WATER GLOBAL PRACTICE • GUIDANCE NOTE

Nutrition-Sensitive Irrigation and Water Management

AUGUST 2019

Elizabeth Bryan, Claire Chase, and Mik Schulte



WORLD BANK GROUP

About the Water Global Practice

Launched in 2014, the World Bank Group's Water Global Practice brings together financing, knowledge, and implementation in one platform. By combining the Bank's global knowledge with country investments, this model generates more firepower for transformational solutions to help countries grow sustainably.

Please visit us at www.worldbank.org/water or follow us on Twitter at @WorldBankWater.

About GWSP

This publication received the support of the Global Water Security & Sanitation Partnership (GWSP). GWSP is a multidonor trust fund administered by the World Bank's Water Global Practice and supported by Australia's Department of Foreign Affairs and Trade; the Bill & Melinda Gates Foundation; The Netherlands' Ministry of Foreign Trade and Development Cooperation; Norway's Ministry of Foreign Affairs; the Rockefeller Foundation; the Swedish International Development Cooperation Agency; Switzerland's State Secretariat for Economic Affairs; the Swiss Agency for Development and Cooperation; Irish Aid; and the U.K. Department for International Development.

Please visit us at www.worldbank.org/gwsp or follow us on Twitter #gwsp.

Nutrition-Sensitive Irrigation and Water Management

Elizabeth Bryan, Claire Chase, and Mik Schulte

WORLD BANK GROUP

Cover photos (left to right): John Hogg / World Bank, Dominic Chavez / The Global Financing Facility, Maria Fleischmann / World Bank.
Cover design: Jean Franz, Franz and Company, Inc.

Interior photos: p. iv, Curt Carnemark / World Bank; p. viii, Mitchell Maher / International Food Policy Institute; p. 2, Michael Foley / Flickr; p. 8, A'Melody Lee / World Bank.

Contents

Boxes

Figure

Table

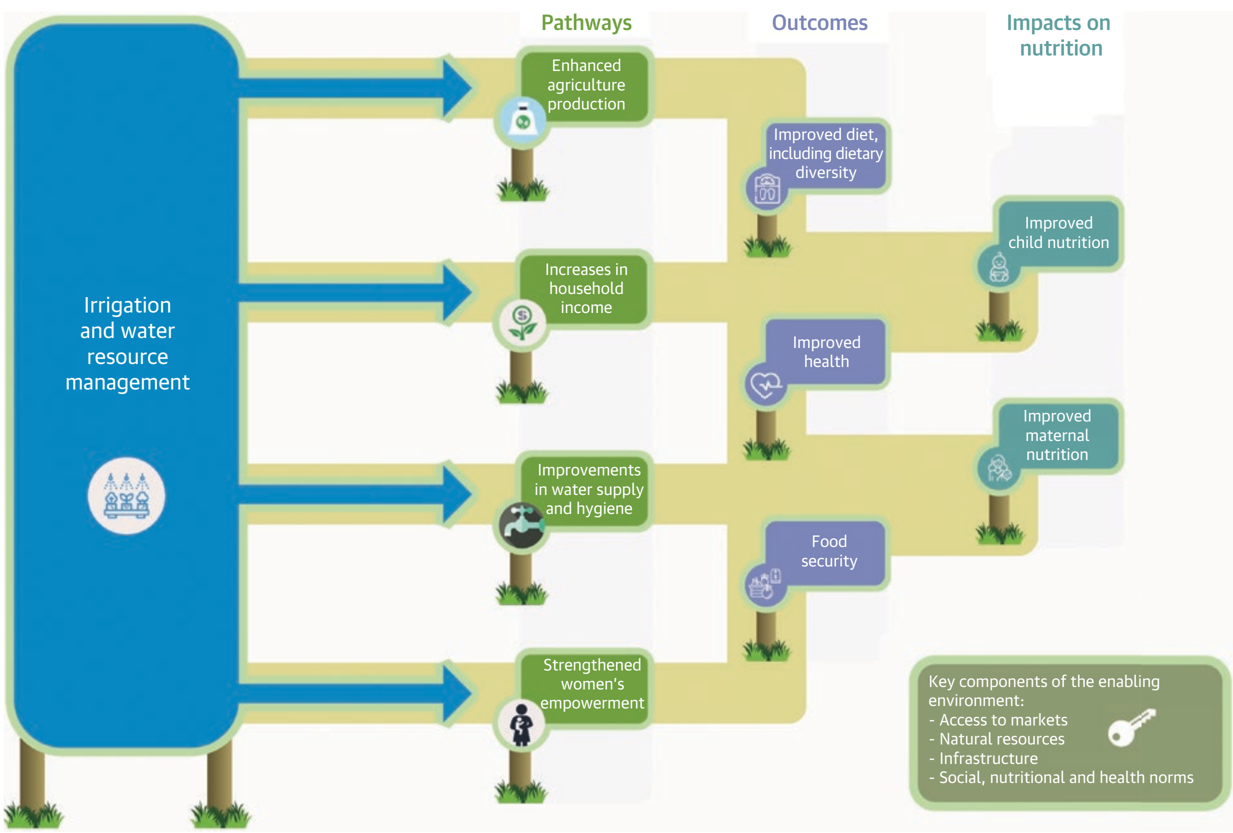
Executive Summary

This document summarizes evidence and guidance on project design and results framework indicators for nutrition-sensitive irrigation and water management investments across water, agriculture, rural development, and other sectors, in which improving nutrition in vulnerable populations is a specific objective of the project.[1] It draws on existing guidance on nutrition-sensitive agriculture developed by the Food and Agriculture Organization (FAO 2015) and the World Bank (2013), with an emphasis on water-related aspects of these guidelines. The recommended actions at the project level depend on an enabling policy environment that prioritizes water use efficiency, nutritious diets, gender equality, and human capital development.

Irrigation contributes to agricultural intensification and farm profitability (Burney, Naylor, and Postel 2013; De Fraiture and Giordano 2014; Giordano and de Fraiture 2014; Giordano et al. 2012; Xie et al. 2014; You et al. 2011), helps farm households to extend the growing season, and is increasingly important for farmer resilience to climate shocks and stressors. Until recently, there has been less attention to other benefits of irrigation, including improvements in household food security and nutrition, health, and women's empowerment.

Irrigation affects nutritional outcomes along the same pathways as broader agricultural interventions, but it does so in specific ways (Domènech 2015; Passarelli et al. 2018). These include a production pathway, an income pathway and a women's empowerment pathway. In addition, irrigation presents a potential fourth pathway to improvements in nutritional outcomes through water, sanitation, and hygiene (figure ES.1).

FIGURE ES.1. Pathways from Irrigation to Nutritional Outcomes



Source: Based on Passarelli et al. 2018.

This note presents evidence for the effects of irrigation on nutritional outcomes for each hypothesized pathway. However, these pathways are only indirectly related to nutritional outcomes, and few studies assess the effects of irrigation on the more immediate determinants of nutrition, such as adequate food and nutrient intake and infectious disease, especially for children in the first 1,000 days of life. More evidence is needed to demonstrate the effects of irrigation and water management interventions on these direct determinants of nutrition and on nutritional outcomes.

Note

1. Project teams that intend for their lending operation or advisory services and analytics activity to be coded under nutrition theme 671 should review the Operations Policy and Country Services guidelines.

Abbreviations

APL	adaptable policy lending
BCC	behavior change communication
BMI	body mass index
FIES	Food Insecurity Experience Scale
HAZ	Height-for-age z-score
HFIAS	Household Food Insecurity Access Scale
IWRM	integrated water resource management
IYCF	infant and young child feeding
IYCMAD	infant and young child minimum acceptable diet
LAZ	length-for-age *z*-score
LSMS	Living Standards Measurement Study
MDD-W	Minimum Dietary Diversity for Women
MLDD	market-level dietary diversity
MUS	multiple-use water system
PSNP	Productive Safety Nets Project
WASH	water supply, sanitation, and hygiene
WEAI	Women's Empowerment in Agriculture Index
WHO	World Health Organization

Chapter 1
The Business Case for Nutrition-Sensitive Water Management

Meeting the United Nations' Sustainable Development Goals requires new policies, interventions, and research that consider the synergies and trade-offs among development objectives and apply cross-sector solutions to meet complex challenges (UN 2018). Interventions in one sector can potentially reinforce and enhance outcomes in another. Water management and irrigation interventions provide farmers with a more reliable source of water for growing food, thereby increasing agricultural yield and profits and contributing to food availability and access, which ultimately affect household health and nutrition. However, evidence from the agriculture sector shows that interventions are more likely to directly affect nutritional outcomes when they intentionally address factors that are important for nutrition, such as those that incorporate health and water, sanitation, and hygiene practices or promote adoption of biofortified crops to address particular micronutrient deficiencies (Ruel, Quisumbing, and Balagamwala 2018).

Effective integrated approaches must also consider the challenges and opportunities that cut across sectors, such as those related to climate change. Climate change largely affects agricultural producers through changes in water availability because of changing rainfall patterns; more frequent and extreme droughts, floods, and storms; and higher rates of evapotranspiration, which will increase the water demand of crops and the need for alternatives to rainfed irrigation in many parts of the world (Jiménez Cisneros et al. 2014).

Globally, key staple crops are expected to experience significant yield declines because of climate change, on average (Wiebe et al. 2015). Lower yield growth could lead to higher food prices and therefore less affordability of food, lower calorie availability, concomitant changes in diets, and increases in childhood malnutrition in Sub-Saharan Africa (Fanzo et al. 2018; Ringler et al. 2010; Springmann et al. 2016). Furthermore, the nutritional value of key staple crops is expected to be affected by climate change (Beach et al. 2019; Smith and Myers 2017). Both trends pose a challenge for livelihoods, food security, and nutrition.

Irrigation is a key strategy to mitigate these risks. Supplemental irrigation can stabilize yields under climate change (Nangia and Oweis 2016), thereby potentially reducing the need for emergency relief and insurance payouts following climate shocks. When combined with seed varieties designed to meet local climate challenges and nutritional needs (for example, through biofortification), irrigation interventions could also reduce the negative effects of climate change on nutritional outcomes. Small-scale irrigation has been found to be profitable in Sub-Saharan Africa under both a drier and a wetter climate future (using the most extreme climate scenarios available at the time), as well as under alternative crop price and irrigation cost trajectories (Xie et al. 2014). By the same token, policies and investments in sustainable water management can mitigate the effects of climate change by improving the quality of natural capital (for example, soils, water, and forests) and increasing the resilience of ecosystems that support agricultural production to withstand climate shocks and stressors (Tompkins and Adger 2004).

Chapter 2
Pathways Linking Irrigation and Water Management with Nutritional Outcomes

Pathway 1: Enhanced Agricultural Production

Irrigation affects agricultural production in several ways. It increases crop productivity and broadens the range of crops that farmers can cultivate, including crops that are more sensitive to drought stress, such as many vegetables, or those that have higher water requirements, such as some fruit trees. Many of these also have higher nutritional value (Alaofè et al. 2016; Burney et al. 2013; De Fraiture and Giordano 2014; Passarelli et al. 2018).

Increased production of nutritious crops because of irrigation has also been shown to increase the availability of and access to nutritious foods for home consumption and through market purchases (Burney et al. 2010; De Fraiture and Giordano 2014; Namara et al. 2011; Namara, Upadhyay, and Nagar 2005). Increased water access may directly benefit women and their children, given that increased rainfall has been linked to decreased risk of low birth weight for farm households regardless of household wealth, birth season, or country of residence (Grace et al. 2015).

Production and nutritional outcomes depend on the type of irrigation intervention. For instance, studies of irrigated home garden production in Burkina Faso have found that irrigation programs increased production of fruits and vegetables, increased food security, and improved nutrition (Olney et al. 2015). Similarly, Kabunga, Ghosh, and Griffiths (2014) have found that in Uganda, women in farm households producing fruits and vegetables have higher intake of these foods and better health and nutritional outcomes.

Although irrigation appears to increase production diversity and consumption of home-produced, micronutrient-rich foods (Alaofe et al. 2016; Passarelli et al. 2018), there is less evidence for the link between increased production diversity and enhanced dietary diversity. In general, studies show mixed results: in some cases, increased production diversity leads to improved diet quality, but in other cases, it does not (Sibhatu, Krishna, and Qaim 2015).

There is also little evidence for the link between irrigation and resilience to climate shocks and stressors. Still, some studies show that irrigation interventions affect the availability and stability of food supply by enabling more cropping seasons, including during dry periods (Aseyehegn, Yirga, and Rajan 2012), and by reducing the risks of rainfed production (Fox and Rockström 2003; Oweis and Hachum 2006). A study in South Africa found that irrigating farmers were less likely to perceive climate change, as irrigation buffered droughts and heat stress (Gbetibouo, Hassan, and Ringler 2010), and a study in Kenya found that irrigation was the most preferred climate change adaptation strategy of farmers, identified by almost half of all farmers interviewed (Bryan et al. 2013).

In theory, combining irrigated production with improved processing and storage practices would offer even greater potential for improved stability of food supply. More evidence is needed to determine the extent to which these value chain improvements would increase the benefits of irrigation.

Pathway 2: Increases in Household Income

Irrigation influences nutritional outcomes through a second pathway: the income pathway. Irrigation facilitates the production and increases the yields of higher-value crops, which can increase farm income through the sale of these crops. The literature from several contexts demonstrates that irrigation contributes to increased income from agricultural production (Burney and Naylor 2012; Passarelli et al. 2018).

An evaluation of a solar irrigation project in Benin shows that modern irrigation technologies increase consumption expenditures and increase asset accumulation while reducing poverty. Households that engaged in solar-powered irrigation had higher expenditures, including spending on total food purchases, nutritious foods, health care, and education (Alaofè et al. 2016; Burney and Naylor 2012). Evidence from Ethiopia and Tanzania also shows higher income among irrigating households, which led to higher dietary diversity in the case of Ethiopia (Passarelli et al. 2018). Several studies also point to employment benefits created by irrigation that expand the economic benefits and potential nutritional outcomes beyond the farm household (Namara et al. 2011).

Ex ante analyses on the regional scale also show considerable potential for further economic gains through the expansion of irrigation in Sub-Saharan Africa (Xie et al. 2014; You et al. 2011). Income gains can be used to purchase foods that improve the nutritional status of household members, such as animal-source foods like meat and eggs, or can be used to purchase health services or pay school fees.

Pathway 3: Improvements in Water Supply and Hygiene

Irrigation also has the potential to affect the water, sanitation, and hygiene (WASH) environment. This is the third pathway through which irrigation can indirectly influence nutritional status, although there is less evidence for this pathway. Changes in the WASH environment affect health risks, health status, and utilization of nutrients from food.

The relationship between WASH and irrigation depends on the available services, water source, and system in place. Some systems are hybridized for both rainfed and irrigated supply, such as water catchments for rainfall. Vectors for the WASH pathway have different entry points in on-farm and off-farm irrigation systems. On-farm irrigation interventions (such as on-farm storage, pump irrigation, or bucket irrigation) have relatively contained water sources, compared with larger off-farm irrigation conveyance infrastructure that may be multipurpose, such as for recreation or drinking water. Attention has narrowed on wastewater reuse for irrigation, and as alternative sources of irrigation water are considered, more evidence for this pathway will be uncovered.

The literature suggests that poor WASH conditions, such as fecal contamination of the household environment (Curtis, Cairncross, and Yonli 2000; Marquis et al. 1990), soil contaminated with human and animal feces (Curtis et al. 2000; Pickering et al. 2012), and unsafe disposal of infant and child feces, contribute significantly to the diarrheal disease burden (Mara et al. 2010). Repeated episodes of diarrhea in young children contribute to growth stunting (Checkley et al. 2008). Evidence demonstrates an association between enteric infection and stunting independent of diarrheal disease or poor diet in The Gambia (Campbell, Elia, and Lunn 2003; Lunn, Northrop-Clewes, and Downes 1991).

Irrigation can improve household access to water for hygienic and other domestic purposes. For example, van der Hoek, Feenstra, and Konradsen (2002) showed in Pakistan that the use of irrigation water for domestic purposes can significantly reduce diarrhea, thereby improving the nutritional status of children. However, in some cases, the quality of irrigation water may not be appropriate for human consumption. Moreover, irrigation may increase health risks, if not properly managed, through an increase in vector-borne diseases caused by standing or slow-moving water (Keiser et al. 2005). In addition, Audibert, Mathonnat, and Henry (2003) showed that large-scale irrigation could increase the prevalence of water-based parasites that reduce the potential for nutritional uptake. Irrigation may also increase runoff of agricultural chemicals, such as fertilizers and pesticides, which can affect water quality and human health (Mateo-Sagasta et al. 2017). Irrigation with poorly treated wastewater can increase exposure to pathogens resulting in schistosomiasis, diarrhea, or other ailments (Amoah et al. 2009). Poor water quality, because of agricultural runoff or poor WASH practices, increases the risk of infection and disease and ultimately of undernutrition. In this weakened state, the body becomes more susceptible to infection and disease, creating a vicious cycle of poor health.

Pathway 4: Strengthened Women's Empowerment

Several studies from various contexts have identified a relationship between women's empowerment and improved development outcomes, such as nutritional status, dietary quality, and education expenditures (Malapit et al. 2015; Malapit and Quisumbing 2015; Sraboni et al. 2014; Yimer and Tadesse 2015). Irrigation interventions have the potential to affect women's empowerment through changes in their control over agricultural production decisions, income decisions, and time use. An increase in women's decision-making authority over production and income decisions could lead to the adoption of irrigation systems that provide them with benefits, such as reduced labor burden, and may have implications for the health and nutritional status of women and their children.

Emerging evidence suggests that the link between irrigation and women's empowerment is context specific. In some contexts, social norms and other barriers prevent women from benefiting directly from irrigation interventions, given their limited control over the technology and income from the sale of irrigated produce (Theis et al. 2018). In other contexts, irrigation activities targeted toward women, such as through irrigated home gardens, have been shown to increase women's control over irrigated produce and income.

Irrigation can also affect women's time by either relieving their time burden or adding to it. This has implications for women's ability to care for their children and could result in negative nutritional outcomes. For example, an increase in the agricultural workload of pregnant women is known to increase the risk of preterm birth (Owens et al. 2015). The literature shows that the extent to which irrigation affects women's labor varies, with some studies suggesting that an increased labor burden results in poor nutritional outcomes (Riley and Krogman 1993; Steiner-Asiedu et al. 2012) and others finding time savings or a shift in labor allocation toward men (Bryan 2019).

Changes in women's empowerment are likely to intersect with the three previously described pathways in important ways. In terms of the production pathway, women have different preferences compared with men for the types of crops that are planted and how these crops are used (for example, sold in the market or consumed at home; Carr 2008). Because women often produce crops for home consumption, interventions targeted to women around irrigated home gardens have been shown to improve nutritional outcomes in some contexts (Burney et al. 2010; Iannotti, Cunningham, and Ruel 2009; Olney et al. 2009, 2015). Similarly, in terms of the income pathway, women also have different preferences compared with men for how income is spent, and they tend to prioritize food and health care purchases (Gillespie, Harris, and Kadiyala 2012; Meinzen-Dick et al. 2012). Studies of irrigation projects targeted to women's groups have found that women often control income from the sale of irrigated crops grown on their plots (Burney et al. 2010; van den Bold, Quisumbing, and Gillespie 2013).

In terms of the water supply pathway, women tend to prefer multiple-use water systems (MUS) close to the homestead that provide water for both productive and domestic purposes. Such systems can save time and energy and can improve the WASH environment, depending on the quality of water and the way it is managed (Theis et al. 2018; van Koppen et al. 2009). In addition, reducing the time that caregivers spend fetching water lowers diarrhea and improves nutritional outcomes in children under age 5 (Pickering and Davis 2012) through improved hygiene practices (Aiello et al. 2008; Motarjemi et al. 1993), more time available for child care (Burger and Esrey 1995; Cairncross and Cuff 1987; Diaz, Esrey, and Hurtado 1995; Miller and Urdinola 2010), or income-generating activities (Koolwal and Van de Walle 2013). However, some studies show that irrigation reduces the amount of time that mothers spend on household activities like cooking and caring for their children (Bénéfice and Simondon 1993; Brun, Reynaud, and Chevassus-Agnès 1989; Vaughan and Moore 1988), with potential negative consequences for nutrition.

Chapter 3
The Enabling Environment: Infrastructure, Institutions, and Information

Which pathways matter? Studies that look at the link between irrigation and nutritional outcomes do not necessarily examine the causal pathways. For example, a study from Mali showed increases in total consumption and calorie and protein intake among irrigating households, although the pathway of these outcomes was not clear (Dillon 2008). Passarelli et al. (2018) have examined changes in dietary diversity because of the income and production pathway and found that irrigation was associated with increased dietary diversity in Ethiopia as a result of increased income from irrigation, rather than through an increase in production diversity; however, the results were not significant in Tanzania. More evidence is needed to determine the pathways and conditions under which production changes and income increases because of irrigation improve diet quality and nutritional outcomes.

In addition to household changes and dynamics, pathways from irrigation to nutrition are also shaped by the enabling environment, including natural resource availability and management, access to markets, infrastructure, institutions, and social norms. For example, more developed markets, transportation and logistics infrastructure, and developed value chains can increase farmers' income from selling produce, as well as increase consumers' access to nutritious foods. Norms and knowledge around nutrition shape the extent to which consumers spend their income on nutrition- and health-enhancing goods and services and provide appropriate care to infants and young children.

Institutions at multiple levels, from the state to community organizations, shape the enabling environment for irrigation, nutrition and health, by serving as platforms for governance (including laws and regulations to protect natural resources, such as water, as well as human health), agency strengthening, management and monitoring, and information dissemination. Much literature exists on the role of institutions in ensuring adequate water quantity and quality for agricultural production and other water uses, whether through collective groundwater management in India (Meinzen-Dick et al. 2016), water transfers in China (Khan, Hanjra, and Mu 2009), river basin management of transboundary hydrological systems, water user associations to promote the effective and equitable use of irrigation flows, or the promotion of water-saving irrigation technologies.

Integrated water resource management (IWRM) operations exert influence on the enabling environment for food security and nutrition through changes in the quality, quantity, and stability of the water supply and by influencing the distribution of infrastructural assets (for example, water harvesting structures), leveraging institutional platforms for social and behavioral change communication around nutrition and social inclusion, and using information systems (for example, groundwater monitoring and hydrological and meteorological services) to provide water quality monitoring and early warning indicators of water-related threats and disasters (for example, floods and flood-induced infectious diseases). IWRM can play an important role in effective flood management, which can be critical to increasing soil fertility and agricultural productivity while mitigating damage to agriculture, fisheries, and infrastructure. Because these factors do not influence nutritional outcomes directly, there is no literature linking such institutional factors to nutritional outcomes. However, increased understanding of irrigation-to-nutrition linkages and the role of water management among policy makers and other stakeholders can increase the likelihood that agricultural water is available and used in ways that enhance nutritional outcomes.

Chapter 4
Entry Points for Improved Nutritional Outcomes

The body of evidence for the links among irrigation, water management, and nutrition provides important clues as to what nutrition-sensitive enhancements could achieve greater impacts on early child nutrition. The following approaches are recommended to improve the nutritional impact of irrigation and water management investments.

Incorporate Nutritional Considerations into Project Design at the Concept Stage

The concept stage of project design is an opportune time to consider nutrition objectives of the project and incorporate these considerations. For example, one consideration may be to prioritize investments to an area of the country that is facing challenges of food or water insecurity. Another possibility could be to focus on areas where large numbers of young children are undernourished. These are also likely to be areas where other nutrition-related interventions are taking place, providing the opportunity to converge geographically and leverage common community-based platforms.

Decisions around crop choice may also take place at the concept stage. Understanding the nutritional profile of the beneficiary population, such as the prevalence and types of micronutrient deficiencies (for example, lack of food sources rich in vitamin A or iron), deficiencies in the consumption of certain food groups, and dietary diversity, can inform which crops could bring both income and nutritional benefits.

Maintain and Improve the Natural Resource Base

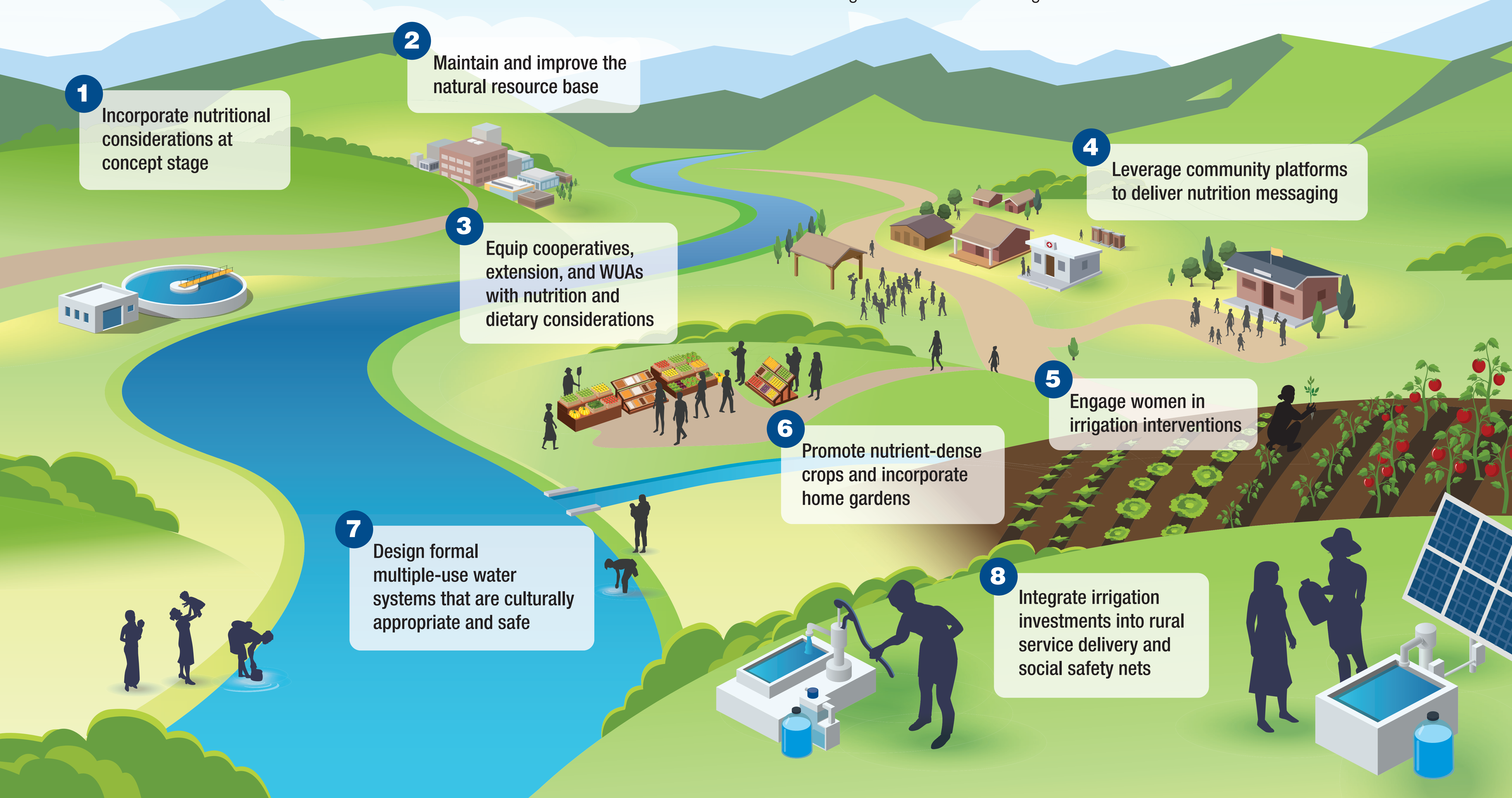
Productive livelihoods and resilience that are essential for food security and nutrition depend on the quality and availability of land, soil, and water resources. Conservation and restoration activities, including reforestation programs, wetland restoration, or buffer strips to reduce nutrient and sediment runoff from agricultural land into waterways, can affect downstream sedimentation, runoff, fisheries, and agricultural productivity. Transboundary water policies also need to consider the food security and nutritional implications of water availability, quality, and continuity of supply for all users.

Equip Cooperatives, Agricultural Extension, and Water User Associations for Nutrition and Dietary Considerations

Nutrition-specific behavior change communication (BCC) is needed to bring about alterations in nutrition practices. Yet effective BCC demands substantial time and commitment from staff and beneficiaries (Ruel, Quisumbing, and Balagamwala 2018). Often, BCC is not intense enough in frequency or the quality of information, is not culturally sensitive, and/or is insufficient to address barriers to improving nutrition practices. Using existing platforms to communicate messages related to household nutrition could be a cost-effective way to reach target populations. Information is shared with farmers through different mediums and extension services. Better coordination linking agriculture and health extension workers and information systems could ensure complementary and coordinated messages are delivered at appropriate times. Membership-based organizations that build social capital, such as river basin organizations, can also be used as a platform to disseminate nutrition and health training and education. Topics might include healthy diets, resource planning and food storage practices to ensure food availability throughout the year, food safety, and hygiene. Identifying approaches

Entry Points for Improved Nutritional Outcomes

The current body of evidence on the links between irrigation, water management, and nutrition provides important clues as to what nutrition sensitive enhancements are needed to achieve greater impacts on early child nutrition. The following approaches are recommended to increase the nutritional impact of irrigation and water management investments.



to target information to both men and women would increase the likelihood of uptake.

Leverage Community Platforms to Deliver Nutrition Messaging

Other community-based platforms that target pregnant women and households with young children could be equipped with information and messaging to promote household nutrition and healthy diets and reinforce the messaging through the irrigation-related platforms. Schools, health centers, savings groups, and so on, are present in most communities.

Engage Women in Irrigation Interventions

Inclusion of women cuts across all pathways to influence nutritional outcomes. Evidence shows that irrigation interventions targeted to women can improve dietary quality and nutritional outcomes in some contexts (Burney et al. 2010; Iannotti, Cunningham, and Ruel 2009; Olney et al. 2009). For example, women are more likely to make nutrition-related decisions in the home, so they are more likely to set aside nutrient-dense crops for home consumption or to spend additional income on health food and other inputs that lead to better nutritional outcomes. Improvements in the availability of water and less time spent irrigating as a result of irrigation investments could free time for women to spend on caregiving or productive activities, contributing to better outcomes at home. Finally, including women as beneficiaries of irrigation investments may influence women's empowerment across several domains. This depends on many factors, including women's control over decisions regarding which technologies are adopted and how they are used, who performs the labor for irrigation, and who controls irrigated output and income from the sale of irrigated crops (Passarelli et al. 2018; Theis et al. 2018). Identifying interventions that reduce women's time burden and support their authority over irrigated production could thus help accelerate nutritional gains and increase benefits.

Promote Nutrient-Dense Crops and Incorporate Home-Gardening Components in Irrigation Projects

Promotion of nutrient-dense crops could lead to improvements in household nutrition, in which a portion of that production is diverted to household consumption or in which these crops make their way to be sold in local markets, benefiting a wider population. This includes promotion of biofortified crops to address micronutrient deficiencies. In some parts of

BOX 4.1. Strengthening Water Security and Resilience in Somalia

The Water for Agro-Pastoral Productivity and Resilience Project aims to tackle water for both crop and livestock productivity and community resilience. Somalia is subject to repeated cycles of devastating droughts, averaging one every 4 years, and has experienced five major flood events between 2006 and 2018, affecting hundreds of thousands of people. The last drought in 2016–17 led to 6.2 million Somalis requiring humanitarian assistance and close to 400,000 reported cases of acute child malnutrition. Livestock losses were estimated at US$2 billion, with people losing between 40 and 60 percent of their herd. The proposed project will provide access to multiple-use water resources (for human consumption, livestock, and small-scale irrigation) in dry lands of Somalia. The small-scale water infrastructure will be designed to deliver both improved human health outcomes and water for productive uses, including agricultural production as well as agroforestry services for landscape restoration.

Africa, irrigation is used to produce fodder for livestock (Frenken 2005). Irrigated fodder production can increase livestock and dairy productivity, providing a greater supply of animal-source foods and protein intake for young children (Murphy and Allen 2003).

Promotion of home gardens alongside irrigation interventions could be an explicit way to encourage consumption of a more diverse diet in the home. Several reviews have found a positive relationship between home gardens and consumption of fruit and vegetables (Berti, Krasevec, and FitzGerald 2004; Masset et al. 2012; Ruel, Quisumbing, and Balagamwala 2018). Though these reviews do not assess the effects of irrigation on nutrition specifically, other studies have found that the addition of irrigation and access to water year-round improve the uptake of home and small-scale gardens, as well as the outputs from these food sources (Bhagowalia, Headey, and Kadiyala 2012; Hirvonen and Headey 2018; Olney et al. 2013).

Design Formal Multiple-Use Water Systems That Are Culturally Appropriate and Safe

Irrigation water is sometimes used for domestic purposes when access to other sources of domestic water is seasonally limited or non-existent (Domènech 2015; Ensink et al. 2002; Meinzen-Dick 1997; van Koppen et al. 2009). Water systems designed for multiple purposes may reduce overall time spent collecting water, freeing time for productive uses and caregiving, both inputs to better nutritional outcomes. However, irrigation infrastructure is not typically designed to collect or distribute water for domestic consumption, so this can lead to both positive and negative health effects (Domènech 2015). Formal multiple-use water systems (MUS) are designed to support both domestic and irrigation uses, and as such have the potential to increase health and nutritional outcomes through multiple pathways (see box 4.1) (van Koppen et al. 2009).

Incorporate Irrigation into Community-Based Platforms for Rural Service Delivery

Social protection and livelihood programs use community-based platforms for delivery of small-scale infrastructure, as well as financial safety nets that protect households from shocks and provide resources for recovery (see box 4.2). These programs often use targeting systems that enable both geographic and demographic (first 1,000 days of a child's life) targeting of

BOX 4.2. Linking Public Works Projects with Water Management and Irrigation

The Ethiopia Productive Safety Nets Project (PSNP) is a core element of the government of Ethiopia's pro-poor development agenda. The World Bank supports PSNP through an Adaptable Policy Lending (APL) instrument with the overall development objective to reduce household vulnerability, improve resilience to shocks, and promote sustainable community development in food-insecure areas of rural Ethiopia. The project targets chronically food-insecure households with safety net transfers based on completion of public works labor and/or soft conditions related to health and nutrition. Now in its fourth phase (PSNP IV), the project has continually harnessed evidence from ongoing impact evaluations and targeted studies to inform the design of implementation and improve outcomes.

box continues next page

BOX 4.2. continued

For example, impact assessments of PSNP in 2011 and 2012 demonstrated that linking public works, such as road and embankment construction, with livelihood investments, such as micro- and small-scale irrigation, water harvesting, and soil and water conservation, leads to greater impacts. Small-scale irrigation from water sources developed by PSNP helped to expand livestock for 4 to 12 percent of households and increased incomes by 4 to 25 percent. When compared with rainfed cultivation, small- and microscale irrigation projects were yielding an additional 3,652 Ethiopian birr per hectare per year (approximately US$ 125), contributing substantially to household livelihoods and food security. Based on these findings, a subsequent phase of PSNP intends to methodically link the design of public works with access to livelihood services.

nutrition-related services without incurring additional costs. Such services may include the following:

- Construction and/or rehabilitation of small-scale irrigation infrastructure
- Drought insurance products to enable households to recover from unexpected weather shocks
- Promotion of home gardens to diversify household diet
- Nutrition-sensitive messaging around healthy diets, resource planning and food storage practices, food safety, and hygiene

Integration of irrigation infrastructure and services into social protection and livelihood programs may face limitations if these programs are not equipped to address institutional capacity needs that are required to sustain service delivery. For example, without adequate operational and maintenance support to keep irrigation infrastructure functioning, they can break down, resulting in households reverting to labor-intensive irrigation approaches.

Chapter 5
Practical Guidance for Nutrition-Sensitive Monitoring and Evaluation

Despite growing evidence, the potential for nutrition-sensitive irrigation and water management to affect nutritional outcomes has not been fully explored (Domènech 2015). Evidence is mostly observational, with only a few rigorous impact evaluations of the links along the pathways between irrigation interventions and nutritional outcomes. Building this evidence base requires enhancement of existing monitoring and evaluation efforts to capture impacts along the key pathways to nutritional outcomes. Table 5.1 presents a set of results framework indicators that link to each pathway to support nutrition-sensitive lending operations. These indicators can also be used for irrigation components of agriculture projects and projects in other sectors. The selected indicators would need to be adapted to the project context, including data availability, project components, and monitoring and evaluation capacity.

Production and Income Pathway Indicators

As shown in the framework, one of the key pathways to improved nutrition is through changes in food production. The nutrition-sensitive indicators proposed in table 5.1 adhere to traditional irrigation project indicators but focus the measurement of these indicators on either (1) reach of the project among nutritionally vulnerable populations or (2) production of nutrient-dense crops. Additional nutrition-sensitive indicators measure whether increases in agricultural production (the production pathway) and/or increases in agricultural income (the income pathway) have led to changes in diet at the household level.

Share of Beneficiary Area and/or Water Users Experiencing Food Insecurity at Baseline

The first nutrition-sensitive indicators measure coverage of the project for vulnerable populations experiencing food insecurity and are recommended for projects that aim to target food-insecure communities with irrigation services. Household food insecurity can be measured using the Household Food Insecurity Access Scale (HFIAS) or the Food Insecurity Experience Scale (FIES).[1] Both can be generated using a short household survey module. The HFIAS captures households' behavioral and psychological manifestations of insecure food access, such as having to reduce the number of meals consumed or cut back on the quality of the food because of a lack of resources. Similarly, the FIES captures the range of food insecurity severity at either the individual or the household level. Both measures are useful inputs for informing population-level targeting and monitoring and evaluating food access–related activities.

Average Crop Production, Intensity, and Diversity

Irrigation has been shown to increase crop yields, the first step in the production pathway. Yields of irrigating households can be used to measure the effects of irrigation on crop production, and disaggregating these yields by crop type can explore how irrigation enables farmers to grow more nutrient-dense crops. Irrigation interventions may directly promote the adoption of micronutrient-rich foods, such as leafy green vegetables or orange-flesh sweet potatoes, but even where these are not promoted, farmers may choose to plant such crops for practical and economic reasons.

Crop yield per unit of area is an indicator traditionally used to determine cropland productivity.

TABLE 5.1. Nutrition-Sensitive Indicators for Irrigation and Water Management Lending Operations

Key results indicators for irrigation operations	*Additional* key results indicators for nutrition-sensitive irrigation operations	Data source and calculation	Can be gender disaggregated
Production pathway			
Area provided with new or improved irrigation or drainage services (ha)[a]	Share of area provided with new or improved irrigation or drainage services that was food insecure at baseline (%)	Project-level data collected by implementing agencies; calculation of HFIAS in project area at baseline (see below)	
Water users with improved irrigation and drainage services	Water users with improved irrigation and drainage services who were food insecure at baseline (%)	Project-level data collected by implementing agencies; calculation of HFIAS at baseline (see below)	
Average crop production	Average crop production and diversity (disaggregated by type of nutrient-dense crop)	Project-level data collected by implementing agencies; LSMS crop production modules in project area	✓
Average cropping intensity	Average cropping intensity of nutrient-dense crops (%)	Project-level data collected by implementing agencies	
None	Months of crop production by nutrient-dense crop (number)	Project-level data collected by implementing agencies	
Increase in agricultural production sold (%)	Increase in nutrient-dense agricultural production sold (%)	Project-level data collected by implementing agencies	
None	Cumulative home gardens established (number)	Project-level data collected by implementing agencies	
None	Availability of nutrient-dense crops in local market	Baseline and follow-up market assessment	
None	Beneficiaries that report improved consumption of nutrient-rich food (%)	Baseline and follow-up household surveys	
Income pathway			
None	Targeted farmers that report increased agricultural income (%)	Project-level data collected by implementing agencies	✓
WASH pathway			
People provided with access to improved water sources	None	Project-level data collected by implementing agencies	✓
People provided with access to improved sanitation	None	Project-level data collected by implementing agencies	✓
Reduction in time spent obtaining water (hours)	None	Baseline and follow-up household surveys	✓
Women's empowerment pathway			
Farmers reached with agricultural assets or services**	Female farmers reached with agricultural assets or services**	Project-level data collected by implementing agencies	✓
Farmers adopting improved agricultural technology	Female farmers adopting improved agricultural technology and/or equipment (%)	Project-level data collected by implementing agencies	✓
	Women providing extension or other agricultural cooperative services (%)	Project-level data collected by implementing agencies	✓

table continues next page

TABLE 5.1. continued

Key results indicators for irrigation operations	*Additional* key results indicators for nutrition-sensitive irrigation operations	Data source and calculation	Can be gender disaggregated
Enabling environment			
Irrigation strategy or policy developed and approved	Irrigation strategy or policy developed and approved that incorporates food security and nutrition policy measures	Project-level data	
Basin plan established or improved	Basin plan established or improved that addresses food security and nutrition objectives	Project-level data	
Reduced erosion and improved water quality	None	Project-level data or MIS	
	Households receiving behavioral messages on healthy diet and nutrition (number)	Project-level data collected by implementing agencies	
	Extension agents trained in healthy diet and nutrition (number)	Project-level data collected by implementing agencies	✓

Note: HFIAS = Household Food Insecurity Access Scale; LSMS = Living Standards Measurement Study; MIS = Management Information System; WASH = water supply, sanitation, and hygiene.
a. Core sector indicator.

Although yield is a good indicator of land productivity for cropping systems with a systematic planting pattern, in more complex cropping systems with more than one crop planted in a plot, measures such as value of crop production per unit area can be used to determine the productivity of the output. Because irrigation also extends the timeline for crop cultivation into the dry season, crop counts over the course of one production season or year can capture differences between households producing irrigated crops during the dry season (in addition to rainfed production) and those depending on rainfall. This can provide a measure of the stability of the food supply throughout the year.

Data for calculating crop production, diversity, and value of production can be collected using agricultural household surveys, such as those administered by the Living Standards Measurement Study (LSMS).[2] These modules can also be used to measure the share of production that is allocated to consumption, sale, seed, and so on.

Market-Level Dietary Diversity

Poorly functioning markets in rural areas could form an important factor that influences access to and consumption of diverse foods by local populations, but this information is not captured by household-level indicators of dietary diversity. The diversity of foods available in local markets, called a market-level dietary diversity (MLDD) score by Pingali et al. (2014), represents the number of distinct foods or food groups available in a local market at a given point in time. Although this indicator has not been fully developed or widely used, it presents an opportunity to fill a gap in the data on factors, such as availability and access to food, that influence household and individual diet diversity.[3]

Household Dietary Diversity

Changes in agricultural production and increases in income from agriculture can lead households to change their diet. Diet quality as measured by increase in intake of micronutrients such as vitamin A, iron, and zinc can demonstrate improvements in nutritional status associated with irrigation interventions. The following indicators capture dietary diversity for different household members.[4] Micronutrient intake can also be calculated for individual household members.

Minimum Dietary Diversity for Women. The Minimum Dietary Diversity for Women (MDD-W) score is an indicator of dietary diversity validated for women of reproductive age (15 to 49 years). Women who have consumed at least 5 of the 10 possible food groups over a 24-hour recall period are classified as having minimally adequate diet diversity. Data are gathered from a questionnaire administered to female respondents in the specific age range.

Infant and Young Child Minimum Acceptable Diet. The Infant and Young Child Minimum Acceptable Diet (IYCMAD) indicator is one of eight core indicators for assessing infant and young child feeding (IYCF) practices developed by the World Health Organization (WHO) This indicator is calculated for both breastfed and nonbreastfed children. It is a composite indicator based on two components: minimum dietary diversity and minimum meal frequency. This indicator be disaggregated and reported for the following age groups: 6 to 11, 12 to 17, and 18 to 23 months of age.

Micronutrient Intake (Vitamin A, Iron, and *Zinc*). Micronutrient deficiency continues to be a widespread problem in low-income economies, especially for iron, vitamin A, and zinc. These nutrients are essential not just for infants and children, to ensure proper growth and development, but also for adults, to ensure productivity, healthy pregnancies, and overall cognitive and physical health. Individual micronutrient intake can be a useful indicator in assessing the need for or effect of nutrient-specific interventions, including nutrition-sensitive irrigation projects, biofortification, and supplementation. In addition, if micronutrient intake data are available for all members of a household, this indicator could shed light on the dynamics of intrahousehold allocation of food. To estimate individual daily intake of micronutrients, data from a quantitative 24-hour dietary recall method or a weighed food record are required.[5]

Agricultural Income and Farm Profits

Increased household income is one of the key pathways through which irrigation can improve nutritional outcomes, especially if this income leads to greater spending on nutritious foods or other nutrition inputs. Data to calculate net profits of agricultural production can be collected through production modules as part of farm household surveys. Data on expenditures, such as total food expenditures; spending on animal-source foods, vitamin A–rich foods, and iron-rich foods; and health expenditures, could be measured, as well as part of an expenditure module of a household survey.

Water, Sanitation, and Hygiene Pathway Indicators

Irrigation interventions can provide unique opportunities to improve water, sanitation, and hygiene (WASH) conditions in the beneficiary population, but they can also potentially introduce risks. For example, irrigation interventions provide a reliable source of water that can be used for practicing household hygiene and can substantially reduce the amount of time spent fetching water, freeing that time for caregiving, education, or productive pursuits that are inputs to nutrition. As an underlying determinant of nutritional outcomes, measurement of WASH indicators in nutrition-sensitive irrigation interventions can provide context as to how well food can be used by beneficiaries. Irrigation water may also introduce risks if the water is consumed by the household, if it is untreated, or if improper management of irrigation water increases the incidence of vector-borne diseases, such as malaria and schistosomiasis.

Women's Empowerment Pathway Indicators

Given that women's empowerment can influence decision making over production and income, the extent to which women are empowered with access to agricultural services, assets, and inputs (including irrigation technologies) and with control over these resources can influence the effects of irrigation on household nutritional outcomes. Therefore, an understanding of women's empowerment and engagement in project activities is important for nutrition-sensitive irrigation projects.

Understanding who has access to and who controls agricultural assets and equipment can provide insights into men's and women's bargaining power over irrigation decisions. Emerging evidence shows that when households own modern irrigation equipment, such as motorized pumps, men tend to control and use these assets; in contrast, women tend to use traditional irrigation methods, such as buckets or watering cans, that are more labor intensive. In some cases, irrigation equipment provided to women is still considered owned by men (Theis et al. 2018). Men and women often have different production preferences. Inclusion of women both as providers and recipients of agricultural extension services can influence production decisions, such as what crops to plant, what animals to raise, and for what purposes (sale or household consumption).

The Women's Empowerment in Agriculture Index (WEAI) captures women's empowerment across several domains, including decision making related to agricultural production, access to and control over productive resources, control over income, community leadership, and time allocation. A shorter, streamlined version of the WEAI, the Abbreviated WEAI, was developed to simplify the index and shorten the interview time while maintaining cross-cultural applicability.

Enabling Environment Indicators

Protection and restoration of watersheds can help to ensure the availability of sustainable ecosystems, reduce erosion and other risks to water quality, and increase overall water availability for livelihoods and resilience. Key policy actions and conditions in the enabling environment, such as institutional capacity, infrastructure, strategy, and planning for sustainable water management, can influence nutritional outcomes, but it is important to include food security and nutrition as specific objectives.

Watershed and Water Quality Improvements

Water quality indicators can report on the establishment of water quality monitoring stations and track availability and access to data on groundwater and sedimentation by season. Changes in water quality can be measured directly to demonstrate improvements related to project interventions. Projects can also track the establishment of hydrometeorological water monitoring stations to monitor droughts and floods and incorporate surveillance and reporting of water-related disease outbreaks.

Training and Communication of Behavior Change Messages on Diet and Nutrition

The enabling environment for better household nutrition is supported through complementary messaging on healthy diet and nutrition that can be integrated into irrigation and water management investments using existing platforms or leveraging other community-based platforms.

Measuring Health and Nutritional Outcomes

Irrigation can potentially affect health and nutritional outcomes through changes in diet, changes in health care practices and risks, and the WASH environment. However, including health outcomes in the project results framework raises issues of attribution and cost. These challenges are outlined here for various outcome measures. It is uncommon even for health operations to measure these outcomes. For multisectoral projects that adopt a convergence approach, it may be appropriate to measure health and nutritional outcomes at the program or portfolio level so that projects share accountability for health and nutritional outcomes and no single project claims attribution.

Diarrheal Disease

Prevalence of diarrhea is relatively easy to collect, but it is highly variable and requires large sample sizes to estimate with precision. Self- or caregiver-reported diarrhea can be biased downward because of placebo effects, social desirability bias, and recall attenuation bias; therefore, such reports may show impact where there is none. Moreover, diarrhea is caused by multiple factors, and without an appropriate research design to attribute causality, data may not be sufficiently specific to demonstrate impact. Measures of diarrhea include incidence of diarrhea in previous 7 days (or 2 weeks) for children under 5 years of age or for adults, symptom-based recall of watery stools and three or more stools per day, or blood in stool.

Anthropometrics

Child anthropometrics are objective measures of nutrition, but they are costly to measure because they require specialized equipment and well-trained staff. Moreover, they have low specificity, because growth can be influenced by many factors. Some growth measures, such as height for age, are best measured over the long term, which is not always practical for typical project and evaluation time frames. Systematic administrative data on height and weight are uncommon, and population-level data are typically only collected every 5 years. Measures include height and length for age, weight for age, and head and arm circumference.

Stunting

Stunting is defined as the share of the population of children under 5 years of age whose height-for-age z-score (HAZ) or length-for-age z-score (LAZ) is less than two standard deviations below the median of the reference population. National-level statistics on prevalence of stunting are typically updated every 5 years. In some cases, figures are available at regional, provincial, or district levels.

Body Mass Index of Women of a Reproductive Age

Body mass index (BMI) is one measure often used to assess the nutritional status of women of childbearing age. BMI is an individual's weight in kilograms divided by the square of that person's height in meters. BMI can be used to screen for weight categories that may lead to health problems. A high BMI can be an indicator of overweightness and obesity, and a low BMI can indicate someone is underweight.

Anemia

Anemia, measured by levels of hemoglobin in the blood, is an objective measure of nutrition, but it requires a finger prick, specialized equipment, and training, which may not be practical for most projects. Moreover, anemia has many causes that are not affected by WASH.

Micronutrient Status (Vitamin A, Iron, and Zinc)

To determine actual micronutrient status (as opposed to micronutrient intake) different biomarkers are needed (for example, blood or urine samples) depending on the nutrient being measured. For more information on how to collect and analyze micronutrient status through population-based surveys, see Gorstein et al. (2007).

Notes

1. For further details on the HFIAS and the FIES, including household modules, translations, and calculation methods, see https://inddex.nutrition.tufts.edu/data4diets/indicators.
2. Further details on the LSMS can be found at http://surveys.worldbank.org/lsms/programs/integrated-surveys-agriculture-ISA.
3. Further details on the MLDD are available at https://inddex.nutrition.tufts.edu/data4diets/indicators.
4. Further details on indicators of dietary diversity are available at https://inddex.nutrition.tufts.edu/data4diets/indicators.
5. For more information on how this indicator is constructed, see chapter 2, "Overview of the WHO Intake Monitoring, Assessment and Planning Program (IMAPP)," of the WHO (2010) report.

References

Aiello, A. E., R. M. Coulborn, V. Perez, and E. L. Larson. 2008. "Effect of Hand Hygiene on Infectious Disease Risk in the Community Setting: A Meta-Analysis." *American Journal of Public Health* 98 (8): 1372–81.

Alaofè, H., J. Burney, R. Naylor, and D. Taren. 2016. "Solar-Powered Drip Irrigation Impacts on Crops Production Diversity and Dietary Diversity in Northern Benin." *Food and Nutrition Bulletin* 37 (2): 164–75. doi:10.1177/0379572116639710.

Amoah, P., P. Drechsel, R. C. Abaidoo, and E. M. Abraham. 2009. *Improving Food Hygiene in Africa where Vegetables Are Irrigated with Polluted Water*. Paper prepared for the West Africa Regional Sanitation and Hygiene Symposium, 10-12 Nov 2009, Accra, Ghana.

Aseyehegn, K., C. Yirga, and S. Rajan. 2012. "Effect of Small-Scale Irrigation on the Income of Rural Farm Households: The Case of Laelay Maichew District, Central Tigray, Ethiopia." *Journal of Agricultural Sciences* 7 (1): 43–57.

Audibert, M., J. Mathonnat, and M. C. Henry. 2003. "Malaria and Property Accumulation in Rice Production Systems in the Savannah Zone of Cote d'Ivoire." *Tropical Medicine & International Health* 8 (5): 471–83.

Beach, R., T.B. Sulser, A. Crimmins, N. Cenacchi, J. Cole, N.K. Fukagawa, D. Mason-D'Croz, S. Myers, M.C. Sarofim, M. Smith and L.H. Ziska. 2019. "Combining the effects of increased atmospheric carbon dioxide on protein, iron, and zinc availability and projected climate change on global diets: a modelling study." Lancet Planet Health. 3:e307-17.

Berti, P. R., J. Krasevec, and S. FitzGerald. 2004. "A Review of the Effectiveness of Agriculture Interventions in Improving Nutrition Outcomes." *Public Health Nutrition* 7 (5): 599-609. doi:10.1079/PHN2003595.

Bhagowalia, P., D. Headey, and S. Kadiyala. 2012. "Agriculture, Income, and Nutrition Linkages in India Insights from a Nationally Representative Survey." IFPRI Discussion Paper 1195, International Food Policy Research Institute, Washington, DC.

Brun, T., J. Reynaud, and S. Chevassus-Agnes. 1989. "Food and Nutritional Impact of One Home Garden Project in Senegal." *Ecology of Food and Nutrition* 23 (2): 91–108.

Bryan, E., C. Ringler, B. Okoba, C. Roncoli, S. Silvestri, and M. Herrero. 2013. "Adapting Agriculture to Climate Change in Kenya: Household Strategies and Determinants." *Journal of Environmental Management* 114, 26–35.

Bryan, E. 2019. "Small-Scale Irrigation and Women's Empowerment: Evidence from Ghana." Unpublished manuscript.

Burger, S. E., and S. A Esrey. 1995. "Water and Sanitation: Health and Nutrition Benefits to Children." In *Child Growth and Nutrition in Developing Countries: Priorities for Action* 153–74. Ithaca, New York: Cornell University Press, 1995. 153-75.

Burney, J. A., and R. L. Naylor. 2012. "Smallholder Irrigation as a Poverty Alleviation Tool in Sub-Saharan Africa." *World Development* 40 (1): 110–23. doi:10.1016/j.worlddev.2011.05.007.

Burney, J. A., R. L. Naylor, and S. L. Postel. 2013. "The Case for Distributed Irrigation as a Development Priority in Sub-Saharan Africa." *Proceedings of the National Academy of Sciences* 110 (31): 12513–17. doi:10.1073/pnas.1203597110.

Burney, J., L. Woltering, M. Burke, R. Naylor, and D. Pasternak. 2010. "Solar-Powered Drip Irrigation Enhances Food Security in the Sudano-Sahel." *Proceedings of the National Academy of Sciences* 107 (5): 1848–53. doi:10.1073/pnas.0909678107.

Cairncross, S., and J. L. Cuff. 1987. "Water Use and Health in Mueda, Mozambique." *Transactions of the Royal Society of Tropical Medicine and Hygiene* 81 (1): 51–54.

Campbell, D. I., M. Elia, and P. G. Lunn. 2003. "Growth Faltering in Rural Gambian Infants Is Associated with Impaired Small Intestinal Barrier Function, Leading to Endotoxemia and Systemic Inflammation." *Journal of Nutrition* 133 (5): 1332–38.

Carr, E. R. 2008. "Between Structure and Agency: Livelihoods and Adaptation in Ghana's Central Region." *Global Environmental Change* 18 (4): 689–99. doi:10.1016/j.gloenvcha.2008.06.004.

Checkley, W., G. Buckley, R. H. Gilman, A. M. Assis, R. L. Guerrant, S. S. Morris, K. Mølbak, P. Valentiner-Branth, C. F. Lanata, and R. E. Black. 2008. "Multi-Country Analysis of the Effects of Diarrhoea on Childhood Stunting." *International Journal of Epidemiology* 37 (4): 816–30.

Curtis, V., S. Cairncross, and R. Yonli. 2000. "Domestic Hygiene and Diarrhoea—Pinpointing the Problem." *Tropical Medicine & International Health* 5 (1): 22–32.

De Fraiture, C., and M. Giordano. 2014. "Small Private Irrigation: A Thriving but Overlooked Sector." *Agricultural Water Management* 131: 167–74. doi:10.1016/j.agwat.2013.07.005.

Diaz, E., S. A. Esrey, and E. Hurtado. 1995. *Social and Biological Impact Following the Introduction of Household Water in Rural Guatemala*. Ottawa, Canada: International Development Research Center.

Dillon, A. 2008. "Access to Irrigation and the Escape from Poverty: Evidence from Northern Mali." IFPRI Discussion Paper 782, International Food Policy Research Institute, Washington, DC.

Domènech, L. 2015. "Improving Irrigation Access to Combat Food Insecurity and Undernutrition: A Review." *Global Food Security* 6: 24–33. doi:10.1016/j.gfs.2015.09.001.

Ensink, J. H. J., M. Rizwan Aslam, F. Konradsen, P. K. Jensen, and W. van der Hoek. 2002. "Linkages between Irrigation and Drinking Water in Pakistan." IWMI Working Paper 46, International Water Management Institute, Colombo, Sri Lanka.

FAO. 2015. *Designing Nutrition-Sensitive Agriculture Investments*. Checklist and guidance for programme formulation. Rome: FAO.

Fanzo, J., C. Davis, R. McLaren, and J. Choufani. 2018. "The Effect of Climate Change across Food Systems: Implications for Nutrition Outcomes." *Global Food Security* 18: 12-19.

Fox, P., and J. Rockström. 2003. "Supplemental Irrigation for Dry-Spell Mitigation of Rainfed Agriculture in the Sahel." *Agricultural Water Management* 61 (1): 29-50. doi:10.1016/S0378-3774 (03)00008-8.

Frenken, K. 2005. "Irrigation in Africa in Figures: AQUASTAT Survey, 2005." FAO Water Reports 29, Food and Agriculture Organization, Rome. doi:10.1111/j.1467-6346.2007.00685.x.

Gbetibouo, G.A. 2009. "Understanding farmers' perceptions and adaptations to climate change and variability: The case of the Limpopo Basin, South Africa." IFPRI Discussion Paper No. 849. Washington D.C.: IFPRI.

Gillespie, S., J. Harris, and S. Kadiyala. 2012. "The Agriculture-Nutrition Disconnect in India: What Do We Know?" IFPRI Discussion Paper 1187, International Food Policy Research Institute, Washington, DC.

Giordano, M., and C. de Fraiture. 2014. "Small Private Irrigation: Enhancing Benefits and Managing Trade-Offs." *Agricultural Water Management* 131: 175-82. doi:10.1016/j.agwat.2013.07.003.

Giordano, M., C. de Fraiture, E. Weight, and J. Van Der Bliek. 2012. *Water for Wealth and Food Security: Supporting Farmer-Driven Investments in Agricultural Water Management*. Synthesis Report, AgWater Solutions Project, Colombo, Sri Lanka.

Gorstein J, Sullivan KM, Parvanta I, Begin F. Indicators and Methods for Cross-Sectional Surveys of Vitamin and Mineral Status of Populations. The Micronutrient Initiative (Ottawa) and the Centers for Disease Control and Prevention (Atlanta), May 2007.

Grace, K., F. Davenport, H. Hanson, C. Funk, and S. Shukla. 2015. "Linking Climate Change and Health Outcomes: Examining the Relationship between Temperature, Precipitation and Birth Weight in Africa." *Global Environmental Change* 35: 125-37. doi:10.1016/j.gloenvcha.2015.06.010.

Hirvonen, K., and D. Headey. 2018. "Can Governments Promote Homestead Gardening at Scale? Evidence from Ethiopia." *Global Food Security* 19: 40-47.

Iannotti, L., K. Cunningham, and M. Ruel. 2009. "Improving Diet Quality and Micronutrient Nutrition: Homestead Food Production in Bangladesh." IFPRI Discussion Paper 928, International Food Policy Research Institute, Washington, DC. doi:10.1037/0003-066X.55.5.469.

Jiménez Cisneros, B. E., T. Oki, N. W. Arnell, G. Benito, J. G. Cogley, P. Döll, T. Jiang, and S. S. Mwakalila. 2014. "Freshwater Resources." In *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by C. B. Field, V. R. Barros, D. J. Dokken, K. J. Mach, M. D. Mastrandrea, T. E. Bilir, M. Chatterjee, K. L. Ebi, Y. O. Estrada, R. C. Genova, B. Girma, E. S. Kissel, A. N. Levy, S. MacCracken, P. R. Mastrandrea, and L. L. White, 229-69. Cambridge, U.K.: Cambridge University Press.

Kabunga, N., S. Ghosh, and J. K. Griffiths. 2014. "Can Smallholder Fruit and Vegetable Production Systems Improve Household Food Security and Nutritional Status of Women? Evidence from Rural Uganda." IFPRI Discussion Paper 1346, International Food Policy Research Institute, Washington, DC. doi:10.2139/ssrn.2483967.

Keiser, J., M. Caldas de Castro, M. F. Maltese, R. Bos, M. Tanner, B. H. Singer, and J. Utzinger. 2005. "Effect of Irrigation and Large Dams on the Burden of Malaria on a Global and Regional Scale." *American Journal of Tropical Medicine and Hygiene* 72 (4): 392-406.

Khan, S., M. A. Hanjra, and J. Mu. 2009. "Water Management and Crop Production for Food Security in China: A Review." *Agricultural Water Management* 96 (3): 349-60. doi:10.1016/j.agwat.2008.09.022.

Koolwal, G., and D. Van de Walle. 2013. "Access to Water, Women's Work, and Child Outcomes." *Economic Development and Cultural Change* 61 (2): 369-405.

Lunn, P. G., C. A. Northrop-Clewes, and R. M. Downes. 1991. "2. Chronic Diarrhoea and Malnutrition in The Gambia: Studies on Intestinal Permeability." *Transactions of the Royal Society of Tropical Medicine and Hygiene* 85 (1): 8-11.

Malapit, H. J. L., S. Kadiyala, A. R. Quisumbing, K. Cunningham, and P. Tyagi. 2015. "Women's Empowerment Mitigates the Negative Effects of Low Production Diversity on Maternal and Child Nutrition in Nepal." *Journal of Development Studies* 51 (8): 1097-123. doi:10.1080/00220388.2015.1018904.

Malapit, H. J. L., and A. R. Quisumbing. 2015. "What Dimensions of Women's Empowerment in Agriculture Matter for Nutrition in Ghana?" *Food Policy* 52: 54-63. doi:10.1016/j.foodpol.2015.02.003.

Mara, D., J. Lane, B. Scott, and D. Trouba. 2010. "Sanitation and Health." *PLoS Medicine* 7 (11): e1000363.

Marquis, G. S., G. Ventura, R. H. Gilman, E. Porras, E. L. B. A. Miranda, L. Carbajal, and M. Pentafiel. 1990. "Fecal Contamination of Shanty Town Toddlers in Households with Non-Corralled Poultry, Lima, Peru." *American Journal of Public Health* 80 (2): 146-49.

Masset, E., L. Haddad, A. Cornelius, and J. Isaza-Castro. 2012. "Effectiveness of Agricultural Interventions That Aim to Improve Nutritional Status of Children: Systematic Review." *BMJ* 344 (7843): 1-7. doi:10.1136/bmj.d8222.

Mateo-Sagasta, J., S. M. Zadeh, H. Turral, and J. Burke. 2017. *Water Pollution from Agriculture: A Global Review.* Food and Agriculture Organization of the United Nations and the International Water Management Institute, Rome.

Meinzen-Dick, R. 1997. "Valuing the Multiple Uses of Water." In *Water: Economics, Management and Demand*, edited by M. Kay, T. Franks, and L. Smith, 50-58. London: E. & F. N. Spon.

Meinzen-Dick, R., J. A. Behrman, P. Menon, and A. Quisumbing. 2012. "Gender: A Key Dimension Linking Agricultural Programs to Improved Nutrition and Health." In *Reshaping Agriculture for Nutrition and Health: 2020 Conference Book*, edited by S. Fan and R. Pandya-Lorch, 135-44. Washington, DC: International Food Policy Research Institute. http://www.ifpri.org/sites/default/files/publications/oc69ch16.pdf.

Meinzen-Dick, R., R. Chaturvedi, L. Domenech, R. Ghate, M. A. Janssen, N. D. Rollins, and K. Sandeep. 2016. "Games for Groundwater Governance: Field Experiments in Andhra Pradesh, India." *Ecology and Society* 21 (3): 38.

Miller, G., and B. P. Urdinola. 2010. "Cyclicality, Mortality, and the Value of Time: The Case of Coffee Price Fluctuations and Child Survival in Colombia." *Journal of Political Economy* 118 (1): 113–55.

Motarjemi, Y., F. Käferstein, G. Moy, and F. Quevedo. 1993. "Contaminated Weaning Food: A Major Risk Factor for Diarrhoea and Associated Malnutrition." *Bulletin of the World Health Organization* 71 (1): 79.

Murphy, S. P., and L. H. Allen. 2003. "Nutritional Importance of Animal Source Foods." *Journal of Nutrition* 133 (11 Suppl 2): 3932–35.

Namara, R. E., J. A. Awuni, B. Barry, M. Giordano, L. Hope, E. S. Owusu, and G. Forkuor. 2011. *Smallholder Shallow Groundwater Irrigation Development in the Upper East Region of Ghana*. IWMI Research Report 143, vol. 139. Colombo, Sri Lanka: International Water Management Research Institute. doi:10.5337/2011.214.

Namara, R. E., B. Upadhyay, and R. K. Nagar. 2005. *Adoption and Impacts of Microirrigation Technologies: Empirical Results from Selected Localities of Maharashtra and Gujarat States of India*. IWMI Research Report 93, vol. 30, Colombo, Sri Lanka: International Water Management Research Institute.

Nangia, V., and T. Oweis. 2016. "Supplemental Irrigation: A Promising Climate-resilience Practice for Sustainable Dryland Agriculture." In *Innovations in Dryland Agriculture*, Farooq, M. and Siddique, K. (Eds.) 549–64. Cham, Switzerland: Springer.

Olney, D. K., A. Pedehombga, M. T. Ruel, and A. Dillon. 2015. "A 2-Year Integrated Agriculture and Nutrition and Health Behavior Change Communication Program Targeted to Women in Burkina Faso Reduces Anemia, Wasting, and Diarrhea in Children 3–12.9 Months of Age at Baseline: A Cluster-Randomized Controlled Trial." *Journal of Nutrition* 145 (6): 1317–24. doi:10.3945/jn.114.203539.

Olney, D. K., A. Talukder, L. L. Iannotti, M. T. Ruel, and V. Quinn. 2009. "Assessing Impact and Impact Pathways of a Homestead Food Production Program on Household and Child Nutrition in Cambodia." *Food and Nutrition Bulletin* 30 (4): 355–69. doi:10.1177/156482650903000407.

Olney, D. K., S. Vicheka, M. Kro, C. Chakriya, H. Kroeun, L. S. Hoing, A. Talukder, V. Quinn, L. Iannotti, E. Becker, and T. Roopnaraine. 2013. "Using Program Impact Pathways to Understand and Improve Program Delivery, Utilization, and Potential for Impact of Helen Keller International's Homestead Food Production Program in Cambodia." *Food and Nutrition Bulletin* 34 (2): 169–84. doi:10.1177/156482651303400206.

Oweis, T., and A. Hachum. 2006. "Water Harvesting and Supplemental Irrigation for Improved Water Productivity of Dry Farming Systems in West Asia and North Africa." *Agricultural Water Management* 80 (1): 57–73. doi:10.1016/j.agwat.2005.07.004.

Owens, S., R. Gulati, A. J. Fulford, F. Sosseh, F. C. Denison, B. J. Brabin, and A. M. Prentice. 2015. "Periconceptional Multiple-Micronutrient Supplementation and Placental Function in Rural Gambian Women: A Double-Blind, Randomized, Placebo-Controlled Trial." *American Journal of Clinical Nutrition* 102 (6): 1450–59. doi:10.3945/ajcn.113.072413.

Passarelli, S., D. Mekonnen, E. Bryan, and C. Ringler. 2018. "Evaluating the Pathways from Small-Scale Irrigation to Dietary Diversity: Evidence from Ethiopia and Tanzania." *Food Security* 10 (4): 981–97. doi:10.1007/s12571-018-0812-5.

Pickering, A. J., and J. Davis. 2012. "Freshwater Availability and Water Fetching Distance Affect Child Health in Sub-Saharan Africa." *Environmental Science & Technology* 46 (4): 2391–97.

Pickering, A. J., T. R. Julian, S. J. Marks, M. C. Mattioli, A. B. Boehm, K. J. Schwab, and J. Davis. 2012. "Fecal Contamination and Diarrheal Pathogens on Surfaces and in Soils among Tanzanian Households with and without Improved Sanitation." *Environmental Science & Technology* 46 (11): 5736–43.

Pingali, P.L. and K. D. Ricketts. 2014. "Mainstreaming Nutrition Metrics in Household Surveys—Toward a Multidisciplinary Convergence of Data Systems." *Annals of the New York Academy of Sciences* 1331 (1): 249–57.

Riley, P. J., and N. T. Krogman. 1993. "Gender-Related Factors Influencing the Viability of Irrigation Projects in Lesotho." *Journal of Asian and African Studies* 28 (3–4): 162–79.

Ringler, C., T. Zhu, X. Cai, J. Koo, and D. Wang. 2010. *Climate Change Impacts on Food Security in Sub-Saharan Africa: Insights from Comprehensive Climate Change Modeling*. Washington, DC: International Food Policy Research Institute.

Ruel, M. T., A. R. Quisumbing, and M. Balagamwala. 2018. "Nutrition-Sensitive Agriculture: What Have We Learned So Far?" *Global Food Security* 17: 128–53. doi:10.1016/j.gfs.2018.01.002.

Sibhatu, K. T., V. V. Krishna, and M. Qaim. 2015. "Production Diversity and Dietary Diversity in Smallholder Farm Households." *Proceedings of the National Academy of Sciences* 112 (34): 10657–62. doi:10.1073/pnas.1510982112.

Smith, M., and S. S. Myers. 2017. "Measuring the Effects of Anthropogenic CO_2 Emissions on Global Nutrient Intakes: A Modelling Analysis." *The Lancet* 389: S19.

Springmann, M., D. Mason-D'Croz, S. Robinson, T. Garnett, H. C. J. Godfray, D. Gollin, M. Rayner, P. Ballon, and P. Scarborough. 2016. "Global and Regional Health Effects of Future Food Production Under Climate Change: A Modelling Study." *The Lancet* 387 (10031): 1937–46.

Sraboni, E., H. J. Malapit, A. R. Quisumbing, and A. U. Ahmed. 2014. "Women's Empowerment in Agriculture: What Role for Food Security in Bangladesh?" *World Development* 61: 11–52. doi:10.1016/j.worlddev.2014.03.025.

Steiner-Asiedu, M., B. A. Z. Abu, J. Setorglo, D. K. Asiedu, and A. K. Anderson. 2012. "The Impact of Irrigation on the Nutritional Status of Children in the Sissala West District of Ghana." *Current Research Journal of Social Sciences* 4 (2): 86–92.

Theis, S., N. Lefore, R. Meinzen-Dick, and E. Bryan. 2018. "What Happens after Technology Adoption? Gendered Aspects of Small-Scale Irrigation Technologies in Ethiopia, Ghana, and Tanzania." *Agriculture and Human Values* 35 (3): 671–84. doi:10.1007/s10460-018-9862-8.

Tompkins, E., and W. N. Adger. 2004. "Does Adaptive Management of Natural Resources Enhance Resilience to Climate Change?" *Ecology and Society* 9 (2):10.

UN (United Nations). 2018. *The Sustainable Development Goals Report 2018*. New York: UN.

van den Bold, M., A. R. Quisumbing, and S. Gillespie. 2013. “Women’s Empowerment and Nutrition: An Evidence Review.” IFPRI Discussion Paper 1294, International Food Policy Research Institute, Washington, DC. doi:10.2139/ssrn.2343160.

van der Hoek, W., S. G. Feenstra, and F. Konradsen. 2002. “Availability of Irrigation Water for Domestic Use in Pakistan: Its Impact on Prevalence of Diarrhoea and Nutritional Status of Children.” *Journal of Health, Population and Nutrition* 20 (1): 77–84.

van Koppen, B., S. Smits, P. Moriarty, F. Penning de Vries, M. Mikhail, and E. Boelee. 2009. *Climbing the Water Ladder: Multiple-Use Water Services for Poverty Reduction*. TP series 52. The Hague, The Netherlands: IRC International Water and Sanitation Centre and International Water Management Institute.

Vaughan, M., and H. Moore. 1988. “Health Nutrition and Agricultural Development in Northern Zambia.” *Social Science and Medicine* 27 (7): 743–45.

WHO (World Health Organization). 2010. “Estimating Appropriate Levels of Vitamins and Minerals for Food Fortification Programmes: The WHO Intake, Monitoring, Assessment and Planning Program (IMAPP).” Meeting Report. Geneva: WHO.

Wiebe, K., H. Lotze-Campen, R. Sands, A. Tabeau, D. van der Mensbrugghe, A. Biewald, B. Bodirsky, S. Islam, A. Kavallari, D. Mason-D’Croz, C. Müller, A. Popp, R. Robertson, S. Robinson, H. van Meijl, and D. Willenbockel and Müller, C. 2015. “Climate Change Impacts on Agriculture in 2050 Under a Range of Plausible Socioeconomic and Emissions Scenarios.” *Environmental Research Letters* 10 (8): 085010.

World Bank. 2013. *Improving Nutrition through Multisectoral Approaches: Agriculture and Rural Development*. Washington, DC: World Bank Group.

Xie, H., L. You, B. Wielgosz, and C. Ringler. 2014. “Estimating the Potential for Expanding Smallholder Irrigation in Sub-Saharan Africa.” *Agricultural Water Management* 131: 183–93. doi:10.1016/j.agwat.2013.08.011.

Yimer, F., and F. Tadesse. 2015. “Women’s Empowerment in Agriculture and Dietary Diversity in Ethiopia.” ESSP Working Paper 80, Ethiopia Strategy Support Program, Addis Ababa, Ethiopia.

You, L., C. Ringler, U. Wood-Sichra, R. Robertson, S. Wood, T. Zhu, G. Nelson, Z. Guo, and Y. Sun. 2011. “What Is the Irrigation Potential for Africa? A Combined Biophysical and Socioeconomic Approach.” *Food Policy* 36 (6): 770–82. doi:10.1016/j.foodpol.2011.09.001.

GWSP
GLOBAL WATER
SECURITY & SANITATION
PARTNERSHIP

WORLD BANK GROUP

SKU W18058