Abstract

Freshwater is an essential resource for human life, the economy and the environment. Virtually every economic sector from agriculture, power generation and manufacturing to beverage, apparel and tourism, relies on freshwater to sustain its business. Yet water is becoming increasingly scarce globally and every indication points to it becoming even more so in the future.

Global Water Stress Is Severe and Will Worsen in the Near Future

Availability of freshwater in sufficient quantities and adequate quality is a prerequisite for human societies and natural ecosystems. In many parts of the world, excessive freshwater consumption and pollution by human activities put enormous pressure on this availability, which subsequently has an impact on food security, environmental quality, economic development and social wellbeing. Competition over freshwater resources has been increasing over recent decades due to a growing population, economic growth and increased demand for agricultural products for both food and non-food use. A shift in consumption patterns towards more meat and sugar-based products is also a contributory factor (Shen et al., 2008; Falkenmark et al., 2009; De Fraiture and Wichelns, 2010; Strzepek and Boehlert, 2010; Ercin et al., 2012a, b). It is likely that today's problems related to freshwater scarcity and pollution will be aggravated in the future due to a significant increase in demand for water and a decrease in availability and quality. Many scientists have estimated that our dependency on water resources will increase significantly in the future and cause problems related to food security and environmental sustainability (Rosegrant et al., 2003, 2009; Alcamo et al., 2000, 2003; Bruinsma, 2003, 2009; Ercin and Hoekstra, 2016).

The impacts of global water scarcity have started to become evident. The recent water crisis in Cape Town, as well as the one in São Paulo in 2015, forced many businesses and industries to shut down. It is estimated that 14 of the 20 megacities in the world are in danger of facing severe water scarcity, like that experience by Cape Town and São Paulo (National Geographic, 2018). Droughts have also become more frequent, more severe, and are affecting more people around the world. A recent study by Mekonnen and Hoekstra (2016), reveals that as many as four billion people worldwide are living under water scarcity for at least one month of the year (Fig. 1). Their research shows that earlier estimates did not capture the monthly variability of water scarcity and that the number of people affected by severe water scarcity is much higher. For example, the entire population of 37 countries and more than half of the population of 97 countries live under severe water scarcity during at least one month of the year (Fig. 2). This information is key when addressing Sustainable Development Goal 6.4, which aims to substantially reduce the number of people suffering from water scarcity.

With growing uncertainty of water availability in the face of climate change, governments, businesses and communities are becoming acutely aware that they are vulnerable to a wide range of issues associated with water resources. Furthermore, the ever-rising trend in water demand has significant impacts on the quantity and quality of water available at local, as well as global, scales.

Water crises have been ranked as the top systemic global risk (World Economic Forum, 2016) and the Sustainable Development Goals now include a dedicated water goal, which indicates that water challenges have become a global issue. Two-thirds of the world’s largest companies are reporting exposure to water risks, some of which have potential to limit a company's growth (CDP, 2015). The food sector, which essentially relies on agriculture, a sector that contributes 92% of the total global water footprint (Hoekstra and Mekonnen, 2012), is especially vulnerable to water scarcity globally due to its dependence on water as both a direct ingredient and as an input to agricultural commodity production.
Agriculture touches everyone's lives, whether as a livelihood or through food supply, clothing, fabrics and other products. Yet the sector not only has an impact on people's lifestyles, it also has a significant impact on the world's resources. Its production relies heavily on water, from raw materials to the industrial processing stages. Rising competition for water is already impacting the food and agri-food based sectors, and water constraints will increasingly challenge "business as usual". It is critical for the sector's long-term viability - and for the health of ecosystems and communities - to understand how water is used at every step of the supply chain and to prioritise actions that will ensure it is used as sustainably as possible.

At present, irrigated agriculture is responsible for about 70% of all freshwater abstractions by humans (Bruinsma, 2003; Shiklomanov and Rodda, 2003; UNESCO, 2006; Molden, 2007), while agriculture as a whole is responsible for roughly 92% of worldwide consumptive use of freshwater (Hoekstra and Mekonnen, 2012). In addition to agriculture, industries and households use substantial amounts of water and contribute significantly to water pollution (WWAP, 2009). In many places urban areas, industry, agriculture, and natural ecosystems compete for freshwater (Rosegrant and Ringler, 1998; UNESCO, 2006; Anderson and Rosendahl, 2007).

Given that severe freshwater scarcity is a common phenomenon in many regions of the world, improving the governance of the world's limited annual freshwater supply is a major challenge, not only relevant to water users and managers but also to final
consumers, businesses and policymakers in a more general sense (UNESCO, 2006). About 86% of all water used by humans in the world is for growing food (Hoekstra and Chapagain, 2008). Therefore, food choices can have a big impact on water demand (Steinfeld et al., 2006; De Fraiture et al., 2007; Peden et al., 2007; Galloway et al., 2007, Ervin et al., 2017). In industrialised countries, an average meat-eater consumes the equivalent of about 3600 L of water a day, which is 1.6 times more than the 2300 L used daily by people on vegetarian diets that include dairy products (Hoekstra, 2010).

Growing competition for water, weak regulations, aging water infrastructure, water pollution and climate change are having increasingly adverse effects across food production. The increasing demand for water is escalating water scarcity and water pollution in many regions of the world including China, India and sub-Saharan Africa, where most of the world’s population lives under the threat of water shortages.

The projected increase in the world population growth rate suggests that food demand is likely to rise in the future, which would have a direct effect on agricultural water usage. In addition, as a result of increased water scarcity and drought due to climate change, extensive water use for irrigation is expected to occur in the context of increasing competition between agriculture and other sectors of the economy.

The Sustainable Development Goal’s second target focuses on ending hunger by 2030. Hunger in many countries is related to poverty and to a lack of investment in agriculture, as well as the climate, weather and wars/displacements. One of the ways to eradicate hunger in many countries is to produce more food and increase agricultural yields, which may require the availability of more water for agriculture. This could pose a risk, because some of these countries are already experiencing water scarcity and a majority of their population is already living under severe water scarcity. In some of these countries, particularly in India and China, water scarcity is driven by large population numbers.

Approximately one-third of all food produced for human consumption in the world is lost or wasted.1 This food wastage represents a missed opportunity to improve global food security and also to mitigate environmental impacts and the resource use of food chains. Land, energy and water are the most critical natural resources that are expended in processing, transporting, storing and cooking the wasted food. Food waste that ends up in landfills also produces a large amount of methane, an even more powerful greenhouse gas than carbon dioxide (CO2). With agriculture accounting for 92% of the water used by humans throughout the world, food waste also represents a great waste of freshwater and ground water resources. By throwing out 1 kg of beef, approximately 24,000 L of water is wasted; the quantity required to produce that meat. In the same way, nearly 1000 L of water are wasted when one glass of milk is poured down the drain. Therefore, better food waste management is required in order to reduce such negative environmental impacts.

### Increased Water Scarcity and Drought Under Climate Change

Climate change may affect both the long-term availability and the short-term variability of water resources in many regions. Potential impacts of climate change include increased frequency and magnitude of droughts and floods and long-term changes in mean renewable water supplies. These can occur through changes in precipitation, temperature, humidity, wind intensity, duration of accumulated snowpack, nature and extent of vegetation, soil moisture, and runoff.

Agricultural production is inextricably tied to the climate, making it one of the most climate-sensitive of all economic sectors: crop yield and water use, as well as soil health are directly affected by a changing climate. Climate-related threats to agricultural production include risks such as reduced yields, increased crop water demand and decreased water availability for agriculture. At the same time, climate change can also create opportunities, particularly in the agricultural sector. Increased temperatures can lengthen growing seasons, higher CO2 concentrations can enhance plant growth and, in some areas, rainfall and the availability of water resources can increase as a result of climate change.

Climate is an important factor for agricultural activities and changes in the climate influence agriculture significantly. In addition to extreme weather conditions such as increased floods and/or droughts, global climate change causes lower and more unstable rainfall combined with increased temperature, thus resulting in higher evaporation and water demand. Since the agricultural sector consumes most of the freshwater resources in the world, there is a strong concern over the impacts of climate change on water resources and agricultural production in the future. An increase in temperatures could also lead to a net deficit in atmospheric water content, thus excessive evaporation from soil, water and plant surfaces would occur. Consequently, land ecosystems would require more water to match increased water demand in order to prevent drought. Therefore, it is important to provide information on future regional changes in the climate and possible climate change scenarios in order to inform effective policies and management strategies for the future (Topçu et al., 2017).

### Water Scarcity Is Not Only a Local Problem, It Can Endanger Food Security and Economic Stability Globally

In recent years, it has become increasingly evident that local water depletion and pollution are often closely tied to the structure of the global economy (Hoekstra and Chapagain, 2007; Ervin et al., 2017; Ervin and Hoekstra, 2016; van den Hurk Bart et al., 2017). It has been estimated that about 20% of water consumption and pollution in the world is related to the production of export goods (Hoekstra and Mekonnen, 2012). International trade in commodities implies long-distance transfers of water in virtual form, where virtual water is understood as the volume of water that has been used to produce a commodity and is thus
virtually embedded in it. Knowledge about the virtual water flows entering and leaving a country can cast a new light on the actual water scarcity of a country. For developing a wise national water policy, it is also relevant to consider the linkages between goods consumed in a country and the impacts on freshwater systems where those goods are produced (Dalin et al., 2012, 2017).

As nations work toward securing food, water, energy and other essential inputs for people’s well-being, livelihoods and for economic development, most countries rely on both imports and exports of goods and services. A country may aim to be self-sufficient by relying primarily on goods that can be produced within its borders, or it may choose to reduce the burden on its own natural resources by importing water intensive products. For water-scarce countries it can sometimes be attractive to import virtual water through the import of water-intensive products, thereby relieving the pressure on domestic water resources. This happens, for example, in Libya, Algeria, Saudi Arabia, Mexico and Tunisia, where blue water scarcity prevails for over six months of the year (Ercin et al., 2017).

On the other hand, net virtual water exporters use their internal water resources to produce goods and services that are consumed outside their borders. However, more than 50% of the population of the largest net blue virtual water exporters experience severe water scarcity during at least one month of the year (Water Footprint Network, 2016). This shows that export and trade in these countries is putting pressure on local water resources and indicates that the sustainability of supplies from these countries in the future is at risk.

Although water scarcity is a local issue in the sense that it is more acutely felt in the river basins in which it occurs, it is also a global issue because it threatens food security and economic stability everywhere due to the global nature of the agricultural commodity trade. A good example of this is the European Union (EU). The EU produces most of the agricultural products it needs for the crop and animal products used by its economic sectors, yet meets some of its needs by importing agricultural products from outside its borders. This external dependency varies according to the type of crop product, but accounts for approximately 38% of the EU’s demand for agricultural products (Ercin et al., 2017) (Fig. 3). However, the continued availability of many of these imports, particularly those that rely on water, is at risk because their production is potentially sensitive to water scarcity and drought. For example, the EU relies almost entirely on imports of soybean to meet demand for animal feed in order to produce meat and dairy products. It imports around 30–35 million tons of soybean per year and produces only 0.9 million tons per year domestically. The deficit in soybean production in the EU poses a significant risk to its economy and especially to the EU meat industry due to the high demand for the product, its high reliance on imports and the vulnerability of the crop to climate change in the producing regions (Ercin et al., 2018).

**Food Security and Economic Stability Under Weather Extremes: The EU Case**

The impact of hydrological extremes, for instance droughts, can affect economic activities and ecological systems that depend on the availability of water. For example, lack of water can often result in losses in both crop yields and livestock production. Production losses, combined with changes in demand for products and water by different economic sectors, may lead to local shortages of certain goods, and thus result in a need to import these goods from other regions. However, the availability of these imports, particularly those that rely on water, can be at risk considering that production of many commodities is potentially sensitive to local hydrological extremes and global climate change.
The EU uses approximately 668 km\(^3\) of water for all of the goods it produces, consumes and exports annually.\(^4\) Around 38% of this water comes from outside its borders, which means that the EU economy is highly dependent on the availability of water in other parts of the world. Two-thirds of the foreign water that the EU depends upon comes from 11 countries: Brazil (20%); Argentina (11%); Indonesia (8%); Ivory Coast (8%); Ghana (4%); the United States of America (USA) (4%); Ukraine (3%); Malaysia (3%); and India (3%). Most of this external water demand, in terms of the water embodied in imported products, is for agricultural commodities (98%), followed by industrial products (2%). This means that the EU is particularly vulnerable to lack of water availability affecting supplies of agricultural commodities from these 11 countries.

In the near future, supplies of certain crops to the EU could be disrupted due to water scarcity in other parts of the world; a large portion of the water used in producing soybeans, rice, sugar cane, cotton, almonds, pistachios and grapes for import to the EU comes from areas with significant or severe levels of water scarcity. This means that surface and groundwater resources are already seriously depleted and that there is too much competition for the remaining available water in those areas (Ercin et al., 2016b). Almost all of the crop products imported to the EU from India and Pakistan are sourced from locations with high levels of water scarcity. For sugar cane, 96% from India and 90% from Pakistan is produced in locations that are very highly vulnerable to water scarcity. For rice, 93% from India and 91% from Pakistan is produced in locations that are very highly vulnerable to water scarcity.

Although the immediate risks to the EU economy are due to current water scarcity levels, any disruption to rainfall patterns that could likely occur in the future due to the effects of climate change in the countries of origin of key crops could have a far greater impact on the EU.

Lack of rainfall can lead to drought. Prolonged drought can increase demand for additional water for irrigation. This, in turn, exacerbates water scarcity and reduces the amount of water available which leads to increased competition for the resources that remain. Rain-fed agriculture accounts for as much as 92% of the EU’s total external water demand for agriculture. Because this type of agriculture is so highly dependent on rainfall, any disruption to weather patterns as a result of climate change in these countries would have serious implications on the EU’s economy and on its food security (Ercin et al., 2017).

### Outlook

The major factors that will affect the future of global water resources are: population growth and distribution; economic growth; changes in production and trade patterns; increasing competition over water due to increased demand for domestic, industrial and agricultural purposes; and the way in which different sectors of society respond to increasing water scarcity and pollution.

Water crises have been ranked as the highest concern for the next 10 years on a global scale (World Economic Forum, 2016). In the globalised economy, the impacts that water scarcity and drought have on food production, food security, economic stability and growth are not only local issues in producing regions. Policies and strategies that tackle economic stability or food/supply chain security should perceive water problems as a global issue and should consider the vulnerable to water-related impacts in regions where agri-food products are produced. Consequently, managing water-related risks should encompass both a wide-angled view of the risk spectrum as well as a focused mitigation strategy.

Water scarcity, droughts and climate change impacts should be a key consideration when developing national or international strategies and policies. Climate adaptation strategies, agricultural trade policy and international development strategies should, for example, be considered at national, regional and international levels. In addition, businesses that are reliant on international commodity supplies should map their dependencies, understand their water-related vulnerabilities and put in place measures to secure future supplies in order to sustain their businesses. Investments into measures such as increasing drought resilience and strengthening water governance to ensure sustainable, efficient and equitable water use, can reduce the vulnerability of economies that depend on water resources and help sustain food security.

### References


\(^1\)http://www.fao.org/save-food/resources/key-findings/en/.


\(^3\)Fresh surface and groundwater, in other words, the water in freshwater lakes, rivers and aquifers.

\(^4\)Green and blue water footprints of the European economy. The green water footprint is the amount of rainfall used to grow crops. It is used to assess vulnerabilities due to drought. The blue water footprint is the water consumed from lakes, rivers and aquifers to produce the commodities that are used by the European economy. It is used to assess vulnerabilities due to water scarcity.

\(^5\)Dependences of Europe’s economy on other parts of the world in terms of water resources’ was produced by Water Footprint Network for the Improving Predictions and Management of Hydrological Extremes (IMPREX) project, part of the EU’s Horizon 2020 grant programme. The programme aims to improve society’s ability to anticipate and respond to the impacts of climate change.