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What do we know about
THE FUTURE OF
FOOD SYSTEMS.

CHAPTER 10

What do we know about **THE FUTURE OF WATER IN FOOD SYSTEMS?**

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Key messages

- Demand is growing while supply is uncertain: Globally, the demand for water in agriculture and food systems is growing, alongside competing needs in other sectors. Freshwater consumption is projected to increase by 17 percent between 2020 and 2050, most of it for irrigation, and almost all of it in low- and middle-income countries. At the same time, water availability is becoming increasingly uncertain due to climate extremes, long-term climate change, pollution, and land use changes such as deforestation and wetland degradation. The rising variability and scarcity contribute to competition among different water users.
- The water supply-demand gap must be addressed: As the gap between water supply and demand increases, both tested and new technologies, policies, and institutions are needed to improve water productivity and efficiency. At the same time, more research is needed to identify solutions that mitigate the negative impacts of water shortages, pollution, and poor water management on food systems as well as to curb the adverse impacts arising from inefficient and wasteful food systems on water resources and the environment. Agriculture and food systems drive many of the pressures on freshwater ecosystems. According to the IUCN Red List, 25 percent of freshwater species are threatened with extinction (IUCN 2024). This loss of biodiversity threatens not only the species themselves but also the vital services they and their ecosystems provide to humanity.

- With water a connector across sectors, new approaches to management are critical: With rising water scarcity, decisions in areas such as climate, nutrition, energy, and trade policy will increasingly shape the future of water in food systems. To improve water management in food systems, a more integrated, forward-looking

approach is needed that considers the broader implications of policies and investments across multiple sectors. In addition, strengthening governance and institutions and empowering farmers, as key stewards of water resources, are essential for sustainable outcomes.

RECENT TRENDS AND CHALLENGES

Water is essential for human life and ecosystems. People use water in multiple ways: for food production, processing, preparation, and consumption; for other domestic uses, such as bathing, cleaning, and sanitation; for energy production; and for industrial processes (Figure 1). Estimates suggest that water withdrawals by humans increased nearly eightfold between 1900 and 2010, from around 500 cubic kilometers (km³) to 4,000 km³. Currently, more than 3 billion people live in areas with high or very high levels of water stress (FAO 2020).

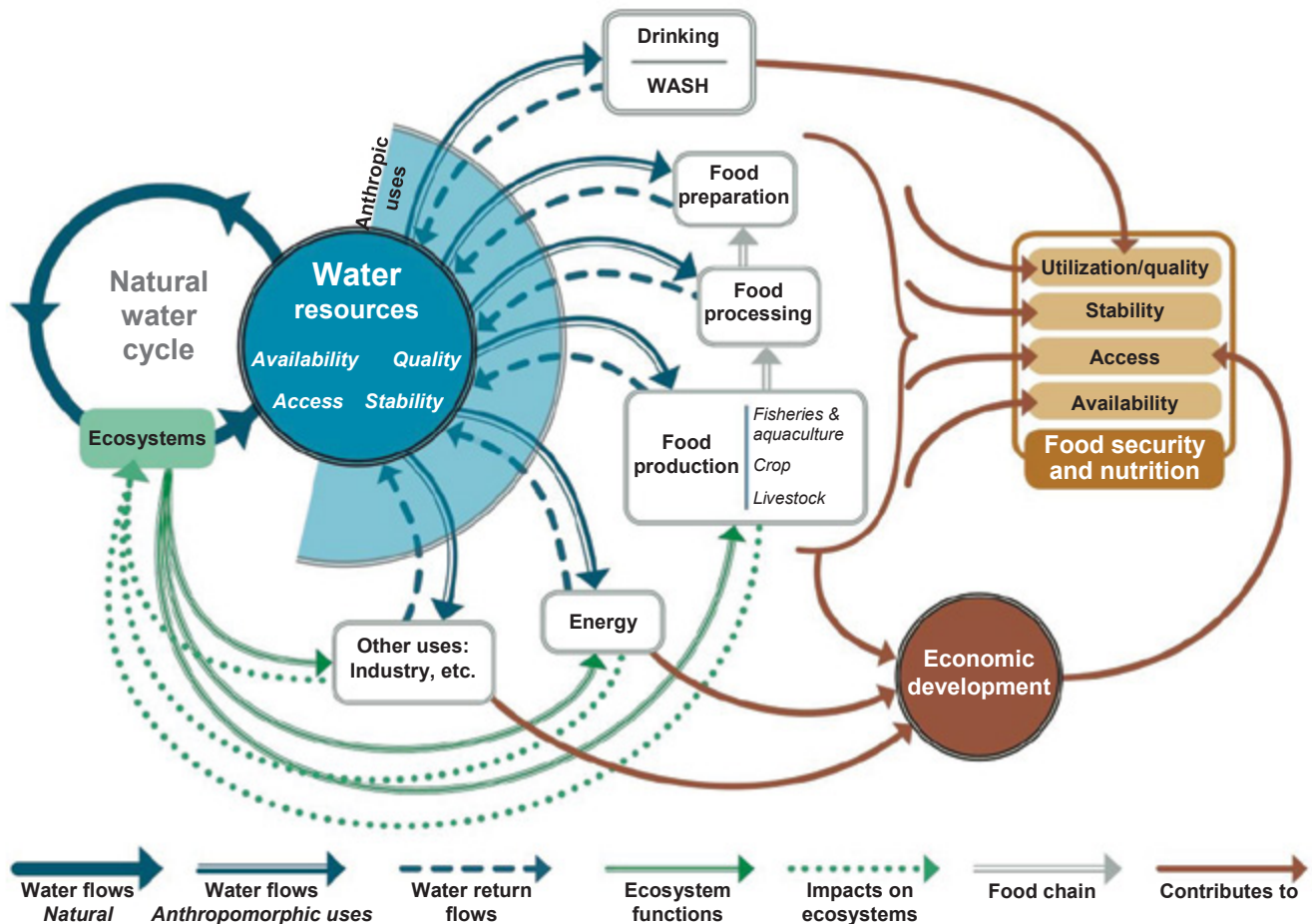
While freshwater ecosystems cover less than 1 percent of the Earth's surface area, they provide vital habitat for 10 percent of all species and one-third of all vertebrate species (Strayer and Dudgeon 2010). The widespread degradation of wetlands, rivers, lakes, and aquifers has led to significant biodiversity loss and negatively impacted water resources that are critical for a wide range of anthropogenic uses, including food systems. Since 1700, an estimated 21 percent of wetlands have been lost (Fluet-Choinard et al. 2023), and freshwater vertebrate species populations have declined by an alarming 85 percent since 1970 (WWF 2024). Environmental degradation is one of the major causes of reduced water storage across landscapes. The cumulative reduction in global terrestrial water storage from 1971 to 2020 is estimated to be on the order of 27,000 km³, far more than the annual total global freshwater use by humans (McCartney et al. 2022).

Around 70 percent of water withdrawn by humans is used to irrigate food crops, in particular rice and wheat, as well as nonfood crops such as cotton. While the global share of water withdrawals used for agriculture slowly declined over the last three decades – because of the faster growth in withdrawals for domestic and industrial uses – absolute withdrawals for agrifood systems continue to increase. A recent study calculated that the area

equipped for irrigation increased by 11 percent between 2000 and 2015 to 330 million hectares, and that slightly more than one-half of the increase occurred in areas that were already water-stressed (Mehta et al. 2024).

Climate change – characterized by higher temperatures; unpredictable precipitation; shorter, more intense rains; and prolonged dry seasons – is severely straining water resources in a rising number of regions. This is intensifying competition for water across sectors, especially between agrifood systems and other uses. Fundamental changes are occurring in freshwater systems worldwide, as a result of which many river systems are experiencing longer periods of below-normal flow (WMO 2024). These disruptions have large negative impacts on aquatic ecosystems and human livelihoods. At the same time, glacier melt has accelerated, particularly in North America and Europe. Peak glacier melt – the maximum melt rate of retreating glaciers – has occurred in these regions, reducing water storage and availability in the long term (WMO 2024).

Growing climate variability is driving increased demand for irrigation. Without it, crop and livestock production are becoming riskier and less profitable in more and more places. Much of the rise in irrigation water demand is being met with groundwater, which has become more accessible due to advances in well-drilling and pump technologies, as well as the availability of free or heavily subsidized electricity in some places. Groundwater now accounts for approximately 40 percent of irrigation globally (Siebert et al. 2010). The greater availability of low-cost solar-powered irrigation pumps that remove the need for electricity or diesel to extract water might accelerate groundwater depletion – the extraction of groundwater beyond the level of recharge (Balasubramanya et al. 2024; Perez et al. 2024).

FIGURE 1 Water use, food security, and nutrition

Source: HLPE (2015).

Water pollution from industrial, domestic, and agricultural sources is also harming water systems, particularly as their capacity to dilute contaminants is diminishing due to growing water shortages. Water pollution poses a significant threat to human and aquatic life. Poor water quality is estimated to cause more than 1 million human deaths annually, although exact figures are not available (Fuller et al. 2022; Schwarzenbach et al. 2010).

LATEST FORESIGHT RESEARCH

Initial water simulations and foresight studies focused on better understanding future availability of surface water resources and the global water cycle at a coarse resolution (Arnell 1999; Vorosmarty et al. 2000). The granularity of global hydrological models has since improved (for

example, Sutanudjaja et al. 2018). Attention is growing on improving the representation of groundwater in foresight studies (de Graaf et al. 2015; Wada et al. 2010; Perez et al. 2024) and on modeling water pollution at different scales (Xie and Ringler 2017). Some studies have explored the potential for unconventional water resources, such as saline and (recycled) wastewater, to meet increasing human needs (Thebo et al. 2017). The untapped potential for wastewater reuse – particularly in irrigation, where nutrients can be recycled – is around 320 km³ per year; this resource is 10 times the level of the current global desalination capacity (UNEP 2023).

Over time, attention has shifted from only understanding water supply to examining future water demand and the critical interlinkages between future supply and demand. Good examples of this include Cai and Rosegrant (2002), Alcamo et al. (2003), Shen et al. (2008), and Wada et al. (2016). Agricultural water demand

remains a central focus, as it represents the largest share of human water withdrawals and is easier to estimate and model than either industrial or environmental water use.

Water-food simulations typically differentiate between rainfed and irrigated systems and incorporate data on seasonal, monthly, or even daily availability of rainfall and other water for crops and production systems. Although the quantity and quality of data on agricultural production systems has improved over the last few decades, no consensus exists on likely future changes in irrigated area and irrigation water demand. Projections suggest both declines and increases depending on underlying assumptions in population and economic growth, climate change, diets, and cropping patterns. Discrepancies also arise in how crop water use is modeled, such as in the representation of deficit irrigation, the effects of rising atmospheric carbon dioxide on crop water use, the modeling of paddy irrigation, and the incorporation of climate extremes. Nevertheless, a larger number of studies suggest that irrigated area and irrigation water use will continue to increase over the coming decades (Cai and Rosegrant 2002; Nechifor and Winning 2017; Perez et al. 2024). Perez et al. (2024) project freshwater consumption will increase by close to 400 km³, or 17 percent, between 2020 and 2050. Irrigation is projected to remain the largest consumptive use of withdrawn freshwater, but its share is expected to decline from 85 percent to 81 percent. Almost all of the projected increase is concentrated in the group of low- and middle-income countries.

As a result of limited supplies and growing demands for water resources, an increasing number of studies have found challenges to meeting future food demand with traditional water management practices. The expansion of freshwater supplies is limited, and the combined pressures of climate change and growing demand will require innovative solutions (Cai and Rosegrant 2002; Hanjra and Qureshi 2010; Rockstrom et al. 2009; UNEP 2023). As an example, foresight studies indicate that a growing number of locations will experience seasonal or annual water shortages, driven in part by climate change, which amplifies the evaporative demand of irrigation water. In the Himalayas, peak glacier melt is expected to reduce water supply in the Brahmaputra, Ganges, Indus, and Yangtze Rivers, threatening the functioning of some of the world's largest irrigation systems (Immerzeel, van Beek, and Bierkens 2010).

KEY GAPS AND OPPORTUNITIES FOR FORESIGHT RESEARCH

To better understand how rapidly worsening water availability and quality is affecting food systems, more attention is needed on modeling the interactions between climate and water, with a particular focus on simulating the impacts of climate extremes. This is particularly important because rainfed and irrigation systems respond differently and complement each other differently under varying climatic conditions. Additionally, different irrigation technologies, systems, and management practices have varying degrees of resilience to different types of climate extremes; these must be better reflected in foresight studies.

A more comprehensive representation of the interactions between water and food systems is also needed, given the multiple feedback loops that exist between the two systems. For example, while increased irrigation development can boost food production and improve nutrition by expanding the availability of fruits and vegetables, it can also negatively affect water availability and quality for domestic uses, including drinking water. This, in turn, can lead to poorer nutrition and health outcomes, even as food diversity improves. Similarly, water pollution from food processing can kill aquatic life, reducing access to fish and other aquatic resources by poor people dependent on common-pool water systems. Expanding irrigation in areas previously reliant on rainfed agriculture can shrink grazing areas for pastoralists, reducing access to milk and livestock products. At the same time, irrigation systems in some places can serve as sources of aquaculture production and of energy production using the flow of water in canals, and they are a key source of domestic water for many rural households.

Existing economic models often fail to account for feedback loops between land use change – including irrigation, wetland degradation, and deforestation – and climate change. The lack of integration of water pollution and groundwater systems in many foresight analyses also limits the accuracy and usefulness of projections. In addition, more research is needed to assess the water needs of ecosystems and the implications of the degradation of freshwater ecosystems for food systems.

Foresight analyses should, moreover, broaden the scope of policy interventions for improving water management in agriculture. Rather than focusing solely on advanced irrigation systems, there is a need to consider institutional changes that can improve water governance. In addition, the distributional impacts of alternative interventions in water-food systems should be considered. For example, while water pricing can improve water use efficiency, it may disproportionately affect poorer farmers, making it harder for them to continue to farm. Similarly, subsidies for advanced irrigation technologies may not reach poorer farmers, who need them most. On the other hand, paying farmers to adopt water-saving practices, such as shifting cropping patterns in water-scarce areas, could incentivize more sustainable water use, including for poorer farmers. Given that farmers are responsible for the majority of global water withdrawals, supporting them to manage water more efficiently is crucial for ensuring the long-term sustainability of food systems and ultimately benefits everyone.

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