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# Irrigation and Women's Diet in Ethiopia

## A Longitudinal Study

Kaleab Baye

Jowel Choufani

Dawit Mekonnen

Elizabeth Bryan

Claudia Ringler

Jeffrey K. Griffiths

Emma Davies

Environment and Production Technology Division

## INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

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## AUTHORS

**Kaleab Baye (**kaleab.baye@aau.edu.et**)** is an Honorary Research Fellow at Bioversity International, and Associate Professor of human nutrition and Director of the Center for Food Science and Nutrition, Addis Ababa University, Addis Ababa, Ethiopia.

**Jowel Choufani** (jchoufani@gwu.edu) was a Research Analyst I in the Environment and Production Technology Division of the International Food Policy Research Institute (IFPRI), Washington, DC.

**Dawit Mekonnen** (d.mekonnen@cgiar.org ) is a Research Fellow in the Environment and Production Technology Division at IFPRI, Addis Ababa, Ethiopia office.

**Elizabeth Bryan** (e.bryan@cgiar.org ) is a Senior Scientist in the Environment and Production Technology Division at IFPRI, Washington D.C.

**Claudia Ringler** (c.ringler@cgiar.org ) is a Deputy Division Director in the Environment and Production Technology Division at IFPRI, Washington, DC.

**Jeffrey K. Griffiths** (jeffrey.griffiths@tufts.edu) is a Professor of Public Health and Community Medicine, and of Medicine, Tufts University School of Medicine, Boston, MA, and Adjunct Professor at the Schools of Engineering, the Cummings School of Veterinary Medicine, and the Friedman School of Nutrition Science and Policy, Tufts University.

**Emma Davies** *(*emma_davies@student.hks.harvard.edu) is a Master Student at Harvard University and a recent intern in IFPRI's Environment and Production Technology Division.

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## Abstract

Some agricultural practices, such as irrigation, have the potential to buffer seasonal dietary gaps and thus improve diets, particularly for subsistence farmers but also for rural and urban households that purchase irrigated produce from local markets. While the seasonality of households and children's diets is well documented, little is known about the seasonality of women's diets and the influence of irrigation. Using longitudinal data from Ethiopia, this study characterized women's diet over time and evaluated the potential implications of seasonality and irrigation on women's diet. Women's dietary diversity was low (3-4 out of 10 food groups) and exhibited high seasonal variability ($P<0.05$). Diets were predominantly plant-based, with little consumption of nutrient-dense foods, such as fruits and animal source foods. High seasonal variability in energy, protein, vitamin C, calcium, iron, and zinc intakes were observed ($P<0.01$). Irrigators were more likely to meet the minimum dietary diversity for women (MDDW), had higher energy and calcium intake, and lower prevalence of anemia, than women from non-irrigating households ($P< 0.05$). No cases of malaria were reported from the three rounds of screening. Our preliminary findings suggest that there is high seasonal variation in women's diet, but this can be partly offset by irrigation practices.



**Keywords:** sustainable intensification, irrigation, dietary diversity, seasonality, irrigation

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# Acronyms

| | |
|---|---|
| DG-LV | Dark-Green Leafy Vegetables |
| FV | Fruits and Vegetables |
| LMIC | Low-and Middle-Income Countries |
| MDDW | Minimum Dietary Diversity for Women |
| MFP | Meat, Fish and Poultry |
| RDT | Rapid Diagnostic Test |
| SIPS-IN | Sustainably Intensified Production Systems' Impact on Nutrition |
| USAID | United States Agency for International Development |
| WASH | Water, Sanitation and Hygiene |
| WDDS | Women's Dietary Diversity Score |

# 1. Introduction

Poor nutrition affects one third of the world's population and is now the highest risk factor associated with the global burden of disease (1,2). The highest burden of undernutrition is found in low- and middle-income countries (LMIC), with Africa south of the Sahara and South Asia being the most affected regions (3). Poor diets, both in quantity and quality, are the underlying proximal causes of all forms of malnutrition (4). Women of reproductive age and children in LMIC are disproportionately affected. Furthermore, the prevalence of undernutrition is often higher in rural than in urban communities.

In rural Ethiopia, seasonal and chronic undernutrition are exacerbated by an over-reliance on rain-fed agriculture that is increasingly becoming unpredictable (5), poor market linkages, and limited basic infrastructure (e.g. electricity, refrigeration) (6, 7). The Ethiopian government has recently increased efforts to expand irrigation, which, if implemented well, could compliment plans to eradicate malnutrition. However, increasing the supply of irrigation water has been linked to an increase in vector-borne diseases, such as malaria, which can adversely affect nutritional status.

While the seasonality of households' and children's diets is well documented, little evidence exists regarding the seasonality of women's diets (8). Moreover, whether irrigation practices bridge seasonal dietary gaps and eventually improve nutrition remains largely unknown. Recent studies suggest that irrigation can improve nutrition indirectly, through changes in production, income, the WASH environment, and women's empowerment (9, 10). However, the evidence remains scant and concerns over increased incidence of malaria have also been reported (11). The lack of research on irrigation-nutrition pathways is unfortunate given the Ethiopian governments' investments in irrigation. This study aims to build the evidence base to provide insight on nutrition-sensitive irrigation development, using panel data on women's diets from three survey rounds at different periods during the production calendar. The results highlight the potential implications of seasonality and irrigation for women's diets.

## 2. Data and Methods

### *2.1 Study sites, design and study participants*

The study was conducted as part of the Sustainably Intensified Production Systems' Impact on Nutrition (SIPS-IN) program funded by the USAID Feed the Future Sustainable Intensification Innovation Lab, which aims to evaluate the impact of irrigated production systems on food security, nutrition and health outcomes. The SIPS-IN program took place in the watersheds of Robit and Dangila districts, Amhara region, in northern Ethiopia. These sites were selected given their high potential for irrigation based on an ex-ante analysis of factors such as groundwater availability, distance to surface water, and market access. Within these sites, households were selected using the following criteria: produce crops, were permanent residents of Robit or Dangila districts, and had at least one child below the age of five. A longitudinal study consisting of household-level and individual-level surveys was conducted, and a total of 364 women of reproductive age and children less than five years of age were surveyed three times: in February-April 2017 (short rainy season--*belg*), October-November, 2017 (harvest), and July-August, 2018 (rainy season--*meher*). The months of July to August, when post-harvest consumption is usually completed but new crops are not yet in the field is typically the height of the lean (i.e. food-scarce) season and coincided with the third survey round. For this paper, we used household and women's data. Analysis of the child-level data will be published separately.

### *2.2 Data*

#### *2.2.1 Socio-demographic and household characteristics*

Information on the socio-demographic characteristics of the study participants was collected using pretested questionnaires that included questions about the age of household members, family size, education level, livelihood strategy, and land size.

#### *2.2.2 Irrigation*

Irrigation status was defined at the household level as whether or not the household reported irrigating any of their plots during any of the agricultural production seasons during the recall period. The study only included individual, smallholder irrigation systems, such as manual or motor pump lifting of groundwater for the irrigation of individual household plots.

#### *2.2.3 Food consumption survey*

Using a quantitative 24-hour recall, food intake was estimated using the multiple pass technique validated for use in developing countries (14). The first pass identified all foods and drinks consumed in the last 24 hours; the second pass identified ingredients and processing techniques applied in preparing the foods. The third pass estimated portion size. To this end, whenever possible, salted-replicas of actual foods were weighed using kitchen scales (Kinlee ACS-EK01); or else, local utensils and graduated models were used. The final pass checked the completeness of the data gathered. All days of the week were equally represented in the final sample.

The foods consumed were categorized into the following 10 nutritionally-relevant food groups, according to the guide for measuring dietary diversity for women (15): 1) grains, white roots and tubers, and plantains; 2) pulses (beans, peas, and lentils); 3) nuts and seeds; 4) dairy; 5) meat, poultry, and fish; 6) eggs; 7) dark green leafy vegetables; 8) other vitamin A-rich fruits and vegetables; 9) other vegetables; and 10) other fruits. The mean women’s dietary diversity score

(WDDS) was calculated and the proportion of women that consumed at least five of the 10 food groups were considered to have met the minimum dietary diversity for women (MDDW) (16).

### *2.2.4 Estimation of energy and nutrient intakes*

Food intake was converted to energy and nutrient intakes using food composition values from the Ethiopian food composition table (17). Missing values were completed using either published literature (18,19) or data from the USDA nutrient database (https://ndb.nal.usda.gov/ndb/), after adjusting for moisture difference. For mixed dishes, energy and nutrient contributions were calculated from recipes.

### *2.2.5 Hemoglobin and malaria screening*

Hemoglobin concentrations were determined using a portable photometer (Hemocue HB 301, Ängelholm, Sweden) from a blood sample from fingerpicks. The hemoglobin readings were adjusted for altitude (average 1900 m above sea level). Women with adjusted hemoglobin concentrations <12 g/dl were considered to be anemic (20) and were referred to local health centers. Screening for malaria was performed using a rapid diagnostic test (RDT).

## *2.3 Ethics*

Ethical approval was obtained by the Human Ethics Committees of Texas A&M, the International Food Policy Research Institute, and the Amhara National Regional State Health Bureau. All questionnaires and consent forms were translated to Amharic prior to the survey and written consent was obtained from study participants.

## *2.4 Quality control*

Data were collected electronically using tablets and Survey CTO software. All survey rounds were conducted by the same experienced and trained enumerators. The enumerators were professionals with at least a Bachelors' degree, fluent in *Amharic* (the local language in the study areas), and whose main occupation was survey data collection in various regions of Ethiopia.

### *2.5 Statistical analyses*

All continuous variables were checked for normality using the Kolmogorov-Smirnov test. The dietary intake data were entered and processed using Nutrisurvey 2007. Medians and inter-quartile range (1st, 3rd quartiles) of energy and nutrient intakes were calculated. All other analyses were conducted using SPSS version 20. The relationship between seasonal variation in dietary diversity, hemoglobin concentration and energy nutrient intakes was assessed. The interaction between these terms and irrigation was assessed by fitting a season x irrigation interaction term in the regression model.

We used the Generalized Estimating Equations (GEE) model as it deals with both continuous and binary outcomes, accommodates unequal number and unequally-spaced observations, and is robust for correlation structure. Using the GEE command in SPSS, a linear regression model was fit for continuous outcomes, with parameter estimation using the maximum likelihood estimation method; whereas, for dichotomous response variables, a binary logistic regression was fit and parameter estimation was done using the hybrid method. An unstructured covariance matrix was chosen and thus each variance and covariance was estimated from the data. Wald-Chi square statistics were used to test model effects, and P-values $< 0.05$ were considered to be statistically significant.

## 3. Results

A total of 364 women were recruited for the study, and ~95% completed all three rounds. However, partial non-compliance reached 18% in the third round for invasive procedures, such as fingerpricks for anemia screening. The average land size owned by a household was 0.36 hectares, with a significant proportion (45- 67%) of households having access to irrigation at different periods of the year (**Table 1**). About 70% of households owned latrines, whereas 28.7% had no toilet facility. The average family size was 6. The women were 39 years old, on average, and well over half had no formal education while 30% had some primary-level education.

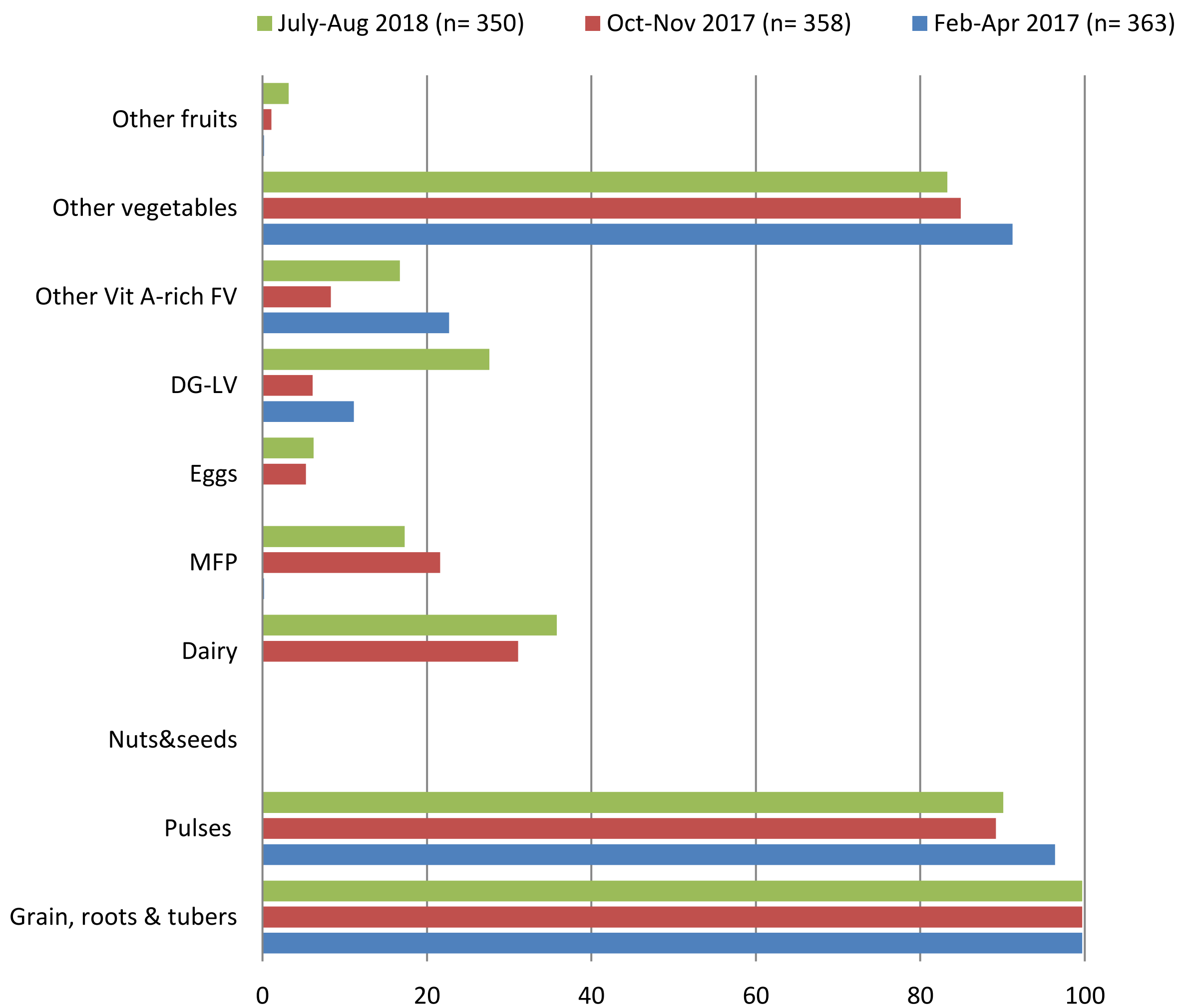
**TABLE 1** Socio-demographic characteristics at baseline

| **Household/women's characteristics (n =364)** | **N (%)** |
|---|---|
| Land size owned (in hectare) | 0.36 ± 0.1 |
| Has access to irrigated plots | |
| Feb-Apr 2017 | 45.7% |
| Oct-Nov 2017 | 67.2% |
| July-Aug 2018 | 61.9% |
| No toilet facility | 28.7% |
| Pit latrine with slab | 68.5 % |
| Ventilated improved pit latrine | <1% |
| Family size (mean ±SD) | 5.8 ± 0.2 |
| Mean age of women (years) | 39.3 ± 11.2 |
| Women with some level of primary education | 30.0 % |
| Women with some level of secondary education | 4.2% |

The values with ± in the table refer to one standard deviation.

The most widely consumed food groups by women were cereals, followed by pulses, and "other vegetables" (**Figure 1**). The consumption levels of more nutrient-dense food groups like eggs, dairy, dark-green leafy vegetables (DG-LV), and meat, fish and poultry (MFP) were low and showed high seasonal variability. For example, the consumption of animal source foods like eggs, MFP, and dairy were extremely low (<1%) in round 1 (Feb-Apr 2017), which corresponded with the Orthodox fasting season, but then gradually increased in the subsequent rounds. Consumption of fruits was very low, while nuts and seeds were absent from the diets of the women.

**FIGURE 1** Food groups consumed by women in the 24h preceding the survey, by season




FV: fruits and vegetables; MFP: meat, fish, and poultry; DG-LV: Dark-Green Leafy Vegetables.

Overall, women's dietary diversity score was very low (3-4 food groups out of 10), but with some variation by season and household irrigation access ($P<0.05$; **Table 2**).

**TABLE 2** Women's dietary diversity, hemoglobin and anemia by season

| | **All** (N=364) | **Irrigators** | **Non-irrigators** | **P-value** (irrigators) | **P-value**[1] (interaction) |
|---|---|---|---|---|---|
| WDDS (mean ± SD) | | | | | |
| Feb-Apr 2017 *(n=363)* | 3.1 ± 0.6 | 3.3± 0.7 | 3.0± 0.6 | | |
| Oct-Nov 2017 *(n=360)* | 3.5 ± 0.9 | 3.6± 0.9 | 3.5± 0.8 | 0.013 | 0.098 |
| July-Aug 2018 *(n=343)* | 3.8 ± 1.1 | 3.9± 1.1 | 3.9± 0.9 | | |
| | | | **P-value** (season) | **<0.001** | |
| Proportion meeting MDDW (%) | | | | | |
| Feb-Apr 2017 *(n= 363)* | 10.4 % | 12.7% | 8.6% | | |
| Oct-Nov 2017 *(n=358)* | 13.7% | 14.1% | 12.8% | 0.089 | 0.484 |
| July-Aug 2018 *(n= 342)* | 23.6% | 27.4% | 19.2% | | |
| | | | **P-value** (season) | **<0.001** | |
| Hemoglobin (mean ±SD) | | | | | |
| Feb-Apr 2017 *(n=347)* | 12.6 ± 1.4 | 12.6± 1.3 | 12.6± 1.5 | | |
| Oct-Nov 2017 *(n= 345)* | 12.5 ± 1.3 | 12.6± 1.3 | 12.2± 1.4 | 0.182 | 0.608 |
| July-Aug 2018 *(n= 305)* | 12.6 ± 1.2 | 12.8± 1.1 | 12.5± 1.2 | | |
| | | | **P-value** (season) | **0.074** | |
| Anemia (%) | | | | | |
| Feb-Apr 2017 *(n=347)* | 29.5% | 28.0% | 30.5% | | |
| Oct-Nov 2017 *(n= 345)* | 30.8% | 26.5% | 39.5% | 0.008 | 0.575 |
| July-Aug 2018 *(n= 305)* | 24.6% | 31.5% | 20.2% | | |
| | | | **P-value** (season) | **0.128** | |

MDDW, minimum dietary diversity for women;
WDDS, women's dietary diversity score;
[1]interaction between season and irrigation estimated using GEE model.
The values following ± in the table refer to one standard deviation.

The proportion of women meeting the minimum dietary diversity score for women (MDDW), corresponding to the consumption of 5 out of 10 food groups, ranged from 10% in round 2 (February-April 2017) to 23% in round 3 (July-August 2018) (P< 0.05). The proportion of women meeting the MDDW was slightly higher among irrigators than non-irrigators in all three rounds (p=0.089). Moreover, the prevalence of anemia was significantly higher in non-irrigating households (P< 0.05). There were no reported cases of malaria of women tested during any of the three survey rounds (data not shown).

**Table 3** presents the energy and nutrient intake of women. High seasonal variability in the intakes of energy, protein, vitamin C, calcium, iron and zinc were observed (P< 0.01). Energy and calcium intakes were significantly higher among irrigators than non-irrigators (P< 0.05). The seasonality of energy, protein, calcium, iron and zinc intakes was modified by irrigation access as reflected by the significant interaction (season x irrigators) in the GEE model.

**TABLE 3** Energy and nutrient intake among irrigators and non-irrigators and by season

| | **Irrigators** | **Non-irrigators** | **P-value** (irrigators) | **P-value**[1] (interaction) |
|---|---|---|---|---|
| **Energy (kcal)** | | | | |
| Feb-Apr 2017 | 1697.8 (1209.7, 2200.5) | 1545.6 (1017.6, 2096.5) | | |
| Oct-Nov 2017 | 2279.5 (1750.3, 2756.3) | 2273.6 (1724.3, 2627.4) | 0.041 | 0.029 |
| July-Aug 2018 | 1943.6 (1610.8, 2289.9) | 1994.0 (1691.4, 2349.8) | | |
| **All rounds** | 1983.5 (1542.2,2485.4) | 1851.1 (1422.9, 2366.0) | | |
| | | **P-value** (season) | **<0.001** | |
| **Protein (g)** | | | | |
| Feb-Apr 2017 | 47.5 (31.2, 58.6) | 41.3 (26.7, 53.7) | | |
| Oct-Nov 2017 | 58.2 (45.7, 73.9) | 57.0 (46.3, 71.1) | 0.357 | 0.043 |
| July-Aug 2018 | 53.8 (42.7, 67.2) | 57.6 (46.0, 71.0) | | |
| **All rounds** | 54.0 (41.5, 67.6) | 49.6 (38.0, 64.3) | | |
| | | **P-value** (season) | **<0.001** | |
| **Vitamin A ($\mu$g)** | | | | |
| Feb-Apr 2017 | 30.0 (17.5, 41.1) | 27.9 (15.7, 42.1) | | |
| Oct-Nov 2017 | 25.7 (5.4, 53.4) | 28.1 (5.0, 57.3) | 0.603 | 0.069 |
| July-Aug 2018 | 15.0 (7.6, 28.1) | 15.7 (8.8, 36.2) | | |
| **All rounds** | 21.1 (8.4, 42.6) | 9.1 (4.7, 17.2) | | |
| | | **P-value** (season) | 0.631 | |
| **Vitamin C (mg)** | | | | |
| Feb-Apr 2017 | 15.1 (7.6, 22.8) | 12.3 (6.7, 20.4) | | |
| Oct-Nov 2017 | 33.0 (24.1, 43.8) | 31.8 (22.7, 40.7) | 0.082 | 0.841 |
| July-Aug 2018 | 32.0 (24.7, 42.1) | 33.3 (24.5, 42.2) | | |
| **All rounds** | 28.7 (18.0, 39.5) | 24.8 (12.1,37.6) | | |
| | | **P-value** (season) | **<0.001** | |
| **Calcium (mg)** | | | | |
| Feb-Apr 2017 | 926.7 (508.2, 1404.8) | 682.6 (350.3, 1152.1) | | |
| Oct-Nov 2017 | 789.1 (621.7, 1030.1) | 765.5 (556.0, 932.5) | 0.006 | 0.001 |
| July-Aug 2018 | 840.9 (634.6, 1120.7) | 939.6 (745.2, 1157.5) | | |
| **All rounds** | 820.7 (621.3, 1133.5) | 818.7 (528.7, 1085.5) | | |
| | | **P-value** (season) | **<0.001** | |
| **Iron (mg)** | | | | |
| Feb-Apr 2017 | 128.6 (80.7, 182.6) | 110.7 (60.5, 176.3) | | |
| Oct-Nov 2017 | 162.5 (123.0, 228.5) | 141.2 (99.0, 194.4) | 0.209 | 0.007 |
| July-Aug 2018 | 148.9 (99.0, 187.3) | 160.3 (101.6, 198.1) | | |
| **All rounds** | 149.7 (103.5, 197.6) | 134.4 (79.6, 190.5) | | |
| | | **P-value** (season) | **0.003** | |
| **Zinc (mg)** | | | | |
| Feb-Apr 2017 | 6.6 (4.7, 8.6) | 5.8 (3.6, 7.8) | | |
| Oct-Nov 2017 | 9.4 (7.2, 11.6) | 9.4 (7.5, 11.7) | 0.911 | 0.005 |
| July-Aug 2018 | 7.7 (6.4, 9.5) | 8.1 (6.7, 10.4) | | |
| **All rounds** | 8.0 (6.3, 10.3) | 7.5 (5.3, 9.8) | | |
| | | **P-value** (season) | **<0.001** | |

[1] interaction between season and irrigation estimated using GEE model;
Intake data was complete for n= 327 for all three rounds.

## 4. Discussion

The present study illustrates that women's dietary diversity was low and exhibited high seasonal variation. Diets were predominantly plant-based with little consumption of nutrient-dense food groups, such as animal source foods. High seasonal variability in energy, protein, vitamin C, calcium, iron and zinc intakes were observed. Women from irrigating households were more likely to meet the MDDW and had higher energy and calcium intake than women from non-irrigating households. No cases of malaria were reported in the three rounds, and anemia prevalence was higher among women from non-irrigating households. The associations between season and energy/nutrient intakes were modulated by small-scale irrigation.

Multiple reasons can explain the high seasonality of the diets of the women. Subsistence farming households primarily rely on their own harvests that, in the absence of irrigation, happen once or twice a year (6). In addition to the limits of relying on rain-fed production, poor market access, limited food processing activities that would extend the shelf-life of perishable goods (7, 21), and high price fluctuations (20, 21) further contribute to the seasonality of diets and consequently to varying levels of energy and nutrient intakes. Such seasonal dietary patterns have been commonly reported from other parts of rural Africa (24, 25), and can have serious adverse effects, including insufficient weight gain during pregnancy and low birth weight of babies (26, 27).

The lowest energy intake, lowest animal-source foods consumption, and most meager overall dietary diversity were found during the first round of the survey (February to April). This is unsurprising given that this period corresponded to the longest period of lent fasting (55 days), a period when observers reduce the number of meals and adopt a vegan diet. The majority of our study subjects are orthodox Christians. Consequently, a slightly higher consumption of vegetables was observed, but consumption of fruits remained low. Given that this period is in the dry season, unless households practice irrigation or have access to affordable vegetables and fruits grown elsewhere, their diets are likely to remain poor in micronutrients.

Women from households that practiced irrigation had a higher dietary diversity and a lower prevalence of anemia than non-irrigating households. Energy and calcium intakes were also higher among women from households practicing irrigation. This is similar to findings on household dietary diversity in Ethiopia (10). The statistically significant interaction between irrigation and season illustrates the buffering effect that irrigation can have on the seasonality of diets and energy and nutrient intakes. Multiple pathways including income, production, and women's empowerment can explain these effects, but further studies are needed to decipher this.

Interestingly, no cases of malaria were reported in the three rounds of the survey, irrespective of smallholder irrigation practice. This supports recent reports of very low levels of malaria in the Amhara region (28), but also indicates that smallholder irrigation—unlike larger-scale irrigation systems with canal systems and higher likelihood of standing water--is not associated with high malaria incidence.

July and August are usually referred to as a lean season for consumption as they coincide with months in which harvest from the previous production season is running out while harvest from current production is not yet available. However, as far as women's diet is concerned, July to August is a season where WDDS and MDDW are higher and the prevalence of anemia is lower (Table 2). We hypothesize that this is related to the higher availability of DG-LV and dairy in the season (Figure 1), partly due to the available rains in June, July, and August, supported by supplementary irrigation during that season, the lower level of seasonal variability of staple foods like cereals, pulses, and vegetables (Figure 1), and the lower consumption of dairy, MFP, and eggs in the February-April season that correspond with the Orthodox fasting season.

The present study has several strengths and limitations that need to be considered when interpreting our findings. The strengths of the study include the longitudinal study design that captured the dry and the rainy seasons, as well as the explicit evaluation of nutrition outcomes. The use of quantitative 24-hour recall data to estimate energy and nutrient intake across multiple seasons also adds value to the study. The relationship between irrigation and diets or nutritional outcomes reported in this study could imply causality; however, readers should exercise caution in this regard given testing for simultaneity bias has not been undertaken. Use of irrigation on plots was broadly defined; hence, whether outcomes vary by level and type of irrigation needs further investigation.

Notwithstanding the above-mentioned limitations, the present study illustrates the seasonal variation of women's diet in rural Ethiopia and shows that this seasonal variability can be partly offset by irrigation. A lower prevalence of anemia and higher energy and nutrient intakes were observed among women from households practicing irrigation. Future studies should investigate whether complementing irrigation interventions with nutrition-related behavioral change communication would lead to greater impact on improving diets and nutritional outcomes of women and children.

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1201 Eye Street, NW
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Tel.: +1-202-862-5600
Fax: +1-202-862-5606
Email: ifpri@cgiar.org