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The Impact of Irrigation on Nutrition, Health, and Gender

A Review Paper with Insights for Africa south of the Sahara

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ABSTRACT

Agriculture in Africa south of the Sahara (SSA) is still largely rainfed. SSA also exhibits the lowest crop yields for major staples in the world, largely due to low use of irrigation and fertilizer. Rainfed agriculture poses growing production risks with increased climate variability and change. At the same time, smallholder irrigation in the region developed rapidly over the past decade, albeit starting from very low levels. In addition to largely demand-driven irrigation development by smallholders, there is a significant push by donors for large-scale irrigation development, as well as some push for smallholder irrigation. There has also been a long-standing debate about whether irrigation in SSA should be large scale or small scale to achieve its potential. However, given the potentially high rewards, but also high possibility of failure, the assessment of irrigation potential must go beyond large scale versus small scale to integrate concerns regarding environmental sustainability, resource use efficiency, nutrition and health impacts, and women's empowerment. The hypothesis underlying this review paper is that how irrigation gets deployed in SSA will be decisive not only for environmental sustainability (such as deciding remaining forest cover in the region) and poverty reduction, but also for health, nutrition, and gender outcomes in the region. The focus of this paper is on the health, nutrition, and gender linkage. We find that to date, few studies have analyzed the impact of irrigation interventions on nutrition, health, and women's empowerment, despite the large potential of irrigation to affect these important variables. Irrigation interventions may have differential effects on different members in the household and in the community, such as irrigators, non-irrigators, children, and women. Measuring and understanding such differences, followed by improving design and implementation to maximize gender, health, and nutrition outcomes, could transform irrigation programs from focusing solely on increased food production toward becoming an integral component of poverty-reduction strategies.

Keywords: irrigation, nutrition, health, gender, Africa south of the Sahara

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ABBREVIATIONS AND ACRONYMS

5DE	five domains of empowerment
AWM	Agricultural Water Management
CAADP	Comprehensive Africa Agriculture Development Programme
DALYs	disability-adjusted life-years
GPI	gender parity index
ITNs	insecticide-treated nets
OPs	OPs
OPHI	Oxford Poverty & Human Development Initiative
SSA	Africa south of the Sahara
USAID	U.S. Agency for International Development
WEAI	Women's Empowerment in Agriculture Index

1. THE IMPORTANCE OF IRRIGATION IN DEVELOPING COUNTRIES, WITH A FOCUS ON AFRICA SOUTH OF THE SAHARA

In areas where rainfall is scarce or erratic, irrigation systems may add great value to cultivated lands. Globally, irrigated areas almost doubled over the past 50 years, from 161 million hectares (ha) in 1961 to 318 million ha in 2010 (FAOSTAT 2013). In the developing world, Asia has the greatest share of irrigated land—37 percent of the total cultivated area is equipped for irrigation; Latin America ranges second, with 14 percent of cultivated area irrigated; and Africa is last, with only 6 percent of cultivated area under irrigation (FAOSTAT 2009). Irrigation has been shown to have significant poverty-reduction and income-generation effects and was an important contributor to lowering real food prices from the 1970s through the 1990s (Hussain and Hanjra 2003; Rosegrant, Ringler, and Zhu 2009). Much of the irrigation development in Asia was supported by government investments in the sector. These investments often covered two-thirds of all agricultural expenditures of Asian countries over a decade or more. At the same time, only a small share of cultivated area—approximately 4 percent—is irrigated in Africa south of the Sahara (SSA) (Svendsen, Ewing, and Msangi 2009). In the SSA region, there was limited support to public irrigation investment and lower population density; thus, larger areas for agricultural expansion put less pressure on making land more productive.

However, the potential for expanding irrigated agriculture in SSA is significant. You et al. (2010) estimated the large-scale irrigation potential at 15 million ha and a complementary small-scale component of 7 million ha. Xie et al. (in progress), focusing on various smallholder technologies, estimated a total potential for motor pumps of 30 million ha, reaching up to 185 million rural beneficiaries across the region. However, although the potential of smallholder irrigation in the region is large, there are significant obstacles, including lack of public investment, to achieving the full potential (Giordano et al. 2012).

If SSA does not increase agricultural productivity through irrigation expansion and associated inputs, net food imports to the region will continue to increase as the population continues to rapidly grow. The medium variant of UN population projections indicates that the region will account for nearly half of all global population growth between 2010 and 2050. By 2050, more than 20 percent of the global population will reside in SSA, and by 2100, every third person will be from SSA (United Nations 2011). If the average economic growth of 5 percent achieved during 2003–09 (ReSAKKS 2010) continues together with rapid population growth, pressure on food and natural resources will grow significantly, increasing demand for irrigated agriculture in its wake.

Rosegrant, Ringler, and de Jong (2009) assessed the effect of aggressive expansion of all of Africa's irrigated agricultural area. If Africa's irrigated area could be tripled by 2050, food supply would increase markedly, with a huge decline in net cereal imports. There would be two million fewer malnourished children than under the lower irrigation development scenario, or about the same level that would be expected in the absence of climate change. Thus, aggressive agricultural water development could help reverse the adverse effects of moderate climate change on food security.

Thus, although the potential of irrigation development is clear, the costs of development will be high. You et al. (2010) estimated investment needs of US$64 billion to achieve area expansion of 22 million ha. Actual development of large-scale systems will also remain limited—despite re-engagement of the World Bank and other multi- and bilateral development agencies in irrigation—given the continued preference of SSA governments to support short-term input subsidies, particularly for fertilizers, over long-term investments. For example, although most of the 24 countries in SSA that signed Comprehensive Africa Agriculture Development Programme compacts with investment plans mentioned the need for irrigation development to achieve envisioned food security goals, as well as most states' need for both small- and large-scale irrigation development, only six countries listed specific plans for area expansion (CAADP 2011; You et al. 2010). As a result, a significant development burden will be placed on the private sector—both end users and smaller agencies engaged in irrigation development.

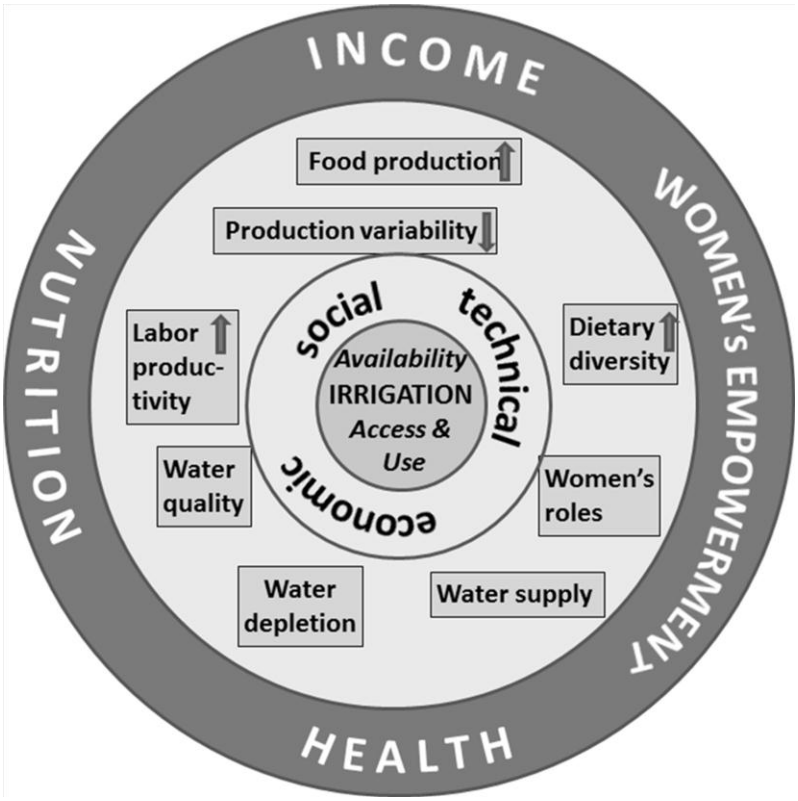
Irrigation systems will affect rural communities in different ways, depending on a number of factors, such as the water source (groundwater, surface water, ponds), the relative water availability (single season, supplementary, or full), the type of technology (drip or sprinkler systems, deep or shallow tube wells, treadle pumps), access to agricultural inputs (land, credit, seeds, fertilizer, and so on), the socioeconomic features of the household, and the institutional rules governing water access and maintenance of water systems (Lipton, Litchfield, and Faurès 2003). Impacts of irrigation on communities and households include higher yields and planting crops in a second season. Irrigation also impacts time use, nutrition and health outcomes and women's status; and environmental outcomes.

Given the high cost of irrigation development and the potentially high rewards, as well as the high possibility of failure, the assessment of irrigation potential must go beyond large scale versus small scale to integrate concerns regarding environmental sustainability, resource use efficiency, nutrition and health impacts, and women's empowerment. The hypothesis underlying this review paper is that the way in which irrigation is deployed in SSA will be decisive not only for environmental sustainability (such as deciding remaining forest cover in the region) and poverty reduction, but also for health, nutrition, and gender outcomes in the region. The focus of the paper is on the health, nutrition, and gender linkage.

2. CONCEPTUAL FRAMEWORK

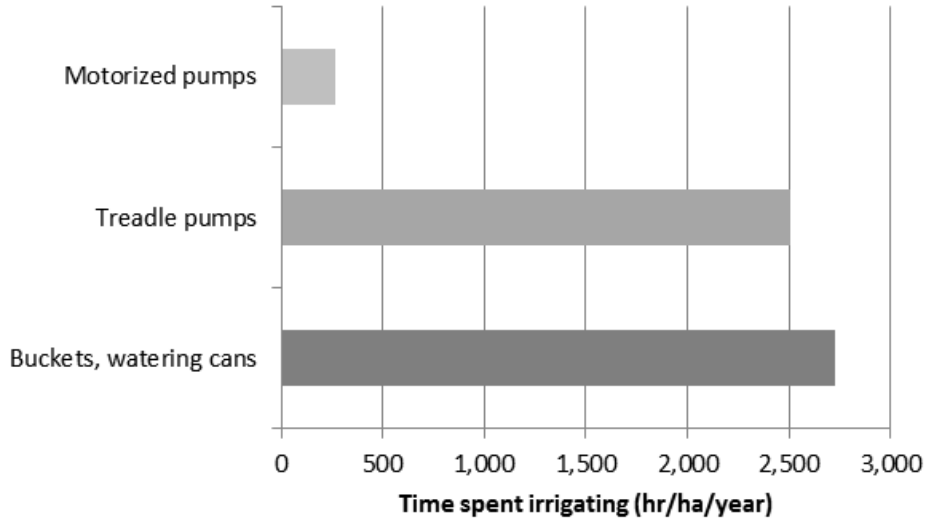
Irrigation interventions can transform the lives of farmers and their communities through a number of pathways (Figure 2.1). All three dimensions of irrigation—availability, access, and use—have an impact on how farmers are affected by irrigation interventions and thus on the success of irrigation development. Availability of water for irrigation is essential, as irrigation technologies will only be sustainable if there is a sustainable source of water. In Zimbabwe, between 2002 and 2006, about 70,000 low-cost drip irrigation kits were distributed to farmers, along with vegetable seeds and introductory training, as part of humanitarian relief efforts. Belder et al. (2007), studying 232 adopters and 85 nonadopters, found that only 16 percent of the kits were still in use after three years due to unreliable water access and lack of follow-up support and capacity building. The kits had been handed out as a relief effort without the supporting institutional infrastructure (Belder et al. 2007). This example also shows that the irrigation technology used to access water—both to draw the water from the source and to apply the water to the field—is important, because different technologies have different environmental and social implications and technical complexities, as well as impacts on agricultural production. The Agricultural Water Management (AWM) Solutions project, for example, found that treadle pumps in Tanzania barely reduced labor hours as compared with buckets (Figure 2.2); and Nkonya et al. (2011) found that women are less likely than men to own, access, or use smallholder irrigation technologies, particularly pumps (Figure 2.3). Finally, irrigation water use—and the associated value chain—also matters. If irrigation is not used for marketable, highly profitable crops, then farmers either will not adopt or will disadopt the technology quickly.

Figure 2.1—Conceptual framework



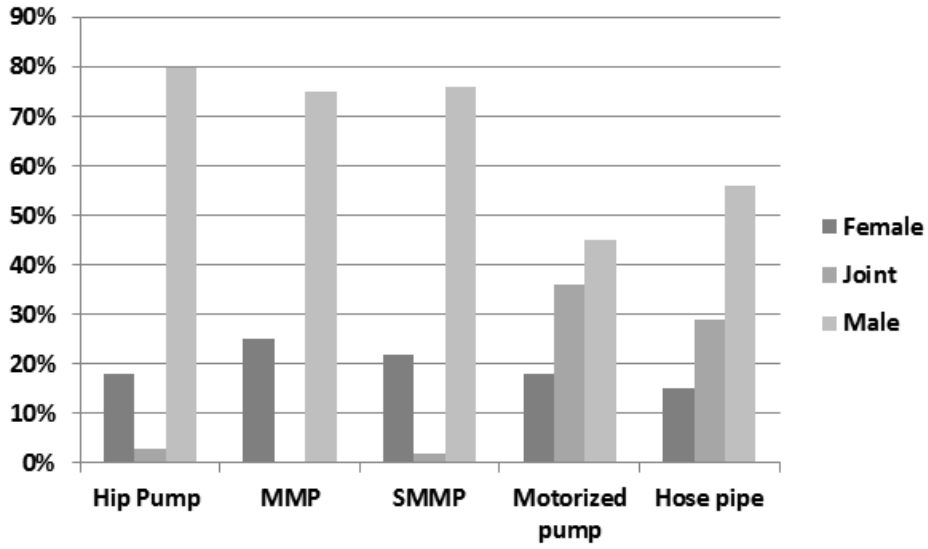
Source: Authors' elaboration.

Figure 2.2—Time spent irrigating one hectare of vegetables: Tanzania



Source: Keraita and de Fraiture (2011).

Figure 2.3—Pump control by gender: Kenya



Source: Nkonya et al. (2011).
Notes: MMP = MoneyMaker Pump; SMMP = Super MoneyMaker Pump. MMP, SMMP, and Hip Pump are products of Kickstart (www.kickstart.org) products.

The availability, access, and use of water for irrigation can increase agricultural productivity significantly, especially during the dry season. The AWM Solutions project estimated large yield improvements from smallholder irrigation in SSA. Irrigated maize yields could increase by 141–195 percent and paddy yields by 270–283 percent, compared to rainfed yields based on an ex ante smallholder irrigation technology assessment (Table 2.1). However, social, institutional, and technical challenges and opportunities need to be overcome in order to achieve actual productivity increases.

Table 2.1—Potential yield improvements from agricultural water management investments in SSA

Crop	Low-input, rainfed yield (t/ha)	High-input, irrigated Yield increase (%)
Maize	1.4	141–195
Paddy	1.1	270–283
Groundnuts	0.7	238–251
Sweet potato	4.3	200–212
Tomato	20	76–79

Source: Giordano et al. (2012).
Note: Yield improvements differ across technologies, ranging from in situ rainwater harvesting to full-irrigation technologies. Yields are area-weighted across SSA.

The type of crops that farmers grow will also change with irrigated agriculture. The type of technology used, the size of landholding, and the system (large-scale versus small-scale irrigation) can influence crop selection and diversity (monoculture versus vegetables and fruits). Smallholder irrigation systems are frequently used to grow vegetables and fruits during the dry season. Thus, they can directly provide enhanced food security and nutrition to farmers and other community members, due to greater availability and stability of food supplies during the dry season and crop diversification. Increased consumption of micronutrient-rich vegetables and fruits will also lead to positive health outcomes. Furthermore, irrigated areas are usually more labor intensive than rainfed areas, and therefore, demand for employment is likely to increase in irrigated communities, with positive impacts on the income of non-irrigators. On the other hand, larger systems might be managed more intensively and might be better linked to larger markets, including international ones, and thus might indirectly lead to improved health and nutrition through higher incomes.

Irrigation interventions can also affect women's empowerment (or disempowerment) depending on gender roles in agriculture, which vary from case to case. Improved access to water supply may release women from water-collection chores and might allow women to invest more time in income-generating activities, such as agricultural production. If women are farming their own plots and have access to irrigation technologies, then the productivity of female-managed plots may increase, and income from the increase in productivity may also grow (if women control income of crops sold in the market). But women might also lose control over their plots when irrigation becomes available or they might not obtain access to the irrigation technology. Hygiene and sanitation practices may also improve due to greater water availability and lead to important health benefits. On the other hand, irrigation can crowd out domestic water access, increase water pollution, and increase water-borne diseases.

If appropriate management practices are not put in place, irrigation schemes may cause detrimental effects for health and the environment. Irrigation accounts for 70 percent of total water withdrawals (Rosegrant, Ringler, and Zhu 2009), and therefore, the widespread use of water for irrigation may contribute to surface water and groundwater resources depletion. The use of wastewater and arsenic-contaminated water for irrigation purposes, as well as pesticide application, may also lead to soil and crop contamination and adverse nutrition and health outcomes.

Thus, how water availability, access, and use lead to changes in food production, production variability, dietary diversity, labor productivity, changes in water supply, water quality, water depletion, and changes in women's roles will depend on locally, nationally, and internationally driven social, technical, and economic factors. How these changes play out will also have impacts on nutrition, gender, and health outcomes.

The impacts of irrigation interventions reviewed here—income, nutrition, health, and women's empowerment—are interconnected. An improvement in one impact (such as income) can lead to improvements in the others (such as nutrition, health, and women's empowerment). For instance, higher income due to increased food productivity or from new employment opportunities created by irrigation schemes can lead to additional food purchases (vegetables, fruits, animal-source foods) and greater investments in health (medicines, healthcare, insecticide-treated nets) and education, which in the long term can also benefit women's empowerment.

Although the impact of irrigation interventions on poverty alleviation and the income of the benefitting communities have been extensively covered in the literature (Bhattarai and Narayanamoorthy 2003; Lipton, Litchfield, and Faurès 2003; Aseyehegn, Yirga, and Rajan 2012; Burney and Naylor 2012), the potential of irrigation to improve nutrition, health, and gender outcomes has been less documented. Thus, this paper aims to review the existing literature on the impacts of irrigation on nutrition, health, and gender, with the objective of identifying the main areas in need of further research.

3. EVIDENCE FROM THE LITERATURE AND USEFUL INDICATORS

The Impact of Irrigation on Nutrition

Agricultural interventions, such as irrigation, increase food production and availability. But does more food always lead to better nutrition? Increased food availability is likely to result in better nutrition, though this might not always be the case. Other factors such as food access and utilization are also important determinants of food security and related nutrition outcome (Berti, Krasevec, and FitzGerald 2003).

Food security is usually defined according to three dimensions that need to be fulfilled simultaneously and maintained over time: food availability, food access, and food utilization (FAO 2008). *Food availability* refers to the existence of adequate food supply from domestic agriculture or food imports. *Food access* involves a household's ability to obtain food in the market or from other sources, which is usually determined by a household's income and the existence of markets. Finally, *food utilization* refers to the ability to consume nutritious foods and benefit from them (Burney et al. 2010). Irrigation schemes are likely to provide enhanced food security and nutrition to farmers due to a greater availability and stability of food supplies and crop diversification (Molden 2007).

Mangisoni (2008) analyzed the impact of small-scale irrigation on food security in Malawi by asking adopters and nonadopters of treadle pumps about their food security situation. In this study, *food security* was defined as having enough food to last until the next harvest (May) of every year. Before the installation of the treadle pumps, more than 70 percent of the households stated that they were food insecure; after adoption of the new technology, only 9 percent of the households reported experiencing food insecurity. Food security was also analyzed in the same study by comparing the maize deficit—defined as less than 270 kilograms of maize equivalent per year per capita—of treadle pump users and nonusers. Maize deficit was detected only in 9 percent of the users, compared to 60 percent of the nonusers. Burney et al. (2010) also reported positive impacts of irrigation on food security among users of irrigated communal gardens in the Sudano–Sahel region. The consumption of vegetables during the dry season increased, and irrigators were 17 percent less likely to feel chronically food insecure (Burney et al. 2010).

The use of irrigated agriculture enables crop production during the dry/lean season, which increases the number of harvests per year and leads to increased yields and crop diversification. In Ethiopia, farmers using irrigation systems produced crops twice, and sometimes even three times, per year (Aseyehegn, Yirga, and Rajan 2012). Cropping pattern changes were also reported by Namara, Upadhyay, and Nagar (2005) in India after the installation of microirrigation technologies, with microirrigation adopters producing more diverse crops, including high-value and water-intensive crops.

Smallholder irrigation systems are mostly used to grow vegetables in the dry season; consequently, vegetable consumption among irrigation users and their communities usually increases (Burney et al. 2010; Aseyehegn, Yirga, and Rajan 2012). Vegetables are rich in micronutrients and provide important benefits, especially for children. Irrigation systems are also likely to improve the intake of animal-source foods as a result of higher incomes and improved livestock productivity. Aseyehegn, Yirga, and Rajan (2012) concluded that income gains from livestock were 14 percent higher among irrigation users compared to nonusers. Animal-source food is an important source of vitamin A, iron, riboflavin, calcium, zinc, and vitamin B_{12}, which are all important for young children (Murphy and Allen 2003). A more varied diet is associated, among others, with positive effects on birth weight, child anthropometric status, and improved hemoglobin concentrations (Hoddinott and Yohannes 2002; Namara et al. 2011).

Conversely, if the installation of irrigation systems leads to monocropping, negative impacts on nutrition may be also found. According to Hossain, Naher, and Shahabuddin (2005), an increase in rice production resulting from investments in small-scale irrigation in Bangladesh led to increased rice intake and reduced dietary diversity among the poorest households.

Dietary diversity is a useful food security indicator and is defined as the number of different foods or food groups consumed over a given period of time (Hoddinott and Yohannes 2002). Two indicators of dietary diversity were used in East Africa to measure the impacts of treadle pumps in the region: number of food groups consumed by children in the previous 24 hours and number of different food groups consumed by a household in the past seven days (Nkonya et al. 2011). Namara et al. (2011) compared the Household Dietary Diversity Score of farmers using rainfed agriculture with that of farmers using groundwater irrigation in Ghana (Namara et al. 2011). Farmers were asked about the consumption of a set of 12 food groups during the 24-hour period prior to the interview. However, nonsignificant differences between rainfed farmers and irrigated farmers were found.

Von Braun, Puetz, and Webb (1989) assessed the links among production, income, consumption, and nutrition in rice irrigation projects in The Gambia. The cultivation of rice increased real income of farmers by 13 percent per household. The study also concluded that an additional 10 percent in annual income led to a 9.4 percent increase in food expenditure and a 4.8 percent increase in calorie consumption (von Braun, Puetz, and Webb 1989).

Irrigation systems also have important impacts on the communities surrounding them, though studies measuring this outcome are scarce. Nonirrigators are likely to benefit from higher food availability and employment opportunities created by irrigation schemes. Aseyehegn, Yirga, and Rajan (2012) reported that 45 percent of the users of small-scale irrigation in Ethiopia faced labor shortages, whereas only 25 percent of the non-irrigators faced labor shortages for rainfed activities. In other words, irrigated land is more labor intensive and, therefore, increases hiring opportunities. About 77 percent of irrigation users solved the labor shortage through hiring and 23 percent through labor exchange mechanisms (Aseyehegn, Yirga, and Rajan 2012).

A study of the impact of treadle pumps in East Africa revealed that irrigators sold a greater proportion of irrigated crops as compared with rainfed crops. In Kenya and Tanzania, 73 percent and 83 percent, respectively, of the irrigated crops produced by men were commercialized. A significant share of the crops grown (tomato, kale, cabbage, and amaranth) was sold in the local village market or to neighbors, thus increasing food availability in the community (Nkonya et al. 2011). Sometimes farmers do not have access to reliable markets, which may hinder irrigation farming activities (Chazovachii 2012). Aseyehegn, Yirga, and Rajan (2012) also underlined the importance of having access to information about the demand and supply of agricultural products and the right time to sell these products in order to sell perishable farm products without loss of quality. Ethiopian households with access to market information earned US$1,297 more than households that had deficient market information.

Finally, irrigation programs can also affect food prices. Nonirrigators may benefit from reduced prices due to a greater availability of staples and other food products (Lipton, Litchfield, and Faurès 2003).

The Impact of Irrigation on Health

Maternal and child undernutrition is responsible for 3.5 million deaths, 35 percent of the disease burden in children younger than 5 years, and 11 percent of total disability-adjusted life-years (DALYs) (Black et al. 2008). As a result of enhanced access to fresh vegetables and animal sources of food, irrigation systems can improve nutrition and health, particularly of children. Consumption of iron-rich foods, such as dark green leafy vegetables, can reduce incidences of anemia. Iron deficiency is a risk factor for maternal mortality and is responsible for 115,000 deaths and 0.4 percent of global total DALYs (Black et al. 2008). Vitamin A–rich foods (such as orange-fleshed sweet potatoes, pumpkins, and so on) can reduce night blindness and susceptibility to illness. Deficiencies of vitamin A and zinc cause 0.6 million and 0.4 million deaths, respectively, and a combined 9 percent of global childhood DALYs (Black et al. 2008). Furthermore, access to greater quantities of nutritious food can reduce incidences of underweight and wasting. If children are exposed prenatally and during the first two years of life to a better diet, increases in height-for-age and reductions in the incidence of stunting are probable. Positive impacts of agricultural

interventions in height-for-weight ratios, morbidity, and biochemical/clinical indicators, as a result of a more balanced diet, have been documented in previous studies (Berti, Krasevec, and FitzGerald 2003).

Irrigation interventions may also lead to greater water availability within the household. Access to greater volumes of water can result in better hygiene and sanitation practices and better health overall. A study from Pakistan about the impact of irrigation on domestic water use proved that greater water availability was associated with a lower prevalence of diarrhea and stunting (van der Hoek, Feenstra, and Konradsen 2002). Diarrheal diseases associated with poor water and sanitation cause 1.73 million deaths each year and are the sixth-highest burden of disease on a global scale (Howard and Bartram 2003).

Higher family incomes as a result of irrigation can translate into increased household expenditures for healthcare, education, water, and sanitation (Keiser et al. 2005). However, the little evidence available is mixed. For example, Burney et al. (2010) found nonsignificant changes in healthcare expenditures for irrigators compared to non-irrigators. Overall, the number of studies analyzing the direct linkage between irrigation and health investments is still scarce; therefore, current evidence is still inconclusive.

Although irrigation interventions can have many positive effects on health, its negative effects are also important. Irrigation schemes may affect the risk of vector-borne diseases, such as malaria, dengue, and schistosomiasis, because vector-breeding habitats may be altered by irrigation practices. Studies analyzing the effect of irrigation systems on vector-borne diseases are numerous (see, for example, Ijumba and Lindsay 2001; Keiser et al. 2005) and the results depict a complex picture. The effect of irrigation on the incidence of vector-borne diseases depends on multiple factors, such as the epidemiologic setting, the ecology of the area, or the socioeconomic status of the population (Keiser et al. 2005; Wielgosz et al. 2012).

Keiser et al. (2005) analyzed the results of 11 studies conducted in irrigation areas of stable malaria transmission in Africa. None of the studies found evidence of increased prevalence of malaria in irrigated villages as compared with nonirrigated villages. A lower incidence of malaria was even reported in some of the studies; this lower incidence was attributed to improved socioeconomic status, effective vector-control programs, and changes in health-related behavior (Keiser et al. 2005). Another explanation for the lower incidence of malaria in certain contexts was found in the use of insecticide-treated nets (ITNs) and the differing presence of cattle in irrigated villages. Unprotected cattle seemed to attract mosquitos diverted by ITNs (Keiser et al. 2005). On the other hand, a greater risk of malaria incidence was found in irrigation villages with unstable malaria prevalence, where people have little or no immunity to malaria parasites (Keiser et al. 2005). Similarly, Ijumba, and Lindsay (2001) concluded that irrigation systems do not seem to increase malaria risk in Africa, with the exception of areas of unstable transmission.

Negative outcomes of irrigation on health may also result from the increased use of complementary inputs, such as pesticides, fertilizers, and other chemical products, due to the higher-input intensity of irrigated agriculture. However, the number of studies addressing this issue is still limited. Pesticides may cause acute poisoning through intentional or accidental exposure and through long-term exposure—for instance, through the ingestion of pesticide residues on food and drinking water. Human poisoning by pesticides is becoming a growing concern in developing countries, where the use of pesticides is mostly unregulated and where handling practices are usually inadequate or unsafe. The most reported health problems associated with pesticide exposure include neurological abnormalities; respiratory diseases; and reproductive, endocrinological, and dermal problems (Kesavachandran et al. 2009). Successful capacity building in safe pesticide management remains an important area for action research in SSA.

The World Health Organization (1990) estimated that every year, three million people are poisoned by pesticides, causing 220,000 deaths worldwide, including many suicides. Some evidence of the negative effects of pesticide exposure on human health is provided in a study conducted in Ghana among irrigation workers. This study researched the prevalence of symptoms associated with organophosphorus pesticides (OPs) and carbonates (Clarke et al. 1997). The study revealed that the three symptoms of headache, blurred vision, and nausea/vomiting were significantly higher (at 5 percent

significance level) among irrigators, as compared with a control group of teachers, which suggests that farm laborers and owners of irrigated lands are more likely to be exposed to harmful chemicals. The level of cholinesterase was significantly lower in the subjects exposed to pesticides than in controls, indicating a lower activity of the enzyme acetyl cholinesterase. OPs and carbonates inhibit the enzyme acetyl cholinesterase at nerve endings (Clarke et al. 1997).

The use of groundwater naturally contaminated with arsenic for irrigation purposes poses another potential risk for human health. Bangladesh is the country most affected by arsenic contamination, though high levels of arsenic in groundwater have also been reported in other countries, such as China, India, Nepal, Thailand, Argentina, and Chile. Several studies have shown that the use of arsenic-contaminated water for irrigation can lead to arsenic accumulation in the soil and successive contamination of crops, which can pose a threat to human health and long-term loss of yields. Rice crops are prone to arsenic contamination, because their cultivation demands high volumes of water and flooded conditions. A review study by Heikens (2006) concluded that none of the existing toxicity data represent field conditions sufficiently well. It also noted that a better understanding of the relationship between arsenic in the soil and its uptake and toxicity is needed.

Wastewater from urban and periurban areas are increasingly used for irrigation purposes in water-scarce regions. Although wastewater provides important nutrients for soils and plant growth, it can also contain heavy metals and pathogens that can be harmful for soils and crops irrigated with wastewater. Furthermore, wastewater is often used without taking appropriate precautions to diminish health and environmental risks (Jawahar and Ringler 2009). It has been estimated that around 20 million hectares are irrigated with wastewater, mainly in Asia, Europe, South America, and the United States of America, and about 10 percent of the world's population could be consuming foods produced with wastewater (van der Hoek 2004; Hamilton et al. 2007; WHO 2006). Srinivasan and Reddy (2009) compared the morbidity rates of six villages that used wastewater for irrigation with one control village irrigated with normal-quality water in the periurban areas of Hyderabad, India. Higher rates of morbidity, especially among females, were observed in the villages using wastewater as an irrigation source. The costs of illness, including direct and indirect costs, were also analyzed, but no statistically significant differences were found between control and wastewater irrigating villages.

The Gender Implications of Irrigation

Women produce about two-thirds of the food in developing countries (UNDP 2006). Several studies have shown that women's agricultural productivity is as efficient as that of men, provided that women have equal access to resources and information (van Koppen 2002). However, women often have limited access to land, water, labor, capital, technology, and other assets (Molden 2007; Goh 2012). Aseyehegn, Yirga, and Rajan (2012) concluded in a study conducted in Ethiopia that male-headed households were 38 percent more likely to participate in irrigation activities than female-headed households, because the latter had lower income and faced a shortage of labor and market information. Consequently, women frequently ended up renting or sharing out their land.

Irrigation interventions can be accompanied by improvements in water supply that reduce the time women have to spend collecting water (Upadhyay, Samad, and Giordano 2005). However, women's agricultural workload may increase with irrigated agriculture. A study about smallholder irrigation schemes in Zimbabwe conducted by FAO (2000) concluded that women provided the bulk of the labor required on surface irrigation systems. Similarly, Upadhyay, Samad, and Giordano (2005) found that women using microirrigation technologies in Nepal spent significantly more time producing vegetables than their male counterparts, who only contributed 12 percent of the time. Moreover, if women have control over the income and the food generated from irrigation activities, chances are high that the diet of children and the rest of the family will improve (Upadhyay, Samad, and Giordano 2005; Goh 2012).

According to van Koppen (2002) the impact of irrigation interventions on women's empowerment largely depends on whether women are farm decisionmakers or simply family laborers. The type of approach used in irrigation interventions—*gender blind* versus targeting women; market-

driven and individual approaches versus group-based communal gardens—may also determine gender-related outcomes. Burney et al. (2010) provided an example of an irrigation project specially directed to women's agricultural groups. Women kept 18 percent (8.8 kilograms per month) of the food grown and sold the rest in the local market. Their standard of living increased as compared to non-irrigators—their consumption of vegetables reached the U.S. Department of Agriculture's recommended daily allowance, and additional income was used to purchase staples and protein during the dry season.

Van Koppen (2002) described the gender performance indicator for irrigation to analyze the presence or absence of gender-based differences in collectively managed schemes. Three main aspects are considered as part of the indicator: who are the farm decisionmakers, participation in forums (such as water associations), and leadership positions. According to van Koppen (2002), if women mobilize inputs themselves and are included in irrigation institutions, they are more likely to benefit from irrigation interventions.

Another indicator that could potentially be used to measure the effect of irrigation interventions on gender is the Women's Empowerment in Agriculture Index (WEAI), developed by the U.S. Agency for International Development (USAID), IFPRI, and Oxford Poverty & Human Development Initiative (OPHI). This indicator comprises two subindexes—five domains of empowerment (5DE) and a gender parity index, the latter of which reflects the percentage of women who are as empowered as the men in their households. The 5DE are (USAID, IFPRI, and OPHI 2012):

- Production: Decisions about irrigated production
- Resources: Access to and decisionmaking power about productive resources and assets, such as land, agricultural inputs, or credit
- Income: Control of irrigated outputs and expenditures
- Leadership: Involvement in water users' associations and other social or economic groups
- Time: Allocation of time to irrigated agriculture and domestic tasks

Although the WEAI has not yet been used to evaluate the impact of irrigation on women's empowerment, at least one proposal to do so is currently under review.

4. CONCLUSIONS

The linkages among irrigation, nutrition, health, and gender outcomes are multiple and highly complex and a better understanding of the different pathways that lead to these outcomes are needed. The actual impact of irrigation on nutrition, health, and gender empowerment will depend on the technical, social, and economic characteristics of water availability, access, and use, which will differ by SSA geography, country, market, and social group. However, general guidelines can be developed based on existing and new case study evidence that has yet to be developed. Gaining this knowledge can be important for the successful implementation of new irrigation projects, especially in SSA, where the potential to expand irrigation is large and where IFPRI projections indicate that childhood undernutrition will continue to increase over the next two decades.

Irrigation interventions can improve nutritional outcomes through increased productivity and availability of food supplies and improved diet (in quantity and quality). To date, few studies have analyzed the impact of irrigation interventions on food security and dietary diversity, which are important factors for children`s development. Nutritional gains can have positive effects on height-for-weight ratios, morbidity, and biochemical/clinical indicators and thus can have beneficial, long-term effects on health.

Even if irrigation interventions are likely to improve the diets and nutrition of rural communities, some exceptions are also found when irrigation systems lead to monocropping or when unsafe water is used for irrigation. Toxicity data about how the use of pesticides, arsenic-contaminated water, or wastewater can affect the health of people exposed to these contaminants is still limited.

Irrigation interventions can also affect women's empowerment (or disempowerment). The gender outcome of irrigation programs is still not well understood, as gender roles in agriculture vary depending on the context. Greater food availability, increased income, and new employment opportunities may favor women's empowerment. Similarly, access to improved water and sanitation may reduce female water-collection chores and allow women to invest more time in other activities. Overall, more research is needed to better understand how irrigation programs may be designed to increase women's empowerment.

Irrigation interventions may have differential effects on different members in the household and in the community, such as irrigators, non-irrigators, children, and women. Measuring and understanding such differences will be critical to design and implement effective irrigation interventions. If risks are controlled and benefits maximized, irrigation programs can become an important component of poverty-reduction strategies.

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