TOWARDS FAIR WATER FOOTPRINTS

UNDERSTANDING THE WATER FOOTPRINTS OF THE GLOBAL NORTH AND DEPENDENCY ON WATER USE IN THE GLOBAL SOUTH

A. CHAPAGAIN AND M. MEKONNEN

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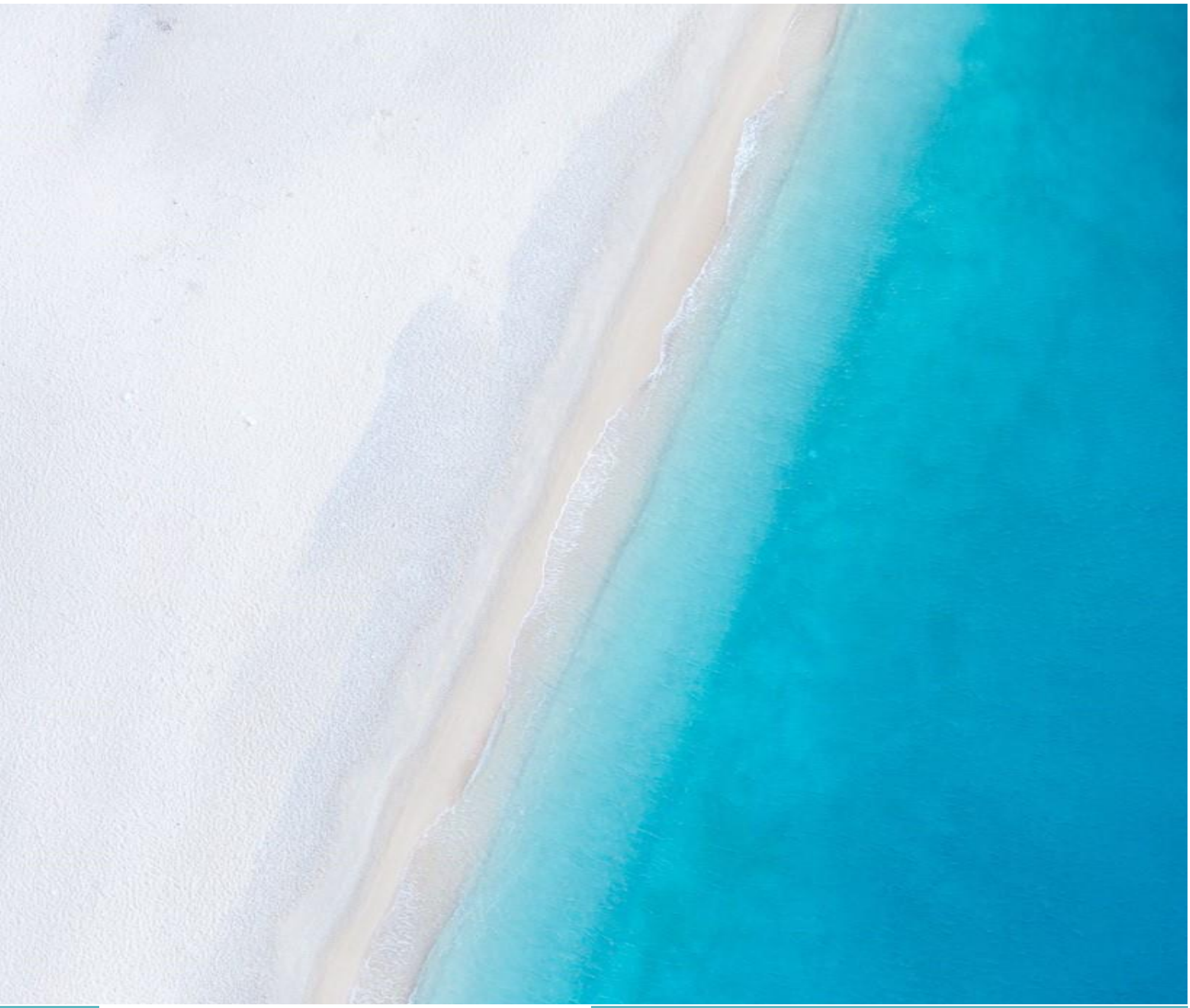

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EXECUTIVE SUMMARY

The signing of the Glasgow Declaration for Fair Water Footprints at COP26 in November 2021 demonstrates a clear global ambition to better understand the implications of the water footprints (WF) of consumer societies, and to take action to ensure sustainable, equitable and resilient water use in countries producing goods and services. It reflects recognition that where water use is sustainable and equitable, it is a vital driver of jobs, livelihoods, and mutual resilience, and that the strategic imperative is not always to reduce water footprints but to ensure that they are 'fair', defined as demonstrating zero pollution, sustainable withdrawal, universal access to safe water, sanitation, and hygiene (WASH), protection of nature, and climate resilience. With commitment already in place from 26 'producer' and 'consumer' governments, leading multi-nationals, investors, civil society organisations (CSOs), researchers and networks, this growing coalition offers a unique opportunity to establish accountability for sustainable water use and water stewardship as the global business norm.

To support informed debate and targeted action towards fair water footprints, this study provides a comprehensive and up-to-date analysis of the water footprints associated with crop, livestock and industrial production, global trade and consumption. Prior to the analysis presented here, data on the water footprints of nations were limited to the period 1996 to 2005. The study updates data on the national water footprint of consumption and production for targeted countries between 2000-2020. It appraises the nature and composition (blue, green, grey) of these water footprints, whether they are external or internal, and the degree to which the external blue water footprint is sustainable.

The selected 'Global North' economies are, United Kingdom, Austria, Switzerland, the Netherlands, Germany, France, Italy, Finland, Sweden, Denmark, Japan, the USA, and Canada. The study also analysed the WF of the EU27. The 'Global South' economies selected for study are: Africa (Cote d'Ivoire, Democratic Republic of Congo, Egypt, Ethiopia, Gabon, Kenya, Lesotho, Morocco, Tanzania, Mauritius, Madagascar, Malawi, South Africa, Zimbabwe, and Zambia), Latin America (Argentina, Bolivia, Brazil, Chile, Guatemala, Columbia, Mexico, Peru, Costa Rica, and Panama), and South-East Asia (Bangladesh, Cambodia, China, Laos, Myanmar, Thailand, Vietnam, Indonesia, Pakistan, and the Philippines).

We find an overall upward trend in the dependency on external water footprints, expressed as a percentage of the total water footprint of consumption in the Global North during the study period. European nations and Japan currently depend on external water use to meet typically 40% to 80%, and as much as 94% (Netherlands) of consumptive needs. For the Global North economies studied this dependency has increased by 4% between 2000 and 2020, whilst the EU27 dependency on external water use remains consistent at 40%. The increase in the proportional dependency of the total external water footprint for the individual countries, ranked in decreasing order are Sweden (6.8%), Austria (5.8%), Italy (5.3%), Germany (4.6%), USA (4.3%), Switzerland (4%), Netherlands (2.4%), and Denmark (0.5%). External dependency, potentially mirroring patterns of trade, has declined marginally for France (-0.5%), Japan (-0.5%) Finland (-2.5%), UK (-2.8%) and Canada (-4.9%). Note that though the proportional dependency may not appear significant for the USA (12%), the sheer scale of its consumption means that its external water footprint is the largest by volume of all countries studied.

These external water footprints can be traced to countries in the Global South where significant volumes of water are appropriated to produce crops, raw materials and goods for export. Many of these 'producer' nations and their citizens face extreme water insecurity as a result of economic and physical water scarcity, stubborn governance, infrastructure, and investment challenges, exacerbated by increasingly severe and frequent climate extremes.

Sustainability assessment using water footprint methodology applies a presumptive environmental flow requirement and finds that the 'blue' water use to meet the needs of 'consumer' nations often exceeds this, pushing catchments and aquifers of production into degradation, depletion, drought, conflict, and vulnerability. Whilst high-level assessment using blue water scarcity as a proxy should be considered as an approximation rather than unequivocal judgement, it is valuable in flagging risks and the need for further scrutiny.

Applying this methodology, we find large proportions of water use within the external water footprints of all the Global North economies to be unsustainable, with the majority of this unsustainable use landing in regions facing severe water scarcity. Half of the external blue water footprint (50%) of the Global North economies is found to be unsustainable and can be traced to areas with moderate to severe blue water scarcity. The level of unsustainable use within the external blue water footprint of individual Global North countries is variable: Japan (61%), Canada (56%), France (45%), USA (48%), UK (40%), Germany (39%), Italy (38%), Switzerland (34%), Sweden (27%), Netherlands (37%), Denmark (26%), Finland (26%), and Austria (24%). Collectively for the EU27, 52% of the external blue WF is unsustainable. 48% of the USA's external blue WF is unsustainable – representing 3,510 Mm^3/year. Again, we need to look beyond proportional shares when considering the significance of these findings.

We have also traced the products, locations of production and trading partners responsible for these virtual water flows to inform strategies for more resilient supply chains and sustainable production and consumption. For example, the top 20 producer countries which account for the unsustainable external blue WF of the Global North are Spain (24.7%), Pakistan (15.5%), Mexico (14.1%), India (11.8%), Turkey (7.2%), China (7.1%), Egypt (2.3%), Greece (1.4%), Thailand (1.3%), Kazakhstan (1.2%), South Africa (1.2%), Morocco (1.2%), Argentina (1.2%), Australia (1%), Israel (0.9%), Peru (0.8%), Iran (0.6%), Tunisia (0.6%), Chile (0.5%), and Portugal (0.5%). The top-20 products and sectors accounting for the total unsustainable blue WF of the Global North are cotton (35.2%), olives (9.6%), citrus fruit (9%), rice (6.6%), barley (3.9%), sugarcane (3.6%), grapes (3.5%), soybean (3.1%), industrial products (2.5%), castor beans (2%), Hazelnuts (1.9%), Avocados (1.4%), Linseed (1%), Almonds (1%), Sunflower (1%), Maize (0.9%), Banana (0.9%), Peppers/pimento (0.8%), Mangoes (0.7%) and Fresh fruit (0.7%).

The current study also provides a time series database (2000 to 2020) for the WF of production in Global South economies, and the WF of consumption of the Global North countries, per agricultural products traded internationally. It provides data on virtual water import and export for the selected countries and their internal water footprint of domestic and industrial water use. Such an extensive and up-to-date database can assist in developing programmes, policies, and advocacy responses to enable fairer water footprints. Following this high-level prioritization per consumer and producer country, a more detailed assessment using locally available data is needed to further elaborate the situation on the ground. Verifying sustainable use within our water footprints requires rigorous local assessment which considers the context and temporal nature of impacts. For example, it is possible for water use within a WF landing in a scarce water location to be sustainable where there is an abstraction in line with seasonal water availability, the needs of downstream ecosystems and users, and/or via seasonal water storage. Equally, water footprints falling outside of water-scarce regions can be unsustainable through multiple impact pathways - over abstraction, uncontrolled pollution, or impacts on ecosystems and community water access.

For producer nations in the Global South, the study findings should cause alarm, since they suggest that water use in priority sectors for growth, job creation and export revenue are also driving water insecurity, ecosystem collapse and vulnerability to climate change, undermining the health and wellbeing of citizens and future economic prospects. They signal the urgent need to redouble efforts to implement Integrated Water Resource Management (IWRM) and to allocate water in equitable and sustainable ways to meet the needs of the economy, people and the environment. They also underscore the need for new approaches to policy, practice and financing to ensure that the beneficiaries of water use in their countries contribute more meaningfully to improved water management and the shared water security upon which they also depend.

For consumer nations in the Global North, these findings should also cause great alarm, since they reveal that strategically important supply chains are highly precarious, and that the well-being and food security of their citizens are both dependent on, and actively undermining water security around the world. Facilitating shared water security in the places where these water footprints land is in the self-interest of consumer nations to protect supply chains from disruption, spiralling costs and questions about their legitimacy. There is also an ethical obligation, and an opportunity, for new forms of collaboration to strengthen policy, law, and practice on water so that trade between nations doesn’t come at the cost of water crises and injustice.

1 INTRODUCTION AND BACKGROUND

The launch of the Glasgow Declaration for Fair Water Footprints at COP26 in 2021 reflects a growing recognition of the role that our water footprints and their local impacts play in shaping the vulnerability of communities, economies and ecosystems to climate change, resource depletion, environmental degradation, and other shocks and stresses. It responds to increasing concerns about the impacts of producing agricultural commodities, food and clothing, and of sourcing metals and minerals in the Global South for the benefit of consumers in the Global North (See Hepworth et. al, 2010; Hepworth et. al., 2021). Numerous stakeholders are now seeking to take constructive action in response to the obligations and opportunities presented by water footprints which connect citizens, consumers, companies and countries in the Global North to some of the most water-insecure places on earth. This renewed interest in the water footprint of consumer society holds significant potential for advancing environmental sustainability, social justice and economic and social progress in countries producing water-intensive goods and services.

This report supports these efforts by providing a contemporary analysis of the water footprint of nations for the period 2000 to 2020. Prior to the analysis presented in this report, datasets and assessments on the water footprint of nations were limited to the period 1996 to 2005. To support informed debate and targeted action, the new analysis presented here provides comprehensive and up-to-date data on the water footprints associated with the production, global trade and consumption of goods and services. It quantifies water used in agricultural, industrial and domestic (households) sectors, and characterises the type of water used in the production process.

The report is organised into six sections and supported by comprehensive annexes presenting time-series data at a higher degree of granularity (see Section 2 for the list of data presented in the Appendix as Excel files).

Section 1 introduces the foundational concepts of virtual water, water footprints and their blue, green and grey components, and briefly elaborates key concepts of national water budgets, the internal and external nature of footprints, along with the differences between water footprints of consumption and production. This Section also introduces the concept of a Fair Water Footprint, and its relevance for global water governance and management. It concludes with the objectives of the study and its approach.

Section 2 presents the method and data used in the study and their limitations. Section 3 presents, the water footprint assessment of the 'Global North' economies, and Section 4 presents the water footprint of production of the 'Global South' economies. The discussion and next steps are presented in Section 5, with the list of references in Section 6.

1.1 VIRTUAL WATER & WATER FOOTPRINTS

In the early 1990s, Professor Tony Allan conceived the concept of 'virtual water', to represent the export of water-intensive commodities as 'virtual water flows' (Allan, 1993). The volume of virtual water 'hidden' or 'embodied' in a given product is defined as the volume of water used in the production of that product (Allan 1997). Initially, the concept of virtual water only included the volume of freshwater (blue and green) used in crop production. The concept of 'grey virtual water' was later introduced by Chapagain and Hoekstra (2006) to account for the volume of freshwater needed to assimilate the pollutants released into bodies of water.

The water footprint of a product can be understood as an empirical indicator of how, and how much, water is consumed in its production, measured across the entire supply chain. The water footprint is a multi-dimensional indicator, showing volumes but also making explicit the type of water use (evaporation of rainwater, surface water or groundwater, or pollution of water) and the location and timing of water use. The water footprint of an individual, community, or business is defined as the total volume of freshwater that is used to produce the goods and services consumed by the individuals, communities, or used by businesses. The 'virtual-water content of a product or service' is the same as 'the water footprint of a product or service'. However, virtual water refers to the volume of water required to produce each unit of product/service, whereas water footprint in addition also indicates the type of water used (green, blue, grey) and the 'when' and 'where' – the temporal and spatial dimensions of water use.

Water footprint assessment helps us to understand human appropriation of the world's limited freshwater resources. It provides a basis for assessing the impacts that goods and services on have on the freshwater system and their functions and other users, and for formulating strategies to reduce those impacts. As an analogy to the ecological footprint (Wackernagel and Rees, 1996), Hoekstra and Hung (2002) introduced the concept of water footprint as a tool to show people their impact on natural resources. Initially, only water use in crop production was included but subsequent refinement by Chapagain and Hoekstra (2006) expanded the scope to include national-level water use in other sectors including industrial and domestic water use. The impact of wastewater discharges into freshwater (Chapagain *et.* al, 2006) was also included to establish the first global assessment of the water footprint of nations (Hoekstra and Chapagain, 2007). Building on this foundational research, Hoekstra and Chapagain (2008) developed a comprehensive framework to analyse linkages between human consumption, appropriation and sustainable use of global freshwater.

1.2 BLUE, GREEN AND GREY WATER FOOTPRINT

Traditional analyses of water use in the economy have focused on measuring 'water withdrawals' and 'direct water use' at production sites. The water footprint accounting method adopts a broader perspective, considering both direct and 'indirect' water use, the latter referring to water use in the supply chain. The water footprint, thus, links final consumers, intermediate businesses, and traders to water use along the entire production chain of a product. This is relevant because typically, direct water use by a consumer or a business is relatively small when compared to their indirect water use via the supply chain and the production and processing of raw materials within it. Thus, water footprint analyses provide us with a lens through which we gain a radically more accurate picture of the water resource dependencies and impacts of consumers, businesses, and nation-states.

Freshwater availability on earth is determined by annual precipitation above land. A portion of the precipitation returns to the atmosphere through evaporation and the remaining portion - broadly speaking - runs off to the ocean through aquifers and rivers. Both the evaporative flow and the runoff flow can be harnessed productively to meet the multiple needs of society.


Green water footprint


Blue water footprint


Grey water footprint

The **green water footprint** refers to the part of the rainwater that is stored as soil moisture and consumed before it becomes runoff flow. It is the evaporative flow used for crop growth or left for maintaining natural ecosystems. The green water footprint measures that part of the total evaporative flow which is appropriated for human purposes.

The **blue water footprint** refers to the volume of surface and groundwater abstracted and consumed (evaporated and evapotranspired, not returned to the water resource) from springs, rivers, lakes, reservoirs and aquifers to produce goods. This runoff flow can be used for all sorts of purposes, including irrigation, washing, processing, and cooling. The blue water footprint measures the volume of groundwater and surface water consumed, i.e., withdrawn and then evaporated.

The **grey water footprint** is defined as the volume of freshwater that is required to assimilate a pollutant load in a freshwater body, based on natural background concentrations and existing ambient water quality standards. It provides a useful indicator of water resource appropriation through pollution, and a tool to help assess the sustainable, efficient and equitable use of water resources. By quantifying water pollution as the volume of water which would be polluted in the absence of prior treatment, grey water can be included in the analysis alongside green and blue water.

For example, depending upon the pollution load, a litre of untreated effluent from a factory or farm could render many thousands of litres of freshwater unsuitable for further use downstream within the water body where it is discharged. Whilst some wastewater receives adequate pre-treatment before discharging, it is estimated that as many as 90% of the world's wastewater flows do not. Hence, calculating grey water in this way is a valid approach to appraising water resource appropriation. More in-depth calculations of the grey water footprint can be applied following the water footprint guidelines developed by Franke *et.* al (2013).

The definitions of the different components of the water footprint are taken from Hoekstra and Chapagain (2008).

A pictorial view of the green, blue and grey water footprint in a hydrological cycle is provided in Figure 1 (WWF & AfDB, 2012). The rainfall in any catchment can become either a blue water flow (surface runoff, baseflows, rivers, snow-caps, lakes, groundwater recharge etc.), or stored as soil moisture (that can be used by vegetation, crops depending upon the land use practice at these locations). The part of the soil moisture used, and evaporated in forests, grazing lands etc. is the green WF of the nature and ecosystem that benefits from it. The irrigated cropland can receive and meet the crop water requirement (the maximum amount of water needed to grow a crop to its full potential) from two sources, irrigation water or rainfall (rainwater stored as soil moisture) depending on the location of the agricultural land and available irrigation services. The part of crop evapotranspiration met from irrigation supplies is called the blue WF of irrigated agriculture, and the evapotranspiration demand met from the soil moisture maintained by rainfall is the green WF. In areas with no irrigation facilities, the crops are grown fully under rainfed conditions using rainfall as the only source of crop water requirements. Thus, the evaporation from rainfed crop land is always only the green WF.

A portion of the fertilizers and pesticides used in the agriculture fields can reach freshwater sources (rivers, lakes, groundwater, etc.) and degrade freshwater quality limiting their use and functions downstream. The volume of freshwater needed to assimilate these pollutants in these locations is the grey WF of agriculture.

A portion of blue water flows in the hydrological cycle can be used in households for domestic water supplies and by industrial sectors. The evaporation of blue water supplied to these sectors constitutes their blue WF, and the return flow (wastewater) results in their grey WF.

In this way, green, blue and grey water footprints measure different modalities of water appropriation and taken together usefully illustrate the total water needs of production. One can further classify the water footprint into more specific components, for example, by distinguishing between ground and surface water use in the case of the blue water footprint.

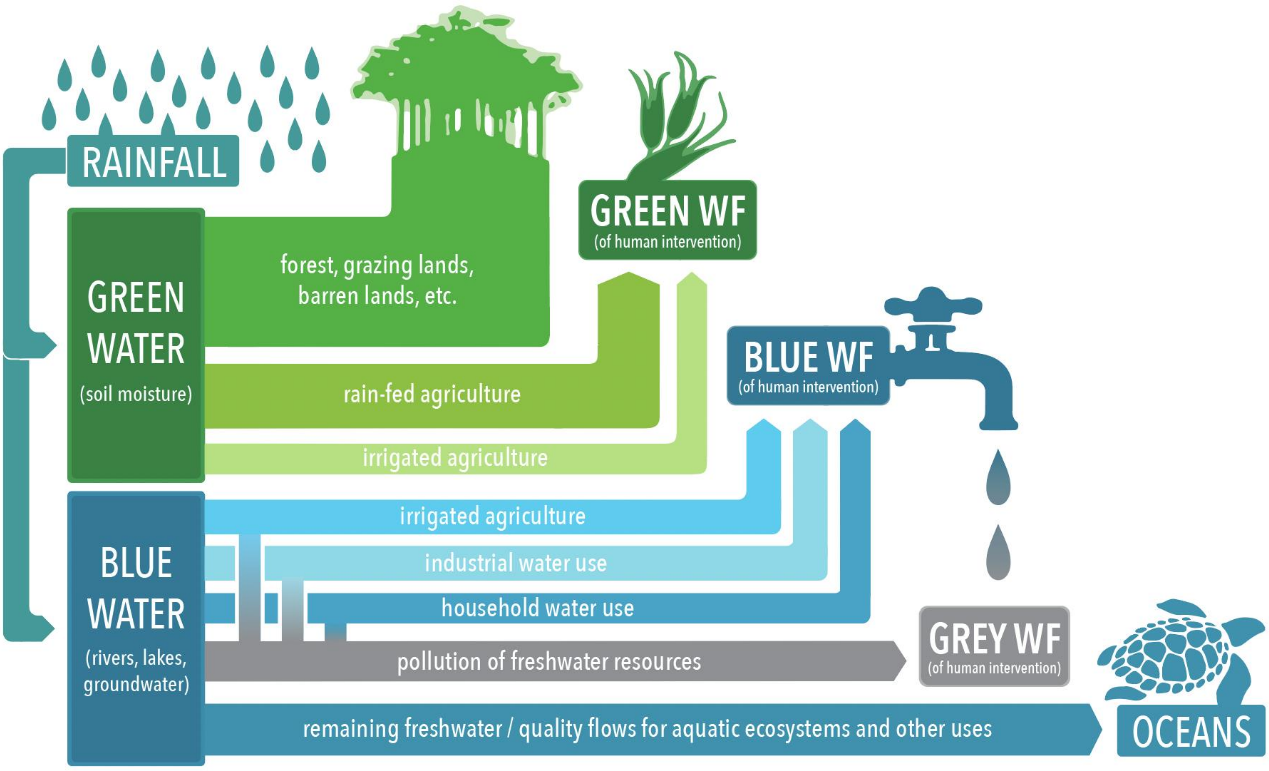


Figure 1. Water flows, water use, and footprint in a hydrological cycle. Source: Adapted from WWF & AfDB, 2012.

1.3 NATIONAL WATER BUDGET

In securing food, water, energy, and other goods and services, most countries rely on a combination of imported and exported goods and services. These water-intensive imports and exports, combined with domestic water resources, comprise a nation's 'water budget'.

A nation's water budget is made up of two components: 1) locally available water resources, and 2) 'virtual' water (embedded in products) imported from other countries. It is important to note that not all of a nation's water budget is consumed by the inhabitants of that country. A part of the total water available is exported in the form of water-intensive goods and services, also called 'virtual water export'. Likewise, a portion of the virtual water imported from other countries may be subsequently incorporated into products and 're-exported' (See Figure 2).

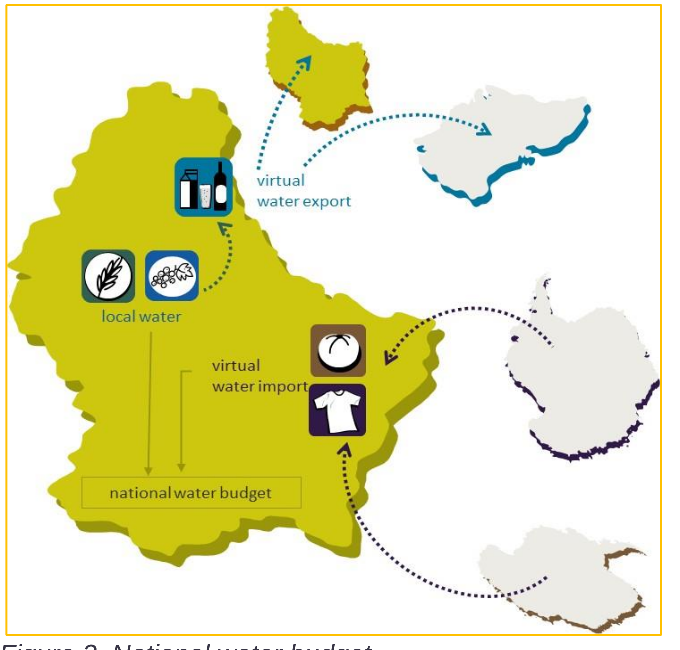


Figure 2. National water budget.

1.4 THE INTERNAL AND EXTERNAL WATER FOOTPRINT OF NATIONS

The water footprint of a nation, sometimes referred to as the '***water footprint of national consumption***', is defined as the total volume of fresh freshwater used to produce the goods and services consumed by the inhabitants of that nation. Due to the import and consumption of water-intensive goods and services, a part of this water footprint lies outside the territory of the nation. This is the '***external water footprint of a nation'***.

The remaining portion of the water footprint of national consumption – specifically, the appropriation of domestic water resources for producing goods and services that are consumed domestically – constitutes the '***internal water footprint of a nation'*** (Figure 3).

The term '***water footprint of a nation'*** should not be confused with the '***water footprint of national production***'. The former refers to the total volume of water consumed directly or indirectly by the inhabitants of the nation, whereas the latter refers to the volume of water used within the national territory to produce goods and services that may or may not be used within the nation i.e., exported.

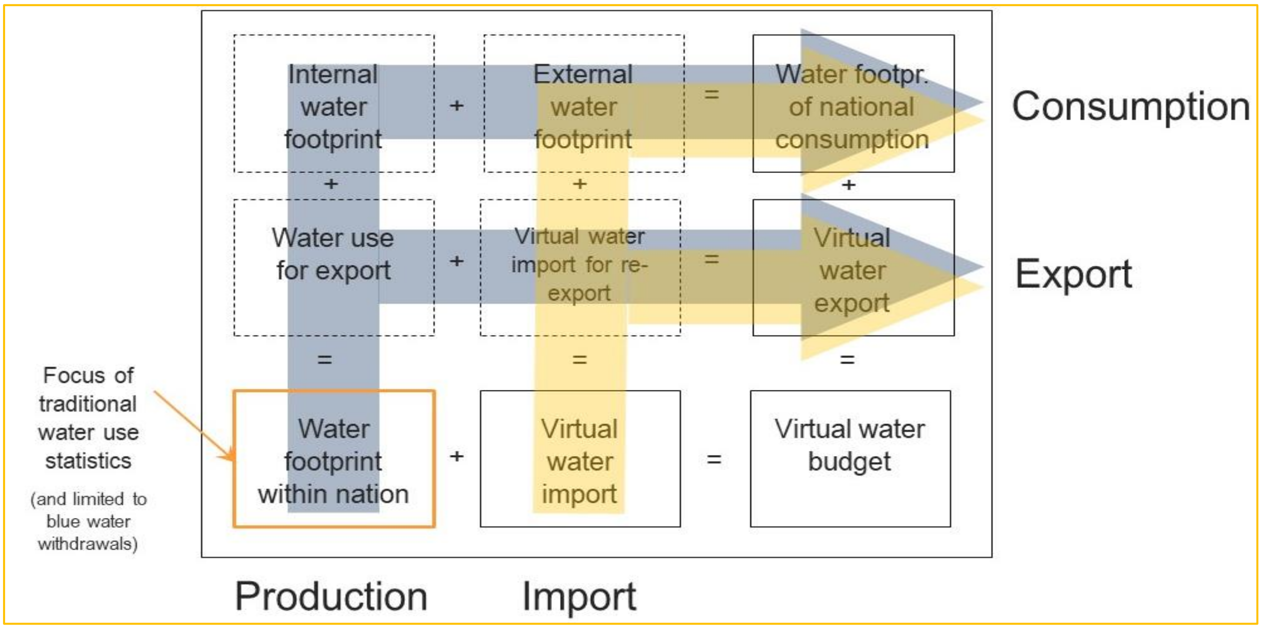


Figure 3. Various components of national water footprint accounting schemes. Source: Hoekstra et. al, 2011.

1.5 Water Footprint Assessment

Understanding the nature of the external water footprint of a nation associated with international trade is crucial from multiple perspectives, to:

- drive and target action for sustainable water management across the global value chain,
- support fair and equitable water policy (allocation and management) at the national, river basin and local levels,
- support national policy on land and water resource allocation, trade, energy, environment, agriculture etc., and
- build mutual water security, climate resilience and resilience of supply chains and economies via international trade and associated virtual water flows.

However, the water footprint assessment methodology focuses only on freshwater availability and use, and does not address other key drivers of change such as climate change, environmental degradation, fragmentation of habitats, social and economic issues (access to safe drinking water, WASH, equitable use of water resources, employment, poverty reduction etc.). Whilst it provides a foundation for nations, investors and multinational companies to analyse and understand their water-related dependencies and risks (WWF's Risk filter Suite: Water Risk Filter, Biodiversity Risk Filter etc.), the quantification of a water footprint is 'value-free': it doesn't tell us whether the water footprint is having a negative or positive affect, only when and where that water is used. Hence, additional parameters are needed to assess the sustainability or vulnerability of a water footprint (Hoekstra *et.* al, 2011).

It is also particularly important to understand that the total size of a water footprint is not always the most important parameter, and efforts to reduce water use, or make water use more efficient are not always the priority goals. The natural replenishment of water within the hydrological cycle, and water storage, means that in many locations there exists a level of use which is sustainable without imposing negative impacts on other water users, communities, or nature. Pursuing water footprint reduction at all costs could therefore be damaging to economic development, trade, and job creation for countries and communities which depend on the export of thirsty agricultural commodities, extractives, mining, and manufacturing for global supply chains. The priority concern is therefore whether our water footprints impose sustainable, equitable or 'fair' water use and resource management in the specific contexts within which they occur.

1.6 FAIR WATER FOOTPRINTS

Research suggests that our globalized water footprints are often associated with negative impacts for the people and places associated with production, through a combination of: pollution caused by farms, factories or mines; over-abstraction and conflict over water; the denial of the human right to safe water supply and sanitation; degradation of ecosystem and landscapes, or exacerbation of drought and flood impacts. For example, Hoekstra and Mekonnen (2016) have assessed previously that 50% of the UK's external blue water footprint lands in river basins and aquifers where water use is unsustainable. In many settings, our water footprints have significant implications for environmental sustainability, social justice and economic and social progress. This is because the business activities which use water create employment and generate export revenue, often making a significant contribution to the national GDP.

Multiple investigations into the impacts of food and clothing production, and mining in the Global South for the benefit of consumers in the Global North suggest that unsustainable, or 'abusive' water use within our water footprints is widespread (Hepworth *et.* al, 2010, Hepworth *et.* al, 2021). To capture the multi-dimensional impacts of our water footprints and their implications for sustainable development and climate resilience, a further concept has been introduced: that of a 'fair water footprint' (Hepworth, 2021).

During 2021, a global multi-stakeholder process was enacted to define the 'ideal' characteristics of a fair, sustainable and resilient water footprint. This concluded with a 'Fair Water Footprint' being defined as one which demonstrates the following:

- **Zero water pollution**: No adverse impacts on the aquatic environment, other water users or functions arising from wastewater discharges, or diffuse pollution.
- **Sustainable withdrawal and equitable allocation of water**: abstraction and use within the hydrological limits of sustainability, not compromising the human right to water, needs of the environment, communities, or future generations.
- **Protection and promotion of nature**: Ecosystems and landscapes, and their services are protected, and sustainably managed, and nature-based and regenerative solutions are prioritised.
- **Universal access to safe water, sanitation, and hygiene**: Adequate provision in the workplace and collective action to reach underserved communities.
- **Resilience to drought, floods, climate variability, and water conflict:** Effective plans, policies, governance, and investment in place to mitigate water, climate, and conflict risks, with legal compliance and secure water tenure for all.

Economic water use within our water footprints which satisfies these five criteria can ensure that our globalised supply chains support, rather than undermine shared water security, climate resilience, and social justice. There is an emerging consensus among a growing group of sustainability leaders from business, governments, finance, civil society, and academia that action to ensure fair water footprints is both an urgent obligation and opportunity to transform the global economy toward a more sustainable, just, and resilient model of water use.

By prioritizing the fairness of their water footprints, consumers, corporations, banks and governments can mobilise new incentives, investment, and strategic support for sustainable water use and management. Globalised supply chains are estimated to account for or influence over 70% of the world's water use and pollution, employ one in five of the world's population, and reach the places with the most difficult water and climate challenges. Given this scale, reach, and influence, prioritizing fair water footprints has the potential to be globally transformative.

1.7 Objectives of the Study

Before this study, data on water footprints and virtual water flows at the global scale were limited to the period from 1996-2005 (Hoekstra and Mekonnen, 2012). Given changes in economic production, consumption and international trade since then, updated data is needed to inform contemporary policy responses, planning, and action for a fair water footprint, and sustainable use within our footprints.

The primary objectives of this study are two-fold:

1. To establish an accurate and up-to-date understanding, and interrogable, fully traceable data set that details the water footprint of the 'Global North', across three sectors of concern (agricultural, domestic/household, industrial).
2. To evaluate their dependencies on water use within the Global South.

THE STUDY UPDATES THE NATIONAL WATER FOOTPRINT OF CONSUMPTION OF MAJOR GLOBAL CONSUMER COUNTRIES AND THEIR DEPENDENCIES ON WATER USE IN GLOBAL SOUTH COUNTRIES.

Establishing national water footprint accounts

This study aims to estimate the water footprint of selected 'Global North' countries disaggregated by where these water footprints land for three economic water use types or sectors: agricultural water use, domestic water supply, and industrial water use for the period of 2000-2020. The study further aims to analyse the impact of the water footprint of consumption of 'Global North' countries on selected 'Global South' countries using the sustainability assessment method as set out by the Water Footprint Network (Hoekstra *et.* al, 2011).

The selection of the **'Global North'** countries is based on their relatively large scale of consumption and their power and leverage to engage companies and other governments for fair, equitable and sustainable water use. They include **United Kingdom, Austria, Switzerland, the Netherlands, Germany, France, Italy, Finland, Sweden, Denmark, Japan, the USA, and Canada**. The study also examines the water footprints of EU27 countries collectively as a block.

The 'Global South' countries for analysis were scoped based on multiple factors such as: relatively large export of water-intensive products, indicators of social and economic development, climate vulnerability, levels of access to WASH, water-related capacity and governance challenges and water scarcity. The selection of countries for this analysis hasalso been influenced by current or potential for future participation in the COP26 Fair Water Footprints Declaration.

The '**Global South'** countries selected are:

Africa: Cote d'Ivoire, Democratic Republic of Congo, Egypt, Ethiopia, Gabon, Kenya, Lesotho, Morocco, Tanzania, Mauritius, Madagascar, Malawi, South Africa, Zimbabwe, and Zambia
Latin America: Argentina, Bolivia, Brazil, Chile, Guatemala, Columbia, Mexico, Peru, Costa Rica, and Panama
South-East Asia: Bangladesh, Cambodia, China, Laos, Myanmar, Thailand, Vietnam, Indonesia, Pakistan, and the Philippines

National water footprint accounts of the selected countries are calculated for the period of 2000-2020. The study evaluates the virtual water import, export and total water footprint separated by the type of water use (green, blue, and grey).

The calculation of the water footprint of nations requires three major building blocks of analysis:

- The water footprint of consumer goods and services;
- The virtual water imports and exports from these countries, locations and timing of these; and
- Delineation of the water type used to produce these consumer goods and services.

Assessing the sustainability of the external blue water footprint

The dependencies on water use overseas are analysed by calculating the proportion of water used ‘externally’ to meet domestic consumer demand, together with data on the main ‘producing’ nations for each sector and ‘consumer’ country.

In many parts of the world, overconsumption of freshwater resources has led to the depletion of rivers, lakes, and groundwater levels, impacts on communities, and damage to freshwater species and ecosystems. Freshwater scarcity is already a serious threat to sustainable development, as evidenced by multiple global water scarcity studies (Alcamo *et.* al, 2003, Hoekstra *et.* al, 2012, Vörösmarty *et.* al, 2000, Oki and Kanae, 2006). The impact of water footprints can be reflected in ‘water pollution level’ (Liu *et.* al, 2012) or water scarcity at locations where they land. Following the work by Richter *et.* al (2012) on presumptive environmental flow requirements (EFR) - the flow deemed necessary to sustain livelihoods and ecosystems, Hoekstra *et.* al (2012) define the blue WF of a country located at a certain location to be unsustainable when it infringes the EFR. This is calculated as being when the local blue WF exceeds the sustainable yield of locally available water, obtained as the difference between the natural runoff and the EFR. Previously, Mekonnen & Hoekstra (2020) calculated the unsustainable blue water footprint of nations for the period 1996-2005.

The current study assesses the blue water footprint of the selected ‘Global North’ countries for the period 2000-2020, disaggregates the results and ranks unsustainable locations, and products based on their share of the total external water footprint of the selected nations.

2 METHOD

2.1 GENERAL METHOD

The study builds on the foundational method elaborated in Water Footprint Assessment Manual (Hoekstra *et.* al, 2011), the following specific studies:

- The water footprint of products (m^3/t) is calculated using the method presented by Chapagain and Hoekstra (2006).
- The international virtual water flow is calculated by multiplying the volume of exported commodity and the respective volume of virtual water per unit of that product (Hoekstra and Chapagain, 2007).
- The method used to assess the sustainability of the blue water footprint of consumption is adapted from Hoekstra and Mekonnen (2020a).

The virtual water flows and water footprints are quantified using data on the international trade of agricultural and industrial commodities for the period of 2000-2020.

2.2 WATER FOOTPRINT OF CROP PRODUCTS

The total water footprints (WF, in m^3/y) of crops were estimated by multiplying the crop-specific crop water use (m^3/ha) averaged over the period 1996-2005 by the crop specific harvested area for the period 2000-2020. National average crop water use values were obtained from Mekonnen and Hoekstra (2011). The WF (m^3/t) of each crop is then calculated by dividing the total WF (m^3/y) by the crop-specific production (t/y). The crop-specific harvested area and production data per country were obtained from FAOSTAT (FAO, 2022a).

2.3 WATER FOOTPRINT OF INDUSTRIAL AND HOUSEHOLD WATER USE

Following the method by Hoekstra and Mekonnen (2012), the water footprints within nations related to industrial production and domestic water supply were estimated using water withdrawal data from the AQUASTAT database (FAO, 2022b). There are numerous categories of industrial products with a diverse range of production methods, and detailed standardised national statistics related to the production and consumption of industrial products are hard to find. In the absence of precise global data on effluent discharge (return flows from industrial water use), we have assumed that 5% of the total industrial water withdrawn is actual consumption (either evaporated or incorporated in the manufactured products) and that the remaining fraction is return flow. For treatment coverage in the industrial sector per country, data on municipal treatment coverage in urban areas is used as an indicator. The national average water footprint of industrial production (m^3/£) is calculated as the ratio of the total water consumed (or polluted) per dollar added value in the industrial sector (a part of the national GDP, £/year).

For the domestic water supply sector, we have assumed a consumptive portion of 10% as suggested by FAO (2022b). The part of the return flow which is discharged into the environment without prior treatment has been taken as a measure of the grey water footprint, thus assuming a dilution factor of 1. Data on wastewater treatment coverage per country were obtained from the United Nations Statistical Division database (UNSD, 2011). For countries for which there is no data, we assumed zero wastewater treatment coverage. Domestic wastewater treatment coverage data are generally specified for urban areas only; we used data on urban populations per country from FAO (2022a) to estimate the grey water footprint from the domestic water supply in urban areas.

2.4 INTERNATIONAL VIRTUAL WATER FLOWS

The international virtual water flows are calculated using the international trade data from COMTRADE (2000-2020) and the water footprint of production of the exported products (m^3/t for crop and livestock products, and m^3/$ for industrial products) in exporting countries using the method set out by Hoekstra and Chapagain, 2007). To map the global water footprint of consumption for a certain country at a high spatial resolution, we distinguish between mapping the internal and the external water footprint following the method used by Hoekstra and Mekonnen (2012).

The internal water footprint is mapped by distributing the shares of the water footprints across the grid cells within the country which contribute to the water footprint of national consumption.

Mapping the external water footprint is done in two steps:

- First, we quantified the external water footprint per product category per trade partner country based on the relative imports from different trading partners.
- Second, within each trading partner country, we mapped the external water footprint by taking the shares of the water footprints within the different grid cells in the trade partner country that contribute to the water footprint of consumption in the country considered.

We could not trace the external water footprint of imported animal products at the grid level because of data limitations. The water footprint of livestock products is made up of two parts: local water use (local feed and service water used in the industry) and water used in the imported feed. No comprehensive global data sets are available to support tracing the origins of feed crops for different animal types.

When updating the water footprint of the crop products, it has been assumed that the average climatic condition (average over the period of 1969-1999) used in calculating the evapotranspiration in crop fields in the previous study (period 1996-2005) has remained unchanged. Due to improvements in agricultural practices and the use of better-yielding crop varieties, the crop production per hectare of land use has increased globally (FAOSTAT, 2022a). As a result, water use per unit of crop production has decreased. We've taken the average water footprint of crop production (m^3/t) for the period 1996-2005 and extrapolated this to the new period using the pro-rata changes in the crop yield per country in the new period (2000-2020). Basso and Ritchie (2018) found that the water use efficiency has increased over time because the grain yields have increased while water use has remained relatively constant. Similarly, Ali et al. (2018) evaluated different soil management practices and found adding wheat residue at 5 ton/hectare coupled with an irrigation of 350 mm increased soil water availability compared to no residue and increased grain yield by 62% and water use efficiency by 35%. They found that the presence of the wheat residue increased rainfall-use efficiency by 50% because of the reduced soil water evaporation. As the water use efficiency increases, the water footprint (unit of water used per unit of crop produced) decreases. By default, if the crop production per hectare of the land has remained the same in 2020 compared to the period 1996-2005, the water footprint (m^3/t) for that crop remains unchanged. It should be noted that this assumption ignores any changes in irrigation water use, and evaporative demand under different climatic conditions. A similar approach has been applied by Ercin *et.* al (2019) in analysing the vulnerabilities of EU economies due to their external water footprints.

2.5 VULNERABILITY AND RISK ASSESSMENT

The study by Ercin *et* al. (2019) for the period of 2006-2013, used drought risk maps developed by Gassert *et.* al. (2015) to assess the vulnerability of the external green water footprint of the EU. In this study, we've used the sustainability of the blue external WF (Mekonnen and Hoekstra, 2016) as a proxy indicator to highlight where these footprints pose risks due to growing competition, conflict, climate change impacts and other socio-economic factors.

2.5.1 SUSTAINABILITY OF THE BLUE WATER FOOTPRINT

Spatial and temporal variations in water demand and availability are significant, and this leads to water seasonal scarcity in many parts of the world. Mekonnen and Hoekstra (2016) calculated the monthly blue water scarcity per grid cell at a 30 × 30 arc minute resolution as the ratio of the local monthly blue water footprint to the total blue water availability in the same month and associated grid cell. They derived the average monthly blue water footprints at a 5 × 5 arc min resolution for the period 1996–2005 from Mekonnen and Hoekstra (2011) and these were aggregated to a 30 × 30 arc min resolution. The total monthly blue water availability in a grid cell is the sum of locally generated blue water in the grid cell and the blue water flowing in from upstream grid cells (Mekonnen and Hoekstra 2016). They also noted that the estimates of both monthly blue water footprint and monthly blue water availability per river basin can contain an error of ± 20 per cent.

In this study, we have used the four levels of blue water scarcity as defined by Richter *et.* al (2012), which are:

- Low blue water scarcity (<1): the blue water footprint is lower than 20% of natural runoff and does not exceed blue water availability; river runoff is unmodified or slightly modified; presumed environmental flow requirements are not violated.
- Moderate blue water scarcity (1–1.5): the blue water footprint is between 20 to 30% of natural runoff; runoff is moderately modified; environmental flow requirements are not met.
- Significant blue water scarcity (1.5–2.0): the blue water footprint is between 30 to 40% of natural runoff; runoff is significantly modified; environmental flow requirements are not met.
- Severe blue water scarcity (>2.0). The monthly blue water footprint exceeds 40% of natural runoff; runoff is seriously modified; environmental flow requirements are not met.

Figure 4 shows the annual average monthly blue water scarcity at 30x30 arc minutes (Hoekstra and Mekonnen, 2016). The green-coloured grid cells are not water scarce on annual basis, whereas the darker the red colour, the higher the degree of blue water scarcity in these cells.

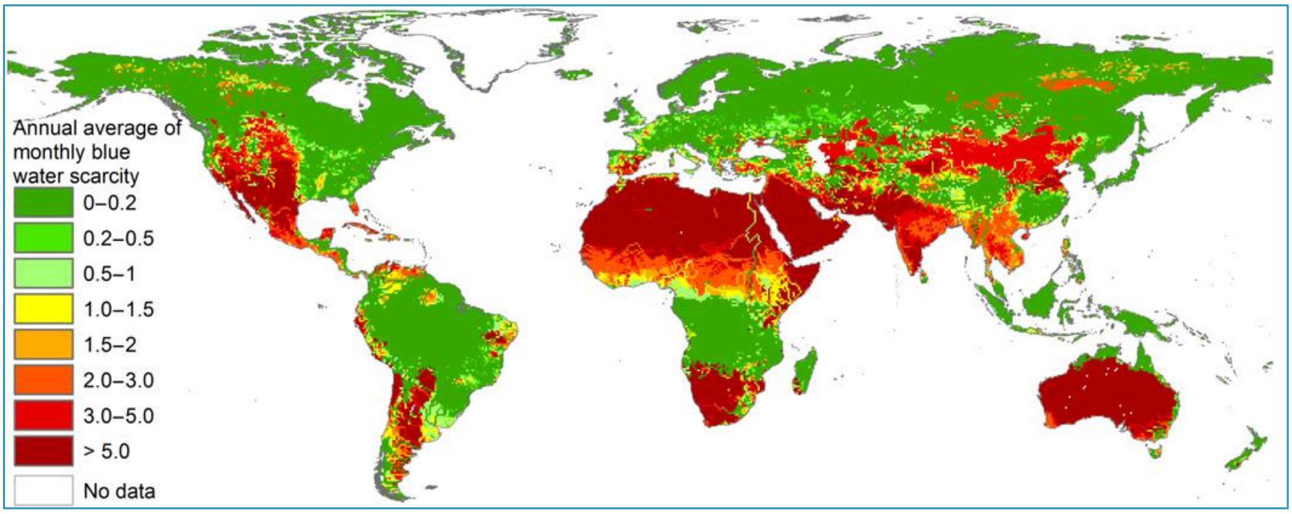


Figure 4. Annual average of monthly blue water scarcity. Source: Hoekstra and Mekonnen, 2016.

Due to limitations in data availability, the annual water withdrawal figures from AQUASTAT were distributed equally over the twelve months of the year, and withdrawals and use for industrial and domestic sectors were assumed to be constant throughout the year. However, the blue water footprint in agriculture varies from month to month depending on the timing and intensity of irrigation (Mekonnen and Hoekstra, 2012). Similarly, natural runoff and blue water availability vary across basins and over the year.

Establishing the sustainability of the blue water footprint is based on the method presented by Hoekstra *et.* al (2012). The external blue water footprint maps are overlaid on the blue water scarcity maps, and depending on the level of blue water scarcity, and the sustainability of the blue water footprint in those locations is derived accordingly.

2.5.2 DEFINING BLUE WATER SCARCITY

A note from Hoekstra *et.* al, 2012

Following Hoekstra *et al*, (2011), the blue water scarcity in a river basin in a certain period is defined as the ratio of the total 'blue water footprint' in the river basin in that period to the 'blue water availability' in the catchment and that period.

Tharme (2003) found at least 207 individual methodologies for setting environmental flow requirements, across six main types in use for 44 countries. Hydrology-based methods constituted the highest proportion of the recorded methodologies, followed by habitat simulation methodologies. The Presumptive Environmental Flow (PEF) requirement approach is based on the notion that there is a minimum flow required to maintain the ecological health of a river or stream, and to maintain key services for downstream communities, and that this flow can be determined through the study of historical flows, the ecology of the river or stream, and the impacts of human activities on the flow regime. It can be calculated by using a combination of historical data, ecological information, and hydrological models to estimate the flow required to maintain the ecological integrity of the river or stream. The PEF has been used as a guideline for setting minimum flow requirements for water management and allocation where such detailed data is unavailable. Hoekstra *et.* al, (2012) established 80% of the total natural runoff as the PEF value when calculating and mapping blue water scarcity (Figure 4).

Monthly runoff data at a 30 by 30 arc minute resolution were obtained from the Composite Runoff V1.0 database (Fekete *et.* al, 2002). These data are based on model estimates calibrated against runoff measurements for different periods, with the year 1975 as the mean baseline year. To arrive at the natural runoff, they added the aggregated blue water footprint per basin as in 1975.

The monthly blue water availability within a river basin for a certain period has been calculated as the 'natural runoff' in the basin minus the 'environmental flow requirement'.

In Figure 4, if the area is green (water scarcity <1.0) it implies that less than 20% of the available blue water flow (total natural runoff) in that grid cell is being used. However, if the water scarcity level is >5.0, the blue water footprint exceeds or equals the available blue water flows (driving widespread drying of rivers and aquifers, and mining of fossil groundwater). The area shaded from light yellow to dark red, represents an increasing level of blue water scarcity, and the severity of unsustainable water use.

2.6 DATA AND LIMITATIONS OF THE STUDY

2.6.1 DATA SOURCES

The various data sources and the period used in the study are presented in the following Table 1.

Table 1. Key data sources and period.

Data type	Reference/source	Period
Water footprint of crop and livestock production	Hoekstra and Mekonnen (2011, 2012)	1996-2005
International trade data (agricultural and Industrial products)	COMTRADE	2000-2020
Crop and livestock production	FAOSTAT (2022a)	2000-2020
Blue water withdrawal per sector (national data)	FAOSTAT (2022b)	2000-2020
Blue water scarcity	Mekonnen and Hoekstra (2016)	1996-2005
Reference evapotranspiration 10 arc minutes	FAO (2008b)	1969-1999
Population	FAOSTAT (2022b)	2000-2020

2.6.2 LIMITATIONS

The accuracy and validity of calculations of international virtual water flows and water footprints are dependent on the availability and quality of data used to establish these accounts. Whilst our analyses are considered to present a valid macro-level view of global water footprints and virtual water flows, there are limitations to the data that should be considered when interpreting the findings and when undertaking future studies. Key considerations and issues concerning these databases are set out here.

Industrial and domestic water withdrawal data

The FAOSTAT database on industrial water withdrawal and domestic water use per country is incomplete (FAOSTAT, 2022b). Most countries lack a complete dataset for all years. For countries where data are available only intermittently, a linear trend in withdrawals has been assumed between two known dates and data is extrapolated for missing years.

Crop production data

Data on the crop production area, irrigated area, production volumes, crop yields, and water withdrawals are based on national-level data made available through FAOSTAT. This is the only comprehensive database available with the requisite global coverage. However, there is a risk of variation in accounting methods, data reporting formats, and reporting periods across databases. This study has applied logic to handle errors and clean the data on a case-by-case basis to enable use of these databases where validation using other sources is not possible. Errors in the calculations may arise because of aggregation or disaggregation of products and by-products, outdated irrigation databases, sporadic availability of water withdrawal data per sector, double counting in feed and crop balance sheets in some cases etc. Cross-checking- with other national databases has been undertaken where these are available (EUROSTAT), but due to the complexity and the size of the database, manual scrutiny may fail to capture some errors and inaccuracies. Annual water footprint and virtual water flows can also be averaged over 5-year periods to support the identification of broad trends irrespective of data errors and outliers within individual years.

International trade data

Trade data is drawn from UN COMTRADE - the United Nations International Trade Statistics Database. It is the largest available depository of international trade data containing over 5 billion data records starting in 1962 and is publicly available on the internet. Data are derived from national reports of imports and exports by volume which are used to establish taxation and tariffs, and these data are used extensively for statistical analysis of international trade and to support policy making e.g. UNSD (conflict in Ukraine and trade), FAO (Food Security), UNCTAD (economic analysis and policy formulation, disseminated through UNCTAD's annual flagships reports (e.g. the Trade and Development Report, the World Investment Report, the Least Developed Countries Report, Economic Development in Africa Report, the Commodities and Development Report etc.), World Bank etc. One challenge is that the categorisation and structure of the trade data in COMTRADE (aggregation and disaggregation of the products traded) have changed several times over the period selected (2000-2020). The cleaning and processing of this data has used filters to automate the process as there are millions of data points, supported by manual cross-checking for significant anomalies. However, it is possible that smaller errors may not have been identified. As an example of the types of error seen, a country may report exports of bovine leather greater than its total production and imports. Such anomalies have been identified manually where they involve orders of magnitude, which likely result from switching the units of measurement between years e.g. converting from kilograms to tonnes. Uncertainty also arises where imports reported by one country do not coincide with exports reported by its trading partner. Identifying such outliers can be difficult as the values of the reported commodity data do not necessarily sum up to the total trade value for a given country. Additionally, some data is considered confidential and countries may not report details of trade concerning commercially or militarily sensitive topics.

2.6.3 BLUE WATER SCARCITY AND SUSTAINABILITY METHOD AND DATA

The monthly blue water scarcity (Mekonnen and Hoekstra, 2016) has been calculated based on irrigation maps for the base period of 2005 available from FAO's AQUASTAT (which includes a global map of irrigated areas). It is assumed that the area equipped for irrigation has remained the same as in the original studies, and that water use in irrigation has not changed in the new period. The current sustainability analysis does not reflect any change in blue water scarcity in the new period. While the blue water footprint in agriculture varies from month to month depending on the timing and intensity of irrigation, the domestic water supply and industrial production were assumed to remain constant throughout the year. As the water footprint of national production cannot be calculated on a month-by-month basis, the alignment of actual water scarcity and water use (blue water footprint) can be problematic. The blue water scarcity could be higher than estimated in this study as maximum irrigation demand most often coincides with hot and dry seasons, when water availability in rivers, lakes and groundwater will tend to be at its lowest.

Establishing the sustainability of the blue water footprint is based on the method presented by Hoekstra *et.* al (2012) which presumes that only 20% of total blue water flow is available for human consumption, and that the remaining 80% is presumed to be the environmental flow requirement. This method determines unsustainable use to be any use over 20% of natural flows. There are two major considerations in this assessment. Firstly, different locations will have different environmental flow requirements based on ecosystem requirements and contextually determined downstream flow needs. Secondly, it has been argued that setting a 'hands off' flow of 80%, with only 20% of flows allocated for human use may set the bar too high for some water-scarce contexts. However, Mekonnen and Hoekstra (2016) found that global water scarcity levels are not very sensitive to the Environmental Flow Requirement (EFR). For example, if the EFR is assumed to be 60% instead of 80%, the number of people living in water scarcity area at least 1 month in a year would still be 4.0 billion compared to the

4.3 billion based on the higher EFR assumption. Hence, in the absence of reliable data based on the local context, we maintain that the method is useful and valid in highlighting the risks of unsustainable abstraction.

It is important to note that these high-level assessments of sustainability should be considered as guidance only rather than unequivocal judgements of the status of water used in production. Conclusive statements regarding the sustainability of a water footprint will always require locally verified (ground-truth) data which considers the context and temporal nature of impacts. For example, it would be possible for water use within a water footprint landing in a scarce water location to be sustainable where there is carefully managed abstraction in line with the sustainable hydrological yield and the needs of downstream ecosystems and users, or seasonal water storage. Equally, water footprints falling outside of water scarce regions can be wholly unsustainable through multiple impact pathways - over abstraction, uncontrolled pollution etc. Furthermore, the Hoekstra *et.* al (2012) method doesn't consider what happens during drought or flood events, account for disturbance to habitats, water conflict or access to WASH. Nevertheless, as an entry point and screening exercise to understand where the risks of unsustainability are greatest, the approach remains useful.

3 WATER FOOTPRINT AND VIRTUAL WATER FLOWS OF 'GLOBAL NORTH' ECONOMIES

This section explores the water footprint of production for selected Global North economies, the virtual water imports and exports related to the international trade of industrial and agricultural products, and the internal and external water footprint of national consumption for the selected countries.

For detailed results and tabulated data, please see the Appendix of Excel files detailed in Table 2.

Table 2. Description of the Excel files for the complete set of results of this study.

Result description	Excel file	Remarks
Detail virtual water import/export per country and product	*VWflows_CropLivestockInd_2000_2020.xlsx*	There are 3 tabs in this file for virtual water import and export per country for 3 categories: crop, livestock, and industrial products
Time series results:		
- Virtual water flows time series (2000-2020)	*VWflows_CropLivestockInd_2000_2020.xlsx*	Time series data on virtual water flows for crop, livestock and industrial products
- Water Footprint of consumption time series (2000-2020)	*Countries_WF*	Tab: WF_consumption
- 5-year average for all countries	*Countries_WF*	Tab: WF_consumption_5yearAvg
- 5-year average for Global North countries	*Countries_WF*	Tab: WF_consumption_globalNorth
Disaggregation of WF by sector	*Countries_WF*	Tab: WF_consumption_perCrop2

3.1 WATER FOOTPRINTS OF PRODUCTION FOR THE GLOBAL NORTH

The average annual water footprint of production in the selected Global North economies is presented in Table 3. This figure represents the total water used in the production of goods and services within national boundaries. A portion of this is consumed by the inhabitants of the nation, and the remaining part is exported.

Table 3. The average annual water footprint of production of the Global North countries. Mm^3/year. (Period: 2016-2020)

Country/ group	Water footprint related to crop production + livestock				Water footprint related to domestic water supply			Water footprint related to industrial production		
	Green	Blue	Grey	Total	Blue	Grey	Total	Blue	Grey	Total
Austria	5370	203	656	6230	72	296	368	135	179	313
Canada	107112	1305	17968	126385	1079	4041	5120	1894	10186	12081
Denmark	6033	561	1077	7671	39	80	119	2	6	8
Finland	2985	91	90	3166	40	111	151	90	326	416
France	58501	3382	10440	72322	557	1788	2345	968	3677	4644
Germany	39370	1960	10278	51608	586	1400	1985	1610	1529	3139
Italy	33801	4121	4085	42007	941	4355	5296	383	2258	2642
Japan	15016	2677	1845	19539	1455	5057	6512	548	3437	3986
Netherlands	4284	841	752	5877	186	157	343	307	58	366
Sweden	3849	132	748	4729	98	219	316	69	184	253
Switzerland	2435	109	393	2937	97	247	344	32	18	51
UK	18258	827	4022	23107	617	1037	1654	50	24	74
USA	565819	70991	103307	740117	5868	52816	58684	10569	200814	211384
EU27	360710	33157	54573	448439	4095	14982	19076	5254	19821	25076
Global North	862833	87198	155663	1105695	11635	71603	83239	16659	222698	239357

3.2 TOTAL VIRTUAL WATER IMPORT BY GLOBAL NORTH ECONOMIES

Total virtual water flows related to international trade of agricultural (crop and livestock) and industrial products are presented in Table 4 for the selected Global North economies. Net virtual water imports are calculated by subtracting the virtual water export from the import.

Table 4. Average annual virtual water flow related to agricultural and industrial products (Mm3/year). Period 2016-2020.

Country/group	Import				Export				Net = Import-Export			
	Green	Blue	Grey	Total	Green	Blue	Grey	Total	Green	Blue	Grey	Total
Austria	9847	988	2359	13194	6197	583	837	7616	3651	405	1522	5578
Canada	20097	2018	5025	27140	83437	1046	14919	99402	-63340	972	-9894	-72262
Denmark	9192	784	1442	11418	7426	745	1178	9348	1766	39	264	2069
Finland	2594	294	618	3506	1279	107	223	1608	1316	188	395	1898
France	52098	6134	6047	64279	55925	5591	8833	70349	-3828	543	-2785	-6070
Germany	97134	7985	13253	118372	53048	4234	9414	66696	44086	3751	3839	51676
Italy	65876	7033	9663	82572	21658	2776	2705	27139	44218	4257	6958	55433
Japan	79012	4346	10473	93831	893	204	496	1593	78120	4142	9976	92238
Netherlands	93519	3722	7352	104593	59083	3397	3379	65859	34436	325	3972	38734
Sweden	8359	743	1368	10470	2630	201	494	3326	5729	542	874	7144
Switzerland	9532	803	2103	12438	6859	168	1233	8260	2673	635	870	4178
UK	44475	5844	6830	57149	12087	1117	1747	14950	32389	4727	5083	42199
USA	153145	10604	17835	181584	192022	27028	49987	269037	-38876	-16425	-32152	-87453
EU27	273709	18894	33492	326095	108881	15345	17385	141611	164828	3549	16107	184484
Global North*	460151	35617	52418	548186	317812	31516	63496	412823	142339	4101	-11078	135363

**Note: The sum of imports or exports of individual countries in the group 'Global North' is not equal to the total import or export by the 'Global North countries' as there is trade between countries within each group.*

3.3 WATER FOOTPRINT OF CONSUMPTION OF GLOBAL NORTH ECONOMIES

The average water footprint of consumption has been calculated for the selected Global North economies for the 2016-2020 and the results are presented in Table 5 separated by external water footprint, internal water footprint and type (blue, green and grey water footprint).

Table 5. The average annual water footprint of consumption – Global North and EU 27 (Mm^3/year). Period 2016-2020.

Country	Water footprint of national consumption				External water footprint of national consumption					Internal water footprint of national consumption				
	Green	Blue	Grey	Total	Green	Blue	Grey	Total	% of total WF	Green	Blue	Grey	Total	% of total WF
Austria	9021	814	2653	12489	5838	543	1765	8145	**65%**	3184	271	889	4343	35%
Canada	43772	5250	22303	71325	6915	1544	2593	11052	**15%**	36857	3707	19709	60273	85%
Denmark	7799	642	1427	9868	4708	362	848	5918	**60%**	3090	280	579	3950	40%
Finland	4300	409	922	5631	2000	235	488	2722	**48%**	2301	174	433	2909	52%
France	54673	5450	13119	73242	25754	2746	3425	31925	**44%**	28919	2704	9694	41317	56%
Germany	83456	7906	17046	108408	59386	4877	8556	72819	**67%**	24070	3030	8490	35589	33%
Italy	78019	9703	17657	105378	51562	5342	8051	64955	**62%**	26456	4361	9605	40423	38%
Japan	93136	8822	20316	122274	78262	4242	10220	92725	**76%**	14874	4580	10096	29549	24%
Netherlands	38720	1660	4940	45319	37024	1085	4352	42462	**94%**	1696	575	587	2858	6%
Sweden	9578	841	2024	12443	6558	587	1088	8233	**66%**	3020	254	937	4210	34%
Switzerland	5109	873	1576	7557	4069	659	1311	6039	**80%**	1040	214	265	1518	20%
UK	50647	6221	10166	67035	35906	4871	5855	46632	**70%**	14741	1350	4312	20402	30%
USA	526943	71004	324785	922732	112243	7257	13165	132665	**14%**	414700	63747	311620	790066	86%
EU27	525537	46055	105483	677075	226734	13739	28147	268620	**40%**	298803	32316	77336	408455	60%
Global North*	1005172	119594	438934	1563700	349612	27054	41995	418661	**27%**	655561	92540	396939	1145039	73%

**Note: As the external WF of individual Global North countries also falls within other members of the Global North group, the total external WFs of individual Global North country does not equal the total external WF of the collective Global North countries.*

3.4 MAPPING THE EXTERNAL WATER FOOTPRINT OF GLOBAL NORTH ECONOMIES

In general, there is a trend of increasing dependency on external water footprints in comparison to the total green, blue and grey water footprint of the Global North countries during the study period. For the Global North countries, the external water footprint as a proportion of the total has increased from 23% (period 2001-2005) to 27% (period 2016-2020). The average annual share of external water use for the EU27 countries remained at 40% during 2001-2020. The increase in the share of the total external water footprint for the individual countries, ranked in the decreasing order, are Sweden (6.8%), Austria (5.8%), Italy (5.3%), Germany (4.6%), USA (4.3%), Switzerland (4%), Netherlands (2.4%), and Denmark (0.5%). However, proportional dependency has declined marginally for France (-0.5), Japan (-0.5%) Finland (-2.5%), UK (-2.8%) and Canada (-4.9%). Although the growth trend may not seem very high, external footprints already represent a significant portion of the total water footprint for most countries (more than 40%) except for the USA (12%) and Canada (18%). These percentages should be considered alongside the absolute volume of the external water footprint. For example, the USA has the largest external footprint by volume of all countries studied despite this only representing 14% of national needs.

Trends in the share of the external WF to the total WF of consumption are presented in Table 6.

Table 6: Share of external water footprint to the total water footprint of consumption.

Share of the external water footprint to the total water footprint of consumption (5-year average)				
	2001-2005	2006-2010	2011-2015	2016-2020
Austria	59%	64%	64%	65%
Canada	20%	20%	16%	15%
Denmark	59%	62%	59%	60%
Finland	51%	52%	51%	48%
France	44%	45%	44%	44%
Germany	63%	67%	67%	67%
Italy	56%	58%	59%	62%
Japan	76%	75%	74%	76%
Netherlands	91%	92%	93%	94%
Sweden	59%	63%	65%	66%
Switzerland	76%	78%	78%	80%
UK	72%	72%	68%	70%
USA	10%	11%	12%	14%
EU27	40%	40%	38%	40%
Global North	23%	24%	25%	27%

The average annual water footprint of consumption (total water footprint including green, blue and grey) is mapped for the Global North countries (Figure 5) and the EU27 (Figure 6). Figure 7 to Figure 19 present the total water footprint (agriculture, industry, domestic) of the individual Global North economies.

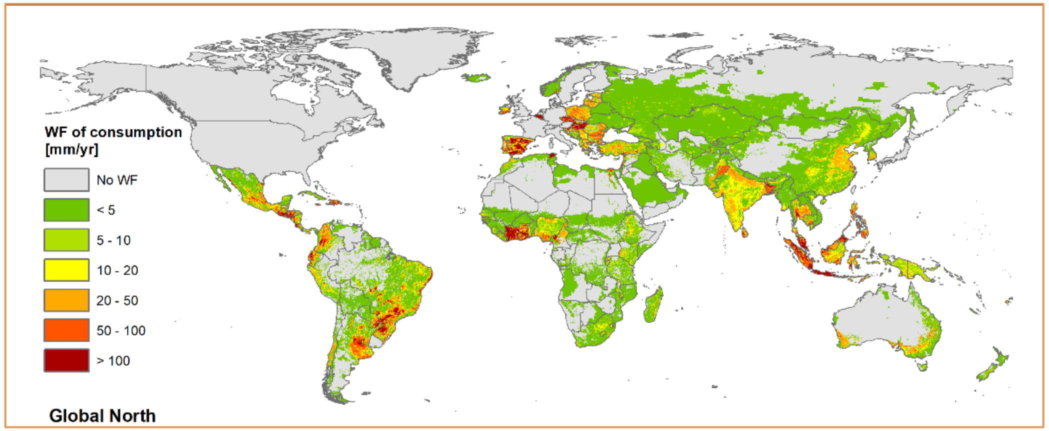


Figure 5. External water footprint of consumption of the Global North countries

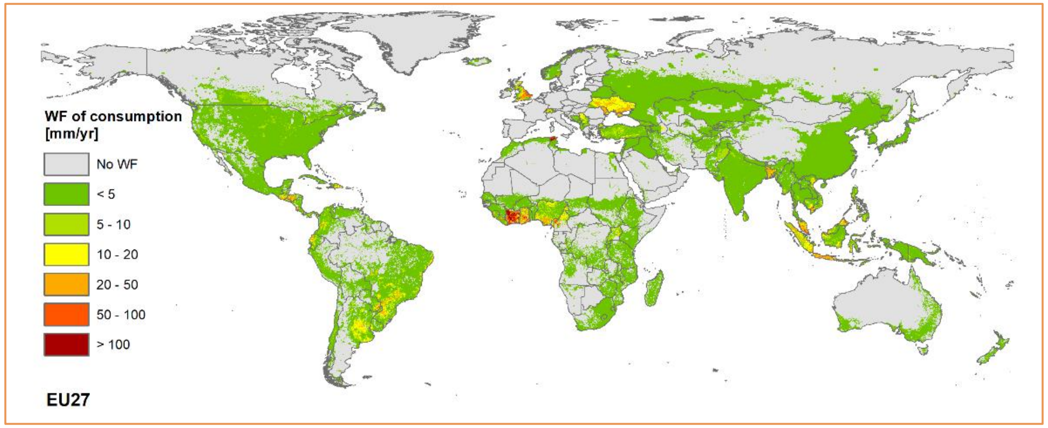


Figure 6. External water footprint of consumption of the EU27 countries

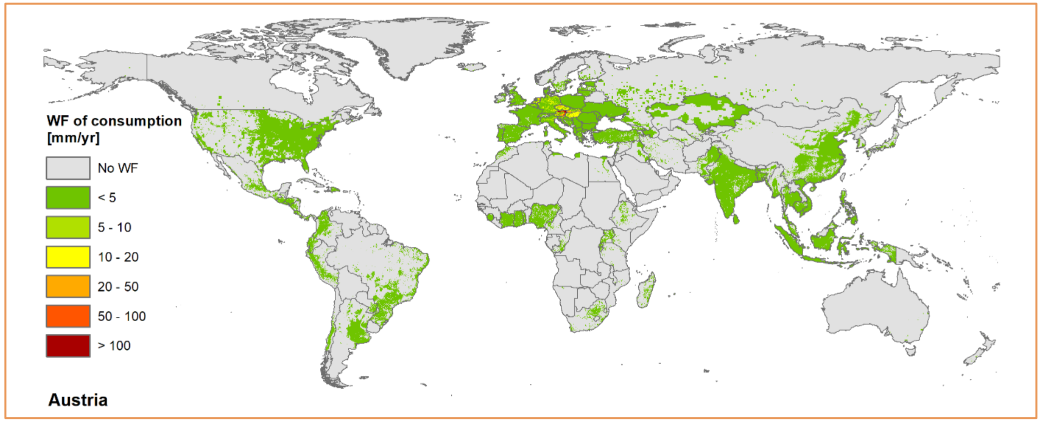


Figure 7. Total water footprint (agriculture, industry, domestic) of consumption of Austria

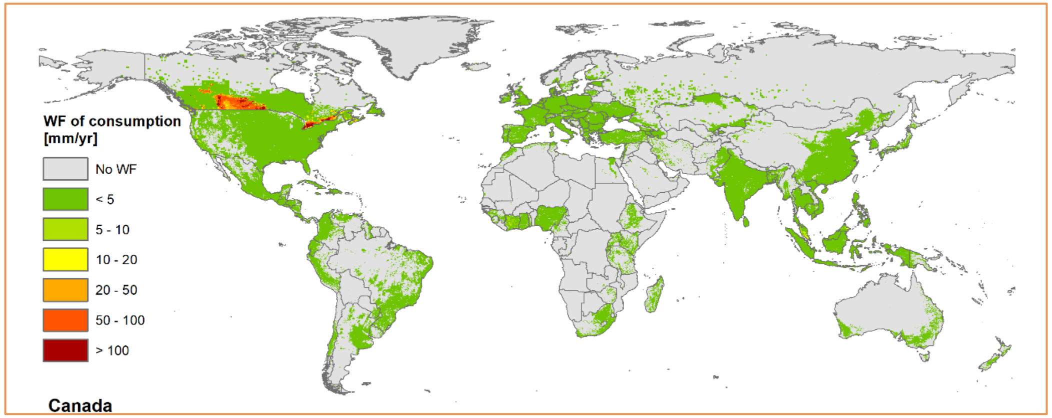


Figure 8. Total water footprint (agriculture, industry, domestic) of consumption of Canada

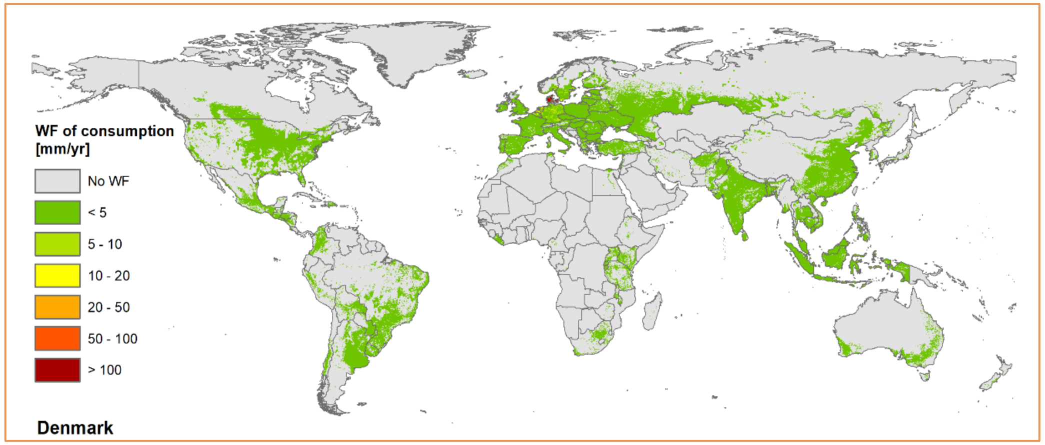


Figure 9. Total water footprint (agriculture, industry, domestic) consumption of Denmark

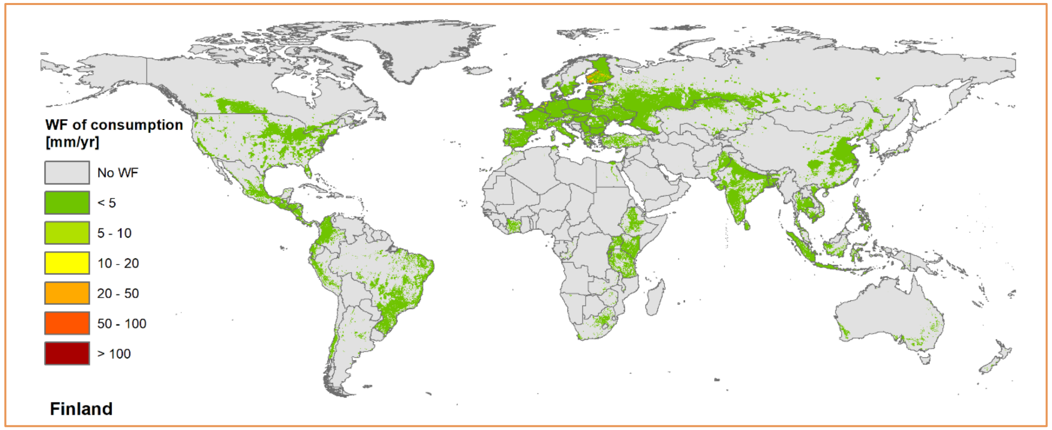


Figure 10. Total water footprint (agriculture, industry, domestic) of consumption of Finland

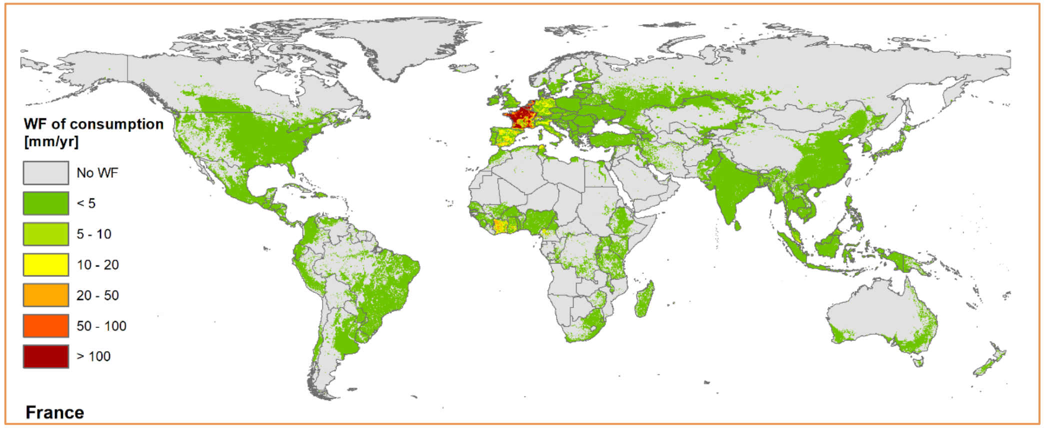


Figure 11. Total water footprint (agriculture, industry, domestic) of consumption of France

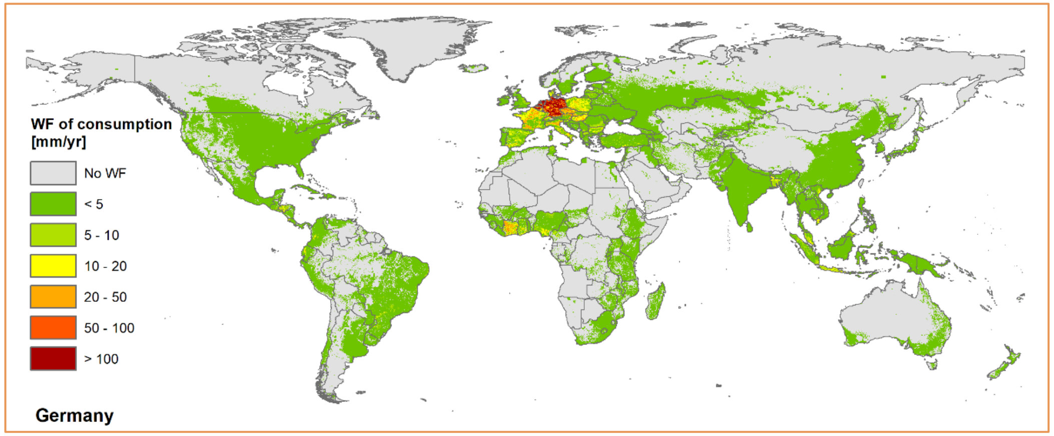


Figure 12. Total water footprint (agriculture, industry, domestic) of consumption of Germany

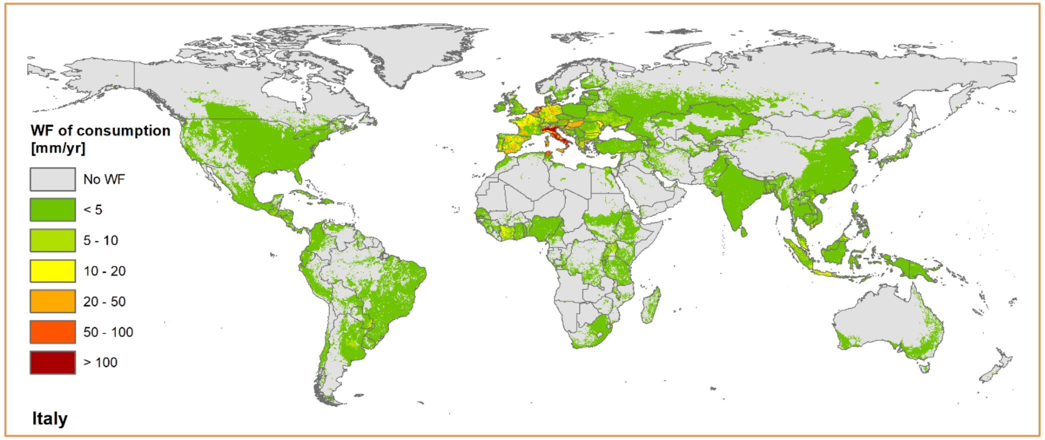


Figure 13. Total water footprint (agriculture, industry, domestic) of consumption of Italy

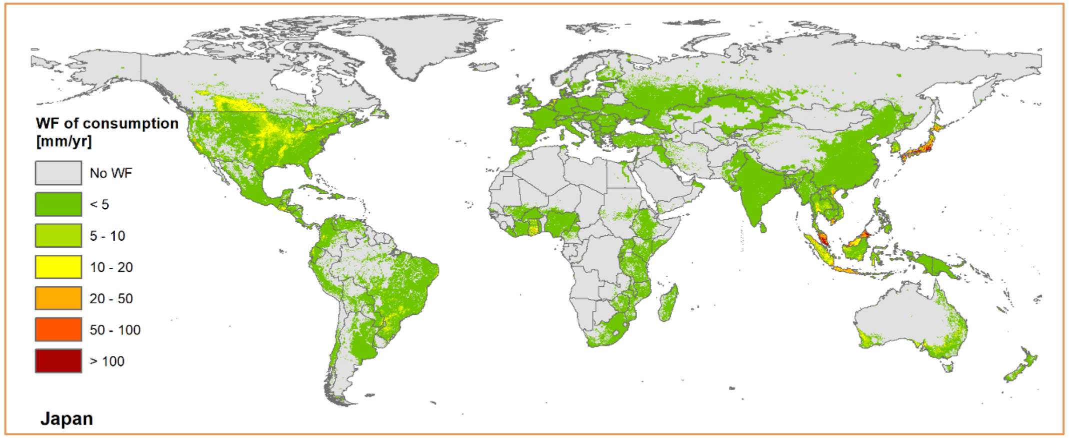


Figure 14. Total water footprint (agriculture, industry, domestic) of consumption of Japan

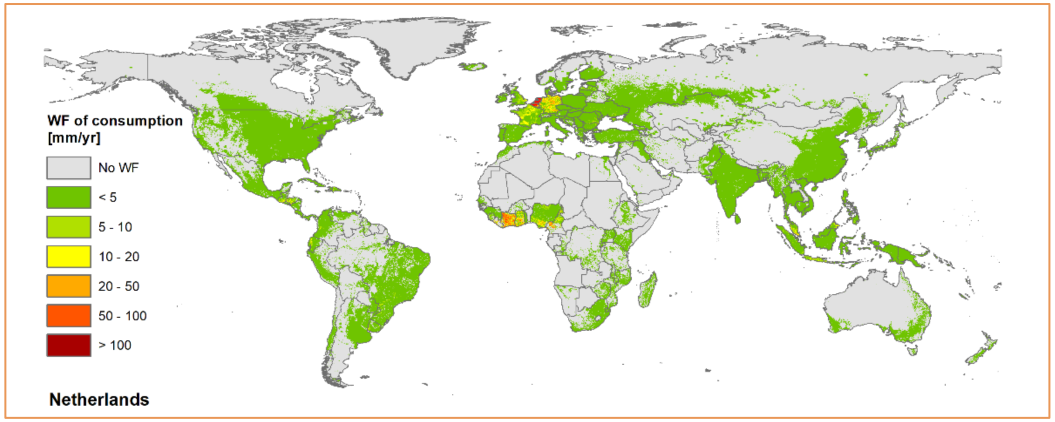


Figure 15. Total water footprint (agriculture, industry, domestic) of consumption of the Netherlands

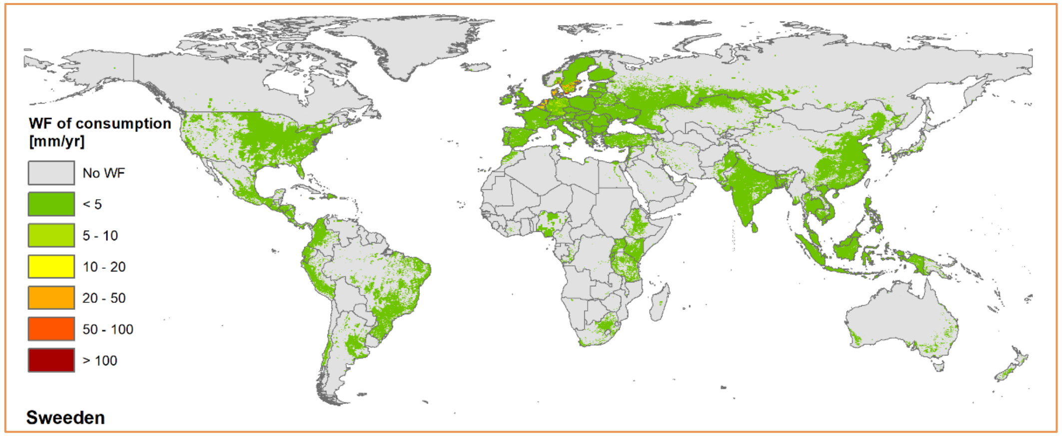


Figure 16. Total water footprint (agriculture, industry, domestic) of consumption of Sweden

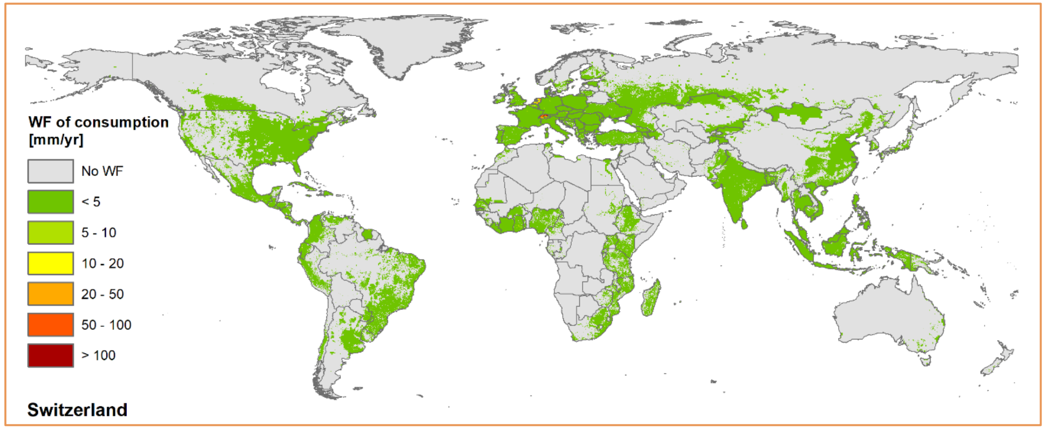


Figure 17. Total water footprint (agriculture, industry, domestic) of consumption of Switzerland

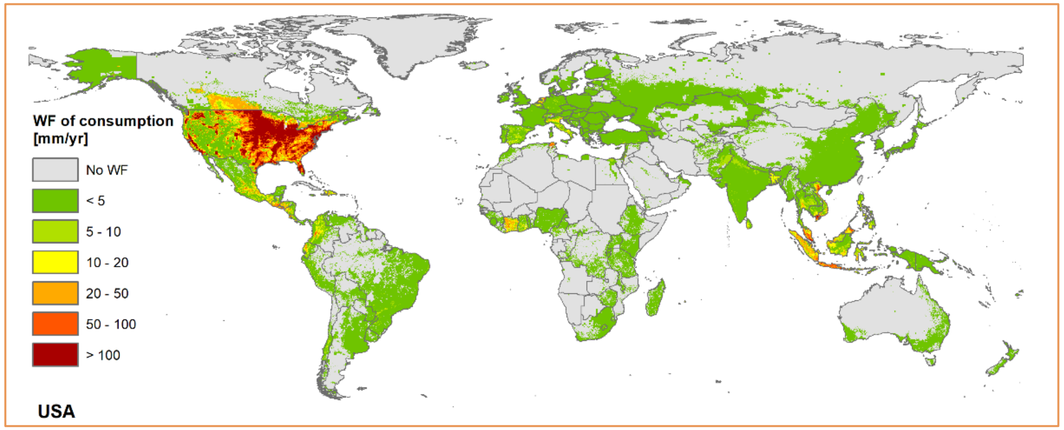


Figure 18. Total water footprint (agriculture, industry, domestic) of consumption of the USA

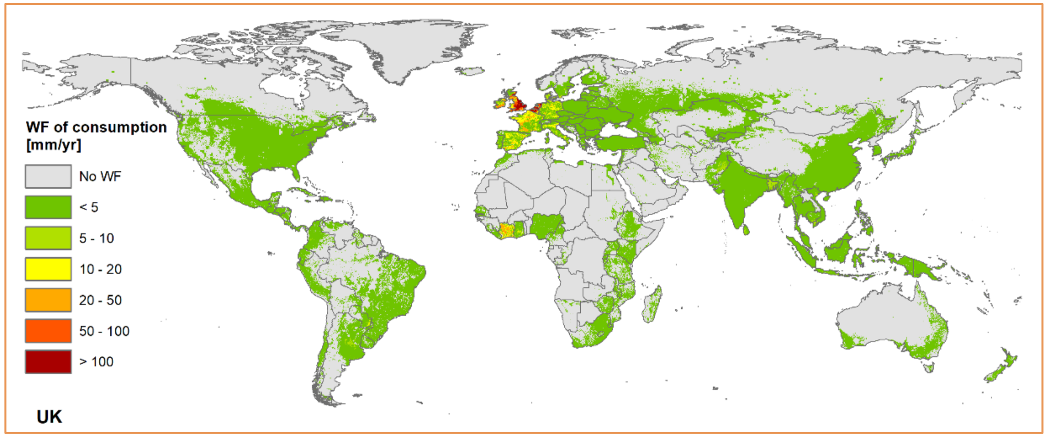


Figure 19. Total water footprint (agriculture, industry, domestic) of consumption of the UK

3.5 Sustainability Assessment

The results of the sustainability assessment of the external blue water footprint of the 'Global North' are presented here, together with a list of key agricultural products and regions where these footprints originate.

3.5.1 SUSTAINABILITY OF THE EXTERNAL BLUE WATER FOOTPRINT OF GLOBAL NORTH COUNTRIES

Applying the water footprint methodology, the blue component of the water footprint is considered to be unsustainable when it exceeds the volume of renewable blue water which is available locally, thereby violating the environmental flow standard and depleting groundwater. The study uses the sustainability of the external blue WF as a proxy indicator to highlight where these footprints are vulnerable to, and likely to exacerbate water conflict, resource depletion and degradation and climate impacts. Hoekstra and Mekonnen (2016) found that during 1996-2005, 52% of the blue WF of global consumption originates in locations where the blue WF exceeds the available blue water and infringes on the environmental flow requirement.

Building on their approach, we further characterise those locations where the external blue water footprints of the Global North countries land depending on the severity of blue water scarcity they face. To achieve this, we mapped the external blue water footprint of the Global North countries and overlayed these with the global blue water scarcity maps to identify locations. As the global average water footprint increases in line with economic activity, population growth, and changing consumption habits, there is also an upward trend in the share of the blue water footprints of consumer societies landing in regions with greater levels of blue water scarcity.

The shares of the annual average external blue water footprint of the Global North countries landing in water scarce regions are summarised in Table 7.

Table 7. The share of the annual average external blue water footprint of the Global North countries. Period: 2016-2020.

Country	External water footprint of national consumption, Mm³/year			Unsustainable part of the external blue WF	Share of unsustainable part in the external blue WF	Distribution of unsustainable blue per level of blue water scarcity*		
	Grey	Green	Blue			Moderate WS	Significant WS	Severe WS
Austria	1765	5838	543	129	23.8%	12.9%	9.3%	77.4%
Canada	2593	6915	1544	860	55.7%	10.2%	9.5%	80.2%
Denmark	848	4708	362	94	25.9%	12.0%	7.1%	80.6%
Finland	488	2000	235	60	25.6%	12.4%	9.0%	78.3%
France	3425	25754	2746	1228	44.7%	7.1%	7.8%	85.0%
Germany	8556	59386	4877	1897	38.9%	9.9%	9.2%	80.7%
Italy	8051	51562	5342	2039	38.2%	10.1%	8.9%	80.7%
Japan	10220	78262	4242	2577	60.7%	10.2%	10.4%	79.3%
Netherlands	4352	37024	1085	401	37.0%	13.4%	10.4%	76.1%
Sweden	1088	6558	587	161	27.5%	10.4%	7.9%	81.3%
Switzerland	1311	4069	659	226	34.3%	14.4%	10.1%	75.1%
UK	5855	35906	4871	1930	39.6%	8.5%	6.7%	84.7%
USA	13165	112243	7257	3510	48.4%	4.7%	4.7%	90.4%
EU27	28147	226734	13739	7199	52.4%	7.7%	8.3%	84.0%
Global North	41995	349612	27054	13501	49.9%	6.1%	6.6%	87.3%

**Note: for the explanation of the level of blue water scarcity, please see 'Section – Method and Data'.*

Half of the external blue water footprint (50%) of the Global North countries can be traced back to the areas with moderate to severe blue water scarcity. There is variation in the share of the unsustainable external blue water footprint of individual Global North countries: Japan (61%), Canada (56%), France (45%), USA (48%), UK (40%), Germany (39%), Italy (38%), Switzerland (34%), Netherlands (37%), Sweden (27%), Denmark (26%), Finland (26%), and Austria (24%). Collectively for EU27 countries, the share of unsustainable external blue WF is 52%.

Though the share of unsustainable external blue water footprint of a country is important information for national policymaking concerning trade and water, for a global discussion, it is also important to understand the size of these footprints. For example, among the Global North countries, 48% of the USA's external blue WF is assessed as unsustainable and for Canada, 56%. As the total external blue WF for the USA is 7,257 Mm^3/year compared to 1,544 Mm^3/year for Canada, the unsustainable blue WF of the USA (3,510 Mm^3/year) is significantly bigger than that for Canada (860 Mm^3/year).

Understanding the unsustainable component of the external water footprints and where they land is a crucial piece of information, it is also important to be able to trace which products and agencies are responsible for these virtual water flows to develop strategies for more resilient supply chains, and sustainable production and consumption. For example, about 87% of the unsustainable external blue water footprint of the Global North countries are in Spain (24.7%), Pakistan (15.5%), Mexico (14.1%), India (11.8%), Turkey (7.2%), China (7.1%), Egypt (2.3%), Greece (1.4%), Thailand (1.3%), Kazakhstan (1.2%). The top-30 key products and sectors related to the total unsustainable blue WF are: cotton (35.2%), olives (9.6%), citrus fruit (9%), rice (6.6%), barley (3.9%), sugarcane (3.6%), grapes (3.5%), soybean (3.1%), industrial products (2.5%), castor beans (2%), Hazelnuts (1.9%), Avocados (1.4%), Linseed (1%), Almonds (1%), Sunflower (1%), Maize (0.9%), Banana (0.9%), Peppers/pimento (0.8%), Mangoes (0.7%), Fresh fruit (0.7%), Wheat (0.7%), Fresh vegetables (0.7%), Nuts (0.6%), Tea (0.6%), Apples (0.5%), Pistachios (0.5%), Asparagus (0.5%), Peaches/nectarines (0.5%), and Tobacco (0.5%).

A list of the top 20 countries where the unsustainable component of the external blue water footprint is located for each Global North economy and the major crops and their share of the total unsustainable external blue water footprint is presented in Table 8. For the full list of countries, and crops, please see Appendix 'Countries_WF.xls' file.

Table 8: Top-20 countries where the unsustainable component of the external blue water footprint is located, and the major crops and their shares to the total external blue water footprint.

Country	Major countries where the unsustainable blue WF is located	Major crops
Austria	Pakistan-16.5%; Spain-16.5%; Turkey-11.5%; USA-9.6%; Italy-9%; India-6.6%; China-3.5%; Kazakhstan-3.4%; Greece-2.3%; Israel-2%; Egypt-2%; Hungary-1.9%; Germany-1.6%; France-1.5%; Turkmenistan-1.2%; Romania-1.1%; Morocco-1.1%; Mexico-1.1%; Chile-0.8%; South Africa-0.7%	Cotton-39.8%; Industrial products-14.6%; Olives-5.2%; Almonds-3.6%; Rice-3.4%; Citrus fruit nes-3.2%; Grapes-2.5%; Hazelnuts (filberts)-2.1%; Oranges-2.1%; Linseed-2%
Canada	USA-62.8%; Mexico-6.7%; India-6.6%; Pakistan-4%; Spain-2.9%; China-2.7%; Turkey-2%; Thailand-1.2%; Egypt-1.1%; Argentina-1.1%; Italy-1%; Australia-0.9%; Iran-0.8%; South Africa-0.7%; Peru-0.5%; Morocco-0.5%; Tunisia-0.4%; Israel-0.3%; Costa Rica-0.3%; Greece-0.3%	Rice-11.8%; Cotton-10.6%; Almonds-8.9%; Soybean-7%; Grapes-5.7%; Maize-5.2%; Sugarcane-5.1%; Olives-4.4%; Industrial products-4.4%; Wheat-2.7%
Denmark	Pakistan-19.2%; USA-14%; Spain-13.6%; Turkey-12.8%; China-9.4%; India-8.3%; Italy-3.5%; Russian Federation-2.1%; South Africa-1.9%; France-1.9%; Australia-1.6%; Germany-1.6%; Argentina-1.4%; Ukraine-1.1%; Netherlands-1%; Iran-0.9%; Egypt-0.8%; Belgium-0.6%; Greece-0.5%; Sweden-0.5%	Cotton-39.7%; Industrial products-13.1%; Almonds-9.2%; Grapes-9.1%; Rice-5.4%; Soybean-4.7%; Maize-2.7%; Olives-2.6%; Citrus fruit nes-1.8%; Oranges-1.3%
Finland	Spain-33.5%; USA-9.4%; Pakistan-8.8%; Turkey-7.4%; India-6%; China-4.8%; Italy-3.7%; Egypt-2.9%; South Africa-2.1%; Russian Federation-1.8%; France-1.6%; Costa Rica-1.5%; Australia-1.3%; Israel-1.2%; Greece-1.2%; Kazakhstan-1.2%; Germany-1%; Mexico-1%; Portugal-1%; Argentina-1%	Cotton-23.1%; Rice-14.3%; Industrial products-12%; Grapes-10.5%; Citrus fruit nes-5.6%; Olives-5.3%; Oranges-5.2%; Almonds-2.2%; Banana-1.7%; Avocados-1.4%
France	Spain-53.7%; Pakistan-10.2%; India-8.2%; USA-5.2%; Turkey-4.9%; Morocco-2.9%; China-2.7%; Italy-2.4%; Portugal-1%; Egypt-1%; Israel-0.8%; South Africa-0.6%; Thailand-0.6%; Kazakhstan-0.5%; Tunisia-0.5%; Mexico-0.4%; Iran-0.3%; Romania-0.3%; Peru-0.3%; Madagascar-0.2%	Cotton-19.8%; Citrus fruit nes-14.5%; Soybean-10.7%; Olives-7.5%; Rice-7.5%; Grapes-5.2%; Sugarcane-4.3%; Almonds-4.3%; Castor beans-3.7%; Industrial products-3.4%
Germany	USA-19.1%; Spain-14.8%; Pakistan-13.7%; Turkey-12.6%; India-9.2%; Kazakhstan-4.6%; Italy-3.7%; China-2.9%; France-1.8%; Egypt-1.8%; Iran-1.7%; Israel-1.5%; Morocco-1.4%; South Africa-1.2%; Greece-1.1%; Ukraine-0.6%; Chile-0.5%; Australia-0.4%; Mexico-0.4%; Azerbaijan-0.4%	Cotton-32.8%; Almonds-11.4%; Grapes-5.7%; Hazelnuts (filberts)-4.7%; Linseed-4.4%; Soybean-4.1%; Industrial products-3.8%; Pistachios-3%; Olives-2.8%; Rice-2.6%
Italy	Spain-35%; Pakistan-13.6%; USA-11%; Turkey-9.4%; Greece-5.7%; India-5.1%; Egypt-3.8%; Tunisia-1.7%; Ukraine-1.6%; China-1.4%; France-1.3%; Mexico-0.9%; Kazakhstan-0.9%; Iran-0.7%; Portugal-0.6%; Azerbaijan-0.5%; Turkmenistan-0.5%; Chile-0.5%; Morocco-0.5%; Argentina-0.5%	Olives-28.2%; Cotton-26%; Almonds-6.6%; Rice-4.8%; Hazelnuts (filberts)-3.8%; Soybean-3.4%; Wheat-2.6%; Sugarcane-2.6%; Maize-2.6%; Walnuts-2.5%
Japan	USA-61.5%; China-13.2%; Pakistan-3.9%; Spain-3.8%; India-3.3%; Thailand-2.7%; Australia-2.6%; Mexico-1.9%; Israel-1.1%; Greece-0.8%; Turkey-0.7%; Italy-0.6%; Russian Federation-0.5%; Canada-0.4%; Argentina-0.4%; South Africa-0.3%; Ecuador-0.2%; Indonesia-0.2%; Viet Nam-0.2%; France-0.2%	Maize-23.2%; Cotton-16.4%; Rice-13.3%; Soybean-11.3%; Wheat-7.3%; Almonds-6.8%; Olives-3.8%; Grapes-2.4%; Industrial products-2%; Walnuts-1.5%
Netherlands	Spain-18.1%; USA-17.1%; Pakistan-13.6%; India-8.8%; Turkey-5.5%; Ukraine-5.1%; France-4.2%; China-3.7%; South Africa-3.3%; Egypt-3.2%; Peru-1.9%; Israel-1.3%; Morocco-1.1%; Argentina-1%; Chile-1%; Italy-0.9%; Mexico-0.9%; Russian Federation-0.9%; Romania-0.7%; Thailand-0.6%	Cotton-20.5%; Soybean-12.7%; Rice-9.9%; Maize-9.3%; Industrial products-5.8%; Oranges-4.1%; Almonds-3.8%; Castor beans-3.1%; Citrus fruit nes-3%; Avocados-2.8%
Sweden	Spain-21.9%; Pakistan-18.4%; USA-13.9%; India-7.9%; Turkey-7.5%; China-4.9%; Italy-4.2%; France-1.8%; South Africa-1.7%; Egypt-1.6%; Greece-1.3%;	Cotton-28.2%; Rice-11.1%; Industrial products-8.5%; Almonds-8%; Grapes-7.7%; Citrus fruit nes-7.5%; Olives-5.5%; Oranges-3.6%; Maize-1.4%; Banana-1.1%

Country	Major countries where the unsustainable blue WF is located	Major crops
	Cyprus-1.1%; Argentina-1%; Russian Federation-0.9%; Thailand-0.8%; Iran-0.8%; Morocco-0.8%; Australia-0.8%; Syria-0.7%; Germany-0.7%	
Switzerland	USA-16.5%; Spain-16.3%; Turkey-13.3%; Pakistan-7%; India-6.5%; Italy-6.4%; France-4%; China-3.4%; Egypt-2%; Kazakhstan-2%; Israel-1.5%; Fmr Sudan-1.3%; Greece-1.3%; South Africa-1.3%; Tajikistan-1.2%; Brazil-1.1%; Thailand-1%; Mexico-0.9%; Germany-0.9%; Argentina-0.9%	Cotton-18.6%; Industrial products-16.8%; Almonds-12%; Rice-8%; Hazelnuts (filberts)-7.7%; Grapes-5.2%; Olives-4.4%; Oranges-1.9%; Sunflower-1.4%; Asparagus-1.4%
United Kingdom	Spain-30.3%; Pakistan-19.8%; India-10.7%; USA-8.7%; Turkey-5.2%; China-4.4%; South Africa-2.2%; Egypt-2.1%; France-2%; Australia-1.8%; Italy-1.7%; Mexico-1.3%; Argentina-1%; Portugal-0.7%; Ukraine-0.7%; Morocco-0.6%; Israel-0.6%; Malawi-0.5%; Thailand-0.5%; Peru-0.5%	Cotton-31.3%; Rice-14.5%; Citrus fruit nes-10.6%; Grapes-7.4%; Olives-4.2%; Industrial products-3.2%; Almonds-3.1%; Sugarcane-3%; Maize-2.8%; Soybean-2.1%
USA	Mexico-33.6%; India-15.9%; Pakistan-14.2%; China-10.3%; Spain-5.8%; Turkey-2.6%; Thailand-2%; Egypt-2%; Argentina-1.7%; Italy-1.4%; Peru-1.3%; Canada-1%; Tunisia-0.7%; Chile-0.6%; Morocco-0.6%; Ecuador-0.6%; Costa Rica-0.6%; Australia-0.4%; Honduras-0.4%; Guatemala-0.4%	Cotton-43.7%; Olives-9.8%; Barely-5.9%; Rice-3.9%; Citrus fruit nes-3.1%; Sugarcane-2.7%; Industrial products-2.6%; Avocados-2.5%; Oranges-2.4%; Pimento, allspice-2%
EU27	USA-19.9%; Pakistan-19.2%; Turkey-13.7%; India-10.9%; Kazakhstan-7.2%; China-4.4%; Egypt-3.5%; Morocco-2.9%; Ukraine-2.6%; South Africa-1.3%; Iran-1.2%; Israel-1.1%; Tunisia-1%; Uzbekistan-1%; Russian Federation-1%; Argentina-0.9%; Mexico-0.9%; Peru-0.6%; Chile-0.6%; Syria-0.6%	Cotton-38.7%; Almonds-10.6%; Linseed-6.6%; Rice-6.1%; Industrial products-4.2%; Soybean-3.9%; Maize-2.9%; Hazelnuts (filberts)-2.8%; Olives-2.5%; Sugarcane-2.2%
Global North	Spain-24.7%; Pakistan-15.5%; Mexico-14.1%; India-11.8%; Turkey-7.2%; China-7.1%; Egypt-2.3%; Greece-1.4%; Thailand-1.3%; Kazakhstan-1.2%; South Africa-1.2%; Morocco-1.2%; Argentina-1.2%; Australia-1%; Israel-0.9%; Peru-0.8%; Iran-0.6%; Tunisia-0.6%; Chile-0.5%; Portugal-0.5%	Cotton 35.2%; Olives 9.6%; Rice 6.6%; Citrus fruit nes 5.8%; Barely 3.9%; Sugarcane 3.6%; Grapes 3.5%; Soybean 3.1%; Oranges 2.8%; Industrial products 2.5%

3.5.2 SUSTAINABILITY MAPS FOR THE GLOBAL NORTH COUNTRIES AND EU27

The following figures present the sustainable (shaded in green) and unsustainable (shaded in yellow to dark red) parts of the national blue WF of consumption for Global North. Figures 20 and 21 present the sustainability of the external blue water footprint of the Global North and the EU27 countries respectively. The green-coloured grid cells are not water scarce on an annual basis, whereas the colour range from light yellow to dark red represents an increasing level of blue water scarcity The sustainability of the external blue water footprint of the individual Global North countries are presented in Figures 22 to 34.

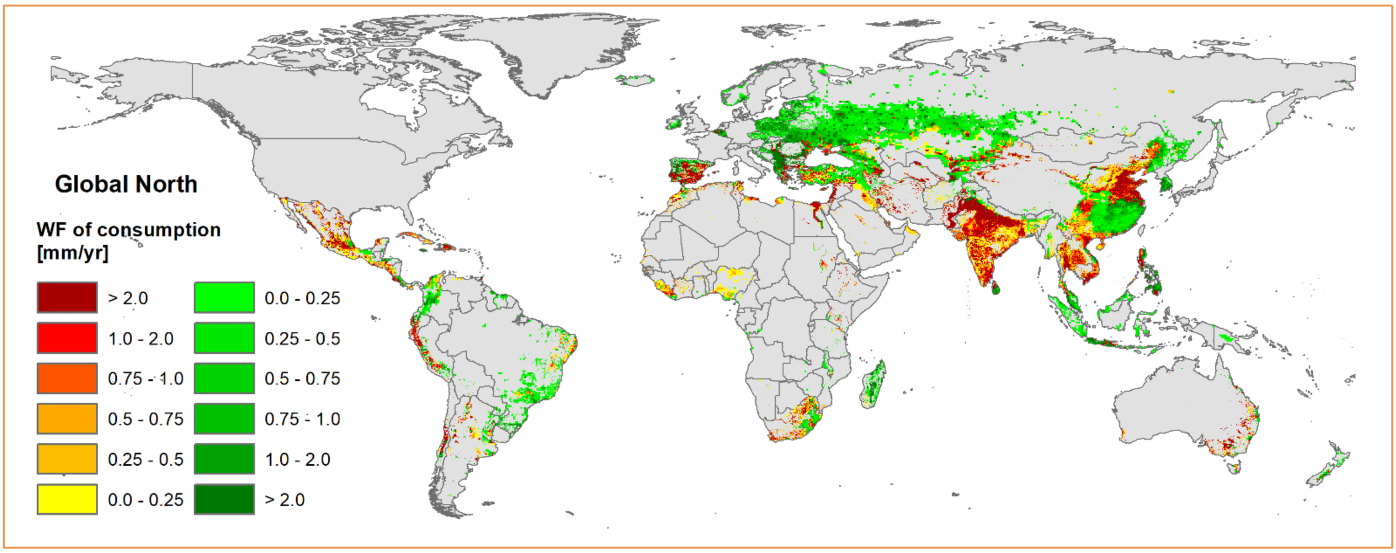


Figure 20. Sustainability of the external blue water footprint of the Global North.

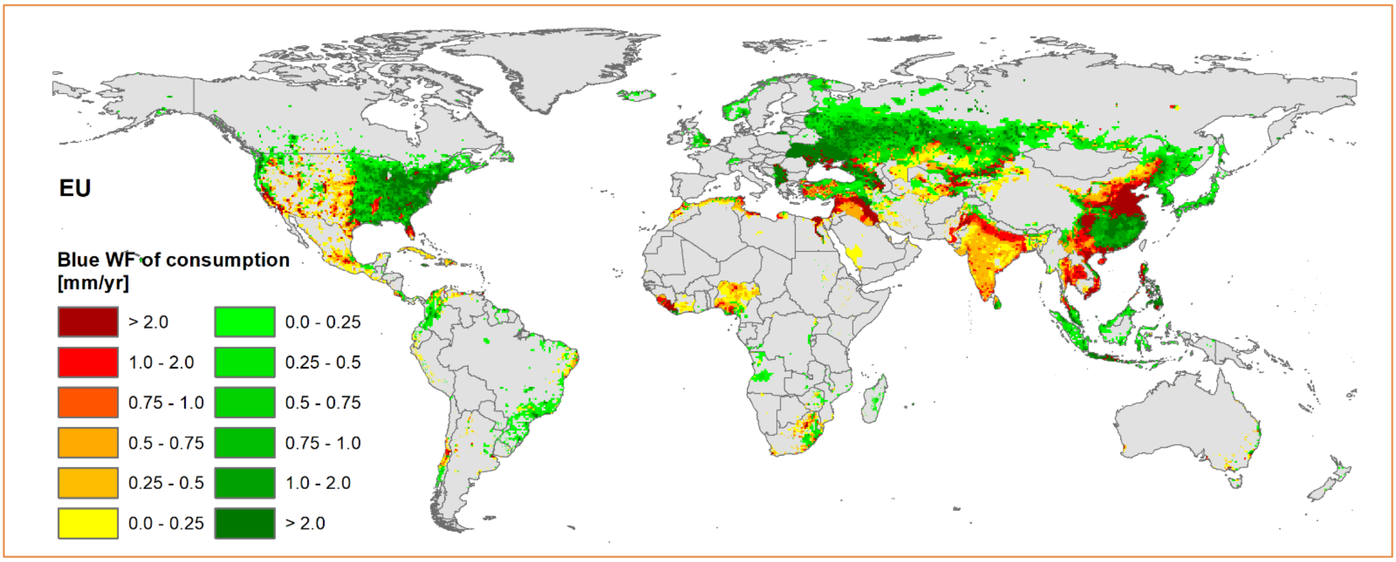


Figure 21. Sustainability of the external blue water footprint of the EU27

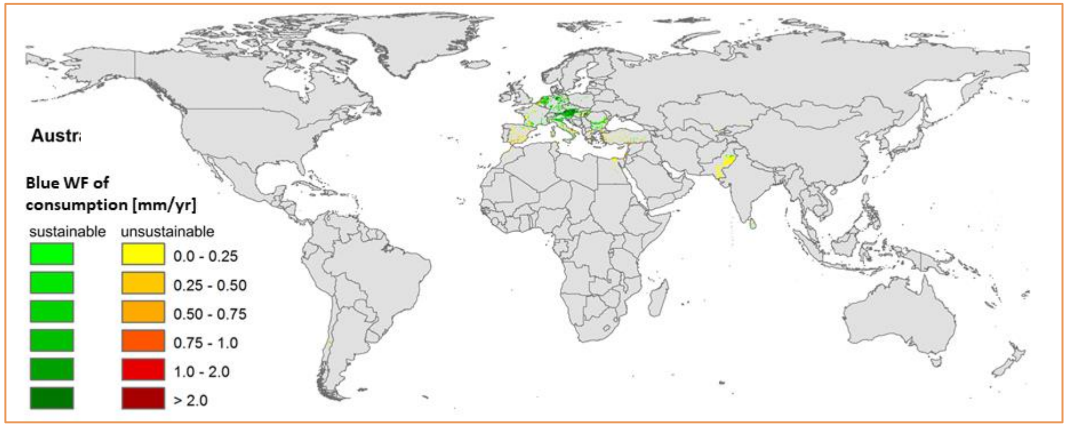


Figure 22: Sustainability of the blue water footprint of consumption of Austria

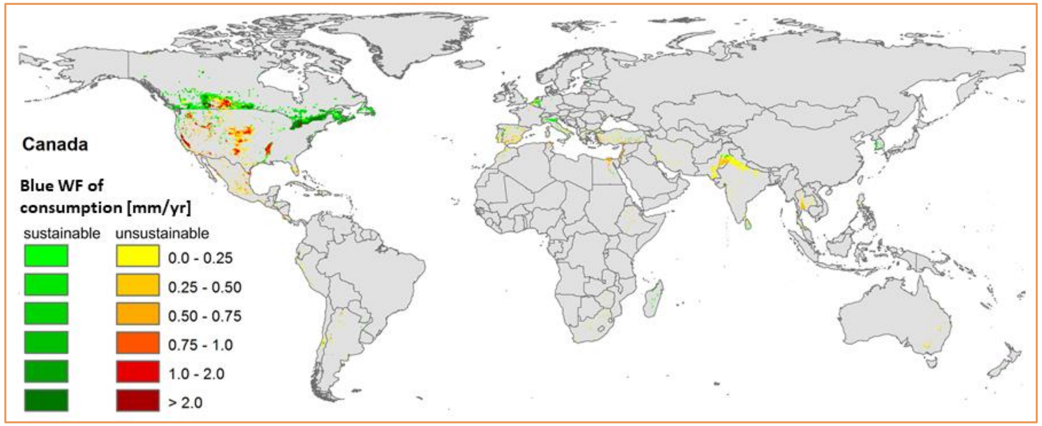


Figure 23: Sustainability of the blue water footprint of consumption of Canada

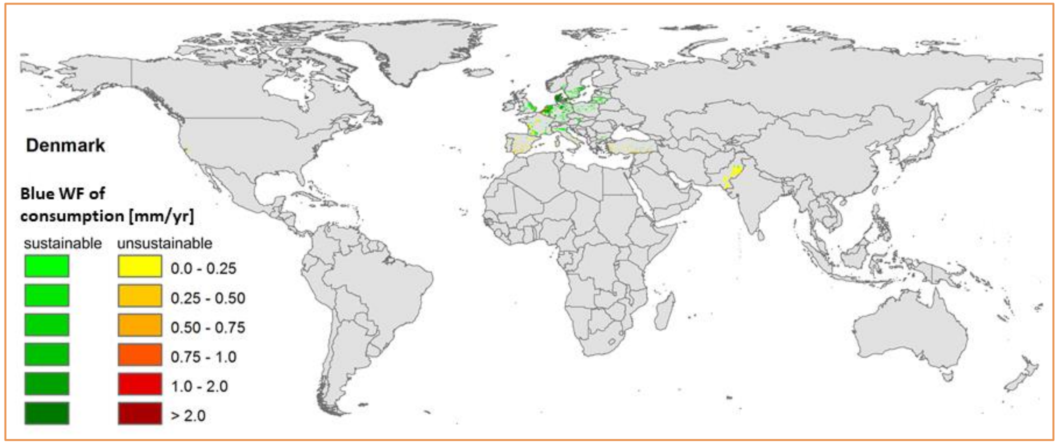


Figure 24. Sustainability of the blue water footprint of consumption of Denmark

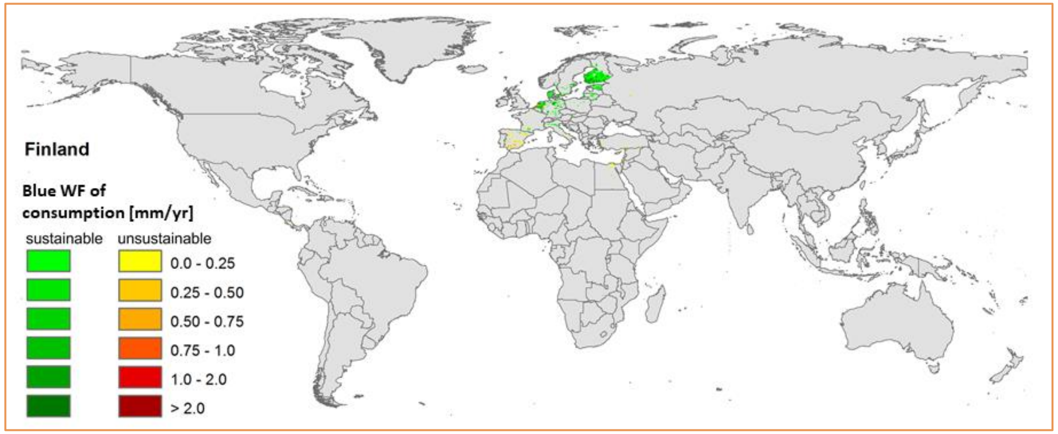


Figure 25. Sustainability of the blue water footprint of consumption of Finland

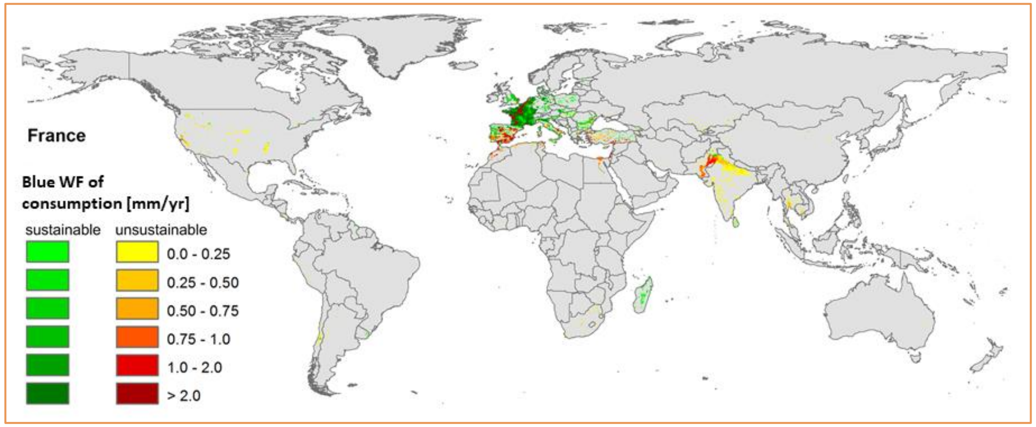


Figure 26. Sustainability of the blue water footprint of consumption of France

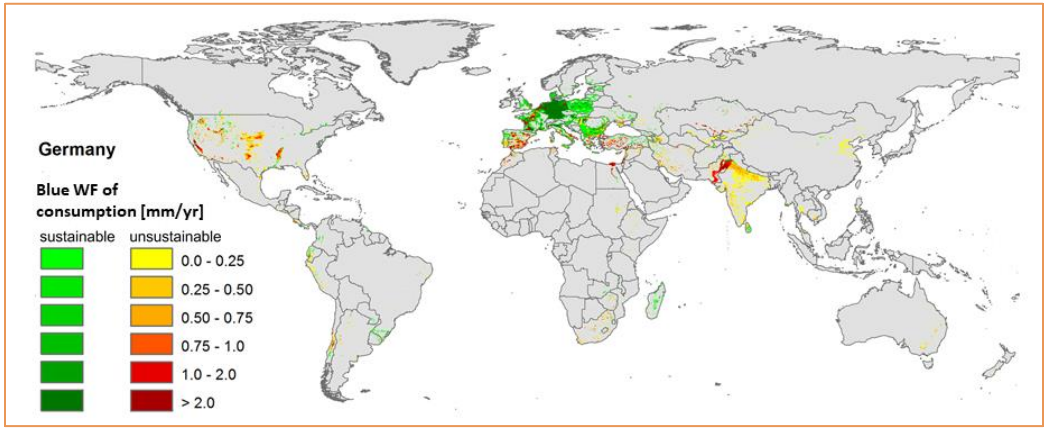


Figure 27. Sustainability of the blue water footprint of consumption of Germany

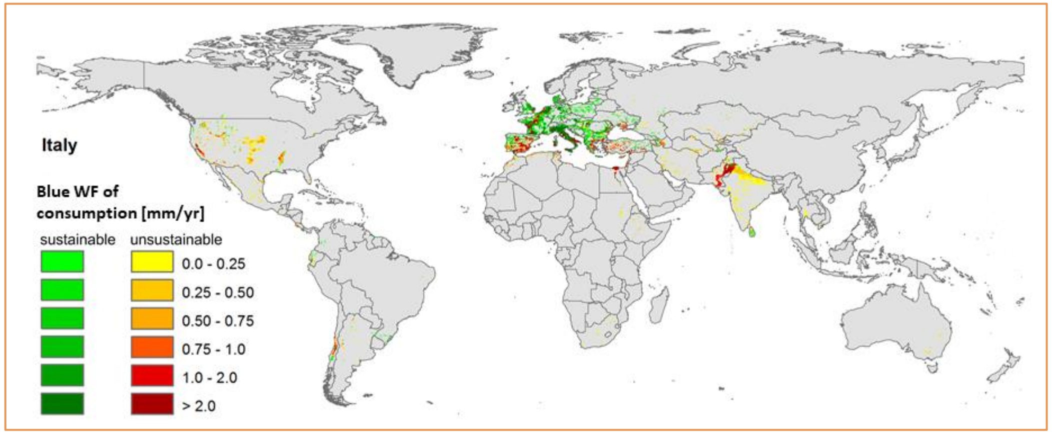


Figure 28. Sustainability of the blue water footprint of consumption of Italy

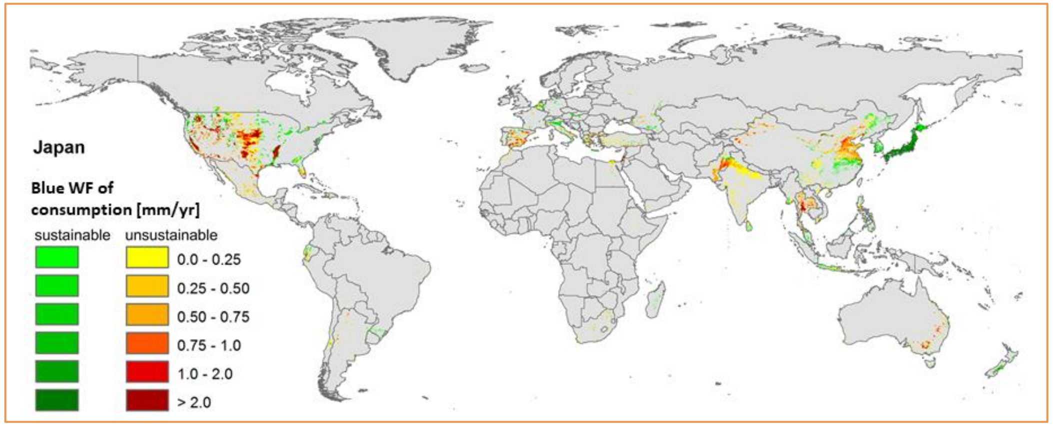


Figure 29. Sustainability of the blue water footprint of consumption of Japan

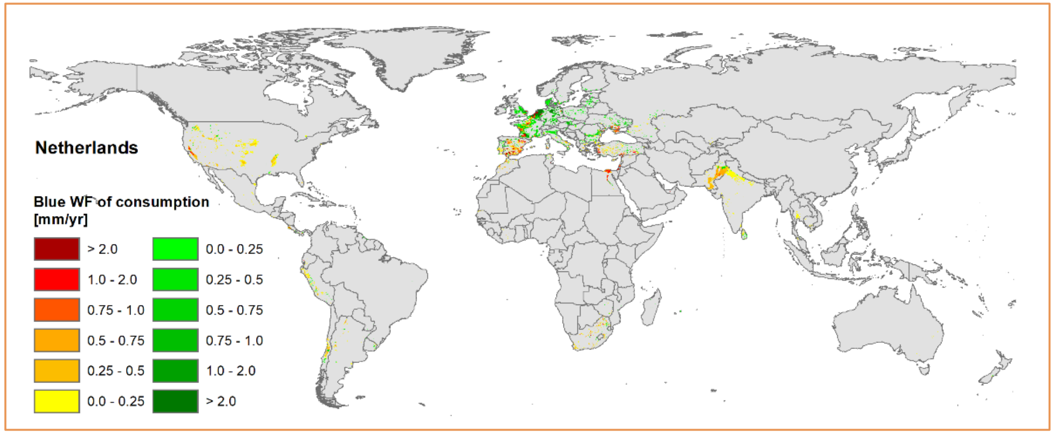


Figure 30. Sustainability of the blue water footprint of consumption of the Netherlands

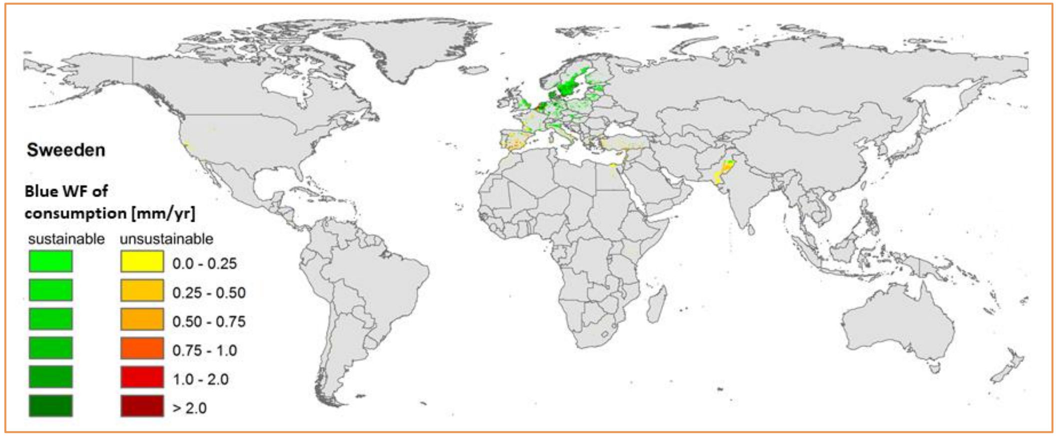


Figure 31. Sustainability of the blue water footprint of consumption of Sweden

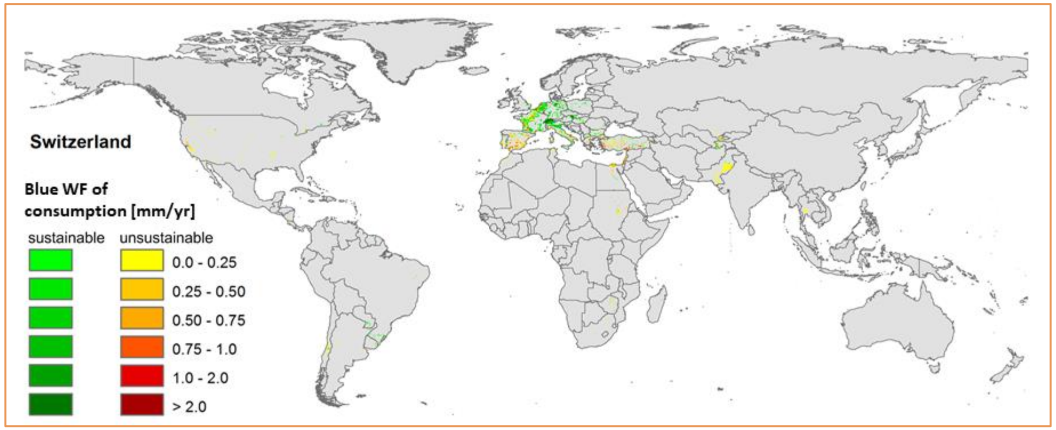


Figure 32. Sustainability of the blue water footprint of consumption of Switzerland

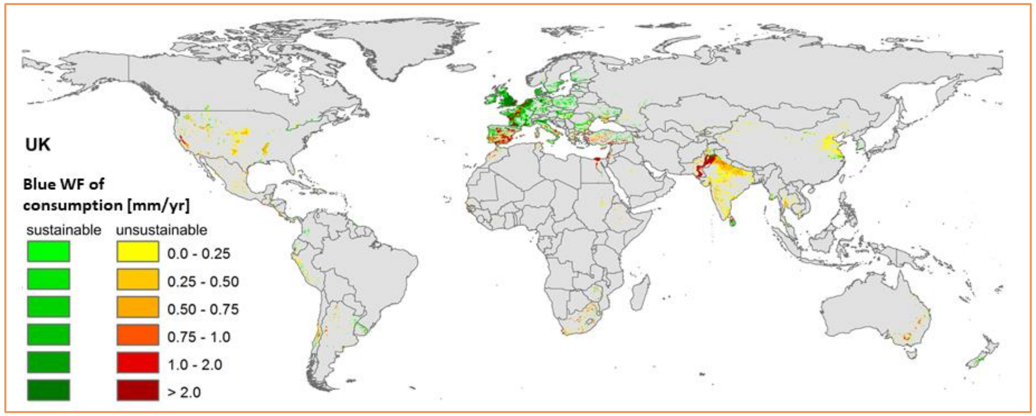


Figure 33. Sustainability of the blue water footprint of consumption of the UK

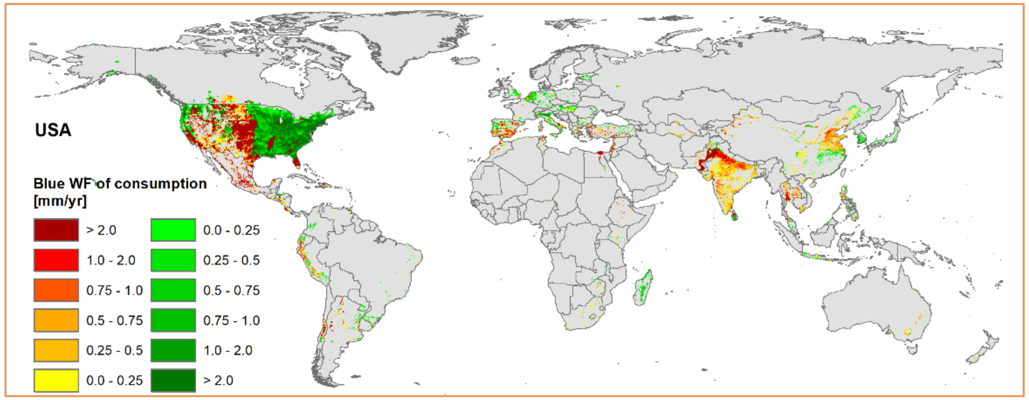


Figure 34. Sustainability of the blue water footprint of consumption of the USA

4 WATER FOOTPRINT OF PRODUCTION OF GLOBAL SOUTH ECONOMIES

4.1 THE WATER FOOTPRINT OF PRODUCTION

The share of water footprint represented by crop production is dominant when compared to other sectors (domestic and industrial). However, it is notable that the majority of the WF of crop production is green - rainfed - in these countries which means they are sensitive to changes in rainfall patterns imposed by climate change. The water footprint of production of the selected Global South countries are presented for the period 2016-2020 in Table 9.

Table 9. Water footprint of national production of Global South countries (Mm^3/year). Period 2016-2020.

Country	WF of crop production (Mm^3/year)					WF of domestic water supply (Mm^3/year)				WF of industrial production (Mm^3/year)				Total WF of national production (Mm^3/year)			
	Green	Blue	Grey	Total (crop)	% of Total WF	Blue	Grey	Total (domestic)	% of Total WF	Blue	Grey	Total (industrial)	% of Total WF	Green	Blue	Grey	Total WF
Argentina	201700	5628	6502	213829	97.2%	590	3237	3828	1.7%	202	2204	2406	1.1%	201700	6420	11943	220063
Bangladesh	78725	9640	11448	99813	95.8%	362	3260	3623	3.5%	39	736	775	0.7%	78725	10041	15445	104211
Bolivia	45065	754	128	45947	99.6%	14	123	137	0.3%	2	31	32	0.1%	45065	769	282	46116
Brazil	642451	14114	21655	678220	97.0%	1689	11779	13468	1.9%	505	7105	7610	1.1%	642451	16308	40540	699299
Cambodia	25015	1496	85	26596	99.5%	10	89	99	0.4%	2	32	33	0.1%	25015	1508	205	26728
Chile	6651	2469	1855	10975	93.2%	130	316	446	3.8%	86	273	359	3.0%	6651	2684	2444	11780
China	1907568	147485	314260	2369313	94.0%	7620	55378	62998	2.5%	6445	82591	89035	3.5%	1907568	161549	452229	2521346
Columbia	56456	2066	2504	61026	88.9%	361	3246	3606	5.3%	200	3792	3992	5.8%	56456	2626	9542	68624
Costa Rica	5963	378	244	6585	88.5%	63	560	624	8.4%	12	218	230	3.1%	5963	453	1022	7438
Cote d'Ivoire	126697	403	594	127694	99.6%	33	295	328	0.3%	12	234	247	0.2%	126697	448	1123	128268
DR Congo	60396	85	12	60493	99.0%	47	427	474	0.8%	7	142	150	0.2%	60396	140	581	61117
Egypt	11717	39483	13625	64826	80.1%	1083	9749	10832	13.4%	264	5019	5283	6.5%	11717	40831	28393	80941
Ethiopia	104718	3231	484	108433	99.2%	82	741	823	0.8%	3	49	52	0.0%	104718	3316	1274	109308
Gabon	1569	18	6	1594	94.1%	9	77	86	5.1%	1	14	14	0.8%	1569	28	98	1694
Guatemala	21339	595	1059	22992	94.3%	80	721	801	3.3%	29	549	578	2.4%	21339	704	2329	24371
Indonesia	539913	14909	35439	590261	94.7%	2381	21431	23812	3.8%	472	8963	9435	1.5%	539913	17762	65833	623508
Kenya	37799	532	446	38776	97.9%	53	473	526	1.3%	15	271	286	0.7%	37799	600	1189	39588
Laos	9497	768	2	10267	97.1%	13	118	131	1.2%	9	163	172	1.6%	9497	789	283	10569
Lesotho	1409	16	0	1425	97.3%	2	18	20	1.4%	1	19	20	1.4%	1409	19	37	1466
Madagascar	20801	2237	40	23078	97.6%	40	361	402	1.7%	8	156	165	0.7%	20801	2285	558	23644
Malawi	16541	542	837	17920	98.9%	15	131	145	0.8%	2	46	48	0.3%	16541	559	1014	18114

Country	WF of crop production (Mm³/year)					WF of domestic water supply (Mm³/year)				WF of industrial production (Mm³/year)				Total WF of national production (Mm³/year)			
	Green	Blue	Grey	Total (crop)	% of Total WF	Blue	Grey	Total (domestic)	% of Total WF	Blue	Grey	Total (industrial)	% of Total WF	Green	Blue	Grey	Total WF
Mauritius	583	27	9	619	70.9%	27	218	245	28.1%	1	8	9	1.0%	583	55	236	873
Mexico	110108	16099	11181	137388	89.9%	1354	8769	10123	6.6%	395	4876	5271	3.4%	110108	17848	24826	152782
Morocco	33111	6687	1386	41184	98.5%	107	482	589	1.4%	11	41	51	0.1%	33111	6805	1909	41825
Myanmar	89923	3636	1253	94813	96.1%	334	3003	3337	3.4%	25	475	500	0.5%	89923	3995	4732	98650
Pakistan	99471	79821	22132	201424	94.7%	977	8793	9770	4.6%	71	1347	1417	0.7%	99471	80869	32272	212612
Panama	2580	103	135	2818	84.7%	76	431	508	15.2%	0	3	3	0.1%	2580	180	569	3329
Peru	22802	4739	2068	29608	95.2%	139	1250	1389	4.5%	6	107	113	0.4%	22802	4883	3425	31109
Philippines	122542	4574	4281	131397	83.8%	957	8617	9575	6.1%	793	15069	15862	10.1%	122542	6325	27967	156834
South Africa	39010	3946	2008	44965	90.8%	406	2274	2680	5.4%	206	1682	1888	3.8%	39010	4558	5964	49533
Tanzania	68283	1741	347	70371	99.2%	54	483	537	0.8%	1	24	25	0.0%	68283	1796	854	70933
Thailand	144789	20467	8512	173769	96.9%	274	2469	2744	1.5%	139	2643	2782	1.6%	144789	20881	13625	179295
Vietnam	83152	8369	10490	102011	96.0%	121	1092	1213	1.1%	155	2937	3092	2.9%	83152	8645	14519	106316
Zambia	14519	751	243	15514	97.3%	30	266	295	1.9%	7	126	132	0.8%	14519	787	635	15941
Zimbabwe	9213	864	339	10416	93.9%	59	534	593	5.3%	4	80	84	0.8%	9213	928	953	11093

4.2 VIRTUAL WATER EXPORT RELATED TO AGRICULTURE PRODUCTS

Table 10 sets out the virtual water exports for agricultural products from the Global South Economies.

Table 10. Virtual water export related to agricultural products from Global South countries (Mm³/year). Period 2016-2020

	Crop			Livestock			Total export			Virtual water re-export			Export of domestically made products		
	Green	Blue	Grey	Green	Blue	Grey	Green	Blue	Grey	Green	Blue	Grey	Green	Blue	Grey
Argentina	115246	1785	3572	3975	165	29	119221	1950	3600	5625	47	102	113595	1903	3498
Bangladesh	8342	28	2848	6	1	0	8348	28	2848	2733	8	733	5615	20	2115
Bolivia	6545	19	19	569	5	0	7114	24	19	160	1	7	6954	23	12
Brazil	189381	877	4808	32994	696	227	222375	1573	5035	7740	105	328	214635	1468	4707
Cambodia	5076	156	247	3	0	0	5079	156	247	246	11	167	4833	146	80
Chile	2366	898	560	362	156	115	2728	1053	674	1846	211	210	882	842	464
China	34737	4417	11337	6371	77	271	41108	4494	11607	6098	474	684	35010	4020	10923
Columbia	14703	122	1297	308	5	0	15010	127	1297	2770	42	534	12241	85	763
Costa Rica	3113	205	179	344	8	9	3457	213	188	1025	90	109	2433	123	79
Cote d'Ivoire	61153	37	154	12	1	0	61166	38	154	1920	25	66	59246	13	87
DR Congo	367	0	0	1	0	0	368	0	0	8	0	0	360	0	0
Egypt	920	4557	1280	83	400	170	1003	4957	1451	694	192	152	309	4765	1299
Ethiopia	5360	422	23	203	7	0	5563	429	23	330	117	15	5233	312	8
Gabon	179	0	0	1	0	0	179	0	0	52	0	0	128	0	0
Guatemala	9599	225	479	53	1	1	9652	226	481	1519	102	154	8133	124	327
Indonesia	220155	247	18326	80	3	2	220235	251	18329	20045	42	1574	200190	209	16754
Kenya	4311	68	119	108	4	0	4419	72	119	883	54	77	3536	18	42
Laos	1136	36	21	1	0	0	1137	36	21	120	6	21	1018	31	0
Lesotho	296	59	28	1	0	0	296	59	28	82	52	28	214	7	0
Madagascar	1538	327	31	0	0	0	1538	327	31	128	82	27	1410	245	4
Malawi	1111	174	86	0	0	0	1111	174	86	39	12	6	1072	161	80
Mauritius	1144	142	73	2	0	0	1146	143	73	787	127	67	359	16	6
Mexico	15278	4288	1755	5014	428	164	20292	4716	1919	5914	990	713	14377	3727	1206
Morocco	1162	1241	112	325	293	6	1487	1534	118	403	251	52	1084	1283	66
Myanmar	7074	370	515	9	1	0	7083	370	515	412	91	148	6671	279	367
Pakistan	7496	18429	4535	1031	40	16	8527	18469	4551	2009	3668	458	6518	14801	4093
Panama	742	39	101	104	2	19	846	41	120	296	27	77	550	14	43
Peru	4114	608	371	194	13	5	4309	620	376	1515	79	144	2794	541	231
Philippines	8167	94	182	45	1	1	8212	95	183	1518	26	66	6694	69	117
South Africa	5409	1889	548	1545	174	43	6953	2063	591	1931	515	206	5022	1548	386
Tanzania	5054	106	100	19	1	0	5074	107	100	217	17	42	4857	90	58
Thailand	44013	5618	4013	617	27	20	44630	5645	4033	6210	302	543	38420	5343	3490
Vietnam	53566	1000	6151	150	8	15	53716	1008	6166	17279	283	1359	36437	726	4807
Zambia	1114	142	28	3	0	0	1117	142	28	65	17	5	1053	125	23
Zimbabwe	833	221	46	2	0	0	835	221	46	154	58	14	681	163	32

4.3 VIRTUAL WATER EXPORT RELATED TO INDUSTRIAL PRODUCTS

Table 11 sets out the virtual water exports for industrial products from the Global South Economies.

Table 11: Virtual water export related to industrial products from Global South countries (Mm³/year). Period 2016-2020.

	Total virtual water export		Virtual water re-export		Virtual water export related to domestically made products	
	Blue	Grey	Blue	Grey	Blue	Grey
Argentina	19.06	208.25	2.89	36.76	16.17	171.49
Bangladesh	0.75	14.22	0.25	3.70	0.50	10.53
Bolivia	0.55	10.37	0.44	7.58	0.11	2.79
Brazil	62.73	881.94	10.19	126.55	52.54	755.39
Cambodia	0.82	15.55	0.65	11.77	0.17	3.77
Chile	11.11	35.26	3.44	22.86	7.67	12.40
China	467.11	5986.21	19.39	231.50	447.72	5754.71
Columbia	33.10	628.93	4.42	62.66	28.68	566.27
Costa Rica	4.21	78.19	2.27	39.39	1.94	38.80
Cote d'Ivoire	1.91	36.26	0.62	8.21	1.29	28.05
Democratic Republic of Congo	1.51	28.63	0.49	6.41	1.02	22.22
Egypt	40.62	771.84	4.94	60.32	35.68	711.52
Ethiopia	0.05	1.02	0.04	0.72	0.01	0.30
Gabon	0.32	6.04	0.21	3.00	0.11	3.04
Guatemala	2.74	52.00	0.83	13.99	1.91	38.02
Indonesia	59.07	1122.36	6.73	94.41	52.34	1027.95
Kenya	0.89	16.04	0.32	4.59	0.57	11.45
Laos	3.77	71.59	0.84	13.93	2.93	57.66
Lesotho	0.48	9.05	0.25	3.09	0.22	5.96
Madagascar	1.81	34.32	0.27	3.08	1.53	31.24
Malawi	0.06	1.11	0.02	0.28	0.04	0.83
Mauritius	0.13	1.90	0.11	1.50	0.02	0.40
Mexico	62.39	770.53	15.38	185.71	47.01	584.81
Morocco	3.44	13.09	2.60	11.54	0.85	1.55
Myanmar	2.99	56.72	0.67	9.96	2.31	46.75
Pakistan	3.23	61.32	0.64	8.50	2.59	52.82
Panama	0.06	0.54	0.06	0.53	0.00	0.01
Peru	0.81	15.36	0.66	11.74	0.15	3.62
Philippines	164.99	3134.90	7.03	97.14	157.97	3037.76
South Africa	82.79	676.40	13.25	144.41	69.54	531.99
Tanzania	0.17	3.28	0.14	2.35	0.04	0.93
Thailand	58.82	1117.55	23.56	377.61	35.25	739.93
Vietnam	128.80	2447.24	35.73	534.62	93.07	1912.61
Zambia	2.83	53.84	1.21	15.34	1.63	38.50
Zimbabwe	0.72	13.72	0.34	4.11	0.38	9.61

4.4 TOTAL VIRTUAL WATER EXPORT RELATED TO AGRICULTURAL AND INDUSTRIAL PRODUCTS

Table 12: Total export related to agricultural and industrial products and their share in the use of domestic water resources (Mm^3/year). Period 2016-2020.

	Total export			Virtual water re-export			Virtual water export related to domestically made products			Share of domestic products to the total export (Agricultural products)			Share of domestic products to the total export (Industrial)	
	Green	Blue	Grey	Green	Blue	Grey	Green	Blue	Grey	Green	Blue	Grey	Blue	Grey
Argentina	119220.8	1969.1	3808.3	5625.3	49.7	138.9	113595.5	1919.4	3669.4	95%	98%	97%	85%	82%
Bangladesh	8348.0	29.1	2861.9	2732.5	8.6	736.5	5615.5	20.5	2125.5	67%	71%	74%	67%	74%
Bolivia	7114.3	25.0	29.4	160.2	1.9	14.9	6954.1	23.1	14.5	98%	94%	61%	20%	27%
Brazil	222374.5	1635.4	5917.3	7739.5	114.8	455.0	214635.0	1520.6	5462.3	97%	93%	93%	84%	86%
Cambodia	5079.1	157.3	263.0	246.1	11.2	179.2	4833.0	146.1	83.7	95%	93%	32%	21%	24%
Chile	2728.0	1064.6	709.3	1845.8	214.8	232.8	882.2	849.8	476.5	32%	80%	69%	69%	35%
China	41107.8	4961.3	17593.6	6097.9	493.4	915.7	35009.9	4467.9	16677.9	85%	89%	94%	96%	96%
Columbia	15010.3	160.1	1926.1	2769.6	46.0	596.6	12240.7	114.0	1329.4	82%	67%	59%	87%	90%
Costa Rica	3457.4	217.0	266.1	1024.7	92.1	148.6	2432.7	124.9	117.6	70%	58%	42%	46%	50%
Cote d'Ivoire	61165.7	39.8	189.9	1919.5	26.0	74.6	59246.2	13.8	115.3	97%	33%	57%	67%	77%
DR Congo	368.1	1.8	29.1	8.2	0.7	6.8	360.0	1.1	22.3	98%	36%	9%	68%	78%
Egypt	1003.4	4997.5	2222.5	694.2	197.0	212.0	309.2	4800.5	2010.5	31%	96%	90%	88%	92%
Ethiopia	5562.7	429.1	24.0	329.8	117.5	15.7	5232.8	311.6	8.3	94%	73%	35%	23%	29%
Gabon	179.4	0.5	6.3	51.6	0.3	3.2	127.8	0.1	3.1	71%	22%	14%	35%	50%
Guatemala	9652.2	228.9	532.6	1519.1	102.5	167.6	8133.1	126.4	365.0	84%	55%	68%	70%	73%
Indonesia	220234.9	309.8	19451.1	20044.6	48.7	1668.9	200190.3	261.0	17782.3	91%	83%	91%	89%	92%
Kenya	4418.9	72.7	134.8	883.3	54.3	81.1	3535.6	18.4	53.7	80%	25%	36%	64%	71%
Laos	1137.1	40.0	92.8	119.6	6.4	34.7	1017.5	33.6	58.1	89%	85%	2%	78%	81%
Lesotho	296.2	59.3	36.9	82.3	52.5	30.8	213.9	6.8	6.1	72%	11%	0%	47%	66%
Madagascar	1537.9	329.0	65.7	128.3	82.2	30.3	1409.5	246.8	35.4	92%	75%	13%	85%	91%
Malawi	1111.0	173.9	86.7	39.3	12.5	6.2	1071.6	161.4	80.5	96%	93%	93%	64%	75%
Mauritius	1145.7	142.7	74.8	786.6	126.7	68.7	359.1	16.0	6.2	31%	11%	8%	18%	21%
Mexico	20291.6	4778.7	2689.1	5914.4	1005.0	898.4	14377.1	3773.8	1790.6	71%	79%	63%	75%	76%
Morocco	1486.7	1537.7	131.4	402.7	253.7	63.8	1084.0	1284.0	67.7	73%	84%	56%	25%	12%
Myanmar	7082.8	373.4	571.7	412.2	92.0	158.4	6670.6	281.4	413.4	94%	75%	71%	77%	82%
Pakistan	8526.9	18472.2	4612.3	2009.3	3668.8	466.2	6517.6	14803.4	4146.2	76%	80%	90%	80%	86%
Panama	846.0	41.1	120.4	296.3	26.7	77.0	549.7	14.4	43.4	65%	35%	36%	3%	2%
Peru	4308.5	621.1	390.9	1515.0	79.9	156.0	2793.6	541.2	234.9	65%	87%	62%	18%	24%
Philippines	8212.0	260.0	3317.7	1517.6	32.8	163.5	6694.3	227.3	3154.3	82%	73%	64%	96%	97%
South Africa	6953.3	2145.6	1267.9	1930.9	527.8	350.0	5022.4	1617.8	917.9	72%	75%	65%	84%	79%
Tanzania	5073.5	107.0	103.4	216.6	17.0	44.6	4856.9	90.0	58.9	96%	84%	58%	21%	28%
Thailand	44629.8	5704.2	5150.4	6209.8	325.8	920.3	38420.1	5378.4	4230.2	86%	95%	87%	60%	66%
Vietnam	53716.0	1137.0	8613.3	17279.3	318.3	1893.4	36436.6	818.7	6720.0	68%	72%	78%	72%	78%
Zambia	1117.4	144.7	81.7	64.8	18.1	20.1	1052.6	126.5	61.5	94%	88%	83%	57%	72%
Zimbabwe	834.6	221.6	59.7	153.9	58.5	18.2	680.7	163.2	41.5	82%	74%	69%	53%	70%

Analysis of the virtual water export from the Global South countries, the composition of the virtual water export (whether it is blue, green or grey virtual water) (see Table 12), importing partner countries and their relative share of imports can reveal further insights for the implications of trade for water resources. In Table 13, we've taken examples from Kenya, Madagascar, Malawi, and Peru to illustrate the geographical distribution of virtual water export from the Global South countries. From an exporting country's perspective, such information can help to identify strategically important water resources and guide further engagement with importing countries. Detailed tracking of individual products, and importing partners from one basin or location, provide useful insights and can guide action to improve the resilience of the supply chains of importing partners, whilst supporting equitable and sustainable use of local water resources to ensure that the economic benefits of trade are sustainable.

Table 13: Total volume of virtual water export related to the export of agricultural products from Kenya, Madagascar, Malawi, and Peru and separated by the type of virtual water (blue, green and grey) and the top importing countries, top export products.

Exporting country	Type	Total virtual water export (million m^3/year)	Top 20 countries	Top 20 products
Kenya	Green	4419	Pakistan-17.7%, Egypt-9%, USA-8.4%, United Kingdom-7.8%, India-6.2%, United Arab Emirates-5.2%, Germany-4.7%, Afghanistan-2.6%, Russian Federation-2.5%, Indonesia-2.4%, Sweden-2.3%, Uganda-2.1%, Rep. of Korea-2%, Sudan-1.6%, Switzerland-1.6%, Yemen-1.6%, Saudi Arabia-1.5%, Kazakhstan-1.4%, Spain-1.3%, Finland-1.3%	Tea-51.1%, Coffee, Green-28.3%, Seed Cotton-4.8%, Cocoa Beans-3.3%, Livestock-2.1%, Beans, Dry-1.9%, Oil Palm Fruit-1.4%, Pulses nes-1.3%, Tobacco Leaves-1.3%, Barley-0.7%, Avocados-0.7%, Jute-0.3%, Maize-0.3%, Mangoes-0.2%, Cereals nes-0.2%, Pineapples-0.2%, Sesame Seed-0.2%, Sugar Cane-0.1%, Citrus Fruit nes-0.1%, Beans, Green-0.1%
	Blue	72	USA-28%, Germany-10.4%, India-10.2%, Sweden-5.2%, Rep. of Korea-4.4%, United Arab Emirates-3.8%, Switzerland-3.4%, Finland-2.9%, United Kingdom-2.6%, Netherlands-1.8%, Norway-1.7%, Australia-1.6%, Uganda-1.5%, France-1.4%, United Rep. of Tanzania-1.3%, Belgium-1.2%, Japan-1.1%, Canada-1%, Saudi Arabia-1%, Pakistan-0.9%	Coffee, Green-63.2%, Seed Cotton-22%, Livestock-4.8%, Tea-2.8%, Industry-1.2%, Avocados-0.7%, Cereals nes-0.4%, Citrus Fruit nes-0.4%, Sugar Beets-0.4%, Vegetables Fresh nes-0.4%, Sesame Seed-0.4%, Grapes-0.3%, Jute-0.2%, Carrots-0.2%, Oilseeds nes-0.2%, Onions+Shallots, Green-0.2%, Spices nes-0.2%, Sugar Cane-0.2%, Peas, Green-0.1%, Olives-0.1%
	Grey	119	India-12.1%, Pakistan-11.8%, USA-10.8%, Egypt-6.6%, United Arab Emirates-6.4%, Uganda-6.3%, United Kingdom-6.2%, Germany-4%, United Rep. of Tanzania-2.3%, Rep. of Korea-1.9%, Sweden-1.9%, Afghanistan-1.9%, Russian Federation-1.8%, Rwanda-1.8%, Switzerland-1.3%, Sudan-1.2%, Yemen-1.1%, Finland-1.1%, Kazakhstan-1.1%, Netherlands-1%	Tea-37.1%, Coffee, Green-23.2%, Industry-11.8%, Pulses nes-11.1%, Seed Cotton-7.6%, Oil Palm Fruit-1.8%, Cocoa Beans-1%, Tobacco Leaves-1%, Peas, Dry-0.9%, Jute-0.9%, Barley-0.7%, Avocados-0.4%, Potatoes-0.3%, Beans, Green-0.3%, Sugar Beets-0.2%, Pineapples-0.2%, Peas, Green-0.2%, Grapes-0.2%, Mangoes-0.1%, Wheat-0.1%
Madagascar	Green	1538	USA-17.9%, India-14.7%, France-12.6%, Indonesia-10%, Singapore-8.7%, Germany-6.1%, Switzerland-3.7%, Netherlands-2.8%, Mauritius-2.4%, Malaysia-1.9%, Canada-1.9%, South Africa-1.6%, United Arab Emirates-1.5%, Spain-1.2%, Morocco-1.2%, Australia-1.2%, Japan-1.2%, Pakistan-1%, Italy-0.7%, Belarus-0.6%	Cloves, Whole+Stems-37%, Vanilla-28.2%, Cocoa Beans-13.9%, Seed Cotton-10.7%, Coffee, Green-2.4%, Pepper,White/Long/Black-1.2%, Beans, Dry-1.1%, Fruit Fresh nes-1%, Cinnamon (Canella)-0.9%, Pulses nes-0.8%, Sugar Cane-0.6%, Onions+Shallots, Green-0.3%, Lettuce-0.2%, Groundnuts in Shell-0.2%, Pears-0.2%, Peaches and Nectarines-0.2%, Maize-0.2%, Tobacco Leaves-0.1%, Pineapples-0.1%, Broad Beans, Dry-0.1%

Exporting country	Type	Total virtual water export (million m^3/year)	Top 20 countries	Top 20 products
	Blue	327	USA-42.3%, France-18.6%, Germany-10.7%, Mauritius-4.3%, Canada-4.1%, Australia-3.3%, Netherlands-2.7%, South Africa-2.4%, Japan-2.1%, Poland-1.4%, Switzerland-1.2%, Spain-1.1%, United Kingdom-0.7%, India-0.5%, Kenya-0.5%, Austria-0.4%, Rep. of Korea-0.4%, Ireland-0.3%, United Arab Emirates-0.3%, Belgium-0.3%	Vanilla-81.7%, Seed Cotton-17%, Industry-0.5%, Sugar Cane-0.4%, Broad Beans, Dry-0.1%, Sugar Beets-0.1%
	Grey	31	USA-22.8%, France-12.5%, Japan-7.5%, United Arab Emirates-7.5%, South Africa-7%, China-5.3%, Mauritius-4.3%, Rep. of Korea-4.3%, Spain-4%, India-3.9%, Taiwan-3%, Germany-2.6%, Sweden-1.9%, Netherlands-1.5%, Kenya-0.9%, Ireland-0.9%, United Kingdom-0.8%, Indonesia-0.8%, Switzerland-0.8%, Singapore-0.7%	Industry-52.3%, Seed Cotton-45.5%, Broad Beans, Dry-1.1%, Sugar Beets-0.4%, Sugar Cane-0.2%, Tobacco Leaves-0.1%, Chick-Peas-0.1%, Chillies&Peppers, Green-0.1%, Nuts nes-0.1%, Barley-0.1%
Malawi	Green	1111	Germany-10.8%, South Africa-10%, United Rep. of Tanzania-8.1%, Russian Federation-7.4%, Zimbabwe-6.8%, USA-5.5%, Poland-5.2%, Kenya-4.7%, United Kingdom-3.9%, Egypt-3.4%, Ukraine-3.2%, Belgium-2.2%, Rep. of Korea-2.1%, Turkey-2%, China-1.7%, France-1.7%, India-1.4%, Mauritius-1.3%, United Arab Emirates-1.3%, Netherlands-1.1%	Tobacco Leaves-52.8%, Tea-13.8%, Groundnuts in Shell-11.4%, Soybeans-10.2%, Seed Cotton-3.9%, Sugar Cane-2.4%, Sunflower Seed-1.5%, Sesame Seed-1.1%, Pimento, Allspice-0.6%, Maize-0.6%, Coffee, Green-0.3%, Pulses nes-0.3%, Sugar Beets-0.2%, Beans, Dry-0.2%, Peas, Dry-0.1%, Cereals nes-0.1%, Lentils-0.1%, Rice, Paddy-0.1%, Sorghum-0.1%
	Blue	174	South Africa-29.4%, United Kingdom-20.2%, USA-12.4%, United Rep. of Tanzania-7.4%, Germany-6.7%, Poland-3.6%, Rwanda-2.7%, Zimbabwe-2.3%, Kenya-1.7%, China-1.6%, Burundi-1.3%, United Arab Emirates-1.1%, India-0.9%, Japan-0.9%, Saudi Arabia-0.8%, Russian Federation-0.8%, Botswana-0.8%, Pakistan-0.7%, Egypt-0.6%, Belgium-0.4%	Tea-76.9%, Sugar Cane-16.4%, Soybeans-2.3%, Coffee, Green-1.8%, Pimento, Allspice-1.3%, Sugar Beets-0.5%, Sesame Seed-0.4%, Pulses nes-0.2%,
	Grey	86	Germany-15.4%, Russian Federation-11.7%, Poland-7.3%, USA-5.4%, Egypt-5.3%, Ukraine-5.1%, United Rep. of Tanzania-3.7%, Zimbabwe-3.7%, Belgium-3.4%, Rep. of Korea-3.4%, Kenya-2.8%, Turkey-2.8%, France-2.7%, South Africa-2.4%, United Arab Emirates-2.2%, China-2%, Netherlands-1.8%, Portugal-1.5%, Indonesia-1.4%, Japan-1.2%	Tobacco Leaves-84.6%, Groundnuts in Shell-5.7%, Soybeans-2.4%, Sugar Cane-2.1%, Industry-1.2%, Pulses nes-1.2%, Sugar Beets-0.9%, Sesame Seed-0.7%, Coffee, Green-0.5%, Maize-0.5%, Rice, Paddy-0.2%, Broad Beans
Peru	Green	4309	USA-23.7%, Germany-16.3%, Netherlands-8.7%, Colombia-7.3%, Italy-3.4%, Spain-3.3%, France-3%, Sweden-2.6%, United Kingdom-2.6%, Belgium-2.5%, Chile-2.3%, Rep. of Korea-2.3%, Canada-2.3%, Indonesia-2%, Mexico-1.9%, Switzerland-1.4%, Malaysia-1.3%, Japan-1.1%, Russian Federation-1%, Ecuador-0.8%	Coffee, Green-45.5%, Cocoa Beans-25.4%, Avocados-3.4%, Oil Palm Fruit-3.4%, Bananas-3.4%, Mangoes-2%, Livestock-1.8%, Ginger-1.7%, Grapes-1.7%, Pimento, Allspice-1.7%, Asparagus-1.3%, Seed Cotton-1.2%, Sugar Cane-1%, Onions+Shallots, Green-0.9%, Fruit Fresh nes-0.8%, Olives-0.6%, Oilseeds nes-0.4%, Maize-0.3%, Barley-0.3%, Beans, Dry-0.3%
	Blue	620	USA-29.1%, Colombia-11.3%, Netherlands-11.2%, Spain-7.5%, Germany-4.7%, United Kingdom-4.3%, Chile-4.1%, Ecuador-3.1%, Mexico-2.9%, France-2.8%, Canada-2.5%, Russian Federation-1.7%, Bolivia (Plurinational State of)-1.6%, Brazil-1.4%, Switzerland-0.9%, China-0.9%, China, Hong Kong SAR-0.7%, Japan-0.7%, Italy-0.6%, Saudi Arabia-0.6%	Mangoes-15.5%, Avocados-14.6%, Seed Cotton-12.6%, Sugar Cane-9.7%, Pimento, Allspice-8.8%, Asparagus-8.1%, Fruit Fresh nes-5.4%, Bananas-3.8%, Citrus Fruit nes-2%, Cranberries-1.9%, Olives-1.8%, Onions+Shallots, Green-1.8%, Rice, Paddy-1.4%, Cereals nes-1.4%, Beans, Dry-1.3%, Oranges-1%, Livestock-0.9%, Barley-0.8%, Tang.Mand.Clement.Satsma-0.7%, Vegetables Fresh nes-0.7%

Exporting country	Type	Total virtual water export (million m³/year)	Top 20 countries	Top 20 products
	Grey	376	USA-24.8%, Colombia-11.8%, Germany-10.7%, Netherlands-8%, Chile-4.3%, Spain-3.7%, Ecuador-2.6%, United Kingdom-2.5%, Italy-2.4%, Canada-2.4%, France-2.4%, Mexico-1.8%, Belgium-1.6%, Indonesia-1.6%, Rep. of Korea-1.5%, Brazil-1.5%, Sweden-1.5%, China-1.3%, Bolivia (Plurinational State of)-1.2%, Switzerland-1.1%	Coffee, Green-24.8%, Cocoa Beans-19.5%, Seed Cotton-8.6%, Oil Palm Fruit-8.3%, Avocados-4.9%, Industry-3.6%, Grapes-3.4%, Onions+Shallots, Green-2.9%, Sugar Cane-2.7%, Mangoes-2.4%, Cranberries-1.9%, Bananas-1.9%, Asparagus-1.8%, Olives-1.6%, Pimento, Allspice-1.2%, Ginger-1.1%, Fruit Fresh nes-1.1%, Beans, Dry-0.9%, Groundnuts in Shell-0.7%, Rice, Paddy-0.7%

**nes: not specified.*

The following Figures (35 – 54)represent the distribution of the total water footprint of production in the selected Global South countries. The maps indicate the water footprint expressed in mm/year per grid cell.

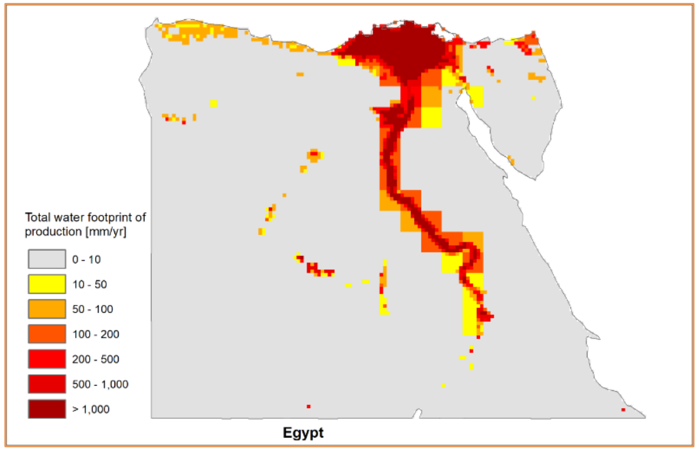


Figure 35: Water footprint of production in Egypt

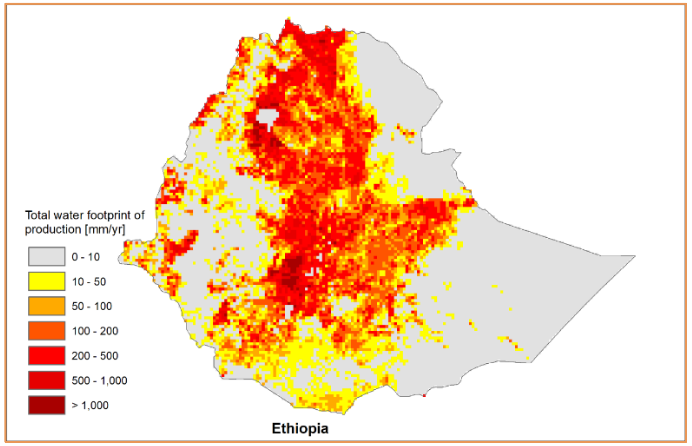


Figure 36: Water footprint of production in Ethiopia

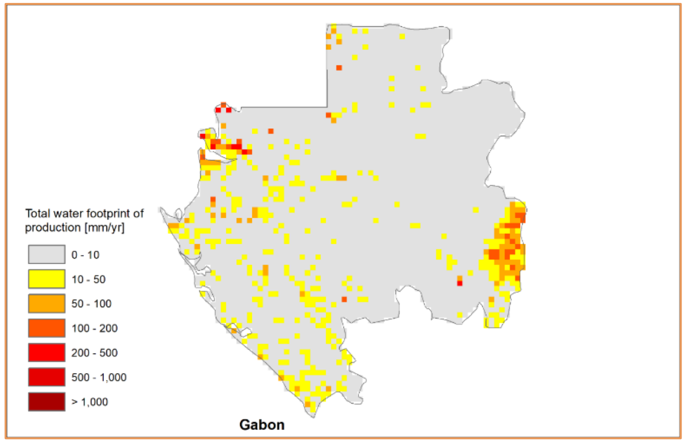


Figure 37: Water footprint of production in Gabon

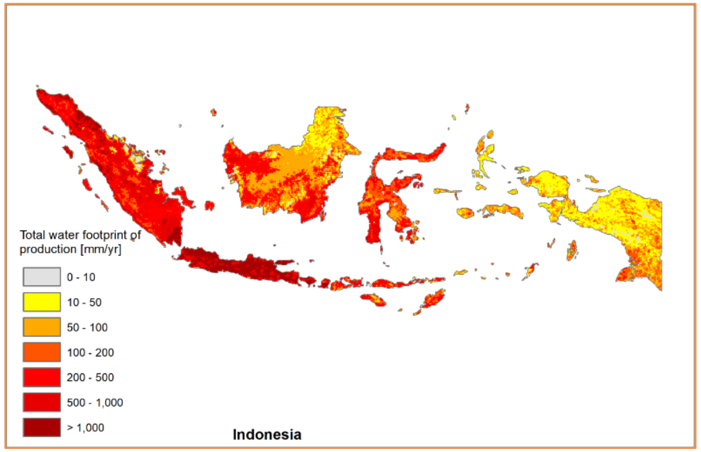


Figure 38: Water footprint of production in Indonesia

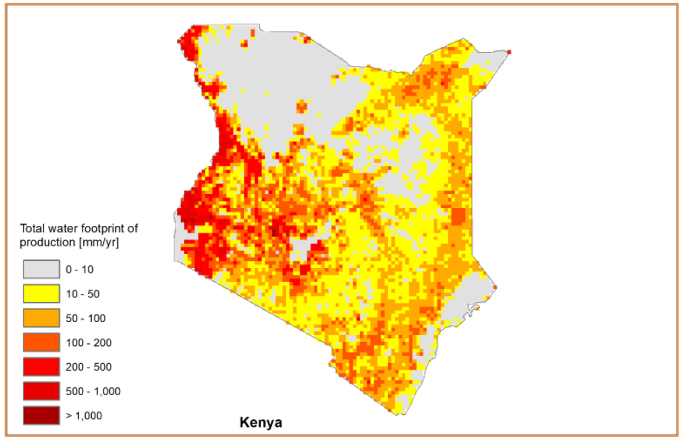


Figure 39: Water footprint of production in Kenya

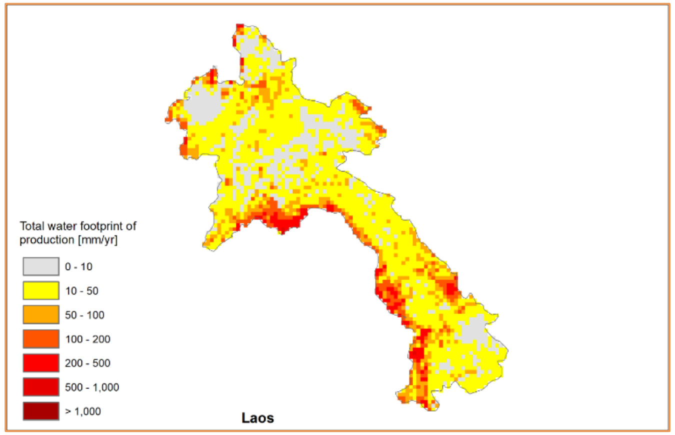


Figure 40: Water footprint of production in Laos

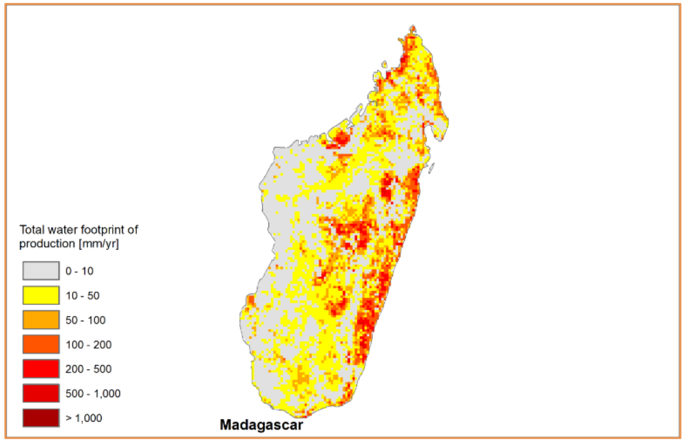


Figure 41: Water footprint of production in Madagascar

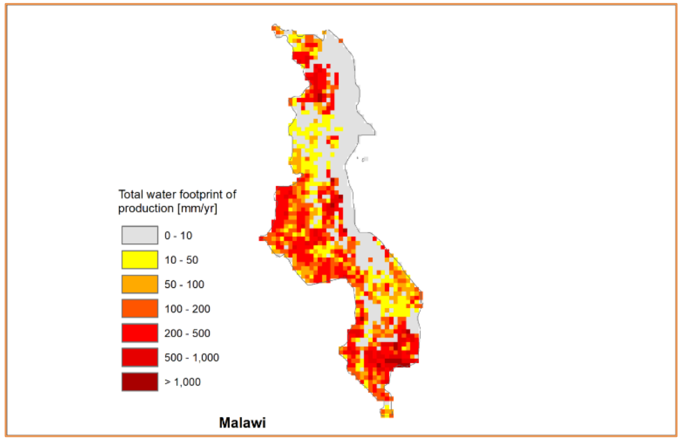


Figure 42: Water footprint of production in Malawi

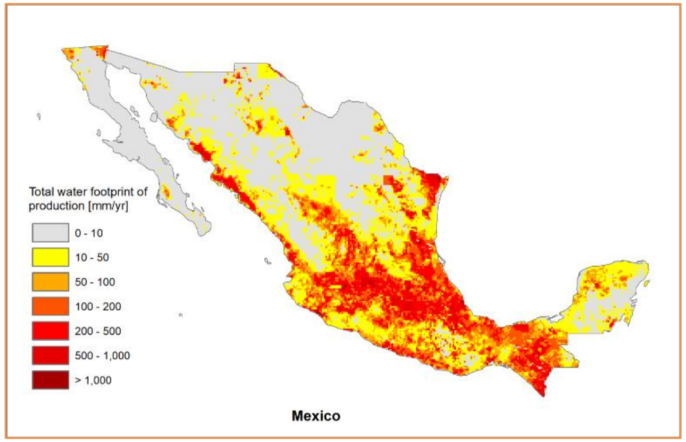


Figure 43: Water footprint of production in Mexico

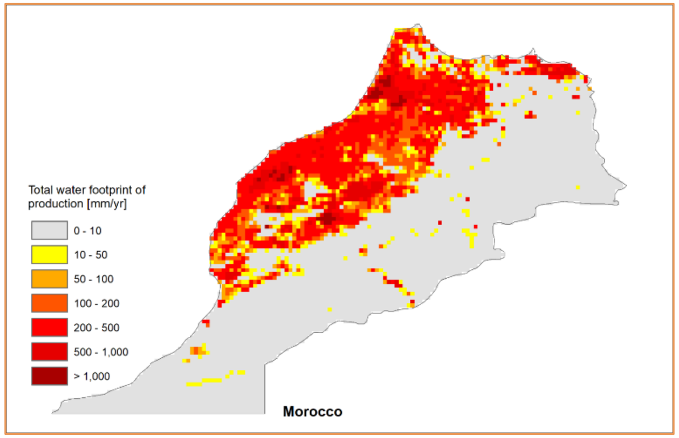


Figure 44: Water footprint of production in Morocco

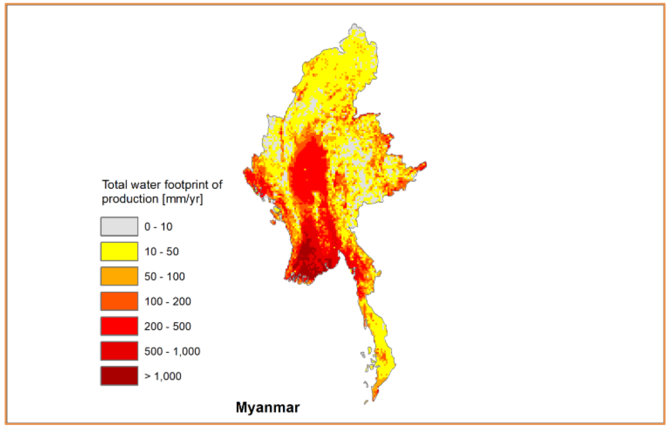


Figure 45: Water footprint of production in Myanmar

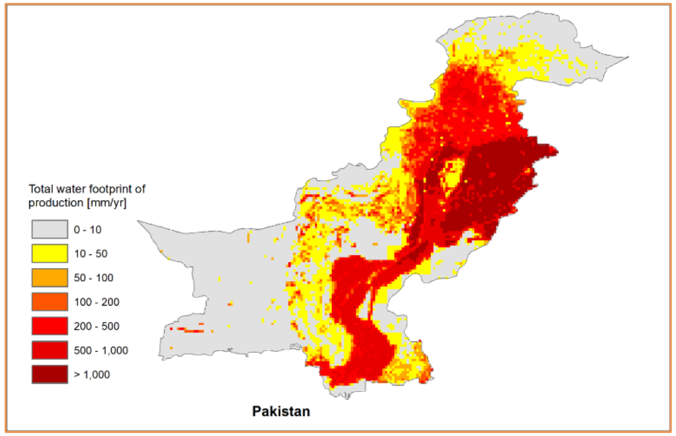


Figure 46: Water footprint of production in Pakistan

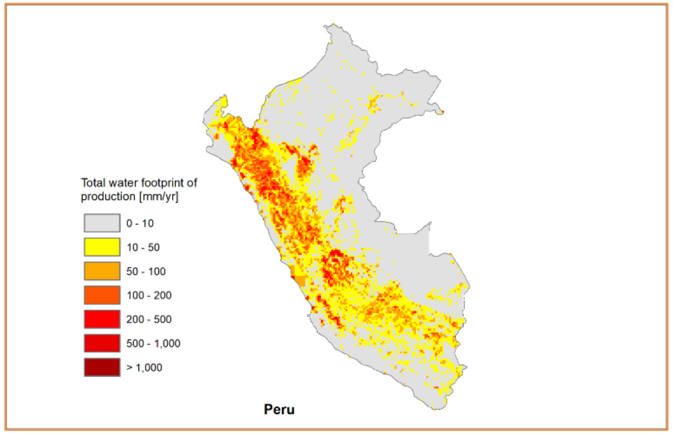


Figure 47: Water footprint of production in Peru

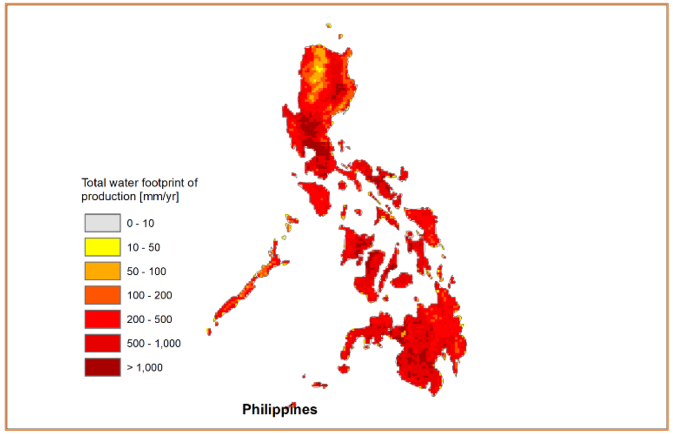


Figure 48: Water footprint of production in the Philippines

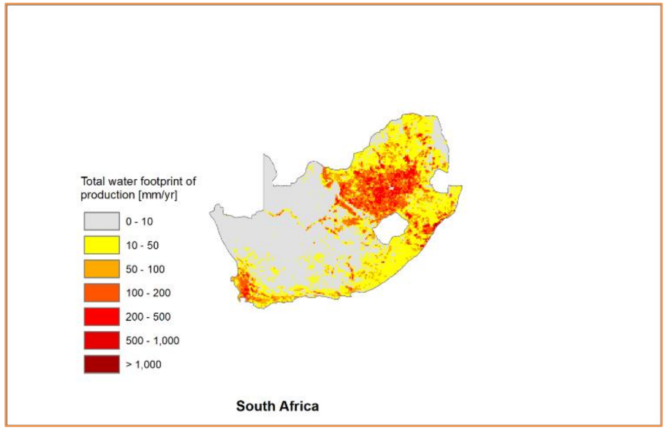


Figure 49: Water footprint of production in South Africa

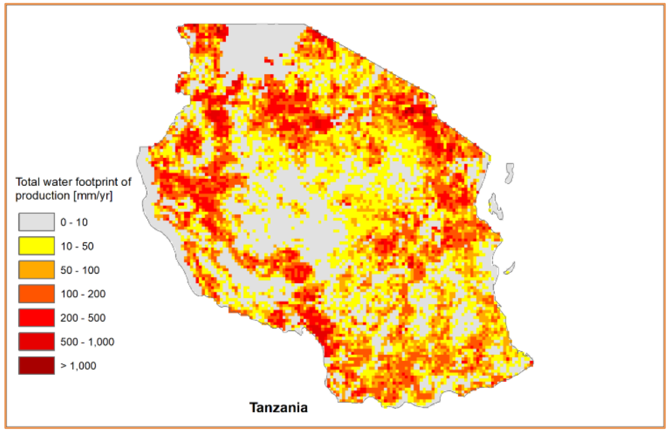


Figure 50: Water footprint of production in Tanzania

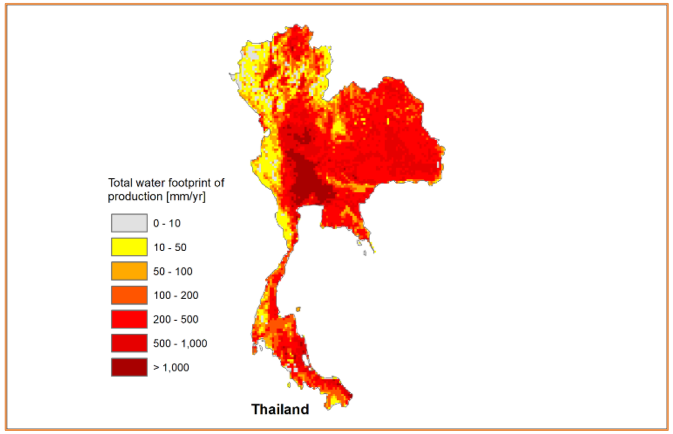


Figure 51: Water footprint of production in Thailand

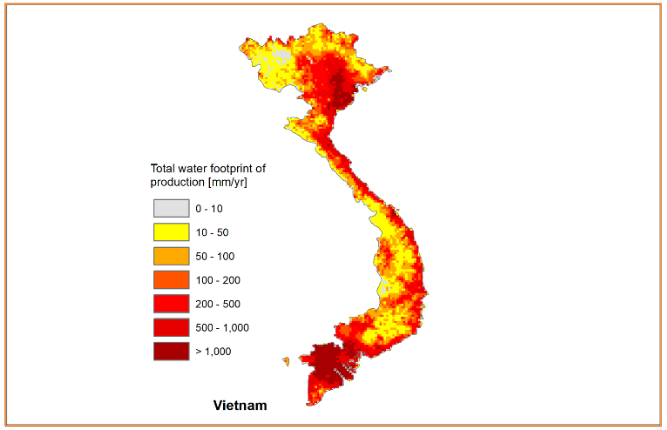


Figure 52: Water footprint of production in Vietnam

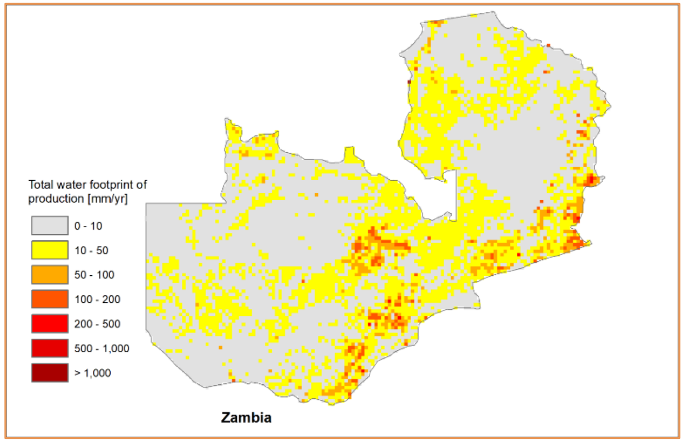


Figure 53: Water footprint of production in Zambia

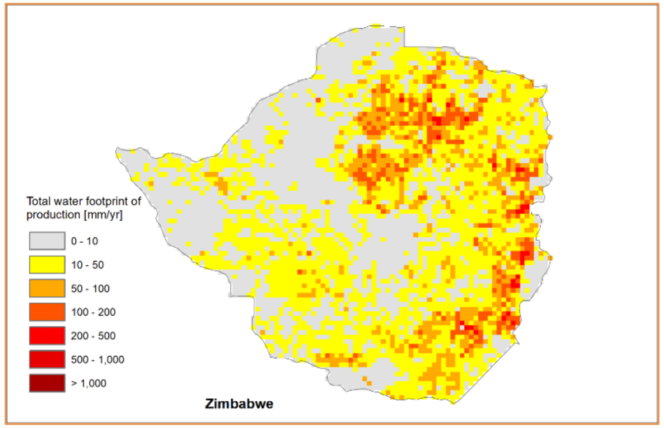
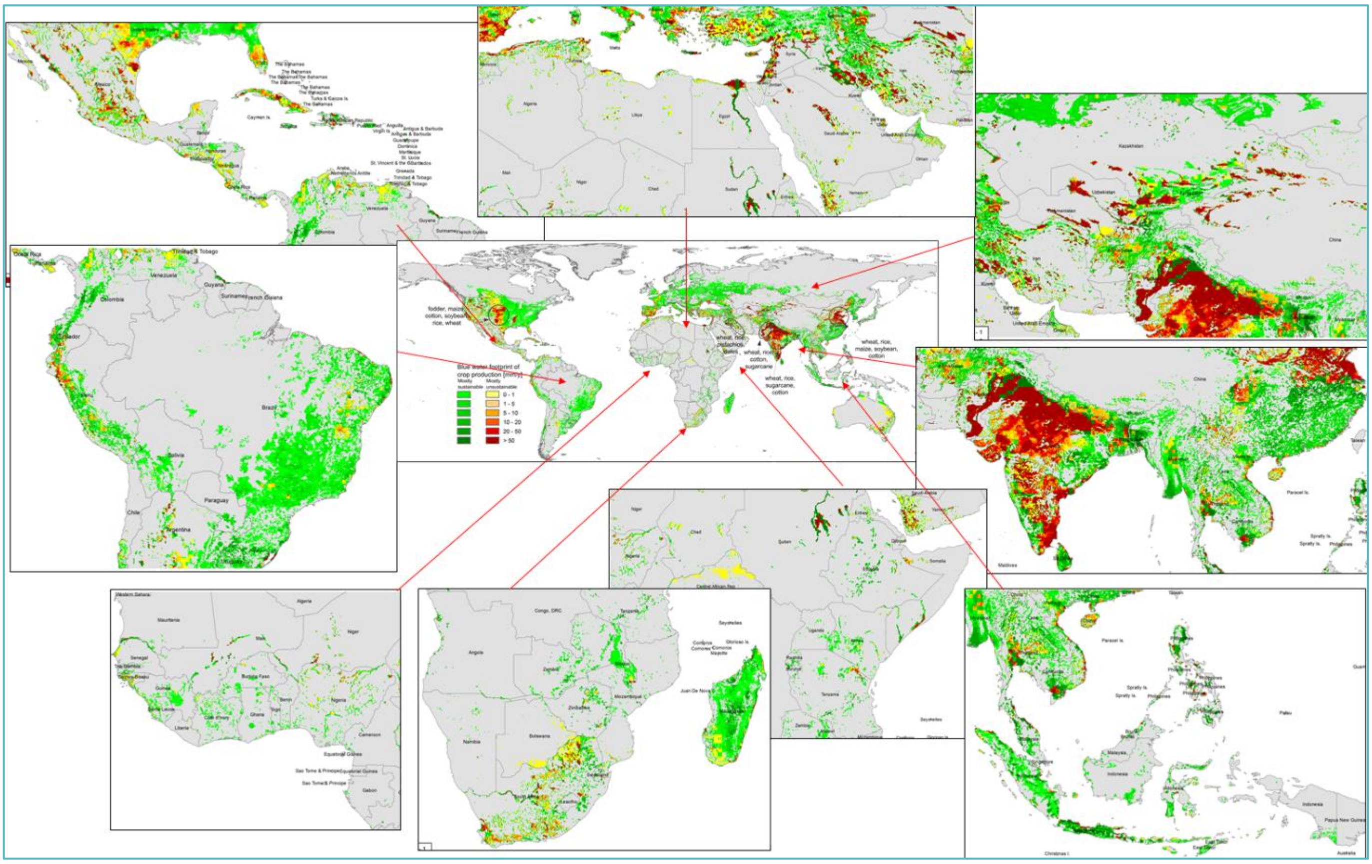


Figure 54: Water footprint of production in Zimbabwe

4.5 SUSTAINABILITY OF BLUE WATER FOOTPRINT OF PRODUCTION

The global map (Figure 55) shows the locations where the crops are produced in regions of water scarcity (red grid cells) or with no water scarcity (green grid cells). The Tables 14 and 15, present the WF of production in Ghana and Pakistan as an example to show which major crops contribute to the total water footprint of production, which are the largest importing countries from these two nations, and the share of the virtual water export by the source of water use (blue, green and grey virtual water).

Figure 55: The sustainable (green) and unsustainable (yellow to dark red) parts of the global blue water footprint of crop production.



The Global North economies import 30% of their virtual water imports from the Global North countries (internal trade among this group) and 34% from the Global South countries. Whereas the Global South countries import 46% from the Global South and 22% from the Global North. A point to highlight here is that Global North countries import 46% of their livestock products related virtual water import from within the block, whereas they import 72% of their crop imports from outside the block. We can also see that Global South countries import nearly half (48%) of their crop products from within the block. Given that majority of the virtual water imports are associated with the import of crop products (both import by the Global North countries and import within the Global South countries), and also given that most of these crop products are highly dependent on rainfall in the Global South, the vulnerability of the supply chain under most climate change scenarios are likely to be very high.

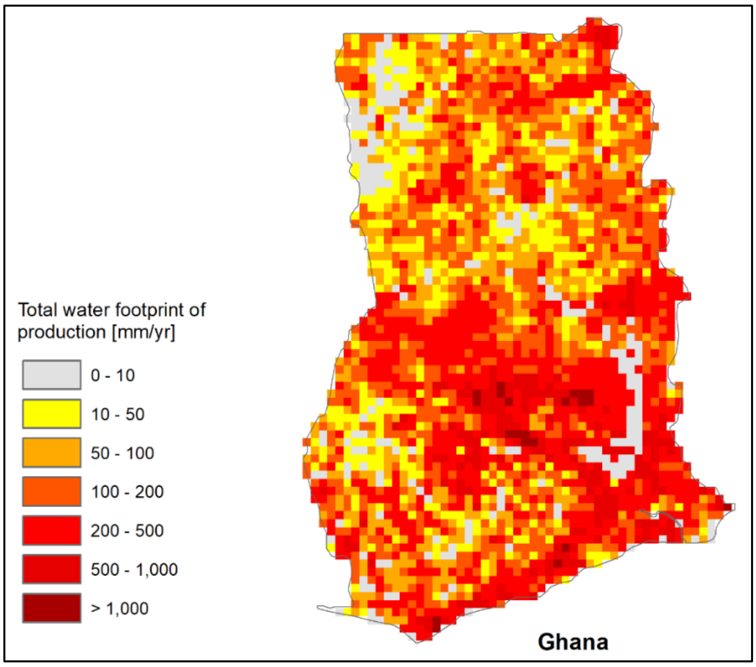


Figure 56: Total water footprint of production in Ghana.

Table 14: The share of water footprint of production in Ghana exported and the major importing nations.

	WF of production				Destination countries
Product	Contribution to the total WF (%)	Green	Blue	Grey	
Cocoa	31.0%	99.9%	-	0.1%	France-7%, Germany-6%, Japan-6%, Malaysia-6%, Netherlands-21%, Spain-4%, USA-6%, UK-9
Cassava	13.8%	99.9%	-	0.1%	USA-84%
Maize	11.3%	99.4%	-	0.6%	Niger-76%, Burkina Faso-11%, Uruguay-5%
Oil palm	8.5%	99.9%	-	0.1%	Senegal-55%, Niger-17%, Benin-9%, Burkina Faso-5%,
Plantains	8.2%	99.6%	-	0.4%	Senegal-56%, Burkina Faso-32%,
Cashew nuts	3.7%	99.9%	-	0.1%	-
Ground nut	3.3%	99.7%	-	0.3%	Viet Nam - 25%, Togo-23%, Germany-11%, 31%
Rice	2.9%	95.3%	2.0%	2.7%	Togo-58%, Mali-26%, Benin-10%
Yams	2.9%	99.8%	-	0.2%	-
Sorghum	2.3%	99.5%	-	0.5%	Burkina Faso-100%
Feed for animals	2.3%	100.0%	-	-	-
Coconuts	1.6%	99.9%	-	0.1%	Italy-69%, Netherlands-8%, US-5%
Taro (coco yam)	1.5%	99.6%	0.2%	0.2%	-
Millet	1.1%	99.3%	-	0.7%	US-88%, Senegal-8%
Natural rubber	0.8%	99.9%	-	0.1%	-
Domestic water use	0.7%	-	10.0%	90.0%	
Sweet potatoes	0.5%	99.8%	-	0.2%	Canada-28%, Netherlands-19%, Italy-17%, France-12%, Niger-8%, UK-6%
Tomatoes	0.5%	95.0%	4.0%	1.1%	-
Pulses nes	0.5%	99.2%	-	0.8%	Togo-82%, UK-9%, US-7%
Fruit fresh nes	0.3%	99.6%	-	0.4%	Germany-42%, Saudi Arabia-26%, Netherlands-24%

**nes: specified.*

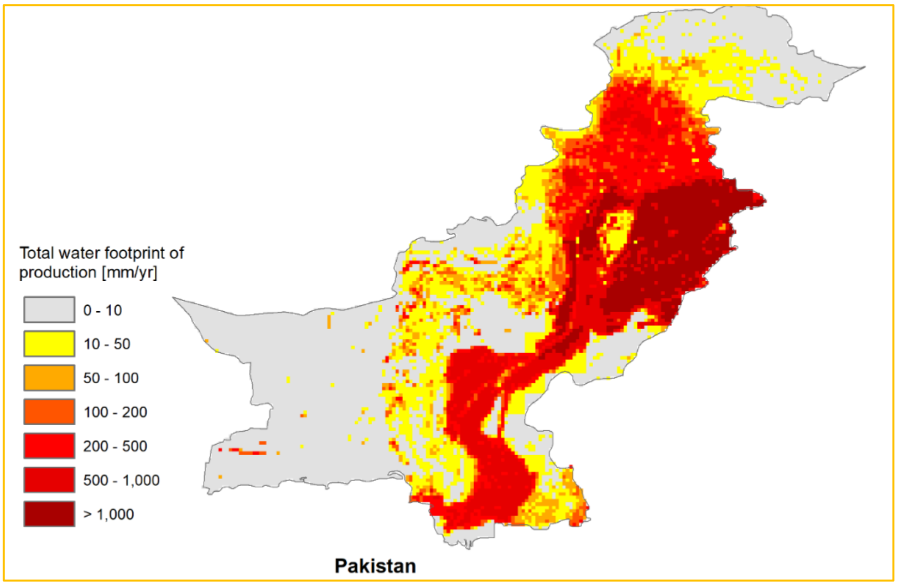


Figure 57: Total water footprint of production in Pakistan. The grid cells are mm/year.

Earlier in Table 13, we presented the largest virtual water importing nations from the selected countries, whereas in Tables 14 and 15, the information is presented based on the type of crop, their share to the total water footprint of production and the composition of this footprint. Such information can help producing countries to develop most suitable agricultural policy (which product to grow for internal consumption or export), trade negotiations (which products and which importing partner) etc.

Table 15: The share of water footprint of production in Pakistan and the major importing nations.

Product	WF of production				Destination countries
	Contribution to the total WF (%)	Green	Blue	Grey	
Grazing	26.6%	100.0%	-	-	-
Wheat	24.4%	25.3%	58.0%	16.7%	Afghanistan-48%, Bangladesh-11%, Indonesia-11%, Sri Lanka-10%, United Arab Emirates-7%
Rice	11.3%	21.3%	69.9%	8.8%	China-12%, Kenya-12%, Indonesia-5%, Iran-4%, Madagascar-4%
Sugarcane	9.1%	25.3%	66.4%	8.3%	Afghanistan-41%, Myanmar-9%, Saudi Arabia-5%, Taiwan-5%, Tajikstan-8%, USA-6%, Uzbekistan-6%
Cotton	8.0%	25.5%	56.0%	18.5%	China-22%, USA-14%, UK-6%, Spain-5%, Italy-5%, Germany-8%, Bangladesh-5%,
Domestic	4.6%	0.0%	10.0%	90.0%	-
Maize	3.9%	59.2%	20.8%	20.0%	Sri Lanka-22%, Afghanistan-13%, Kenya-19%, Malaysia-13%, United Arab Emirates-8%, Viet Nam-5%
Chick-peas	2.1%	45.4%	7.1%	47.6%	Iran-90%, Afghanistan-4%
Mangoes	1.1%	40.0%	51.4%	8.6%	United Arab Emirates-41%, Iran-13%, Afghanistan-10%, Saudi Arabia-11%, Oman-7%, UK-6%
Fruit fresh others	1.0%	49.9%	40.7%	9.3%	Afghanistan-17%, India-13%, USA-11%, Saudi Arabia-10%, Finland-7%, Bahrain-7%, United Arab Emirates-6%
Millet	0.9%	78.0%	18.2%	3.7%	United Arab Emirates-73%, Afghanistan-14%
Oranges	0.7%	33.5%	58.8%	7.7%	Afghanistan-28%, Philippines-24%, Saudi Arabia-15%, India-8%,
Industrial	0.7%	0.0%	5.0%	95.0%	-
Beans, dry	0.5%	44.1%	12.2%	43.8%	India-46%, Iran-37%, Afghanistan-10%
Onions	0.5%	16.6%	71.2%	12.2%	Saudi Arabia-23%, Malaysia-21%, United Arab Emirates-11%, Qatar-9%, Bahrain-9%, Kuwait-6%
Potato	0.4%	17.3%	42.9%	39.7%	United Arab Emirates-32%, Sri Lanka-21%, Malaysia-8%, Uzbekistan-7%, Afghanistan-5%
Appels	0.4%	49.9%	40.7%	9.3%	United Arab Emirates-20%, Libya-12%, Afghanistan-11%, Turkey-8%, Uzbekistan-7%, Angola-5%, Bahrain-5%, Qatar-5%
Sorghum	0.4%	63.5%	32.2%	4.2%	United Arab Emirates-42%, Canada-26%, Benin-13%, Oman-11%,
Rapeseed	0.3%	48.4%	38.9%	12.8%	Viet Nam-84%, Afghanistan-9%
Pimento, allspice	0.3%	32.1%	50.5%	17.4%	United Arab Emirates-30%, Mexico-29%, Saudi Arabia-17%

5 DISCUSSION AND NEXT STEPS

Our results show that the global average water footprint is increasing in line with upward trends in global consumption and changing consumption patterns. There is a corresponding upward trend in the share of the blue water footprints of consumer societies which land in regions facing blue water scarcity. The blue water footprint is unsustainable when it exceeds the available renewable blue water, thereby violating the environmental flow standard and depleting groundwater. The study uses sustainability of the external blue WF as a proxy indicator to highlight where these footprints are vulnerable to and drivers of water resource depletion, degradation, water conflict and climate impacts. We find that:

- High-income economies across the Global North and the well-being of their citizens are heavily dependent on water use in other countries to meet their needs for food, clothing and other goods. Most European nations, and Japan currently depend on external water use to meet typically 40% to 80%, and as much as 94% (Netherlands) of consumptive needs.
- These external water footprints can be traced to countries in the Global South where significant volumes of water are used to produce crops, raw materials and goods for export. Many of these ‘producer’ nations and their citizens face extreme water insecurity as result of economic and physical water scarcity, stubborn governance, infrastructure, and investment challenges, exacerbated by increasingly severe and frequent climate extremes and the climate emergency.
- Large volumes of water use within these external water footprints, ranging from 24% (Austria) to 61% (Japan) are assessed to be unsustainable, and most of this is found to land where there is severe water scarcity. Assessment using water footprint methodology applies a presumptive environmental flow requirement and finds that the ‘blue’ water use to meet the needs of ‘consumer’ nations often exceeds this, potentially pushing catchments and aquifers of production into degradation, depletion, drought, conflict, and vulnerability. Whilst high-level assessments using blue water scarcity as a proxy should be considered as approximations rather than unequivocal judgements, they are valuable in flagging risks and the need for further scrutiny. Conclusive assessment of sustainability will always require locally verified, ground-truthed data which considers the context and temporal nature of impacts. For example, it is possible for water use in places of scarcity to be sustainable where abstraction is managed in line with the hydrological yield and downstream flow requirements, or seasonal water storage. Equally, water footprints in places of water plenty can be unsustainable through multiple impact pathways: over-abstraction, uncontrolled or diffuse pollution, or impacts on ecosystems.
- For producer nations in the Global South, these findings should cause alarm, since they suggest that water use in priority sectors for growth, job creation and export revenue are also driving water insecurity, ecosystem collapse and vulnerability to climate change, undermining the health and wellbeing of citizens and future economic prospects. They signal the urgent need to redouble efforts to implement Integrated Water Resource Management (IWRM) and to allocate water in equitable and sustainable ways to meet the needs of the economy, people and the environment. They also underscore the need for new approaches to policy, practice and financing to ensure that the beneficiaries of water use in their countries contribute more meaningfully to improved water management and the shared water security upon which they also depend.
- For consumer nations in the Global North, these findings should cause even greater alarm, since they reveal that strategically important supply chains are highly precarious, and that the wellbeing and food security of their citizens are both dependent on, and actively undermining water security around the world. Facilitating shared water security in the places where these water footprints land is in the self-interest of consumer nations to protect supply chains from disruption, spiralling costs and questions about their legitimacy. There is also an ethical obligation, and an opportunity, for new forms of collaboration to

strengthen policy, law, and practice on water so that trade between nations doesn't come at the cost of water crises and injustice.

The current study provides a time-series database for the water footprint of production in the Global South countries, and the water footprint of consumption of the Global North countries, for agricultural and industrial products traded internationally. It also provides data on virtual water imported, and exported as well as the internal water footprint of domestic and industrial water use for the period of 2000-2020. Such an extensive and up-to-date database is vital for developing programmes, policies and advocacy responses to enable fairer water footprints. This work provides for high-level prioritization and a detailed assessment using locally available data to further elaborate the level of sustainable water use is recommended to support action planning. It is important to note that these high-level assessments of sustainability and risk assessment using blue water scarcity as a proxy should be considered as guidance rather than unequivocal judgements of the status of water used in production. Reliable answers about the sustainability of a water footprint require locally verified (ground-truth) data which considers the context and temporal nature of impacts. For example, it would be possible for water use within a water footprint landing in a scarce water location to be sustainable where there is carefully managed abstraction in line with the sustainable hydrological yield and the needs of downstream ecosystems and users, or seasonal water storage. Equally, water footprints falling outside of water scarce regions can be unsustainable through multiple impact pathways - over abstraction, uncontrolled pollution and ecosystem impacts.

Multiple opportunities exist to improve both the methodology and data available for studies of this nature. For example, the opaque nature of some supply chains using metals and minerals, extractives and animal feed need to be resolved urgently, and the quality and regularity of data reported on trade can be vastly improved. Nevertheless, as an entry point and screening exercise to understand where the risks of unsustainability in our supply chains are greatest, the approach remains useful.

Based on this high-level assessment of the sustainability of our water footprints, further refinements in the assessment using local data sources at prioritized locations is recommended. Formulating appropriate policy and collective action responses requires us to go beyond sustainability assessment solely based on water scarcity alone. Further dimensions of sustainability including environmental, social, and economic components should be considered to support appropriate policy responses. Finally, in the dynamic world where the operating contexts and the parameters are shifting unpredictably, response strategies, policies and action should also be guided by modelling of extreme scenarios such as the impacts of climate change, political upheaval and global pandemics.

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