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Irrigation-Nutrition Linkages: Evidence from Northern Ghana*

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Abstract

We analyze the linkages between irrigation and nutrition using data from irrigators and non-irrigators in Northern Ghana. The results show that (i) there is a modest difference in the overall household dietary diversity score between irrigators and non-irrigators, (ii) there are significant differences in the consumption of animal source foods between irrigators and non-irrigators, (iii) there are significant differences in the consumption of fruits and vegetables as well as sugar and honey between irrigators and non-irrigators, and (iv) the sources of food consumption differ between irrigators and non-irrigators. The analysis shows strong association between households' nutritional status and their access to irrigation, with evidences suggesting that the irrigation-nutrition linkages play out both through the income and production pathways in Northern Ghana.

keywords: Irrigation, Nutrition, Ghana, Irrigation-Nutrition Linkages

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1 Introduction

Ghana has made significant progress in reducing childhood undernutrition over the last decade (GSS, 2015). However, regional variations and urban-rural differences in childhood undernutrition persist (GSS, 2015; Amugsi et al., 2013). Stunting prevalence in children under 5 years is highest at 33% in the Northern region and is higher in rural areas (22%) compared to urban areas (15%) of Ghana (GSS, 2015). Wasting is highest in the Upper East region, at 9% compared to national prevalence of 5%, and is also higher in rural than in urban areas of Ghana (6% vs 4%, respectively) (GSS, 2015). Stunting and wasting prevalence in these regions are classified as severe, according to the World Health Organization (De Onis and Blössner, 1997). The high prevalence of malnutrition is further confirmed by the fact that 66% of children aged 6-59 months in Ghana have some level of anemia (GSS, 2015), with the highest prevalence in the Northern region at 82%. Chronic malnutrition is also found in women aged 15-49, where 42% of women in Ghana are anemic and 40% are overweight or obese (GSS, 2015). This alludes to the potential existence of the double burden of malnutrition amongst individuals but also within households.

The disproportionate burden of undernutrition in the Northern and Upper East regions of Ghana may be linked with the high poverty rates in the region (Amugsi et al., 2013; de Poel et al., 2007; United Nations Development Programme-Ghana, 2012). The association between poverty and undernutrition is the result of children living in poorer conditions, with higher levels of food insecurity, higher susceptibility to infections and lack of access to basic health services (Mason et al., 2001). Calorie availability per capita in Ghana has doubled between 1982 and 2010 which has contributed to improvements in household food security. However, the primary source of this increase in calorie availability was from staple foods, and not from nutrient-dense foods, such as animal-source foods. This suggests that the Ghanaian diet has become richer in calories but not necessarily richer in nutrients (Ecker and Van Asselt, 2017).

In rural Ghana, 62% of the population relies on agriculture, forestry and/or fishing for their livelihood (Ghana Statistical Service, 2016). In Northern Ghana, rainfed agriculture is only possible six months out of the year, and agricultural households must find other livelihood sources during the long dry season. In addition, climate change trends, such as changes in seasonal rainfall patterns, more erratic rainfall, and temperature increases are already straining agricultural production and these trends are predicted to continue or worsen into the future (Laube et al., 2012). The impact of climate change is exacerbated by population growth, which places pressure on agricultural land and fuelwood, resulting in deforestation, overgrazing, bushfires, soil degradation and other environmental challenges (Laube et al., 2012).

In this context, the potential for irrigation to contribute to agricultural income, food security, improved nutrition, and resilience to climate and environmental change is high. Irrigation can encourage crop diversification and the production of more diverse foods for household consumption, can provide greater income through the sale of cash crops, and can improve the Water, Sanitation, and Hygiene (WASH) environment to the extent that water is used for multiple purposes.

Several studies have highlighted the benefits and challenges associated with small-scale irrigation in Ghana across a range of approaches. Studies focused on state-sponsored irrigation schemes found some benefits of irrigation, despite many challenges and limited ongoing public investments in operation, maintenance, and advisory services (Adam et al., 2016; Dinye and Ayitio, 2013). Dinye and Ayitio (2013) showed higher employment and agricultural output among farmers accessing the Tono irrigation scheme but only a modest difference in poverty levels compared to farmers located outside the scheme. A descriptive study from Bolgatanga Municipality in the Upper East region found that farmers registered to practice irrigation in three different irrigation schemes perceive benefits in terms of poverty reduction, employment generation, diversified income sources, reduced out-migration, and improved household nutritional status (Adam et al., 2016).

Other studies that have compared the outcomes of irrigators and non-irrigators in

Northern Ghana show potential for irrigation to improve income, increase employment, and provide other benefits across a range of different technologies and water sources (Balana et al., 2018; Dinye and Ayitio, 2013; Adimassu et al., 2016; Akudugu et al., 2016). Studies examining the profitability of different types of small-scale irrigation schemes find that most small-scale systems (including some traditional systems) are economically feasible even when the cost of family labor is taken in to account, although traditional schemes have limited area coverage (Balana et al., 2018; Namara et al., 2011b). Owusu (2016) finds that groundwater irrigators using motor pumps have higher financial returns to irrigation and higher value-added output per family worker compared to other types of irrigation schemes. Apart from the income benefits of irrigation, other studies point to additional benefits in terms of increased employment, consumption, food security, expansion of non-farm income-generating activities (Akudugu et al., 2016) and, in some cases, reduced poverty (Namara et al., 2011a). While most studies examine the impacts of dry season irrigation, supplemental irrigation during the rainy season also provides benefits in terms of increased income and resilience to erratic rainfall patterns (Adimassu et al., 2016).

Studies of different types of irrigation schemes highlight several constraints that limit the benefits to irrigators, including inadequate access to credit, poor water supply for irrigation, ineffective technical assistance and lack of technical knowledge, lack of storage facilities for perishables, inadequate access to markets, tenure insecurity, lack of credit access, competition with livestock, and unavailability of labor (Dinye and Ayitio, 2013; Namara et al., 2011b). Moreover, while the importance of small-scale irrigation has gained attention and recognition in Ghana's irrigation policy, these schemes still lack adequate public support in terms of monitoring and regulation, and advisory services (Namara et al., 2010).

Although the role of small-scale irrigation in improving agricultural production is growing, its role in improving nutrition is less clear, mostly due to a lack of rigorous studies assessing the impacts of irrigation on nutrition (Domènech, 2015). A few studies highlight the potential for irrigation to decrease risk of diarrhea and stunting in children through increased supply of water for domestic use (van der Hoek et al., 2001, 2002). Other studies have shown that irrigation is associated with increased dietary diversity, greater income, higher expenditure on food, education, and health care (Alaofè et al., 2016; Benson, 2015; Bhagowalia et al., 2012). More evidence from rigorous evaluations is needed, however, to identify the pathways through which small-scale irrigation affects nutrition in order to inform the design of nutrition-sensitive irrigation policies and programs.

This study contributes to the emerging literature on welfare implications of small scale irrigation in four ways. First, it documents differences in households' economic access to food as measured by the household dietary diversity score between irrigators and non-irrigators. Second, it documents structural shifts in diets by irrigators towards animal source foods, fruits and vegetables, as well as sugar and honey. Third, it documents substitution effects from markets to own-production for vegetables, as well as meats and poultry, and from own-production to markets for sugar and honey by irrigators, compared to non-irrigators. Finally, it makes methodological contributions that enrich the construction of household dietary diversity scores (HDDS) to include additional information on (i) food sources (own production, gifts, and market purchases) and (ii) the number of specific food types consumed within a food category, while preserving the original categories and assumptions of HDDS.

2 Background on Irrigation in Ghana

Governments and donors in West Africa have traditionally invested in large-scale irrigation infrastructure but are now increasingly understanding the benefits of and need to support, or at least, understand the expansion and potential of small-scale irrigation technologies and schemes, which show great potential for expansion in the region (Giordano and de Fraiture, 2014; Dittoh et al., 2013; Burney et al., 2013; Giordano et al., 2012). Evidence suggests that the greatest gains in terms of profitability and economic and environmental sustainability will come from expansion of such small-scale irrigation technologies (Xie et al., 2014; You et al., 2011). However, farmers using small-scale irrigation in the region still tend to rely on traditional methods for water extraction and application, such as hand dug wells and buckets, so improvements to existing small-scale irrigation are also needed (Dittoh et al., 2013).

The Government of Ghana has similarly started to recognize the limited effectiveness of government-led large-scale schemes (Owusu, 2016; Dittoh et al., 2013; Laube et al., 2012). From the 1970s to the 1990s, the Government of Ghana invested in a series of large scale irrigation schemes in Northern Ghana that have not delivered anticipated economic benefits (Owusu 2016). Irrigation schemes like the Vea Irrigation Scheme and the Tono Irrigation Project in the Upper East region and the Bontanga Irrigation Project in the Northern region operate below expectation due to poor operation and maintenance, lack of support services, and land expropriation among other factors (Owusu, 2016; Dittoh et al., 2013; Laube et al., 2012). More recently, the Ghanaian government, with support from donors and NGOs, has invested heavily in the construction of small dams and dugouts in the Upper East region and is exploring further development of groundwater and water harvesting schemes with the aim of increasing the yields of small-holder producers (Adam et al., 2016; Ministry of Food and Agriculture and Ghana Irrigation Development Agency, 2012). At the same time many smallholder producers have developed their own informal irrigation facilities and practices (Laube et al., 2012).

The Ghana Irrigation Development Authority (GIDA), under the Ministry of Food and Agriculture (MoFA), is the leading government organization charged with promoting agricultural growth through irrigation development and agricultural water management. In 2010, MoFA released the Ghana Irrigation Policy which aims to sustainably increase and enhance performance of irrigation by increasing the productivity of agricultural water, increasing public and private investment in irrigation, developing new irrigation areas and improving existing ones, and enhancing services while paying attention to issues of social inclusion and environmental sustainability (Ministry of Food and Agriculture, 2010). Investments in irrigation development are given a high priority under MoFA's second Medium Term Agricultural Sector Investment Plan (METASIP-II) comprising 54% of the budget under the program on Food and Nutrition Security and Emergency Preparedness program and 25% of the entire budget (all 6 program areas) (Ministry of Food and Agriculture, 2015).

One challenge to irrigation development is the lack of information both on the availability of groundwater for irrigation and the extent of ongoing private small-scale irrigation. Official estimates of irrigated area do not include land under informal irrigation and, therefore, underestimate the extent of irrigation in the country (Namara et al., 2011a). There is also limited information on the availability of shallow groundwater for irrigation (and a perceived scarcity of the resource) apart from one study showing considerable room for expansion of groundwater irrigation in the Atankwidi Catchment (Barry et al., 2010). Similarly, information on the proliferation of small-scale irrigation pumps has not been well documented and there has been inadequate institutional and policy support for private smallholder farmers investing in irrigation (Namara et al., 2014, 2010; Owusu, 2016).

3 Study Area and Data

The study was conducted in the Upper East and Northern regions of Ghana, which form part of the Northern Savannah Zone (NSZ) of Ghana. Specifically, the survey was conducted in Bihinayilli in the Savelugu-Nantong District of the Northern region; and in the Garu-Tempane, Kasena-Nankana East and Nabdam Districts of the Upper East region. Study sites were selected due to their high potential for irrigation based on ex-ante analysis. The other main selection criterion was the presence of irrigation interventions that promoted the use of modern small-scale irrigation equipment, such as motor pumps. The number of farmers surveyed per village was based on the number of participants in the interventions. Both farmers who received small-scale irrigation technologies, as well as those that did not, were included in the survey for a total of 902 farm households. The survey was implemented by the University of Development Studies, Tamale Ghana between December 2017 and January 2018 , before the irrigation interventions were implemented.

The ten-year average regional rainfall between 2006 and 2015 in the Upper East and Northern regions was 927mm and 1122mm, respectively (Ministry of Food and Agriculture, 2016), typically concentrated between May to October but subject to intermittent droughts between June -July, and occasional floods and windstorms in August/September. Difficult savannah agro-ecological conditions, such as annual flooding, erratic rains, drought (dry spells) and poor soils, constrain agricultural production. The monomodal pattern of rainfall implies that between May and October there is adequate moisture for crop production followed by about 8 months of dry season with severe water deficits for domestic use and agriculture. Rain-fed agriculture (about 95% of agriculture) is the mainstay of the economy of the study area and many crop and livestock farmers operate on a subsistence basis.

Even though efforts have been made to construct dams and dugouts, mechanized boreholes, hand-dug and shallow wells; and to use appropriate rain water harvesting techniques to harness and supply rain water in the dry season for domestic, agriculture and agro-processing, rural industry and other uses, water insecurity and stress during the long dry season is a common occurrence in the project area. With droughts becoming more intense and frequent, the increased competition for limited water resources among households is expected to be more critical; resulting in further water insecurity. As a result, Northern Ghana as a whole and the study sites in particular provide opportunities for the development of small- and large-scale commercial irrigated agriculture. Given the availability of land, water resources, human resources and well-structured traditional systems of farming, potential practical interventions at community level for irrigation and soil fertility management can promote sustainable agriculture and other livelihood enterprises in the area, leading to long-term growth and increased welfare.

The survey data shows that irrigation in the study area is highly dominated by onions, followed by okra, tomato, red pepper, and water melon. Groundwater is the main source of irrigation water for half the irrigators. Groundwater is usually obtained by hand dug well in the riverbed during the dry season, with irrigated plots typically located close to the water source. Dams (small reservoirs) provide irrigation water for another quarter of households in the study area. Dams provide easier access to water for households located in communities near the dam with fewer issues related to scarcity. Watering cans and buckets dominate irrigation in the area, both as the main method of obtaining water from the source and as a method of irrigation application. The prevalence of buckets and cans in irrigation can limit the amount of land households allocate to irrigated production and the type of crops they cultivate.

4 Conceptual Framework

Numerous studies are exploring the potential for agricultural interventions to contribute to improved nutrition (Ruel et al., 2018). There are various pathways through which agricultural interventions may affect nutrition outcomes, both positively and negatively (Ruel and Alderman, 2013; Herforth and Harris, 2014; Masset et al., 2012; Hoddinott, 2012). The main pathways identified are: the production pathway through which crop production choices directly influence consumption, the income pathway where income from crop sales is used to purchase food, and the women's empowerment pathway through which changes in women's status (e.g. time use and decision making authority) influence health and nutrition outcomes. A review paper by Domènech (2015) identifies five main impact pathways specifically linking irrigation to nutrition and health outcomes. The first describes how irrigation can influence the production pathway through increased agricultural productivity, shifting crop types to more nutrient-rich crops, such as fruits and vegetables, and extending the production calendar into the lean season, all of which could contribute to improved food security, dietary diversity, and nutritional status (De Fraiture and Giordano, 2014; Aseyehegn et al., 2012; Namara et al., 2011a; Burney et al., 2010; Dillon, 2008; Namara et al., 2005). Second, irrigation can contribute to better nutrition through the income pathway by increasing income from market sales of crops grown with irrigation as well as irrigation-related employment (Alaofè et al., 2016; Burney and Naylor, 2012; Namara et al., 2011a). Third, irrigation can be a potential entry point for women's empowerment through increased asset ownership, due to the transfer of time spent on water-collection to other income-generating activities, and control over resources from selling crops produced on their own plots. Fourth, irrigation can improve the water supply, sanitation, and hygiene environment (by providing for multiple water uses). Fifth, irrigation can increase health risks from vector-borne diseases and water pollution (from agrochemicals). The last two irrigation-nutrition linkages are indirectly related to agriculture. These pathways are further described in Passarelli et al. (2018).

While the evidence is growing, the potential for irrigation to affect nutrition outcomes has not been fully explored in the literature (Domènech, 2015). Because changes in production, income, the WASH environment or women's empowerment do not influence nutritional outcomes directly, there is a dearth of evidence linking irrigation and changes in nutritional status. Most studies of the impact of irrigation that go beyond production and income benefits, examine outcomes related to the various aspects of food security and diet quality, two intermediate outcomes along the various pathways from irrigation to nutrition, both of which are associated with improved nutrient adequacy of the diet (Arimond and Ruel, 2004). Passarelli et al. (2018) tests the impact of irrigation along two of the pathways (production and income) on dietary diversity. They find that irrigation was associated with increased dietary diversity in Ethiopia through the income pathway, rather than through an increase in production diversity, while the results were not significant in Tanzania.

It is important to keep in mind that different indicators are available on the impact pathway from small scale irrigation to improved nutrition, including changes in food security, diet quality, and nutritional status of women and children. Any of these chosen indicators will have its strengths and weaknesses and different data requirements. For example, to observe changes in dietary diversity requires an increase or decrease in the number of food categories consumed by a household (or woman of reproductive age). However, this indicator is sensitive to the selection of food categories and will not capture changes in diets involving shifts from one food to another within the same category. The present study takes advantage of a unique data set that includes data on the source of each food consumed in the household (e.g. whether it was produced at home or purchased in the market) to explore the relationship between irrigation and different measures of household food security and diet quality. Using different measures provides a more complete and nuanced picture of the impact of irrigation on food security and diet quality.

5 Empirical Model

Our objective in this paper is three-fold. First, we want to explore whether there is a statistically meaningful difference in household dietary diversity score between irrigators and non-irrigators. Second, we want to explore whether irrigation affects the food categories (as normally used in HDDS computations) that households consume. Even in the absence of differences in the dietary diversity score, it is possible that the composition of consumption may shift to more income elastic food categories, such as animal source foods, if irrigation increases income from production, or enables households to grow fruits and vegetables they would otherwise purchase on the market. Third, we want to explore the share of market purchases of food in irrigating versus non-irrigating households. Differences in the share of food obtained from different sources (market vs own production) for a given food category provide insights about systematic substitution effects by irrigation status. That is, we are interested to explore whether or not households consume more of the foods they produce with irrigation, which releases income to be spent on the purchase of other foods. This is important because even while irrigators and non-irrigators may share similar consumption patterns in terms of food groups, households with irrigation may change production in a way that facilitates access to a more diverse diet through the purchase of other food groups, such as fish and other animal source foods.

The answer to the first two research questions is based on the validated FANTA household dietary diversity score (HDDS) and its component food categories, the construction and interpretation of which is well documented in the nutrition literature (Swindale and Bilinsky, 2006). As such, we do not present details of how the score is constructed or interpreted. To explore the third research question on the share of purchased and own-produced food from each category, we use a weighting scheme to integrate food source information for each food within the HDDS categories as explained below. This is done in a manner that is consistent with the categories of the household dietary diversity score (Swindale and Bilinsky, 2006), and adds an additional dimension to the usually computed HDDS.

HDDS-consistent weights for food source information

The adapted HDDS module uses open recall, but asked about 85 individual food items instead of the standard 12 food groups. Moreover, the adapted module included a 7-day recall as opposed to a 1-day recall. Though this introduces higher recall bias, we chose to include a 7-day recall to have a more comprehensive understanding of food sourcing. Data collected on the consumption of specific food items were categorized by origin of the food item and then aggregated into the standard HDDS categories indicating the relative weight by source. This allowed us to capture detailed changes and patterns in the sources of the different food categories. Including the weights enables us to preserve the original categories of the HDDS while enriching the indicator by including (i) the source of food, i.e, - markets, own-production, or gifts, and (ii) the number of specific food types consumed within the same food category. Because the source of a given food does not affect the HDDS, we assign equal weights to each food source.

An HDDS-consistent score that also has information on food sources requires certain strict procedures to associate the information on food sources with the score. First, each source of a food item (market, own-production, and gifts) should get a share that is proportional to the number of sources for this food item. For instance, a food item acquired from three different sources implies the three sources would each have a 1/3rd weight. Having three sources for a food item, however, does not imply every source gets a weight of 1/3. This occurs only in the special case that the food type for the household comes from all three sources. Rather, the weight of a source depends on the total number of sources for the food type, making the weight to be set dynamically for each food type. That is, if a household gets food type f only from the market, this source gets a weight of 1 and the other sources get a weight of zero. Likewise, if the household gets food type f from markets and own-production, then markets and own-production each get a weight of 1/2.

To operationalize this, we denote market sources by M, own-production by A, and gifts by G. M, A, and G are indicator variables that get a value of 1 if at least some of the food item f comes from that source and 0 otherwise. Thus, the weights for markets for food item f are given by $m_f = \frac{M}{M+A+G}$. The weights for own-production, i.e. agriculture, for food item f are given by $a_f = \frac{A}{M+A+G}$. Likewise, the weights for gifts for food item f are given by $g_f = \frac{G}{M+A+G}$. By construction, the weights m_f, a_f, and g_f sum up to 1 if a household ate the specific food and 0 otherwise. Hence, this preserves the usual approach to aggregating food items into food categories consistent with the HDDS.

Second, dietary diversity or other similar diversity scores are not based on individual food items but on food categories. As such, whether a household eats rice and maize, or only one of the two, the corresponding value for the cereals and grains category is 1. Likewise, if a household eats cassava, yam, and white potato, or only one of these food items, it gets a value of 1 for the roots and tuber category. To be consistent with this notion of the computation of dietary diversity, we give equal weights to each food item within a food category. Thus, we count the total number of food items N that household h ate from food category c, which we denote as N_{hc}. Each food item f within food category c, then gets a weight of $w_f = 1/N_{hc}$. This ensures that the sum of the weights of each food item within a food category adds up to 1 ($\sum w_f = 1$) if the household ate at least one item of food from that food category and zero otherwise. This is consistent with the usual computation of dietary diversity as it only takes one food item for the food category to get a value of 1.

Third, the interaction of the food sources and number of food items within a category should result in a value of 1 for the food category if the household ate at least one food item from any source, and zero otherwise.

$$\begin{aligned}\text{Food Category} = w_1[m_{f1} + a_{f1} + g_{f1}] + w_2[m_{f2} + a_{f2} + g_{f2}] + ... + \\ w_N[m_{fN} + a_{fN} + g_{fN}]\end{aligned} \tag{1}$$

where $f1$, $f2$,...,fN refers to N food types within a food category; m_{fi}, a_{fi}, g_{fi} $\forall i = 1, ..., N$ refer to the share of market purchases, own-production, and gifts for food type i in the food category; and w_f is the weight of a given food item in the food category as discussed above. Equation (1) always results in either zero or one because all the terms in parenthesis sum to 1 if the household ate that specific food type from any source and zero otherwise, and $\sum w_f = 1$ if the household ate at least one food item from the food category and zero otherwise.

Rearranging equation (1)

$$\begin{aligned}\text{Food Category} = & [w_1 m_{f1} + w_2 m_{f2} + ... + w_N m_{fN}] \\ & +[w_1 a_{f1} + w_2 a_{f2} + ... + w_N a_{fN}] \\ & +[w_1 g_{f1} + w_2 g_{f2} + ... + w_N g_{fN}]\end{aligned} \tag{2}$$

The terms in square bracket in the first row of equation (2) refer to the share of purchased food items within the food category, which is the sum of the shares of purchased food items weighted by the inverse of the the number of food items the household consumed in the food category. Likewise, the terms in square brackets in the second and third rows of equation (2) refer to the shares of consumption in the food category obtained from own production and gifts, respectively. Given that the $w_1 = w_2 = ... = w_N = 1/N$ and $\sum w_f = 1$, equation (2) reduces to

$$\begin{aligned} \text{Food Category} = & [m_{f1} + m_{f2} + ... + m_{fN}] \\ & +[a_{f1} + a_{f2} + ... + a_{fN}] \\ & +[g_{f1} + g_{f2} + ... + g_{fN}] \end{aligned} \tag{3}$$

where the parentheses in the first, second, and third rows of equation (3) show the relative shares of purchases, own-production, and gifts in the food category used in the construction of HDDS. This simple arithmetic shows that the shares are constructed in a way consistent with the construction of HDDS, are not affected by quantity of consumption for any given food item, and can be adopted for any number of sources and food items within a food category.

6 Results

6.1 Household Dietary Diversity Score by irrigation status

The HDDS presented in Table (1) shows that irrigators, on average, consumed 6.7 food groups out of a total of 12 food groups in the seven days prior to the survey. Non-irrigators, on the other hand, consumed 6.2 food groups. Thus, irrigators had access, on average, to about 8% more diverse food than non-irrigators. The difference between irrigators and non-irrigators is quantitatively modest but statistically significantly different from zero.

Figure (1) shows the cumulative distribution of HDDS by irrigation status, making the case that irrigators have better access to a diverse group of foods. The distribution of

Table 1: Household dietary diversity score (HDDS) by irrigation status

	(1)
	Household dietary diversity score
Non-irrigators	6.23
Irrigators	6.72
Differences	-0.49
p-values	0.001
Non-irrigators	305
Irrigators	405
N	710

HDDS for irrigators is moved to the right compared to that of non-irrigators, showing that at any given HDDS, the proportion of households that ate that number of food groups or less is higher for non-irrigators compared to irrigators. As shown in the discussion section below, the HDDS gap between irrigators and non-irrigators remains the same even when we use a 24-hour recall instead of the 7-days recall.

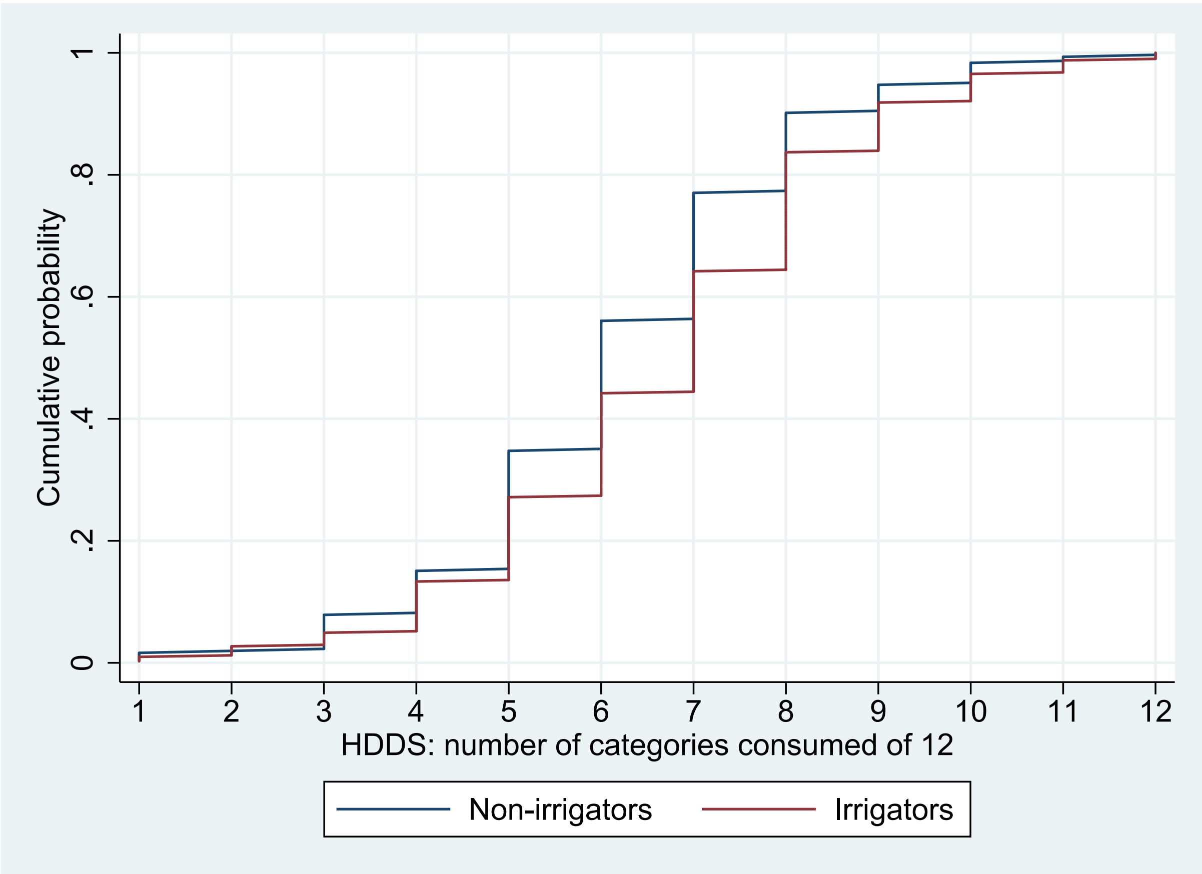
6.2 Differences in food categories consumed

In the seven days prior to the survey, almost all households reported consumption of cereals, 93% consumed vegetables, 83% consumed pulses, legumes, and nuts, 82% consumed fish and other sea foods, 66% consumed oils and fats, 51% consumed sugar and honey, 27% consumed meat and poultry, 20% consumed white tubers and roots, 15% consumed fruits, 7% consumed eggs, and 6% consumed milk and milk products.

Table (2) presents the share of households that reported consumption of at least one food item from the food category in the seven days prior to the survey date. The results show that there are statistically significant and economically meaningful differences between irrigators and non-irrigators in the share of households who reported consuming meat and poultry, milk, sugar and honey, fruits, and vegetables.

Twenty-two percent of non-irrigators reported consuming meat, poultry, and offal in the seven days prior to the survey compared to 32% of irrigators, a 45% difference (Table 2). While only 3% of non-irrigators reported consuming milk and milk products, 9% of

Figure 1: Cumulative Distribution of HDDS by Irrigation Status: Northern Ghana



irrigators did, a 200% difference. Finally, 43% of non-irrigators reported the consumption of sugar and honey, compared to 58% of irrigators, a 35% difference. In addition, there is a modest difference in the share of households who consume fruits and vegetables by irrigation status. The share of irrigating households that consume fruits and vegetables is 42% and 4% higher, respectively, compared to non-irrigators (Table 2).

We did not find differences between irrigators and non-irrigators in the consumption of cereals, tubers, eggs, fish, oils and fats, as well as pulses, legumes, and nuts in the seven days prior to the survey (Table 2).

However, even for food categories where we did not find statistically significant differences in percentages of households that had consumed at least one item from the broad category between irrigators and non-irrrigators, we do find differences in the number of food items consumed within the category. An example is the cereals food category, where irrigators consume a larger variety compared to exclusively rainfed farming households (Table 3). We see similar differences in the diversity of fruits irrigators eat, compared to non-irrigators (Table 3). Increased diversity within the food category provides important information on nutrition since different food items within a food category have different nutritional values.

Table 2: Share of households that consume specific food groups in the last seven days by irrigation status

	Cereals	Tubers	Veget.	Fruits	Meat	Eggs	Fish	Pulses	Milk	Oils/ fats	Sugar/ honey
Shares:											
Non-irrigators	0.99	0.19	0.91	0.12	0.22	0.08	0.80	0.82	0.03	0.66	0.43
Irrigators	1.00	0.21	0.94	0.17	0.32	0.07	0.84	0.83	0.09	0.67	0.58
Difference	-0.01	-0.03	-0.04	-0.05	-0.10	0.00	-0.04	-0.00	-0.06	-0.01	-0.15
p-values	0.158	0.400	0.083	0.047	0.004	0.947	0.147	0.884	0.001	0.761	0.000
Observations:											
Non-irrigators	305	305	305	305	305	305	305	305	305	305	305
Irrigators	405	405	405	405	405	405	405	405	405	405	405

Irrigators and non-irrigators were assumed to have unequal variances in the test.

Table 3: Number of food items consumed within a food category by irrigation status: conditional on the household consuming from the food category

	Cereals	Tubers	Veget.	Fruits	Meat	Egg	Fish	Pulses	Milk	Oils/ fats	Sugar/ honey
Non-irrigators	2.24	1.23	2.15	1.08	1.25	1.00	1.03	1.83	1.11	1.01	1.12
Irrigators	2.40	1.35	2.22	1.22	1.21	1.00	1.06	1.90	1.06	1.01	1.11
Difference	-0.16	-0.12	-0.07	-0.13	0.04	0.00	-0.03	-0.07	0.05	-0.00	0.00
P-values	0.020	0.239	0.204	0.075	0.617	.	0.103	0.348	0.657	0.637	0.906
Observations:											
Non-irrigators	303	57	277	36	67	23	243	251	9	200	130
Irrigators	405	86	382	69	128	30	340	335	35	270	235

Irrigators and non-irrigators were assumed to have unequal variances in the test.

6.3 The contribution of markets, own production, and gifts to household consumption

The data show that market purchases and own production are the major sources of food consumption in the households surveyed in Northern Ghana. Overall, more than two-thirds of all items consumed by farm households over the seven days prior to the survey was purchased from the market, while 27% was obtained from households' own production. Gifts contribute for about 4% of households' consumption.

In our sample, we find a significant difference in the the role of markets and own-production across the different food categories that make up the HDDS. Markets contribute 99.8% of the consumption of fish and sea food, 97% of sugar and honey, 94% of milk and milk products, 90% of oils and fats, 87% of white tubers and roots, 71% of vegetables, 61% of fruits, 61% of pulses, legumes, and nuts, 53% of meats and poultry, 23% of cereals, and 18% of eggs.

The role of markets, own production, and gifts in households' consumption also vary by households' irrigation status. The results in Tables (4, 5, and 6) show this difference in food sources by irrigation status, using the weights and definitions we have proposed in section 5.

The role of markets and own-production in the consumption of vegetables differs between irrigators and non-irrigators, a meaningful difference both economically and statistically. Irrigators rely more on own-production than markets for their consumption of vegetables, compared to non-irrigators. This likely reflects the preference to irrigate vegetables rather than to subject them to less certain rainfall conditions. The share of vegetable consumption purchased from markets is 79% for non-irrigators, and a lower 66% for irrigators (Table 4). Conversely, the share of vegetable consumption obtained from own production is only 10% for non-irrigators, but 30% for irrigators (Table 5). This reflects the difference in production of specific food groups by households' irrigation status. Table (7) shows that 97% of irrigators produce vegetables, compared to 11% of non-irrigators, an 86 percentage point difference that is both economically and statistically significant. Irrigation also significantly reduces the role of gifts in the consumption of vegetables. Gifts contribute for 10% of the consumption of vegetables for non-irrigators, while this share declines to 4% for irrigators (Table 6).

Irrigation makes a significant difference in the source of consumption for meat, poultry, and offal. Markets contribute 70% of the consumption of meat, poultry, and offal for non-irrigators, while this share declines to 44% for irrigators (Table 4). Conversely, own-production contributes for 17% of the consumption of meat, poultry, and offal for non-irrigators, while this share increases to 45% for irrigators (Table 5). This is reflected in production differences of this food group by irrigation status (Table 7). Table (7) shows that irrigators are five percentage points more likely to produce meat and poultry.

Irrigators are more likely to consume eggs from their own-production than non-irrigators. The share of own-production in the consumption of eggs is 85% for irrigators, and 61% for non-irrigators (Table 5). This is supported by a higher share of irrigators producing eggs on their farm compared to non-irrigators, a 10 percentage point difference (Table 7). We have not seen differences in the share of markets and gifts in the consumption of eggs between irrigators and non-irrigators. However, it is to be noted that very few households reported egg consumption in the seven days prior to the survey, and the small number of observations for egg consumption may not be enough to pick up differences in the roles played by different sources.

Irrigation improves the share of white tubers and roots consumed from own production by seven percentage points, albeit from a low base (Table 5). The result is statistically significantly different from zero.

There is a modest difference in the source of consumption of pulses, legumes, and nuts by irrigation status. Irrigators tend to rely more on own production for their consumption of pulses, legumes, and nuts; the share is 28% for non-irrigators and 34% for irrigators, a statistically meaningful difference (Table 5).

Only nine non-irrigators and 35 irrigators reported that they have consumed milk and milk products in the seven days prior to the survey (Table 4). Despite this small share of households, irrigators are more likely to receive these milk and milk products as gifts (Table 6) and less from markets (Table 4), compared to non-irrigators. No one reports consumption of milk from own production (Table 5) .

Though much of the consumption of sugar and honey comes from markets, there is a modest difference by irrigation status. Irrigators almost entirely rely on markets (99%) for their consumption of sugar and honey, while this share reduces to 94% for non-irrigators (Table 4).

There is no statistically meaningful difference in the the source of consumption by household's irrigation status for cereals, fruits, fish and sea foods, as well as oils and fats.

Table 4: Share of consumption purchased from the market by irrigation status

	Cereals	Tubers	Veget.	Fruits	Meat	Egg	Fish	Pulses	Milk	Oils/ fats	Sugar/ honey
Non-irrigators	0.24	0.89	0.79	0.61	0.70	0.26	1.00	0.63	1.00	0.90	0.94
Irrigators	0.23	0.85	0.66	0.61	0.44	0.12	1.00	0.59	0.93	0.90	0.99
Difference	0.02	0.03	0.13	-0.00	0.26	0.14	-0.00	0.04	0.07	-0.00	-0.04
P-values	0.455	0.533	0.000	1.000	0.000	0.197	0.817	0.191	0.096	0.910	0.036
Observations:											
Non-irrigators	303	57	277	36	67	23	243	251	9	200	130
Irrigators	405	86	382	69	128	30	340	335	35	270	235

Irrigators and non-irrigators were not assumed to have equal variances.

Table 5: Share of consumption from own-production by irrigation status

	Cereals	Tubers	Veget.	Fruits	Meat	Egg	Fish	Pulses	Milk	Oils/ fats	Sugar/ honey
Non-irrigators	0.73	0.03	0.10	0.24	0.17	0.61	0.00	0.28	0.00	0.10	0.03
Irrigators	0.74	0.10	0.30	0.29	0.45	0.85	0.00	0.34	0.00	0.08	0.00
Difference	-0.01	-0.07	-0.20	-0.06	-0.28	-0.24	0.00	-0.06	0.00	0.02	0.03
P-values	0.629	0.049	0.000	0.502	0.000	0.056	.	0.058	.	0.531	0.064
Observations:											
Non-irrigators	303	57	277	36	67	23	243	251	9	200	130
Irrigators	405	86	382	69	128	30	340	335	35	270	235

Irrigators and non-irrigators were not assumed to have equal variances.

Table 6: Share of consumption obtained as gifts by irrigation status

	Cereals	Tubers	Veget.	Fruits	Meat	Egg	Fish	Pulses	Milk	Oils/ fats	Sugar/ honey
Non-irrigators	0.02	0.09	0.10	0.15	0.13	0.13	0.00	0.09	0.00	0.01	0.02
Irrigators	0.03	0.05	0.04	0.09	0.11	0.03	0.00	0.07	0.07	0.02	0.01
Difference	-0.01	0.04	0.06	0.06	0.02	0.10	0.00	0.02	-0.07	-0.01	0.01
P-values	0.327	0.373	0.001	0.396	0.652	0.229	0.817	0.290	0.096	0.145	0.398
Observations:											
Non-irrigators	303	57	277	36	67	23	243	251	9	200	130
Irrigators	405	86	382	69	128	30	340	335	35	270	235

Irrigators and non-irrigators were not assumed to have equal variances.

Table 7: Share of households producing specific food groups and overall households' production diversity score (HPDS)

Averages	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
	cereals	veg	fruit	pulses	tubers	oils	sweets	fish	meats	bees	eggs	dairy	HPDS
Non-irrigators	0.99	0.11	0.00	0.43	0.01	0.03	0.00	0.02	0.92	0.01	0.81	0.79	4.11
Irrigators	1.00	0.97	0.00	0.44	0.02	0.03	0.00	0.02	0.97	0.01	0.91	0.88	5.24
Differences	-0.00	-0.86	0.00	-0.00	-0.01	0.00	0.00	0.00	-0.05	-0.01	-0.10	-0.09	-1.13
Observations:													
p-values	0.462	0.000	.	0.910	0.182	0.853	.	0.816	0.006	0.277	0.000	0.001	0.000
Non-irrigators	305	305	305	305	305	305	305	305	305	305	305	305	305
Irrigators	405	405	405	405	405	405	405	405	405	405	405	405	405

Irrigators and non-irrigators were not assumed to have equal variances.
HPDS: Household production diversity score.

7 Discussion

The analysis in the preceding section has provided evidence that shows that (i) there is a modest difference in the overall household dietary diversity score between irrigators and non-irrigators, (ii) there are significant differences in the consumption of animal source foods between irrigators and non-irrigators, (iii) there are significant differences in the consumption of fruits and vegetables as well as sugar and honey between irrigators and non-irrigators, and (iv) the source of consumption of vegetables, meats and poultry, milk and milk products, as well as sugar and honey significantly differs between irrigators and non-irrigators. In this section, we discuss these results and insights for the pathways through which irrigation may affect nutritional outcomes.

The 8% difference in the household dietary diversity score between irrigators and non-irrigators suggests that irrigation can play a role in improving nutritional outcomes, considering that improving nutritional outcomes was not the explicit reason why farmers adopt irrigation. The adoption of irrigation in the study area was not accompanied by any nutrition-related behavioral change communication or other nutrition-related interventions.

Importantly, we find statistically and economically significant association between the consumption of meats and poultry, as well as milk and milk products, with households' access to irrigation. Underconsumption of animal-source-foods is common in Ghana across seasons, pointing to a high risk of micronutrient inadequacy, especially for vulnerable sub-populations like school-aged children (Abizari et al., 2017; Colecraft et al., 2006).

The statistically meaningful results from Tables (1,2, 4, 5, and 6) are summarized in Table (8) in a manner that allows us to deduce the suggestive pathways through which irrigation can influence nutrition. In the results section, we have shown that irrigators' consumption of vegetables is higher than that of non-irrigators by a modest 4%. However, compared to non-irrigators, much of this increased vegetable consumption by irrigators is from own production (Table 8). Hence, if irrigators consume more vegetables, and largely from own production, this suggests the presence of a production pathway through which irrigation affects households' nutrition. Likewise, irrigators consume more meats, poultry, and offal (by about 45%) compared to non-irrigators. The key source of the higher consumption is again higher own production, with no statistically meaningful difference in the role of gifts by irrigation status (Table 8). This also suggests the presence of the production pathway at play through which irrigation affects nutritional outcomes of households.

On the other hand, we found that irrigators consume 35% more sugar and honey but source these largely from markets, with the role of gifts showing no difference by irrigation status (Table 8). This suggests the presence of an income pathway trough which irrigation affects nutrition.

Although we have shown that irrigators are more likely to consume milk and milk products as well as fruits compared to non-irrigators, these differences do not easily lend themselves to draw conclusions on the production and income effects through which irrigation may affect nutrition. For milk and milk products, the share of markets as a source of consumption is lower for irrigators, and the role of gifts higher, with the role of own-production showing no statistically meaningful difference by irrigation status (Table 8). It is possible that irrigators might have a higher social capital (as they have more to offer from their other produces), enabling them to get more milk and milk products in exchange as gifts. But this is only a conjecture with no data points to substantiate. More importantly, we believe the lack of a meaningful difference to detect income and production pathways is mainly because of the small sample size of households who reported consumption of milk and milk products. Only 3% of non-irrigators (or 9 households) and 5% of irrigators (or 35 households) consumed milk and milk products in the seven days prior to our survey. Hence, we don't have enough statistical power to dissect the data by sources of consumption. Likewise, only 12% of non-irrigators (or 36 households), and 17% of non-irrigators (or 69 households) reported the consumption of fruits in the preceding seven days prior to the survey, posing a similar small sample size problem. The statistically meaningful difference in the consumption of fruits by irrigation status, does not support further disaggregation of the data by sources of consumption. However, differences in the consumption and sources of consumption of vegetables, meat and poultry, as well as sugar and honey indicate the presence of both the production and income effects through which irrigation can affect households' nutritional outcome.

Our findings add to the literature on how income, production, and access to markets

Table 8: Suggestive pathways through which irrigation affects nutrition

HDDS category	Irrigators' consumption compared to non-irrigators	Share of markets on irrigators' consumption compared to non-irrigators	Share of own-production on irrigators' consumption compared to non-irrigators	Share of gifts on irrigators' consumption compared to non-irrigators	Suggestive pathway
Vegetables	higher	lower	higher	lower	Production pathway
Meat & poultry	higher	lower	higher	No difference	Production pathway
Sugar & honey	higher	higher	lower	No difference	Income pathway
Milk & milk products	higher	lower	No difference	higher	Inconclusive
Fruits	higher	No difference	No difference	No difference	Inconclusive

all play a role in dietary diversity in rural agricultural settings (Sibhatu and Qaim, 2017). Production diversity has a stronger effect on dietary diversity the farther away the market is, suggesting the importance of the production pathway in settings with limited access to markets (Signorelli et al., 2017). Therefore, we expect that improving access to markets (in terms of both income and proximity) will change the way households source food, ultimately affecting dietary diversity through the income pathway or a shift towards the income pathway.

This study has potential limitations. The recall bias introduced by extending the HDDS module from a 1-day to a 7-day recall is important. However, we do not expect systematic differences in recall bias between irrigators and non-irrigators. In addition, we have administered both the 1-day and 7-day HDDS modules, even though we collected sources of consumption only for the latter. Comparing the 1-day HDDS with the 7-day HDDS shows that the 1-day HDDS is slightly lower (6.2 versus 6.1 for non-irrigators for the 7-day HDDS versus the 1-day HDDS and 6.7 versus 6.5 for irrigators for the 7-day and 1-day recalls, respectively), but the gap between irrigators and non-irrigators remains the same in both the 1-day and 7-day HDDS. Hence, we do not see a systematic bias in our use of the 7-day HDDS for our analysis, while this allows us to include analysis on the sources of consumption.

The data used is cross-sectional which does not allow us to attribute differences in food consumption and sourcing to irrigation. Moreover, the data provide only a snapshot of people's diets and does not reflect potential seasonal variations in dietary diversity. A study on school-aged children in Northern Ghana showed seasonal variations in dietary diversity, where dietary diversity was higher in the rainy season due to increased consumption of fruits and vegetables compared to the dry season (Abizari et al., 2017).

8 Conclusions and Policy Implications

We analyze the linkages between irrigation and nutrition using cross-sectional data from irrigators and non-irrigators in Northern Ghana. The results show that (i) irrigators have better economic access to food, as measured by a household dietary diversity score, compared to non-irrigators, (ii) irrigators are more likely to consume animal source foods, particularly meats, poultry, offal, as well as milk and milk products, compared to non-irrigators, (iii) irrigators are more likely to consume fruits and vegetables as well as sugar and honey, compared to non-irrigators, and (iv) there is a substitution effect in the sources of consumption from markets to own production in the consumption of vegetables, as well as meats and poultry, and from own production to markets in the consumption of sugar and honey by irrigators, compared to non-irrigators. Analysis of the differences in the types of food categories irrigators consume more and the sources of this consumption (market purchases, own production, and gifts) indicates that irrigation affects nutrition outcomes in Northern Ghana both through an income pathway and a production pathway.

Irrigation is shown to have a strong association with household's economic access to food and higher consumption of animal source foods, fruits, and vegetables. Realizing the full potential of irrigation to significantly contribute to reduce malnutrition, however, requires deliberate policy actions and interventions that would promote irrigation on its merit to improve nutrition. First, food and nutrition security strategies and policies should actively consider irrigation as a nutrition-sensitive intervention. Second, there is a need by policymakers to recognize that a variety of pathways mediate the role of irrigation for nutrition outcomes, including the production and income pathways, and that factors, such as market distance are at play. Third, it is important to accompany nutrition-sensitive irrigation interventions with social and behavioral change communication to help ensure that irrigation enhances not only household dietary diversity but focuses on the enhanced consumption of nutrient-dense crops (rather than increased intake of sweets and honey). Fourth, if irrigation is to have a meaningful effect on nutrition through increased income and diversified food production or availability, there is a need to move away from buckets and cans (the common household irrigation methods in Northern Ghana), and towards sustainable intensification that scales up farmers' irrigation portfolio towards a diverse set of cash crops, increases the amount of land under irrigation per household, and increases the size of irrigated land for the same level of available water and labor through investments in water and labor-saving technologies. Fifth, there is a need for further research on the impact of irrigation interventions with nutrition education and gender trainings, with an eye on differences in intra-household preferences and challenges of men, women, and children.

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