Article title: Assessing SDG indicator 6.4.2 “level of water stress” at major basins level
Authors: Riccardo Biancalani[1], MIchela Marinelli[2]
Affiliations: FAO, viale delle Terme di Caracalla, 00153, Rome[1]
Orcid ids: 0000-0002-5221-5260[1]
Contact e-mail: riccardo.biancalani@fao.org

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Cover Letter

We here submit a manuscript entitled “Assessing SDG indicator 6.4.2 “level of water stress” at major basins level”. The article should be considered a technical study based on existing global data and methodologies.

This work describes the computation of the global indicator on water stress by major river basin and demonstrates the limits of aggregating the indicator at national level only. The analysis is based on the metadata of the indicator as published by the Inter-Agency and Expert Group of the Sustainable Development Goals, integrated with the use of Earth Observation data. The method applied consists in disaggregating the indicator’s parameters to pixel level and re-aggregating them according to the basin boundaries, providing a different and more hydrologically sound view on the dynamics of water resources and their use. The work stems from the indications of the United Nations Statistical Commission on the disaggregation of the SDG indicators, and follows other work such as Fehri et al., 2019.

The results of this work are quite relevant for UN Member States and international agencies, as they allow the identification of hotspots where actions can be prioritized and reveal that the area affected by a high or critical water stress spans across all continents with the only exception of Oceania. The method followed offers also the possibility of an analysis of freshwater withdrawals by sector, which may become crucial for the definition of water management policies in the context of the economic development of a country.

Introduction

An increasing competition for natural resources, due to climate change, urbanization, dietary changes, and industrial development, is compromising ecological integrity and agricultural productivity. Agricultural ecosystems cover nearly 40% of the terrestrial surface of the Earth (Ramankutty et al., 2008), and few options remain globally to expand agricultural area without significant environmental, social, and economic costs (FAO, 2017). Water scarcity, defined as an "imbalance of supply and demand" (FAO, 2012), is a global problem which can affect water security even in countries with ample water resources (Ahopelto et al., 2019). Already 40% of the world's rural population live in river basins that are classified as water scarce (FAO, 2017).

Water stress has an impact on countries of every continent and hinders the sustainability of natural resources, as well as economic and social development. By 2050, nearly 4 billion people could be subject to severe water stress (Sadoff et al., 2015). Levels of water withdrawal per capita vary significantly across the world because they depend on different factors such as latitude, climate, and the importance of a country's agricultural or industrial sector. In some countries water withdrawn for irrigation only exceeds the total amount of renewable freshwater resources (Scheierling and Treguer, 2016; WWAP, 2016; FAO, 2017).

The Sustainable Development Goals (SDGs) aim to address these issues, and SDG 6 in particular aims to ensure the availability and sustainable management of water and sanitation for all sectors, including agriculture and the environment (United Nations, 2015). Target 6.4 seeks to ensure sustainable withdrawals and supply of freshwater to address water scarcity. Two indicators have been selected for monitoring the target: indicator 6.4.1 monitors the change in water-use efficiency, tracking the relation between the economic growth and the use of water resources, while indicator 6.4.2 on the level of water stress tracks how much freshwater is being withdrawn by all economic activities, compared to the total renewable freshwater resources available, after having taken into account environmental flows requirements. The two indicators offer a complementary view on a country's path to achieving target 6.4.

In order to support the policy making process towards achieving the SDGs, the monitoring system has to be capable to provide detailed and accurate information to each level of decision makers, particularly at country and sub-country level. Methods to disaggregate the indicator at higher spatial and temporal resolutions have been already tested (Fehri et al., 2019).

In fact, while country level reports are useful for a global overview of the indicator, the Statistical Commission of the United Nations (UNSC) has stated that *"…improving data disaggregation is fundamental for the full implementation of the indicator framework and to fully reflect the principles of the 2030 Sustainable Development Agenda to ensure that no one is left behind, and stressed that efforts should be made to strengthen national capacities in that area and to develop the necessary statistical standards and tools…*"[i]. Following this statement, the Inter-Agency and Expert Group of the SDG (IAEG-SDG) established a Working Group on data disaggregation, which concludes to strongly encourage both countries and custodian agencies to disaggregate the indicators following various criteria. In particular, the Working Group identified both the hydrological unit and the economic sector as the two main criteria for the disaggregation of the indicator 6.4.2 on water stress.

Disaggregating the indicator 6.4.2 will bring its expression nearer to users and stakeholders, either physically or socially and economically. That will contribute to increase the sense of participation and ownership that is needed for the ultimate achievement of the SDGs, and for ensuring that no one is left behind (IISD, 2017).

The aim of this paper is to present and discuss the methodology followed for the disaggregation of the indicator 6.4.2 by major river basins.

1. Materials and method

1.1 The Indicator 6.4.2

The development of the methodology for this indicator evolved from the existing Millennium Development Goals (MDG) indicator 7.5: proportion of total water resources used. The MDG indicator was defined as "the total volume of groundwater and surface water withdrawn from their sources for human use (in the agricultural, domestic/municipal and industrial sectors), expressed as a percentage of the total actual renewable water resources" (UNSD, 2000).

In the preparation of the set of SDG indicators, such methodology was amended with the inclusion of the environmental flows (EF) to better reflect the condition of sustainability which characterizes the SDG framework. This paper refers to the methodology for the calculation of the indicator 6.4.2 described in the metadata (UNSTATS, 2020) approved at the third meeting of the IAEG-SDGs at tier 1, meaning that "(the) indicator is conceptually clear, has an internationally established methodology and standards are available…" (IAEG-SDGs, 2016).

The indicator 6.4.2 is calculated as the ratio between (a) the amount of total freshwater resources withdrawn and (b) the total renewable freshwater resources after detracting the amount of water needed to support existing environmental services (UNSTATS, 2020), also indicated as environmental flows. It is important noting that the total freshwater withdrawals are "gross", as suggested in previous studies (Smakhtin et al., 2004). In other words, the indicator is calculated considering the total water abstraction and it is not considering the return flow which is calculated as the difference between the gross water abstracted and the consumptive water use (SEEA Central Framework Glossary, 2012).

The water stress in percentage can be calculated by Equation 1:

$$Water\ Stress\ (\%) = \frac{\text{Total freshwater withdrawn}}{\text{Total renewable freshwater resources} - \text{EF}} * 100 \qquad \boxed{\text{Eq. 1}}$$

The purpose of this indicator is to show the degree to which water resources are being exploited to meet a country's water demand. It measures the country's pressure on its water resources and therefore the challenge on the sustainability of its water use. *Low water stress* indicates minimal potential impact on resource sustainability and on potential competition among users. *High water stress*, on the contrary, indicates substantial use of water resources, with greater impacts on resource sustainability and the potential for conflict among users.

The Food and Agriculture Organization of the United Nations (FAO), as custodian agency of the indicator 6.4.2, collects annual data on water stress at country level and reports them to the Statistical Division of the United Nations (UNSD). The data collection modality is based on the use of specific questionnaires that are sent to each country every year.

The questionnaires are then elaborated, including quality control, and the resulting statistics of indicator 6.4.2 are reported in AQUASTAT (FAO, 2021), the FAO's global information system on water and agriculture publicly available online. Figure 1 shows the map of the indicator at country level based on the data available for year 2018. According to the indicator's metadata (UNSTATS, 2020), water stressed conditions occur when withdrawals exceed 25 per cent of renewable freshwater resources. 34 countries are experiencing water stress between 25 and 75 per cent, while 25 countries are above 75 per cent and are considered to be seriously stressed.

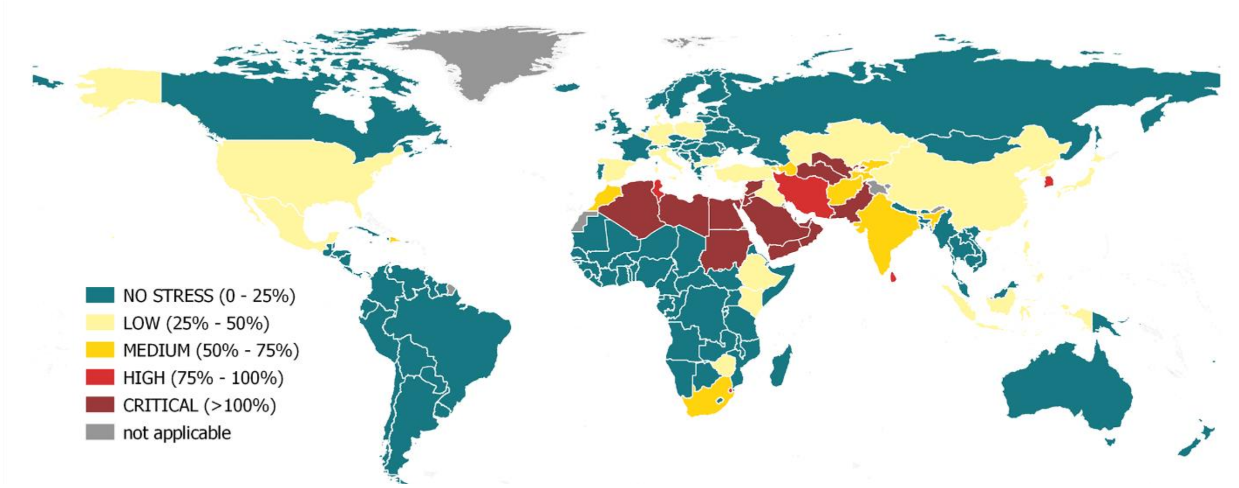

Figure 1: SDG 6.4.2 Level of water stress (in percentage) at country level, based on the official statistical data available in AQUASTAT (reference year 2018). Geographic projection.

As said, the SDG reporting process is based on country data collected by the custodian agency. However, in the case of indicator 6.4.2 the computation by country implies the aggregation of the water resources parameters at country level with no consideration of the actual hydrography. In fact each country may account its water resources irrespectively of how they are shared with its neighbors. This entails the possibility of a double counting of the same water resources when they flow from one country to another. Disaggregating the indicator, and recalculating it at basin level eliminates this situation, providing a different and more hydrologically sound view on the dynamics of water resources and their use.

1.2 Disaggregation criteria

Sustainable management of the water resources cannot disregard the economic needs and choices linked to their use and the environmental and demographic conditions of each area. In fact, the indicator can be calculated as the sum of the withdrawals by different economic sectors divided by the total renewable freshwater resources (TRWR), while considering the EF. This subdivision of the indicator's equation has been implemented in order to be able to spatially distribute the aggregated data of the three parameters of Equation 1.

The economic sectors used for such purpose are those identified in the metadata of the indicator SDG 6.4.1 “change in water use efficiency over time” (UNSTATS, 2019), in order to keep consistency among the two indicators. They are defined following the categories of the International Standard Industrial Classification of All Economic Activities (ISIC), Revision 4, as follows:

- Sector Agriculture: ISIC Section A
- Sector Industry: ISIC Sections B, C, D and F[ii]
- Sector Services: ISIC Section E and Section G to T

The disaggregated formula becomes:

$$Water\ Stress\ (\%) = \frac{V_A + V_S + V_M}{TRWR - EF} * 100 \qquad \boxed{\text{Eq. 2}}$$

with V_A the volume of freshwater withdrawal by the agricultural sector, including: irrigation (including nurseries), livestock (watering and cleaning) and freshwater aquaculture; V_S the Volume of freshwater withdrawal by the service sector; V_M the volume of freshwater withdrawal by the industrial sector; TRWR the total renewable freshwater resources; EF the environmental flows. All the variables are expressed as volumes in million m^3.

The data on water withdrawals in the three sectors are taken from AQUASTAT. The river basins used for this study are the 230 major river basins of the FAO World map of the major hydrological basins. This dataset was obtained by delineating drainage basin boundaries from hydrologically corrected elevation data: HydroSHEDS and Hydro1K (FAO, 2011a). The data on Environmental Flows are from the Global Environmental Flows Information System (GEFIS) database of the International Water Management Institute (IWMI).

1.3 Data and Methodology

The spatial disaggregation by major river basin of indicator 6.4.2 was implemented for the three main economic sectors. Withdrawal data available in AQUASTAT for year 2018 have been spatialized using proxies or related variables as explained in the following sections.

1.3.1 Total renewable freshwater resources

TRWR refer to the freshwater available for use in a territory and include surface waters (lakes, rivers and streams) and groundwater. In this paper the TRWR at basin level have been estimated through GlobWat (Hoogeveen et al., 2015), a global water balance model used by FAO to assess water use in irrigated agriculture. GlobWat can be downloaded online and it is based on spatially distributed high-resolution datasets that are consistent at global level and calibrated against long term averages for internal renewable water resources, as published in AQUASTAT.

GlobWat calculates the water balance in two steps: 1) a "vertical" water balance is calculated per pixel, it includes evaporation from in situ rainfall ("green" water) and incremental evaporation from irrigated crops; 2) a "horizontal" water balance is calculated by basin to determine discharges from river (sub-)basins, taking into account incremental evaporation from irrigation, open water and wetlands ("blue" water). The results of the water balance calculations consist of monthly values by grid cell for generated precipitation, actual evaporation, incremental evaporation due to irrigated agriculture, surface runoff[iii], groundwater recharge and water stored as soil moisture.

To assess the TRWR of each major river basin annually, we have considered the sum of the annual drainage and of the annual groundwater recharge estimated by the model by basin.

$$TRWR = P - ET_{act} = Drainage + GW \qquad \boxed{\text{Eq. 3}}$$

with P the Precipitation, ET_{act} the actual evapotranspiration (water consumption), Drainage the surface runoff (million m^3), and GW the groundwater recharge (million m^3).

1.3.2 Environmental flows

In the computation of indicator 6.4.2, Environmental flows are "…*the quantity and timing of freshwater flows and levels necessary to sustain aquatic ecosystems which, in turn, support human cultures, economies, sustainable livelihoods, and wellbeing*" (Dickens et al., 2019). Water quality and the resulting ecosystem services are excluded from this formulation, which is confined to water volumes. This does not imply that quality and the support to societies, which are dependent on environmental flows, are not important and should not be taken care of. They are indeed taken into account by other targets and indicators of the SDG system, such as 6.3.1 (Proportion of domestic and industrial wastewater flow safely treated), 6.3.2 (Proportion of bodies of water with good ambient water quality), 6.5.1 (Degree of integrated water resources management implementation (0-100)) and 6.6.1 (Change in the extent of water-related ecosystems over time).

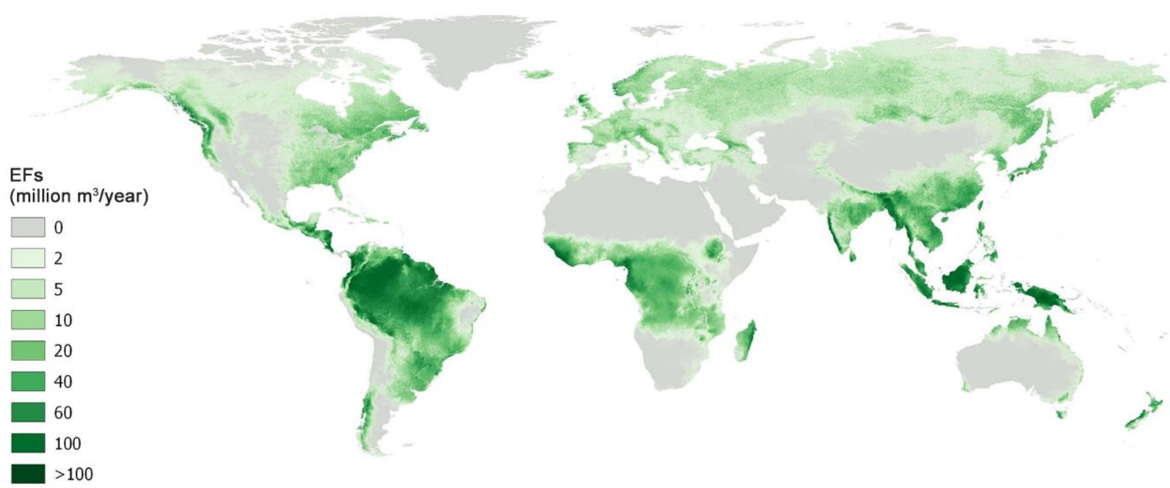

Figure 2: Environmental Flows (EF) based on the values calculated in GEFIS (http://gef.iwmi.org/) and adjusted to the Total Renewable Water Resources estimated with GlobWat. Geographic projection. Resolution 5 arc-minutes (approximately 10 km at the equator).

In this work, EF were assessed using the data published online by the IWMI in the GEFIS. In particular, GEFIS provides the value of EF as percentage of the total actual flow. Such percentage value has been then applied to the amount of TRWR as estimated by GlobWat, in order to have a volume of EF which is consistent with the estimation of water resources available in AQUASTAT. The map of the EF volumes is shown in Figure 2.

1.3.3 Total Freshwater Withdrawal

Total Freshwater Withdrawal (TFWW) is defined as the sum of the relevant withdrawals in the three main economic sectors of agriculture, industry and services.

TFWW includes freshwater and fossil groundwater. It does not include direct use of non-conventional water, i.e. direct use of treated wastewater, direct use of agricultural drainage water and desalinated water. In AQUASTAT total water withdrawals by sector include the non-conventional water sources. For this reason, to be consistent with the equation of the indicator 6.4.2, TFWW was calculated as expressed in Equation 4:

$$TFWW = \Sigma ww_{e} - \Sigma du_{n} \qquad \boxed{\text{Eq. 4}}$$

with TFWW the total freshwater withdrawal (million m^3); ww_e the water withdrawal (million m^3) for the economic sector "e"(agriculture; industry; services); du_n the direct water use (million m^3) from non-conventional source "n" (direct use of wastewater; direct use of agricultural drainage water; use of desalinated water).

Data on the amount of non-conventional water resources are very rare and scattered in AQUASTAT. However, when available, for this paper it was assumed that the drainage water and treated wastewater are mainly used for irrigation and that the desalinated water is mostly used for domestic purposes[iv].

In 2018, at global level, the withdrawal ratios are 72% agriculture, 12% services[v]and 16% industry (FAO, 2021). While agriculture still has a major share of water withdrawals, in the last decades the increase of water withdrawal in the other two sectors has been proportionally much faster (Figure 3).

Of the three main factors driving the increase of water withdrawals (population growth, economic development and change in consumption patterns), population seems to be particularly relevant, as domestic demand will rise by more than threefold in all African and Asian sub regions, and it will more than double in Central and South America.(Burek et al., 2016). By combining the global water withdrawal with the world population it is possible to notice that world population increased almost 4 times over the last century while water withdrawal increased 6 times over the same period.

The following sections will describe the approaches used to geo-spatialize the freshwater withdrawal in each sector.

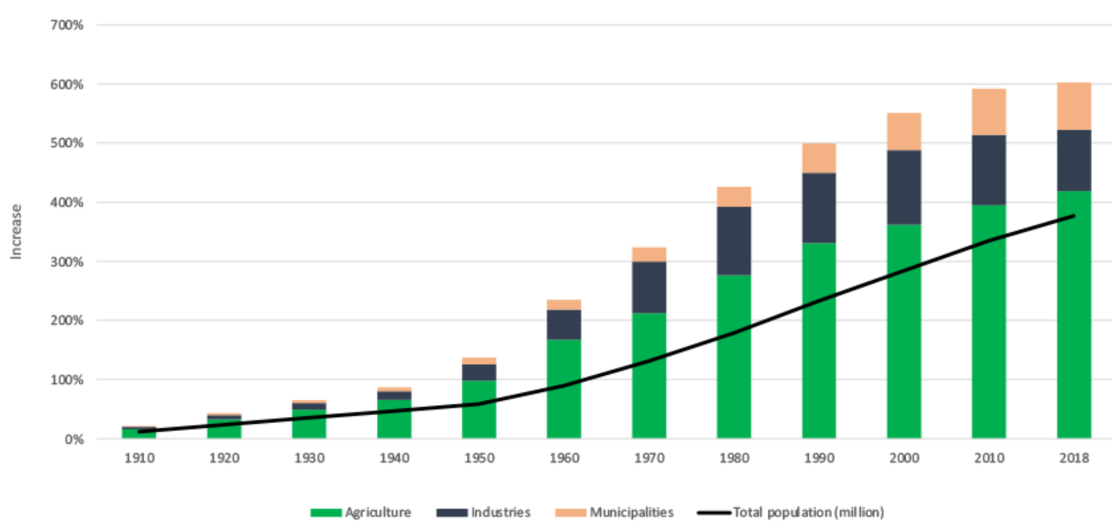

Figure 3: Percentage increase (respect to year 1900) of total population and water withdrawal (km^3 by sector) in the last century. Global water withdrawal and World Population from 1900 to 2018. Source: Shiklomanov 2000 for water withdrawal 1990-2000; AQUASTAT for 2010 and 2018. Population data from FAOSTAT.

1.3.3.1 Agriculture

The Agriculture freshwater withdrawal (V_A) is the volume of water withdrawn for the agricultural sector, including: irrigation (including nurseries), livestock (watering and cleaning) and freshwater aquaculture.

Unfortunately, data disaggregated for irrigation, livestock and aquaculture are available only for a few countries. When available however, irrigation water withdrawal ranges between 70% and 90% of the overall agriculture water withdrawal (FAO, 2021). Therefore, irrigation water withdrawal has been taken as a proxy to estimate V_A.

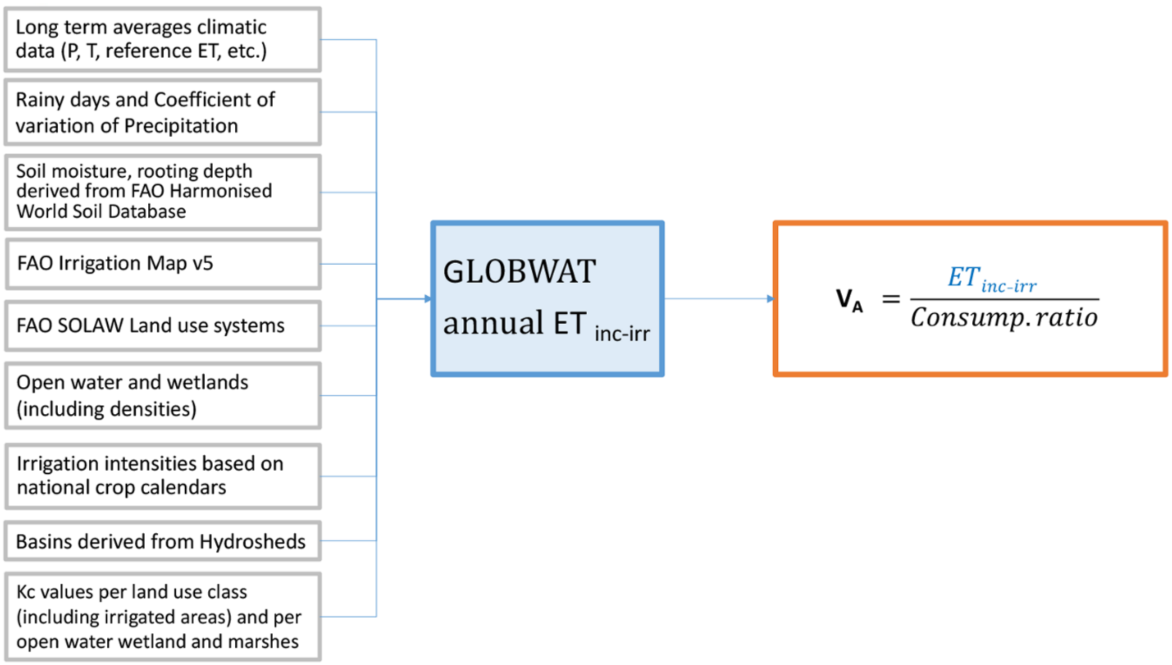

Figure 4: Approach used to spatialize the agriculture freshwater withdrawal (V_A).

To assess the volume of water withdrawn for agriculture, we used GlobWat to assess the annual incremental evapotranspiration due to irrigation ($ET_{inc\text{-}irr}$). This is an estimation of the irrigation *water consumed* in irrigated areas, that is, the share of the water withdrawn actually used by the crop or evaporated from the ground. From $ET_{inc\text{-}irr}$, the spatialization was derived through the consumptive ratio, defined as the ratio between 1) $ET_{inc\text{-}irr}$ estimated with GlobWat and 2) V_A for year 2018 available in AQUASTAT (Figure 4). Figure 5 shows the global map of V_A for year 2018.

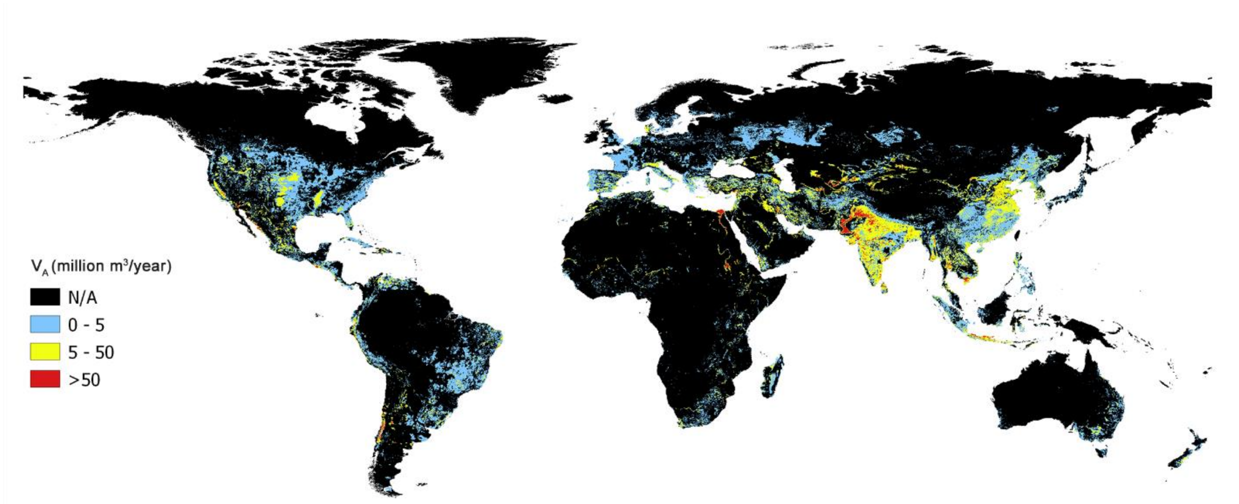

Figure 5: Agriculture freshwater withdrawal for year 2018 ($V_{A\ 2018}$) in million m^3. Geographic projection. Resolution 5 arc-minutes (approximately 10 km at the equator).

1.3.3.2 Services

The Services freshwater withdrawal (V_S) is the volume of water withdrawn for the service sector. In AQUASTAT the sectors included in "services" are referred to as "municipal". It is usually computed as the total freshwater withdrawn by the public distribution networks.

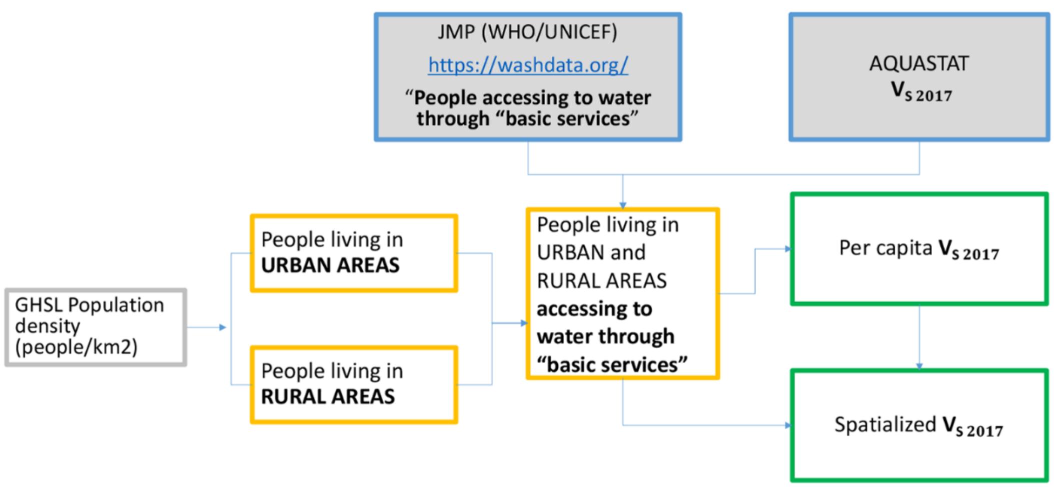

Figure 6: Approach used to spatialize the service freshwater withdrawal (V_S).

The volume of water withdrawn by the Service or municipal sector largely depends on the number of people living in a certain area. Therefore, for this sector we started from the analysis of the population density (Florczyk et al., 2019) and then we considered the access to water through "basic services" both in rural and urban areas. This category includes all the people who can access water through an infrastructure or through a walking distance less than 30 minutes (Figure 6). Then, using the data available in AQUASTAT, the service water withdrawal per capita was calculated for each country and finally the spatialized global map of the service water withdrawal ($V_{S\ 2018}$) was drawn (Figure A1). The dataset used for the population is the Global Human Settlement Layer for the year 2015 (GHSL-2015), which provides also a useful classification of the populated places in rural and urban areas, according to predefined density thresholds. The GHSL-2015 has been adjusted to the year 2018 by multiplying it by the ratio between the national population of each country in the years 2018 and 2015. To determine the number of people accessing to water through "basic services", we used the dataset produced by the Joint Monitoring Programme (JMP) for Water Supply, Sanitation and Hygiene. For those countries for which JMP data were not available, the analysis was based only on the Global Human Settlement Layer (GHSL) population data (e.g. Timor Leste).

1.3.3.3 Industry

The Industry freshwater withdrawal (V_M) is the Volume of water withdrawn for mining and quarrying, manufacturing, constructions and energy. This sector refers to self-supplied industries not connected to the public distribution network. It includes water for the cooling of thermoelectric and nuclear power plants, but it does not include hydropower.

Globally, approximately 16 percent of total water withdrawals are used for industrial purposes. Industrial water use has the largest share in high-income countries with a total of 48% in Europe and North America (FAO, 2021).

Considering that global data on the distribution of industrial settlements are not available, it was assumed that the population density layer (GHSL), based on the Nighttime lights satellite data, would provide a good proxy of where electricity is requested and consumed and so where industries are located over the world, in order to estimate how much water each inhabitant uses for this sector.

As shown in Figure 7, it was decided to apply an approach similar to the one used for the spatialisation of V_S.

Starting from the population density, we considered the percentage of people with *access to electricity* and living in rural and urban areas. This information is publicly available for several years on the World Bank website (SE4ALL, 2010). Then, using AQUASTAT data, we calculated the industrial freshwater withdrawal per inhabitant per year and finally the global map industrial freshwater withdrawal ($V_{M\ 2018}$) expressed in volumes (Figure A2).

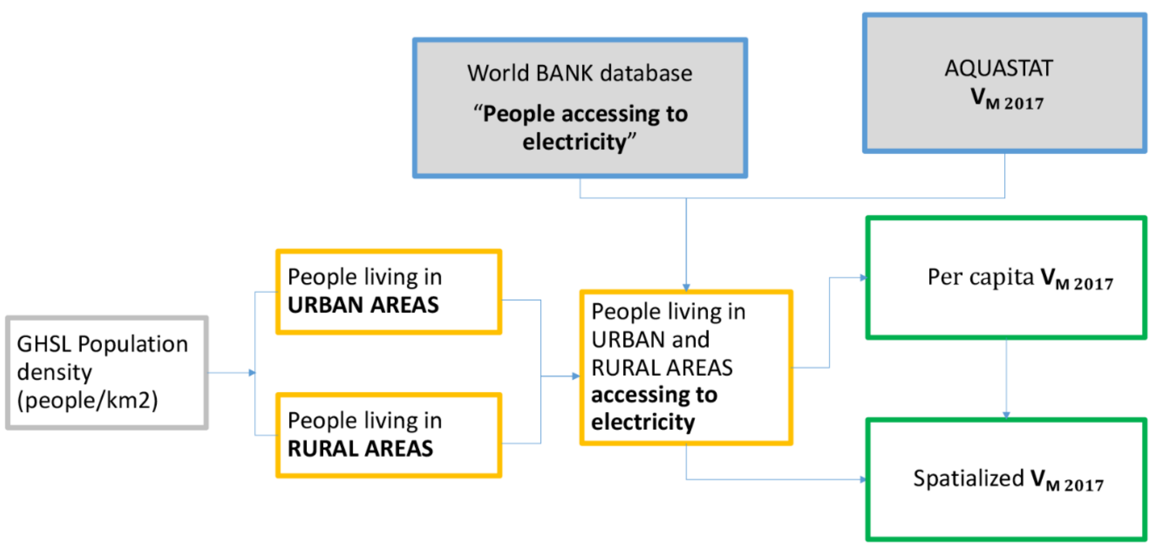

Figure 7: Approach used to spatialize the industry freshwater withdrawal (V_M).

This analysis suffers of a number of weak points that will be discussed in the limitation section of this article. Here, we wish to notice that the assumption that the nightlights can identify correctly the areas of production and consumption of electricity for industrial purposes would need to be revised as new data become available.

2. Results and discussion

The calculation of the SDG 6.4.2 by basin was carried out using the FAO global map of hydrological basins, derived from Hydrosheds and downloadable from Geonetwork, the FAO geospatial catalogue (http://www.fao.org/geonetwork). By aggregating all the variables described in the previous sections by major basin, the resulting SDG 6.4.2 map is shown in Figure 8.

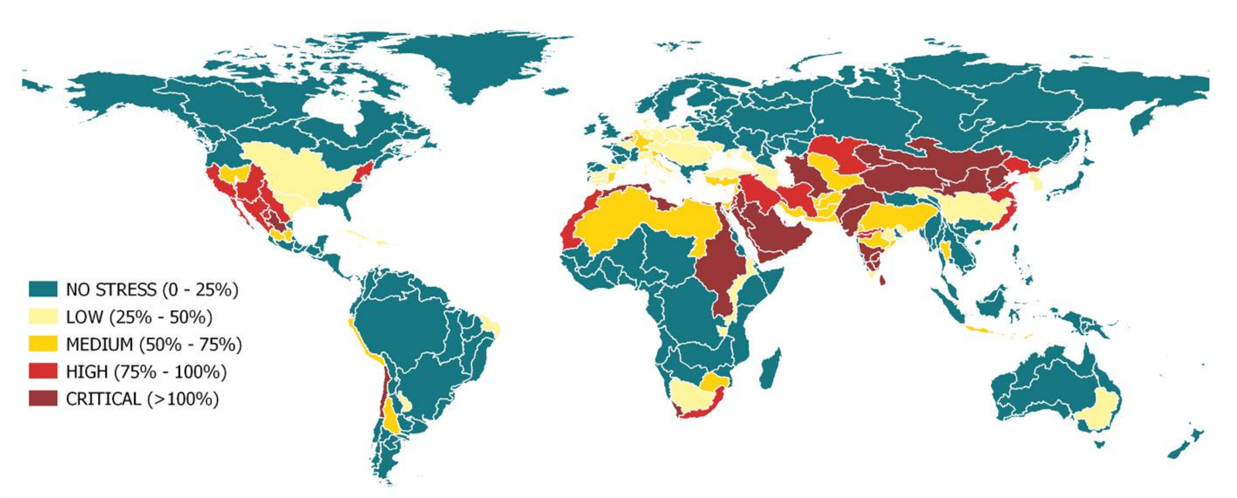

Figure 8: SDG 6.4.2 – Level of water stress, by major river basin expressed in percentages. Reference year 2018. Geographic projection.

The analysis of country data on water stress put in evidence that countries that may appear to have a low level of water stress can be part of a much more stressed basin. In fact, when a river basin spans across more than one country, the water stress calculated by country can be very different from the one computed at river basin level due to the double counting of the renewable freshwater resources from one country to another. This problem is solved once the accounting of the water resources is done on the major river basin as a whole. Following the thresholds established in the metadata for this indicator (UNSTATS, 2020), major river basins with an indicator's level lower than 25% have no water stress. Those basins with a water stress greater than 75% have a high or critical water stress. High values of water stress mean more water users are competing for limited water supplies.

Compared with the map of water stress at country level (Figure 1), the disaggregation by river basin reveals that the area affected by a severe water stress spans across all continents with the only exception of Oceania. This is not evident from the map of the indicator at country level, and may have relevant implications for the formulation of appropriate water management policies in the interested areas. Disaggregating the indicator offers another perspective, which may become particularly important in the context of the economic development of a country and the consequent changes in the structure of its economy.

The possibility of analyzing the indicator and its components against other spatially distributed information (e.g. population density, land cover, precipitation etc.) allows to increase the value of the information provided by the indicator alone. As agriculture is the main water user (Figures A3 and A4), we have analyzed the major agricultural systems (FAO, 2011b) against the classes of water stress. Irrigated agriculture is the most frequent type of agricultural system in basins with high and critical water stress while paddy rice is prevalent in medium stressed basins (Figure A5). Enabling conditions to optimize water use by increasing the crop water productivity is essential for these areas.

One of the objections related to this water stress indicator is that it does not consider the return flow, which could be a relevant component in some countries, as also demonstrated by recent studies (Simons et al., 2020). Vanham et al., 2018, elaborate on this point, coming to the suggestion to calculate two versions of the indicator, with and without the computation of the return flow. While the SDG indicator cannot be modified unilaterally, its interpretation can be improved and facilitated by providing such information.

As data on the return flow are not available in most cases, in order to have an idea of the impact of the return flow, we have applied the indicator's formula replacing freshwater withdrawal with water consumption:

$$WS_c(\%) = \frac{ET_{inc\text{-}irr} + (V_S * 0.1) + (V_M * 0.1)}{TRWR - EF} * 100 \qquad \text{Eq. 5}$$

with WS_c the water stress calculated considering the return flow; $ET_{inc\text{-}irr}$ the incremental ET due to irrigation (derived from GlobWat); V_S the Service freshwater withdrawal, V_M the industrial freshwater withdrawal, TRWR the total renewable freshwater resources (derived from GlobWat) and EF the Environmental Flows (based on GEFIS). All these variables are expressed in volumes (million m^3).

For estimating the consumptive use it was assumed a return flow of about 90% for the services and industrial sectors. For the agricultural sector, the incremental actual ET due to irrigation (estimated using GlobWat) was used as a proxy (Figure A6).

Taking into account the return flow, water stress remains evident in those basins characterized by an intense irrigated agriculture, although the role of large and densely populated cities (e.g. Cape Town or Beijing) needs to be further analyzed.

3. Limitations

One of major efforts of this study was to ensure a consistency between the AQUASTAT national statistical data available for each economic sector and the global geospatial datasets used for their spatialization. For example, for the Service and Industrial sectors, the GHSL database for year 2015 was harmonized to the reference year of the study, using the national population data for year 2018 available in AQUASTAT.

In addition, in the absence of a global layer of the industrialized areas, it was assumed that the population density layer (GHSL), based on the Nighttime lights satellite data, would provide a good proxy of where electricity is requested and consumed and so where industries are located over the world, in order to estimate how much water each inhabitant uses for this sector.

About the uncertainty due to the model, it was mitigated by calibrating the GlobWat against values for internal renewable water resources, as published in AQUASTAT, and its validation was done against mean annual river basin outflows. However, it is worth considering that not all the input data of the GlobWat model are consistent with the reference year of the study, for example the irrigation density map (Siebert et al., 2013) refers to year 2013. Moreover the model doesn't take into account the inter-basin water transfer, which is a limitation of most hydrological models.

In conclusion, both the assumptions made and the global input datasets used to feed the GlobWat could be sources of uncertainty in the output. In the light of these challenges, we will continue our research on the disaggregation with the objective to improve the quality of the final results once more accurate and recent global datasets will become available for this topic.

4. Conclusions

The disaggregation of the water stress indicator by major basin highlights the importance of the proper consideration of the hydrological conditions when assessing the pressure that the use of water for human needs puts on the natural water resources. That provides a more comprehensive view of the global distribution of water stress, increasing the granularity of the information and allowing the identification of those cases where country level assessments may be hiding situations that might be relevant for implementing an integrated management of water resources at regional or sub regional level.

Such analysis provides also the basis for bringing the disaggregation exercise at sub-basin level, so to provide decision makers with a more articulated information on the availability of water resources within a country.

Disaggregating the indicator offers also the possibility of an analysis of freshwater withdrawals by sector, which may become particularly important for the definition of water management policies in the context of the economic development of a country and the consequent changes in the structure of its economy. Finally, considering the role of water consumption provides a further insight into the detail of the dynamics of water use. Such information, properly combined with the spatial disaggregation, would provide essential data to plan a more sustainable use of water resources, particularly in water scarce basins and countries.

In conclusion, depending on the variable analyzed, the disaggregation of SDG 6.4.2 allows the identification of hotspots where actions should be prioritized, highlighting the importance of international cooperation in the management of water resources.

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CONFLICTS OF INTEREST

The views expressed are solely the authors’ and do not represent FAO’s position on the subject.

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[i] See Decision 47/101/n from the 47th UN Statistical Commission (https://unstats.un.org/unsd/statcom/47th-session/documents/Report-on-the-47th-session-of-the-statistical-commission-E.pdf)

[ii] The Industry sector is called “MIMEC” in the metadata of indicator 6.4.1. It includes mining and quarrying, manufacturing, constructions and energy

[iii] Surface runoff is termed “drainage” in GlobWat.

[iv] For Oman, Qatar and Cabo Verde the desalinated water is greater than the water withdrawal for services, so it was assumed that the surplus is used for the industrial sector. This implies that for these countries the freshwater withdrawal for services is considered ‘0’.

[v] In AQUASTAT services are termed as “municipal”.

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Appendix

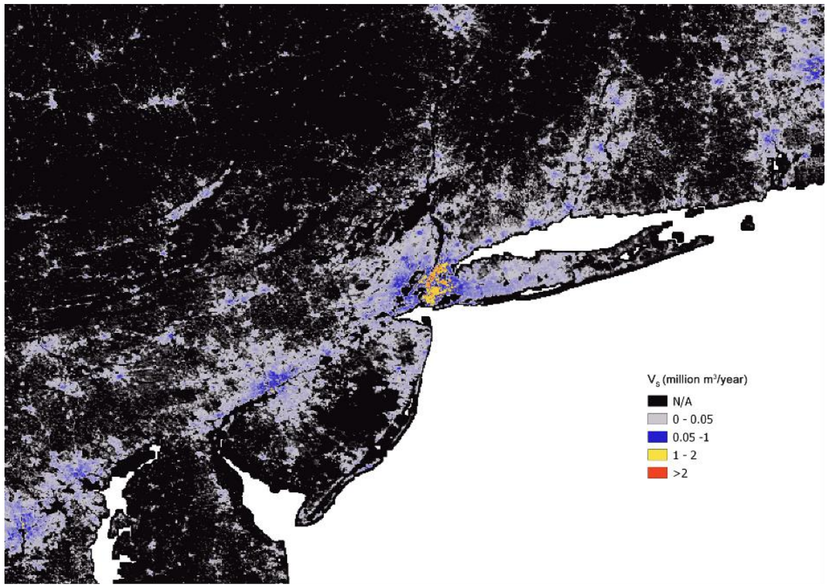


Figure A1: Service water withdrawal for the year 2018 (Vs 2018) spatialized using the GHSL population density layer and the JMP database (access to water through "basic services"). This figure shows the New York area in the USA. Geographic projection. Spatial resolution 30 arc-seconds (approximately 1 km at the equator).

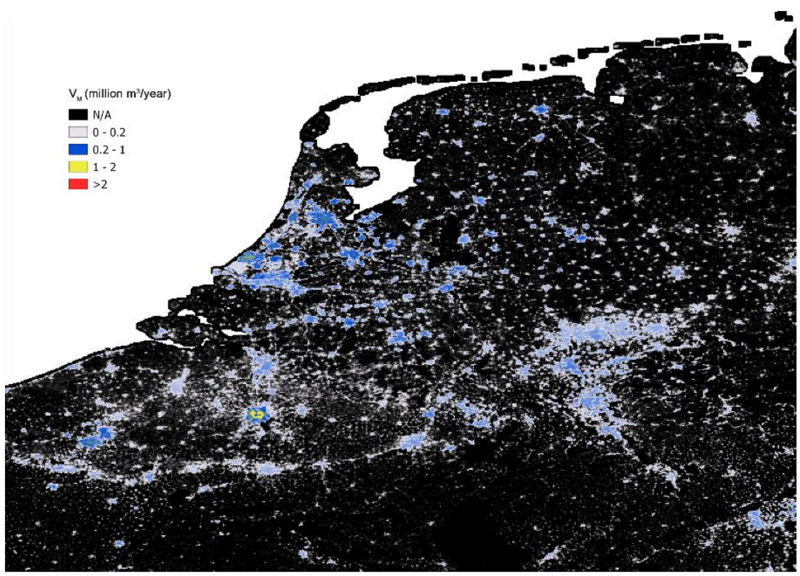
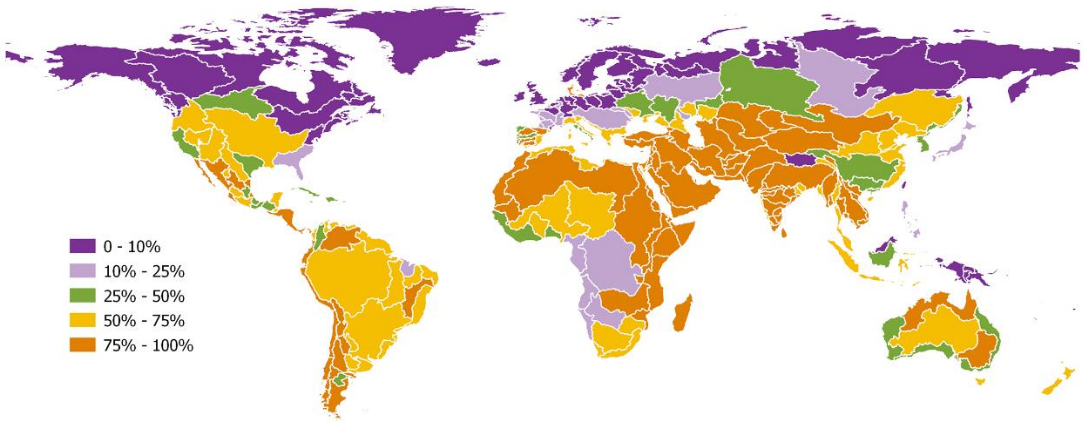
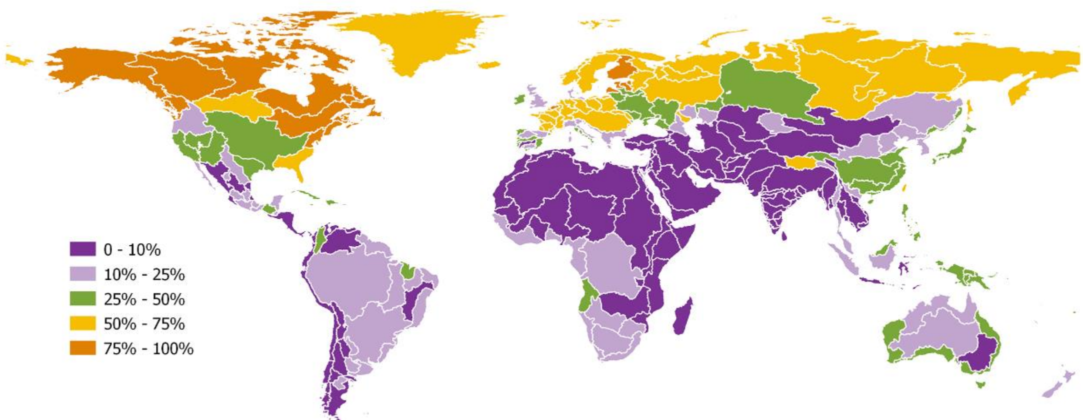


Figure A2: Industry water withdrawal for the year 2018 (V_M 2018) spatialized using the GHSL population density layer and the World Bank database ("access to electricity"). This figure shows an area of the Netherlands and northern Germany. Geographic projection. Spatial resolution 30 arc-seconds (approximately 1 km at the equator).

A) AGRICULTURE



B) INDUSTRY



C) SERVICE

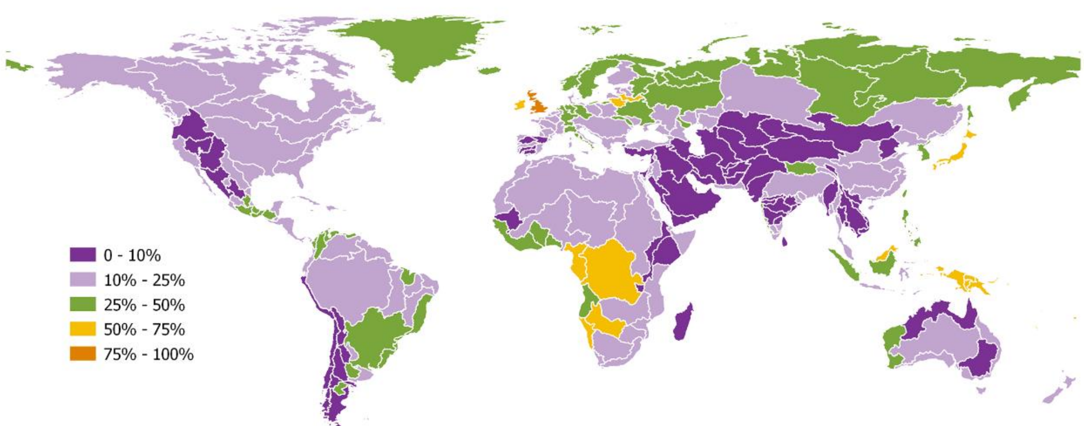


Figure A3: Proportion of the Agriculture (a), Industry (b), and Service (c) sector freshwater withdrawal respect to the total freshwater withdrawal per major river basin (reference year 2018). Geographic projection.

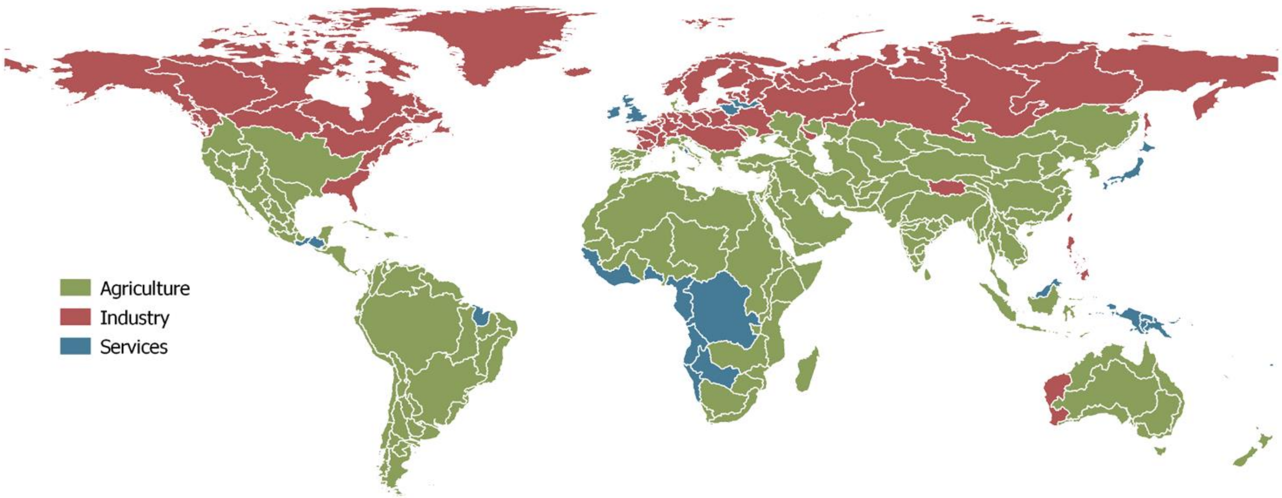


Figure A4: Dominant sector freshwater withdrawal per major river basin (reference year 2018). Geographic projection.

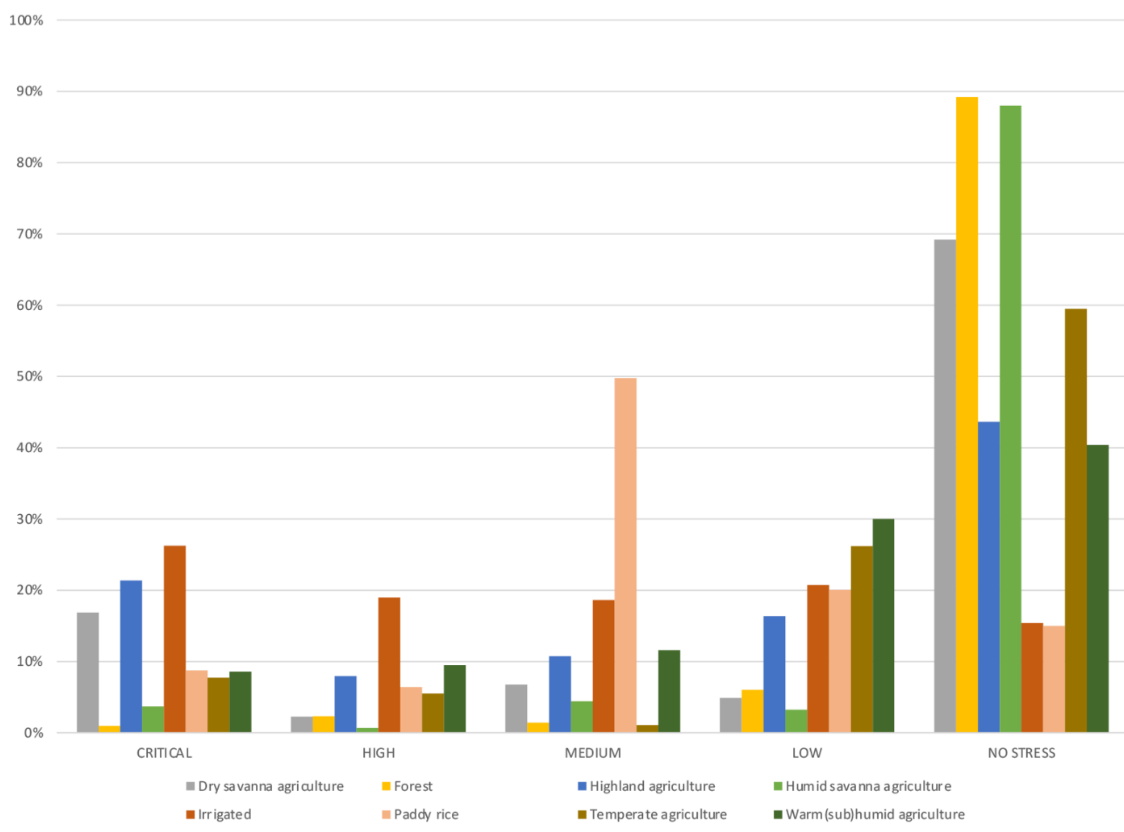


Figure A5: Analysis of the occurrence of some the major agricultural systems in the classes of water stress

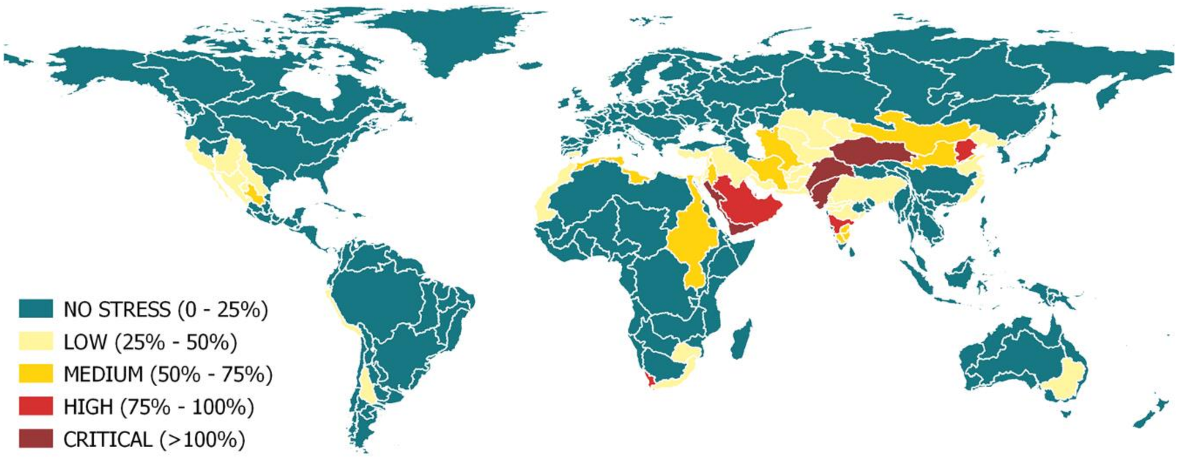


Figure A6: Water stress indicator calculated using the water consumption (percentages). Reference year 2018. Geographic projection.