Overview

# Sustainable, efficient, and equitable water use: the three pillars under wise freshwater allocation

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There are many river basins in the world where human water footprint needs to be reduced substantially. This article proposes three pillars under wise freshwater allocation: water footprint caps per river basin, water footprint benchmarks per product, and fair water footprint shares per community. Water footprint caps for all river basins in the world—setting maximums to the water volumes that can be consumed or polluted by the various human activities per basin—would aim to ensure a sustainable water use within each basin. Water footprint benchmarks for water-using processes aim to provide an incentive to producers to reduce the water footprint of their products toward reasonable benchmark levels. Benchmarks will enable the actors along supply chains—from primary producers and intermediate companies to final consumers—and governments responsible for water allocation to share information about what are 'reasonable water footprints' for various processes and products. The idea of a fair water footprint share per community aims to contribute to the debate about social equity. Water allocation may be environmentally sustainable and efficient from a resource point of view, but that does not automatically imply that water allocation is fair from a societal point of view. We need international agreement on what makes the water footprint of a community of consumers fair or reasonably acceptable, given the limited maximum sustainable water footprint per global citizen.

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## INTRODUCTION

Water pollution is normal. In China, India, and Bangladesh it happens that the color of the river shows which dye is being used in the clothes manufacturing industry.[1–3] In many places in the United States, atrazine concentrations in groundwater and rivers reach beyond acceptable levels owing to overuse of pesticide in agriculture.[4] Overconsumption of water is normal as well. In several places on Earth, groundwater levels drop to alarming levels,[5] in some cases, like in Yemen, by over a meter per year.[6] Several rivers run dry before they flow into the sea, for example, the Yellow River in China or the Colorado River in the United States.[7]

For many people, freshwater scarcity is something that occurs 'elsewhere'. The problems, however, are closer than we may think. Our daily consumer goods are often imported from water-scarce places, so that the water consumption and pollution in remote places is partly ours. For instance, in the UK,

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about 75% of the water footprint of UK consumers lies abroad.[8] It is in our own interest to make water use sustainable, not only nearby but also elsewhere, because we depend on it.

There is a growing recognition that human impacts on freshwater systems can ultimately be linked to human consumption and that issues such as water shortages and pollution can be better understood and addressed by considering production and supply chains as a whole. It is increasingly acknowledged that local water depletion and pollution are often closely tied to the structure of the global economy. The global demand for water that relates to the global demand for food and other commodities is not *a priori* localized in specific river basins. Water demands and supplies need to match at a global scale. This happens through the mechanism of trade.[9] From this perspective, water is no longer a local resource, but a global resource.[10] Many countries have significantly externalized their water footprint, importing water-intensive goods from elsewhere.[8,11–13] This puts pressure on the water resources in the exporting regions, where, too often, mechanisms for wise water governance and conservation are lacking.

Water use in itself is not the problem, but not returning the water or not returning it clean is the problem. Therefore, the 'water footprint' does not measure gross water use but consumptive water use and the volume of water polluted. The conventional way of measuring freshwater use is to look at gross water withdrawals for different human activities. If one is interested in the effect of water use on water scarcity within a catchment, however, it makes more sense to look at the net water withdrawal of an activity,[14] the so-called blue water footprint.[15] The blue water footprint measures the consumptive water use, that is, the volume of water abstracted from the ground or surface water system minus the volume of water returned to the system. The blue water footprint thus refers to evapotranspiration in the process or incorporation of water into the product. There will also be a blue water footprint in a certain catchment when the water is returned to another catchment area or the sea. Looking at blue water consumption alone is not sufficient; the blue water footprint is just one component of humanity's total freshwater appropriation. The *green* water footprint refers to the volume of rainwater consumed in a human activity. This is particularly relevant in agriculture and forestry, where it refers to the total rainwater evapotranspiration (from fields and plantations) plus the water incorporated into the harvested crop or wood. Finally, the *gray* water footprint is an indicator of freshwater pollution. It is defined as the volume of freshwater that is required to assimilate a load of pollutants based on natural background concentrations and existing ambient water quality standards.[16] It is calculated per catchment area as the load of pollutant divided by the critical load times the catchment runoff. The critical load is equal to the difference between the maximum acceptable level and natural concentration of a chemical for the receiving water body times the runoff volume.[15]

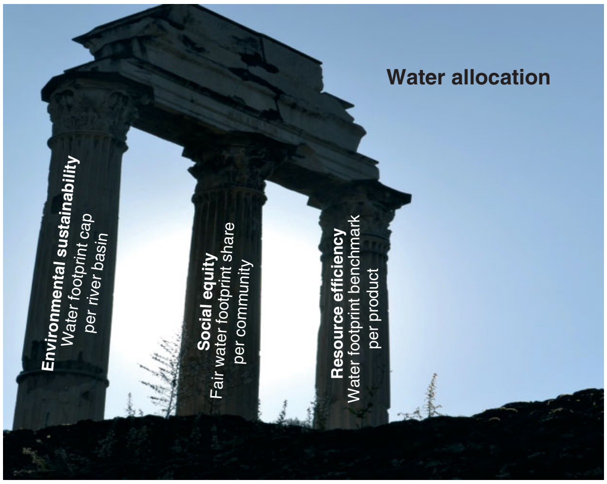

**FIGURE 1** | The three pillars under wise freshwater allocation.

Problems of water scarcity and pollution are not of today. Nevertheless, we have not found ways yet to properly address them. In this article, I propose three pillars for wise water use and allocation, based on my book *The Water Footprint of Modern Consumer Society*.[17] The three pillars should ensure environmental sustainability, resource efficiency, and social equity (Figure 1). First, it is vital that governments agree on water footprint caps for all river basins in the world, in order to ensure sustainable water use within each basin. A water footprint cap sets a maximum to the water volume that can be allocated to the various human purposes, accounting for environmental water needs. It also sets a maximum to pollution given the assimilation capacity of the basin. The total volume of 'water footprint permits' to specific users in a basin should remain below the maximum sustainable level.

Second, we need to establish water footprint benchmarks for the most important water-intensive products, for example, for food and beverage products, cotton, cut flowers, and biofuels. Water footprint benchmarks provide an incentive for producers to reduce the water footprint of their products toward reasonable levels and thus use water more efficiently. The benchmark for a product will depend on the maximum reasonable water consumption in each step of the product's supply chain. In this way, producers who use water, governments that allocate water, and manufacturers, retailers, and final consumers in the lower end of the supply chain share information about what are 'reasonable water footprints' for various process steps and end products. When granting certain water footprint permits to specific users, it makes sense for governments to take into account the relevant water footprint benchmarks for the different users.

Third, the idea of a fair water footprint share per community is introduced. Water allocation may be environmentally sustainable and efficient from a resource point of view, but that does not automatically imply that water allocation is fair from a societal point of view. We need some common understanding of what makes the water footprint of a community of consumers fair or reasonably acceptable, given the limited maximum sustainable water footprint per global citizen. Consumers in the United States and Southern Europe use nearly two times more water than the global average.[8] We need a political debate at the international level about equitable sharing of the world's freshwater resources. This implies that we will need to reconsider our consumption pattern.

We will discuss the three pillars under wise freshwater allocation one by one. In the discussion it is argued why none of the three pillars will be sufficient in itself to secure sustainable, efficient, and equitable water use. All three pillars are fundamental and complement each other.

## WATER FOOTPRINT CAP PER RIVER BASIN

Within a river basin, water resource availability is constrained by the amount of precipitation. The precipitation that adds to the water in a river basin will leave the basin again by evaporation or by runoff to the ocean. The evaporative flow (green water) can be made productive in crop fields or production forests. In this way, the evaporative flow is not 'lost' to the atmosphere but productively used. The runoff flow (blue water) can be made productive as well, by withdrawing water from aquifers and rivers and using it in industries or households or for irrigating crop fields. In this way, the runoff flow is not 'lost' to the ocean, but consumed for useful purposes. We can use all the green and blue water available in a river basin in a certain period. Temporarily, we can even use more than that by depleting groundwater and lake reservoirs but, in the longer term, from a sustainability point of view, we cannot use more than the rate of replenishment. The upper limit to consumptive water use within a river basin is the precipitation within the basin. However, this is really an upper-upper limit; the actual upper limit lies substantially lower. The 'loss' of water to the atmosphere through nonbeneficial evapotranspiration and the 'loss' of water to the ocean are not real losses. These flows are essential for the functioning of ecosystems and of societies depending on those ecosystems (think of in-stream water uses like fisheries and navigation). Substantial amounts of the green and blue water flows therefore need to be maintained to support ecosystems and should not be allocated to human purposes.

The upper limit to the green water footprint in a river basin is formed by the total evapotranspiration from the land that can be made sustainably available for agricultural production or forestry. As a rough indication, about 25–50% of the land has to be reserved as a natural area to sustain biodiversity.[18] Besides, areas are needed for living and infrastructure, and some areas, like deserts and steep mountains, are unsuitable for production, so that only a fraction of the land is available for agriculture and forestry. Only the green water flow in this area can be productively employed to produce food, feed, fiber crops, timber, paper, etc. Besides, only the green water in the growing season can be employed. The 'maximum sustainable green water footprint' (or shortly 'green water availability') in a river basin is only a fraction of the total evaporative flow.

The upper limit to the blue water footprint in a river basin is given by the total natural runoff from the basin minus the so-called environmental flow requirement. Environmental flow requirements are the flows that need to remain in the river to sustain freshwater and estuarine ecosystems and the human livelihoods that depend on these ecosystems.[19] The idea that all runoff can be consumed without a price is wrong. Biodiversity along rivers and in river deltas obviously depends on the presence of river water. As a rough indication, about 80% of the natural river flow needs to be maintained in order to prevent major changes in natural structure and ecosystem functions along the river and in its delta.[20] As a rule of thumb, the 'maximum sustainable blue water footprint' (or 'blue water availability') in a river basin is only 20% of the runoff from the basin.

For the gray water footprint, a similar logic applies. The impact of water pollution depends on the size of the pollution. The 'maximum sustainable gray water footprint' in a river basin is reached when the size of the gray water footprint equals the runoff from the basin. In this case, the anthropogenic load of chemicals to the river has reached the so-called critical load, which is defined as the difference between the maximum allowable level and the natural concentration of a chemical in a river × the runoff of the river.[15] In the United States, the concept of critical load is known under the term 'total maximum daily load'. The essence is that loads that go beyond the maximum or critical load cause an exceedance of ambient water quality standards. When the gray water footprint exceeds runoff, the waste assimilation capacity has been fully used.

In the case of carbon and ecological footprints, it makes sense to speak about global maximum sustainable levels.[21,22] This is different in the case of the water footprint. The maximum green, blue, or gray water footprint will always depend on location and time. A certain blue water footprint, for example, may cause little change in one catchment area, whereas the same-sized footprint can cause depletion of water in a much drier catchment area. The same difference can occur over time: while a certain blue water footprint may be considered small during a wet month, it can be considered huge in a dry month in the same catchment area. When we aggregate the blue water footprints of all human activities over all the river basins in the world and over the months in a year, we can speak about the global blue water footprint in a year, but it does not make sense to compare this global annual blue water footprint to the aggregated blue water availability in the world over the year. Water shortage in one basin cannot be crossed against water abundance in another basin, and water shortage in one specific month cannot be crossed against the abundance of water in another month. Water scarcity, water overexploitation, and water pollution manifest themselves in specific areas at specific times.[23]

Establishing maximum sustainable water footprints per month per river basin can be regarded as a scientific challenge. It will be a political challenge to translate knowledge on maximum sustainable water footprints into agreements on practical water footprint caps per river basin. Agreeing, for example, on a blue water footprint cap would be a useful concept for all river basins in the world, although obviously most vital for the basins where the current blue water footprint already exceeds a maximum sustainable level. Whether a river basin falls within one nation or is shared among different nations, agreeing on a blue water footprint cap is a political matter, whereby it can be expected that the level of the cap set will depend on negotiations and trading off different interests. For basins in which blue water resources are currently overexploited, it is most realistic to agree on a blue water footprint cap that gradually moves in time from the current blue water footprint level down to a level that can be regarded as sustainable. Over time, the necessary measures can then be taken to increase water-use efficiencies, so that the same levels of production can be achieved at a smaller blue water footprint. Other types of necessary measures may include shifting between different crops and—if otherwise impossible to meet the blue water footprint reduction target—reducing production levels altogether.

The idea of a cap on water use is not entirely new. In the Murray–Darling Basin in Australia, for example, a cap on surface water diversions was adopted as a response to growing water use and declining river health.[24] It was agreed that the cap be defined as 'the volume of water that would have been diverted under 1993/94 levels of development'. The question is still whether the cap puts a sufficient limit on water use to make water use really sustainable in the long term. A shortcoming of the cap in the Murray–Darling Basin is that it does not include groundwater abstractions, so that as a result of the cap on surface water diversions, the use of groundwater in the basin accelerated. Another deficiency is that the cap manages diversions rather than consumptive use.

The gray water footprint in a river basin needs to be capped as well. This is easier than reaching an agreement on capping the blue water footprint, because most countries already have ambient water quality standards in existing legislation. Together with natural concentrations and river runoff, this implies a certain critical load per chemical. The maximum sustainable gray water footprint in a catchment area is reached when the total load of a chemical equals the critical load; in this case, the gray water footprint is the size of the river runoff. The challenge here is to rationally translate ambient water quality standards per chemical to critical loads and agree on devising institutional mechanisms that ensure that critical loads are not exceeded. The contribution of diffuse sources of pollution should thereby not be ignored. In most basins of the world, it is still common practice that diffuse pollution (e.g., from fertilizers and pesticides used in agriculture) is not properly regulated. For point sources of pollution, often effluent standards are not strict enough given the number of effluent disposal licenses issued. Besides, sometimes illegal wastewater disposals take place. As a result, critical loads are easily surpassed.

I do not argue for setting green water footprint caps per river basin, because it is more straightforward to agree on reserving lands for nature. Indirectly, this means that the green water resources attached to these lands will not be available for crop production or forestry. In fact, by determining which lands can be used for agriculture and for forestry, one simultaneously allocates the green water resources in a basin.

Agreement on blue water footprint caps and critical loads per contaminant by river basin would be an enormous step forward in managing our global freshwater resources wisely. The problem with overdraft from aquifers and rivers and water pollution is that proper mechanisms to set limits are generally absent. Setting the limits clearly is one step toward better regulation. As a next step, the challenge will be to translate maximum water consumption levels and critical loads to limits for individual users. In international river basins, there will be the intermediate step of translating basin limits to national limits for that basin.

Water footprint caps need to be specified spatially—by river basin but also by subcatchment—and temporally—for example, by month. Specific attention will need to go to issues of interannual variability, because a potential trap is that limits are set for an average year, which will inevitably lead to problems in drier years. We can see this, for example, in the Murray–Darling Basin in Australia, where the overdraft of water in recent years has been partly blamed on the fact that water use permits to farmers were issued based on a too optimistic assessment of blue water availability. Once a blue water footprint cap for a river basin has been set, regular monitoring will be needed to evaluate if the level of the cap is still appropriate, given the changing environmental conditions like climate or improved knowledge regarding environmental flow requirements.

## WATER FOOTPRINT BENCHMARK PER PRODUCT

Based on the variability of water footprints found across regions and among producers within regions, for each water-using process, a certain benchmark can be established that can act as a reference and target for all producers that have water footprints above the benchmark. The water footprint benchmark for a certain process can be chosen, for example, by looking for a water footprint that is not exceeded by the best 20% of the producers. This can be done on a regional basis, in order to account for differences in environmental conditions (climate and soil) and development conditions, but it can also be done on a global basis, given the fact that for each process there is some reasonable level of water productivity (water footprint) that can be achieved in every location in the world.

The idea of a water footprint benchmark can be illustrated with an example for growing cotton. The global average green plus blue water footprint of seed cotton is 3600 L/kg.[25] The best 20% of the globally produced seed cotton, however, has a green–blue water footprint of 1820 L/kg or less. In Uzbekistan, the largest cotton producer in Central Asia, the green–blue water footprint is 4426 L/kg of seed cotton. The worst 20% of cotton production in the world has a green–blue water footprint of about 5000 L/kg, a value that is surpassed by producers in Turkmenistan and Tajikistan, the next most important cotton producers in Central Asia. There is nothing unique in the region that justifies such low water productivities compared with other regions in the world. If the three most important cotton-producing countries in the region—with, on average, a green–blue water footprint of about 5000 L/kg of seed cotton—would all manage to reduce the water footprint to the global 20th percentile benchmark of 1820 L/kg, the region would reduce cotton-related water consumption by nearly a factor of 3.

Looking at the best 20% of global production is one way of establishing water footprint benchmarks for water-consuming activities. Another way is to identify ‘best-available technology’ and take the water footprint associated with that technology as the benchmark. In agriculture, precision irrigation using microirrigation techniques is much more advanced than using sprinklers, so it can be a choice to set these techniques and the associated water footprint of the crop as a benchmark. In industrial consumption, closed water-cooling systems have a smaller blue water footprint (possibly zero) than open water-cooling systems and systems that recapture the heat from warm effluents have a smaller gray water footprint than systems that do not.

Water footprint benchmarks for different water-using processes can be useful as a reference for farmers and companies to work toward and as a reference for governments in allocating water footprint permits to users. Business associations within the different sectors of economy can develop their own regional or global water footprint benchmarks, though governments can take initiatives in this area as well, including the development of regulations or legislation. The latter will be most relevant to completely ban worst practices.

Benchmarks for the various water-using processes along the supply chain of a product can be taken together to formulate a water footprint benchmark for the final product. An end-product point of view is particularly relevant for the companies, retailers, and consumers that are not directly involved in the water-using processes in the early steps of the supply chains of the products they are manufacturing, selling, or consuming, but that are still interested in the water performance of the product over the chain as a whole.

## FAIR WATER FOOTPRINT SHARE PER COMMUNITY

At the start of the 21st century, the average world citizen had a water footprint of 1385 $m^3$/year.[8] There were, however, large differences between and within countries. The average consumer in the United States had a water footprint of 2842 $m^3$/year, whereas the average citizens in China and India had water footprints of 1071 and 1089 $m^3$/year, respectively. The global total has brought us where we are now: overexploitation of blue water resources in roughly half of the world's river basins[23] and pollution beyond assimilation capacity in at least two thirds of them.[26] We can try to shift the burden to some extent from overexploited to not-yet overexploited river basins to find better regional balances between water consumption and water availability and between water pollution and waste assimilation capacity. In this way, we may be able to better accommodate our current global water footprint. It is hard to imagine, however, that an increase of the current global water footprint can work out sustainably.

According to the medium population scenario of the United Nations, the world population is expected to increase from 6.1 billion in the year 2000 to 9.3 billion in 2050 and 10.1 billion by the end of this century.[27] This means that, if we want to make sure that the water footprint of humanity as a whole will not increase over the coming century, the average water footprint per capita will have to decrease from 1385 $m^3$ in 2000 to 910 $m^3$ in 2050 and 835 $m^3$ in 2100. If we assume an equal water footprint share for all global citizens, the challenge for countries like China and India is to reduce the current water footprint per capita level by about 22.5% over the 21st century. For a country like the United States, it means a reduction of the average water footprint per capita by about 70%. Improved technologies alone will not be sufficient to reach this goal.

There is an urgent need to evaluate the sustainability of current consumption patterns in the light of limited freshwater resources and a growing world population. As about 29% of the water footprint of humanity relates to growing feed for farm animals,[8] addressing the level of meat and dairy consumption will be one of the key issues. The second most important issue is probably to address the growth of water use for growing crops for biofuels.[28] Wise water policies for the future will definitely need to include meat and biofuel paragraphs.

How can developing countries like China and India grow economically without enlarging their water footprint per capita or even while reducing it? In India, where meat consumption is relatively low, the government should try and keep it that way. The major challenge will be to reduce water consumption in cereal production. In China, the number one concern should be meat consumption. In both countries, policies should aim at reducing food waste and developing industries with best-available technology, so that industrial development will not go hand in hand with an industrial water footprint as we can see in industrialized countries. For most of the developing countries, the challenge is threefold: improving water productivities in agriculture; ensuring that industrial developments are based on best-available technology; and staying with or moving toward low-meat diets.

The challenge in the industrialized world is probably even bigger than in the developing world. Taking the UN's medium population growth variant and assuming that all countries will need to move toward a fair share in the global water footprint of humanity, countries like the United States, Canada, Australia, Spain, Portugal, Italy, and Greece will need to reduce their water footprint per capita roughly by a factor of 3 during the period 2000–2050. If these countries will not move toward their fair share, it means that the water footprint of humanity will inevitably increase, because it is hard to imagine that developing countries will compensate. The idea of a 'fair share' is challenging and probably difficult to accept for many countries that currently have a water footprint per capita beyond the global average.

The limited availability of freshwater in the world implies a ceiling for humanity's water footprint. The question for the global community is how this global maximum can be transferred to the national or even the individual level. In other words: what is each nation's and each individual's 'reasonable' share of the globe's water resources? And what mechanisms could be established in order to make sure that people do not use more than their 'reasonable' share? Maximum levels of water consumption and pollution to guarantee a sustainable management of the world's freshwater resources could be institutionalized in the form of an international agreement on 'water footprint allowances' specified per nation. Such a 'water footprint allowance' would be the total water footprint that the consumers within a nation are allowed to have within the international agreement. The allowance would reflect the share that the consumers within a nation have in the total water footprint of humanity. The levels of the allowances per country would need to be negotiated among countries, and will therefore probably lie somewhere between the country's current water footprint levels and the 'fair share' per country based on population numbers.

Politically, different steps are to be taken. First, national governments need to reach consensus about the need to halt the continued growth of the water footprint of humanity as a whole. Second, given projected increases in the global population, international consensus needs to be reached about water footprint reduction targets or maximum water footprint increase levels per country. Third, nations would be responsible for translating the national reduction targets into national policy in order to meet the target. Enforcement can be done in the form of penalties when not meeting the agreed targets. Targets would need to be specified, for example, by water footprint component (green, blue, and gray water footprint); they could also be specified by sector or product category. Obviously, water footprint allowances or reduction targets can develop over time and would need to be negotiated on a regular basis, like every 10 years or so. The similarity with international negotiations about carbon footprint reductions is clear.

An international agreement on water footprint allowances or water footprint reduction targets per nation would be somehow comparable to the Kyoto Protocol on the emissions of greenhouse gases.[29] The Kyoto Protocol—which was drafted in 1997 and became effective in 2005—is based on the understanding that, to prevent human-induced climate change, a maximum is to be set to the volume of greenhouse gas emissions from human activities at the global level. The protocol is an international agreement to cut greenhouse gas emissions, with specific reduction targets by country. The overall goal was a collective reduction of greenhouse gas emissions by 5.2% in 2012 compared to the reference year of 1990. The experience with the Kyoto Protocol is both hopeful and discouraging. The good side of the experience is that the global community has shown that it is able to collaborate toward a common interest, but the downside is that the agreement did not have enough reach and teeth to be really effective: humanity's carbon footprint has continued to increase.[30] It would be good if, in the global talks about addressing the global water footprint, lessons were drawn from the experience with the Kyoto Protocol.[21] Simply adopting the same kind of format, with tradable emission credits, appears to be a bad idea, because the possibility of offsetting offers an escape route away from actual footprint reduction. We have to acknowledge that, after all, the idea of offsetting is not such a good idea as it seemed at the time it was invented. The achievement of the Kyoto Protocol is the establishment of the whole idea of setting nation-wise concrete footprint reduction targets. With hindsight, however, we can conclude that the mechanisms that were installed to reach those reduction targets are flawed.

## DISCUSSION

There are many river basins in the world in which our water footprint needs to be reduced substantially. That can be achieved by setting a water footprint cap per river basin, setting water footprint reduction targets for specific products and by changing consumption patterns so that they become less water intensive. One could argue that regulating the maximum water footprint per basin would be a sufficient measure, because it would automatically translate into an incentive to use water more efficiently and put a constraint to consumption. The geographic focus, however, is insufficient, as we will illustrate through a simple example.

Suppose the hypothetical case of two river basins with the same surface (Table 1). Basin A is relatively dry and has, on an annual basis, 50

**TABLE 1** | Example of How Overexploitation in a Water-Stressed River Basin (A) Can Be Solved by Increasing Water Productivity in a Water-Abundant Basin (B)

| | | Current Situation | | Possible Solution | |
|---|---|---|---|---|---|
| Parameter | Unit | Basin A | Basin B | Basin A | Basin B |
| Maximum sustainable water footprint | Water units per unit of time | 50 | 250 | 50 | 250 |
| Water footprint | Water units per unit of time | 100 | 200 | 50 | 200 |
| Production | Product units per unit of time | 100 | 100 | 50 | 200 |
| Water footprint per product unit | Water units per product unit | 1 | 2 | 1 | 1 |
| Water productivity | Product units per water unit | 1 | 0.5 | 1 | 1 |

water units available: the maximum sustainable water footprint. The maximum level, however, is exceeded by a factor of 2. Farmers in the basin consume 100 water units/year to produce 100 crop units. Basin B has more water available, 250 water units/year. Water is more abundant in Basin B than in the first basin, and water is used less efficiently. Farmers in the basin consume 200 water units/year to produce 100 crop units, the same amount as in the first basin, but using two times more water per crop unit. A geographic analysis shows that in basin B, the water footprint (200) remains below the maximum level (250), so this is sustainable. In basin A, however, the water footprint (100) by far exceeds the maximum sustainable level (50), so this is clearly unsustainable. The question is now: should we categorize the crops originating from basin A as unsustainable and the crops from basin B as sustainable? From a geographic perspective, the answer is affirmative. In basin A, the water footprint of crop production needs to be reduced, which seems to be the crux. However, when we take a product perspective, we observe that the water footprint per crop unit in basin B is two times larger than that in basin A. If the farmers in basin B would use their water more productively and reach the same water productivity as in basin A, they would produce twice as many crops without increasing the total water footprint in the basin. It may well be that farmers in basin A cannot easily further increase their water productivity, so that—if the aim is to keep global production at the same level—the only solution is to bring down the water footprint in basin A to a sustainable level by cutting production by half, while enlarging production in basin B by increasing the water productivity. If basin B manages to achieve the same water productivity level as in basin A, the two basins together could even increase global production while halving the total water footprint in basin A and keeping it at the same level in basin B.

This example is not a theoretical one. In the real world we can see a lot of semiarid regions where water is relatively efficiently used, but overexploited, while we see water-abundant regions, where no overexploitation takes place but where water productivities are comparatively low. From a geographic perspective, the weak spots in the whole system lie in the regions with water overexploitation, where the total water footprint is too large. From a production perspective, the weak spots in the system lie in the regions with low water productivities, where water footprints per unit of production are unnecessarily large. In order to move the whole system in a sustainable direction, two things need to happen at the same time: total water footprints need to be reduced in the geographic areas where maximum sustainable levels are exceeded and water footprints per unit of production need to be reduced in those areas where this can be achieved most easily. From a global perspective, sustainability requires that maximum water footprint levels for all individual geographic areas are maintained but, in order to achieve that, water-use efficiencies need to be improved everywhere, wherever feasible, also in regions where water is abundant. From this global perspective, a product cannot be considered sustainable simply because it was produced in an area where maximum water footprint levels are maintained. Given certain global demands for various products and global constraints to water availability, water footprints per unit of product need to remain within certain limits. In practice, an important part of the solution to overexploitation of blue resources in water-scarce catchments is to use green water resources more productively in water-abundant catchments. Even though many people, including most water professionals, are inclined to focus on the main problem (irrigated agriculture in dry regions) and look for solutions there (increase blue water productivity), an essential element of the global solution is to invest in increasing productivities in rain-fed agriculture in wet regions (increase green water productivity).[31]

The above shows that one should be careful with a focus on the water-scarce areas alone. A significant part of the solution of water scarcity experienced in various places lies in using water more efficiently in water-abundant parts of the world. However, one should be cautious for an overoptimistic expectation of the environmental gains of increased water-use efficiency as well. From energy studies, we know a phenomenon that is called the 'rebound effect'.[32–34] Rebound refers to a typical response in the market to the adoption of new techniques that increase the efficiency of resource use. The typical response is that if resources are saved, they become available for additional production, so that in the end the original environmental gain is partly or completely offset. Sometimes, consumption even increases (rather than decreases) as a result of the efficiency increase. This specific case of the rebound effect is known as the Jevons paradox. There are only a few studies on the rebound effect in the field of freshwater use, but there is no reason to assume that it does not occur in this sector.[35,36] Imagine those vast areas in the world where land is readily available, but water is not. If a farmer is used to pumping water for irrigating his land and finds out that he can obtain the same yield with less water, he may well decide to irrigate more land, thus increasing his total production, using more efficient irrigation techniques but in total the same volume of water. It is not extraordinary to assume that water productivity increases in food supply will facilitate an even quicker shift to the production of biofuels.

Regulating maximum water footprints per river basin, providing incentives to lower water footprints of products to reasonable benchmark levels, and changing our consumption patterns to less water-intensive levels will be complementary measures to drive toward sustainable, efficient, and equitable water use. As allocation of water is essentially political, it is time that politicians put water scarcity and water allocation higher up on their agendas.

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