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The Impacts of Small-scale Irrigation on Nutritious Diets and Women Empowerment: Evidence from Ethiopia

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Abstract

Small-scale irrigation is increasingly recognized as a pivotal strategy for improving agricultural productivity and food security in sub-Saharan Africa, especially amidst growing climate variability and changes. Over the past decades, small-scale irrigation has expanded rapidly in sub-Saharan Africa, providing smallholder farmers with an opportunity to improve their livelihoods, diets and resilience to climate change. While existing evidence highlights its wide-ranging benefits, including improved food security, crop diversification, and employment opportunities, less attention has been devoted to understanding its effects on nutritious diets, women's empowerment, and gender equality. This study seeks to fill this gap by rigorously examining the causal impacts of small-scale irrigation on these critical dimensions, utilizing data from the "Megetch Pump Irrigation and Drainage Project (MPIDP)" in Ethiopia's Amhara Regional State. Employing a plot-level Geographic Regression Discontinuity (GRD) design and survey data, we estimate the causal impact of access to irrigation on women's empowerment and nutrition diets, leveraging the unique topographical setup of the irrigation command area and canal construction. Our finding suggests that access to irrigation does not exhibit a significant impact on overall empowerment levels for both women and men. Gender parity among the beneficiaries remains largely unchanged. It is worth noting that empowerment levels were already relatively high in the study area, across various pro-WEAI indicators. Despite the overall impact, access to irrigation enhances women's likelihood of achieving empowerment in terms of decision-making power in productive activities and access to financial services. This instrumental agency measure suggests a positive step towards economic empowerment. However, there is a noteworthy decrease in some individual empowerment indicators, particularly in terms of respect among household members and self-efficacy. Even with observing a significant increase in dry-season crop production attributed to irrigation, there is no substantial evidence of improvement in nutritional outcomes. This result may be influenced by the government's focus on increasing wheat production, directing irrigated land towards this crop.

Key Words: Irrigation, Nutrition, Dietary diversity, pro-WEAI, Women's empowerment, Gender parity, Ethiopia

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1. Introduction

In many developing countries, the majority of the population continue to live in rural areas depending on agriculture for their livelihoods. For example, in Ethiopia, agricultural employs 75 percent of the labor force and contribute 40 percent of its GDP (USAID).[1] While agriculture has the potential for ensuring food and nutrition security and promoting gender empowerment, such potential is hampered by poor performance of the sector, such as low productivity, due to changes in rainfall patterns. Hence, small-scale irrigation construction, among others, has been promoted to increase agricultural production and improve welfare of rural agricultural households. The literature has robustly confirmed that irrigation can increase agricultural production and income of small-holder farmers (Balana et al., 2020; Burney and Naylor, 2012; Giordano and de Fraiture, 2014; Ngango and Hong, 2021; Solomon and Ketema, 2015; Xie et al., 2018). However, evidence on whether these production and income gains translate into favourable nutrition is mixed and the evidence on gender outcomes is scant (Alaofè et al., 2016; Bryan and & Garner, 2022; Mekonnen et al., 2019; Passarelli et al., 2018; Theis et al., 2018), limiting our understanding of the impact of small-scale irrigation on nutritious diet and women empowerment. This study examines the effect of irrigation on productivity, nutritious diet and women empowerment as well as its distributional effects.

Irrigation influences nutrition and gender outcomes in multiple ways. First, through the production pathway, irrigation enables production during both dry/lean and rainy seasons, which allows farmers to cultivate the primary staple crops during the rainy season and shorter cycle horticulture products during the dry season with the availability of irrigation (Jones et al., 2022). This helps rural households in increasing annual production, availability and stability of food supply, production of a variety of nutrient rich crops such as fruits and vegetables, as well as improving dietary diversity and nutrition status of households (Alaofè et al., 2016; Burney and Naylor, 2012; Domenech and Ringler, 2013; Passarelli et al., 2018). Second, through the income pathway, irrigation increases income of farm households from sale of crop products and employment opportunities in irrigated farms (Alaofè et al., 2016; Burney and Naylor, 2012; Mekonnen et al., 2019; Passarelli et al., 2018). The increase in income due to irrigation may lead to increased expenditure on food and non-food items, as well as improve food availability and choice, providing nutritional gains within the household. In addition, increased income contributes to women empowerment by fostering financial independencies, decision-making

[1] Agriculture and food security, https://www.usaid.gov/ethiopia/agriculture-and-food-security

power, community participation and improved well-being. Third, through the women's empowerment pathway, irrigation is expected to reduce women's time for fetching water by providing access to water, reducing water collection chores and enabling them to engage more in income generating activities. The generated income may be used to buy nutritious food increasing the consumption of nutritious diet. Moreover, irrigation improves women empowerment by increasing accumulation of assets, which provide opportunities to earn additional income, increase their decision making and well-being (Meinzen-Dick et al., 2011).

Previous studies that link irrigation interventions with nutrition outcomes (e.g., Passarelli et al. 2018; Mekonnen et al. 2019) and gender outcomes (Imburgia et al., 2021; Lefore et al., 2017; Nkhoma and Kayira, 2016; Padmaja et al., 2019; Theis et al., 2018; Bryan and Lefore, 2021) are qualitative or less rigorous to estimate the causal effects. Our study addresses this by employing a rigorous research design – Geographic Regression Discontinuity (GRD) design. We use the variation in irrigation use from the Megech Pump Irrigation and Drainage project (MPIDP) due to differences in the slope of the location of farms. Using a geospatial supported survey data, the GRD design will credibly estimate the causal impact of Megech Pump Irrigation on nutrition security and women's empowerment in Ethiopia. We complement the quantitative method using qualitative analysis. This study aims to investigate the causal impacts of the "Megetch Pump Irrigation and Drainage Project (MPIDP)," a small-scale irrigation project, on women's economic empowerment, gender equality, and women's economic, social, and institutional resilience in the Amhara Regional State of Ethiopia. Using plot-level Geographic Regression Discontinuity (GRD) design and using survey data, the study estimates the causal effects of irrigation on women empowerment, gender-equality and nutritious diets. The study also seeks to advance understanding of the potential pathways by which improvements in physical infrastructure support markets, diets, and women's economic empowerment by enhancing their control over and access to productive assets.

2. Literature review

Adoption of small-scale irrigation has been promoted in developing countries where agriculture production and productivity has been severely constrained by erratic nature of rainfall. The extant literature amicably portrayed that small-scale irrigation has the capability to enhance productivity, improve income, ensure food and nutrition security, and improve livelihoods of smallholder farmers. For example, Jones et al. (2022) using a natural experiment in plot level spatial discontinuity design on hill-side irrigation adoption in Rwanda found that irrigation

adopters registered a pronounced growth on their annual cash profits. In Ethiopia, Mekonnen et al. (2022) examined the agricultural transformational role of irrigation. Their results show that adoption of irrigation technology led to farm households generating income as they sold a sizable share of their harvest and increased spending on food and non-food consumption. It also facilitated the adoption of other technologies through the complementarity role as adopters are found to apply more fertilizer and agro chemicals than non-adopters. Balana et al., (2020) studied the feasibility of adoption of different small-scale irrigation technologies and their role in improving income and nutrition of farm households in Northern Ghana. Their results show that adopters registered more than 100% increase in their net farm profits. Their findings also affirm that enhancements in crop yields of adopters resulted in significant improvement in nutrition level of farm households. A study by Ngango & Hong, (2021) using propensity score matching found a similar result that adoption of small-scale irrigation enhances productivity of small holders in Rwanda.

Evidence on the impact of small-scale irrigation on women's empowerment, gender equality and nutritious diets is relatively scarce. Few existing studies, however, indicate that small-scale irrigation could improve women's empowerment and nutrition security. For example, Nkonya et al., (2020) studied the drivers of adoption of small-scale irrigation and its impact on nutritious diets across sex of adopters in Mali. Their findings show that even though the rate of adoption of irrigation technologies of women farmers is relatively lower than their male counterparts, increments in income of those who adopted are found to enable them consumption of nutritious-rich food which improves the household's nutrition.

Passarelli et al., (2018) undertook a cross country study to examine the impact of irrigation on nutrition outcome and understand the pathway through which irrigation affects nutrition security of farm households in Ethiopia and Tanzania. Measuring nutrition status using household dietary diversity scores, they find that irrigating households in both countries have produced more diversified crops and recorded higher dietary diversity compared with non-irrigating households. Their regression results further indicated that irrigation improves nutrition status through the income pathway. However, they find that the income pathway does not work for both countries. It does not work for Tanzania which led them to conclude that the impact of irrigation on diets is more context specific. Mekonnen et al., (2019) also studied the effect of irrigation on nutritious diets in Northern Ghana. They found that irrigators registered higher household dietary scores due to consumptions in animal sources of food and

consumption of fruits and vegetables. Their findings also show that irrigation affects dietary diversity through the production and income pathways. Another study Alaofè et al. (2016), using descriptive statistics, evaluated the role of solar powered drip irrigation system on production and nutrition diversity on groups of women who adopt this technology in Northern Benin. Their results show that the irrigator women groups engaged more in the production of fruits and vegetables than non-irrigator groups. Besides the irrigator women groups are found to have three times more likelihood of consuming fruits and vegetables than non-irrigators.

Bryan & Garner (2022), using a qualitative design explored the role that irrigation plays to women's empowerment in the Upper East Region of Ghana. Their study shows that the irrigation-women's empowerment linkage is rather indirect, and women are constrained by factors related to resources such as access to land and water; and social and gender related norms that inhibit women's ability to control farm assets. Despite these constraints, participation in irrigation has led to empowerment by increasing their agency and wellbeing achievements.

Ragasa et al. (2020) evaluated the role of Agriculture Development Support Project (ADSP) on women's empowerment, gender equality and nutritious diets in Myanmar. The ADSP, which runs from 2015 to 2022, provides irrigation infrastructure and technical support to irrigation governance with an objective of increasing crop yields and cropping intensity in selected irrigation sites. Using Pro-WEAI, they find that, overall, 53% of women and 25% men respondents are not empowered and there is a gender gap in 45% of dual adults. Comparing irrigation user and non-user households in both men and women, the study reported that non-users are found to be disempowered in multiple empowerment dimensions than irrigation user households. Regarding the impact of the project in improving nutrition security measured based on household diet diversity score, the researchers, however, do not find significant differences between irrigation user households and other households.

In summary, the studies reviewed showed that adoption of irrigation ensures nutrition security by enabling irrigator households consume a relatively diversified food and improve women's empowerment. This study contributes to the growing literature on the impact of irrigation on women empowerment and nutritious diet this by employing a rigorous research design - Geographic Regression Discontinuity (GRD) design. We use the variation in irrigation use from the Megech Pump Irrigation and Drainage project (MPIDP) due to differences in the slope of the location of farms. Using a geospatial supported survey data, the GRD design will

credibly estimate the causal impact of Megech Pump Irrigation on nutrition security and women's empowerment in Ethiopia. We complement the quantitative method using qualitative analysis.

3. Conceptual Framework

3.1 The Irrigation-Nutrition relationship

The primary goal of agricultural interventions is to enhance productivity and income and thus improve nutrition of households and women economic empowerment. There are different pathways at play regarding agriculture interventions that may impact nutrition. The main ones identified include 1) production pathway, 2) income pathway, and 3) women's empowerment pathway (Herforth and Harris, 2014). Domènech's (2015) review illustrated the pathways specifically linking irrigation intervention with nutrition and health outcomes. Passarelli et al. (2018) also elaborate these pathways based on Herforth and Harris (2014) agriculture-nutrition conceptual pathway by considering irrigation as a productive asset that helps households transform their agricultural livelihoods. In this study we adopted this framework to illustrate how small-scale irrigation relates to nutrition (see figure 1).

The first is the production pathway. Adequate food production at a household level is important for the diets and nutrition of individuals in small-holder farm households (Herforth and Harris, 2014). Adoption of irrigation technologies increases production and thus availability and stability of food supply by enabling multiple farming through the dry/lean season in addition to the rainy season. Besides, irrigation also improves production and availability of food through complementarity effects of adoption (Feder, 1982) which requires the adoption of other technologies such as fertilizer to maximize the benefit of irrigation. In addition to increasing availability, irrigation helps farm households cultivate a variety of produce such as fruits and vegetables which can directly provide enhanced diets and nutrition to farmers during the dry season (Domenech & Ringler, 2013). Evidence indicated that irrigators have a relatively better household diet diversity score (HDDS)-a proxy measure of households' diverse food access compared to non-irrigators (Mekonnen et al., 2019). However, self-sufficiency in terms of quantity of produced food alone does not guarantee nutrition security. Nutrition knowledge is also essential for decisions on what to produce, what to sell and buy with their income; and for decisions about the processing and storage of food (Herforth & Harris, 2014).

Changes in agricultural income is the second pathway through which irrigation affects nutrition. Recent literature has provided robust evidence on the role of irrigation in increasing income of farm households from market sales of crops and from irrigation related employment and then improving nutrition (Alaofè et al., 2016; Burney and Naylor, 2012; Mekonnen et al., 2019; Passarelli et al., 2018). However, a change in income may not directly translate into nutrition outcome. It also depends on food market environment factors related to convenience to purchase, who decides what to be purchased and others (Herforth and Harris, 2014). Irrigation also affects nutrition through the water supply pathway. Irrigation schemes bring water closer to farm household villages. These households may use irrigation water for different domestic purposes such as drinking, washing, bathing, and hygiene which improve water supply, sanitation, and hygiene (WASH) environment in communities suffering from sufficient supply of water (Domènech, 2015).

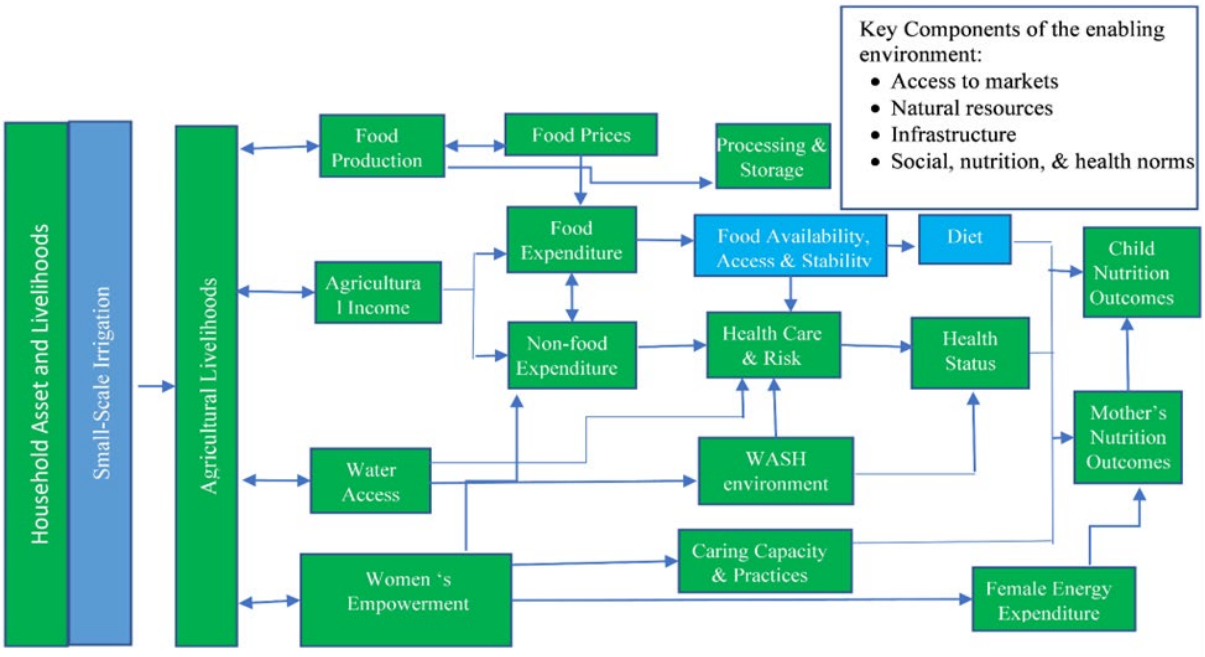


Figure 1. Pathways from irrigation to nutrition (Adopted from Passarelli et al., 2018)

The other pathway through which irrigation interventions could impact the nutrition outcome is through the women's empowerment pathway. Women tend to invest more than men in household nutrition, education, and health, and therefore, enhancing women's access to and control over irrigation can have a positive multiplier effect on reducing undernutrition (IFPRI, 2015). On the one hand, improved access to water due to the introduction of irrigation reduces women's water collection chores and enables women to spend more time in income generating

activities. On the other hand, introduction of irrigation could increase productivity of women managed plots which in turn increases farm income of women (Domenech & Ringler, 2013). Women's empowerment and nutrition are interconnected outcomes.

3.2 Irrigation-Women's Empowerment relationship

A conceptual framework relating irrigation with women's empowerment is illustrated in Meinzen-Dick et al. (2019) review work. Women's empowerment in this framework is considered as a process by which individuals improve their ability to make strategic life choices (agency) by utilizing resources (such as natural, physical, human, financial and social), leading to achievement of well-being outcomes (such as food and nutrition security, and/or economic and social status) (Bryan & Garner, 2022; Meinzen-Dick et al., 2019) (see figure 2). Agency is defined in the framework as an individual's ability and freedom to make decisions that achieve goals (instrumental agency), their ability to achieve shared interests through collective action (collective agency), their internal sense of freedom from restriction, self-respect, and self-efficacy (intrinsic agency).

The conceptual framework illustrates a bidirectional relationship between irrigation intervention and empowerment outcomes (Bryan and Garner, 2022; Meinzen-Dick et al., 2019). Empowerment influences adoption of irrigation and irrigation also affects changes in empowerment. That is, women's ability to adopt and use small-scale irrigation depends on: 1) their access to productive resources, like land, water and other agricultural inputs, 2) their ability to exercise various types of agencies (intrinsic, instrumental and collective), and 3) the institutional environment (or opportunity structure) that governs their behaviour awithin different gendered farming and livelihood systems (Bryan and Garner, 2022).

Once adopted, small-scale irrigation can increase well-being achievements through several pathways, such as changes in income, changes in food security, and changes in women's empowerment. Irrigation affects women empowerment by providing women with economic opportunities through participation in irrigation activities, increasing decision-making power and increased income and involvement community leadership roles. Even though there are different channels through which irrigation affects women's empowerment, evidence shows that the effects are not only limited to the direct channels such as control of resources and productive assets. A qualitative study by (Bryan and Garner, 2022) indicated that irrigation affects women empowerment through indirect ways such as reduced labor burden in

agriculture, particularly in irrigated production. This study also finds that resource constraints related to irrigated land deter women from practicing irrigation.

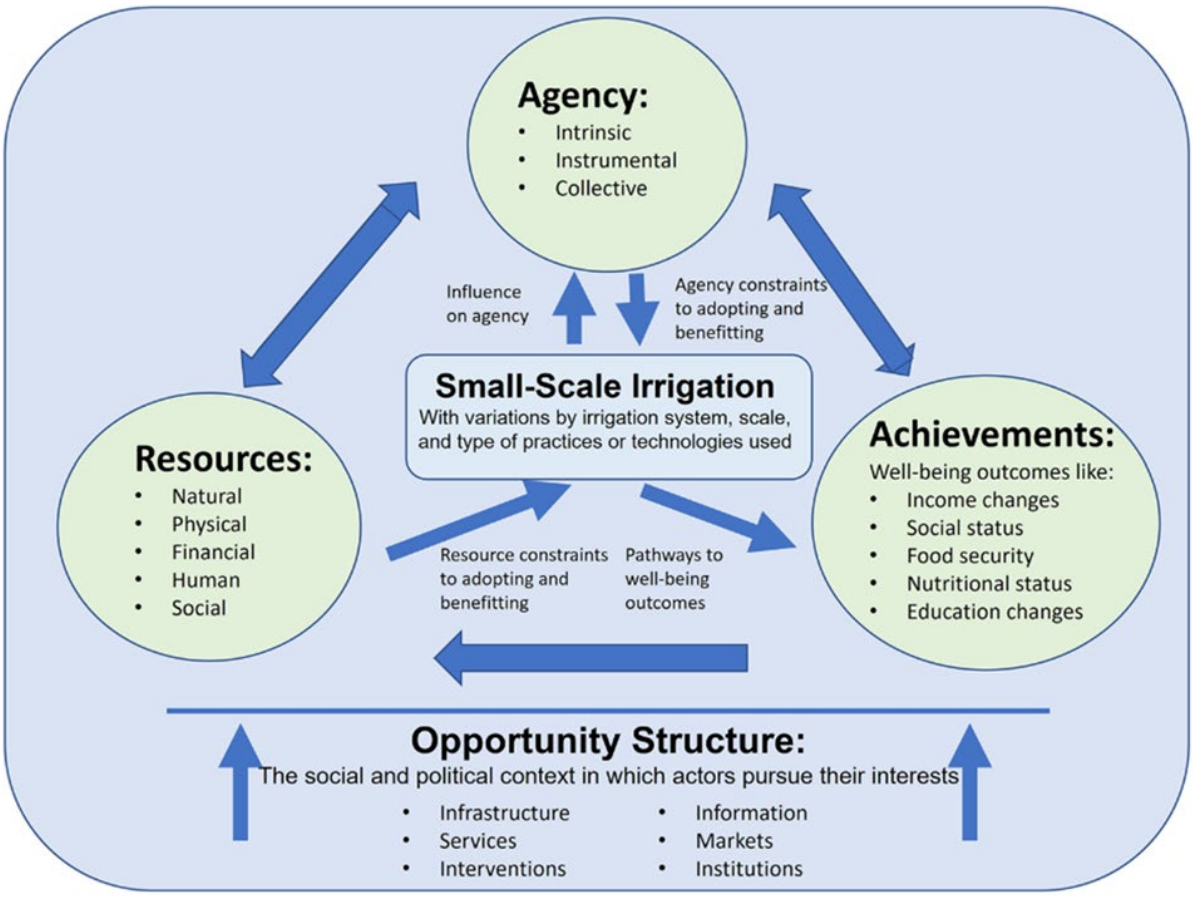


Figure 2. Framework for Small-Scale Irrigation and Women's Empowerment (Adapted from Bryan and Garner, 2022).

4. Empirical context

4.1 Policy Context

Ethiopia is endowed with high water resources potential, encompassing mainly 12 river basins. The Ethiopian Nile (Abbay) River Basin constitutes the largest basin and includes lakes and major primary and secondary tributaries. Agriculture, which contributes about 35.45% of GDP (Plecher, H., 2020) and employs 67% of the population (World Bank, 2021), is the mainstay of the Ethiopian economy. The economy has experienced rapid growth for about over a decade since 2005/06 which has been driven by aggressive public investments in agriculture,

infrastructure and rural services and the subsequent substantial increase in cereal yields of smallholders.

The country has considerable potential for irrigation which is estimated to be about 4.3 million hectares of land (Moreda T., 2017). And agriculture is dominated by smallholder farming which makes up 95% of total production (CSA, 2021) and it has largely a rain fed farming system and consequently is vulnerable to rainfall uncertainties. In its effort to reduce rainfall risks and increase crop production, ensure food security and reduce poverty, the government prioritized expansion of irrigated areas in its agricultural policy and investment framework for the period between 2010 and 2020 (Demese et al., 2010). By then, for example, only about 5% of the cultivated land in Ethiopia was irrigated with traditional forms of small-scale irrigation schemes (hand-dug wells and buckets) included (Awulachew et al., 2010). Besides the agricultural policy and investment framework (2010-2020), investment in irrigation has been targeted in the second Growth and Transformation Plan (GTP II, 2015-2020) and comprised the largest share of the total budget of $582 million of the Agricultural Growth program (National Planning Commission, 2015). In the GTP II, the government set a target of 4.1 million hectares of irrigated land by small-scale irrigation schemes and approximately 658,000 to 954,000 hectares by medium and large-scale irrigation schemes. Irrigation continues as a key strategy in the 10 years perspective development plan of the country (Plan and development commission, 2020).

The government has also made an effort for equitable distribution of land across gender in some parts of the country, which include Amhara region. For example, in the 1995 Federal constitution women and men have equal rights with respect to the use, transfer, administration and control of land. It also guarantees that women shall enjoy equal treatment in the inheritance of property. Despite the effort, studies and government documents show that rural women in general and female-headed households in particular have less control over land and are less empowered on the ground. This relates to household structures as male are more likely to be the head and they make the major decisions in the household. When females are the head of the household, most of the time due to divorce or widows, they are more likely to rent out their land due to lack of capitals (oxen, farmer and other inputs). However, the benefit from the land market is also biased against women. Evidence indicates that there is a systematic productivity difference between land of female and male owned lands. As female landlords face higher transaction costs in the land rental markets and have larger difficulties in searching and finding more efficient tenants, there are differences in the productivity across female and male owned

lands (Bezabih and Holden, 2006). Therefore, access to irrigation is expected to close this gap and increase female empowerment not only in the household but also in their community.

4.2 Project context

Megech River is one of the many rivers found in Lake Tana, Sub-Basin of the Abbay Basin, and was identified as potentially suitable for the development of irrigation in the area. However, irrigated agricultural practices have been developed only to a limited extent. For example, in 2015/2016 crop year, the total irrigated land was 2,740 hectares. The major crops grown under the irrigated system of production are bananas, papayas, tomatoes, onions, peppers, black cumin, white cumin, potatoes and cereals (Dembia Woreda Rural Development and Agriculture Office, 2016).

The Megech Pump Irrigation and Drainage Project (MPIDP) was initiated within the framework of the Ethiopian-Nile Irrigation and Drainage Project and suggested as the first phase in the Abbay River Basin Master Plan. The project is situated in East and West Dembia districts, Central Gondar Zone, Amhara National Regional State, Ethiopia. The area is located to the southwest of Gonder town, at a distance of about 60 km. The project is on the lake plain, begins at a point about 15 km north of the lake, where the river breaks out of the steep canyon area into the lake plain. The irrigation water is pumped from Lake Tana using a contour main canal extending up to the Old Megech River. The main objective of the MPIDP is to develop small-medium- and large-scale irrigation for food security and food self-sufficiency at household and national level as well as for producing industrial raw materials and crops for export.

The project command area (PCA), which is estimated to be some 5, 254 hectares, covers eight kebeles (Seraba-Dabelo, Achera, Debir-Zuria, Aberjeha, Arebia, Guramba – Bata, Janguwa, Chanker). The project is designed to cover 5,281 households or 31,686 people. The PCAproduced almost all categories of crops except for the fiber crops (cotton, sisal, etc.), more than 19 types of crops are produced, mostly field crops (cereals and pulses), but also fruits and oilseeds. According to the project feasibility study, the distribution of production among crop groups before the introduction of the irrigation project is dominated by cereal production (66.4%). Cereal production is followed by Pulses (19.8%), Vegetables (6.9%), and Oilseeds (0.9%) (Dembia Woreda Rural Development and Agriculture Office, 2016). Farmers in PCA have been producing a variety of horticultural and field crops under traditional irrigation for a long time; however, the area coverage and management level are far below those required to

significantly impact the development of crop production. Based on the feasibility study result, among products produced vegetables have high yield in any anticipated scenarios. Farmers use furrow irrigation in the production of nutritious products such as vegetables and row planted stalk crops, and border and flood irrigation for other broadcast crops.

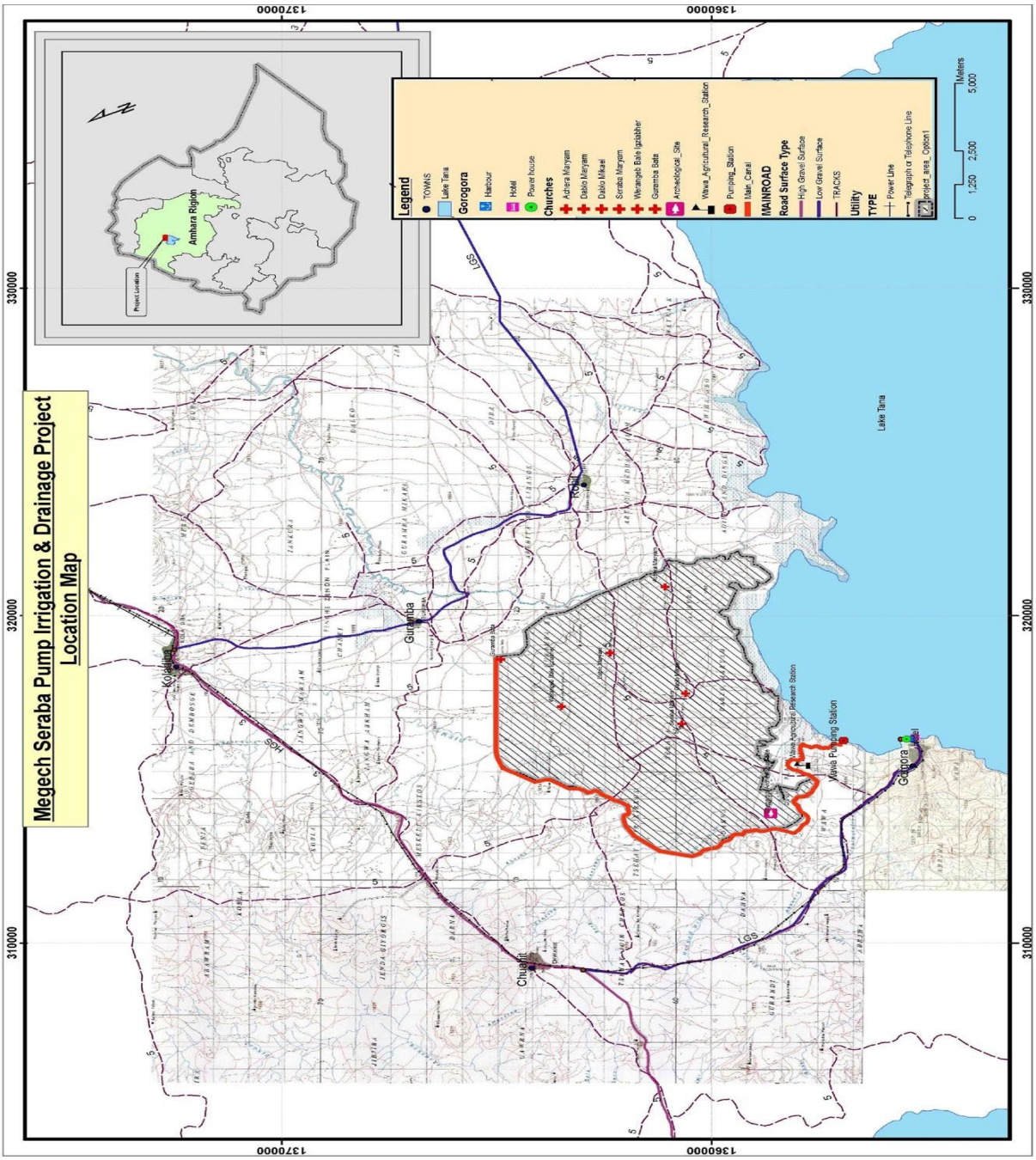


Figure 3. Location Map of Megech Pump Irrigation and Drainage Project (MPIDP)

Similarly, women in the command area are found to be industrious but they receive less recognition and are less empowered in terms of possessing their own wealth and productive assets, such as land and capital and do not have a voice in decision-making processes (Dembia Woreda Rural Development and Agriculture Office, 2016). Females generally work both in the house and in the field for a total of 14.22 hours every day, while males work 11.49 hours (Dembia Woreda Rural Development and Agriculture Office, 2016). Given the findings from the project feasibility study, it is expected that access to irrigation may bring significant benefits to females.

5. Sampling and Data

We capitalized on the spatial discontinuity in irrigation access created by the command area and employed a randomized sampling method for nearby plots. Initially, we established a uniform grid of points across the catchment area at a 30-meter resolution. From this grid, we randomly selected points, restricting the sample within 800 meters of the command area boundary to ensure sufficient density at the discontinuity. We excluded sample points within 10 meters of each other to avoid undue proximity.

Subsequently, field visits were conducted to identify the sample plots and the cultivators associated with each plot. The plot selected or the closest to the selected point was first identified, and then the owner of this plot was determined. With assistance from a local administrator, relevant information such as the cultivator's name, contact details, and plot description was recorded.

The list of households generated through this procedure constitutes our main sample households. For each cultivator, we formed sample plots by randomly selecting from the identified plots obtained through the grid points. In the empirical analysis, we will limit the sample plots based on the presence of a viable boundary of cultivable land both inside and outside the command area of the irrigation project.

5.1 Data

We conducted a household survey involving 792 spatially sampled households from May 1 to May 22.[2] Within each household, we privately or separately interviewed adult female and male

[2] In April 2023, we conducted pilot testing across the selected kebeles.

respondents, including their spouses or partners. Among the surveyed households, 684 had both male and female respondents, while 108 households had female-only respondents. The comprehensive survey collected detailed information on various aspects, including agricultural production during both the dry and rainy seasons, access to irrigation, demographics, household food security, nutrition, household assets, and livestock. Additionally, we administered the Women's Empowerment in Agriculture Index (WEAI) module, which covered topics such as participation in decision-making, income-generating activities, participation in local social institutions, attitudes towards domestic violence, and time use. While all questions in the WEAI module are posed for both men and women, questions related with household and child nutrition sections of the WEAI module are exclusively directed to women. In contrast, questions related with household level information, including agricultural production, livestock, assets and food security questions, are presented to the household head.

In addition to the household survey, we conducted a series of focus group discussions (FGDs) and key informant interviews (KIIs). For the study, a total of 12 FGDs were carried out, involving both female and male farmers. These FGDs included mixed groups with both female and male participants, as well as female-only groups. Additionally, we conducted 18 in-depth interviews with selected households and district officials and 6 KIIs. The FGDs were facilitated by experienced supervisors skilled in qualitative research and data collection, along with local facilitators directly supervised by the authors of the paper. The selection of villages and participants was made with the assistance of local facilitators. Each FGD consisted of seven to nine participants.

Table 1. Demographic characteristics of respondents, %

	Male	Female	Total
Age group			
18-25	11.0	7.3	9.0
26-45	26.4	48.5	38.3
46-65	45.3	34.4	39.5
>65	17.3	9.7	13.2
Education			
Never attended school	50.0	79.8	66.0
Less than primary	23.6	3.8	12.9
Primary	18.6	11.5	14.8
Secondary	5.4	3.4	4.3
Undergraduate or higher	2.3	1.5	1.9
Marital status			
Married	83.1	74.0	78.2

Unmarried (never married)	13.5	3.3	8.0
Unmarried (Previously married)	3.4	22.7	13.8

Source: own calculations using data from the household survey.

Measure of outcome variables

Women's Empowerment: To measure women's empowerment, we adopt the project level Women Empowerment in Agriculture Index (WEAI) as in Ragasa et al. (2020). The Women Empowerment in Agriculture Index (WEAI) measures the empowerment, agency, and inclusion of women in the agricultural sector, and it is a widely used index in empirical studies to measure women's empowerment (Alkire et al., 2013). The WEAI was initially developed as a monitoring and evaluation (M&E) tool for the US Government's Feed the Future (FTF) initiative to track changes in women's empowerment in agriculture over time and assess differences across countries, regions, and population subgroups. Since then, the WEAI methodology has gone through various improvements and adaptations by researchers and practitioners. A project level WEAI (pro-WEAI) is one that is developed based on the original WEAI. Pro-WEAI is a survey-based tool aimed to measure the impact of a given agricultural development project on women's and men's empowerment. (Malapit et al., 2019).

The pro-WEAI enables direct comparison between women and men in the same household. The index consists of two subindices: the Three Domains of Empowerment index (3DE) and the Gender Parity Index (GPI). The 3DE aggregates women's and men's achievements across 12 equally weighted indicators that measure three types of agencies: intrinsic, instrumental, and collective. Indicators of intrinsic agency are autonomy in income, self-efficacy, attitudes about intimate partner violence (IPV) against women, and respect among household members; indicators of instrumental agency are input in productive decisions, ownership of land and other assets, control over use of income, access to and decisions on financial services, freedom of movement and work balance; and indicators of collective agency are group membership and membership in influential groups. The GPI compares the achievements of women and men in the same household (for dual-adult households only). Following Ragasa et al. (2020), in this study we will use pro-WEAI to measure the differential impact of traditional and modern irrigation schemes on women's empowerment.

Nutrition diets: To measure nutrition security, we use the Household Dietary Diversity Score (HDDS) which is a diet quality indicator measured based on the number of food groups consumed by a household over the previous 24 hours recall period (Hendriks et al., 2016;

FANTA, 2006). The HDDS measure of household food access comprises 12 food groups (Bilinsky & Swindale, 2010) and has strong associations with micro- and macronutrient adequacy (Ruel, 2003). While HDDS does not measure nutritional outcomes directly, it is a commonly used, well-understood, and well-validated measure that captures an intermediary step between food availability and nutritional status at the household level.

6. Empirical strategy

The impact of access to irrigation on empowerment and nutrition outcomes are measured using indicators and sub-indicators of the pro-WEAI. Our empirical strategy is to use a regression discontinuity design leveraging a spatial discontinuity in access to irrigation following Jones et al. (2022) and Duflo and Pande (2007). The topographical set up of the project command area (PCA) and construction of the main canal provides a unique context for our identification strategy (see Fig.1). The irrigation project is introduced to the existing farming area where, due to the natural topography, only farmers to the right sides of the main canal have access to irrigation water. The main canal is constructed along the mountainous, steep slopes in the southwestern and western parts with a maximum elevation in the western (1,900 m amsl) and northern (1975m) parts. Hence, plots to the right side of the command area boundary (main canal) are just below the canal and have access to irrigation water while plots to the left are just above the canal and do not have access to irrigation water. Our main estimating equation is:

$$\boldsymbol{y_i^h} = \beta_1 CA_i^h + \beta_2 D_i^h + \beta_3 CA_i^h * D_i^h + \delta X_i^h + \alpha L_i^h + \varepsilon_i^h$$

Where, y_i^p is outcome y for member $\boldsymbol{h}$ of household i, $\boldsymbol{CA_i^h}$ is an indicator for individual $\boldsymbol{h}$ being in the project command area, $\boldsymbol{D_i^h}$ is the distance of the sample household from the command area boundary which would be positive for households with plots inside the command area and negative for those outside the command area, and $\boldsymbol{X_{is}^h}$ is the household characteristics and L_i^h is plot characteristics. Hence, we will control for plot characteristics in our empirical model (e.g., area of sample plots). ε_i is robust standard errors. Our coefficient of interest is β_1, the effect of the command area on outcome y. We explore production decisions for the observed effect.

The key problem here will be the endogeneity between the outcome and the assignment of the treatment. Comparing these two groups, however, is not an issue in the RDD model (Hahn, Todd, and Van der Klaauw, 2001). The basic idea in regression discontinuity is that the

endogenous component of the error, ε_i, is similar in expectation as we approach the eligibility threshold. The difficulty in capturing and defining this relationship is that understanding ε is inherently a theoretical exercise since ε is defined by all the information not captured by x. Therefore, we emphasize that defining the source of endogeneity and determining an appropriate remedy must always be accompanied by a theoretical rationale of variables or events that will cause x to be related to ε.

7. Results

7.1 Descriptive results

In this section, we present results of the outcomes derived from women's empowerment, employing the robust pro-WEAI indicators as our analytical framework. Focusing specifically on the impact of irrigation, we examine how access to irrigation affects women empowerment in the study area. By analyzing individual empowerment indicators, we aim to uncover tangible improvements that have manifested in the lives of women. Furthermore, we investigate the impact of access to irrigation on the nutritional well-being of smallholder farmers, affording us a comprehensive understanding of how irrigation resonates throughout the community, ultimately shaping its overall welfare. This comprehensive analysis serves to shed light on the multifaceted impact of irrigation on women's lives and the broader socio-economic landscape.

The women empowerment is measured by classifying each respondent in pro-WEAI as either adequate or inadequate in a given indicator based on their response (see Table A3). The empowerment score of an individual is determined as a weighted average of their adequacy scores across the 12 indicators. Individual with a score of 75% or higher are classified as empowered, while those with a score below 75% are classified as disempowered. This individual level scores are then aggregated to construct the pro-WEAI.

Table 2 presents the pro-WEAI results, differentiation between households with and with out access to irrigation. The result reveals some insight into gender disparities within these contexts. Among non-irrigators, the aggregate pro-WEAI score for women is 0.82. While, in irrigator household, the pro-WEAI score for women was slightly higher at 0.83 indicating a marginal improved situation. The aggregate pro-WEAI score is the weighted average of 3DE score for women and the gender parity index (GPI).

Table 2. Women empowerment in Agriculture index (Pro-WEAI) results

Indicator	Non-irrigators		Irrigators	
	Women	Men	Women	Men
Number of observations	314	276	334	296
3DE score	0.81	0.9	0.82	0.89
Disempowerment score (1 – 3DE)	0.19	0.10	0.18	0.11
% achieving empowerment	0.57	0.74	0.58	0.72
% not achieving empowerment	0.43	0.26	0.42	0.28
Mean 3DE score for not yet empowered	0.57	0.61	0.57	0.59
Mean disempowerment score (1 – 3DE)	0.43	0.39	0.43	0.41
Gender Parity Index (GPI)	0.92		0.93	
Number of dual-adult households	276		296	
% achieving gender parity	0.65		0.68	
% not achieving gender parity	0.35		0.32	
Average empowerment gap	0.22		0.22	
Pro-WEAI score	0.82		0.83	

Source: own elaboration based on survey data.

The pro-WEAI analysis provides further insight into the empowerment dynamics within both non-irrigators and irrigator households. Among non-irrigators, approximately 57% of women are empowered, a figure that slightly increases to 58% in irrigators households. This indicates a marginal improvement in empowerment level of women in households with access to irrigation. However, a notable disparity emerges when examining male empowerment. Among non-irrigators, 74% of men are considered empowered, whereas in irrigator, the figures slightly drop to 72%.

Among the women identified as disempowered, there is similarity in the mean adequacy score, which is 0.57 for both irrigator and non-irrigator. This indicates that, on average, these women achieve adequacy in 57 percent of the indicators. This similarity in the adequacy score indicates a shared experience of marginalization and limited access to resources as we all as participation in decision making among these women, irrespective of their involvement in irrigation activities. In contrast, disempowered men demonstrate different level of adequacy score. Among those who do not engage in irrigation, they attain adequacy in an average of 61 percent of the indicators, whereas the irrigators achieve adequacy in an average 59 percent of the indicators.

Looking at the gender parity index (GPI), it becomes clear that the GPI is approximately 0.92 for non-irrigators and 0.93 for irrigators. This implies the presence of higher inequality in empowerment levels between men and women within the same household. Specifically, when examining women who do not achieve gender parity, the disparity is more pronounced. On

average, these women face an empowerment gap of 22 in comparison to the men in their households. This means that, within these households' women are systematically disadvantaged in terms of their agency, access to resources, and ability to participate in main decision-making processes.

The pro-WEAI results provides a comprehensive analysis of disempowered individuals, enabling us to assess their level of adequacy across various indicator. For this purpose, we use the censored head count ratio, which measures the percentage of individuals who are identified both as disempowered and inadequate in each indicator. This allows us to gain insights into the extent of inadequacy experienced within each indicator, facilitating targeted intervention and policy recommendation to improve the empowerment level of marginalized communities.

Table 3 presents the proportion of respondents who are disempowered and inadequate in a given indicator (the headcount ratio) and contribution to disempowerment. The results suggest significant gender disparities in empowerment. It is evident that a greater percentage of women, in comparison to men, face inadequacy across all indicators, except for involvement in productive use and control over use of income. For individuals not engaged in irrigation practices, the most pronounced gap in adequacy between gender is observed in factors related to autonomy in income, self-efficacy, and work balance. In contrast, among those involved in irrigation, the most notable gap in adequacy pertains to autonomy in income, self-efficacy, and attitudes about domestic violence. These result highlight specific areas where targeted intervention for gender empowerment may yield the most substantial impact.

Table 3. Headcount ratio and relative contribution of each indicator to disempowerment (%)

	Censored headcount ratio (%)				Proportional contributions to disempowerment (%)			
	Non-irrigators		Irrigators		Non-irrigators		Irrigators	
Indicator	Men	Women	Men	Women	Men	Women	Men	Women
Autonomy in income	18.9	35.0	16.7	38.5	14.0	16.3	13.7	17.2
Self-efficacy	9.8	22.8	8.0	20.1	7.2	10.6	6.5	8.9
Attitudes about domestic violence	14.2	24.0	9.1	22.9	10.5	11.2	7.4	10.2
Respect among HH members	12.8	20.1	9.4	19.4	9.5	9.4	7.7	8.7
Input in productive decisions	14.9	12.6	14.5	14.6	11.0	5.9	11.9	6.5
Ownership of land and other assets	4.1	5.1	3.6	8.6	3.0	2.4	3.0	3.8
Access to and decisions on financial services	6.8	13.5	9.1	17.2	5.0	6.3	7.4	7.7
Control over use of income	15.2	12.0	14.1	12.4	11.2	5.6	11.6	5.5
Work balance	10.8	21.0	13.4	22.9	8.0	9.8	11.0	10.2
Visiting important locations	11.8	19.8	12.0	20.4	8.7	9.2	9.8	9.1
Group membership	7.1	11.7	4.7	9.6	5.2	5.4	3.9	4.3

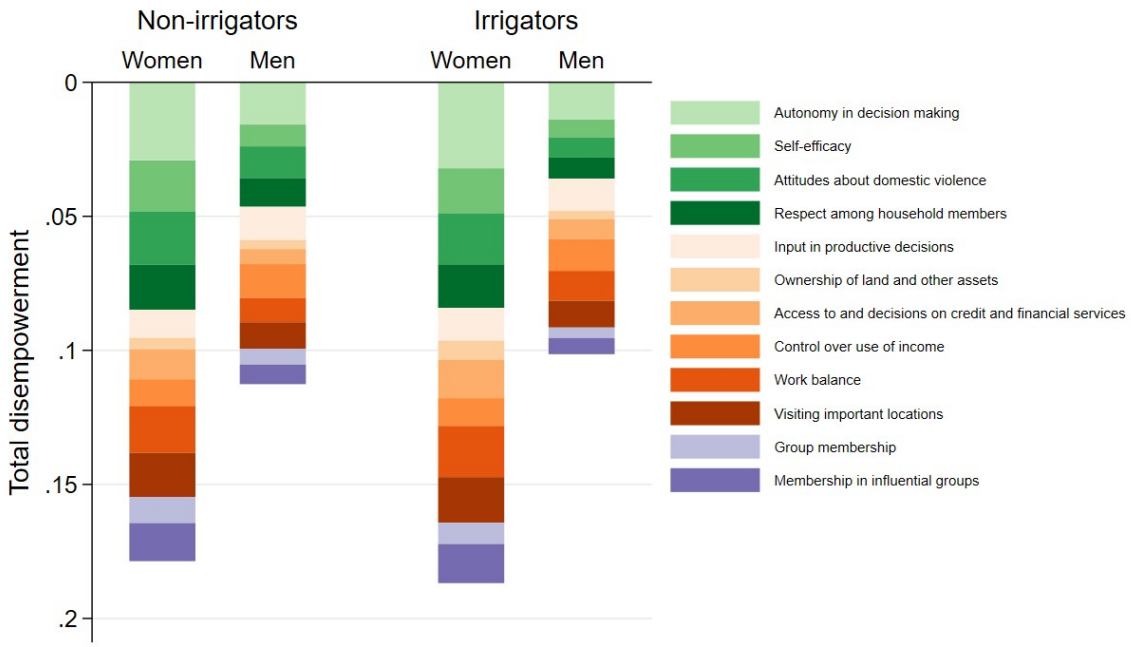
Membership in influential groups	8.8	17.1	7.2	17.5	6.5	8.0	6.0	7.8

Notes: The Headcount ratio is the proportion of respondents who are disempowered and inadequate in a given indicator. Source: own elaboration based on survey data.

Analyzing proportional contribution of each indicator to disempowerment provides crucial insights into the dynamics of empowerment dynamics. This process helps in the identification of key factors that significantly influence the level of disempowerment. It essentially shows the extent to which each indicator contributes to disempowerment among individuals who have not achieved empowerment. The finding indicates that the main factors contributing to women's disempowerment revolve around their autonomy in income, attitudes about domestic violence and work balance. These indicators collectively play a significant role in limiting women's agency and decision-making power in various aspects of their lives. In contrast, in the case of men, the most contributors of disempowerment revolve around their autonomy in income, input in productive decisions, and control over use of income.

Figure 4 illustrates the absolute contribution of each indicator to disempowerment, which disaggregate the 3DE score into the contributions to disempowerment across the groups by gender. The results confirm that, for women in both irrigator and non-irrigator groups, the largest contributors to disempowerment are autonomy in income and attitude about domestic violence within the intrinsic agency domain. Additionally, within the instrumental agency domain, work balance emerges a significant factor contributing to disempowerment. These findings underscore the critical importance of addressing these specific areas to promote empowerment and advance gender equality within these communities.

Figure 4. Contribution of each indicator to disempowerment



Based on the analysis of intrahousehold empowerment patterns, our study focused on data obtained from both male and female adults residing in dual-adult households. The findings, as presented in *Table 4*, reveal a notable trend; in the majority of dual-adult households, men (on average 58 and 59) are adequate in more indicators compared to women, in both irrigators and non-irrigators, respectively. In contrast, it is worth noting that women demonstrate adequacy in more indicators than the man. Specifically, in 23 percent of non-irrigator households and 19 percent of irrigator households, women are adequate in more indicators than men. Further, 19 and 20 percent of households within the two groups, the man and woman are equally adequate.

Examining the empowerment levels in dual-adult households based on gender reveals significant disparities. In both irrigators and non-irrigators, a striking 17 percent of dual-adult households witnessed neither the man nor the woman achieved empowerment. This finding contrast with the overall sample, where the majority of women (43 percent) and men (around 26 percent) experience disempowerment. In addition, within the dual-adult households, around 25 percent of non-irrigators and 26 percent irrigator households exhibits a scenario where only men are empowered. In contrast, around 11 percent of non-irrigators and 8 percent of irrigator households witness only women achieving empowerment.

Table 4. Intrahousehold patterns of empowerment, %

	% of dual-adult households	
	Non-irrigators	Irrigators
Male adequacy score > female adequacy score	58.4	58.6

Female adequacy score > male adequacy score	22.9	21.0
Female adequacy score = male adequacy score	18.7	20.3
Only male is empowered	24.7	25.7
Only female is empowered	10.8	8.3
Both male and female are empowered	47.6	48.6
Neither male nor female are empowered	16.9	17.4

Source: own elaboration based on survey data.

7.2 Regression results

7.2.1 Impact on women's empowerment

Table 5 and Table 6 depict the findings of the study. The results indicate that access to irrigation does not have a significant impact on the overall empowerment of both women and men, nor does it significantly affect gender parity among the beneficiaries. It is noteworthy that, across various pro-WEAI indicators, the empowerment levels in both the treatment and control groups are already relatively high in the study area.

Analyzing the specific indicators of empowerment yields limited evidence of the influence of irrigation access on women and men, with a few exceptions. Notably, access to irrigation appears to enhance women's likelihood of achieving empowerment in terms of input in productive decisions and access to financial services, which serves as an instrumental agency measure. This suggests that the program has been effective in fostering cooperation and influencing household decisions related to production and financial matters. However, caution is advised in interpreting the results concerning decision-making, as households led solely by female decision-makers are more likely to be identified as empowered (Alkire et al., 201). Conversely, there is a notable decrease in some individual empowerment indicators, particularly in terms of respect among household members and self-efficacy. Turning to men's empowerment, we observe that access to irrigation leads to an increase in self-efficacy, but it is accompanied by a decrease in group membership empowerment. This suggests that men who have access to irrigation might dedicate additional time to agricultural tasks, given the demanding nature of the irrigation program.

Table 5. Impact of irrigation program on women empowerment

	Women		Men	
Indicators	Coef.	se	Coef.	se
Autonomy in income	-0.052	(0.032)	-0.029	(0.082)
Self-efficacy	-0.130**	(0.053)	0.127***	(0.038)

Attitudes about IPV	-0.072	(0.050)	-0.055	(0.065)
Respect among household members	-0.170**	(0.077)	-0.096	(0.076)
Input in productive decisions	0.098**	(0.043)	-0.021	(0.050)
Ownership of land and other assets	-0.016	(0.030)	0.007	(0.038)
Access to and decisions on financial services	0.095*	(0.054)	-0.003	(0.039)
Control over use of income	0.010	(0.050)	0.005	(0.050)
Work balance	-0.066	(0.052)	0.051	(0.075)
Visiting important locations	0.078	(0.057)	-0.018	(0.049)
Group membership	-0.056	(0.040)	-0.084**	(0.039)
Membership in influential groups	-0.023	(0.048)	-0.062	(0.051)
Empowered	-0.021	(0.055)	0.038	(0.075)

Note: number of observations is 799 female and 660 males. *** p<0.01, ** p<0.05, * p<0.1. Each row is a separate regression (using each indicator as a dependent variable) and include control variables. Source: own elaboration based on survey data.

7.2.2 Impact on nutrition

Irrigation provides another avenue to enhance household nutrition by increasing food production and availability. Smallholder farmers gain the capacity to cultivate crops two or even three times annually with access to irrigation. This allows for increased yields and a wider variety of crops due to the higher frequency of harvests, particularly during dry or lean seasons. To test whether access to irrigation increased nutrition outcomes of the beneficiaries, we first estimate whether it increased dry-season crop production and then examine ethe impact on household dietary diversity score (HDDS). The findings indicate that access to irrigation facilitates crop cultivation even in dry season, leading to a substantial increase for farmers employing this technique. Households equipped with irrigation are 74 percent more likely to experience this advantage compared to those without access to irrigation.

This study investigated the potential link between irrigation and nutrition. The findings indicate that having access to irrigation does not seem to significantly enhance nutrition outcomes. There could be several factors contributing to the lack of strong association between irrigation and nutrition in this context. One possibility is that if irrigation leads to monocropping farming practices, it could potentially have adverse effects on nutrition. For example, Namara et al. (2011) found no significant difference in dietary diversity between households with and without access to irrigation in Ghana. In contrast, in Bangladesh, Hossain et al. (2005) observed a decrease in dietary diversity among the poorest households, despite the increase in rice

production due to small-scale irrigation. While it is anticipated that irrigation would positively influence nutrition by facilitating the cultivation of a wider variety of crops, such as vegetables during the dry season for smallholder farmers, this may not always be the case. This is especially evident in Ethiopia, where the government's initiative to increase wheat production through widespread planting campaigns means that all land with access to irrigation is directed towards wheat cultivation.

Table 6. Impact of irrigation program on household dietary diversity

VARIABLES	(1) Dry-season production	(2) HDDS	(3) HDDS
Access irrigation	0.742***	-0.158	-0.325
	(0.028)	(0.144)	(0.218)
Female household head	-0.057	-0.302	-0.289
	(0.043)	(0.217)	(0.216)
Household size	0.005	0.096***	0.095***
	(0.007)	(0.036)	(0.036)
Marital status	0.007	0.088	0.086
	(0.026)	(0.134)	(0.133)
Highest education level	-0.005	0.654*	0.655*
	(0.062)	(0.357)	(0.357)
Farm size	-0.002	-0.006	-0.006
	(0.002)	(0.008)	(0.008)
Dry-season production			0.225
			(0.219)
Constant	0.132	5.365***	5.335***
	(0.100)	(0.530)	(0.529)
Observations	691	691	691

Notes: Source: own elaboration based on survey data.

Another potential factor is the influence that irrigation may have on local communities, such as the increased availability of food, the employment opportunities generated by irrigation schemes, and its effects on food prices. Since irrigated land demands more labor, it can potentially lead to agricultural job opportunities for local workers (Aseyehegn et al., 2012), offering them income-generating opportunities. In addition to the potential rise in income from wage labor, a significant portion of the produced vegetables are sold in the local market, ensuring food accessibility within the community (Nkonya et al., 2011). Additionally, this increased availability of food products may lead to reduced prices, further benefiting the community. Hence, evaluating the causal impact of irrigation access on household-level

outcomes in local communities, especially when comparing irrigators to non-irrigators, can be challenging due to these various factors at play.

Finally, this study focuses on smallholder farmers, and the timing of the household survey could potentially impact the measured nutrition outcomes. The household diversity refers to the variety of food consumed within the past 24 hours. Hence, the diversity of diets is likely to be impacted by the variety of crops accessible during the survey period, given that our data was gathered during the planting season. Smallholder farmers in developing country often face challenges in maintaining consistent access to a diverse range of food throughout the year. While they may be able to cultivate a variety of crops and vegetables during the harvest season, factors such as limited storage facilities, lack of access to markets, and seasonal variations in weather can make it difficult to sustain this diversity beyond the harvest period. This can lead to periods of food scarcity or reliance on a limited range of staples, which can have negative impacts on the nutritional quality of their diets. Finding sustainable solutions to extend the availability of diverse and nutritious food options for smallholder farmers is crucial for improving their food security and overall well-being. This may involve interventions such as improved post-harvest storage techniques, better market access, access to market and price information, and support for diversification of crops.

7.3 Findings from qualitative data

We turn to qualitative data to understand the dynamics and level of empowerment in the study area and clearly. The results from the qualitative data collection are presented by the different agency domains and indicators.

Decision making on income and autonomy. According to the participants, both spouses are involved in the decision-making process. However, it was noted that there are differences in their ultimate role in the process. Based on the interview findings, it is evident that women experience limited control over use of income and autonomy in decision-making process. Even when women perform equally to men, they perceive themselves as having minimal influence in the final decision-making process. Moreover, the community's cultural norms further restrict women's participation in these crucial determinations. While women do contribute their insights to the decision-making process, ultimate approval is typically reserved for men. Additionally, women often lack control over the income generated.

"...we (husband and wife) discuss together about what to buy, what to sell and how to use the income generated from the sales. We make decisions mutually about what to sell and what to change. For example, if we have a fattened bull, we feed it more, and if we are in trouble, we sell that bull and buy another one at a lower price. We manage our house with the remaining money. However, the final decision maker is always the husband…"

To explain the dynamics of decision-making participants used the saying in Amharic, which closely translates to "to whatever extent women are capable, men have the final say." This adage sheds light on the prevailing gender dynamics in certain households. Despite women in these households earning substantial incomes, women still had limited authority in decision-making compared to men, despite their contributions and capabilities equalled those of their male counterparts. This discrepancy highlights a deep-seated societal bias that persists despite the progress in economic empowerment for women. It underscores the need for a broader shift in attitudes and beliefs surrounding gender roles and responsibilities. Recognizing and valuing the capabilities of women, not just in terms of financial contributions but in all aspects of life, is crucial for achieving true gender equality. It's a reminder that true empowerment goes beyond economic independence; it encompasses the recognition of women's agency, voice, and influence in decision-making processes within families and communities.

"...If a man/husband is not diligent in his work, the woman hastened to support her family. If a woman works like men, then she is said to be "superior to women; inferior to men"..."

This study's findings align with prior research in this area. Gaddis et al. (2018) discovered significant disparities between men and women regarding ownership, utilization, and authority over assets throughout Africa. Similarly, studies conducted by Njuki et al. (2014) in Tanzania and Alkire et al. (2013) in Uganda affirmed that while women are actively involved in all aspects of agricultural activities, their authority and influence over income-related decisions are notably lower compared to men.

The limited or absent influence of women in matters concerning income source and utilization may be rooted in the established normative laws of the community. As illustrated in a study by Karimli et al. (2021), economic interventions alone may not be sufficient to substantially enhance women's decision-making power. This underscores the importance of considering the

socio-cultural context of the community when designing interventions. To effectively promote women's empowerment and achieve gender equality, programs must be seamlessly integrated with the local context. This approach will likely yield more impactful and sustainable outcomes.

Work Balance: rural women bear the weight of household chores and agricultural tasks. According to participants:

> *"...Women spent most of their time in household chores (cooking, baking, collecting water and firewood, kitchen routines, cleaning, care of children, spinning cotton, and preparing local beer). In addition to domestic work, they also participate in agricultural activities (weeding, threshing, harvesting, etc.). Women get up in the morning, cook and feed the family. Then they go out for farming. And at night they again cook and feed the family. Life is miserable for them…"*

The result from the qualitative interview suggests that women in the community are doubly burdened, juggling between household chores and farming responsibilities. They manage household tasks alone, and work alongside their husbands in the fields. Their rest is often compromised as they return home to the demands of cooking for the family and caring to their children. Surprisingly, women dedicating the bulk of their time to household responsibilities are occasionally characterized as "non-working." It is important to consider that in Ethiopia, the winter season sees a rise in social gatherings, adding even more pressure on women's schedules. This points to the fact that the irrigation season, which aligns with many of these events, becomes an especially demanding period for women. It underscores a substantial convergence in women's roles, encompassing both domestic tasks and agricultural endeavours, a balance less frequently observed among men. The combined workload of women, encompassing both paid and unpaid tasks, serves to disempower them. This is consistent with the findings of Malapit et al. (2013). Therefore, gaining access to irrigation may inadvertently escalate the workload of women, further diminishing their empowerment. This aligns with the observations made by Belete and Melak in 2020.

Attitudes about domestic violence. Although there has been progress in improving attitudes towards domestic violence in Ethiopia, there remains a need to further enhance understanding of the unequivocal unacceptability of such harmful behavior. For example, in the study area cultural norms still exists that downplay the seriousness of domestic violence. The qualitative

finding suggests that women themselves accept domestic violence and regarded their husbands as their protectors and symbols of honor. According to focus group participants:

> *"...Women usually consult with their husbands even to go to the market and church. How do we go without husbands' permission? Unless she is a woman who has no husband, the woman will not go to a secluded place for firewood collection. Ho! If she is seen alone in a secluded place, it is said that she is a deviant; her husband may have attack her. The community will have a negative outlook on her and call her "Naughty" who is outside the fence (her husband). A fence for a woman is her husband. And if we do not respect the rights of our husbands, our honour will be stripped away. Thus, in this community, a woman works at the behest of her husband and if there are women who decide on their own initiative, it often leads to violence ..."*

Based on our interviews, it has become evident that women in the study area face significant challenges in protecting themselves from domestic violence. Shockingly, certain forms of violence against them are not only socially accepted but even endorsed by some women themselves. Their autonomy is severely restricted, especially in terms of mobility. Without obtaining permission from their husbands, women are unable to venture far from their homes. This applies to both irrigator and non-irrigator women; any deviation from this norm is seen as grounds for spousal retribution. They are only granted freedom for basic, routine activities such as attending local funerals, visiting the village church, or having coffee with neighbours.

Previous studies in Ethiopia by Abdurashid and Tesfahun (2013) as well as Semahegn, Belachew, and Abdulahi (2013) have affirmed that women going out without informing their husbands is a significant trigger for domestic violence against women. This deeply ingrained pattern is rooted in historical and socially constructed patriarchal values. Guracho and Bifftu's systematic review and meta-analysis study in Ethiopia (2018) further substantiates this, revealing that over 50% of female participants accepted domestic violence. It has even reached the point where some women perceive physical punishment as a warped expression of love, as noted by Tilahun (2006). Given this entrenched societal framework, community norms dictating women's mobility are deeply entrenched and resistant to change, even in the face of policy interventions like irrigation projects.

Self-efficacy. The study participants underscored that, even as women are becoming more self-assured in their agricultural capabilities, there remains a prevailing reliance on men's validation, especially when it comes to pivotal decisions in agricultural activities.

> *"...A woman who makes and implements important decisions in her own way is called a prudent woman. Those women who think ahead of their annual consumption and plan a year in advance differ from men in that they do not plow land with oxen. However, women often work at the behest of her husband and there are no women who decide and act on their own initiative and without men supervision. How dare a woman work without the husband's directives…?"*

This is connected to the reality that men's extensive familiarity with crop cultivation might hinder women's engagement in decision-making concerning farming. In consideration of this, participants have shared the following perspectives:

> *"...It is the man who knows the nature of the land. Thus, only men know what to sow and where to sow. There are some women who make decisions more than their husbands but, occasionally there are those who insult the man and say that he is being surrendered by women. If there is no husband in the house and if there is a matured son, the mother will decide together with him. Therefore, women do what men dictate us to do…"*

Consequently, while there are certainly women who independently make significant decisions, men, whether the husbands or sons, play a crucial role in the decision-making process and overall life of women. It is particularly noteworthy that decisions pertaining to land matters are seldom made by women. Given that rural livelihoods are fundamentally tied to land, women may feel less assured in performing tasks vital for their sustenance. As a result, they may struggle to achieve outcomes that hold significance for their lives. These rooted attitudes could clarify the lower participation of women in paid activities. In line with this discovery, a study conducted by Tsige, M. (2019) in Ethiopia underscores that societal norms impose restrictions on women, inhibiting them from asserting their self-interest in gendered negotiations.

Input in productive decisions. Participants indicates that having access to irrigation empowers women to play a more significant role in making productive decisions. Participants

in the interviews have conveyed their experiences regarding the level of labor required for an irrigation project.

> *"...Previously, we used to sow once a year and women did not work in the fields. She used to bring water and lunch and go home, but after the irrigation started, farming has been done all year round. Now, the saying "male for outdoor activities; female for indoor activities" is gradually changing. Husband and wife become a hand and a glove…"*

The findings underscore that access to irrigation serves as a catalyst for women's active involvement in making crucial decisions. Given the demanding nature of irrigation projects and the collaborative decision-making required, women have taken part in determining which crops to cultivate, selecting seeds, and deciding on land rentals. In the study area, women predominantly focus their intensive efforts on cultivating vegetables like cabbage and red root. This aligns with the findings from a solar garden initiative in Benin, which saw an increase in women participating in fruit and vegetable production (Alaofe et al., 2016). While women's irrigated production primarily centers on smaller-scale sales of vegetables (Theis et al., 2018), often involving lower value crops (Njuki et al., 2014), their engagement in agricultural decision-making is notably higher in irrigated production compared to rainfed methods (Van Koppen, Hope, and Colenbrander, 2012).

Access to and decisions on financial services. Participants revealed the profound impact of irrigation projects on women's access to and decision-making power regarding financial services. These discussions shed light on the pivotal role that irrigation plays in enhancing economic empowerment and independence for women in rural communities.

> *"...Yeah, irrigation improves both access to and decisions on financial services. Those who have irrigated land seem to have a foreigner (diaspora relative). Non- irrigators ate what we produced and finished it in June. But irrigators are getting 20/30 quintals of grain and sales income in the off season. They deposit this extra revenue to send their children to a higher level of education and buy houses in the city. My brother, one kilo of garlic is 200/210 birr; they sell whatever they need…"*

Access to irrigation stands as a transformative force in enabling women to not only access but also assert their control over financial services. The ability to extend growing seasons and diversify crops through irrigation leads to asset accumulation and increased earnings, particularly from off-season produce sales. This influx of income provides a tangible pathway

to financial empowerment. Moreover, access to irrigated land empowers women to cultivate high-demand vegetables, further bolstering their economic standing. The result is a positive feedback loop where enhanced agricultural productivity directly translates into increased financial agency and independence for women, ultimately contributing to their broader economic inclusion and empowerment.

8. Conclusion

This study sheds light on the impacts of small-scale irrigation, emphasizing the importance of considering a wide array of outcomes beyond mere agricultural productivity. To comprehensively analyze the impact of the irrigation program on women's empowerment and nutritional outcomes, a mixed research approach was employed. This included the implementation of both household surveys and qualitative interviews. The household survey provided a quantitative lens, allowing for the collection of vital statistical data regarding factors such as income, decision-making, access to resources, and dietary habits. Simultaneously, the qualitative survey examined deeper into the lived experiences and narratives of women directly affected by the irrigation program. Through open-ended discussions and in-depth interviews, we gained valuable insights into the nuanced ways in which the program impacted their sense of agency, decision-making power, and overall well-being. This combined methodology not only enabled a comprehensive assessment of the program's effects but also allowed for a rich, contextual understanding of the dynamics at play in the lives of these women, underscoring the program's broader implications for women's empowerment and nutritional outcomes.

Results from this study suggest that while irrigation may not lead to have a significant impact on the overall empowerment levels or gender parity, it has a significant and positive contribution to instrumental agency measures. Access to irrigation enhance women's likelihood of achieving empowerment in terms of input in productive decisions and access to financial services. However, we observe a decline in certain empowerment indicators, such as in terms of respect among household members and self-efficacy, which serves as a stark reminder of the nuanced and complex nature of this matter.

While the impact of irrigation is evident, it remains on the margin of significant change. Women in irrigator households experience a marginal improvement in their empowerment levels compared to their non-irrigator counterparts. However, this advancement is tempered by the continuing gender disparities that persist. This discrepancy highlights a significant gender gap,

with men consistently exhibiting higher levels of empowerment across both types of households. These findings underscore the need for targeted interventions aimed at bolstering female empowerment, particularly in non-irrigator households, where the gender disparity is most pronounced. This reveals a concerning trend, where disempowered women, irrespective of their involvement in irrigation, face similar challenges of marginalization and restricted access to vital resources. Thus, the study also underscores the pressing need for targeted interventions that specifically address these systemic barriers.

The Gender Parity Index (GPI) also provide an insight on the significant empowerment gap that exists between men and women within the same households both in the households with and without access to irrigation. This index highlights the deep-rooted inequalities in agency, resource accessibility, and decision-making power. Women who did not achieve gender parity face a considerable disparity, illustrating a systemic disadvantage that affects their lives. This disparity is a clear indication that within these households, women continue to face barriers that impede their ability to exercise agency and participate in significant decision-making processes.

Furthermore, the finding that show the lack of significant improvement in nutritional outcomes underscores the importance of adopting a comprehensive strategy. This involve not only focusing on irrigation, but also considering factors such as crop diversification and dietary practices. This calls for policymakers to delicately balance crop production objectives with the broader goals of improving nutrition and empowerment. It emphasizes the need for a more integrated approach in the design and execution of small-scale irrigation projects, one that considers the multi-layered dimensions of women's empowerment and nutritional well-being.

To effectively address the challenges faced by marginalized communities, particularly disempowered women, there is a need to target women's agency in decision-making processes and challenging norms that perpetuate violence, these policies aim to create an environment conducive to empowerment and gender equality. Furthermore, initiatives to alleviate the burden of household chores and enhance financial access offer practical steps towards a more equitable distribution of resources and opportunities. The integration of modern irrigation technologies and advocacy for women's land rights further solidify the commitment to leveling the playing field. While more research is needed to understand the link between nutrition and irrigation, it is remains crucial to implement irrigation projects that are specifically tailored to produce substantial nutritional benefits.

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Appendix

Table A 1. Summary statistics by access to irrigation

	non-irrigators	Irrigators
Household characteristics		
Female head	0.29	0.26
Age	56.40	54.50
Marital status	0.74	0.75
Household size	5.07	5.10
HDDS	5.27	5.42
Number of children <5 age	1.31	1.38
Literate	1.61	1.59
Completed primary education	0.05	0.04
Plot characteristics		
Number of plots	2.50	2.32*
Land size	5.70	5.55
Land ownership	0.94	0.97
Land use certificate	0.91	0.92
N	380	371

Notes:

Table A 2. Uncensored Headcount rations and relative contribution of each indicator to disempowerment (%)

	Uncensored headcount ratio				proportional contributions to disempowerment			
	Non-irrigators		Irrigators		Non-irrigators		Irrigators	
Indicator	**Men**	**Women**	**Men**	**Women**	**Men**	**Women**	**Men**	**Women**
Autonomy in income	55.4	81.1	54.7	82.5	14.0	16.3	13.7	17.2
Self-efficacy	16.9	30.2	21.4	27.1	7.2	10.6	6.5	8.9
Attitudes about domestic violence	29.1	42.8	23.6	39.8	10.5	11.2	7.4	10.2
Respect among HH members	23.0	27.5	19.2	22.6	9.5	9.4	7.7	8.7
Input in productive decisions	24.0	13.5	22.5	16.2	11.0	5.9	11.9	6.5
Ownership of land and other assets	6.8	8.1	6.9	10.2	3.0	2.4	3.0	3.8
Access to and decisions on financial services	12.8	21.9	13.4	24.2	5.0	6.3	7.4	7.7
Control over use of income	24.3	12.6	24.3	14.0	11.2	5.6	11.6	5.5
Work balance	26.0	34.7	33.7	41.1	8.0	9.8	11.0	10.2
Visiting important locations	29.7	32.3	23.2	32.2	8.7	9.2	9.8	9.1
Group membership	11.1	13.2	5.4	9.9	5.2	5.4	3.9	4.3
Membership in influential groups	14.2	19.8	10.1	19.1	6.5	8.0	6.0	7.8

Notes: The proportion of respondents who are inadequate in a given indicator, regardless of their empowerment status.
Source: own elaboration based on survey data.

Table A 3. Pro-WEAI indicators, definitions of adequacy

	Indicators	Descriptions
Intrinsic agency	**Autonomy in income**	A respondent is considered adequate when they are more motivated by their own values than by coercion or fear of others' disapproval in how to use income generated from agricultural and non-agricultural activities, calculated as when their Relative Autonomy Index is greater than or equal to one
	Self-efficacy	a respondent is considered adequate when they have a score of 32 or greater on the New General Self-Efficacy Scale, meaning that they answer "agree" or greater on average to a set of self-efficacy questions
	Attitudes about intimate partner violence	A respondent is considered adequate when believe that a husband is not justified in hitting or beating his wife in all of five scenarios
	Respect among household members	A respondent is considered adequate when they report that they respect, are respected by, trust, and feel comfortable disagreeing with their spouse, the other respondent in the household, or another adult household member
Instrumental agency	**Input in productive decisions in agriculture**	A respondent is considered adequate when, for all of the agricultural activities they participate in, they make decisions solely, make decisions jointly and have at least some input in the decisions, or feel that they could make decisions if they wanted to at least a medium extent
	Ownership of land and other assets	A respondent is considered adequate when they solely or jointly own at least three small assets, two large assets, or land
	Access to and decisions on financial services	A respondent is considered adequate when they participate in decisions about at least one source of credit used by their household in the past year, belong to a household that did not use credit in the past year but could have if they wanted to, or have sole or joint access to a financial account
	Control over use of income	A respondent is considered adequate when they have input in decisions about how to use both income and output from all agricultural activities they participate in, and have input in decisions about how to use income from all non-agricultural activities they participate in
	Work balance	A respondent is considered adequate when they work less than 10.5 hours per day, where workload is calculated as the time spent on work as a primary activity plus half of the time spent on childcare as a secondary activity
	Visiting important locations	A respondent is considered adequate when they visit at least two of three locations in their community at least once per week – city, market, and family/relative – or visit a health facility or public meeting at least once per month
Collective agency	**Group membership**	A respondent is considered adequate when they are an active member of at least one community group
	Member of an influential groups	A respondent is considered adequate when they are an active member of at least one group that they report can influence the community to at least a medium extent

Note: All indicators are equally weighted (1/12) in the pro-WEAI.
Source: Malapit et al. (2019).