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The role of water in transforming food systems

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ABSTRACT

The United Nations Food Systems Summit aimed to chart a path toward transforming food systems toward achieving the Sustainable Development Goals. Despite the essentiality of water for food systems, however, the Summit has not sufficiently considered the role of water for food systems transformation. This focus is even more important due to rapidly worsening climate change and its pervasive impacts on food systems that are mediated through water. To avoid that water "breaks" food systems, key food systems actors should 1) Strengthen efforts to retain water-dependent ecosystems, their functions and services; 2) Improve agricultural water management; 3) Reduce water and food losses beyond the farmgate; 4) Coordinate water with nutrition and health interventions; 5) Increase the environmental sustainability of food systems; 6) Explicitly address social inequities; and 7) Improve data quality and monitoring for water-food system linkages.

1. Introduction

Water is essential for all life and is integral to the function and productivity of the Earth's ecosystems, which depend on a complex cycle of continuous movement of water between the Earth and the atmosphere. Water is integral to food systems and improved food systems are essential to meet Sustainable Development Goal (SDG) 6 on clean water and sanitation (UN, 2018; Uhlenbrook et al., 2022). However, currently, neither SDG 2 on zero hunger nor SDG 6 are on track; with estimates suggesting that by 2050, every second person, half the world's grain production, and close to half the globe's Gross Domestic Product might well be at risk from water stress, defined here as areas where water withdrawal levels exceed 40 percent of renewable resources (Ringler et al., 2016). This is up from one third of humanity around 2010 (UNSCN, 2020; Ringler et al., 2016). Other studies have similarly noted rapidly growing water stress. FAO (2020, p. xvi) finds that 3.2 billion people already "live in agricultural areas with high to very high water shortages or scarcity" while the UN's World Water Assessment Report (WWAP, 2018) calculates that close half the globe's population lives in potential water scarce areas at least one month per year if variability is taken into account.

Progress on reducing water stressors in food systems, which we define as all processes and structures related to the production, distribution, consumption and disposal of food and related items, has been slow. In fact, key indicators suggest that water is exerting increasingly negative impacts on food systems outcomes. Similarly, food systems increasingly stress water systems. A key underlying factor is the lack of coordination among water and food systems actors, resulting in siloed water, food security and nutrition strategies, often with sub-optimal outcomes. Other important factors include poor management of water use in agriculture, wastage of water and food along the entire value chain, and a lack of collection of joined-up data on water-food system linkages. All action areas emanating from the 2021 Food Systems Summit, including restoring degraded and protecting natural ecosystems, making food safer, increasing access to more nutritious food, and strengthening the climate resilience of food systems depend on better use of water in food systems (FAO, 2020, 2021a; UN-Water 2021).

The cost of poor coordination of water and food security interventions is heightened as a result of climate change and other environmental and societal changes (e.g. land use changes, irrigation

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development, biodiversity loss, urbanization, and changing lifestyles and diets) that are increasingly impacting the dynamics of natural water and nutrient cycles and water resource availability with multiple impacts on food systems (IPCC et al., 2021). This calls for changes in the governance and management of water, including increased cross-sectoral coordination, a focus on agricultural water productivity and consideration of hard water use limits, integrated water and food storage solutions, accelerated land restoration as well as smarter water infrastructure and distribution to support food systems, while also reducing impacts on the domestic, industrial, and energy water use sectors and the environment. The objectives of this paper are (i) to describe the critical importance of water for transforming food systems and achieving SDG 2 and (ii) to identify intervention areas that jointly improve water, food, and nutrition security.

2. Linkages between water and food systems

As described by the High Level Panel of Experts on Food Security and Nutrition (HLPE, 2015) and illustrated in Fig. 1, the key dimensions of water that are of importance for humanity are its availability, access, stability, and quality. These have multiple, close linkages and feedback loops with food systems – which can be defined as the activities involved in the production, processing, distribution, preparation, and consumption of food within a wider socio-economic, political, and environmental context (HLPE, 2017).

Freshwater-related ecosystems include wetlands, rivers, aquifers, and lakes sustaining biodiversity and life (UN Environment, 2018). Although they cover less than 1 percent of the Earth's surface, these habitats host approximately one third of vertebrate species and 10 percent of all species (Stayer and Dudgeon, 2010), including mammals, birds (IUCN, 2019), and fish (Fricke et al., 2020). More than half of all natural wetland areas have been lost due to human activity since 1900 and forest degradation affects streamflow (Sun et al., 2017). In parallel, declining soil health (including compaction, erosion and sediment transport, reduced soil organic matter) reduces soil infiltration and water storage capacity, negatively affecting crop production and water productivity per land unit (Bhoopander and Varma, 2020). Soil health is also critical for terrestrial ecosystems that are vital for the functioning of aquatic ecosystems, providing regulating, provisioning, and cultural services (Martin-Ortega et al., 2015).

Water cycles are accelerating as a result of climate change in many regions worldwide (IPCC et al., 2021), and increasing temperatures lead to increasing evaporation resulting in more severe hot and dry periods. More concentrated precipitation events can be the cause of catastrophic flooding, followed by longer and more intense drought periods. In Asia the ten major rivers originating from the Himalayas, that provide water and food security to large parts of Asia and hundreds of millions of people, are glacier-fed in the upper part (particularly in the Western and Northern regions of the Himalayas; Immerzeel et al., 2020). According to IPCC et al. (2021), from 2010 to 2019, glaciers lost more ice mass than at any time since observations began. At the same time, the growing frequency and severity of floods and droughts in many regions of the world (IPCC et al., 2021) also increase competition over water resources.

About 70 percent of all freshwater withdrawals are currently used for agriculture, and about 85 percent of withdrawn resources are consumed in irrigated agricultural production (FAO 2021a). With these resources, irrigated crop areas generate 40 percent of global food production on only about 20 percent of the total cropland (FAO 2020). Irrigation has long been recognized to serve what has been termed "productive" and "protective" functions. This reflects higher yields on irrigated areas compared to rainfed areas as well as the higher climate resilience of irrigated production compared to rainfed production (Miller et al., 2021; Mehta et al., 2019). Given that agriculture continues to serve as the main source of livelihoods for large parts of the world, absent insurance markets, there will be continued reliance on supplemental irrigation to mitigate downside output risk associated with climate variability and change and ensure food security and nutrition. However, as climate change impacts and non-irrigation demands for water grow, the development of irrigation in highly water-scarce areas can grow vulnerabilities in times of drought (Damania et al., 2017).

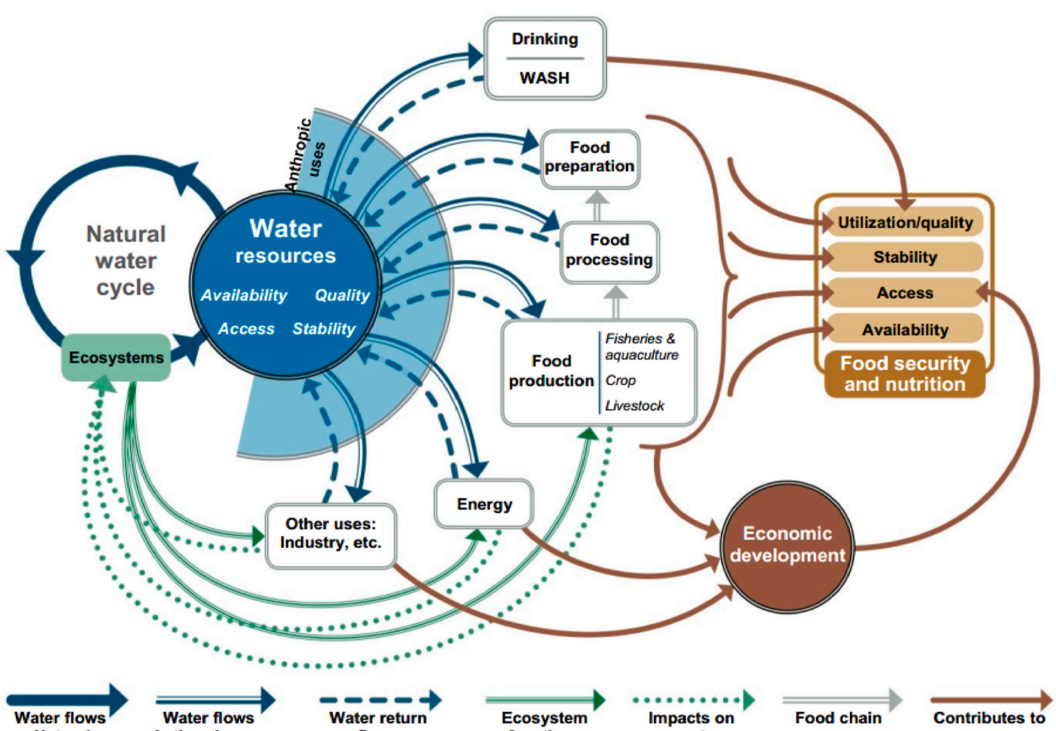

Fig. 1. The linkages between water and food security and nutrition
Source: HLPE (2015).

Another key water-food system linkage is water supply for WASH (water, sanitation and hygiene), which is important for human health and well-being, and can support nutrition outcomes, particularly if combined with other interventions (Cuesta and Maratou-Kolias, 2019; Cumming et al., 2019; Mbuya and Humphrey, 2016; UNSCN, 2020; Ringler et al., 2018). Safe water and sanitation reduce the incidence of diarrhea. Prüss-Üstun et al. (2014) note that the majority of diarrhea incidences are linked to unsafe water supply and sanitation and poor hygiene. Basic water supply and sanitation are also human rights, underlining the importance of achieving progress in fulfilling these rights; as is the right to food. While the right to food is affected by poor water access, these two human rights remain largely siloed as the right to water does currently not include water for food production (Mehta et al., 2019).

Safe water is also essential for agricultural processing and for food preparation. Water is itself essential for all bodily functions and processes and drinking water is an important source of nutrients (Jéquier and Constant, 2010; UNSCN, 2020; Miller et al., 2021) (Fig. 1).

There are important feedback loops from water use in food production to water-dependent ecosystems. For example, waste streams from food processing often re-enter water bodies without proper treatment, affecting other components of food systems, such as drinking water supply (WWAP, 2017).

Furthermore, water is essential for energy production, commerce and industry (Willet et al., 2019), sectors, which support food systems functioning but also compete with food systems for water resources. The energy sector is responsible for almost 10 percent of global water withdrawals (FAO, 2020) and, in 2020, hydroelectricity accounted for 60 percent of global renewable electricity generation (IEA, 2020). Water consumption is particularly large for first-generation biofuels, suggesting trade-offs between climate mitigation, water, food and energy security (Chaturvedi et al., 2015; De Fraiture and Berndes, 2009).

In places where water is contested, it is not unusual to see competition between water use for drinking and for irrigation. As an example, Sadeque (2000) shows how the advancement of irrigation technologies in Bangladesh has led to increased competition between poorer farmers relying on manually operated tubewells for domestic water uses and irrigators who use motorized pumps drawing larger volumes of water from deeper wells for rice irrigation during the dry season. Other drinking water sources are becoming saline or polluted with agro-chemicals; and yet other sources suffer from high *E. coli* concentrations due to proximity to latrines or contamination with livestock faeces (Gwimbi et al., 2019).

While water availability differs dramatically around the globe, differences in access are more often due to politics, policy failures, lack of capacity, and flawed water management strategies as well as exclusions due to geography (i.e. remote rural areas), gender, ethnicity, caste, race, and class. In many cases, water does "flow uphill" to power and money (Mehta et al., 2019; Wang et al., 2016; HLPE, 2015). Furthermore, increasing urbanization and changing diets are changing the demand and supply of water resources for food systems and aggravating water stress in many parts of the world. Urban consumers do not only use more water per capita directly, because they tend to be wealthier and more often have access to tap water (UNICEF and WHO, 2022), but they also consume more and more varied food per capita (FAO, 2021b) and thus indirectly consume large amounts of water. Managing inequities in water access and use is particularly a challenge in water-scarce areas of low/middle income countries where coping capacity is often insufficient (WWAP, 2018).

Progress on achieving the water and sanitation targets of SDG 6 has been unsatisfactory and uneven, putting food systems functioning and food and nutrition security at risk. More than 2 billion people live in places with high water stress (FAO SOFA, 2020; UN, 2018), and in 2017, approximately 2.2 billion people lacked access to safely managed drinking water, and 4.2 billion people lacked access to safely managed sanitation services (UNICEF and WHO, 2019). Poor women and girls, who are responsible for more than 70 percent of all domestic water collection, spend about 200 million hours a day on this task, reducing their learning opportunities and undermining their health and livelihood opportunities (Geere and Cortobius, 2017; UNICEF, 2016). With respect to the other SDG 6 targets, such as water quality (SDG 6.3), water use efficiency (SDG 6.4), water-dependent ecosystems (SDG 6.6), and integrated water management (SDG 6.5), progress has been slow and is often not well understood due to the lack of effective monitoring mechanisms and insufficient data, as evidenced by updates on SDG 6 on water and sanitation (UN-Water, 2021). To address this, urgent changes in water economics, engineering and management are needed (Sadoff et al., 2020). These should include assessing the true cost of water mismanagement (including externalities), considering multiple values of water (UN, 2021), innovating water engineering (e.g., including nature-based solutions; WWAP 2018), and building on circular economy approaches.

Similarly, progress on SDG 2 (zero hunger) has been slow. Between 720 and 811 million people faced hunger in 2020, dramatically growing food insecurity over 2019 levels. Moreover, 149 million children below the age of five were stunted, 45 million were wasted, and another 39 million were overweight (FAO, IFAD, UNICEF, WFP, WHO, 2021). Climate change, conflicts and, more recently, Covid-19, have been key causes for the faltering of food security and nutrition achievements (FAO, IFAD, UNICEF, WFP, WHO, 2021). Linked to these causes are insufficient water availability and use for food production, such as irrigation for fruits and vegetable production, and for energy production supporting storage and cooling of perishable foods. As a result of all these factors, an estimated 3 billion people cannot afford a healthy diet. The largest concentration of people who cannot afford a healthy diet is in Sub-Saharan Africa where food production is largely rainfed and seasonal, energy access is low, market systems are under-developed and governance challenges abound (Headey et al., 2020; Herforth et al., 2020; FAO, IFAD, UNICEF, WFP, WHO, 2021; Faures et al., 2007; Baye et al., 2022; Passarelli et al., 2018).

But farmers across the world continue to rely heavily on rainfall for food production; 80 percent of the cropland is rainfed and produces 60 percent of the global food. More than 62 million hectares of crop and pastureland experience severe water stress and drought, affecting about 300 million people (FAO SOFA, 2020). With climate change, temperatures and crop evapotranspiration levels are increasing, and uncertainty about the timing, duration and quantity of rainfall is growing, thereby increasing the risks of food and nutrition insecurity and undermining the livelihood security of the majority of rural people (AUC, 2020; IPCC et al., 2018).

A key contributor to poor nutritional outcomes in subsistence farming households in low-income countries is the seasonality of production, leading to the seasonality of diets, hunger and disease episodes which can affect pregnancy outcomes, productivity and child growth as well as mental development (Baye and Hirvonen, 2020; Madan et al., 2018). Well-managed irrigation systems can buffer seasonal gaps in diets and smoothen consumption, for example when income from surplus sales is used to purchase additional foods – contributing to improved food security and nutritional outcomes (Passarelli et al., 2018; Baye et al., 2022). Even smaller, irrigated kitchen gardens can contribute to better diets (Hirvonen and Headey, 2018).

At the same time, overweight continues to dramatically increase around the globe, including for children. Latin America, in particular, suffers from the associated public health burden. Overall, rural areas currently experience the most rapid rate of increase in overweight (NCD Risk Factor Collaboration, 2019). Given these trends, neither the 2025 World Health Assembly nutrition targets nor the 2030 SDG nutrition targets will be met. As with inequities in access to water, inequities in access to food and nutrition are highest in rural areas (Perez-Escamilla et al., 2018).

3. Solutions to improve food systems outcomes and improved water security

Thus, to end hunger and malnutrition will require more recognition and action on linkages across water and food systems. This includes changes in food systems for meeting SDG 6 targets: through reducing food loss and waste in food value chains (SDG 12.3), and lowering pollution from slaughterhouses, food processing, and food preparation.

Finally, it is important to consider environmental sustainability in food-based dietary guidelines as healthy diets are often highly water intensive, linked to the consumption of animal source foods as well as fruits and vegetables (Lundqvist and Unver, 2018). With climate change, conflicts and other crises intensifying, poor and siloed water management will increasingly disrupt food systems functioning and food and nutrition outcomes with largest impacts for the poorest populations in the Global South.

To maintain food and water system functioning, the following actions are proposed for uptake by governments, the private sector, and civil society.

3.1. Strengthen efforts to retain water-dependent ecosystems and their functions and services

The ecological processes underlying the movement, storage, and transformation of water are fundamental for sustainable and productive food systems. These ecosystems are also under severe threat from deforestation, erosion, and pollution, with impacts on local, regional, and global water cycles (WWAP, 2018). In addition to a direct halt to deforestation and destruction of water-regulating ecosystems, nature-based solutions that use or mimic natural processes to enhance water availability (e.g., groundwater recharge), improve water quality (e.g. riparian buffer strips), and reduce risks associated with water-related disasters and climate change (e.g. floodplain restoration) should be strengthened (WWAP, 2018). Such measures will require substantial investments and management efforts to sustain the effectiveness and functions of ecosystems.

However, nature-based solutions are not a panacea. For instance, they might not be able to deal with heavily contaminated water, fully replace classical engineering ('grey') infrastructure, or increase water availability and access. Therefore, limits to water consumption might additionally be necessary in highly water-stressed locations to stay within sustainable water use limits; these limits will need to be carefully balanced with the human right to water (Yu et al., 2021; Mehta et al., 2019).

3.2. Improve agricultural water management for food security and nutrition

Around 3 billion people on this planet cannot afford a healthy diet, particularly dairy, fruits, vegetables, and protein-rich foods (FAO, IFAD, UNICEF, WFP, WHO, 2020). Both rainfed and irrigated systems play essential roles in lowering the prices of nutrient-dense foods, growing incomes to afford these foods, and strengthening the diversity of foods available in local markets (Hirvonen et al., 2017). Rainfed systems produce the bulk of food, fodder, and fiber, and most animal feed is produced under rainfed conditions (Rockström et al., 2009; Heinke et al., 2020). These systems are under severe and growing stress from climate change, including extreme weather (FAO SOFA, 2020).

A series of measures can support rainfed water management, including terracing, soil bunds and precision cultivation practices, investment in drainage, and improved agronomic practices including mechanization (Yu et al., 2021). Better institutions and incentives for water management in rainfed systems are key. They include payments for watershed conservation, watershed committees and improved land tenure systems (Bellver-Domingo et al., 2016; World Bank, 2010). Improved production capacity in rainfed areas not only reduces land degradation but also lowers pressure on freshwater withdrawals for irrigation (Rockström et al., 2009).

As irrigation accounts for the largest share of freshwater withdrawals, the potential for water conservation is also the largest in this sector. Irrigation development, which has suffered from under-investment (f.ex. FAO, 2002), needs to take place keeping environmental limits – which are increasingly affected by climate change – in mind; this includes reining in groundwater depletion (Bierkens and Wada, 2019).

The potential for increasing water and nutrition productivity in irrigation remains large. It includes crop breeding for transpiration efficiency, increased climate resilience and micronutrients. For example, drought- and heat-stress tolerant crops can survive without irrigation and under higher temperatures, reducing adverse impacts from water shortages under climate change (Rosegrant et al., 2014). Other measures include integrated water storage solutions—such as joint use of natural (f.ex. wetlands) and so-called grey infrastructure—advanced irrigation technology and precision technologies, such as soil moisture sensors (Rosegrant et al., 2009). Precision agricultural techniques, including for water and agro-chemicals, are particularly important for nutrient-dense foods, such as fruits and vegetables that depend on irrigation in many parts of the world (but the water content of the end product also tends to be high) and could be important water polluters without advanced irrigation techniques (Meenakshi and Webb, 2019). Importantly, to reduce the cost of adverse flood impacts for food production, for example (Li et al., 2019), it is important to also grow investment in drainage systems (Castellano et al., 2019).

Moreover, water use in livestock systems, particularly for livestock feed, but also watering, manure management and climate change impacts, needs to be managed much more directly to reduce the sub-sector's environmental impacts (Doreau et al., 2012). However, extensive livestock systems operate on marginal land with generally poor soils subject to low levels of highly variable precipitation. Here, water resources are insufficient for food crop production and livestock production often provides the only income and food production option. In other areas, semi-intensive rainfed grazing provides important income and protein sources for pastoralists and smallholder farmers and does not deplete water resources (Sloat et al., 2018; Randolph et al., 2007; Ridoutt et al., 2012).

Awareness raising and social learning interventions can help internalize the water externality of water-intensive crops. An example are behavioral games to increased groundwater governance in parts of India (Meinzen-Dick et al., 2018). Improved coordination of water with other agricultural inputs can also enhance yield per drop of water. This requires access to technology packages as well as to better agricultural information (Lundqvist et al., 2021), which is increasingly supported by information and communication tools (ICT) (Asenso-Okyere and Mekonnen, 2012). Moreover, subsidies for water-intensive crops, such as rice, milk, and sugar should be removed. As an example, Frisvold (2004) describes the water savings from the removal of the sugar and dairy subsidies in the United States. Subsidies for nutritionally harmful crops, such as sugar, and for commodities that cause pollution and climate change, should be increasingly hard to justify. For water-scarce countries, importing virtual water via food and other commodities will remain essential (Allan, 1997).

Globally, 80 percent of municipal sewage, agricultural and industrial wastewater with heavy metals, solvents, toxic sludge, pharmaceuticals, and other waste, are directly discharged into water bodies without proper treatment, affecting the safety of food, particularly vegetable production, and also, directly, human health (WWAP, 2017). Agriculture also directly pollutes aquatic ecosystems with pesticides, organic matter, fertilizers, pathogens, and saline drainage, with potentially adverse impacts on human health (UNEP, 2016). Key measures to address agricultural and overall water pollution include breeding crops with higher crop nutrient use efficiency, better agronomic practices including precision agricultural technologies, the expansion of nature-based solutions for pollution management, low-cost pollution monitoring systems, improved incentive structures for pollution abatement, and continued investment and innovation in wastewater treatment, including approaches such as the 3R (reduce, reuse, and recycle) of the circular economy across the entire food system (Mateo-Sagasta et al., 2018).

3.3. Reduce water and food losses beyond the farmgate

Food losses and waste are always linked to losses of associated natural resources. As an example, Kummu et al. (2012) find that one quarter of the produced food supply is lost within the food supply chain and that lost and wasted food crops account for 24 percent of total freshwater resources used in food crop production.

Many high-value crops, such as fruits and vegetables are irrigated to ensure a return on investment of these systems and in response to the water requirements of these crops. This is true in many parts of the world, including East Africa (Nkonya et al., 2011) or the United States, where even in the late 1990s two thirds of all vegetables and three quarters of all fruit were irrigated (Howell, 2001). At the same time, many irrigated crops, such as fruits and vegetables, are highly perishable products that require careful post-harvest management or processing and efficient market linkages to consumption centers. Strengthening market linkages includes investment in physical infrastructure that supports on-farm production (irrigation, energy, transportation, pre- and post-harvest storage), efficient trading and exchange (telecommunications, covered markets), value addition (agro-processing and packaging facilities), and improved transportation and bulk storage (Warner et al., 2008).

Investments are also needed in ICTs that facilitate farmers' access to localized and tailored information about weather, water availability and consumption, diseases, yield, and input and output prices (Elsabber, 2020).

3.4. Coordinate water with nutrition and health interventions

Governance and management of water for various uses and functions, as shown in Fig. 1, follow different institutional arrangements. Similarly, professionals engaged in various roles within water-related institutions have different kinds of training and experiences. Few irrigation engineers have a professional background or skills related to WASH, and few WASH professionals have the technical skills needed to design and manage water infrastructure for multiple uses. The notion of Integrated Water Resources Management (SDG 6.5) has been promoted as a principle to overcome problems due to sectoral division but evidence on positive impact is limited (f.ex. Biswas, 2004). Coordination particularly at the lowest appropriate levels is urgently needed between WASH and irrigation for improved food security, nutrition, health outcomes and also to strengthen women's agency. Several promising approaches are being piloted. They include multiple use water systems that consider productive and domestic water uses (van Koppen et al., 2014), capacity building of extension officers on nutrition-sensitive irrigation and better coordination between irrigation and health sectors in irrigation system design and operation. An example is managing irrigation infrastructure for improved malaria control, which affects absorption of nutrients (Reis et al., 2011).

Nutrition and health experts need to join forces with water managers at the farm household level, at the community level, and at the government level to strengthen positive transmission pathways between both rainfed and irrigated agriculture, and food and nutrition security. A recent guidance (Bryan et al., 2019) introduces eight actions to increase the nutrition sensitivity of water resources management and irrigation as well as indicators for monitoring progress. They include involving women in irrigation interventions, integrating irrigation investments into rural service delivery and social safety nets, and promoting nutrient-dense crops. Indicators to monitor progress on nutrition-sensitive irrigation developed as part of this guidance are being piloted in Uganda and the guidance is being adjusted to the Malian context.

3.5. Integrating environmental sustainability in food systems and particularly diets

Environmental sustainability concerns transcend food production systems and cover the entire food system, with a particular focus on food consumption patterns.

The water footprint of diets varies dramatically between rich and poor countries, but also by socio-economic group within countries. Diets of richer households tend to require substantially larger amounts of water in a case study of Ethiopia, for example (Lundqvist et al., 2021). A recent review of the use of precipitation and irrigation water across diets finds that healthier diets could reduce use of precipitation but not of irrigation in total food consumption. The review calls for a better understanding of the amount and type of water used in food production to make informed policy decisions (Harris et al., 2020).

Food-based dietary guidelines should consider the environmental footprint of proposed diets. Several countries, such as Brazil and Sweden's guidelines consider environmental concerns of diets. Additionally, government regulations and consumer awareness should be strengthened to reduce over-consumption of food, including the water embedded in these foods (UNSCN, 2020).

3.6. Explicitly address social inequities in water-nutrition linkages

Vulnerable groups, in particular women, minorities and other socially disadvantage groups, such as the disabled, need to be proactively included in the development of water services, including incorporating their needs and constraints into infrastructure design. Women, for example, need access to credit for irrigation technologies that does not require collateral or high up-front investment costs. They also strongly prefer labor-saving irrigation technologies, and information services that can be accessed at the home due to mobility and time constraints (Lefore et al., 2019).

For rural smallholders in the Global South who suffer most from lack of water and food security, irrigation design should consider multiple uses of water, such as drinking, irrigation, and livestock watering to meet women's and men's needs. While women make up a large part of the agricultural workforce, they often lack recognition and formal rights, and farmers are often considered to be 'male' in many parts of the world.

Women's productive roles should be promoted, and they should be trained in irrigation and water management. Supporting their management of irrigation and water resources has important benefits for food security (Meinzen-Dick et al., 2021; Balasubmaranya, 2019). It is also important to ensure that women and disadvantaged social groups (e.g. lower castes, stigmatized social groups) have equal access to knowledge, credit, irrigable land, labor, and markets to buy agricultural inputs and sell their produce (Mehta et al., 2019; UNSCN, 2020; Theis et al., 2018).

3.7. Improve monitoring for water-food system linkages, drawing on innovations in ICT

You cannot manage what you do not measure. However, much better data are needed to truly understand the water-food system linkages of diets, and devise policies that co-maximize water and food security and nutrition goals. Challenges include poor water and poor food intake data and a lack of indicators connecting the two; but improvements are emerging (Bryan et al., 2019; HWISE network; Lundqvist et al., 2021). Better and more data will support better water management and food systems and increase transparency in decision making. This requires sustained investments in the monitoring of a wide range of hydrological and food-related parameters worldwide. Modern Earth observation methods (e.g., data from satellites or drones) can support larger-scale assessment (FAO, 2019), but need to be complemented by dedicated field measurements (e.g., in-situ measure of soil water, evaporation, yields, vegetation parameters).

4. Conclusions

Access to sufficient and clean freshwater is essential for all life. Water is also essential for food system functioning, but its role has not been adequately recognized. This is particularly worrisome as climate change, mediated through changes in the timing, quantity and quality of water, will increasingly affect all facets of food systems. To address these growing challenges—and avoid that water systems starve food systems—and food systems drain water systems—we propose seven intervention areas that can help overcome siloed SDG 2 and SDG 6 development for a more resilient and sustainable food system transformation. These include efforts to 1) retain water-dependent ecosystems, their functions and services; 2) improve agricultural water management; 3) reduce water and food losses beyond the farmgate; 4) coordinate water with nutrition and health interventions; 5) increase the environmental sustainability of food systems; 6) explicitly address social inequities; and 7) improve data quality and monitoring for water-food system linkages. These inter-linked interventions across key water and food systems could support mutually reinforcing water and food and nutrition securities while strengthening ecosystem health.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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