheds/basins. As such, we cannot simulate hypothetical flows ($Q_{in}$ and $Q_{out}$) that may have occurred in the case of zero withdrawals. Flows reported in existing hydrological models such as PCR-GLOBWB2 (Hofste et al., 2019) reflect current or historical human withdrawals, so represent a ‘status quo’ rather than a hypothetical case of natural flow conditions.

If, however, we assume that at every point across an entire area under investigation, the only source of river flows is ultimately Precip minus Evap, and if we then assume that consumptive withdrawals ($Q_C$) are never allowed to be more than 50% of Precip minus Evap, then it should follow that the river flows (after consumptive withdrawals) will be at least 50% of the flow that would have occurred if there were no withdrawals.

Therefore, we can consider criterion 1 to be approximately met by ensuring, at all cells within the spatial extent being considered, that consumptive water use does not exceed a threshold value. However, at the local cell level, non-consumptive use may affect local water availability as return flows may plausibly occur downstream. This means that for the allocation to be conservative, non-consumptive use should be treated as if it were consumptive. The environmental flow criterion is thus applied to gross withdrawals by specifying the threshold $Q_{GW,max}$:

$$Q_{GW,max} = 0.5 \times (\text{Precip} - \text{Evap}). \tag{11}$$

### 2.1.2 | Interpretation of criterion 2 (BWS and consumptive use)

A conservative approach was taken to determining the threshold for gross withdrawals, but we must still check the impact if all withdrawals across a catchment were at that threshold ($Q_{GW,max}$) and if these withdrawals were all taken for consumptive uses ($Q_C = Q_{GW,max}$). For the special case where $Q_C = Q_{GW,max}$, the calculation of baseline water stress becomes:

$$\text{BWS} = \frac{Q_{GW}}{Q_{net}} = \frac{Q_{GW,max}}{\text{Precip} - \text{Evap} + Q_{in} - Q_{GW,max}}. \tag{12}$$

Similar to our treatment of EFR, we do not have values of $Q_{in}$ for a hypothetical undisturbed case, nor are we simulating the hydrology as would be required to determine $Q_{in}$ for a case where entire catchments are being managed sustainably and for a satisfactorily low level of BWS. We therefore propose, as a simplifying step, that the inflow, $Q_{in}$, from an adjacent upstream cell can be rapidly approximated using EO data as 50% of the Precip minus Evap in the current cell. We note that this is a simplifying assumption (i.e., it assumes that the adjacent cell's climate is similar to the current cell) but the approximation is justified on the basis that it avoids us having to simulate entire basin hydrology to estimate which cells contribute net discharge into which of their adjacent cells.

Thus in the case where all withdrawals are consumptive ($Q_{GW} = Q_C$), BWS is approximated by:

$$\mathrm{BWS} = \frac{0.5\times(\mathrm{Precip}-\mathrm{Evap})}{\mathrm{Precip}-\mathrm{Evap}+0.5\times(\mathrm{Precip}-\mathrm{Evap})-0.5\times(\mathrm{Precip}-\mathrm{Evap})}, \tag{13}$$

that is, BWS = 0.5. This would be classified as 'high risk' according to established guidelines on water stress (Hofste et al., 2019) and is deemed unsatisfactory in relation to criterion 2. We therefore interpret criterion 2 as being required to find the maximum level of consumptive water use ($Q_{C,\max}$) in the cell that would result in BWS = 0.4 (upper limit for 'medium risk') when gross withdrawals are at their threshold ($Q_{GW,\max}$):

$$\mathrm{BWS} = \frac{Q_{GW}}{Q_{net}} = \frac{Q_{GW,\max}}{\mathrm{Precip}-\mathrm{Evap}+Q_{in}-Q_{C,\max}} = 0.4. \tag{14}$$

Applying the same simplifying assumption for $Q_{in}$ as above, we have, in a given cell:

$$\frac{Q_{GW,\max}}{1.5\times(\mathrm{Precip}-\mathrm{Evap})-Q_{C,\max}} = 0.4. \tag{15}$$

Substituting for $Q_{GW,\max}$ we get:

$$\frac{0.5\times(\mathrm{Precip}-\mathrm{Evap})}{1.5\times(\mathrm{Precip}-\mathrm{Evap})-Q_{C,\max}} = 0.4. \tag{16}$$

Rearranging, we get:

$$Q_{C,\max} = 1.5\times(\mathrm{Precip}-\mathrm{Evap}) - \frac{0.5\times(\mathrm{Precip}-\mathrm{Evap})}{0.4}. \tag{17}$$

Which finally results in:

$$Q_{C,\max} = 0.25\times(\mathrm{Precip}-\mathrm{Evap}). \tag{18}$$

Thus criterion 2 can be considered to be approximately met as long as consumptive use in each cell does not exceed half of the maximum allowable gross withdrawals.

## 2.2 | Allocation of water for economic use

Water for economic use is the water available after water for the environment (aka EFR) is provided for, and after setting aside water for domestic use. Thus we have two 'Water for Economy' allocations: Wecon, GW and Wecon, C (Table 1), representing the water available for economic use within the context of the facility in terms of gross withdrawals and consumptive use, respectively.

It is evident that under the above formulation, $Q_C$,max will always be less than $Q_{GW}$,max. However, it may not always represent the stricter allocation at the facility level, as some facilities may use water in a largely (or even completely) non-consumptive way. It is therefore important to specify both gross and consumptive thresholds to determine whether a given facility is appropriating water in a fair manner with respect to either, or both.

## 2.3 | Defining the geographic context for a water consuming facility

There are many problems associated with determining the appropriate catchment scale or spatial context for a given facility. Our initial consideration proposed to take the location of the facility, as well as the points of water source and discharge, and use a topographic catchment delineation model to determine the minimum catchment scale that includes all these locations. This approach intended to account for the fact that facilities may depend on reticulated supplies where the water originates some distance away from the local catchment. However, this method proves difficult in practice as reticulated supplies may draw water from multiple catchments; moreover, if relying on facilities to self-report on a distant location from which their water supply originates, it may be difficult to guarantee accuracy. Even if distant point sources can be accurately located, it is conceivable that inter-basin transfer schemes (for instance where there is pumping over a mountain range) could be missed or significantly misrepresented by a topographically defined catchment model, which delineates catchments by following dendritic channels. This is depicted in Figure 4.

Even if we assume that an appropriate catchment boundary polygon could be determined based on following the source water upstream of a facility (accounting for inter-basin transfers through pumping, etc.), a separate issue emerges from the fact that the same catchment may support a large amount of GDP-generating activity elsewhere, outside the polygon. If the 'allocation' of water to a facility is based on following the source to the catchment, and then assessing the economic activity within the spatial area of the catchment, then this may miss significant economic activity supported by that same catchment, outside the polygon. The inverse is also true: economic activity counted within one catchment polygon may be largely dependent on water that originates in an entirely different catchment.

In summary, it is highly likely that there will be a (potentially significant) mismatch between the spatial area corresponding to the water resources from which the facility's water is being allocated, and the spatial area corresponding to the economic activities supported by those same water resources. Our rapid assessment therefore requires a method that accounts for the spatial heterogeneity of GDP activity and water resources and develops the local context for the water allocation / efficiency indicator without direct dependence on the spatial boundary of an arbitrary local catchment. The method below is proposed to deliver this, while mitigating the problems summarized above.

The proposed approach involves a major simplifying step, which is to assume that a facility's local context—in terms of both water resources and economic activity used to determine the water allocation—can be approximated by a circular area centered on the facility. The ideal radius of this circle would depend on the distance(s)

**TABLE 1** Water for economic use according to Gross Withdrawals (GW) and baseline water stress (BWS) criteria

| | | Facility-level indicator, ≤1 = sustainable | |
|---|---|---|---|
| **Water use category** | **$W_{econ}$: Water available for economic use** | **GDP-based** | **Population-based** |
| Gross withdrawals | $W_{econ,GW} = Q_{GW,max} - Q_{dom,GW}$ | $\frac{W_{facility,GW}}{GDP_{facility}} / \frac{W_{econ,GW}}{GDP_{region}}$ | $\frac{W_{facility,GW}}{POP_{facility}} / \frac{W_{econ,GW}}{POP_{region}}$ |
| Consumptive use | $W_{econ,C} = Q_{C,max} - Q_{dom,C}$ | $\frac{W_{facility,C}}{GDP_{facility}} / \frac{W_{econ,C}}{GDP_{region}}$ | $\frac{W_{facility,C}}{POP_{facility}} / \frac{W_{econ,C}}{POP_{region}}$ |

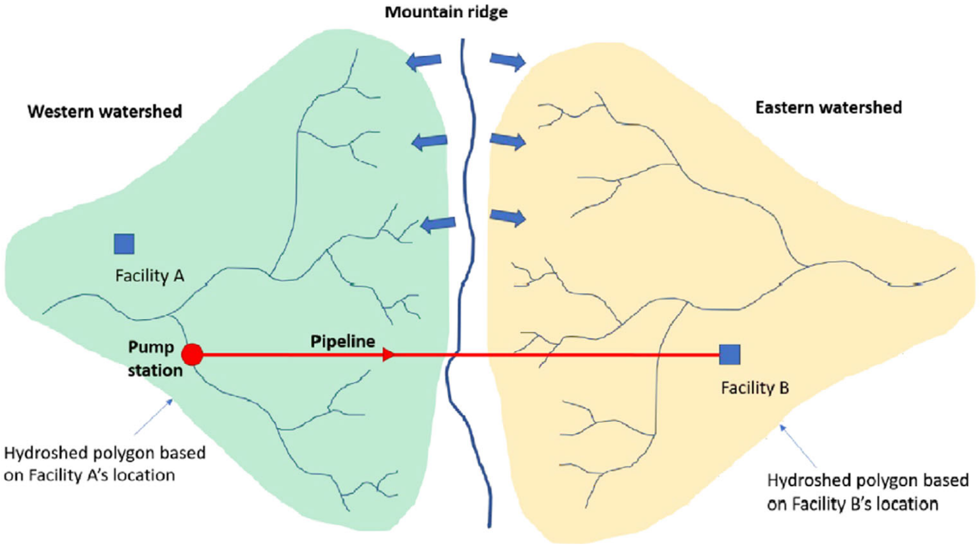

**FIGURE 4** Illustration of the problem of inter-basin transfer when mapping source catchments [Colour figure can be viewed at wileyonlinelibrary.com]

from which water is procured from one or more catchments, and the distance(s) to which other economic activities take place that share the same water resources. However, for the reasons outlined above, the distances from the various water sources and to the various economic destinations are not expected to be uniform, nor easy to determine.

One means by which a suitable distance may be approximated is to measure the economic and demographic context of the facility. McDonald et al. (2014) determined that there is a relationship between urban economic activity and the distance over which a city's water is transported. It is plausible that based on the work of McDonald et al. (2014), an approximate radius could therefore be chosen depending on local population and/or economic activity in the vicinity of the facility, as shown in Table 2.

The radius in Table 2 is the sum of two distances: the first is an approximate water transport distance, while the second accounts for the additional distance that water may be expected to flow through natural catchments prior to being collected and transported via a reticulated network to the facility. In this way, facilities located in close proximity to large population centers are assumed to be able to access water that comes from a larger zone (consider a large city with reticulated water from multiple catchments and inter-basin transfers), while facilities in low populations are assumed to access water from a more local setting. It is recognized that the circular zone will not correspond to the precise physical area from which a facility's water is taken. However, it does represent a method for determining (from EO data) the contextual scale of the local zone from which a facility's water could plausibly be obtained. Further work is recommended in refining the radius.

For this paper, we chose to extract water allocations for circular regions of 10, 50, 100, 200, and 300 km surrounding the facility location. By performing this calculation at several contextual scales, we believe the metrics provide insight as to the context-sensitive nature, and in particular the sensitivity to scale, of the metric. Presenting the metric over multiple radii allows facilities to determine for themselves the appropriate context based on their understanding of the local resources and economy, while allowing further work to be done to refine the areal approach.

For each radial extent, EO data are used to conduct the water allocation. Precipitation, evaporation, population, and economic data are available on a pixel-by-pixel basis. Here we use spatially explicit annual estimates of total precipitation, total evapotranspiration, population in hydrographic context, and GDP in hydrographic context. This is accomplished by adding up the cells within the hydrographic radius of the facility from the following datasets: FLDAS (https://ldas.gsfc.nasa.gov/fldas) rainfall and precipitation data (~10 km × 10 km cells). The global human settlement layer (GHS https://ghsl.jrc.ec.europa.eu/datasets.php), and the PCRG-GLOBWB 2 data (https://gmd.copernicus.org/articles/11/2429/2018/) (Figure 5).

## 2.4 | Data inputs, data extractions, and SDPI outputs

The SDPI we present here is derived from data provided by particular facilities. This input data consists of location (latitude and longitude), Gross Water withdrawals, Non-consumptive use (i.e. wastewater discharge), Gross Revenue of facility (USD$ per year), and number of full-time equivalent employees of the facility.

The reported population of the facility (POPfacility) is expressed as a 'per capita equivalent' (PCE) or 'population equivalent' value, based on the total collective time employees spend at work. This is calculated using the assumption that one full-time employee (1920 h/year) is the equivalent of 0.219 humans in the general population (i.e., 1920 h/year divided by 8760 h/year). Using this scaling technique, the number of full-time employees working at a facility can be compared to the general population, allowing a population-based allocation to the facility of water for economic activity, $W_{\text{facility}}$(GW,POP) and $W_{\text{facility}}$ (C,POP). This is intended to complement the GDP-based economic allocation.

**TABLE 2** Example of relationship between local population and water procurement radius

| Population within 10 km of facility | Proposed water procurement radius |
|---|---|
| Low (<30,000) | 20 km transport + 50 km catchment = 70 km radius |
| Middle (30,000–300,000) | 50 km transport + 100 km catchment = 150 km radius |
| High (>300,000) | 100 km transport + 200 km catchment = 300 km radius |

### 2.4.1 | Scaling regional GDP

The method for allocating a share of regional water resources to a facility, based on its proportionate contributions to regional GDP ($\text{GDP}_{\text{region}}$), assumes that $\text{GDP}_{\text{region}}$ is congruent with the assessed amount water available for economic activity ($W_{\text{econ}}$) in the region. However, it is noted that there may be a discrepancy between activity that is currently occurring ($\text{GDP}_{\text{region}}$, derived from the EO data) and its corresponding level of water use (which is not computed), versus the amount of economic activity that may be deemed a 'maximum sustainable level of activity' that could correspond to the water available for economic use ($W_{\text{econ}}$) that is computed from EO data.

To serve its purpose as an indicator of whether a facility is using water sustainably or not, it is important that the SDPI indicator considers a facility's water use not just in the context of today's regional water use and economic activity, but also in terms of some plausible future economic activity that may correspond to 'sustainable' regional water use. It is far beyond the scope or purpose of this SDPI indicator to prescribe region-wide scenarios of economic use that could align with maximum sustainable water resource use. Indeed, there are infinite possible permutations of future economic activity and corresponding water use (consumptive and non-consumptive) in any region. For simplicity, we adopt an idealized approach to scaling regional GDP to give an indicative level of future activity that plausibly aligns to maximum sustainable water use, noting that there is significant room for variability.

Maximum sustainable use here is arbitrarily assigned as BWS = 0.4 (medium risk), although it is noted that a world in which

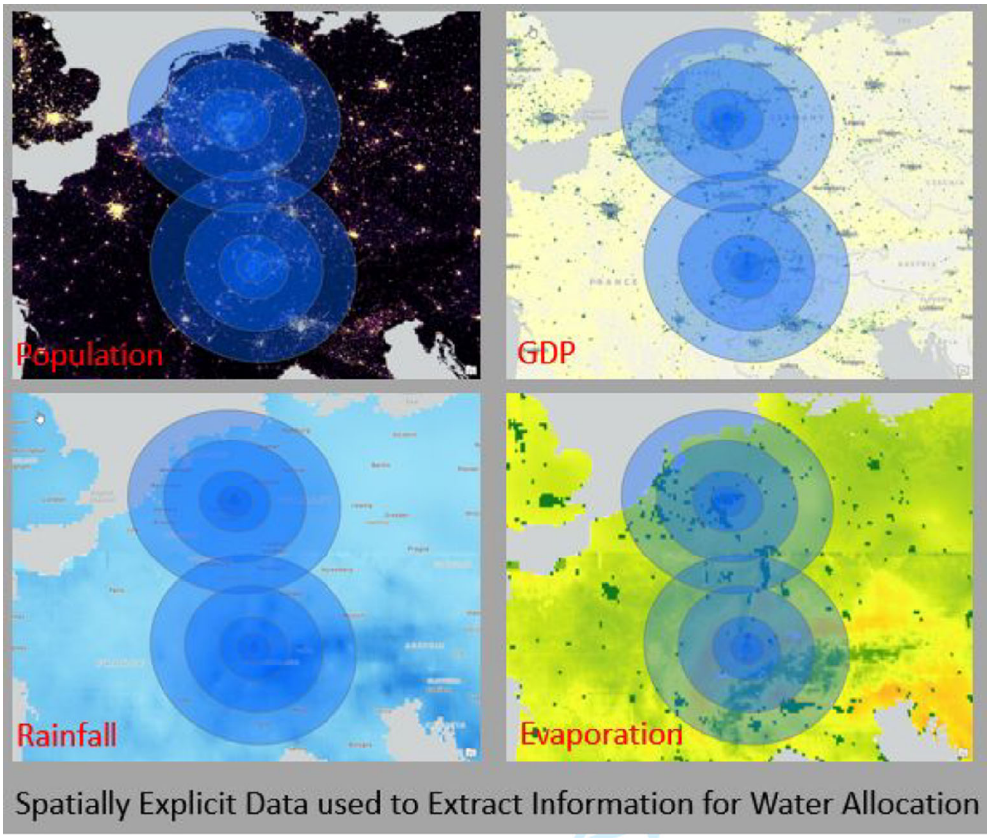

**FIGURE 5** Example of spatial data and 'context' buffers for two facilities in Europe [Colour figure can be viewed at wileyonlinelibrary.com]

every single catchment is managed to medium risk may not necessarily represent a desirable future. The method here is deliberately parsimonious, so that results can readily be re-computed for agreed lower levels of BWS if desired. The scaled regional GDP ($\text{GDP}_{\text{region,scaled}}$) is determined as follows:

$$\text{GDP}_{\text{region,scaled}} = \text{GDP}_{\text{region}} \times \frac{0.4}{\text{BWS}_{\text{region}}}, \tag{19}$$

where BWS is obtained from Aqueduct Global Maps (Gassert et al., 2013).

$\text{GDP}_{\text{region,scaled}}$ is not intended to be used as any projection of future economic activity, but rather to provide an instructive comparison between the sustainable water allocation that may be determined from today's regional activity and some future (higher or lower) level of activity. This comparison will show if a facility's water use can be deemed 'sustainable' in both present and future regional economic scenarios, or in neither, or in one but not the other, all of which are potentially useful in terms of facility-level planning for sustainable water use for the long-term.

## 3 | RESULTS

The spatio-temporal analysis performed within a GIS extracts Population, Precipitation, Evapotranspiration, and GDP (Wang et al., 2019) within circles of 10, 50, 100, 200, and 300 km centered on the facility. These numbers are used to calculate facility-level water allocations based on each radial context, for gross withdrawals ($W_{\text{econ,GW}}$) and consumptive use ($W_{\text{econ,C}}$). The indicators are derived from these allocations such that the facility has four separate sustainability scores for each radius of geographic context.

Numerical results of the relevant figures (e.g., water for nature, water for economy, water allocated to facility, sustainability index, etc.) are summarized in the supplemental document titled 'Facilities Template' (Appendix S2). The companies are anonymized in this document; however, a list of several of the companies that have volunteered information to develop this indicator can be found here (UNRISD Facilities). A key contribution of the project is to design a set of indicators that can help these economic entities gauge whether they are on a pathway to a future that is consistent with the transformative goals and vision of the 2030 Agenda for Sustainable Development. Data were provided by 26 facilities; however, complete information was provided by only three of these facilities at this point. The three facilities with complete information were Company B01, C01, D01, which are in different industrial sectors. Fortunately, these three facilities do provide a wide sampling of the variability of the SDPI we are proposing.

### 3.1 | Example of a not sustainable facility

Company B01 exceeded sustainable use of water across all geographic scales of context (Figure 6). To support interpretation of the results we describe the 50 km context of this facility as follows: Within 50 km of this facility there are 24,124,505 people, and this area produces a little over $689 billion of GDP per year. The facility consumes 451,000 cubic meters of water per year and produces $2.98 million dollars of revenue per year. The GDP based sustainability of this index using Gross Withdrawals ranges from 111.44 at the 50 km context to 14.84 at the 300 km context. The GDP based index using Consumptive use ranges from 222.88 to 29.68 over the same range. The corresponding population-based values range from 1177 to 188 (Gross withdrawals) and 2355 to 377 (Consumptive Use). These values suggest that this facility's use of water is not sustainable and that their water allocation based on their geographic context would be significantly smaller than their current actual use.

In this analysis, all the radial areas have BWS values that are near or exceeding 0.4. Thus in a future catchment management scenario in which water withdrawals are reduced, scaled regional GDP could (plausibly) be proportionally smaller. This has the effect of slightly lowering the values of the indicator (in other words, the economic water efficiency of the facility in its current form increases, relative to the

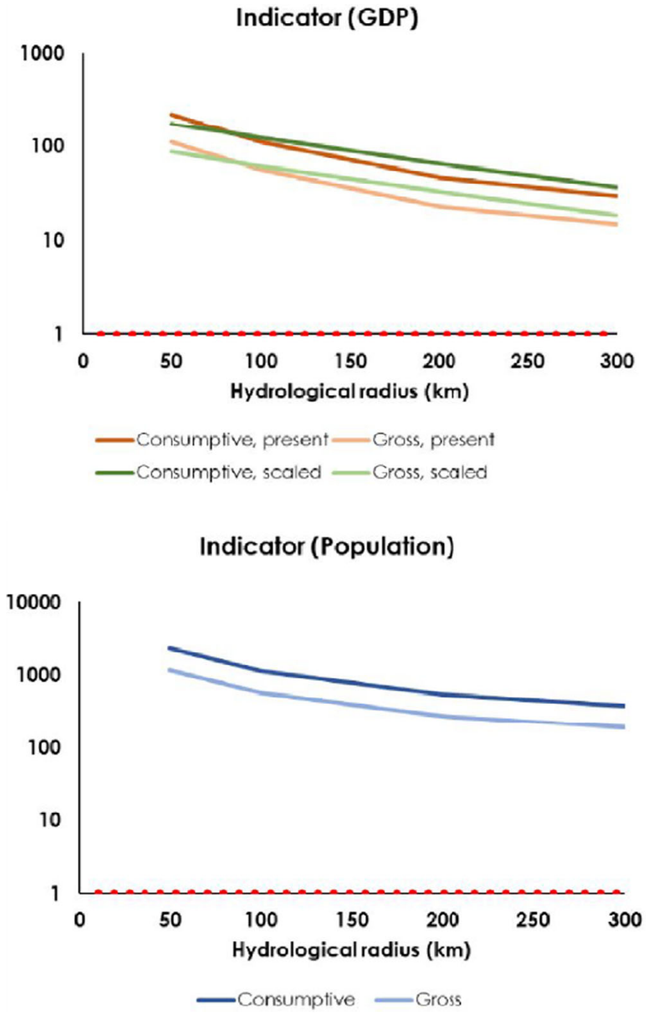

**FIGURE 6** Results for company B01 showing indicator >1 (unsustainable) for both gross withdrawals and consumptive use, across all scales and contexts [Colour figure can be viewed at wileyonlinelibrary.com]

corresponding efficiency of the catchment). However, in this case all values of the GDP-based indicator remain far above 1. This result implies that the facility does not represent sustainable economic use of water, now or in the future, and may be better suited to a different location that has more abundant resources relative to economic activity.

## 3.2 | Example of a sustainable facility

Company D01 used less than its SDPI allocation of water across all geographic scales of context using current GDP and population estimates (Figure 7). Within 50 km of this facility there are 7,824,783 people, this area produces a little over $446 billion of GDP per year. The facility consumes 3164 cubic meters of water per year and produces $22 million dollars of revenue per year. The GDP based sustainability index using Gross Withdrawals ranges from 0.09 at the 50 km context to 0.05 at the 300 km context. The GDP based index using Consumptive use ranges from 0.18 to 0.10 over the same range. The corresponding population based values range from 0.386 to 0.252 (Gross withdrawals) and 0.772 to 0.505 (Consumptive Use). These values suggest that this facility's use of water is very sustainable and that their water allocation based on their geographic context could be significantly larger than their current actual use.

It should be noted that all the contexts have BWS values that are much lower than those in the context of the aforementioned Company B01's facility. When GDP is scaled up (to bring BWS up to 0.4 in order to approximate a 'fully developed' catchment), the performance of the facility decreases relative to the surrounding catchment. Using $GDP_{region,scaled}$, the GDP-based indicator is higher, exceeding the threshold of 1 at the smallest radius (1.52 at 10 km) and almost exceeding 1 at the next scale (0.91 at 50 km). At larger radii, the $GDP_{region,scaled}$ result is similar to the results using current regional

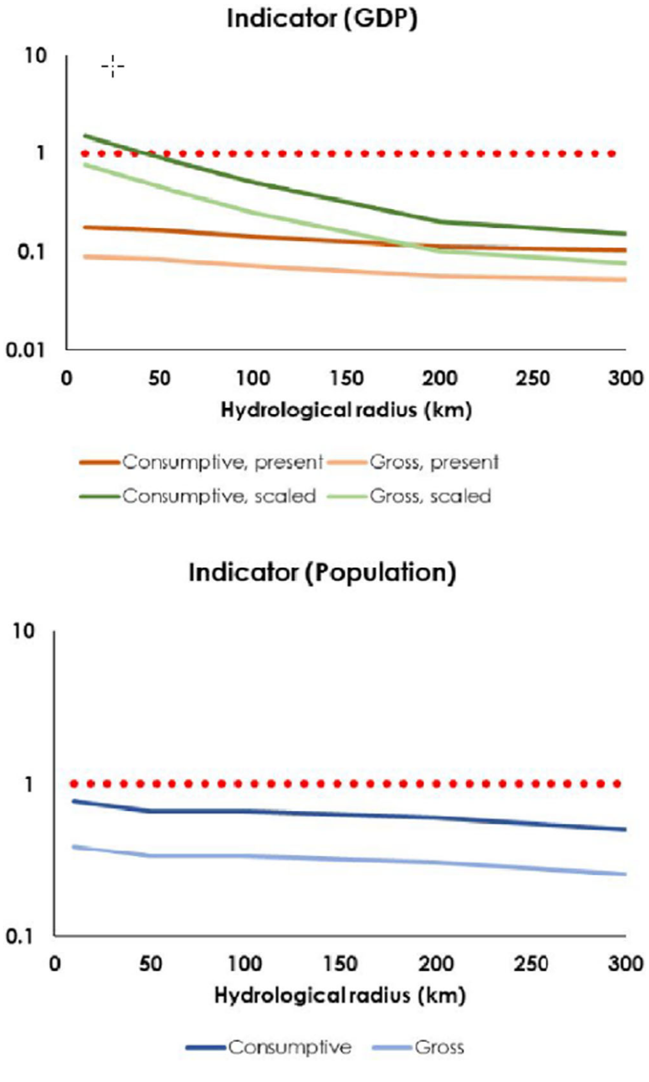

**FIGURE 7** Results for company D01, showing mostly sustainable water use but potentially unsustainable in the scenario of scaled-up regional gross domestic product [Colour figure can be viewed at wileyonlinelibrary.com]

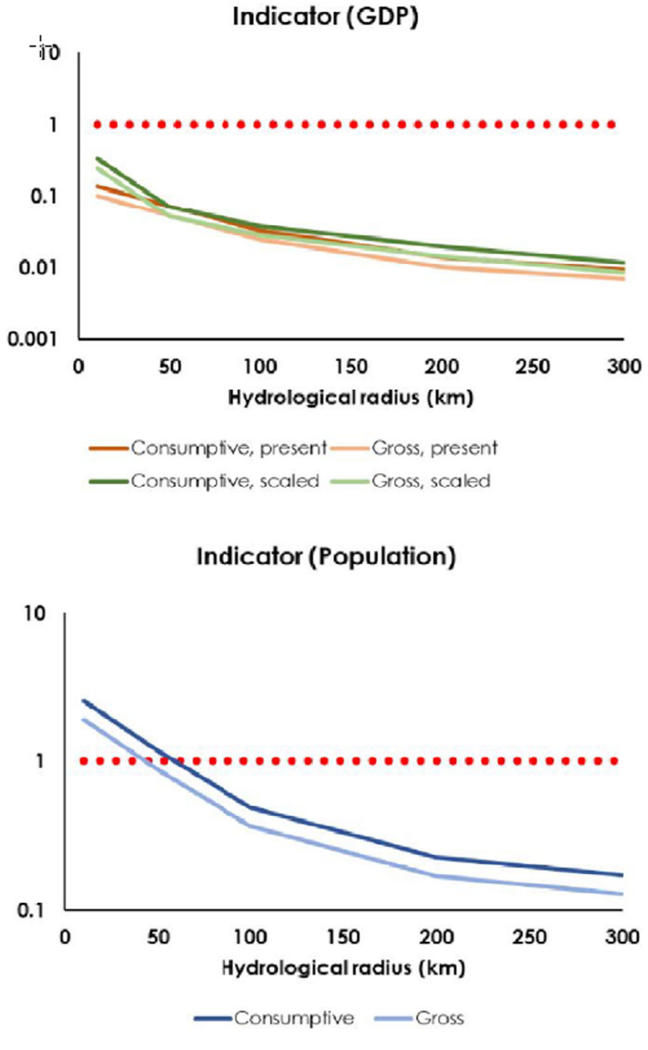

**FIGURE 8** Results for company C01, showing sustainable water use based on GDP but unsustainable water use based on population [Colour figure can be viewed at wileyonlinelibrary.com]

**TABLE 3** Interpretation of present versus scaled gross domestic product (GDP) indicator, and facility-level actions

| | | **Based on scaled regional GDP** | |
|---|---|---|---|
| | | **>1 (unsustainable)** | **<1 (sustainable)** |
| Based on present regional GDP | >1 (unsustainable) | Interpretation of result: Facility water use appears unsustainable both now and in the future.<br>Recommended action: Unless facility water use can be reduced at the same time as water stress is reduced across the catchment, the only real option is relocation to a more water-abundant catchment | Interpretation of result: Current facility water use appears unsustainable due to excessive economic activity, placing undue stress on the catchment, and would be potentially sustainable in a lower-GDP scenario<br>Recommended action: Facility should encourage collective action to reduce water use at catchment scale |
| | <1 (sustainable) | Interpretation of result: Current facility water use appears sustainable due to low level of development and water stress in the catchment, but in a fully developed catchment the allocation would reduce below current levels<br>Recommended action: If catchment is protected from future growth in water use, action may be limited. If catchment develops and becomes more water stressed, facility may need to reduce water use or relocate | Interpretation of result: Facility water use appears sustainable now and into the future, so long as the catchment is not over-developed to the point of placing excessive stress on water resources<br>Recommended action: Facility should maintain current levels of water use efficiency, and participate in catchment-level governance to ensure the continued sustainability of water resources |

GDP. These results are somewhat counterintuitive: a facility that appears to be using water sustainably within a catchment that is not currently experiencing undue water stress may be considered unsustainable (and therefore allocated less water) in the future. What this means is that the low values of the GDP-based indicator reflect a relatively low level of economic development in the catchment relative to the water that is potentially available for economic use.

The results provide spatial and temporal context for planning of this facility's sustainable water use, which needs to take into account both the hydrological conditions and the economic development (and resultant water use) context of the region. Importantly, the extent to which the facility's water use will be sustainable or not in the future depends on the scale of water procurement for this facility and its economic neighbors: if water is sourced and used across a large area (say, 100 km radius or more) then the facility's present high level of sustainability is likely to endure into the future, whereas if the facility sources water from a local area (say, less than 50 km) then its present water use may no longer be sustainable.

## 3.3 | Example of a facility showing mixed results

Company C01, showed mixed results from this analysis (Figure 8). For the most part the sustainability indices were less than one; however, for the smaller geographic contexts using the population-based metric the indices exceeded one at the 10 km scale (1.89 GW, and 2.54 Consumptive) and for consumptive use at the 50 km scale (1.17). All other values were less than one and tended to decrease with larger geographic contexts. Within 50 km of this facility there are 23,431,538 people, this area produces a little over $643 billion of GDP per year. The facility consumes 395 cubic meters of water per year and produces $5.6 million dollars of revenue per year. The GDP based sustainability of this index using Gross Withdrawals ranges from 0.10 at the 50 km context to 0.01 at the 300 km context. The GDP based index using Consumptive use ranges from 0.14 to 0.01 over the same range. The corresponding population-based values range from 1.899 to 0.128 (Gross withdrawals) and 2.546 to 0.172 (Consumptive Use). These values suggest that this facility's use of water is mostly sustainable and that their water allocation based on their geographic context would be significantly larger than their current actual use for most geographic contexts.

As all of the contexts have BWS values that are close to the threshold value of 0.4, there is little change in the indicator based on present versus future (scaled) GDP.

## 3.4 | Summary of results for facilities with incomplete data

The other 23 facilities often provided enough data to perform water allocation and sustainability index calculations for either the GDP-based indicator OR the Population-based indicators. Of the calculable GDP-based indices we derived the following: three ‘Sustainable’, one ‘Not sustainable’, and two ‘mixed’. Of the calculable Population-based indices we derived the following: one ‘Sustainable’, nine ‘Not sustainable’, and three ‘mixed’.

## 4 | DISCUSSION AND CONCLUSION

Our sample size is too small and non-random to make conclusions as to what the nature of the distributions of sustainability indices will be for facilities in general or specific categories of facilities. We are nonetheless pleased that the indicator we have presented produces values that are on both sides of the 'sustainable or not sustainable' question. We contend that this SDPI context-based water metric and related sustainability index is sufficiently simple in concept, and relatively easy to calculate, using globally available EO Data and numbers reported by the facility.

In the cases discussed here–and elsewhere, too, where similar context-based water metrics with economic and population-based allocations have been used (McElroy & Van Engelen, 2012)—it is almost always the case that allocations and performance scores will be most favorable when viewed through the economic allocation lens. The argument in support of this disparity tends to be that the economic allocation method offers a better solution for making fair, just and proportionate allocations of water resources, since the per capita or population-based alternative fails to recognize the full value-added contributions of commercial enterprises to society. Indeed, proponents of the economic allocation method would say that if what society wants is the ability to outsource the production of food and other goods and services to specialized producers, then it should be prepared in turn to provide them, disproportionately, with the resources they need to function accordingly. At the same time, however, we can also say that the allocations of resources to such enterprises should never be any less than what its workers might be entitled to receive on a per capita basis, hence the additional relevance of the per capita allocation method. In effect, employees bring their per capita entitlements to resources into the workplace with them every day. Thus, whereas we can say that the economic method might specify an upper limit of allocable water to a facility, the per capita method specifies a lower limit.

The SDPI metric allows rapid categorization of facility water use across a variety of sustainability thresholds. In practice, a 'traffic light' system may be adopted, in which all green lights would imply a facility with water use that is deemed sustainable with respect to: both gross withdrawals and consumptive use, both GDP and population, all relevant context radii, and in both present and future GDP contexts. Such a facility could categorically claim that their water use is 'sustainable' in their regional context. Mixed results could be cautiously interpreted depending on the threshold(s) at which the result changes. In addition, we note that results can appear counterintuitive when comparing the indicator based on present GDP against the result for scaled GDP. Recommendations for interpretation of differing results are summarized in Table 3.

In this way, the information drawn from the context-based water matric can help companies to establish their sustainable water use strategy considering the location of facilities, contribution to GDP, and the size of population. Further, by providing information on a substantial number of companies in various geographic contexts, the metric can help governments establish spatial planning taking into consideration the water use of existing and proposed facilities, which contribute to meeting future water needs in a sustainable manner.

## ACKNOWLEDGMENTS

The authors would like to thank Marguerite Mendell, Peter Utting, Samuel Bruelisauer, and Sonja Novkovic for their valuable participation in the discussion on context-based water indicator methodology and r3.0, in particular Bill Baue and Ralph Thurm for collecting the information on water data of the companies and social and solidarity economy organizations and enterprises. This paper is based on research conducted for the United Nations Research Institute for Social Development project "Sustainable Development Performance Indicator", funded by the Center for Social Value Enhancement Studies (CSES).

## CONFLICT OF INTEREST

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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## SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

**How to cite this article:** Wang, X., Hopeward, J., Yi, I., McElroy, M. W., & Sutton, P. C. (2022). Supporting the Sustainable Development Goals: A context sensitive indicator for sustainable use of water at the facility level. *Sustainable Development*, 1–16. https://doi.org/10.1002/sd.2310

## APPENDIX A

### Determining Geographic Context of a Facility

We used a range of circular regions centered on the facility location as our 'geographic context'. The rationale for using a circular 'context' polygon for each facility is as follows. 'Watershed determinations' based on elevation derived geographic watersheds will unavoidably be wrong in most cases while they will also vary dramatically in areal extent. Circular boundaries will have errors also but are more defensible as a proxy of context and easier to explain to the operators of the facility.

The basic premise of the SDPI water indicator is that for a 'facility' that produces a given amount of economic activity (indicated in terms of GDP contribution of facility), there is a fair allocation of water derived from a geographic context (areal extent i.e. polygon) that provides water for economic activity and produces GDP. Defining a geographical context of a facility from which we extract the information on GDP, population, precipitation, and evapotranspiration needs to take into consideration several issues. We explored applying the HydroSHEDS database (https://www.hydrosheds.org/) to a variety of approaches for defining hydrographic context. Some issues are discussed below.

### Issue #1: *Transboundary Water Issues* (National borders cutting through watersheds)

In theory, the most comprehensive geographical context can be the highest level of hydro shed, which may include several national boundaries. Transboundary basins account for roughly 60 percent of global freshwater resources. Of 192 countries, 153 share 310 rivers and lakes, and 592 aquifers. These water resources are estimated to serve over 40 percent of the global population. Transboundary water cooperation and management is critical to governance and management of water resources for sustainable and equitable development. This can be problematic for defining a 'context' polygon. Existing distribution of economic activity within a trans-boundary context can inadvertently privilege the country with the higher level of economic development with the result being that the majority of the transboundary Water allocated for economic activity goes to that country.

### Issue #2: Interbasin Transfers

Inter-basin transfer or trans-basin diversion are terms used to describe human-made conveyance schemes which move water from one river basin where it is available, to another basin where water is less available or could be utilized better for human development. The purpose of such designed schemes can be to alleviate water shortages in the receiving basin, to generate electricity, or both. For instance, 55% of the city of

Adelaide's water comes from outside any ‘basin’ we would identify with a Hydro Shed database that was smaller than the entire continent. Seventy percent of the water used by the city of Los Angeles comes from outside of basins that HydroSHEDS would identify for Los Angeles without taking almost all of North America into account (In reality LA uses water from basins that go all the way to Colorado). Inter-basin transfers are problematic for defining this ‘context’ polygon.

### Issue #3: The ‘goldilocks’ area

The geographical context defined with too large of watersheds cannot provide accurate information of available water to different areas. For example, if we used national boundaries instead of smaller watershed based ‘contexts’ the nation of Australia would have very wet northern areas counted as part of the available water for very dry (semi-arid) southern contexts. There is no practical way for water to move from Darwin to Adelaide. Clearly specifying a polygon that is too large defeats the purpose of having a ‘context sensitive’ metric. However, we can also be too small such as when we use HydroSHEDS basins for certain cities that utilize inter-basin transfers such as Adelaide, Los Angeles, and Denver. Inter-basin transfers are so significant as to make cascaded hydroshed definition of ‘contexts’ unrealistic. Also, in the case of small island nations HydroSHEDS will include water from off-island: for example, what HydroSHED would be appropriate for the city-nation-state of Singapore?

The following case studies show the results of several urban cases familiar to the authors to understand the potentially large differences in catchments intercepted via an automated GIS algorithm, based on a circle encompassing a given population (see Table above). In some cases (e.g. Santa Barbara, California), the circle intersects a collection of catchments that correlate reasonably well to the actual water resources utilized by the population, and the resultant polygon is plausible. In other cases (e.g. Burlington, Vermont) the polygon is vastly oversized.

### Case Study #1: Santa Barbara, California

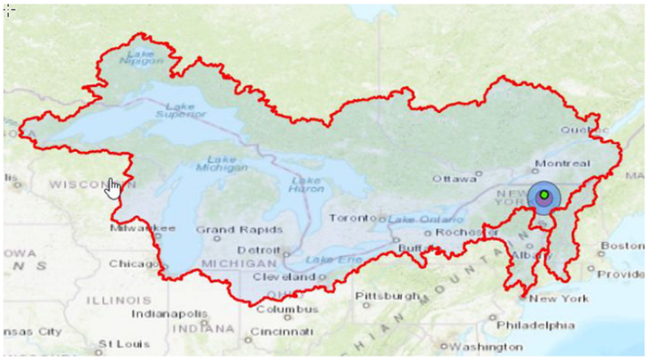
Population in Pink Circle (50 km radius, pop: 234,974) Watershed Buffer Radius 100 km.This is fairly close to the actual watersheds that Santa Barbara draws its water from. The Bakersfield, Santa Clarita, Channel Islands, and Carrizo Plain are outside of the ‘true’ area but the rest are a reasonable characterization of the regions that Santa Barbara draws its water from.

**TABLE A1** Water procurement radii derived from population within 10 km of facility

| Population within 10 km of facility | Water procurement radius |
|---|---|
| Low (<30,000) | 20 km transport + 50 km catchment = 70 km radius |
| Middle (30,000–300,000) | 50 km transport + 100 km catchment = 150 km radius |
| High (>300,000) | 100 km transport + 200 km catchment = 300 km radius |

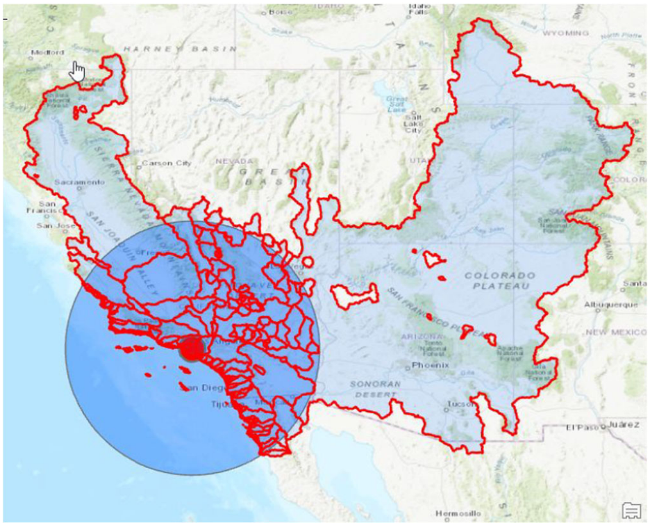
### Case Study #2: Burlington, Vermont

Population in Pink Circle (50 km radius, pop: 202,417) Watershed Buffer Radius 100 km.Clearly, applying the same ‘rules’ that worked reasonably well for Santa Barbara, CA do not work very well for comparably populated Burlington, VT.



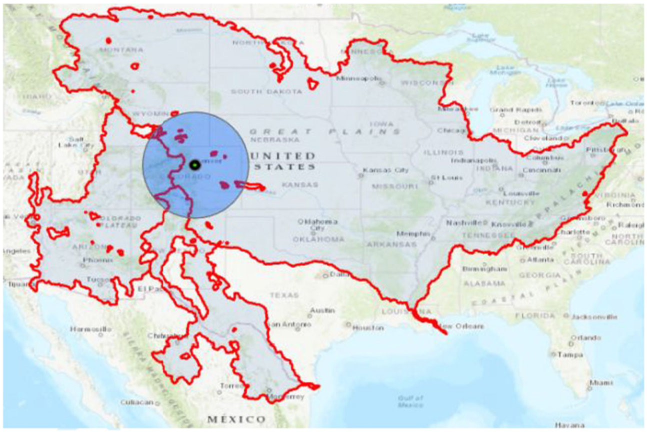
### Case Study #3: Los Angeles, California

Population in Pink Circle (50 km radius, pop: 9,233,507) Watershed Buffer Radius 500 km.This is a fairly good representation of the ‘reach’ that Los Angeles has with respect to securing water. This reaches all the way to the western slope of the Rocky Mountains and the California Aqueduct delivers water from the Central Valley. However it does not capture the watershed of the Eastern Sierra which Los Angeles also draws from (See the classic movie: Chinatown).



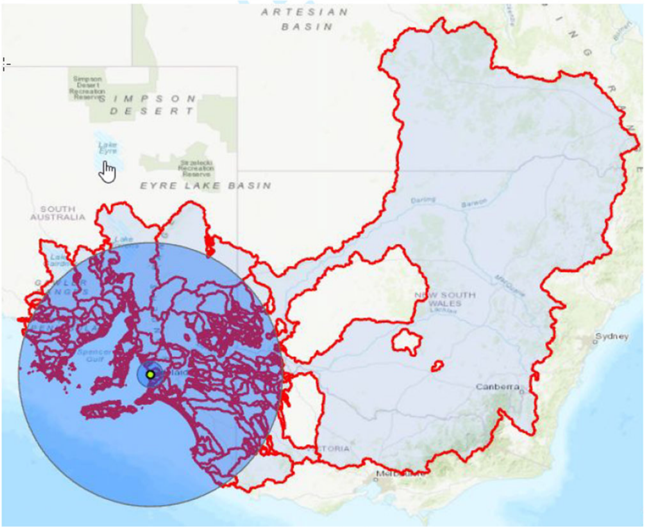
**Case Study #4: Denver, Colorado**

Population in Pink Circle (50 km radius, pop: 2,618,392) Watershed Buffer Radius 500 km.Denver is at a relatively high elevation in the Mississippi watershed. It does not use much water from that large watershed (some on the eastern slope of the Rockies but not much else). It does use water from the western slope of the Rockies via inter-basin transfers effected through long tunnels under the mountains. The Rio Grand watershed does not make much sense though.



**Case Study #5: Adelaide, Australia**

Population in Pink Circle (50 km radius, pop: 1,215,477) Watershed Buffer Radius 500 km.Adelaide does not pull much water from the Eyre, and York Peninsulas to the west; however, they do draw water from the Murray river via inter-basin transfers that does include the huge Murray-Darling watershed polygon to the east. This is a reasonable but not accurate representation of the water reach of Adelaide.



There is no automated mapping procedure that will allow water to be accurately allocated to a point of use (i.e. a facility) from the physical resource (i.e. the watershed, or watersheds) from which it receives its water. Indeed, such allocation of resources is a non-trivial manual task considering the hydrological, economic/demographic, infrastructure and land use conditions specific to a given catchment, and this is the role of dedicated water resource managers operating at the local to regional scale.

However, it is possible to derive an indicator variable that is sensitive to local hydrological and economic context, and which can be mapped using an automated procedure. Whilst it is not possible for this indicator to connect a given facility's water consumption with the precise physical resource(s) from which it draws its water, it can still serve as a proxy measure of the sustainability of the facility's water allocation within the local context.

Our suggested procedure of identifying “water procurement radius” is as follows. Based on the work of McDonald et al. (2014), there is a relationship between urban economic activity and the distance over which a city's water is transported. We adopt a hypothetical ‘water procurement radius’, which for simplicity is taken as a circular zone centered at the facility's location and extending to a radius that varies according to the local economic context. Population within 10 km of the facility is used as a proxy for local economic activity.

The radius is the sum of two distances: the first is an approximate water transport distance, derived from values presented by McDonald et al. (2014), while the second accounts for the additional distance that water may be expected to flow through natural catchments prior to being collected and transported via reticulated network to the facility.

In this way, facilities located in close proximity to large population centers are assumed to be able to access water that comes from a larger zone (consider a large city with reticulated water from multiple catchments and inter-basin transfers), while facilities in low populations are assumed to access water from a more local setting.

Again, it is recognized that the circular zone will not correspond to the precise physical area from which a facility's water is actually taken. However, it does represent a replicable method for determining a local zone from which water could plausibly be obtained, subject to the availability of surplus water for economic use.

## APPENDIX B

**TABLE B1** : Data sources for hydrological assessment

| Data | Source | Extent | Link | Comment |
|---|---|---|---|---|
| GDP | NASA/NOAA | Global | https://eogdata.mines.edu/products/vnl/ | GDP data developed based on annual NTL data |
| Precipitation | NASA/NOAA | Global | https://ldas.gsfc.nasa.gov/fldas | Monthly data |
| Evapotranspiration | NASA/NOAA | Global | https://ldas.gsfc.nasa.gov/fldas | Monthly data |
| Population | GHSL | Global | https://ghsl.jrc.ec.europa.eu/ | |
| Watershed Boundaries | HydroSHEDS | Global | https://www.hydrosheds.org/downloads | Current Version: 3.6 |
| Non-Consumptive Water withdrawals | PCRglobalWB | Global | https://gmd.copernicus.org/articles/11/2429/2018/ | Current Version: 2.0 |