The International Centre for Evaluation and Development
Your Global South research and innovation in evaluation partner
www.iced-eval.org

Women's Empowerment and Nutrition in Ghana: The Role of Market and Storage Infrastructures

Hamdiyah Alhassan
Abdul Hanan Abdallah
Mensah Tawiah Cobbinah

About ICED

The International Centre for Evaluation and Development (ICED) fills an important gap in the global evaluation architecture. With its operating headquarters in Kenya and an office in West Africa, it is the first Africa-based international think-tank that combines research and innovation with extensive practical experience in evaluation for development in Africa. ICED conducts rigorous assessment of programs to determine their effectiveness and impact. It also provides expert advice and support to organisations in designing and implementing development initiatives.

About the report

ICED has approved the final version of the report titled "Women's Empowerment and Nutrition in Ghana: The Role of Market and Storage Infrastructures," as part of the Grant Agreement INV-035360 (Prime Agreement) awarded to the International Centre for Evaluation and Development (ICED) to support the project "Infrastructure's Impacts on Nutritious Diet, Women's Empowerment, and Gender Equality (IINDWEGE)." The report is deemed technically sound, and ICED will publicly release this final version of the report in its received form, with no further modifications made.

Women's Empowerment and Nutrition in Ghana: The Role of Market and Storage Infrastructures

Hamdiyah Alhassan [1], Abdul Hanan Abdallah [2] and Mensah Tawiah Cobbinah [3]

1. Director, Kazuhiko Takeuchi Centre for Sustainability and Resilience, University for Development Studies (UDSEmail: abena567@yahoo.co.uk
2. Department of Agricultural and Food Economics, University for Development Studies, Tamale; aahanan@uds.edu.gh
3. Department of Agribusiness University for Development Studies, Tamale; mensahtawiahcobbina@yahoo.com

Small Evaluation Report 002
April 2023

The International Centre for Evaluation and Development

Acknowledgements

We acknowledge valuable contributions and support of various institutions and persons during this study. First, we thank the International Centre for Evaluation and Development (ICED) and their funding partners for their financial support for this study under the Infrastructure's Impacts on Nutritious Diet, Women's Empowerment and Gender Equality (IINDWEGE) project. We also thank the Management of the University for Development Studies, Tamale, for their cooperation and assistance. We acknowledge with deep appreciation the key informants that participated in this study and their respective organisations for their support. We are also very grateful to our research assistants for offering excellent research assistance. Finally, special thanks go to the hardworking women and men who participated in the focus groups discussions held across the country.

Summary

Women play a significant role in household nutrition, so their empowerment is critical. Physical infrastructure such as market and storage facilities may offer a potential solution to enhance women's empowerment, gender equality, and nutrition outcomes by increasing incomes, diversification, assets, and employment opportunities for the household, but the effects may vary depending on the type and mix of physical infrastructures. However, information on the impact of physical infrastructures on nutrition and gender outcomes is scant in the literature despite its policy relevance. Moreover, existing studies on the impact of physical infrastructure, focused mainly on measuring infrastructure as a single variable, and thus fail to capture the heterogeneity of multiple physical infrastructures. Against this backdrop, this study sought to examine the effects of using storage facility only, market facility only, and both infrastructures on (1) women's empowerment, (2) gender equality, (3) nutrition, and (4) hidden hunger in Ghana.

We revisited the Feed the Future data to generate two-round panel data using the first panel as the baseline and a subsample of the second-round data as the second panel. A subsample of 1,492 households was obtained for the analysis. The explanatory sequential mixed design was employed. This entailed collecting quantitative data, followed by qualitative interviews (Focus Group Discussions and Key Informant Interviews) to validate and interpret initial unexpected and surprising quantitative results. The quantitative data was analyzed using the multinomial endogenous switching regression (MESR) and multinomial endogenous treatment regression (METE) models, while the qualitative data was analyzed using content analysis. We controlled for time-varying unobserved fixed and random effects in the MESR and METE models using the Mundalk's approach. Furthermore, we conducted mediation analysis to identify the pathways between infrastructure use and the outcomes using Hayes macro-application "PROCESS" for SPSS. We also conducted a falsification test to check the validity of the instruments used.

The results show that use of market only, storage facility only, and both infrastructures have significant positive impact on hidden hunger (measured using available cereal per adult equivalent). The effect size is relatively large for households that use storage facility only than users of market facility only and both infrastructures. The results suggest that access to storage and market facilities may promote the production and consumption of energy-dense food than micronutrient-rich foods. The mediation analysis revealed that the pathway through which the use of both market and storage facilities may impact on hidden hunger is through lower crop diversification. The results also reveal that the use of market and storage facilities plays a significant role in nutrition outcomes. Specifically, the use of market facility only, storage facility only and both infrastructures significantly increase minimum dietary diversity of women (MDD-W) and child's dietary diversity score (CDDS). The mediation analysis revealed that the pathways through which the use of market and storage facilities may impact on women's dietary diversity were through higher crop diversification, increased income, and more accumulated assets. Likewise, the positive impact of market and storage facilities on CDDS was mediated through higher crop diversification and more accumulated assets. As expected, the use of both infrastructures has the largest impact on MDD-W and CDDS. Moreover, for child malnutrition, the use of market only, storage facility only, and both infrastructures are negatively associated with wasting and underweight in children under five. Except for the use of market only, the use of storage facility only and both infrastructures have significant and negative impact on stunting. The negative impact of use of both market and storage facilities on stunting was mediated through higher crop diversification.

Further, the results show that households that used market facility only and both infrastructures attained gender equality and had significantly more empowered women than those who did not. However, use of storage facility only positively impacted on women's empowerment but has no significant effect on gender equality. One important finding is that the effect size is relatively large for households that use both infrastructures as compared to those that use market facility only and storage facility only. This finding is

plausible because different physical infrastructures have distinct strengths that, when combined, result in greater benefits for households The mediation analysis also shows that the mechanism and pathways through which the use of both infrastructures may improve women's empowerment are through the ownership of asset, and lower crop diversification. We conclude that interventions that encourage the development of both market and storage infrastructure have the potential to empower women and promote gender equality more than a single infrastructure. Households, on the other hand, must be willing to use both infrastructures to support policies that promote women's empowerment and gender equality. The key implication of our findings is that using both market and storage facilities has substantial benefits on households and should be extended. Interventions to foster the provision of both market and storage facilities could improve nutrition and empower women, thus reducing malnutrition and gender inequality.

Table of Contents

List of Figures and Tables

Abbreviations and Acronyms

ACPAE	Available cereal per adult equivalent
AfDB	African Development Bank
AGDI	African Gender and Development Index
BMI	Body mass index
CDDS	Children's dietary diversity scores
CIA	Conditional Independence Assumption
DD	Difference-in-Difference
DHS	Demographic Health Survey
EAs	Enumeration areas
ESR	Endogenous switching regression
FANTA	Food and Nutrition Technical Assistance
FAO	Food and Agricultural Organization
FEI	Female Entrepreneurship Index
GEDI	Gender, Equality, Diversity and Inclusion
GEI	Gender Equality Index
GIPA	Ghana Investment Promotion Agency
GoG	Government of Ghana
GPS	Global Positioning System
GPX	Global Positioning System Exchange format
HAZ	Height-for-age Z-scores
HLSI	Household livelihood security index
IDM	Individual Deprivation Measure
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy and Research Institute
ILO	International Labour Organization
IV	Instrumental variables
M_0S_1	Storage facilities
M_1S_0	Market facilities
M_1S_1	Multiple infrastructures
MDD-W	Minimum dietary diversity for women
MESR	Multinomial endogenous switching regression
METE	Multinomial endogenous treatment effect
MGII	Multidimensional Gender Inequalities Index
MNPS	Multinomial propensity score
MoFA	Ministry of Food and Agriculture
NIP	National Infrastructural Plan
NRGP	Northern Rural Growth Programme
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary Least Squares
PBC	Perceived behaviour control
Pro-WEAI	Project-level women's empowerment in agriculture index
PSM	Propensity score matching
SD	Standard deviation
SDGs	Sustainable Development Goals
SIGI	Social Institutions and Gender Index
SSA	Sub-Saharan Africa
SWPER	Survey-based Women's Empowerment Index
TCT	Transaction cost theory

TOC	Theory of change
TPB	Theory of planned behaviour
UN	United Nations
UNDP	United Nations Development Programme
US$	United States Dollar
USAID	United States Agency for International Development
WAZ	Weight-for-age Z-scores
WBL	Women, Business and the Law Index
WE3	Women's Economic Empowerment and Equality Dashboard
WEAI	Women’s empowerment in agriculture index
WEE	Women’s economic empowerment
WEI	Women’s Empowerment Index
WEOI	Women's Economic Opportunity Index
WFP	World Food Programme
WHO	World Health Organization
WHZ	Weight-height-for-age Z-scores
WPSI	Women, Peace, and Security Index
ZOI	Zone of Influence

1. Introduction

Good nutrition enhances one's physical and mental health, laying the foundation for advancement in education, employment, and economic growth. Women play a significant role in household nutrition, so it is important to empower them (Malapit & Quisumbing, 2015; Heckert et al., 2019; Kassie et al., 2020). However, in sub-Saharan Africa (SSA), women have fewer opportunities and resources than men, forcing them to work in less productive and profitable sectors, or informal, unpaid jobs. This problem widens the gender gap and weakens women economically, making it difficult to invest in a nutritious diet. Consequently, malnutrition has been a widespread problem among women and children in SSA.

Physical infrastructure such as roads, storage, and market facilities may offer a potential solution to tackle malnutrition by enhancing women's empowerment in Africa (NEPAD, 2003; Development Initiatives, 2017; Turley & Uzsoki, 2018). Several studies (including Djurfeldt et al., 2010; Ricker-gilbert & Jones, 2015; Omotilewa et al., 2018) revealed that the use of physical infrastructure improves nutrition by enhancing household incomes and food security, but the impacts may vary by type and mix of infrastructures. For instance, production infrastructure like irrigation facilities can increase output by shifting the production frontier (Bravo-Ureta et al., 2020; Edeme et al., 2020) or promoting diversification into non-staple crops (Djurfeldt et al., 2010). Post-production and distribution infrastructures such as driveable roads and well-developed market facilities may facilitate market access and continuous stable food supply and distribution, ensuring greater access and availability of high-quality foods (von Braun & Eileen, 1994). Furthermore, the use of warehouses and storage facilities may eliminate post-harvest losses, thereby increasing food availability (Omotilewa et al., 2018; Ricker-gilbert & Jones, 2015; Turley & Uzsoki, 2018). Information infrastructure such as telecommunication masts and information centres can inform as to where and how to access food, thereby ensuring equitable food distribution. Physical infrastructures can help actors in an integrated value chain, particularly women, reduce risk and increase efficiency, thereby, economically empowering them (Djurfeldt et al., 2010; Turley & Uzsoki, 2018). Due to the strong direct link between infrastructure and socio-economic development, the Government of Ghana (GoG) invests US$1.2 billion per year in a myriad of physical infrastructure nationwide to lay a strong foundation and create a favourable environment for businesses to thrive. Ghana Investment Promotion Agency (GIPA) has registered 89 projects with a total investment of US$2,852.62 million over the last 21 years (ILO, 2017).

However, to the best of our knowledge little is known about how the use of different physical infrastructures influences women's empowerment, gender equality, nutrition, and hidden hunger in Ghana. Existing studies (including Djurfeldt et al., 2010; Kodongo & Ojah, 2016; Omotilewa et al., 2018; Ricker-gilbert & Jones, 2015) on the impact of infrastructure, focused mainly on measuring infrastructure as a single variable, and thus failed to capture the heterogeneity of multiple infrastructures. The potential consequences of hidden hunger on nutrition and education have recently been highlighted in the literature (e.g., Pangaribowo & Gerber, 2016; Gödecke et al., 2018; Abdallah et al., 2020), but there is little research on the nexus between the use of different infrastructure and hidden hunger. The objectives of this study are to examine the impacts of the use of single and multiple infrastructures on (1) women's empowerment, (2) gender equality, (3) nutrition, and (4) hidden hunger in Ghana.

This study seeks to provide new evidence on the pathways connecting physical infrastructural development to nutrition, women's empowerment, and gender equality. Such understanding would contribute to bringing SSA countries closer to achieving the Sustainable Development Goals (SDGs) 2, 3, 5, and 10. Furthermore, this study will provide evidence of the use of physical infrastructure by households, which could help in the design of policies, programmes, and strategies for infrastructure expansion or infrastructure enhancement. Ghana is developing a National Infrastructure Plan (NIP) with the goal of creating world-class infrastructure assets that are efficient, dependable, resilient, functional, accessible, and inclusive,

capable of supporting Ghana's export-led growth and improving the quality of life for all Ghanaians. To achieve this, more research like the current study is needed to inform the government and other key stakeholders about where to direct investments and stimulus interventions to maximize returns.
The rest of this study is organized as follows: Section two reviews the literature on key concepts. Section three presents the methodology, whereas section four presents and discusses the results. Section five provides the conclusion and recommendations of the study.

2. Literature Review

This section presents the conceptual, theoretical, and empirical literature review on link between physical infrastructure use and nutrition, women's empowerment, and gender equality in Ghana and elsewhere.

2.1 Conceptual review

Defining and contrasting nutrition measures

Nutrition has long been considered an important health issue in the social, economic, cultural, and psychological development of people and societies. Srilakshmi (2006) defined nutrition as the science of foods, the nutrients, and other substances therein, their action, interaction, and balance in relationship to health and disease; the process by which the organism ingests, digests, absorbs, transports, and utilizes nutrients and disposes of their end products. Improved nutrition may be best achieved through regular consumption of nutritious diets. Nutritious diets are essential for maintaining good health and well-being (Di Giosia *et al*., 2022). It consists of ample quantities of vegetables, fruits, whole grains, nuts, legumes, fish, oils enriched in monounsaturated fat, and fiber, and is lower in fatty red meat and refined grains (Marshall *et al*., 2022). Furthermore, nutritious diets avoid simple sugars, processed foods, and trans and saturated fats (Marshall *et al*., 2022). A nutritious diet can maintain a healthy weight, boost energy levels, improve cognitive function, improve immune system, and reduce the risk of chronic diseases such as heart disease, diabetes, and certain types of cancer (Santos, 2022; Craig, 2010).

There are different ways of measuring nutrition. The most popular of all are dietary quality indicators and anthropometric indicators (Bakhtsiyarava & Grace, 2021; Lowe, 2021; Ekholuenetale *et al*., 2020; Fongar *et al*., 2019; Jones *et al*., 2019. The diet quality indicators measure the diversity in diet. The anthropometric measurements include the body mass index (weight in kg)/square of height in meters) and height-for-age Z-scores (HAZ), weight-for-age Z-scores (WAZ), and weight-height-for-age Z-scores (WHZ) for children. According to WHO Growth Standards Median, a woman is underweight (if BMI<18.50 kg/m^2), healthy weight (if BMI>=18.50-24.99 kg/m^2), overweight (if BMI>=25.00-29.99 kg/m^2), and obese (if BMI>=30.00 kg/m^2). Stunting occurs when children have a HAZ less than-2 standard deviations (SD) of WHO Growth Standards Median. Wasting describes child's weight relative to height and is a measure of acute malnutrition. Wasting occurs when children have WHZ is less than -2 SD of WHO Growth Standards Median. Underweight occurs when children have WAZ is less than -2 SD of WHO Growth Standards Median.

Dietary diversity is a measure of the range of foods belonging to different food groups, consumed by an individual over a defined time (Lowe, 2021). The indicator is recommended by the United Nations Food and Agriculture Organization (FAO) as a simple and valid measure of women's dietary diversity through the consumption of food items belonging to nine food groups. The greater the diversity of a diet, the lower the risk that the diet is insufficient in terms of micronutrient supply. Thus, understanding dietary patterns is an important tool in designing the strategic approach to combat hidden hunger. Dietary diversity can be calculated at the household or individual levels with variations in the food group classifications. At the individual level, minimum dietary diversity is calculated primarily for women of reproductive age (15–49 years) and young children aged 6-23 months or 6-59 months. Women's dietary diversity score (WDDS) is a continuous indicator of nutrition denoting the number of the following 9 food groups (starchy staples, green leafy vegetables, other vitamin-A-rich fruits and vegetables, other fruits and vegetables, organ meat, meat and fish, eggs, legumes and nuts, and milk and milk products) consumed based on 24-hour recall (Kennedy et al., 2010). Children's dietary diversity score (CDDS), on the other hand, is a continuous indicator of nutrition, denoting the number of the following food groups (grains, roots, and tubers, legumes and nuts, dairy products, flesh foods, eggs, vitamin-A-rich fruits and vegetables, and other fruits and vegetables) consumed based on 24-hour recall (Fongar *et al*., 2019). Another indicator of nutrition is the Minimum Dietary Diversity for Women (MDD-W). The MDD-W measure has ten food groups.

Table 1: Indicators of nutrition

Outcome Domain	Sub-Outcome	Indicator
Nutrition	Food and nutrition security	- Quantity of food produced (kg/tons) - Per capita dietary energy supply (DES) kcal /per capita/day - Food Insecurity Experience Scale (FIES) - Household Food Insecurity Access Scale (HFIAS)
	Diet quality (nutrient adequacy)	Individual dietary diversity scores: - Minimum Acceptable Diet (MAD) for infant/child (6 to 23 months) - Minimum Dietary Diversity (MDD) for infant/child (6 to 23 months) - Minimum Dietary Diversity for Women between 15 - 49 years (MDD-W) - Mean adequacy ratio (MAR): measures an individual's intake of nutrient
	Socioeconomic and cultural dimensions of foods	- The volatility of food prices - Weather seasonality in agriculture - Income variation in food access - Women's empowerment in nutrition index (WENI)
Anthropometry	Health dimensions of food	- Body-mass index for infant/child (6 to 23 months) and women for infant/child (15 to 49 years) - Height-for-age for infant/child (6 to 23 months) and women for infant/child (15 to 49 years) - Weight-for-age for infant/child (6 to 23 months) and women for infant/child (15 to 49 years) Anaemia status for women for infant/child (15 to 49 years)
Hidden hunger	Staple food production adequacy	- Deficiency in energy intake for infant/child (6 to 23 months) and women for infant/child (15 to 49 years) - Micronutrient deficiencies (particularly iron, zinc, iodine, and vitamin A) for infant/child (6 to 23 months) and women for infant/child (15 to 49 years)

Source: Author's illustration.

The MDD-W separates legumes, nuts, and seeds into two food groups; legumes, and nuts and seeds, and subsumes organ meat into animal meat food group. It also separates other fruits and vegetables into two food groups: other fruits and other vegetables. Due to this, we adopted the MDD-W rather than the WDDS to capture more diversity in women's diet. Hidden hunger could also be used as a measure of micronutrient deficiency. Hidden hunger is the presence of multiple micronutrient deficiencies (particularly iron, zinc, iodine, and vitamin A), which can occur without a deficit in energy intake because of consuming an energy-dense, but nutrient-poor diet (Lowe, 2021). Hidden hunger increases with the consumption of these staples. Therefore, a household who is self-sufficient in starchy staples is more likely to have a high hidden hunger than another who is less sufficient in starchy staples. Below is a summary of the indicators of nutrition.

Defining and contrasting women's empowerment and gender equality and their measurements

Women's empowerment and gender equality are closely related development policy objectives that nations strive for (Malhotra *et al*., 2002; Alkire *et al*., 2013). Feminists used these two concepts to get women's rights onto the international development agenda in the 1980s and 1990s (Cornwall & Rivas, 2015). However, the concepts became more prominent in the 2000s following a United Nations proclamation to end gender inequality and gender discrimination in all its forms (Manuh & Anyidoho, 2015). The declaration was determined to achieve a 'just and lasting peace 'in which there is 'respect for the equal rights of all, without distinction as to race, sex, language, or religion' (Cornwall & Rivas, 2015). Gender equality can be defined from two streams of life outcomes (World Bank, 2001): (1) equality under the law or equality of opportunity (which means that both men and women have equal rewards for work and equal access to human capital and other productive resources that enable opportunity) and (2) equality of voice (which means that both men and women have the ability to influence and contribute to the political development and economic decision-making processes). Gender equality appears to be a simple concept, but defining women's empowerment is more difficult (Alkire *et al*., 2013).

Women's empowerment is a broad concept with varying definitions depending on the circumstance or context, which can be analytically or operationally, subjectively, or objectively (Alkire *et al*., 2013; Alsop & Heinsohn, 2012). For instance, Kabeer (2001) defines empowerment as the expansion of people's ability to make strategic life choices, particularly in contexts where this ability had been denied to them. Bennett (2002) also defines empowerment as "the enhancement of assets and capabilities of diverse individuals and groups to engage, influence and hold accountable the institutions which affect them." Batliwala (1994) also describes empowerment as "how much influence people have over external actions that matter to their welfare, while Keller & Mbwewe (1991) define women's empowerment as "a process whereby women become able to organize themselves to increase their own self-reliance, to assert their independent right, to make choices, and to control resources which they need to undertake challenging tasks and eliminate their own subordination". Another widely used concept in women's empowerment is the concept of human agency. In defining women's empowerment, it is also important to consider how women should be able to define self-interest and choice, and consider themselves as not only able, but entitled to make choices (Sen, 1993, Nussbaum, 2000; Kabeer, 2001).

Women's empowerment measurements have changed over time, giving rise to two distinct research streams: one that focuses on a specific indicator of women and another that employs a diverse range of metrics. For example, Jeejebhoy *et al*. (2001) assessed women's empowerment using women's autonomy. Tzannatos (1999) used "agency" as a proxy for women's empowerment, while Quisumbing *et al*. (1999) used "women's land rights" to measure women's empowerment. Other researchers have also measured women's empowerment using "women's domestic economic power" (Mason, 1998), "bargaining power" (Quisumbing & de la Briere, 2000), "power" (Pulerwitz *et al*., 2000), "patriarchy" (Malhotra *et al*., 1995), and "gender equality" (World Bank, 2001). Contrarily, recent studies (Gupta *et al*., 2019; Addison *et al*., 2021) adopted the concept of women's empowerment in agriculture in index (WEAI) or project-level women's empowerment in agriculture in index (pro-WEAI) (Malapit *et al*., 2019; Yount *et al*., 2019; Quisumbing *et al*., 2019; Crookston *et al*., 2021; Waid *et al*., 2022) to evaluate women's empowerment.

Kabeer (1999) proposed three dimensions of women's empowerment: resources, agency, and achievements. “Resources,” also called “preconditions” (in Kabeer, 1999) or “opportunity structures” (in Alsop &Heinsohn, 2012), are the material, human, and social resources as well as institutional environments that would allow one to decide (Malhotra& Schuler, 2005). “Agency” captures critical thinking skills and the ability to make independent decisions regarding women's education, social capital, and asset ownership (Mosedale, 2005). Lastly, “achievements” are the manifestations of the exercise of agency, and include measures such as increased labour market participation, intolerance of domestic violence, and parental time available for childcare. Table 2 (click here for Table 2 in supplementary file) provides a summary of the measures of women’s empowerment.

Women’s economic empowerment (WEE) Indicators: The World Bank was one of the first agencies to adopt the concept of economic empowerment. According to the Bank (2006: p4), “economic empowerment is about making markets work for women (at the policy level) and empowering women to compete in markets (at the agency level)”. The UN (2001) defined women’s economic empowerment in terms of five components: ‘women’s sense of self-worth; their right to have and determine choices; their right to have access to opportunities and resources; their right to have the power to control their own lives, both within and outside the home; and their ability to influence the direction of social change to create a more just social and economic order, nationally and internationally”. The UNDP (2008) sought to extend the five components outlined in the UN (2001) definition to the economic sphere “where women’s economic empowerment can be achieved by targeting initiatives to expanding women’s economic opportunity; strengthen their legal status and rights; and ensure their voice, inclusion and participation in economic decision-making”. WEE is the product of contextual, household, and individual (capabilities) factors (Kabeer, 2012). According to Kabeer (2012), contextual and household factors define economic opportunities for women, separately and jointly. Women’s capabilities include individual (and community) endowments that enable them to exercise agency and take advantage of economic opportunities (Kabeer, 2012). WEE is a narrow measure of women’s empowerment. For instance, it measures women’s agricultural knowledge and behavioural change, yields, employment, income, farm investment, resource use efficiency, assets, livestock, savings, consumption, food security, time use, and participation in community and leadership positions separately. Table 3 shows the indicators of women’s economic empowerment.

Table 3: Indicators of women’s economic empowerment

Outcome Domains	**Sub-Outcomes/**	**Indicators**
Women’s Economic Empowerment	Agricultural knowledge and behavioural change	1. Adoption of agricultural inputs and technologies 2. Agricultural knowledge, information, and skill use
	Economic outcomes (in agriculture)	1. Increases in yield, employment, income, farm investment, resource use efficiency, household assets, livestock, and savings. 2. Consumption and food security
	Social outcomes	1. Time-use and efficiency (proportion of time spent on unpaid domestic work and care by sex and age) 2. Changes in social, cultural, and gender norms 3. Participation in community and leadership positions

Source: Author’s illustration

The WEAI: The WEAI consists of 10 indicators of women's empowerment, which are merged into five domains. The WEAI is rooted in Kabeer's (1999) and Kabeer's (2005) framework of empowerment, which describes empowerment as a process of change on the interrelated dimensions of resources, agency, and achievements and focuses on measuring agency, or the ability of individuals to make strategic choices. According to Alkire *et al*. (2013), the WEAI was developed based on research evidence on agency and empowerment, including the works of Narayan, 2005; Alsop *et al*., 2006; Narayan & Petesch, 2007; Ibrahim & Alkire, 2007) that propose domain-specific measures of empowerment obtained using questions that can be fielded in individual or household surveys. The WEAI can be used more generally to assess the state of empowerment and gender parity in agriculture, to identify key areas in which empowerment needs to be strengthened, and to track progress over time (Malapit *et al*., 2019). Based on the Alkire-Foster methodology, the WEAI is an aggregate index reported at the country or regional level based on individual-level data collected by interviewing men and women within the same households (Alkire *et al*., 2013). The WEAI is an aggregate index, reported at the country or regional level, based on individual-level data collected by interviewing men and women within the same households. The WEAI comprises two subindexes (Alkire *et al*., 2013). The first subindex assesses the degree to which women are empowered in five domains of empowerment (5DE) in agriculture (Alkire *et al*., 2013). It reflects the percentage of women who are empowered and, among those who are not, the percentage of domains in which women enjoy adequate achievements (Alkire *et al*., 2013).

According to Ewerling *et al*. (2017) and Alkire *et al*. (2013), these domains are (1) production (input in productive decisions and autonomy in production), (2) resources (ownership of assets, purchase, sale, or transfer of assets, and access to and decisions about credit), (3) income (control over use of income), (4) leadership (group membership and speaking in public), and (5) time (workload and leisure). Each indicator is a binary indicator that equals one when a respondent achieves a certain threshold in that dimension. A given threshold defines a respondent as either adequate (empowered) or inadequate (not empowered). When a respondent is considered adequate in that indicator, it is assigned a value of one in the binary indicator when calculating the index and zero if otherwise. The second subindex is the Gender Parity Index (GPI), which measures gender parity. GPI is the difference in the male and female empowerment scores. The woman is empowered if the GPI is equal to unity or higher than that of the man (Alkire *et al*., 2013). If the GPI is zero, then there is gender equality in the household. Table 4 provides a summary of the indicators of WEAI, and the weights attached to each.

Table 4: Domains, indicators, and weights in the WEAI

Domain	Indicator	Definition of indicator	Weight
Production	1.1 Input in productive decisions	This indicator reflects the sole or joint decision-making over food and cash crop farming, livestock, and fisheries.	1/10
	1.2 Autonomy in production	A respondent is considered adequate when they are more motivated by their own values than by coercion or fear of others' disapproval in the types of crops to grow or raise, livestock raising, or taking crops or livestock to market, calculated as when their Relative Autonomy Index is greater than or equal to one.	1/10
Resources	2.1 Ownership of assets	This indicator reflects the sole or joint ownership of major household assets	1/15
	2.2 Purchase, sale, or transfer of assets	This indicator measures whether respondent participates in decision to buy, sell, or transfer assets	1/15
	2.3 Access to and decisions about credit	This indicator reflects access to and participation in decision-making concerning credit	1/15

Income	3.1 Control over use of income	This indicator reflects sole or joint control over income and expenditures	1/5
Leadership	4.1 Group membership	This indicator reflects whether respondent is an active member in at least on economic or social group	1/10
	4.2 Speaking in public	This indicator reflects whether respondent is comfortable speaking in public concerning issues relevant to oneself or one's community.	1/10
Time	5.1 Workload	This indicator reflects allocation of time to production and domestic tasks	1/10
	5.2 Leisure	This indicator reflects satisfaction with time for leisure activities	1/10

Source: Ewerling *et al*. (2017)

The Pro-WEAI: The pro-WEAI was proposed and developed by Malapit *et al*. (2019). The Pro-WEAI is made up of 12 indicators of women's empowerment (Malapit *et al*., 2019), which are weighted into 3 domains of empowerment (3DE), including (1) intrinsic agency—power within (autonomy in income, self-efficacy, attitudes about domestic violence, and respect among household members), (2) instrumental agency—power to (input in productive decisions, ownership of land and other assets, access to and decisions on credit, control over the use of income, work balance, and visiting important locations), and (3) collective agency—power with (group membership and membership in influential groups). A respondent is considered adequate in a particular indicator if she or he reaches a certain threshold. A respondent is considered empowered if she or he is adequate in at least 9 out of 12 (75%) of the indicators. The pro-WEAI is a robust and more representative measure of women's empowerment than the WEAI. The pro-WEAI captures women's physical movement, attitudes toward domestic abuse, and intrahousehold relationships, all of which are missing from the original WEAI (Malapit et al., 2019). Additionally, some indicators in the WEAI have been improved in the Pro-WEAI. For example, the pro-WEAI measures autonomy in production by focusing exclusively on the use of income generated from agricultural and non-agricultural activities and uses a new vignette-based survey instrument, whereas the WEAI does not (Malapit *et al*., 2019). The pro-WEAI also measures access to credit by examining respondents' access to financial accounts, whereas the WEAI does not (Malapit *et al*., 2019). The pro-WEAI measures input in productive decisions and control over income using a stricter adequacy cut-off, whereas the WEAI does not (Malapit *et al*., 2019). Like the "workload" indicator in the WEAI, work balance in pro-WEAI only allows for the measurement of secondary activities to a single activity (childcare). The pro-WEAI can be used to compute the Gender Parity Index (GPI), which measures gender parity between men's and women's empowerment (Malapit *et al*., 2019). The GPI reflects the percentage of women who are empowered or whose achievements are at least as high as the men in their households. Table 5 (click here for Table 5 in supplementary file) provides a synopsis of the pro-WEAI indicators.

Gender equality Indicators: The second sub-index of WEAI or Pro-WEAI is the Gender Parity Index (GPI), which measures gender parity between men and women (Malapit *et al*., 2019). The GPI reflects the percentage of women who are empowered or whose achievements are at least as high as the men in their households. If the GPI is equal to zero, then the household has attained gender equality.

Theory of Change (TOC)

Women contribute significantly to household production activities and, as a result, have a vital role in eliminating micro-level poverty, hidden hunger, and malnutrition, especially if they have access to physical infrastructure. Figure 1 presents the conceptual framework of the study based on the theory of change. The focus of this study is on women's empowerment, gender equality, and nutrition outcomes in Ghana. With the available infrastructure, households may choose to use it or otherwise. As shown the blue box, households may have ready access to farm inputs, buyers, diverse food, and security of their produce if they use market and storage facilities. Access to market and storage facilities gives farmers new marketing options and help them choose the right time to sell and increase their income (Dodd *et al*., 2020). We also argue that access to market and storage facilities may ensure greater availability of nutritious foods (Thapa & Shively, 2018). We term these outputs from physical infrastructure use. The outputs also lead to increased yield, production, and crop diversification. These are short-term outcomes. In the long-term, increased yield, production, and crop diversification may lead to improvement in incomes, employment opportunities (livelihood diversification), and asset accumulation. In this study, we identified and used crop diversification, diversification, farm income, and asset accumulation as the pathways (mediators) through which physical infrastructure affects women's empowerment, gender equality, food security, and nutrition. Directly, individuals may be empowered and become healthier by merely using physical infrastructure (see Figure 2.1). We call this the total direct effect. The effect of physical infrastructure use on the mediators is the direct effect. By contrast, the effect of the mediators on the outcomes variables plus the direct effect of physical infrastructure use on the mediators is the indirect effect. The total direct effect plus the indirect effect gives the total effect of physical infrastructure use on the outcome variables through the mediators.

2.2 Theoretical review

Theories of household decision-making

The use of physical infrastructure by households entails risks and rewards as well as human behaviour in evaluating the infrastructure's potential. Since using infrastructure involves expenses, the transaction cost theory (TCT) is used to explain why households choose to do so. The utility theory is also used to explain physical infrastructure use because both the costs and the benefits are thought to influence households' satisfaction levels. The theory of planned behaviour (TPB) (Ajzen, 1991) is used to explain the behavioural and psychological aspects of households' decisions to use infrastructure.

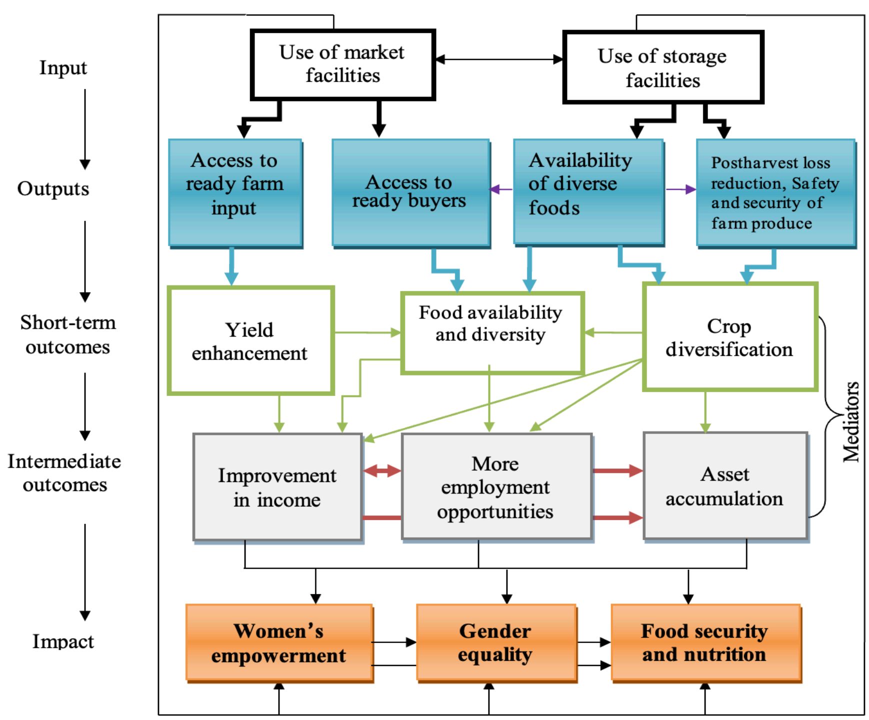


Figure 1: Theory of change guiding the study.
Source: Authors' own construction, 2022

TCT presupposes that there are costs associated with every transaction between parties. These costs influence how the food crop industry changes (Hobbs & Young, 2001). Transaction costs include but are not limited to expenses associated with locating a market, negotiating, and executing a deal. Transaction costs acts as incentive to buyers and suppliers to develop contractual relationships compared to spot market transactions and mode of engagement by the parties is based on its efficiency to minimize transaction costs (Bhattarai, 2013). Higher transaction costs are associated with greater asymmetry of information. According to Bijman (2008), lack of information about market conditions for farmers and quality of products for buyers is a problem in carrying out profitable transactions. Transaction costs are also expected to increase with the frequency of transactions owing to search and negotiation costs associated with each transaction. However, frequency should not be confused with recurrence. Despite its widespread acceptability, it has been chastised for ignoring learning and innovation.

According to the utility theory, households use physical infrastructure when their utility for it was maximized. The utility maximization may come from increased profit, increased leisure, cost reduction, improved environment quality and being in the forefront of technology (Pandit *et al*., 2011). A household's decision to use physical infrastructure will be analysed within a random utility framework. U_c is utility obtained by a household i from using physical infrastructure j and U_n is the utility of non-use of physical infrastructure. Households would choose to use the infrastructure only if the utility derived from using it is greater or equal to the utility from not using that is $U^* = U_c > U_n$. Since the utility is not observable, it is expressed in the following latent structure model.

$$U_{in} = \beta_j X_i + u_i \tag{2.1}$$

where β_i is a vector of coefficients to be estimated and u_i is a vector of random disturbances of the unobserved factors affecting physical infrastructure use. In a smallholder environment with widespread market imperfections, utility maximization may differ from profit maximization. Hence, the variables included in X should cover a broad set of socioeconomic variables that also capture individual market access conditions, connectivity, incentives, ability, and risk preferences.

The theory of planned behaviour (TPB) is an extension of the theory of reasoned action (Ajzen *et al*., 1975) made necessary by the original model's limitations in dealing with behaviours over which people have incomplete volitional control. The TPB starts with an explicit definition of the behaviour of interest in terms of its target, the action involved, the context in which it occurs, and the time frame (Ajzen *et al*., 2020). The TPB depicts behaviour as a function of behavioural intentions and perceived behavioural control (PBC). PBC, on the other hand, is the individual's perception of the extent to which performance of the behaviour is easy or difficult (Ajzen, 1991). The TPB defines one's intention, attitude, subjective norms, and perceived behavioural control in performing a given behaviour or explains actual performance, which may include the use of infrastructure. The use of infrastructure has both intentions to use and actual use (this usually occurs over time). According to the TPB, behavioural intentions are determined by three factors: attitude toward the behaviour, subjective norm concerning the behaviour, and perceived behavioural control (Ajzen *et al*., 2020). The attitude component is a function of a person's salient behavioural beliefs, which represent perceived outcomes or attributes of the behaviour (Conner & Armitage, 1998). Subjective norms consist of a person's beliefs about whether significant others think he or she should engage in the behaviour (Ajzen, 1991). Subjective norms are assumed to assess the social pressures on individuals to perform or not to perform a particular behaviour (Conner &Armitage, 1998). Perceived behavioural control is assumed to be based on accessible control beliefs (Ajzen *et al*., 2020). The control beliefs are concerned with the presence of control factors (required skills and abilities; availability or lack of time, money, and other resources) that can facilitate or impede performance of the behaviour (Ajzen *et al*., 2020). Each control belief contributes to perceived behavioural control in interaction with the factor's perceived power to facilitate or impede performance of the behaviour (Ajzen et al., 2020).

Theories of women's empowerment and gender equality

Theoretically, women's empowerment and gender equality issues are viewed from two development perspectives: (1) economic modernity (thus the classical development perspective) and cultural modernity (thus the human development perspective). Focusing on economic development, the classical modernization perspective considers increases in democracy and human choice as a direct outcome of economic development (Bell, 1999). In relation to gender equality, this approach holds that economic development is central to increasing the pool of women eligible for positions of social power. However, greater access to educational and occupational resources may increase women's chances of professional development, creating a larger pool of women eligible for power positions such as political office at all levels of governance. In theory, it is reasonable to presume that early gains in gender equality take the form of women's greater equality with men in skill development and standard of living. These gains unite women from traditional household activities, setting them free to participate in greater rates in civic activities such as petitions and boycotts. Cultural modernity, on the other hand, emphasises the conversion of economic development into a cultural process of human development that gives rise to an emancipative worldview, reflected in self-expression values that emphasise human choice and autonomy, including the choices and autonomy of women (Welzel *et al*., 2003). Gender inequality can be viewed as stable and ongoing entity, groups in conflict, or through daily intersections and the use of symbols, and the intersection of different factors such as gender, race, and class. These views are what give rise to the most widely used theories of gender inequality. Broadly, gender inequality can be explained through (1) the functionalist perspective, (2) the conflict perspective, (3) the interactionist perspective, and (4) the feminist perspective.

The functionalist perspective typifies human society as a biological organism with various parts that harmoniously form its smooth functioning, or views society as a multifaceted structure with different elements that must work in harmony to ensure the entire system's stability and survival (Olonade *et al*., 2021). The conflict perspective explains the power and privilege distributions that exist between men and women in the household. The interactionist perspective is used to clarify and address the creation and confirmation of gender identity and the construct of power, which often relies on the stratification of masculine power over feminine power (Gussak, 2008). The interactionist gender theory posits that people actively "do" or "perform" their gender roles in every interaction, and as such, they often subconsciously reshape their public gendered personas based on the degree to which they find social acceptance within a given social context (Missinger, 2015). The feminist theory is the most widely used women's empowerment and gender inequality theory in society (Mikkola, 2008). Feminist perspective is a type of conflict theory that looks at gender-related inequalities. The feminist theory seeks to address the questions of how gender can be distinct from sex and how to understand the claim that gender depends on social and/or cultural factors?

2.3 Empirical literature review

Related studies on impact of infrastructure on nutrition

The impact of storage and market infrastructures in promoting societal wellbeing and nutrition is not straightforward and has been well-conceptualized and independently examined in empirical studies. In Ethiopia, for example, Abay et al. (2016) quantified the mitigating role of market access in the impact of seasonality on child nutritional outcomes using panel data from northern Ethiopia. The results showed that children located closer to local food markets are better nourished and consume more diverse diets than those located farther away. Around the same time, Stifel and Minten (2016) revealed that households residing in relatively more remote areas are more food insecure, consume substantially less and had lower school enrolment rates than households nearer to the market. Hirvonen et al. (2017) also tests the role of market access on effect of nutrition knowledge on children's dietary diversity. The results revealed that in areas with relatively good market access, nutrition knowledge enhances children's dietary diversity. Similar results were reported by Usman and Callo-Concha (2021) for southwestern Ethiopian smallholder coffee producers.

In Nepal, the results of Hirvonen et al. (2017) was confirmed by Thapa and Shively (2018) who studied an association between market access implied in district-level transportation infrastructure and district-average child nutritional outcomes. Specifically, the results of Thapa and Shively (2018) indicate that markets access implied in roads infrastructure can influence nutrition by reducing transport costs, input prices, boosting input use and agricultural output, thereby increasing food consumption and better nutrition-related decisions. Kotchofa et al. (2020) also explored the extent of evidence on the causal links between infrastructures, nutritious diets, women's empowerment, and gender equality in low and middle-income countries (LMICs). One of the findings revealed that market infrastructures impact nutritional outcomes for LICs through several channels, including increased availability and accessibility of nutritious foods.

On the other hand, Gitonga et al. (2013) examined the impact of storage infrastructure on households' maize storage, storage losses and food security in Kenya. The findings indicate that food insecurity was lower for households with an improved on-farm storage infrastructure. Using panel estimation techniques on a panel data from Malawian households, Ricker-gilbert and Jones (2015) examine the effect of storage infrastructure on adoption of improved maize varieties. The results indicate that use of storage infrastructure has a significant and positive impact on the probability of adopting improved maize. In Uganda, the finding of Gitonga et al. (2013) and Ricker-gilbert and Jones (2015) were confirmed by Omotilewa et al. (2018) who evaluated the impacts of improved maize storage infrastructure on input use and food security using a panel data from a randomized controlled trial. Specifically, the results of Omotilewa et al. (2018) revealed positive and significant impact of storage infrastructure on adoption of improved maize varieties but no effects on quantity of maize harvested and inorganic fertilizer use. In addition, the results showed positive impact on household's length of storage for consumption.

In contrast, Aggarwal et al. (2018) found no effects of the storage infrastructure on input use in Kenya. In Ethiopia, Tesfaye and Tirivayi (2018) also examined the impacts of postharvest storage innovations on food security and welfare and conclude that improved storage infrastructure enhances food and nutrition security. The results of Tesfaye and Tirivayi (2018) is confirmed by Huss et al. (2021) in Kenya where food insecurity was lower for households equipped with an improved on-farm storage infrastructure. In Ghana, Nkegbe and Mumin (2022) analysed the impact of access to community development initiatives (e.g., silos) and community markets on household nutrition using a country-wide cross-sectional data from 16,772 households. The results showed that access to community development initiatives (such as silos) and community markets improves household nutrition in Ghana. Other related studies are summarized in Table.6 (click here for Table 6 in supplementary file). However, focus of these studies is not on storage and market infrastructure.

Related studies on impact of infrastructure on women's empowerment

Although several empirical studies (for example, Banerjee et al., 2020; Obayelu & Chime, 2020; Khalid et al., 2020; Hadisuyatmana et al., 2021; Mohammed et al., 2021) exist on women's empowerment, studies on the effect of infrastructure on women's empowerment is scanty in literature. Moreover, the few studies that considered the effect of infrastructure on women's empowerment did not focus on market and storage infrastructure on women's empowerment. Recent quantitative studies have only looked at how access to electricity affects women's empowerment with little regard for market infrastructure and storage facilities. For instance, Samad & Zhang (2019) employed PSM to a nationally representative household data set of 40,000 households to examine the causal link between electricity access and women's empowerment. Their results revealed that access to electricity has a significant impact on women's empowerment in India. Like this, Sedai et al. (2022) used principal component analysis and 2-stage least squares instrumental variables (2SLS-IV) regression to assess the impact of electrification quality on women's empowerment in India.

Using a fixed effects regression, Lei et al. (2019) found that access to village transportation infrastructure has a significant effect on women's and men's agricultural and non-agricultural employment in India. Furthermore, Salehi-Isfahani & Taghvatalab (2022) examined the role of rural electrification in gender gap in adult literacy in rural areas. Using PSM and IV estimations, the authors find a significant positive effect of access to rural electrification in reducing gender gap. The authors find that electrification contributed to the narrowing of the gender gap in literacy, thus offering a potential answer for the puzzle of female empowerment in the time of rising patriarchy in Iran. Lee (2020) employed a qualitative case study approach to explore how access to reliable electricity though National Electrification Project's mini-grid project has promoted women's empowerment in a rural village, Myanmar, based on gender needs: practical, productive, and strategic needs.

Wang & Shen (2022) found that rural households with access to clean flush toilets have a significant impact on work time among women than men. According to Abbas et al. (2021), access to information is strongly related to women's empowerment in Pakistan. Similarly, Obayelu &Ogunlade (2006) conducted a descriptive analysis of the use of ICT for gender empowerment and sustainable poverty alleviation in Nigeria. Another line of research (Kabeer, 2005; Pitt et al., 2006; Kim et al., 2007; Garikipati, 2008; Swain et al., 2009; Ashraf et al., 2010) have examined the impact of microfinance or lending activities on women's empowerment. Thus, studies considering the effect of storage and market infrastructure on empowerment is lacking in the empirical literature. The only study in this regard is the study of Kassie et al., (2020) on the moderating effect of women's empowerment on the relationship between agricultural technology adoption and women's dietary diversity in Kenya. Although the role of market access was not a focus of their study, the authors controlled for distance to main market captured in walking minutes.

2.4 Limitations/gaps in the literature

From the ongoing discussions above, two issues are revealed as limitations and or gaps in literature. First, except for Nkegbe and Mumin (2022), much of the evidence in literature showed that the impact of storage and market infrastructure on nutrition has been examined independently in most of the past studies even though storage and market infrastructure may be used jointly by households to deal with multitude of post-production constraints. Second, when compared to other countries, there is a dearth of literature on the effects of storage and market infrastructure on the nutrition in Ghana. The only existing study - to the best of our knowledge - is that by Nkegbe and Mumin (2022). Aside Nkegbe and Mumin' (2022) study, the rest of the past studies focused on other countries and not Ghana. However, these countries have different infrastructural and nutritional policies compared to Ghana, hence the impact of storage and market infrastructure may be different. Third, women's empowerment is a broad term, but the research cited earlier studied it using a narrow set of metrics. The findings of WEAI-based studies have mostly neglected the importance of self-efficacy, attitudes toward domestic abuse, visiting significant locations, and respect among household members in women's empowerment. Given these indicators, Pro-WEAI is determined to be a more representative measure of women's empowerment since it captures women's physical movement, attitudes toward domestic abuse, and intra-household relationships, all of which are missing from the original WEAI. Other gaps that must be addressed include a lack of assessment of nutritional outcomes, a poor identification and empirical strategy for analysing the determinants of women's nutrition and empowerment, and an insufficient empirical understanding of the relationship between infrastructure and women's nutrition and empowerment. Furthermore, the complementing role of multiple infrastructures has yet to be explored, resulting in a lack of clarity in physical infrastructure roles in women's nutrition and empowerment.

2.5 Conceptual framework

Figure 2 presents the conceptual framework of the study. The focus of this study is on women's empowerment, gender equality, and nutrition in Ghana. In this study, we identify three pathways by which physical infrastructure can improve women's empowerment, gender equality, and nutritional outcomes within the households. The first is a production pathway. With access to market and storage facilities, households may achieve higher agricultural productivity by engaging in crop diversification and all-year-round production. Households may produce more food than they need to eat. The second is a marketing pathway. Access to market and storage may improve women's nutrition and empowerment by facilitating continuous food supply and distribution, as well as ensuring greater availability of nutritious foods (Thapa & Shively, 2018). As a result, they need storage facilities to store and preserve foods to eliminate postharvest losses and preserve the nutrition of the products. The third is an income pathway. Access to market and storage facilities gives farmers new marketing options and helps them choose the right time to sell at a better price and increase their income (Dodd et al., 2020). Directly, individuals may be empowered and become healthier by merely using physical infrastructures such as storage and market facilities.

Physical infrastructure use may endogenously determine women's empowerment, gender equality, and nutrition. As shown in Figure 2, availability and access to physical infrastructure, access to information about physical infrastructure, and market potential can be used to understand clearly how physical infrastructure use leads to increased empowerment and nutritional outcomes. Furthermore, women's empowerment and gender equality in turn affect nutrition. In theory, physical infrastructure use, women's empowerment, gender equality, and nutritional outcomes can be impacted by demographic and socio-economic characteristics, farm-specific characteristics, and institutional factors.

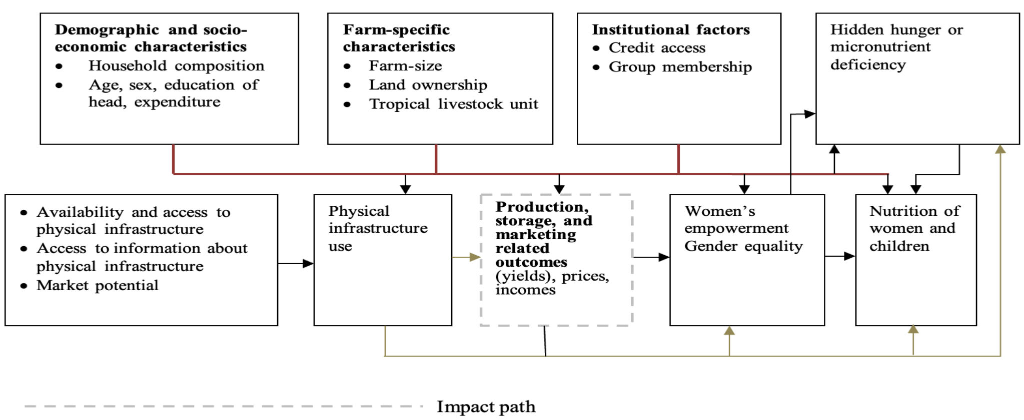


Figure 2: Conceptual framework of the study
Source: Authors' own construction, 2023

3. Research Methodology

3.1 Location of The Research Site in Ghana

The study was conducted in the USAID/Ghana's Zone of Influence (ZOI). Figure 3 shows the study areas. The ZOI constitutes the Northern (now demarcated into Northern, Savannah, and North-East regions), Upper West, and Upper East regions and some areas within the Bono East region (formally part of the Brong Ahafo Region). The study regions are located mainly in the Guinea and Sudan savannah agroecological zones with an annual average rainfall of about 1000 mm. The agroecology of the ZOI supports the production of maize, rice, sorghum, millet, groundnut, soya bean, root and tubers, and tree crops. Agriculture is the main livelihood for most of the working populace. Several cultures and tribes exist within the USAID/Ghana ZOI area with diverse customary practices and traditions that form the basis of agricultural production and gender dynamics. In context, two clear distinctions exist within the area. Households in Brong Ahafo region are culturally and agro-ecologically different from the other regions and is generally considered not to be part of northern Ghana (MOFA, 2020).

The cultural and traditional system is primarily matrilineal which provides women the avenue or right to own and inherit lands. Northern, Savannah, North-East, Upper West and Upper East regions in Ghana constitute northern Ghana. In practice, persons who occupied northern Ghana are predominantly patrilineal with higher dominance of males in decision making, asset control and ownership. Restrictions on women ownership of productive assets are more pronounced among communities of these regions of patrilineal descent (Boateng, 2021). Women lack the customary right to own or inherit family land but obtain the rights to use land through their husbands or sons (Kasanga et al., 2018). There exists a direct and indirect link between landownership and power and empowerment across and within societies and communities (Yokying & Lambrecht, 2020). For a rural farming household like northern Ghana, women's access and ownership of land can increase the security of women economically and, enhance their bargaining power within the household (Wigg, 2013: Yokying & Lambrecht, 2020). This creates an opportunity for women to better allocate resources in their interest and preferences that contributes to improvement in their wellbeing (Mishra and Sam, 2016). While women in northern Ghana remain an integral component of household agricultural labour by helping their spouses, there is little control over land and other productive resources. This system keeps women disempowered economically within the northern spheres of Ghana relative to Bono Region given that they play a supportive role on farms.

The agricultural economy within ZOI is rain-dependent which is susceptible to severe economic consequences from climate variability and change. Food production and food security is also under threat in these areas which are fostered by climate change since most of these farmers are subsistence farmers. Frequent incidence of flood mostly at the peak of the rainy season exposes farmers in the region to crop failures. Intermittent droughts and long duration of the dry season in the region contributes to the plight of farmers. This widens the diversity and poverty between ZOI and other parts of the country. For instance, available statistics from the Ghana Statistical Service (GSS) showed that mean annual per capita expenditure in the study area ranged between GH¢1662 and GH¢3429 with food alone occupying about 36-42.6% of the expenditure (GSS, 2019). Further, expenditure on diets ranged between GH¢204 and GH¢1012 (*ibid.*). The issue of hunger also remains common challenge as households with moderate hunger is represented by about 36% (Nkegbe et al., 2016).

In addition, the incidence of food insecurity remains higher in this area. This is particularly true for northern Ghana where earlier reports by the World Food Programme (WFP) showed that about 38% of Ghana's food insecure population were in Upper West, Upper East, and Northern regions, making them the most food insecure and vulnerable in the country (WFP, 2022) and about 40% of the rural population in northern Ghana are further reported vulnerable to food insecurity (Ministry of Food and Agriculture, 2015b). Employment is better as population of employed 15 years and older range between 241,374 in the Upper East and 1,095,931 in the Brong-Ahafo region while unemployed population ranged between 18,329 in Upper East region and 70,229 in the Brong-Ahafo region. Poor sanitation is likely to be a challenge (GSS, 2019). Apart from Brong-Ahafo region where use of public toilet dominates, majority of the inhabitants in Northern, Upper East and West rely on bush/beach/field as the main toilet facility (*ibid*.). Improving nutritional status, especially of women and children less than five years of age to sustainably reduce global poverty and hunger remains an overarching goal of the USAID/Ghana Feed the Future.

Regarding infrastructure, a substantial increase in investment has been witnessed in the area. For instance, over USD94 million has been injected into infrastructural development by Northern Rural Growth Programme (NRGP), jointly funded by the African Development Bank (AfDB), the International Fund Agricultural Development (IFAD), and the Government of Ghana (African Development Bank, 2017). In addition, the World Bank approved USD150 million to improve connectivity and reduce travel time from Northern region to other parts of the country. Well, including borehole/pump/tube well, protected, and unprotected wells remain the dominant source of water supply in the area and majority of the inhabitants are also connected to electricity from the national grid. Although challenges persist in terms of the quality of services provided from existing infrastructure, Ghana's infrastructure is more advanced, especially when compared with other countries in Africa.

Total length of paved and unpaved roads is about 2.2 percent of Africa's total land (WorldData, 2023). These roads are not only in good condition but are extended to rural areas (Foster & Pushak, 2011) and, thus, highlights the progress made in making markets accessible for rural communities. Similar case can be made for water and electricity in terms of coverage rates. In terms of policy, for instance, infrastructural development is now at the centre-stage of Ghana's national development objectives. To an extent that gender-blind infrastructure can limit access to critical resources and progress towards the empowerment of women, Ghana's National Gender Policy calls for gender mainstreaming approach to infrastructural development to address the gender-based barriers impeding women and girls (Ministry of Gender Children and Social Protection, 2015). Aside from these efforts, current investment in new projects is a little above US$2 billion and projected to reach US$4 billion by 2040 (Ministry of Finance, 2021). Currently, total funds disbursed for routine maintenance, periodic maintenance and minor rehabilitation and upgrading was estimated at 61 per cent of the maintenance needs of each modal network. Table 7 below contains examples of these projects in Northern Ghana.

Table 7: Infrastructure projects in Ghana

Project		Sector	Location	Status
1.	**Naa Gbewaa Interchange and Aboabo Market**	Transport	Tamale Metropolis	Completed
2.	**Tono Dam Rehabilitation and Expansion**	Agriculture	KasenaNankana Municipality	Uncompleted Completed
3.	**Ghana Grain Council Certified Warehouses (AGMSIG Resource, Gunda Produce Company Ltd, Wienco (Ghana) Ltd)**	Agriculture	Northern Region	Completed
4.	**Fufulso-Sawla Road and Markets**	Transport & Commerce	Northern Ghana	Completed
5.	**Eastern Corridor Road**	Transport	Northern Ghana	Uncompleted

Despite all these investments and available opportunities, hopes of improved nutrition is still low, and challenges of meeting the 2030 Agenda for Sustainable Development, including high incidence of poverty, malnutrition, and stunting among children under five years of age remain prevalent in the area. Farmers within the area are the poor and marginalized in terms of households' access to public/private physical infrastructure, human and social capitals/assets and experiencing market exclusivity.

3.2 Research design

Based on the research objectives, the nature of research problem and issues being addressed, the current study employed a mix-method design. The mix-method design focuses more on the research problem and draws on the strengths of the different methods to better understand the phenomenon under study (Creswell, 2009). Specifically, the sequential explanatory design is employed for this study. The choice of this design is largely influenced by the issues being investigated (i.e., role of physical infrastructure on women's empowerment and nutritional outcomes) as well as the interest in testing hypotheses that will help generate new knowledge which a single design might not reveal. The sequential explanatory design allows for second phase qualitative data collection to interpret unexpected and surprising results from the first phase of research. The first phase involves quantitative data collection and analysis while the second phase is a follow-up qualitative data collection to explain and interpret the initial quantitative results (Creswell, 2011). In the case of this study, the quantitative survey data helped to examine and compare the effects of single and joint use of infrastructure on women's empowerment, gender equality, nutrition indicators, and hidden hunger. A qualitative group interviews and Key Informant interviews (KII) were then employed to explain why the outcomes of the results diverge from the study's main expectation. Thus, the quantitative strand provided comparative pictures of how women's empowerment, gender equality, WDDS, BMI, and CDDS),

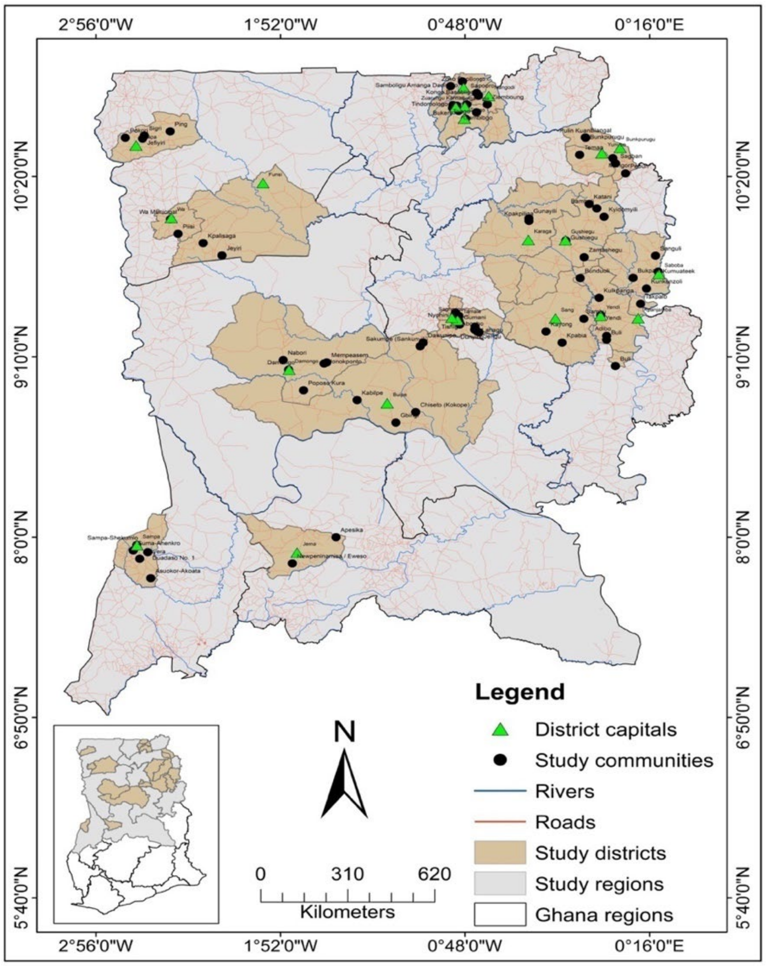


Figure 3: Map of the study area
Source: Own map, 2023

and hidden hunger are affected using single and joint infrastructure, while the qualitative follow-up group interviews and KII helped elaborate on the somewhat unexpected statistical results. This implies that the quantitative and qualitative data are separated, but are connected between data analysis of the first phase quantitative survey and the data collection of the second phase qualitative group interviews (Creswell, 2009; Hanson, Creswell, Clark, Petska, & Creswell, 2005). Figure 3 presents a visual diagram of the study design and flow of the procedures.

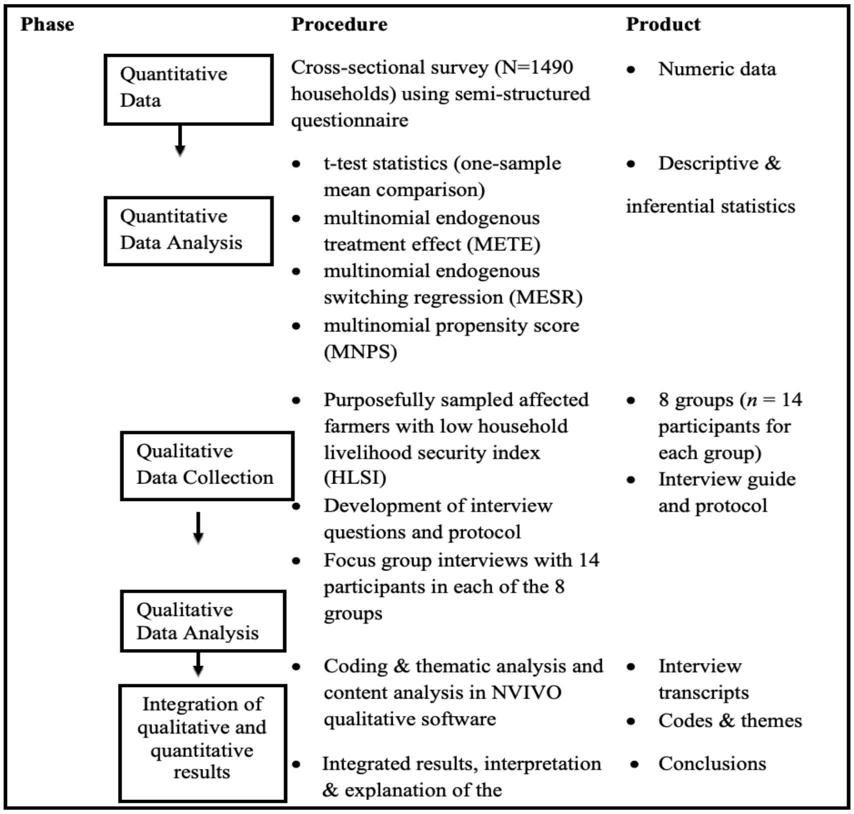


Figure 4: A visual model of mix-method sequential explanatory design and flow of the study
Source: Author's illustration

3.3 Target population

The USAID/Ghana ZOI has multiple regions, agro-ecological zones districts, and communities in the baseline survey covered. The methodology for this study was designed to capture the current condition with regards to gender, infrastructure, nutrition, agricultural production, and women's empowerment of households within the ZOI area. The target population comprised of all households in the ZOI communities. By definition, a target household comprised of a household head and a spouse of the household heads or household member who is not as same sex as the household head. In addition, USAID worked with various stakeholders to effect change across the ZOI area. The study incorporated the views of all relevant stakeholders in the study area. We considered officials of Ghana Grain Council, private owners of storage facilities, local government (District Assembly), gender experts, nutrition experts, and academic researchers. The in-depth information from the stakeholders also helped to explain the outcome of the quantitative results.

3.4 Types and Sources of Data

Qualitative and quantitative data were collected from primary and secondary sources. Data from the primary sources were mainly obtained from household survey and focus group discussions with semi-structured questionnaire and interview guides. These data sources helped to have access to reliable and accurate first-hand information relevant to the study. The qualitative and quantitative data from primary included information on infrastructure such as storage and market facilities; food and nutrition indicators including women's and children's dietary diversity, women's and children's body mass indices, hidden hunger; Pro-WEAI capturing women's empowerment and gender equality; and household, farm, institutional and location characteristics. The secondary data including information on existence of storage and market facilities, marketing and storage, consumption and nutrition was obtained from local government, Ministry of Food and Agriculture, the Ghana Grain Council, Gender, and Nutrition experts in the area. The information from secondary sources facilitated the attainment of the study objectives.

3.5 Sample size and sampling procedure

For the quantitative survey, our basic unit of analysis is the household; hence, the study covered a total of 1492 households. This sample size was considered partly for statistical reasons and partly for logistical considerations. Statistically, the sample size was large enough to study and generalise about the population. The study obtained the subsample using Cochran's (Cochran, 1977) method. To obtain our sample size, a 50% cumulative non-response rate (i.e. 5%/annum) of the Feed the Future data (4,410 observations). The subsample means that the study has a 0.50 proportion of potentially available households. Logistically, there were limited time and funds to consider the sample size equivalent to the population under study. Using the list of districts, enumeration areas (EAs), and household identification numbers as the sampling frame, we selected households for this study through a multi-stage sampling technique. In the first stage, we used a proportionate-to-size random sampling approach to select 2-5 districts from each region in proportion to the number of districts in these regions. In the second stage, we used a proportionate-to-size random sampling approach to select 2-14 EAs were randomly selected from each district in proportion to the number of districts selected in the study regions. In the third and final stage, we selected 18-24 households from each EA in proportion to the number of EAs selected.

The first panel (2012 Feed the Future data set) contained thirty-eight 38 districts, of which 15 were chosen at random for the current analysis. A total of 1,492 households from 74 communities were sampled for interview. However, due to non-responses of some households in the initial communities, additional households from 4 other communities in 3 different districts (Nandam[1], Karaga, and Bunkpurugu[2]) were selected and respondents interviewed along with those sampled from the initial 15 districts (Jaman North, Kintampo South, Gonja Central, West Gonja, Saboba, Gushiegu, Yendi, Tamale Metropolis, Bolgatanga Municipal, Telensi, Bongo, Wa Municipal, Wa East, Jirapa, and Yoyor). About 69.17% of the total households interviewed lived in rural communities. In total, 78 communities were sampled from 18 districts for the study (Table 8). The sampled communities were drawn from 230 enumeration areas (EAs).

Table 8: Sample distribution by study location

Region	Number of sampled districts	Number of sampled communities	Number of households interviewed	% of households living in rural areas
Bono East	2	8	151	74.17
Northern	5	34	634	54.89
North-East	2	7	136	88.24
Savannah	2	10	193	90.67
Upper East	4	12	234	67.52
Upper West	3	7	144	82.64
Total	18	78	1,492	76.355

Source: Field data, 2012 and 2022

3.6 Data collection

Given these nuanced issues surrounding women's empowerment and nutrition and the need to piece together information concerning infrastructure, women's empowerment and nutrition, the study employed

[1] Before the current study, Telensi and Nandam were marked as one district.
[2] Bunkpurugu and Yoyor were marked as one district as well.

household survey in quantitative data collection. Thus, after sampling the households, household survey was conducted for better capturing of information of households. By this method, questions were asked to household head and spouse selected or adult who have much information about the household, and the responses were written by the interviewer or enumerator. In addition, these methods were employed to give the interviewee the opportunity to ask questions for clarification. The survey captured information on households' demographics, household hunger scale, cultivation of crops, women's dietary and children's dietary diversity, anthropometry for women and children, households' dwelling characteristics, women's empowerment in agriculture index, households' expenditure and availability and use of physical infrastructure -market and storage facilities - for the 2021/2022 cropping season. Further issues regarding availability and use of physical infrastructure in the past 10 years were captured.

The group discussions also captured general information on hunger, women's dietary and children's dietary diversity, anthropometry for women and children, women's empowerment in agriculture index, availability, and use of physical infrastructure -market and storage facilities. Regarding the survey, the study resorted to face-to-face interviews and 20 enumerators (2 for each district) were recruited and trained to help interview the selected household heads. Data collection commenced on the 26th of December 2022. Experienced enumerators were recruited and trained on interviewing skills and how to manage the questions. A total of 6 regions were covered. The household survey was conducted in two stages namely, pre-test and main survey of targeted respondents. The main survey was preceded by a pre-test. The purpose of the pre-test was to get feedback regarding the questionnaire structure and the perceived time-cost in administering the question. The pre-test exercise was conducted using twenty households.

The farmers were selected from different communities outside the study area. Specifically, all the households for the pre-test were selected from the Sagnarigu district in the northern region. This provided an opportunity for flaws and deficiencies in the questionnaire to be identified and remedied. The final survey was conducted after all the corrections were made. This covered a period of one month with the enumerators making personal visits to the destinations of the respondents and as well as tracking the respondents. Regarding the tracking of the households, the USAID/Ghana's 2012 Feed the Future dataset contains Global Positioning System (GPS) coordinates of the 2012 households. Based on the GPS coordinates generated, the GPS points for the selected households for 2021/2022 survey were extracted and sorted according to districts. The extracted points of interest were converted into a GPS exchange format (GPX) using the DNR GPS software version 6.1. To ensure that enumerators were able to track the houses of interest even in the remote areas where internet connectivity was a challenge, we relied on the My GPS Coordinates (App) downloaded from Google Play Store. The My GPS Coordinates (App) is an offline application and can operate in areas of no internet connectivity. Finally, the GPX file containing the houses coordinates in a particular district were imported into the My GPS Coordinates (App) for the enumerators based on where they were posted. And knowing their location in a particular community (town), they can navigate to the houses of interest as shown in Figure 5.

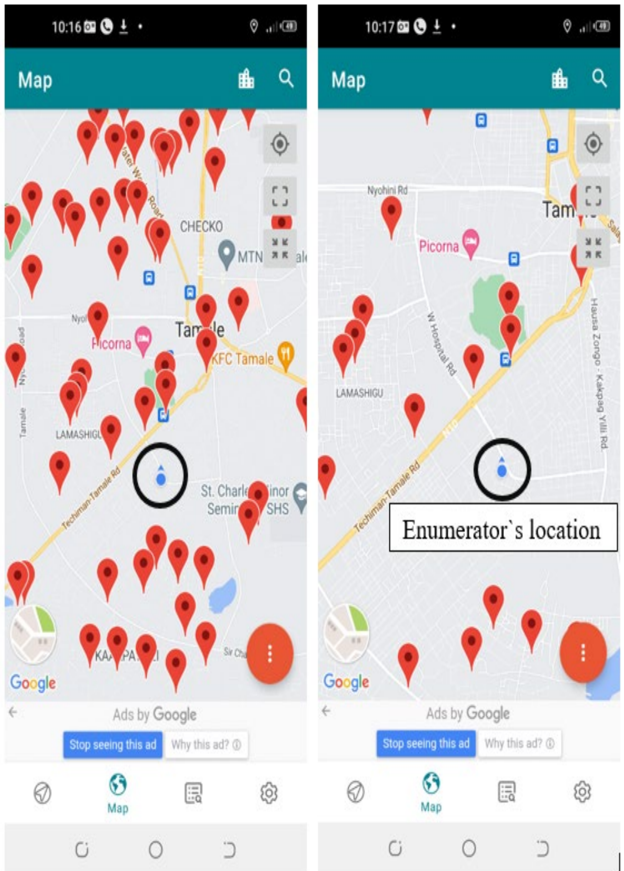


Figure 5: Picture showing enumerator's location and houses to be tracked within the Tamale Metropolis

3.7 Instruments used for data collection.

We adapted a semi-structured for the second-round quantitative survey. The questionnaire consisted of twelve (12) modules. Module one covered information on household identification and consent form. Module two covered information on household demographic characteristics. Module three covered information on household hunger scale and cultivation of key crops. However, questions on key crops cultivated were asked based on the information given about type of crops cultivated. Module four and five covered information on women's and children's dietary diversity respectively; Module six covered information on physical mobility; Module seven and eight covered anthropometry for women and children respectively; Module nine covered information on households' dwelling characteristics. Module ten consisted of information on project-level women's empowerment in agriculture index (Pro-WEIA) including access to financial services, group membership, intrahousehold relationships, autonomy in decision making, time allocation, self-efficacy, life satisfaction and attitude about domestic violence. Module eleven covered information on household and housing expenditure. Finally, module twelve covered information on availability and use of physical infrastructure including storage and market facilities. The questions from each of these sections were loaded in Kobo Toolbox, an online open-source suite of tools for field data collection developed by the Harvard Humanitarian Initiative, Brigham, and Women's Hospital and Kweyo with support from other organisations. The software stores the data in a comma separated value (csv) format of the excel sheet, which can be downloaded and imported into Stata, SPSS, or any statistical software for analysis. Thus, one notable advantage of using the software is that the time needed for data entry is saved for other purposes. The Kobo Toolbox was installed in Android phones - Samsung Galaxy Tab A8 Tablets - for the enumerators and questions from the questionnaire were then loaded onto the Kobo Toolbox and administered directly to the households in the study communities. Explanations and instructions were given to the respondents wherever it was necessary.

3.8 Data validation and cleaning

To make meaning out of the data collected or to facilitate the interpretation of the results of the quantitative survey, as well as draw conclusions, the data was subjected to several stages of processing. First, we read through to ensure that the responses were appropriate, especially with regards to the problem, purpose, and questions of the study. Through the checking, all discrepancies arising from inaccuracies and inconsistencies were corrected through phone calls. This finally ensured accuracy and consistency of all responses. However, even after checking and correcting for inaccuracies and inconsistencies, many of the variables still needed considerable cleaning to get the data to an acceptable level of quality. For instance, some responses from the open-ended questions carried the same message, but in different wording, and were edited further to ensure uniformity of responses. Specifically, these responses were coded to allow the software to easily transform the data into a countable and tabulated form. The data were imported into Stata 17 and analysed using descriptive and inferential statistics as well as econometric models. To begin with, we defined and/calculated some of the outcome variables such as use of infrastructure, hidden hunger, household hunger scale, women's dietary and children's dietary diversity, body mass index, women's empowerment in agriculture index and household's expenditure.

3.9 Data analysis

This section describes the estimation techniques employed to analyse the quantitative and qualitative data collected in this study. To begin with, the measurement of the treatment and outcome variables are presented. The study employed methods drawn from the potential-outcomes/counterfactual framework to analyse the impact of using single and multiple infrastructures on women's empowerment, gender equality, food security, and nutrition. Specifically, the impact of single and multiple use of infrastructure on women's empowerment, and gender equality were examined using multinomial endogenous treatment effect (METE) model, whereas nutrition indicators were examined using the multinomial endogenous switching regression (MESR) model with Mundlak-Chamberlin device. We control for time-varying unobserved fixed and random effects in the MESR and METE models using the Mundalk's approach. Furthermore, we conducted mediation analysis to identify the pathways between infrastructure use and the outcomes using Hayes macro-application "PROCESS" for SPSS (Hayes, 2013). Specifically, we used a parallel mediation model to examine role of farm income, crop diversification, livelihood diversification, and asset ownership in mediating the impact of physical infrastructure use infrastructure use on the outcomes. The Multi-valued treatment effect regression model was employed to confirm the robustness of our results. The results are presented in Tables C1-C10 in the Appendix (click here for Table C1-C10 in supplementary file at the Appendix). We conducted a falsification test to check the validity of our instruments.

Measurement of treatment and outcome variables

In this study, we defined marketplaces to include small village markets and big periodic markets in towns and cities and storage facilities to include storerooms, mud silos, state and privately- silos, granaries, grain banks, and certified warehouses. A household is therefore said to use market infrastructure if it sells or buys from small village markets and big periodic markets in towns and cities. Further, the household as access to a market facility information if it has knowledge of at least one of the following five factors; the market's location, the next market day in the forthcoming month, pricing of basic foods, perceived distance to market, and producer-buyer contract. Similarly, a household is said to be using storage facilities if it stores using storerooms, mud silos, state and privately- silos, granaries, grain banks, and certified warehouses. Further, it is said to have access to storage facility information if it has knowledge of a facility's location, perceived storage capacity, perceived distance to the facility, ownership of the facility, security, and safety at the facility.

Table 9 reveals that 5.76% of the households had no information about any of the physical infrastructures, whereas 17.09%, 6.47%, and 70.68% had access to information about market facility only, storage facility only, and both infrastructures, respectively. In 2022, 78.95% of households had access to information about both infrastructures, up from 62.40% in 2012, which resulted in a 12.2% and 6.3% decrease in those with access to information about market facility only and those without access to information about physical infrastructures, respectively. The number of households that had access to information about storage facility only increased from 5.50% in 2012 to 7.44% in 2022. Overall, more than 50% of the households had access to information about market facilities for selling and buying their items as well as facilities for storing their foods. Between 2012 and 2022, the number of households that had access to both infrastructures increased by 3.5%, whereas households that did not have access to the selected physical infrastructures decreased by 8.98%. Access to markets might provide households with a diverse selection of food products, essential for preparing nutritious meals. Access to storage facilities may also assist households to maintain (or preserve) more essential foods from spoiling during seasons of bounty (or inadequate harvest).

Table 9: Households' information access and access to physical infrastructure

Variable	Full sample %	2012 %	2022 %	Diff.
Access to information				
No information about both infrastructures (yes = 1)	5.76	8.91	2.61	-6.3
Access to information about market facility only (yes = 1)	17.09	23.19	10.99	-12.2
Access to information about storage facility only (yes = 1)	6.47	5.50	7.44	1.94
Access to information about both infrastructures (yes = 1)	70.68	62.40	78.95	16.55
Access to physical infrastructure				
No access to either infrastructure (yes = 1)	11.06	15.55	6.57	-8.98
Access to market facility only (yes = 1)	14.85	16.69	13.00	-3.69
Access to storage facility only (yes = 1)	20.51	15.95	25.07	9.12
Access to both infrastructures (yes = 1)	53.36	51.81	55.36	3.55

Source: Authors' own estimation, 2022 and 2012

Table 10 presents the result of the physical infrastructure use decisions. Physical infrastructure use yields four distinct categories in the study: non-users (M_0S_0), market facility users (M_1S_0) only, storage facility users (M_0S_1) only, and multiple infrastructure users (M_1S_1). Table 10 shows that more households (17.69%) did not use any of the selected physical infrastructures in 2012, than in 2022 (7.64%). About 16.29% of the sampled households used market facilities only, compared to the 12.33% in 2022. Conversely, we find more households using storage facilities only in 2022 (29.29%) than in 2012 (16.02%). This result implies that households stored food more than it used to sell food in the market in the current year. About 50.0% and 50.74% of the sampled households used both market and storage facilities in 2012 and 2022, respectively. More than 80 percent of the households used at least one of the selected physical infrastructures in 2012, whereas 92.36% of the sampled households used at least one of the physical infrastructures in 2022. Such changes may influence nutritional outcomes of households in the area.

Table 10: Decision to use physical infrastructure.

Use set	Combination	Market facility (M)		Storage facility (S)		2012		2022		Diff in %
		M_0	M_1	S_0	S_1	*n*	%	*n*	%	
1	M_0S_0	√		√		264	17.69	114	7.64	- 10.05
2	M_1S_0		√	√		243	16.29	184	12.33	- 3.96
3	M_0S_1	√			√	239	16.02	437	29.29	13.27
4	M_1S_1		√		√	746	50.00	757	50.74	0.74

Source: Author's estimation Field data, 2022

The outcome variables include women's empowerment, gender equality, nutrition, and hidden hunger. Women's empowerment was captured using the Pro-WEAI score. Pro-WEAI is the weighted average of 3 domains from 12 indicators, including autonomy in income, self-efficacy, attitudes about domestic violence, input in productive decisions, ownership of land and other assets, access to and decisions on credit, control over the use of income, work balance, visiting important locations, group membership, membership in influential groups, and respect among household members. These indicators are organised into three domains of empowerment (3DE): intrinsic agency (power within), instrumental agency (power to), and collective agency (power with). A respondent is considered adequate in a particular indicator if she or he reaches a certain threshold. The indicators are weighted equally, and a respondent is considered empowered if she or he is adequate in at least 9 out of 12 (or at least 75%) of the indicators. The gender parity gap (GPG), which is a measure of women's empowerment, was employed to quantify gender equality. GPG is the difference in the male and female empowerment scores. The woman is empowered if the GPG is equal to unity or higher than that of the man. We generated women's empowerment scores and the gender parity index using the IFPRI's pro-WEAI data preparation do-file (https://weai.ifpri.info/weai-resource-center/guides-and-instruments/). Further, hidden hunger was captured using self-sufficiency in the production (SSP) of maize, sorghum, rice, yam, and cassava. Maize, sorghum, rice, yam, and cassava are energy-dense staples and provide small amounts of protein, vitamins, minerals, and other micronutrients (Smith & Subandoro, 2007; IFPRI, 2014). Thus, hidden hunger increases with the consumption of these staples. The SSP captures the total grain produced and available for the household's consumption. SSP is a continuous variable constructed as follows:

$$SSP_i = \frac{Total\ available\ cereal}{Population\ of\ family\ unit} \tag{1}$$

Where: $\text{Total available cereal} = TC + CPH$;

TC is total refined cereal in a maize equivalent basis specified:

$$TC = [(\text{MP} * 0.90 * 0.97) + (\text{SP} * 0.90 * 0.97) + (\text{RP} * 0.65 * 0.99) + (\text{CP} * 0.85)$$

with 0.90, 0.90, 0.65, and 0.85 as the milling ratios for millet, sorghum, rice, and maize respectively, and 0.97, 0.97, and 0.99 as the maize equivalent of millet, sorghum, and rice on a milled basis, respectively. Further, CPH is the cereal in maize equivalent basis that is purchased from cash crops such as cotton, groundnut, cowpea, and other legumes. The calculation of SSP in this study is based on a threshold of 200kg of cereal per annual equivalent employed by (Jolly & Gadbois, 1996). Thus, a household is self-sufficient and has food throughout the 2012 and 2022 cropping seasons if the calculated total grain produced and available for the household's consumption is greater or equal to 200kg and deficient if the value is less than 200kg per capita per annum. Thus, women's empowerment, gender equality, and hidden hunger were captured as binary variables.

Food security is a dummy coded 1 if the household is food secure and 0 if otherwise. We used the household hunger scale as a proxy for household food security. Nutrition on the other hand was captured using the women's dietary diversity score (WDDS), body mass index, children's dietary diversity score (CDDS), stunting, wasting, and underweight. The WDDS is a continuous indicator of nutrition denoting the number of food groups consumed based on 24-hour recall. To calculate women's dietary diversity scores, we followed the FAO guidelines for measuring household and individual dietary diversity (FAO, 2016). The WDDS was calculated by summing the number of food groups (1-10) consumed by women of reproductive age (15-49 years) over the 24-hour recall period. The ten food groups include (1) starchy staples, (2) green leafy vegetables, (3) other vitamin-A-rich fruits and vegetables, (4) other fruits, (5) other vegetables, (6) organ meat, (7) meat and fish, (8) eggs, (9) legumes and nuts, and (10) milk and milk products (FAO, 2016). Similarly, following FANTA (2006) indicator guide, we calculated the children's diversity scores (CDDS) by adding the number of food groups (0-7) consumed by children aged 6-23 months over the 24-hour recall period. The eight food groups include (1) grains, roots, and tubers; (2) pulses, legumes, and nuts; (3) dairy products; (4) flesh foods; (5) eggs; (6) vitamin- A-rich fruits and vegetables; and (7) other fruits and vegetables (Fongar *et al*., 2019).

The zscore06 command in Stata 17 was used to create a height-for-age (HAZ), weight-for-age (WAZ), weight-for-height-for-age (WHZ), and BMI-for-age z-score using a child's age, sex, height, weight, and edema (Leroy, 2011). These indicators were then used to categorize the sample into stunting, wasting, and underweight based on the WHO child growth standards median. We calculated BMI for women by dividing their weight in kilograms by their height in meters squared. According to the WHO, a woman is considered underweight if her BMI is less than 18.50 kg/m^2 (Malapit & Quisumbing, 2015). The impact of physical infrastructure on household food security and hidden hunger is based on a panel data, whereas the impact of physical infrastructure on women's and children's nutrition is based on a cross-sectional data. We used the cross-sectional data for women's and children's nutrition, as well as women's empowerment and gender equality because of incompatible data. Although the panel of households was quite strongly balanced, the individual data for women and children were not. We had different women and children living in the same household for a significant portion of the second panel. We estimated models for the second panel (2022) to assess how physical infrastructure use affects women's empowerment, gender equality, women's nutrition, and children's nutrition.

Table 11 shows the mean values for the household and individual characteristics in the panel data. In 2022, 18 percent of families were headed by a woman, down from 19 percent in 2012. In 2022, the number of females aged 18 years and above was roughly two, up from one in 2012. In 2022 and 2012, the average age of women aged 15 to 49 was about 33 years, with 1,400 and 1,491 observations, respectively. In 2022, less than half (47 percent) of children aged 6-23 months were males, down from 54 percent in 2012, with 769 and 1,217 observations, respectively. Between 2012 and 2022, women and children consumed an average of four and three food groups, respectively. Nonetheless, we had distinct IDs for all children aged 6-23 months and several women in the same household for both panels. Because the individual IDs for 2022 and 2012 were strongly unbalanced, we examined women's empowerment, gender equality, and nutrition of women and children using the second panel. In contrast, the household IDs for both data were strongly balanced, allowing us to examine household food security using the panel data. Household food security appreciated from 50 percent in 2012 to 67 percent in 2022. In 2022, a higher percentage (34 percent) was empowered than in 2012 (30 percent). Also, in 2022, 476 percent of households attained gender equality, up from 46 percent than in 2012. In 2022, we used the pro-WEAI to construct women's empowerment, while in 2012, we used the WEAI.

Table 11: Descriptive statistics of panel data

Variable	Description	2012 Mean	2012 Sample	2022 Mean	2022 Sample
Sex of head	Female headed household (yes = 1; no = 0)	0.19 (0.40)	1492	0.18 (0.39)	1492
Adult females	Number of females aged 18years and above	1.47 (1.03)	1492	2.19 (1.40)	1492
Age of women	Average age of women between the ages of 15 and 49 years	32.52 (5.73)	1491	32.96 (6.18)	1400
Sex of child	Male child (yes = 1; no = 0)	0.54 (0.50)	1217	0.47 (0.50)	769
Women empowerment	Women is empowered (yes = 1; no = 0)	0.30 (0.46)	1492	0.34 (0.47)	1492
Gender equality	Household has gender equality (yes = 1; no = 0)	0.42 (0.49)	1492	0.43 (0.44)	1492

Source: Own estimation based on household survey data, 2012 and 2022.
Legend: ***, **, and * show significance at 1%, 5%, and 10% levels, respectively.

Based on the above definitions and calculations, the study employed methods drawn from the potential-outcomes/counterfactual framework to analyse the impact of single and multiple use of infrastructure on women's empowerment, gender equality, nutrition, and hidden hunger. Specifically, the impact of single and multiple use of infrastructure on women's empowerment, and gender equality were examined using multinomial endogenous treatment effect (METE) model, whereas nutrition indicators and hidden hunger were examined using the multinomial endogenous switching regression (MESR) model with Mundlak-Chamberlin device. Our choice of a specific method was made in consideration of the objective and the potential estimation problems that may come thereof. The details of MESR and METE models for analysing the impacts of the use of single and multiple infrastructures on women's empowerment, gender equality, nutrition, and hidden hunger from survey data are outlined in the next subsections.

Empirical specification and the problem of impact evaluation
To estimate the impact of single and multiple use of infrastructure on women's empowerment, gender equality, nutrition, and hidden hunger, we assumed in this study that each of the outcomes of interest is at least a linear function of a vector of explanatory variables(X_i)and use of single and multiple infrastructures is specified as:

$$Y_i = \beta_0 + \beta_1 I_i + \beta_2 X_i + \eta_i \qquad (2)$$

Where Y_i is the vector of the outcome variables, I_i is a vector of single and multiple infrastructure, X_i is a vector of household, farm/plot, institutional and location factors, β_i are the parameters to be estimated, η_i is a random term. Equation (2) also implies assumption of fixed regressors, that is the observations of the explanatory variables are considered fixed in repeated samples. Given that this assumption holds I_i will be uncorrelated with X_i, η_i and equation (2) can be estimated using OLS or binary choice models including logit or probit models. In this regard, the impacts of single and multiple use of infrastructure on the outcome of interest is considered to be β_i which is unbiased and consistent (e.g. Wooldridge & Semykina, 2005)· Unfortunately, this may not hold for several reasons. First, decisions to use infrastructure respond positively to agricultural opportunities implied in the agro-climatic endowments of a region (Binswanger et al., 1993). It is also important to mention that some types of infrastructure (e.g., unregulated markets, and infrastructure by Ghana Grain Council) are public goods by nature and, therefore, have no excludability, nor rivalry of consumption. Thus, farmers may self-select into use of such infrastructure based on their wealth status or other innate abilities. Second, the decision to use infrastructure, including market and storage facilities is also influenced by both wealth and skills and so does not entirely depend on its existence in a community. However, wealth, skills and proximity to urban centres may be unknown to the researcher (omitted variable problem) and hence, causes a correlation between infrastructure, I_i and η_i. If this is the case, then the assumption that no correlation exists between the error term η_i and infrastructure I_i in equation (2) may be violated i.e., $\rho = corr\ (\eta_i, I) \neq 0$. Failure to account for this potential selection bias could lead to inconsistent estimates of the effect of infrastructure.

To correct for this bias and as well determine the effect of the treatment, several methods have been developed. These include the instrumental variable (IV) regression, Heckman procedures, propensity score matching (PSM), double-difference (DD) methods, regression discontinuity and endogenous switching regression (ESR) models (e.g., Heckman et al., 2005; Imbens & Wooldridge, 2009; Jalan & Ravallion, 2003; Khandker et al., 2010; Loksin, M & Sajaia, 2004). In particular, the PSM techniques have been employed by most studies to examine the impact of treatment on outcome of interest. These studies assumed that treated and non-treatment households are systematically different only in observed characteristics (e.g., age, education, farm size, plot characteristics etc.). However, unobserved characteristics (e.g., farmers' innate abilities etc.) may also simultaneously influence households' exposure to treatment and outcomes of interest. Thus, ignoring such factors may lead to biased estimates. Unlike PSM, the ESR controls for selection bias resulting from both observed and unobserved variables. However, the approach requires a functional form assumption for the outcome equation i.e., use of instrument for proper identification of the treatment. Also, like the ESR, the IV approach to correcting selection bias requires an instrument that is correlated with the treatment but not correlated with unobserved characteristics affecting the outcome.

However, such an instrument is sometimes difficult to come by. In addition, the approach requires functional form assumptions like linearity and normal distribution for the error term in the outcome equation. These would be strong assumptions if not supported by theory (Pangaribowo, 2013). With regards to the DD methods, Khandker et al. (2010) argued that the assumption of time-invariant selection bias is implausible for many targeted treatments in developing countries. Also, the major concerns with the regression discontinuity design are that (a) like the IV, it produces local average treatment effects that are not always generalizable (b) the effect is estimated at the discontinuity, so, generally, fewer observations exist than in a randomized experiment with the same sample size; and (c) the specification can be sensitive to functional form, including nonlinear relationships and interactions (Khandker et al., 2010). Aside the problems raised, both methods can only be executed in the context of binary treatments and, therefore, inapplicable in the context of multinomial treatments.

Approaches such as multinomial propensity score (MNPS), multinomial endogenous treatment effect, (METE) and multinomial endogenous switching regression (MESR) are respectively proposed by Cefalu and Buenaventura (2017) and McCaffrey et al. (2013), Deb and Trivedi (2006) and Bourguignon et al. (2007) for multinomial treatments, and have been employed in most studies (e.g. Kassie et al., 2018; Khonje et al., 2018; Manda et al., 2016; Ng'ombe et al., 2017). However, MNPS relies on conditional independent assumption (CIA) and the assumption of common-support and does not control for bias resulting from unobserved characteristics. Since this study aims to control for bias stemming from observed and unobserved characteristics and as well examine the impact of infrastructure, it employed the MESR models. We, however, employed MNPS methodology to check for robustness of our results since the MESR model may be sensitive to the assumption of exclusion restriction. These methods are presented in the next sections.

Multinomial Endogenous Switching Regression (MESR)

As mentioned previously, use of storage and market infrastructure and nutritional outcomes may be jointly determined by a set of observed and unobserved factors. For instance, government and policy makers may choose to establish market or storage facilities in communities that are better off in terms of production or population before considering less productive or populous areas. But decision to use market or storage is also influenced by production and population which may be unknown to the researcher (omitted variable problem) and hence, causes a correlation between use of these infrastructures and error term in equation (2). Moreover, adoption decisions respond to agroclimatic endowments of a region, use of marketplaces and communication facilities. But decisions to use infrastructure also respond positively to agricultural opportunities implied in the agroclimatic endowments of a region (Binswanger et al., 1993). Further, unobserved household characteristics such as household characteristics such as knowledge and experience in food nutrition may also correlate with time of storage, quantity of sales and market purchases as well as other observed explanatory variables. We combined a two-stage multinomial endogenous switching regression (MESR) model with the Mundlak-Chamberlain technique and panel data to account for time-varying unobserved heterogeneity in infrastructure use, nutrition, and hidden hunger to estimate the effect of infrastructures. The potential sources of heterogeneity include knowledge and experience in food security. The MESR model proceeds in two stages. The first stage involves using the multinomial logit selection (MNLS) model to estimate the factors influencing a household's use of single and multiple infrastructures, including the use of storage and market facilities. In the second stage of the MESR, the relationships between the outcome variables and a set of exogenous variables are estimated for each package of infrastructure, following Dubin and Mcfadden (1984) (hereafter referred to as the DM model) and Bourguignon et al. (2007) to correct for selection bias. The outcome equation for each possible regime (i.e., j= 2, 3, 4) is given as:

$$Regime\ 1 = Q_{ijt} = \delta_j X_{ijt} + \mu_{ijt}\ if\ A = J \tag{3}$$

$$Regime\ J = Q_{ijt} = \delta_j X_{ijt} + u_{ijt}\ if\ A = 2$$

Where Q_{ij} are the nutrition indicators and hidden hunger of the ith household in regime j at time t., the error terms (μ_{ij}) are distributed with $E(\mu_{ij}|z, X) = 0$ at time t, and $var\ (\mu_{ij}|z, X) = \delta_j^2$. Q_{ij} are observed if and only if one of the possible infrastructural combinations is used and this occurs only when $U_{ij}^* > \max(U_{im}^*) j \neq m$.. If the ε_{ij} and u_{ij} are not independent, OLS estimates of δ_i in equation (3) will be biased. For a consistent estimation of δ_i , inclusion of the selection correction terms of the choices in Equation (3) is necessary. For Bourguignon et al. (2007), consistent estimates of $\alpha_i$in the Equation (3) can be obtained by estimating the following MESR models:

$$Regime\ 1: Q_{i1t} = \delta_1 X_{i1t} + +\alpha_1 \hat{\lambda}_{i1t} + \varphi_1 \bar{X}_{i1t} + \varepsilon_{i1t}\ if\ I = 1$$
$$Regime\ 2: Q_{i1t} = \delta_1 X_{i1t} + +\alpha_1 \hat{\lambda}_{i1t} + \varphi_1 \bar{X}_{i1t} + \varepsilon_{i1t}\ if\ I = 2 \tag{4}$$

$$Regime\ J: Q_{iJt} = \delta_J X_{iJt} + \alpha_J \hat{\lambda}_{iJt} + \varphi_J \bar{X}_{iJt} + \varepsilon_{iJt}\ if\ I = J$$

where σ_j is the covariance between ε_{ij} and u_{ij} ; φ_j are unknown parameters of covariates $\bar{X}_{ij}$ at time t. The $\bar{X}_{ij}$ is obtained by constructing the mean values of time-varying explanatory variables in X_{ij} . Such approach is the Mundlak-Chamberlin device which minimizes the problem of unobserved heterogeneity (Mundlak, 1978; Wooldridge, 2002) and has been employed in recent studies (e.g., Kassie et al., 2018; Khonje et al., 2018; Issahaku & Abdulai, 2020) to control for unobserved heterogeneities. The Mundlak approach combines fixed-effects and random-effects estimation approaches. By including the mean of time-varying explanatory variables, we control for time-constant unobserved heterogeneity, as with fixed effects, while avoiding the problem of incidental parameters in nonlinear models such as the multinomial logit (MNL) model (Biru et al., 2020). We corrected the random effects using the Hausman-Taylor (HT) specification, which utilizes random effects and instrumental variable techniques to solve heterogeneity and endogeneity problems. Furthermore, ε_{ij} are error terms with an expected value of zero at time t; and λ_j is the inverse mills ratio computed from the estimated probabilities in Equation (5) as:

$$\lambda_{ijt} = \sum_{m \neq j}^{J} \rho_j \left[\frac{\hat{\rho}_{im} \ln(\hat{\rho}_{im})}{1-\hat{\rho}_{im}} + \ln(\hat{\rho}_{ijt}) \right] \tag{5}$$

where ρ is the correlation coefficient of ε_{ij} and u_{ij}. Standard errors in Equation (3.5) are bootstrapped to account for the heteroscedasticity arising from the generated regressors due to the two-stage estimation procedure. For proper identification of Equation (3.5), the MNLS model must contain at least one instrument in addition to those automatically generated by the nonlinearity of the model. In this study, we use access to information about infrastructure in the MNLS equation but excluded it from the equations for hidden hunger, and nutrition. Access to information about infrastructure and availability of modern grain stores are captured as a binary variable that takes on a value of one if households have access to information about infrastructure or availability of modern storage stores and zero if no information on infrastructure is accessed. Infrastructural information availability and access enhance knowledge of infrastructure including production, post-production, distribution, and information dissemination infrastructure. Thus, access to such information is likely to have a significant influence on the use of infrastructure, but an insignificant influence on the outcome variables. Even though such instruments are intuitively strong, the assumption of exclusion restriction may be violated, especially if it turns out that access to such information also affects nutritional outcomes. Admissibility of these instruments was performed with a simple falsification test following literature (e.g. Di Falco et al., 2010, 2011).

Estimation of average treatment effects on the treated

Using the equations (3), we computed the average treatment effects (ATT) of infrastructure by comparing the expected outcomes of households using infrastructure (actual) and those households that are not using infrastructure (counterfactuals). Following Carter and Milon (2005), Kassie et al. (2018), and Khonje et al. (2018), the following equations were estimated:

$$E[Q_{ijt}|j=J] = \delta_J X_{iJt} + \sigma_J \hat{\lambda}_{iJt} + \varphi_J \bar{X}_{iJt}, \quad j = 2,3,4 \tag{6}$$

On the other hand, the counterfactual expected hidden hunger and nutrition in a household with infrastructural set j that contains one or more infrastructures are computed as follows:

$$E[Q_{ijt}|j=J] = \delta_1 X_{ijt} + \sigma_1 \hat{\lambda}_{i1t} + \varphi_1 \bar{X}_{ijt}, \quad j = 2,3,4 \tag{7}$$

From the above expressions, the average treatment effect on the ATT is the difference between equations (6) and (7) expressed mathematically as:

$$ATT = E\left[Q_{ijt} \mid j=J\right] - E\left[Q_{i1t} \mid j=J\right] = \left(\delta_J - \delta_1\right) X_{iJt} + \left(\sigma_J - \sigma_1\right) \hat{\lambda}_{iJt} + \left(\varphi_J - \varphi_1\right) \bar{X}_{iJt} \tag{8}$$

The first two terms of Equation (3.8) indicate a change in outcome due to the difference in returns to observed characteristics and time-invariant unobserved characteristics, respectively, and the last term is attributed to changes in outcomes due to differences in unobserved heterogeneity. Since two different infrastructures are under study, there are four possible combinations of infrastructure, meaning that the impact of the 3 categories of infrastructure (users of market facility only, users of storage facility only, and users of both market and storage facilities, hereinafter M_1S_0, M_0S_1 andM_1S_1) were estimated and compared to that of nonusers of the infrastructures (M_0S_0), using Equation (7).

In line with literature on infrastructure and nutrition (e.g., Chiputwa & Qaim, 2016; Nkegbe & Mumin, 2022; Bassolé, 2007; Headey, 2013; Jose & Navaneetham, 2010; Ma et al., 2022), the following hypotheses about the relationship between infrastructure and nutrition were tested:

i. There is no significant difference between users of infrastructure (i.e., users of only market facilities, users of only storage facilities, and users of both storage and market facilities) and nonusers of infrastructure in terms of women's dietary diversity.

ii. In terms of children's dietary diversity, there is no significant difference between users of infrastructure (i.e., users of only market facilities, users of only storage facilities, and users of both storage and market facilities) and nonusers of infrastructure.

ii. In terms of women's body mass index, there is no significant difference between users of infrastructure (i.e., users of only market facilities, users of only storage facilities and users of both storage and market facilities) and nonusers of infrastructure.

iii. There is no significant difference between users of infrastructure (i.e., users of only market facilities, users of only storage facilities and users of both storage and market facilities) and nonusers of infrastructure in terms of children's body mass index.

Multinomial endogenous treatment effect (METE) model

As mentioned under earlier, the women's empowerment and gender equality were constructed as binary variables using the Pro-WEAI score. Thus, the MESR model could not be employed in this case because it is only limited to continuous outcomes. To analyse the effect of market and storage infrastructure on binary outcomes like women's empowerment and gender equality, we employed a multinomial endogenous treatment effects (METE) model to analyse the impact of physical infrastructure use on women's empowerment and gender equality. Unlike multinomial endogenous switching regression models (MESR), which estimate only a continuous outcome, the METE can estimate different outcome variables, including normal, gamma, logit, and negative binomial distributions. The estimation of the METE proceeds in two stages (Deb & Trivedi, 2006). Let $\mathbf{d_i}$ denotes a bundle of physical infrastructure for which households are exposed to and is defined as $\mathbf{d_i} = (d_{i1,} d_{i2,} d_{i3}, \dots, d_{iJ})$. Where d_j is the binary variables representing the observed physical infrastructure. Also let l_i represents a latent factor that incorporates unobserved characteristics which are correlated with the type of physical infrastructure and the outcome variables. Likewise, t $\mathbf{l_i} = (l_{i1,} l_{i2,} l_{i3}, \dots, l_{iJ})$ and l_j is the unobserved characteristics of a household using a particular type of physical infrastructure. The first stage regression estimates the probability of use of infrastructure as:

$$\Pr(d_i|z_i, l_i) = g(\alpha_1 z_i + \delta_1 l_{i1}, \alpha_2 z_i + \delta_2 l_{i2}, \cdots, \alpha_J z_i + \delta_J l_{iJ}) \tag{9}$$

Where $\mathrm{z_i}$ is a vector of household and choice characteristics; α_j and δ_i are the associated parameters; and ε_{ij} is the error terms which are independently and identically distributed and assumed to have no influence on l_{ij} ; and $j = 1$ denote the control group (non-use of infrastructure considered in this study). Further, g is an appropriate multinomial probability distribution and assumed to have a Mixed Multinomial Logit (MMNL) structure (Deb & Trivedi, 2006) defined as:

$$\Pr(d_i|z_i, l_i) = \frac{\exp(\alpha_j z_i + \delta_j l_{ij})}{1 + \sum_{k=1}^{J} \exp(\alpha_k z_i + \delta_k l_{ik})} \tag{10}$$

In the second stage, we evaluate the impact of households' use of infrastructure on women's empowerment, gender equality, and child malnutrition as:

$$\mathrm{E}(Q_i|d_i, X_i, l_i) = \beta X_i + \sum_{j=1}^{J} \gamma_j d_{ij} + \sum_{j=1}^{J} \lambda_j l_{ij} \tag{11}$$

where X_i is a set of exogenous covariates with associated parameter vectors β and γ_j denoting the impact of use of infrastructure relative to non-use; $\mathrm{E}(Q_i|\mathbf{d_i}, X_i, \mathbf{l_i})$ is a function of each of the latent factors l_{ij}, and implies that unobserved characteristics that affect selection into use of infrastructure also affect outcomes (i.e. women's empowerment and gender equality). According to Deb and Trivedi (2006), when the factor-loading parameter λ_j, is positive (negative), households' use of physical infrastructure and outcome are positively (negatively) correlated through unobserved characteristics and this further implies positive (negative) selection with the associated parameter vectors γ and λ respectively.

For successful estimation, it is necessary to assume a functional form for the outcome variable. In this study, the functional form distributions were assumed to be logit for the dependent variables (i.e., women's empowerment and gender equality) since they were captured as binary variables (Deb & Trivedi, 2006). In addition, it is required that each model specifies the number of simulations draws used per observation during estimation. In this study, each model was estimated using Maximum Simulated Likelihood (MSL) with draws of 100 simulations. For identification of the treatment equations, it is recommended that the z variables in the exposure model contain at least one selection instrument in addition to those automatically generated by the non-linearity of the selection model. This variable should influence use of infrastructure but not women's empowerment, and gender equality. This study uses as selection instruments, variables related to information. These variables include access to information about infrastructure and availability of modern grain stores defined previously. Although the model is already identified without inclusion of instrument (Deb & Trivedi, 2006), our inclusion of these instrument in z_i is preferable.

This is because the selection correction terms may not be sufficient to identify outcome equations and may lead to multi-collinearity problems. We established the admissibility of these instruments by performing a simple falsification test: if a variable is a valid selection instrument, it will affect the household use of infrastructure. On the other hand, if a variable is not a valid selection instrument it will not affect the outcome of interest. In line with theoretical and empirical literature on infrastructure, women's empowerment, and gender equality (e.g., Welzel et al., 2003; Bell, 1999; Banerjee et al., 2020; Obayelu & Chime, 2020; Khalid et al., 2020; Hadisuyatmana et al., 2021; Mohammed et al., 2021), the following hypotheses about the relationship between infrastructure and women's empowerment and gender equality were tested:

iv. There is no significant difference between users of infrastructure (i.e., users of only market facilities, users of only storage facilities and users of both storage and market facilities) and nonusers of infrastructure in terms of women's empowerment.
v. In terms of gender equality, there is no significant difference between users of infrastructure (i.e., users of only market facilities, users of only storage facilities and users of both storage and market facilities) and nonusers of infrastructure.

Qualitative analysis

For the qualitative data, meaningful statements made by the participants were extracted and entered in NVIVO software for analysis. Specifically, we searched for differences in pattern of words employed by participants when explaining the effect of infrastructure on women's empowerment, gender equality, food security, hidden hunger, and nutritional outcomes. This is because the meanings attached to a particular phenomenon are mostly manifested in words used. Content analyses are particularly suitable for studying communications and answering classic questions of "who says what, to whom, why, how, and with what effect?"(Babbie, 2013). The content analysis was used to determine the presence of certain words, themes, or concepts within the textual information gathered. This study used content analysis to organize and extract meaning from the data collected and to draw realistic conclusions from the impact of storage and market infrastructure on nutrition and women's empowerment in Ghana (Bengtsson, 2016). Specifically, the content analysis was used to explain the reason for deviation of the quantitative results from the study's expectations if any.

4. Result and Discussion

4.1 Descriptive statistics

Household and individual characteristics

Table 12 presents the descriptive statistics of the sampled households by physical infrastructure use. The result reveals that both infrastructures users have more female heads than non-users and users of market facility only and storage facility only. Storage facility users have a higher mean age, than both infrastructure users, market facility users only, and non-users. Comparatively, we find more storage facility users only with postsecondary education, compared to market facility users only, both infrastructure users, and non-users. The number of adult females is approximately 2 people across all categories of physical infrastructure use. A greater percentage (71%) of market facility users only own motor bike, followed by both infrastructure users (62%), non-users (58%), and storage facility users (56%) only.

Concerning the number of households that owned pipe water, it is observed that about 18.0% of both infrastructure users own pipe water whereas more (28%) of market users only own a toilet facility. The percentage of households that have access to electricity connection is highest with both infrastructure users (57%). Most respondents had access to information but a higher percentage (100%) of market infrastructure users only had access to information about market availability while a higher percentage (99%) of storage facility users only had access to information about storage facilities availability. Approximately 6 rooms are available in households that use market infrastructure only, storage infrastructure only, both infrastructures except non-users who have approximately 5 rooms in their houses. More respondents who use storage infrastructure only live in the rural setting (78%) compared to non-users, market facility users only and both infrastructure users. Majority of respondents were in the Northern region.

The mean difference between non-users and users of market facility only, non-users and storage facility only and non-users and users of both infrastructure for farm sizes, market facility availability information and storage facility availability information were statistically significant at 1% level. For the variable household has own toilet, the mean difference between non-users and users of market facility only and non-users and users of both infrastructures were statistically significant at 1% level.

Households' preference for physical infrastructure

Figure 6a-b shows the results of households' preferences for market and storage facilities based on household head. Big periodic markets (77.9 percent) were highly preferred to small village markets (11.48 percent), buying or selling at the farm gate (7.41 percent), farmer groups (2.0 percent), and grain marketing boards (0.47 percent). Big periodic markets provide households with more variety of food and non-food items. However, big periodic markets are in the cities and towns and poorly networked with remote areas. Less than 5 percent of households prefer food sales and purchases at farm gates, farmer groups, or grain marketing boards. Figure 4.1 (a) and (b) also shows that female-headed households have strong affinity for big periodic markets and cold storage facilities than male-headed households. Own storerooms (42.84 percent) and cold storage (42.64 percent) were highly preferred to certified warehouses (11.97 percent), storage bags (1.41 percent), silos (0.87 percent), granaries (0.2 percent), and grain banks (0.07 percent). Own storerooms are cemented rooms, mud rooms, and mud silos in or outside the house.

Table 12: Descriptive statistics of households' use of physical infrastructure

Variable	M_0S_0 (1)	M_1S_0 (2)	M_0S_1 (3)	M_1S_1 (4)	Mean difference 5 = (2-1)	6 = (3-1)	7 = (4-1)
Head is female (yes= 1)	0.19 (0.39)	0.19 (0.39)	0.15 (0.36)	0.21 (0.40)	0.00	-0.04	0.02
Age of head (years)	44.83 (16.49)	45.69 (15.73)	48.21 (15.17)	46.39 (15.64)	0.86	3.38	1.56
Head has postsecondary education (yes= 1)	0.06 (0.24)	0.07 (0.25)	0.11(0.32)	0.09 (0.29)	0.01	0.05	0.03
Household size	6.03 (3.50)	6.40 (3.26)	6.53 (3.52)	6.29 (3.51)	0.37	0.50	0.26
Adult females (number)	1.67 (1.28)	1.86 (1.19)	1.89 (1.38)	1.84 (1.27)	0.19	0.22	0.17
Household owns motor bike (yes= 1)	0.58 (0.49)	0.71 (0.45)	0.56 (0.50)	0.62 (0.49)	0.13	-0.02	0.04
Farm size (acres)	6.02 (8.50)	7.09 (8.53)	8.81 (11.04)	7.35 (8.87)	1.07***	2.79***	1.33***
Household has own piped water (yes= 1)	0.09 (0.29)	0.17 (0.38)	0.07 (0.26)	0.18 (0.38)	0.08	-0.02	0.09
Household has own toilet (yes= 1)	0.12 (0.32)	0.28 (0.45)	0.17 (0.37)	0.27 (0.44)	0.16***	0.05	0.15***
HH has electricity connection (yes= 1)	0.41 (0.49)	0.52 (0.50)	0.51 (0.50)	0.57 (0.50)	0.11	0.10	0.16
Market facility availability information (yes= 1)	0.63 (0.48)	1.00 (0.05)	0.74 (0.44)	0.99 (0.11)	0.37***	0.11***	0.36***
Storage facility availability information (yes= 1)	0.28 (0.45)	0.17 (0.37)	0.99 (0.09)	0.98 (0.12)	-0.11***	0.71***	0.70***
Market potential	0.34 (0.50)	0.22 (0.32)	0.33 (0.45)	0.19 (0.28)	-0.12	-0.01	-0.15
House rooms	5.39 (3.47)	5.62 (3.62)	5.73 (3.10)	5.75 (3.62)	0.23	0.34	0.36
Area of residence (rural = 1)	0.75 (0.43)	0.66 (0.47)	0.78 (0.41)	0.64 (0.48)	-0.09	0.03	-0.11
Area of residence (North-East region)	0.07 (0.25)	0.10 (0.30)	0.06 (0.24)	0.11 (0.31)	0.03	-0.01	0.04
Area of residence (Northern region)	0.41 (0.49)	0.47 (0.50)	0.41 (0.49)	0.42 (0.49)	0.06	0.00	0.01
Area of residence (Savannah)	0.17 (0.38)	0.12 (0.32)	0.21 (0.41)	0.09 (0.28)	-0.05	0.04	-0.08
Area of residence (Upper East region)	0.13 (0.34)	0.14 (0.35)	0.07 (0.26)	0.20 (0.40)	0.01	-0.06	0.07
Area of residence (Upper West region)	0.13 (0.34)	0.07 (0.25)	0.15 (0.35)	0.07 (0.26)	-0.06	0.02	-0.06
Livestock ownership	0.12 (0.32)	0.11 (0.31)	0.08 (0.28)	0.11 (0.32)	-0.01	-0.04	-0.01
HH members below 15 years	2.57 (2.10)	2.64 (2.01)	2.62 (2.12)	2.55 (2.17)	0.07	0.05	-0.02
HH members aged 15-44 years	2.46 (1.62)	2.80 (1.75)	2.78 (1.89)	2.74 (1.78)	0.34	0.32	0.28
HH members aged 45-65 years	0.69 (0.83)	0.65 (0.78)	0.82 (0.83)	0.70 (0.79)	-0.04	0.13	0.01
HH members above 65 years	0.27 (0.56)	0.26 (0.52)	0.25 (0.49)	0.24 (0.51)	-0.01	-0.02	-0.03

Legends: ***, **, and * indicate 1%, 5%, and 10% significance levels, respectively. non-users (M_0S_0); market facility users (M_1S_0) only; storage facility users (M_0S_1) only; and multiple infrastructure users (M_1S_1). Standard deviations are in parentheses.4.2 Impact of physical infrastructure use on nutrition

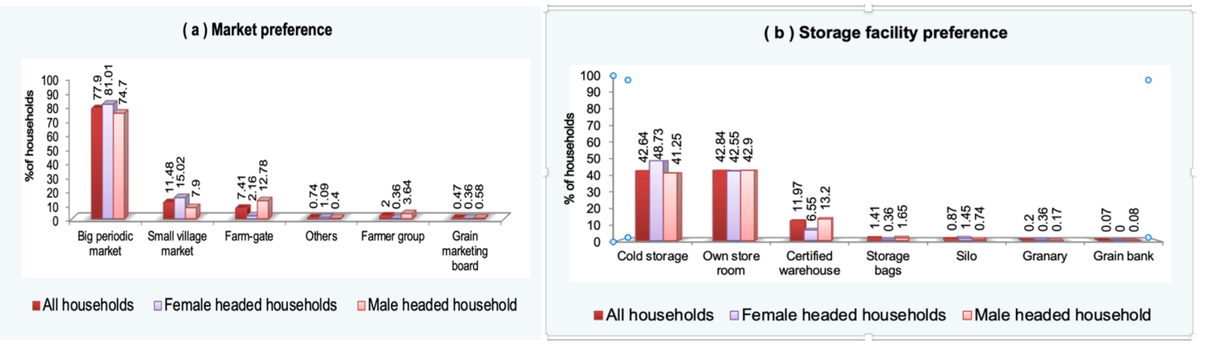


Figure 6: Distribution of household of preference for physical infrastructure
Source: Own estimation of household survey data, 2022

Use of market and storage facilities
Figure 7a-b shows the results of the market and storage facilities used in the study area. Less than 5 percent of households use farm gates, farmer groups, or grain marketing boards for food sales and purchases. Households use storerooms mainly to store grains, roots, and tubers. As a result, cereal, root, and tuber consumption could soar, leading to a state of hidden hunger or micronutrient deficiencies. Just one percent of all households use cold storage such as a fridge (Figure 7b). Only one household has a cold storage facility for selling fish. Bags and storage spaces are more accessible, which increases their use. The focus group discussions confirm that women visit urban marketplaces more than men. There are few public and private silos and certified warehouses. We learnt these statements from the focus group discussions.

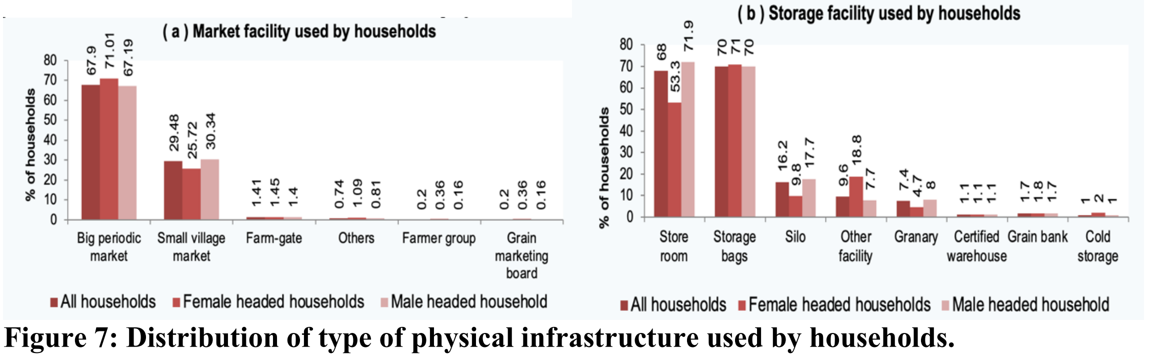


Figure 7: Distribution of type of physical infrastructure used by households.
Source: Own estimation of household survey data, 2022

Levels of use of market facility
Figure 8 describes the status of use of the selected markets measured using how often they sell or buy foods through the respective market outlets. About 65.28 percent of the households were net buyers, while 15.42 percent and 19.3 percent constituted net sellers and trade even. More male-headed households are net buyers than female-headed households. Compared to men, more female-headed households use the market to purchase food the same way they sell food.

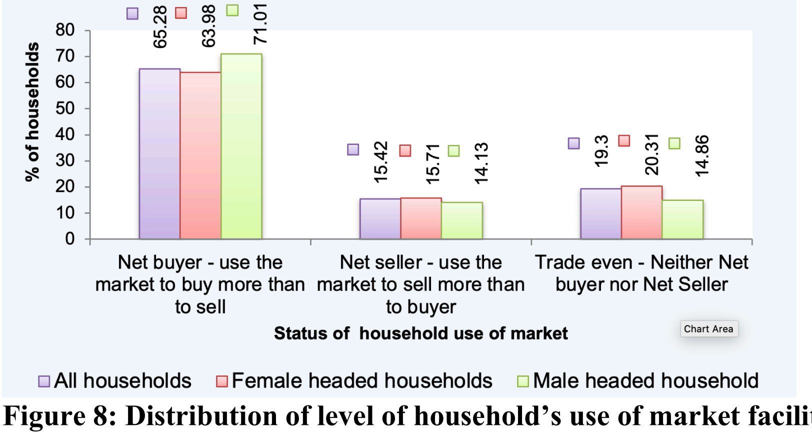


Figure 8: Distribution of level of household's use of market facility
Source: Own estimation of household survey data, 2022

Condition of physical infrastructure used by household.

We asked households to report on the condition of the physical infrastructure they use. Figure 9a-b shows the condition of the market and storage facilities in use. Most market facilities in use required improvement. Except for certified warehouses and cold storage, grain banks, granaries, and storerooms need improvements (Figure 9b). About 66 percent of silos have been closed for rehabilitation and maintenance. This issue is part of the reasons why the use of silos is low. More than 50 percent of all cold storage facilities and certified warehouses have a good state.

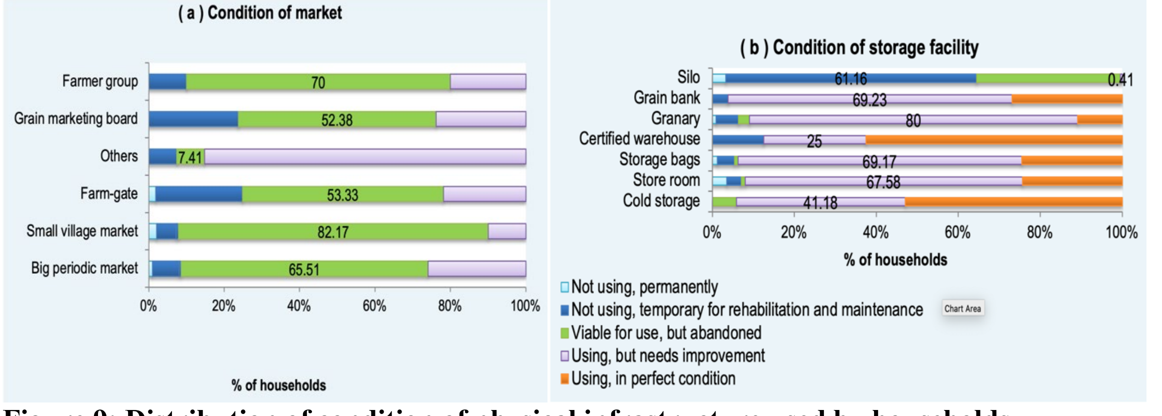


Figure 9: Distribution of condition of physical infrastructure used by households.

Source: Own estimation of household survey data, 2022

Challenges regarding the use of the selected physical infrastructures

Figure 10a-b shows the challenges in using the physical infrastructure. More than half (55.02 percent) of households have difficulty traveling long distances to market facilities. About 65.68 percent of households incur high transportation costs to the market. Around 48 percent of households use poor roads to the market. About 19 percent of households have theft or robbery issues in the market. Rodents and insufficient security are two main challenges that affect the use of storage facilities.

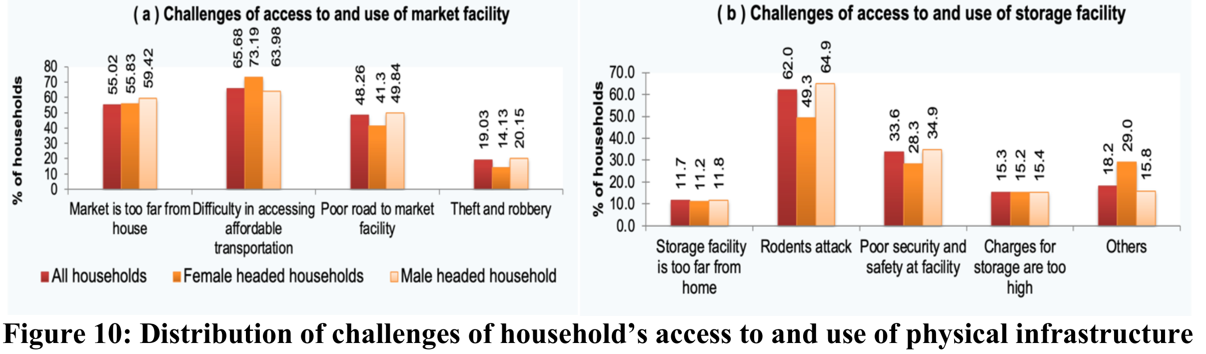
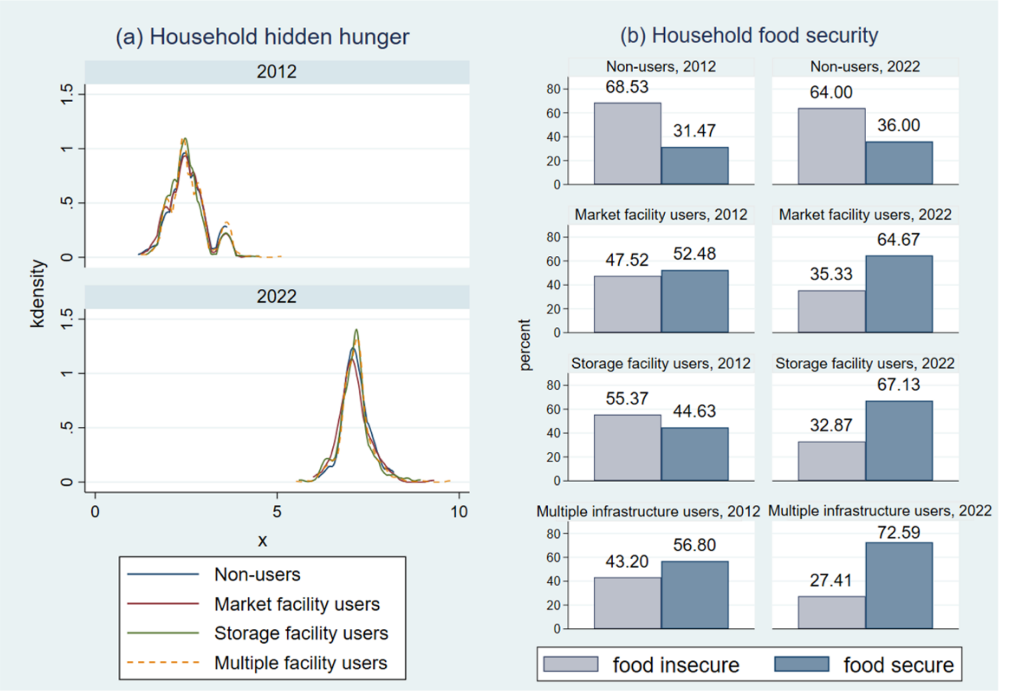


Figure 10: Distribution of challenges of household's access to and use of physical infrastructure

Source: Own estimation of household survey data, 2022

Classification of household's hidden hunger by physical infrastructure use

The distribution of household hidden hunger and food security by physical infrastructure use are presented in (Figure 11a-b). Figure 10a shows the distribution of ACPAE, whereas Figure 11b shows the distribution of HHS. Based on the F-test from the analysis of variance (ANOVA), there were significant differences in hidden hunger and food security between the categories of physical infrastructure use.



(a) F-stat = 17.07; P>F = 0.0000	(a) F-stat = 48.82; P>F = 0.0000

Figure 11: Classification of household diet-related nutritional indicators by physical infrastructure use
Source: Own source: Field data, 2012 and 2022

Surprisingly, users of storage facility only and both infrastructures had higher ACPAE scores, compared to users of market facility only and non-users of physical infrastructure. In 2022, households had significant levels of hidden hunger, compared to 2012. A greater percentage of both infrastructure users (72.59%) were food secure, followed by users of storage facility only (67.13%) and market facility only (64.67%). Non-users of both infrastructures were seen to be food insecure (68.53%) in 2012 and (64%) in 2022. Household food security improved with time for all groups of physical infrastructure users, compared to non-users. Around 36.00% of non-users of physical infrastructures where food secure in 2022, up from 31.47% in 2012.

Distribution of women's empowerment and equality by physical infrastructure use
Figure 12 shows the distribution of women's empowerment and gender equality based on physical infrastructure use. Women's empowerment and gender equality improve by using physical infrastructures. Users of both infrastructures had the highest women's empowerment (39.12 percent), followed by users of market facility only (35.33 percent), and storage facility only (29.20 percent). Also, users of both infrastructures had the highest gender equality (54.54 percent), followed by users of market facility only (47.28 percent), and storage facility only (30.80 percent).

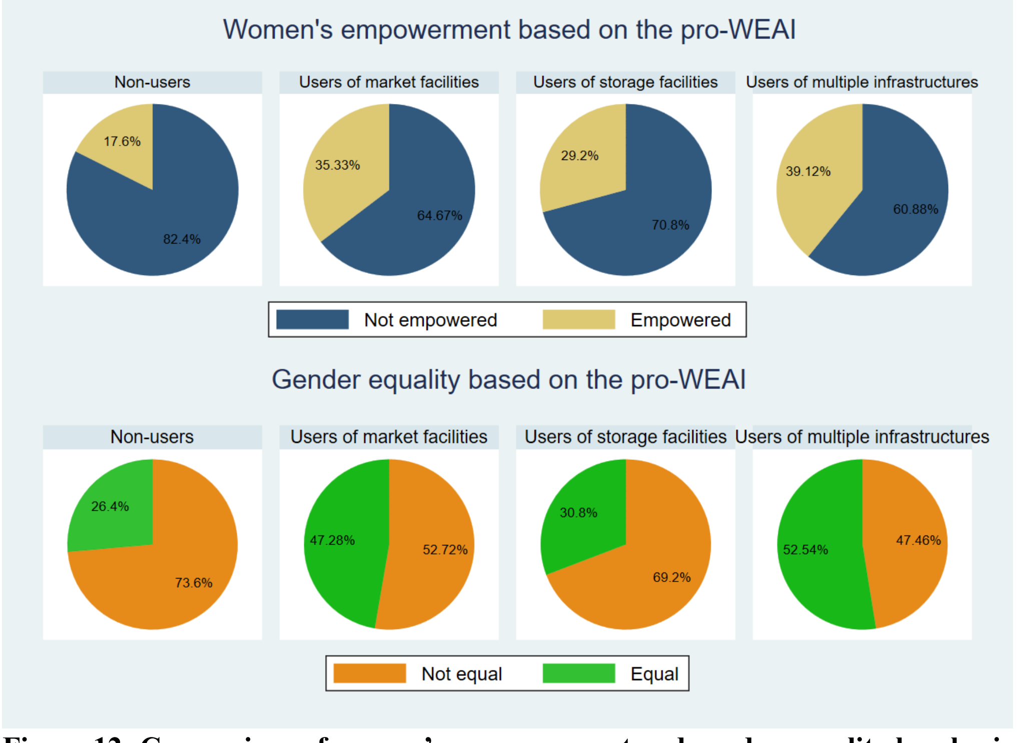


Figure 12: Comparison of women's empowerment and gender equality by physical infrastructure use
Source: Own estimation of household survey data, 2022

Mean minimum dietary diversity for women (MDD-W) by physical infrastructure use.
Figure 13 shows the results of the MDD-W based on physical infrastructure use. Users of physical infrastructure had higher MDD-W than non-users. Users of both infrastructures had the highest MDD-W, followed by users of market facility only and storage facility only. The difference in MDD-W between users and non-users was significant. Women in non-user households had an average MDD-W of 3.88. Women in households that use both infrastructures had mean MDD-W of 4.55. Women in households that use market facility only have a mean MDD-W of 4.28. Women in households that use storage facility only had mean MDD-W of 4.17. Women in households that use storage facility only had lower MDD-W than those that use market facility only or both infrastructures. The use of storage facility only restricts diversity in the diets of women more than the use of market facility only or both does.

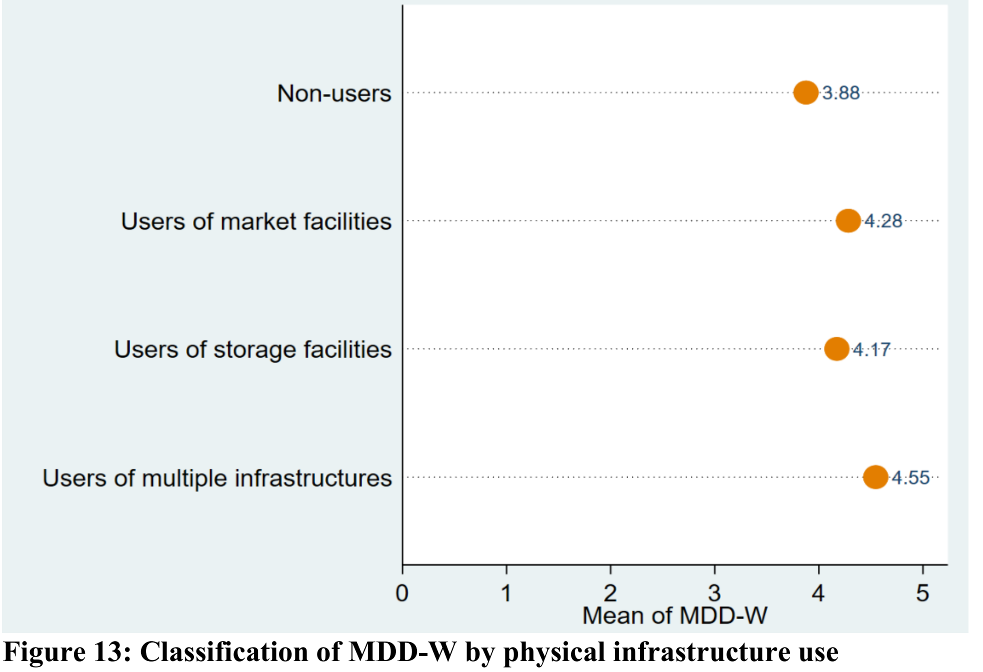


Figure 13: Classification of MDD-W by physical infrastructure use
Source: Own estimation of household survey data, 2022

Mean children's dietary diversity scores (CDDS) by physical infrastructure use

The result of children's dietary diversity scores based on physical infrastructure use is presented in Figure 14. Users had higher CDDS than non-users. Specifically, users of both infrastructures had the highest CDDS, followed by users of market facility only and storage facility only. Non-users had a mean of 2.16 CDDS. Users of both infrastructures had mean CDDS of 3.21, whereas users of market facility only and storage facility only had an average of 3.11 and 2.87 CDDS respectively. This result is like the findings of the minimum dietary diversity for women. In the same way, the use of storage facility only restricts diversity in the diets of children more than the use of market facility or both does.

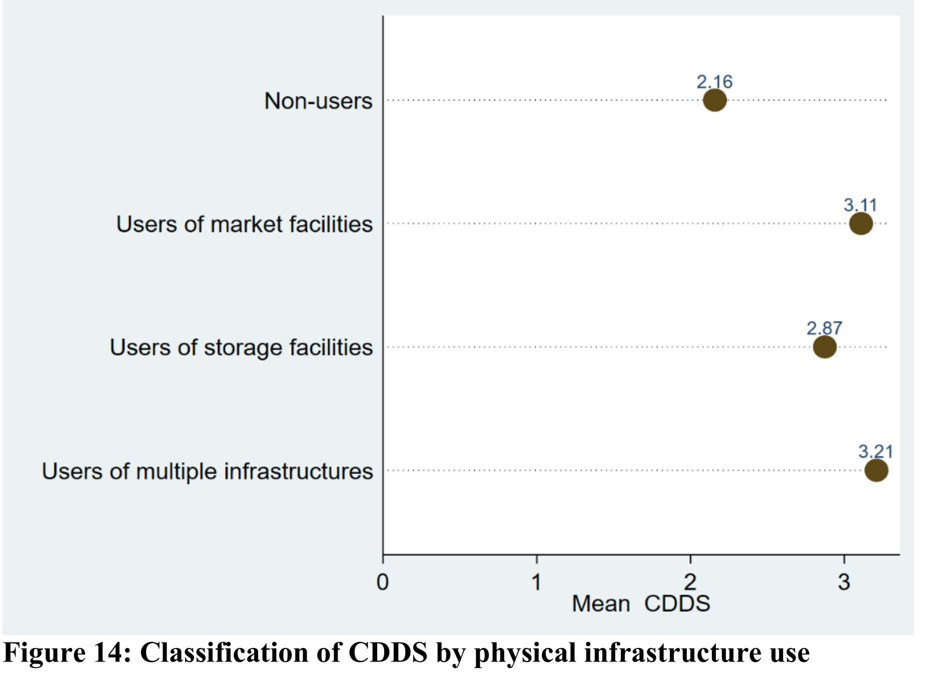


Figure 14: Classification of CDDS by physical infrastructure use

Source: Own estimation of household survey data, 2022

Distribution of children's malnutrition indicators by physical infrastructure use

The results of stunting, wasting, and underweight in children below five years have been presented in Figure 15. Users of infrastructure had more nourishing children than non-users. Users of storage facility only had more non-stunted (66.61 percent) and non-underweight children than all categories of physical infrastructure use. Users of both infrastructures had more non-wasted children than all categories of physical infrastructure use. The result suggests that the use of market and storage facilities was associated with lower malnutrition in children below five years.

4.2 Impact of physical infrastructure use on hidden hunger, nutrition outcomes, women's empowerment, and gender equality

The main objective of this study is to analyse the impact of individual and joint use of market and storage infrastructures on hidden hunger, nutrition outcomes, women's empowerment, and gender equality. For this reason, only the results of the impact of physical infrastructure on hidden hunger, nutrition, women's empowerment, and gender equality are presented. The results of the determinants of physical infrastructure use, hidden hunger, nutrition indicators (i.e., food security, women's and children's dietary diversity scores, children's and women's body mass indices, and child malnutrition), women's empowerment and gender equality are presented in the appendix and are not discussed because of space. Nonetheless, the results showed the relevance of household characteristics, location and institutional factors in physical infrastructure use, hidden hunger, nutrition, women's empowerment, and gender equality in the area. The results of the impact of physical infrastructure use on hidden hunger, nutrition (i.e. food security, women's and children's dietary diversity scores, children's and women's body mass indices, and child malnutrition), women's empowerment and gender equality are presented in the following sections.

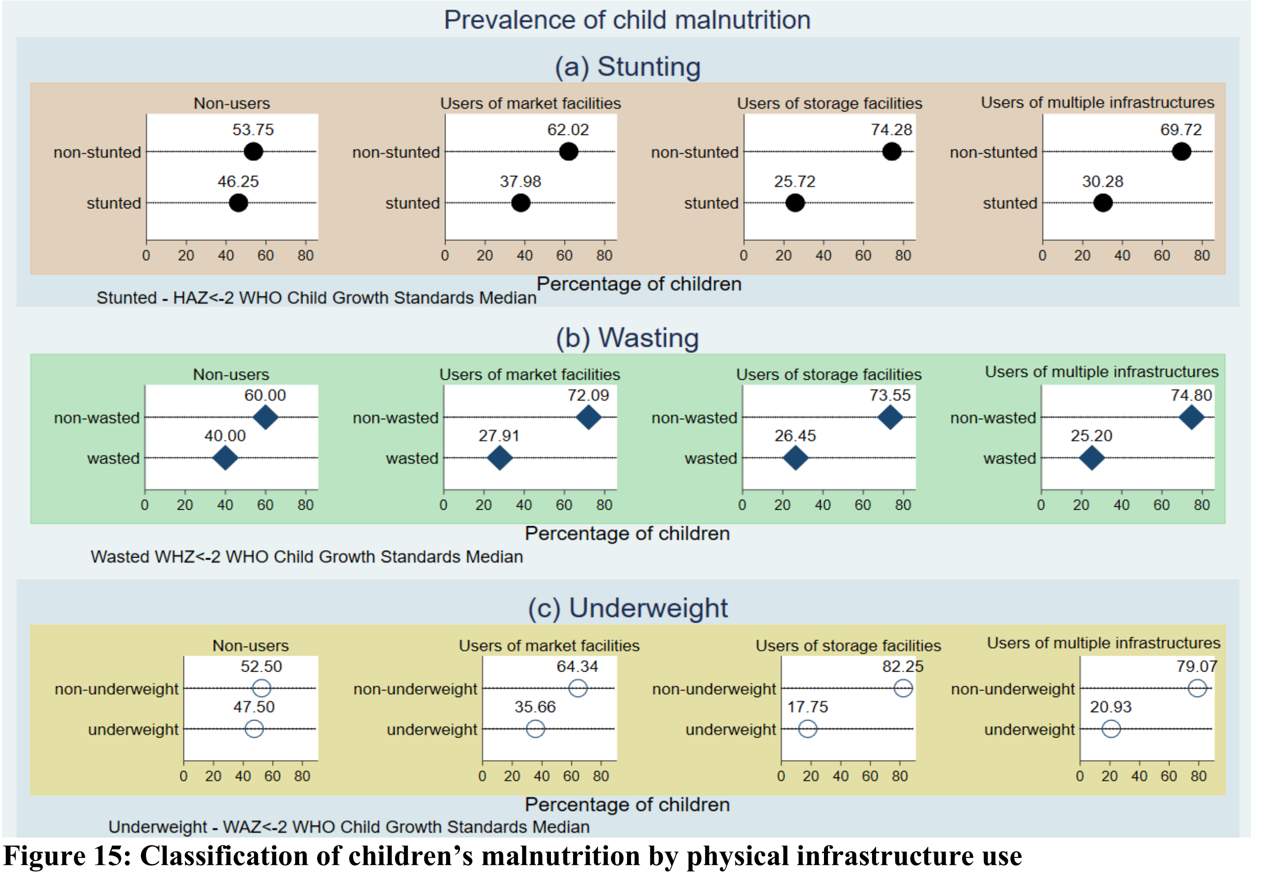


Figure 15: Classification of children's malnutrition by physical infrastructure use
HAZ, WAZ, and WHZ denote height-for-age Z-scores, weight-for-age, and weight-for-height for-age Z-scores.
Source: Own estimation of household survey data, 2022

Physical infrastructure use impacts on household hidden hunger
Table 13 presents the ATT and ATU estimates of the impact of use of market facility only, storage facility only, and both infrastructures on households' hidden hunger. The ATT results are interpreted as percentages since the outcome variable (available cereal per adult equivalent) has been log transformed. According to the ATT results, the effects of use of market facility only, storage facility only, and both infrastructures are all significant and positively related to household hidden hunger (Table 13). The results imply that if households choose to use market facility only, storage facility only, and both infrastructures, their available cereal per adult equivalent will increase by 23.0%, 94%, and 44.0%, respectively, than if they choose not to use them. Alternatively, if non-users choose to use market facility only, their available cereal per adult equivalent can be increased by 127.0% than if they remain non-users. Also, if non-users of physical infrastructure choose to use storage facility only and both infrastructures, their available cereal per adult equivalent will increase by 93.0% and 27.0%, respectively than if they remain non-users. Comparatively, households that use market and storage facilities have a smaller chance of avoiding hidden hunger than non-users. The mediation analysis revealed that the pathway through which use of both market and storage facilities may impacts on hidden hunger is through lower crop diversification (click here for Table B2 in supplementary file at the Appendix). The results suggest that use of storage and market facilities may promote the production and consumption of energy-dense food than micronutrient-rich foods. Households produce more cereals than micronutrient-rich crops when cold storage facilities are unavailable. For example, meats, fish, fruits, and vegetables have a short shelf life. Therefore, households that have no cold storage will keep more cereals in stock rather than perishable foods.

Affirming the above result, a participant reported that the staple food is more, and amount of protein consumed is limited;

"At the household level, many decisions influence it because when you take our dietary patterns, the staples are more, so even if someone has protein in that meal, the protein is less, and we give less priority to the proteins".

Another participant affirms that most of the food they cultivate, store and consume are maize, millet, yam, cassava, which are starchy foods.

"Maize, millet, yam, cassava, and soybeans are the crops we cultivate in this community. When we have enough rain and apply the right quantities of inputs like fertilizer in the case of maize, we have a good harvest, and with the proper storage facilities in place, we can have this foodstuff all year round".

Table 13: ATT and ATU estimates of household hidden hunger.

Outcome variable	Choice of infrastructure	Use status		Treatment effects
		To use	**Not to use**	
		(1)	(2)	3 = (1-2)
ACPAE	M_1S_0	4.56 (0.084)	4.33 (0.05)	ATT= 0.23*** (0.04)
	M_0S_1	5.53 (0.04)	4.60 (0.04)	ATT= 0.94*** (0.01)
	M_1S_1	4.89 (0.04)	4.45 (0.03)	ATT= 0.44*** (0.02)
	M_0S_0	2.90 (0.14)	4.17 (0.06)	ATU = 1.27*** (0.11)
	M_0S_0	5.11 (0.06)	4.17 (0.06)	ATU= -0.93*** (0.02)
	M_0S_0	4.44 (0.09)	4.17 (0.06)	ATU= - 0.27*** (0.06)

Legends: ***, **, and * denote significance levels at 1%, 5%, and 10% respectively. M_1S_0, M_0S_1, and M_1S_1 denote market facility, storage facility, and multiple infrastructures respectively. Standard errors are in parentheses.

Source: Own estimation of household survey 2012 and 2022

Physical infrastructure use impacts on household food security

Table 14 shows the average treatment effects of physical infrastructure use on household food security. The results show that users of market facility only, storage facility only, or both infrastructures are 21.5%, 24.0%, and 26.6% more likely to be food secure than non-users. A market represents a pre-requisite for selling its production and purchasing nutritious food (Poole *et al*., 2019). Utilising market facilities may enhance physical access to food at the household and community levels. Utilizing storage facilities extends storage length and reduces postharvest losses from pests and weather, increasing the physical presence of food (Omotilewa *et al*., 2018; Tefera *et al*., 2011). When a household lacks storage space, it may consume or sell its food shortly after harvest, which leaves little or no food at home at times of scarcity (Adjimoti & Kwadzo, 2018; Tefera *et al*., 2011; Vaitla, Devereux & Swan, 2009). By contrast, storing food from damage provides security for the household to meet its food needs later in the food shortage period and earn fair prices for its produce (Adjimoti & Kwadzo, 2018) This result is congruent with Adjimoti & Kwadzo (2018), who found a positive effect of using storage facilities on food security in rural Benin. Relatedly, Nkegbe & Mumin (2022) found that access to community silos and markets significantly improves household food security in Ghana. All the selection bias correction terms (λ_M_1S_0, λ_M_0S_1, and λ_M_1S_1) are not statistically significant. This result suggests that non-users will have the same impact on food security if they become users. The falsification tests show that the instrumental variables are valid (click here for Table A1 in supplementary file at the Appendix). The Wald test of the selection instruments (access to information) is significant in the multinomial logit model (click here for Table B1 in supplementary file at the Appendix) but not the household food security of non-users (click here for Table B3 in supplementary file at the Appendix), rendering our model more robust. The mediation analysis also shows that the use of both infrastructures' influences household food security indirectly through the mediator of available cereal per adult equivalent (click here for Table D3 in supplementary file at the Appendix).

Table 14: Average treatment effect regression results of household food security

Variable	Coefficient	Std. Err.
M_1S_0	0.214**	0.065
M_0S_1	0.239***	0.076
M_1S_1	0.266***	0.059
Selection bias correction terms		
$\lambda\_M_1S_1$	0.022	0.436
$\lambda\_M_1S_1$	-0.403	0.470
$\lambda\_M_1S_1$	0.410	0.391

Legends: ***, **, and * denote significance levels at 1%, 5%, and 10% respectively. M_1S_0, M_0S_1, and M_1S_1 denote market facility, storage facility, and multiple infrastructures respectively.

Affirming the results, some participants during the focus group discussion indicate the significance of infrastructure to food security:

"Storage facilities help us to store various foodstuffs such as grains, roots, and tubers to provide food for children. It is expensive to buy these food groups daily hence we buy them and store them for household consumption. We gather the starch staples in our storage rooms (rooms) and fetch them to consume in bits".

Another participant affirms that most of the food they cultivate, store, and consume are maize, millet, yam, cassava, which are starchy foods:

"Utilising market and storage facilities may enhance the physical presence of food at the household and community levels. Utilizing market and storage facilities may raise farm incomes, giving the household adequate resources or entitlements to access sufficient food".

We also heard this statement from another participant:

"Maize, millet, yam, cassava, and soybeans are the crops we cultivate in this community. When we have enough rain and apply the right quantities of inputs like fertilizer in the case of maize, we have a good harvest, and with the proper storage facilities in place, we can have this foodstuff all year round.".

Furthermore, we had this statement from another participant:

"*Access to the market facility may enhance households' food production by securing buyers for better prices. When a household lacks storage space, it is compelled to consume or sell its food shortly after harvest*".

Physical infrastructure use impact on women's empowerment and gender equality

Table 15 presents the average treatment effect results of physical infrastructure use on women's empowerment and gender equality. All the selection bias correction terms were not statistically significant in the METE model (Table B5), indicating that non-users will have the same impact if they choose to become users of market and storage facilities. Generally, the use of physical infrastructure significantly improves women's empowerment and gender equality. Specifically, the use of market only, storage facility only, and both infrastructures positively impact on women's empowerment. For gender equality, except for the use of storage facility only which has no significant effect on gender equality, the use of market facility only and both infrastructures positively and significantly impact on gender equality. The size of the effect is relatively large for households that use both infrastructures. Using physical infrastructure may significantly affect women's empowerment and gender equality through effective time allocation among reproductive, productive, and leisure activities (Bago *et al*., 2023). This result is consistent with Alao (2021), who found that access to modern and storage facilities has a positive and significant effect on women's empowerment in rural Southwestern Nigeria. The mediation analysis also shows that the use of both infrastructures' influences women's empowerment indirectly through lower crop diversification and increased assets (Table D1 in Appendix). Thus, the mechanism and pathways through which the use of both infrastructures may improve women's empowerment and gender equality are through the ownership of asset, and lower crop diversification. The falsification tests outlined in Di Falco *et al*. (2011) show that the instrumental variables are valid (click here for Table B2 in supplementary file at the Appendix).

Table 15: Average treatment effect regression results of women's empowerment and gender equality

	Women's empowerment	Gender equality
Variable	**ATE**	**ATE**
M_1S_0	0.211* (0.112)	0.227** (0.105)
M_0S_1	0.219* (0.123)	0.204 (0.127)
M_1S_1	0.220*** (0.076)	0.244*** (0.079)
Selection bias correction terms		
$\lambda\_M_1S_1$	1.167 (0.892)	0.516 (0.756)
$\lambda\_M_1S_1$	- 0.219 (0.775)	- 0.740 (0.618)
$\lambda\_M_1S_1$	1.252 (0.951)	0.889 (0.827)

Legends: ***, **, and * denote significance levels at 1%, 5%, and 10% respectively. M_1S_0, M_0S_1, and M_1S_1 denote market facility, storage facility, and multiple infrastructures respectively. Standard errors are in parentheses.

Source: Own estimation of household survey data, 2022

The focus group discussions further revealed how storage and market facilities affect women's empowerment and gender equality:

"Women use market stalls to store some of their grains, especially soya beans, and when prices increase in future, then they sell the grains. During this period, women could decide at what point to sell and at what price. This helps them gain authority over the income from the sale of the grains…".

"Market facilities basically help in the same way as the storage facility does, it helps to minimize the issue of domestic violence as the woman is very busy going to the market, to earn a living for the entire household, … She is also considered as being supportive to her husband and family; hence the husband will always respect her and what she is doing".

"Women who use the markets have access to credit, and they are usually active members of groups who provide trading credit.".

Another participant reported that:

"So once a woman has access to the market, if a woman has access to the storage facility where she can store a number of things there, definitely from the morning she may save some time, … as I mentioned, they are able to save time to do some other economic activities for themselves to get money".

Physical infrastructure use impact on women's nutrition

The impact of physical infrastructure use on women's nutrition is presented in Table 16. Table 16 shows that users of infrastructures had higher women's dietary diversity score (WDDS) and body mass index (BMI) than non-users. Consistently, the use of both infrastructures improved MDD-W and BMI more than the use of only market and only storage infrastructure. The results are consistent with Tesfaye & Tirivayi (2018), who found that access to improved storage facilities is positively associated with dietary diversity in Ethiopia. The positive impact of physical infrastructure on women's dietary diversity was mediated through higher crop diversification, increased income, and more accumulated assets (click here for Table D4 in supplementary file at the Appendix).

Table 16: Impact of physical infrastructure use on nutrition indicators

Outcome variable	Choice of infrastructure	Use decisions: **To use**	Use decisions: **Not to use**	Treatment effects
	(*j*)	(1)	(2)	3 = (1-2)
Log of women's BMI	M_1S_0	3.104 (0.009)	2.951 (0.007)	0.152***(0.021)
	M_0S_1	3.150 (0.005)	2.951 (0.007)	0.199*** (0.014)
	M_1S_1	3.153 (0.003)	2.951 (0.007)	0.202*** (0.010)
WDDS	M_1S_0	4.238 (0.130)	3.414 (0.054)	0.25*** (0.159)
	M_0S_1	4.152 (0.043)	3.414 (0.054)	0.738*** (0.102)
	M_1S_1	4.524 (0.017)	3.414 (0.054)	1.110*** (0.079)

Notes: *j* represents infrastructures. Legends: ***, **, and * denote significance levels at 1%, 5%, and 10% respectively. M_1S_0, M_0S_1, and M_1S_1

denote users of market facilities, users of storage facilities, and users of multiple infrastructures respectively. Standard errors are in parentheses.
Source: Own estimation of household survey data, 2022

The focus group discussions further revealed how storage and market facilities affect the women's nutrition:

"*We do grow these leafy vegetables for home consumption during the rainy season. However, during the dry season we can get theses vegetables to buy in the market from farmers who are into dry season vegetable farming. These vegetables we buy from the market can either be fresh or processed into other forms.*"

Another participant said this:

"*On market days, meat, fish eggs milk as well as milk products are always available for us to buy. So monies realized from the sale of our goods in the market can be used to buy some of these food items if not all of them. In the household level, we have animals that we rare and occasionally we kill them to eat.*"

This statement is what another participant had to say:

"*Sometimes the maize, cassava, or yam we grow and store them for home consumption from our own farms is not enough. So monies we realized from the sale of our stored produced or from other businesses are used to purchase the maize, yams or cassavas from the market to prepare food these children in the event that what we have at home finishes.*"

Physical infrastructure use impact on children's dietary diversity

Table 17 shows the average treatment effect of physical infrastructure on children's dietary diversity scores (CDDS). The results show that the use of both infrastructures increased CDDS more than the use of only market and only storage infrastructure. Access to markets might provide households with a diverse selection of food products, essential for preparing nutritious meals. Access to storage facilities may also assist households to maintain (or preserve) more essential foods from spoiling during seasons of bounty (or inadequate harvest). The pathway or mechanism through which the use of market and storage facilities promotes children's dietary diversity score is through higher crop diversification and more accumulated assets (click here for Table D4 in supplementary file at the Appendix).

Table 17: Impact of physical infrastructure use on CDDS

Outcome variable	Choice of infrastructure	Use decisions: **To use**	**Not to use**	Treatment effects
	(*j*)	(1)	(2)	3 = (1-2)
	M_1S_0	2.744 (0.105)	2.312 (0.143)	0.432**(0.173)
CDDS	M_0S_1	2.710 (0.027)	2.312 (0.143)	0.398***(0.092)
	M_1S_1	2.873 (0.026)	2.312 (0.143)	0.562***(0.086)

Notes: *j* represents infrastructures. Legends: ***, **, and * denote significance levels at 1%, 5%, and 10% respectively. M_1S_0, M_0S_1, and M_1S_1 denote users of market facilities, users of storage facilities, and users of multiple infrastructures respectively. Standard errors are in parentheses.
Source: Own estimation of household survey data, 2022

Impact of physical infrastructure use on child malnutrition

Table 18 shows the impact of physical infrastructure use on stunting, wasting, and underweight among children below five years. The use of physical infrastructure is significant and negatively associated with stunting, wasting, and underweight in children below five years. The use of both infrastructures had the largest reduction effect on wasting and underweight, whereas the use of storage facility only had the largest reduction impact on stunting in children below five years. By contrast, the use of storage facility only did not have a significant impact on stunting in children below five years. The use of market and storage facilities allow children to have access to nutritious foods. The negative impact of physical infrastructure on stunting was mediated through higher crop diversification (Table D5). The use of physical infrastructure may boost crop diversification and farm incomes, which are associated with better child nutrition (Anuja *et al*., 2022; Khonje *et al*., 2022).

Table 18: Average treatment effect regression results of child malnutrition

	Stunting	Wasting	Underweight
Variable	**ATE**	**ATE**	**ATE**
M_1S_0	- 0.028 (0.082)	- 0.176*** (0.105)	-0.099* (0.059)
M_0S_1	- 0.137** (0.059)	- 0.148** (0.127)	-0.222*** (0.039)
M_1S_1	- 0.133* (0.071)	- 0.216*** (0.079)	-0.261*** (0.075)
Selection bias correction terms			
λ_M_1S_0	- 0.237 (0.376)	1.110** (0.556)	0.568 (0.623)
λ_M_0S_1	- 0.337 (0.358)	0.740 (0.669)	0.591 (0.477)
λ_M_1S_1	- 0.006 (0.363)	0.369 (0.443)	0.526 (0.482)

Legends: ***, **, and * denote significance levels at 1%, 5%, and 10% respectively. M_1S_0, M_0S_1, and M_1S_1 denote market facility, storage facility, and multiple infrastructures respectively. Standard errors are in parentheses.

Source: Own estimation of household survey data, 2022

5. Conclusion and Policy Implications

This study examined the impact of the use of single and multiple physical infrastructures on women's empowerment, gender equality, hidden hunger, and nutrition using a multinomial endogenous treatment effects regression model (METE) and multinomial endogenous switching regression model (MESR) respectively. We also used a multivalued treatment effect (MTE) to analyse the data, making our results more robust. Furthermore, we conducted mediation analysis to identify the pathways between infrastructure use and the outcomes using Hayes macro-application "PROCESS" for SPSS. We also conducted a falsification test to check the validity of the instruments used.

The results show that if households choose to use market facility only, storage facility only, and both infrastructures, their available cereal per adult equivalent will increase by 23.0%, 94%, and 44.0%, respectively, than if choose not to use them. Alternatively, if non-users choose to use market facility only, their available cereal per adult equivalent can be increased by 127.0% than if they remain non-users. Also, if non-users of physical infrastructure choose to use storage facility only and both infrastructures, their available cereal per adult equivalent will increase by 93.0% and 27.0%, respectively than if they remain non-users. Comparatively, households that use market and storage facilities have a smaller chance of avoiding hidden hunger than non-users. The effect size is relatively large for households that use storage facilities only than users of market facilities only and both infrastructures. The mediation analysis revealed that the pathway through which the use of both market and storage facilities may impact hidden hunger is through lower crop diversification. The results suggest that the use of storage and market facilities may promote the production and consumption of energy-dense food than micronutrient-rich foods. Households consume more cereals than micronutrient-rich crops when cold storage facilities are unavailable. For example, meats, fish, fruits, and vegetables have a short shelf life. Therefore, households that have no cold storage will keep more cereals in stock rather than perishable foods.

As expected, the results reveal that the use of market facility only, storage facility only, and both infrastructures significantly increase minimum dietary diversity of women (MDD-W) and children's dietary diversity score (CDDS). The mediation analysis revealed that the pathways through which the use of market and storage facilities may impact women's dietary diversity were through higher crop diversification, increased income, and more accumulated assets. Likewise, the positive impact of market and storage facilities on CDDS was mediated through higher crop diversification and more accumulated assets. As expected, the use of both infrastructures has the largest impact on MDD-W and CDDS. Moreover, for child malnutrition, we demonstrated that the use of market only, storage facility only and both infrastructures are negatively associated with wasting and underweight in children under five. Except for the use of market only, the use of storage facility only and both infrastructures have significant and negative impact on stunting. The negative impact of use of both market and storage facilities on stunting was mediated through higher crop diversification.

Further, it was observed that the use of market facility only, storage facility only, and both infrastructure promotes women's empowerment. Likewise, users of market facility only and both infrastructures increase gender equality, while the use of storage facilities has no significant effect on gender equality.

As expected, the effect size is relatively large for households that use both infrastructures than for those that use only one infrastructure. This finding is plausible because market and storage facilities have distinct strengths that, when combined, result in greater benefits for households. Furthermore, the mediation analysis also shows that the use of physical infrastructures influences women's empowerment indirectly through lower crop diversification and increased assets. Therefore, the additional gains of using market and storage infrastructures can be attributed to lower crop diversification, and asset accumulation.

We conclude that interventions that encourage the development of both market and storage infrastructures have the potential to empower women and promote gender equality more than a single infrastructure. Households, on the other hand, must be willing to use both physical infrastructures to support policies that promote women's empowerment and gender equality. The key implication of our findings is that using both market and storage facilities has substantial benefits on households and should be extended. Interventions to foster the provision of both market and storage facilities could improve nutrition and empower women, thus, reducing malnutrition and gender inequality. In addition, households must be interested in supporting public efforts to build appropriate market and storage facilities and other complementary infrastructures that improve access to and use of infrastructures.

Gains in the use of physical infrastructure (i.e., market and storage facilities) can be sustained through specific rural and infrastructural development policies, such as constructing of the community storage facilities, professional training on the use of these facilities, and establishing community daily markets for a cluster of farmers. Interventions should be directed towards boosting asset base and income security of households so as to achieve the full potential of using physical infrastructure.
Different market and storage facilities have their strengths and weaknesses. For this reason, different types of market and storage facilities may have varying effect on our outcome variables. Therefore, we recommend additional research on the impact of different types of market and storage facilities on women's empowerment, gender equality, food security, and nutrition. This will help policy makers to know which infrastructure needs more investments.

6. Limitations of the Study

Quite a few challenges were encountered locating households for the study. Major limitations bordered on using the phone-based application to locate the specific households selected for the study. There were marginal differences between the current GPS coordinates taken during the data collection and the coordinates of the baseline data made locating households quite challenging. It was also required that the spouse of the household head or an opposite gender of the household head in a selected household who participates in decision making be present at the time of the interview and respond to aspects of the questionnaire. However, some spouses were not present at the time of the interview, which required rescheduling at their convenient time. These situations stretched the time allocated for the data collection and increased the cost of visiting households.

References

Abbas, S., Isaac, N., Zia, M., Zakar, R. and Fischer, F., 2021. Determinants of women's empowerment in Pakistan: evidence from Demographic and Health Surveys, 2012–13 and 2017–18. *BMC Public Health*, *21*(1), pp.1-14.

Abdallah, A.H., Abdul-Rahaman, A. and Issahaku, G., 2020. Production and hidden hunger impacts of sustainable agricultural practices: evidence from rural households in Africa. *Agrekon*, *59*(4), pp.440-458.

Addison, L., Schnurr, M.A., Gore, C., Bawa, S. and Mujabi-Mujuzi, S., 2021. Women's Empowerment in Africa: Critical Reflections on the Abbreviated Women's Empowerment in Agriculture Index (A-WEAI). *African Studies Review*, *64*(2), pp.276-291.

Ahmed, M.H., 2022. Impact of irrigation on farm household diet quality: Evidence from Ethiopia. Irrigation and Drainage, 71(4), pp.1089-1106.

Alarcón-García, G., Buendía-Azorín, J.D. and Sánchez-de-la-Vega, M.D.M., 2022.Infrastructure and Subjective Well-Being from a Gender Perspective.Administrative Sciences, 12(1), p.1-22.

Alkire, S., Meinzen-Dick, R., Peterman, A., Quisumbing, A., Seymour, G. and Vaz, A., 2013.The women's empowerment in agriculture index.*World development*, *52*, pp.71-91.

Alsop, R. and Heinsohn, N., 2012. *Measuring empowerment in practice: Structuring analysis and framing indicators* (Vol. 3510). World Bank Publications.

Ashraf, N., Karlan, D. and Yin, W., 2010. Female empowerment: Impact of a commitment savings product in the Philippines. *World development*, *38*(3), pp.333-344.

Bandiera, O., Buehren, N., Burgess, R., Goldstein, M., Gulesci, S., Rasul, I. and Sulaiman, M., 2020. Women's empowerment in action: evidence from a randomized control trial in Africa. *American Economic Journal: Applied Economics*, *12*(1), pp.210-59.

Bassolé, L., 2007, November. Child malnutrition in Senegal: does access to public infrastructure really matter? A quantile regression analysis. In *African Economic Conference: Opportunities and Challenges of Development for Africa in the Global Arena, Addis Ababa, Ethiopia, Nov* (Vol. 1517).

Batliwala, S., 1994. The meaning of women's empowerment: New concepts from action. *Population policies reconsidered: Health, empowerment and rights*, *17*.

Bell, D.A., 1999. Democracy with Chinese characteristics: a political proposal for the post-communist era. *Philosophy East and West*, pp.451-493.

Bennett, L., 2002. Using empowerment and social inclusion for pro-poor growth: a theory of social change.*Working draft of background paper for the social development strategy paper. Washington, DC: World Bank*.

Biesalski, H.K. and Biesalski, H.K., 2013. Causes of Hidden Hunger.*Hidden Hunger*, pp.51-64.

Binswanger, H.P., Khandker, S.R. and Rosenzweig, M.R., 1993. How infrastructure and financial institutions affect agricultural output and investment in India. *Journal of development Economics*, *41*(2), pp.337-366.

Biru, W.D., Zeller, M. and Loos, T.K., 2020. The impact of agricultural technologies on poverty and vulnerability of smallholders in Ethiopia: a panel data analysis. Social Indicators Research, 147(2), pp.517-544.

Bourguignon, F., Fournier, M., &Gurgand, M. (2007). Selection bias corrections based on the multinomial logit model: Monte Carlo comparisons. *Journal of Economic surveys*, *21*(1), 174-205.

Buvinic, M., O'Donnell, M. and Bourgault, S., 2020. Women's economic empowerment in West Africa: towards a practical research agenda. Center for Global Development Working Paper, 557.

Cefalu, M. and Buenaventura, M., 2017.*Propensity scores for multiple treatments: a tutorial on the MNPS command for Stata users*. RAND.

Cornwall, A. and Rivas, A.M., 2015. From 'gender equality and 'women's empowerment'to global justice: reclaiming a transformative agenda for gender and development. *Third World Quarterly*, *36*(2), pp.396-415.

Creswell, J. W. (2014). *A concise introduction to mixed methods research*. SAGE publications.

Crookston, B.T., West, J.H., Davis, S.F., Hall, P., Seymour, G. and Gray, B.L., 2021. Understanding female and male empowerment in Burkina Faso using the project-level Women's Empowerment in Agriculture Index (pro-WEAI): a longitudinal study. *BMC Women's Health*, *21*(1), pp.1-11.

Datey, A., Bali, B., Bhatia, N., Khamrang, L. and Kim, S.M., 2023. A gendered lens for building climate resilience: Narratives from women in informal work in Leh, Ladakh. Gender, Work & Organization, 30(1), pp.158-176.

Deb, P., &Trivedi, P. K. (2006). Specification and simulated likelihood estimation of a non-normal treatment-outcome model with selection: Application to health care utilization. *The Econometrics Journal*, *9*(2), 307-331.

Deb, P., &Trivedi, P. K. (2006). Specification and simulated likelihood estimation of a non-normal treatment-outcome model with selection: Application to health care utilization. *The Econometrics Journal*, *9*(2), 307-331.

Deb, P., &Trivedi, P. K. (2006). Specification and simulated likelihood estimation of a non-normal treatment-outcome model with selection: Application to health care utilization. *The Econometrics Journal*, *9*(2), 307-331.

Di Falco, S., &Veronesi, M. (2010). On adaptation to climate change and food security: amicro-perspective from Ethiopia. In *CSAE Conference 2010: Economic Development in Africa* 22, 1-33.

Di Falco, S., Veronesi, M. and Yesuf, M., 2011. Does adaptation to climate change provide food security? A micro-perspective from Ethiopia. American Journal of Agricultural Economics, 93(3), pp.829-846.

Dodd, W., Gómez Cerna, M., Orellena, P., Humphries, S., Sadoine, M.L., Zombré, D., Zinszer, K., Kipp, A. and Cole, D.C., 2020. Factors associated with seasonal food insecurity among small-scale subsistence farming households in rural Honduras. International journal of environmental research and public health, 17(3), p.1-16.

Dubin, J.A. and McFadden, D.L., 1984. An econometric analysis of residential electric appliance holdings and consumption. *Econometrica: Journal of the Econometric Society*, pp.345-362.

Ekholuenetale, M., Tudeme, G., Onikan, A. and Ekholuenetale, C.E., 2020.Socioeconomic inequalities in hidden hunger, undernutrition, and overweight among under-five children in 35 sub-Saharan Africa countries. *Journal of the Egyptian Public Health Association*, *95*(1), pp.1-15.

Fongar, A., Gödecke, T., Aseta, A. and Qaim, M., 2019. How well do different dietary and nutrition assessment tools match? Insights from rural Kenya.*Public health nutrition*, *22*(3), pp.391-403.

Gödecke, T., Stein, A.J. and Qaim, M., 2018. The global burden of chronic and hidden hunger: trends and determinants. *Global food security*, *17*, pp.21-29.

Gupta, S., Vemireddy, V., Singh, D. and Pingali, P., 2019.Adapting the Women's empowerment in agriculture index to specific country context: Insights and critiques from fieldwork in India.*Global food security*, *23*, pp.245-255.

Gussak, D., 2008. An interactionist perspective on understanding gender identity in art therapy. *Art Therapy*, *25*(2), pp.64-69.

Hadisuyatmana, S., Has, E.M.M., Sebayang, S.K., Efendi, F., Astutik, E., Kuswanto, H. and Arizona, I.K.L.T., 2021. Women's Empowerment and determinants of early initiation of breastfeeding: a scoping review. *Journal of Pediatric Nursing*, *56*, pp.e77-e92.

Headey, D.D., 2013. Developmental drivers of nutritional change: a cross-country analysis. *World Development*, *42*, pp.76-88.

Heckert, J., Olney, D. K., &Ruel, M. T. (2019). Is women's empowerment a pathway to improving child nutrition outcomes in a nutrition-sensitive agriculture program?: Evidence from a randomized controlled trial in Burkina Faso. *Social Science & Medicine*, *233*, 93-102.

Issahaku, G., &Abdulai, A. (2020).Adoption of climate-smart practices and its impact on farm performance and risk exposure among smallholder farmers in Ghana.*Australian Journal of Agricultural and Resource Economics*, *64*(2), 396-420.

James, A. and Zikankuba, V., 2017. Postharvest management of fruits and vegetable: A potential for reducing poverty, hidden hunger and malnutrition in sub-Sahara Africa. *Cogent Food & Agriculture*, *3*(1), p.1312052.

Jejeebhoy, Shireen J. and Zeba A. Sathar. 2001. "Women's autonomy in India and Pakistan: The influence of religion and region." Population and Development Review 27(4), pp.687-712.

Jones, R., Haardörfer, R., Ramakrishnan, U., Yount, K.M., Miedema, S. and Girard, A.W., 2019. Women's empowerment and child nutrition: The role of intrinsic agency. *SSM-population health*, *9*, p.100475.

Jose, S. and Navaneetham, K., 2010.Social infrastructure and women's undernutrition. *Economic and Political Weekly*, pp.83-89.

Kabeer, N., 1999. Resources, agency, achievements: Reflections on the measurement of women's empowerment. *Development and change*, *30*(3), pp.435-464.

Kabeer, N., 2001. Conflicts over credit: Re-evaluating the empowerment potential of loans to women in rural Bangladesh. *World development*, *29*(1), pp.63-84.
Kabeer, N., 2005. Gender equality and women's empowerment: A critical analysis of the third millennium development goal 1. Gender & development, 13(1), pp.13-24.
Kabeer, N., 2012. Empowerment, citizenship and gender justice: a contribution to locally grounded theories of change in women's lives. Ethics and Social Welfare, 6(3), pp.216-232.
Kassie, M., Fisher, M., Muricho, G. and Diiro, G., 2020. Women's empowerment boosts the gains in dietary diversity from agricultural technology adoption in rural Kenya. *Food Policy*, *95*, p.101957.
Kassie, M., Marenya, P., Tessema, Y., Jaleta, M., Zeng, D., Erenstein, O., et al. 2018. Measuring farm and market level economic impacts of improved maize production technologies in Ethiopia: Evidence from panel data. *Journal of Agricultural Economics,69*(1), pp.76–95.
Kassie, M., Teklewold, H., Marenya, P., Jaleta, M. and Erenstein, O., 2015. Production risks and food security under alternative technology choices in Malawi: Application of a multinomial endogenous switching regression. Journal of Agricultural Economics, 66(3), pp.640-659.
Keller, B. and Mbewe, D.C., 1991.Policy and planning for the empowerment of Zambia's women farmers.*Canadian Journal of Development Studies/Revue canadienned'études du développement*, *12*(1), pp.75-88.
Kennedy, G., Berardo, A., Papavero, C., Horjus, P., Ballard, T., Dop, M., Delbaere, J. and Brouwer, I.D., 2010. Proxy measures of household food consumption for food security assessment and surveillance: comparison of the household dietary diversity and food consumption scores. *Public health nutrition*, *13*(12), pp.2010-2018.
Khalid, M.W., Samargandi, N., Shah, A.H. and Almandeel, S., 2020. Socio-economic factors and women's empowerment: evidence from Punjab, Pakistan. *International Economic Journal*, *34*(1), pp.144-168.
Khandker, S.R. and Koolwal, G.B., 2010. How infrastructure and financial institutions affect rural income and poverty: evidence from Bangladesh. *The journal of development studies*, *46*(6), pp.1109-1137.
Khonje, M. G., Manda, J., Mkandawire, P., Tufa, A. H., &Alene, A. D. (2018). Adoption and welfare impacts of multiple agricultural technologies: evidence from eastern Zambia. *Agricultural Economics*, *49*(5), 599-609.
Kim, J.C., Watts, C.H., Hargreaves, J.R., Ndhlovu, L.X., Phetla, G., Morison, L.A., Busza, J., Porter, J.D. and Pronyk, P., 2007. Understanding the impact of a microfinance-based intervention on women's empowerment and the reduction of intimate partner violence in South Africa.*American journal of public health*, *97*(10), pp.1794-1802.
Koppmair, S., Kassie, M. and Qaim, M., 2017.Farm production, market access and dietary diversity in Malawi.*Public health nutrition*, *20*(2), pp.325-335.
Lei, L., Desai, S. and Vanneman, R., 2019.The impact of transportation infrastructure on women's employment in India.*Feminist economics*, *25*(4), pp.94-125.
Lenaerts, B. and Demont, M., 2021. The global burden of chronic and hidden hunger revisited: new panel data evidence spanning 1990–2017. *Global food security*, *28*, p.100480.
Lokshin, M. and Sajaia, Z., 2004.Maximum likelihood estimation of endogenous switching regression models.*The Stata Journal*, *4*(3), pp.282-289.
Lowe, N.M., 2021. The global challenge of hidden hunger: Perspectives from the field. *Proceedings of the Nutrition Society*, *80*(3), pp.283-289.
Ma, W., Vatsa, P., Zheng, H. and Guo, Y., 2022. Learning to eat from others: Does nutritional information acquired from peers affect nutrition intake?.*Journal of Rural Studies*, *95*, pp.449-457.
Malapit, H., Quisumbing, A., Meinzen-Dick, R., Seymour, G., Martinez, E.M., Heckert, J., Rubin, D., Vaz, A., Yount, K.M., Phase, G.A.A.P. and Team, S., 2019. Development of the project-level Women's Empowerment in Agriculture Index (pro-WEAI).*World development*, *122*, pp.675-692.
Malapit, H.J.L. and Quisumbing, A.R., 2015. What dimensions of women's empowerment in agriculture matter for nutrition in Ghana?.*Food Policy*, *52*, pp.54-63.
Mekonnen, D.K., Choufani, J., Bryan, E., Haile, B. and Ringler, C., 2022. Irrigation improves weight-for-height z-scores of children under five, and Women's and Household Dietary Diversity Scores in Ethiopia and Tanzania. Maternal & Child Nutrition, 18(4), p.e13395.
Mosedale, S., 2005. Assessing women's empowerment: towards a conceptual framework. *Journal of international development*, *17*(2), pp.243-257.
Muhammad, F., Bano, K., Muhammad, K. and Baig, T., 2021. Women empowerment in Pakistan:

assessing the socio-economic determinants. *Studies of Applied Economics*, *39*(3).https://doi.org/10.25115/eea.v39i2.3884
Mundlak, Y. (1978). On the pooling of time series and cross section data.*Econometrica,46*(1), 69–85.
Narayan, D. and Petesch, P., 2007. Agency, opportunity structure, and poverty escapes. *Moving out of poverty: Cross-disciplinary perspectives on mobility*, *1*(1), pp.1-44.
Narayan-Parker, D. ed., 2005.*Measuring empowerment: Cross-disciplinary perspectives*.World Bank Publications.
Nkegbe, P., K. &Yazeed, A., M. 2022.Impact of community development initiatives and access to community markets on household food security and nutrition in Ghana.*Food Policy*: pp. 102282.
Nölle, N., Genschick, S., Schwadorf, K., Hrenn, H., Brandner, S. and Biesalski, H.K., 2020. Fish as a source of (micro) nutrients to combat hidden hunger in Zambia.*Food Security*, *12*, pp.1385-1406.
Nussbaum, Martha. 2000. Women and Human Development: The Capabilities Approach. New York: Cambridge Press.
Obayelu, A. and Ogunlade, I., 2006. Analysis of the uses of information communication technology (ICT) for gender empowerment and sustainable poverty alleviation in Nigeria.*International Journal of Education and Development using ICT*, *2*(3), pp.45-69.
Obayelu, O.A. and Chime, A.C., 2020. Dimensions and drivers of women's empowerment in rural Nigeria.*International Journal of Social Economics*, 47(3), pp. 315-333. https://doi.org/10.1108/IJSE-07-2019-0455.
Pangaribowo, E. and Gerber, N., 2016. Innovations for food and nutrition security: impacts and trends. *Technological and institutional innovations for marginalized smallholders in agricultural development*, pp.41-64.
Passarelli, S., Mekonnen, D., Bryan, E. and Ringler, C., 2018.Evaluating the pathways from small-scale irrigation to dietary diversity: evidence from Ethiopia and Tanzania.Food Security, 10(4), pp.981-997.
Pitt, M.M., Khandker, S.R. and Cartwright, J., 2006. Empowering women with micro finance: Evidence from Bangladesh. *Economic Development and Cultural Change*, *54*(4), pp.791-831.
Poole, N., Amiri, H., Amiri, S.M., Farhank, I. and Zanello, G., 2019. Food production and consumption in Bamyan Province, Afghanistan: the challenges of sustainability and seasonality for dietary diversity. *International Journal of Agricultural Sustainability*, *17*(6), pp.413-430.
Quisumbing, A.R., Meinzen-Dick, R.S. and Malapit, H.J., 2019. Gender equality: Women's empowerment for rural revitalization. *IFPRI book chapters*, pp.44-51.
Quisumbing, Agnes R., Ellen Payongayong, J.B. Aidoo, and KeijiroOtsuka. 1999. Women's Land Rights in the Transition to Individualized Ownership: Implications for the Management of Tree Resources in Western Ghana. Food Consumption and Nutrition Division Discussion Paper No. 58. Washington DC: International Food Policy Research Institute.
Ritchie, H., Reay, D.S. and Higgins, P., 2018. Quantifying, projecting, and addressing India's hidden hunger. *Frontiers in Sustainable Food Systems*, *2*, p.11.
Salehi-Isfahani, D. and Taghvatalab, S., 2022.Electrification and the Closing of the Gender Gap in Education in Rural Iran.*Available at SSRN 4229560*.
Samad, H.A. and Zhang, F., 2019. Electrification and women's empowerment: evidence from rural India. *World Bank Policy Research Working Paper*, (8796).
Sedai, A.K., Nepal, R. and Jamasb, T., 2022.Electrification and socio-economic empowerment of women in India.*The Energy Journal*, *43*(2).
Sell, M. and Minot, N., 2018, November. What factors explain women's empowerment? decision-making among small-scale farmers in Uganda. In Women's Studies International Forum (Vol. 71, pp. 46-55).Pergamon.
Sen, G., 1993. Women's empowerment and human rights: The challenge to policy. *population summit of the world's Scientific Academies*, *294*, pp.1-275.
Shrestha, A., Six, J., Dahal, D., Marks, S. and Meierhofer, R., 2020. Association of nutrition, water, sanitation and hygiene practices with children's nutritional status, intestinal parasitic infections and diarrhoea in rural Nepal: a cross-sectional study. *BMC public health*, *20*(1), pp.1-21.
Shrimpton, R., Victora, C.G., de Onis, M., Lima, R.C., Blossner, M. and Clugston, G., 2001. Worldwide timing of growth faltering: implications for nutritional interventions. *Pediatrics*, *107*(5), pp.e75-e75.
Smith, L. C., &Subandoro, A. (2007). *Measuring food security using household expenditure surveys*

(Vol. 3). Intl Food Policy Res Inst.

Srilakshmi, B., 2006. *Nutrition Science*.New Age International.

Stifel, D. and Minten, B., 2019. Market access, welfare, and nutrition: Evidence from Ethiopia. *Gates Open Res*, *3*(1004), p.1004.

Swain, R.B. and Wallentin, F.Y., 2009. Does microfinance empower women? Evidence from self-help groups in India.*International review of applied economics*, *23*(5), pp.541-556.

Thapa, G. and Shively, G., 2018. A dose-response model of road development and child nutrition in Nepal.Research in Transportation Economics, 70, pp.112-124.

Turley, L. and Uzsoki, D., 2018. *Financing Rural Infrastructure: Priorities and pathways for ending hunger*. International Institute for Sustainable Development (IISD).

Twumasi, M.A., Jiang, Y., Asante, D., Addai, B., Akuamoah-Boateng, S. and Fosu, P., 2021. Internet use and farm households' food and nutrition security nexus: The case of rural Ghana. Technology in Society, 65, p.101592.

Tzannatos, Zafiris. 1999. "Women and labor market changes in the global economy: Growth helps, inequalities hurt and public policy matters." World Development 27(3), pp.551-569.

Vaitla, B., Devereux, S. and Swan, S.H., 2009. Seasonal hunger: a neglected problem with proven solutions. *PLoS medicine*, *6*(6), p.e1000101.

Valdivia, M., 2004. Poverty, health infrastructure and the nutrition of Peruvian children. *Economics & Human Biology*, *2*(3), pp.489-510.

van der Hoek, W., Feenstra, S.G. and Konradsen, F., 2002. Availability of irrigation water for domestic use in Pakistan: its impact on prevalence of diarrhoea and nutritional status of children. *Journal of Health, Population and Nutrition*, pp.77-84.

WHO Multicentre Growth Reference Study Group, & de Onis, M. (2006). WHO Motor Development Study: windows of achievement for six gross motor development milestones. *Actapaediatrica*, *95*, 86-95.

Wooldridge, J. and Semykina, A., 2005. Estimating panel data models in the presence of endogeneity and selection: Theory and application. *Michigan State University*.

Yount, K.M., Cheong, Y.F., Maxwell, L., Heckert, J., Martinez, E.M. and Seymour, G., 2019. Measurement properties of the project-level Women's Empowerment in Agriculture Index.*World development*, *124*, p.104639.

The International Centre for Evaluation and Development

Site
www.iced-eval.org

Ghana
P.O. Box SK 878,
Premier Towers,
Sakumono Broadway, Tema
Tel. +233 24-76-49-610

Kenya
P.O. Box 1838,
Sarit Centre 00606,
Nairobi, Kenya
Tel. +254 714-411-671

USA
9524 Jeanne CT.,
Laurel, MD, USA
20723
Tel. +1 301-648-3417