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Membership of water user association and implications for food security

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A B S T R A C T

Agricultural cooperatives are widely regarded as effective institutions for supporting smallholder farmers, reducing poverty, and improving food security. However, empirical evidence varies with mixed findings across different contexts. This study used a primary data of 820 farm households to examine the relationship between membership of water user association (WUA) and food security, using a quasi-experimental research design. The findings show that WUA membership is significantly influenced by factors including age, marital status, access to extension services, participation in supplementary irrigation (SI) and drought index insurance (DII) initiatives, farm size, and an asset aspiration gap. The results further indicate a positive association between WUA participation and household food security. These findings suggest that rural development policies should focus on strengthening existing WUAs and fostering the establishment of new ones through inclusive approaches that address food insecurity.

1. Introduction

Achieving Sustainable Development Goal (SDG) 2 – Zero Hunger – is one of the most significant and challenging objectives in the pursuit of the "no one left behind" principle central to Agenda 2030 [1]. Currently, about 850 million people worldwide face hunger, with more than two-thirds of the global population suffering from nutrient deficiencies, impacting their diet, quality of life, well-being, and life expectancy [2]. The World Bank Food Project forecasts that by 2030, over a billion people could face food insecurity, exacerbated by climate variability and change [3]. Much of the current discussion on SDG 2 focuses on Africa, a region experiencing rapid population growth and disproportionately severe impacts from climate change ([4,5]; Alhassan et al., 2018; [6,7]). There is also uncertainty regarding the extent of food insecurity in Africa, as doubts about the reliability of agricultural production statistics persist [8].

The pervasiveness of undernourishment in Africa increased from 17.6 % of the population in 2014 to 19.1 % in 2019, more than double the global average and the highest of any region in the world [3]. By 2030, sub-Saharan Africa's population is projected to grow from 1.07 billion to 1.40 billion, and it could reach 3.78 billion by the end of the century (United Nations, 2019). With a young demography – 41 % of the population under 15 years and 19 % between 15 and 24 years – sub-Saharan Africa's population will continue to expand even if growth rates slow (United Nations, 2017). Although a recent study by Vollset et al. (2020) suggests global population projections may be overestimated, it still predicts that sub-Saharan Africa will reach 3.07 billion by 2100. This region is the most vulnerable to food insecurity due to its heavy reliance on cereal imports, rapid population growth, and stagnant agricultural productivity (van Ittersum et al., 2016 [9]). Agriculture remains critical to addressing the food needs of this expanding population, especially given the intensifying impacts of climate change [10].

Several studies in Ghana have highlighted that food insecurity is particularly severe in rural areas where livelihoods depend heavily on agriculture [11]. The Upper East region stands out as having the worst food insecurity rates, with 28 % of its population facing food challenges [12]. The study by Hjelm and Dasori (2012) [13] confirmed the region's status as the most food-insecure in Northern Ghana. This study also

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revealed that three out of the five most food-insecure districts in Northern Ghana were located in the Upper East region. The region's reputation as a hub of food insecurity has been corroborated by further research [12,14].

The aim of achieving the second pillar of the SDGs has the singular objective to end hunger. In this regard, several solutions and factors had been recently proposed to address food security. For instance, land management and climate-smart agriculture [10,10,15–21], advanced biotechnologies (Gressel et al., 2003; [22,23]), and water management [24–27] were implemented to improve agricultural efficiency. Increasing the financial statement of households [28] through new policies to raise the level of education [29] has also shown promising results. Interdisciplinary research has provided valuable findings in the fight against food insecurity, one of which is social capital [17,18,30–34]. Despite the several policy interventions in addressing food insecurity in most developing countries, there is limited study on the impact of social capital on food insecurity. The closest study by Owusu-Sekyere et al. [26] found that farmers' participation in the irrigation management transfer (IMT) scheme enhance their rice yields and net farm returns. Furthermore, Balasubramanya et al. [35] and MacDonald [36] highlighted the critical role of presidential plots and kitchen gardens, which largely rely on irrigation canals, in supporting agricultural production and ensuring food security, particularly for WUA households. Kitchen gardens are characterized by diversified production and are almost entirely used for self-consumption, with vegetables and fruits being the primary crops. In contrast, presidential plots are predominantly utilized for growing fodder and cereals. The production on kitchen gardens is well diversified and almost entirely self-consumed. Vegetables and fruits are usually grown in kitchen gardens and presidential plots are mostly used to grow fodder and cereals.

While extensive research has been conducted on the role of social capital in addressing food insecurity, most studies have focused on rainfed agricultural ecologies, where farming is highly dependent on seasonal rainfall patterns. For example, farmers in rainfed areas often rely on their social ties for informal lending, labour exchange, and sharing farming knowledge or inputs like seeds and fertilizers, which are crucial for ensuring food availability in uncertain and unpredictable climates. However, despite the importance of irrigation agriculture in enhancing food security, very few studies have examined the impact of social capital on food insecurity in irrigation-based ecologies. Irrigation systems provide a more stable and predictable environment for crop production by reducing the dependency on rainfall, which can significantly alter the dynamics of the impact of social capital on food security. In the irrigation ecologies, the management and access to water resources often require collective action, coordination, and cooperation among farmers, making social capital a critical factor for the efficient use of these resources.

Exploring the relationship between social capital and food insecurity in irrigation ecologies could provide unique insights into how networks and social cohesion affect farmers' ability to access water, improve agricultural productivity, and ultimately achieve food security. In such contexts, social capital may influence factors like water allocation, the maintenance of irrigation infrastructure, and the organization of farmer groups for joint investments in machinery or bulk purchasing of inputs, all of which can directly impact food availability and income stability. Given the differences between rainfed and irrigation systems, this study critically examined the association between participation in WUA and farmers' level of food and nutrition security. It is essential to know whether participation in WUA is effective when evaluating food and nutrition security. With this background information, the study tests the hypothesis that participation in WUA is negatively associated with household food and nutrition insecurity.

This study contributes to the literature in two strands. First, while empirical studies have shown that social capital reduces food insecurity [30–34,37–41], and improves productivity and welfare of smallholder farmers in many developing countries ([42]; Kumar et al., 2018 [40,43,44]; Tabe-Ojong, 2022 [45]), there is no conclusive empirical evidence establishing a direct link between WUA membership and food insecurity. To the best of our knowledge, this paper is the first to empirically analyze the effect of WUA membership on food and nutrition insecurity in Ghana's irrigation-based ecologies. The second strand of literature to which we contribute is the broad literature on the implications of self-help groups, agricultural organizations, and producer groups in developing nations. The findings contribute significantly to the policy debate on sustainable interventions and strategies required to curb the high incidence of food insecurity in Ghana and also generate evidence-based results that could inform policy decisions at the national and/or local levels within a developing region context. Additionally, this study contributes to the ongoing efforts to enhance and expand knowledge on irrigation sector reforms initiated by organizations such as the World Bank, FAO, IWMI, and other national and international bodies. It provides valuable insights into how these reforms can address food insecurity in Ghana, offering a better understanding of their impact and effectiveness.

The rest of the paper is structured as follows: Section 2 presents an overview of agriculture and WUA schemes in Ghana. Section 3 presents the data and describes the variables used for the analysis, while section 4 presents and discusses the results. Section 5 provides the concluding remarks and the implications.

2. Background: overview of agriculture and WUA schemes in Ghana

2.1. Overview of agriculture in Ghana

The Ghanaian economy is undergoing structural transformation, with the services sector playing an increasingly significant role in GDP [46]. Despite this shift, agriculture remains vital, employing about 42 % of the workforce and contributing 19.7 % to GDP [47,48]. The agricultural sector is predominantly characterized by small-scale, rain-fed crop and livestock farming, with average farm sizes under 1.2 ha, contributing roughly 80 % of total production [49]. Key subsectors include crops, livestock, fisheries, and forestry, with cocoa being a cornerstone for foreign exchange, employment, and economic growth, making Ghana the world's second-largest cocoa exporter after Ivory Coast [50]. Agriculture's contributions extend beyond economic metrics; it supports food security, employment, and poverty reduction [27,50,51]. Fisheries (marine, inland, and aquaculture) and livestock farming, including ruminants, poultry, and non-traditional species like snails and grasscutters, are essential income sources for many households [51]. However, significant regional disparities persist, with northern Ghana recording the lowest per capita incomes. To address these challenges, Ghana has implemented several policies and initiatives, including the Medium-Term Agriculture Sector Investment Plan (METASIP), the Coordinated Programme of Economic and Social Policies (2017–2024), the Ghana Shared Growth and Development Agenda (GSGDA) II, Food and Agriculture Sector Development Policy (FASDEP I and II), Planting for Food and Jobs (PFJ), and the National Climate Smart Agriculture and Food Security Action Plan. These initiatives aim to promote agricultural growth, enhance food security, reduce poverty, and support regional development, particularly in northern Ghana (World Bank, 2017). Promoting agricultural growth is critical for reducing poverty and driving structural transformation through strong income-consumption linkages [46]. To achieve this, Ghana must prioritize knowledge-driven policies, foster commodity-driven economic growth, and address regional inequalities to ensure inclusive and sustainable development.

2.2. Overview of WUA schemes in Ghana

The WUA initiative was established to manage irrigation systems and promote efficient water use in agricultural settings due to persistent management failures by governments. Organizations such as the World Bank, USAID, FAO, and the International Water Management Institute (IWMI) advocated for transferring irrigation management responsibilities from government agencies to private entities like WUAs [26,40,52–54]. This shift was part of the broader Irrigation Management Transfer (IMT) policy, which began in the mid-1970s [53]. The peak of adoption occurred in the early 1990s, as governments faced increasing financial challenges and growing dissatisfaction with the performance of existing irrigation systems [53,55]. This policy aimed to improve irrigation resources' efficiency, sustainability, and community ownership.

In Ghana, the IMT initiative began in the Volta River Basin in 1999. The operation and management responsibilities transfer occurred at the river basin level, focusing on small-scale schemes of less than 100 ha [53]. The government delegated part of the irrigation system's operation and management to WUA. Farmers within the irrigation scheme's reach were allowed to participate, with voluntary membership and influenced by factors such as water usage fees, expected benefits, timeliness, water quality, and land location. Farmers who join the scheme benefit from various services, including extension services and technical advice on improved farming practices and technology. Additionally, extension agents and NGOs like the Association of Church-based Development NGOs (ACDEP) and Regional Advisory Information and Network Systems (RAINS) provide financial training, organize field trips, and facilitate both local and international tours for farmers under the IMT scheme. This support helps enhance the farmers' productivity, knowledge, and capacity to sustain agricultural production.

Ghana has approximately twenty-two formal irrigation schemes spanning about 8611 ha across various regions [26,55]. A 2007 FAO country report on pilot cases of IMT conducted in the early 2000s revealed that while IMT increased both government and farmer operational and management costs, it improved the efficiency of water usage fee collection. However, the report noted that certain key metrics–such as timely water delivery, equity in water distribution, and waterlogging–remained unchanged after IMT's implementation. Contrary to expectations, the report found declines in maintenance quality, irrigated area, crop yields, and farm income following the introduction of IMT, which was unusual compared to experiences in other countries. This decrease was attributed to poor maintenance of irrigation infrastructure and a lack of technical capacity within the WUAs [53]. Recent policies, such as the Ghana Shared Growth Development Agenda (GSGDA, 2013) and the Coordinated Programme of Economic and Social Development Policies [56], have aimed to address these issues, making significant improvements in maintenance quality and technical facilities. These reforms reflect a shift towards a more sustainable and productive irrigation sector in Ghana.

3. Data and summary statistics

3.1. Data

The data for this study was collected in January–February 2024 from 820 rice farming households in the irrigation ecologies of Ghana's Northern and Upper East regions. We performed a three-stage sampling process as follows: first, the Northern and Upper East Regions were selected based on the predominance of irrigated rice farming in the area; second, randomly sampling of selected 33 communities in the two regions; and third, random sampling of 820 rice farming households from the sampled communities based on a household list provided by the Ghana Irrigation Development Authority (GIDA) and Irrigation Company of Upper East Region (ICOUR) of Ghana.

Rain-fed agriculture is the mainstay of the economy in the study area, and the regions are characterized by uni-modal rainfall. The study focused on rice farmers who cultivate rice both in the wet and dry seasons. The climate in these regions is characterized by a single rainy season lasting from June to October, with annual rainfall ranging between 750 mm and 1100 mm. Rainfall in these regions is notably erratic, with significant variability in both spatial distribution and duration. This irregularity often results in inconsistent water availability, which poses a challenge for agricultural planning and productivity. The short rainy season is followed by a long dry period from November to May, during which rainfall is scarce, further stressing water resources. The data collection began with training enumerators, followed by pretesting and finalizing the questionnaire using the World Bank's app Survey solution on tablets. The primary data for the study focused on socioeconomic characteristics, social capital, crop farming and input use, output and income, irrigation, credit access, food security, and migration.

3.1.1. Measurement of outcome variables

The main outcome variables are household dietary diversity score (HDDS), coping strategy index (CSI), households' expenditure on vegetables and fruits, and protein-rich foods. The HDDS is computed as a count variable based on the consumption of 12 food groups, encompassing fruits, meat, poultry, and offal, eggs, fish and seafood, cereals, roots and tubers, vegetables, pulses, legumes, and nuts, milk and milk products, oils and fats, sugar and honey, and miscellaneous items, over a 24-h or multi-day period (Ecker, 2018). A higher score is indicative of improved food access and higher-quality diets (Vaitla et al., 2009).

The CSI computation followed a three-step approach detailed by Maxwell and Caldwell (2008) as follows. The first step assessed the frequency of each coping strategy employed by households over the past week. In the second step, severity weights are assigned where one denotes early stages of food crises, two indicates an advanced stage, three represents situations with an exceptionally high vulnerability to food crises, and four signifies the stage where coping strategies adopted suggest failure to adequately address food crises, often involving abnormal, destitute, and distress strategies. In the third stage, each coping strategy is multiplied by its respective severity weight to calculate the individual CSI. The individual CSIs are summed to obtain the total CSI. A higher CSI indicates a more severe food crisis, while a lower CSI signifies greater food security.

The final outcomes are household expenditures on vegetables, fruits, and protein-rich foods, expressed in Ghana cedi and United States Dollar Equivalence. These expenditures are calculated based on the types of vegetables, fruits, and protein consumed annually by each household.

3.2. Summary statistics

The dependent and explanatory variables used in the regression are described in Table 1. The result shows that the average HDDS and CSI are 9.45 and 9.48, respectively. Additionally, households spend an average of GHS48.57 (US$3.98) on vegetables and fruits and GHS57.75 (US$4.72) on protein-rich foods. About 65 % of the sampled farmers belong to WUA. The demographic characteristics of the sampled households indicate that the average farmer is 47 years old, placing them in the economically active age group, with 81 % being male, and 86 % married. On average, a sampled farmer has 22 years of farming experience, with 56 % received a formal education. Regarding land ownership, 23 % own land and 94 % of the sampled farmers are natives. The average farm size is 2.7 ha and 49 % have access to extension service. About 49 % of the farmers have access to extension services, while 34 % have access to credit, and 32 % receive remittances. The asset aspirations gap of the farmers is 0.815 on average, meaning households are 81.5 % below their desired asset level. Additionally, 52 % of households have a member who has migrated, and 28 % participate in supplementary irrigation and drought index insurance programs.

We employed the mean difference test on the variables to obtain a preliminary understanding of the observed differences between WUA members and non-members (Table 2). The result shows a statistically significant difference in food and nutrition security outcomes of WUA members and non-members. The study found that WUA members have

Table 1
Descriptive statistics of outcome and explanatory variables.

Variable	Description	Mean	Std. dev.	Min	Max
Outcome variables					
HDDS	Household dietary diversity score	9.452	2.232	0	12
CSI	Coping strategy index	9.479	5.986	1	28
VegFruit	Consumption of vegetables and fruits (GHS)	48.573	45.238	0	350
Protein	Consumption of protein (GHS)	57.754	59.096	0	400
Covariates					
WUA	Water users' association (1 = yes)	0.648	0.478	0	1
Age	Age of household head (years)	46.689	13.020	27	87
FarmExp	Farming experience (years)	22.626	12.252	7	72
MaritStat	Marital status (1 = married)	0.862	0.345	0	1
Sex	Sex of household head (1 = male)	0.810	0.393	0	1
EducDummy	Formal education (1 = yes)	0.557	0.497	0	1
Nativity	Native (1 = yes)	0.940	0.237	0	1
Exten	Access to extension services (1 = yes)	0.487	0.500	0	1
Ownland	Ownership of land (1 = yes)	0.232	0.422	0	1
Landarea	Farm size (hectares)	2.650	1.976	0.08	10
CredDum	Access to credit (1 = yes)	0.341	0.474	0	1
AssetAspGAP	Asset aspirations gap (proportion)	0.815	0.202	0	1
Remit	Receive remittances (1 = yes)	0.324	0.468	0	1
Migrant	Migrant household members (1 = yes)	0.516	0.500	0	1
Treatement	Participate in SI and DII (1 = yes)	0.280	0.450	0	1
Observation		820			

Note: Std. dev. is standard deviation; The exchange rate at the time of the survey (2024) is 1GHS = US$12.23 (Source: Bank of Ghana, 2024).

Table 2
Differences in means between WUA members and non-members.

Description	Mean difference	P-value
Outcome variables		
Household dietary diversity score	−0.522	0.002
Coping strategy index	1.490	0.001
Consumption of vegetables and fruits (GHS)	−10.113	0.002
Consumption of protein (GHS)	−12.903	0.002
Explanatory variables		
Age of household head (years)	2.035	0.035
Farming experience (years)	1.177	0.194
Marital status (1 = married)	−0.065	0.015
Sex of household head (1 = male)	0.016	0.576
Formal education (1 = yes)	−0.032	0.374
Native (1 = yes)	−0.025	0.168
Access to extension services (1 = yes)	−0.212	0.000
Ownership of land (1 = yes)	0.038	0.231
Farm size (hectares)	−0.638	0.000
Access to credit (1 = yes)	−0.041	0.233
Asset aspirations gap (proportion)	0.049	0.000
Receive remittances (1 = yes)	0.001	0.969
Migrant household members (1 = yes)	−0.107	0.003
Participate in SI and DII (1 = yes)	−0.161	0.000
Observation	820	

Notes: Standard deviations in parentheses; The asset aspirations are scaled by 10000. ***p < 0.01, **p < 0.05.

higher HDDS and lesser CSI compared to non-members. Additionally, WUA members recorded a higher expenditure on vegetables, fruits, and protein-rich food than non-members.

The data further shows that WUA members are older than non-members and are likely to have higher farming experience. The result also revealed that WUA members have access to extension service and are more likely to participate in supplemental irrigation (SI) and drought-index insurance (DII) than non-members. We also found that WUA members have lesser farm sizes than non-members. As indicated by Bizikova et al. (2017), farmers' participation in training in water management and agronomical practices, coupled with peer-to-peer learning and community participation, have been found to have a positive impact on agricultural production and food security.

4. Empirical strategy

This study utilized a quasi-experimental research design to compare outcomes between WUA participant households (treatment group) and non-participant households (comparison group). Quasi-experimental designs are commonly employed when random assignment to treatment and comparison groups is not feasible, providing a practical approach to evaluating interventions in real-world settings. The comparison group approximates counterfactual scenarios, capturing what might have occurred to WUA members' food security in the absence of the intervention (i.e., participation in WUAs). This approach allows for a robust analysis of the effect of WUA participation on household food security.

To understand the link between the water user association (WUA) membership and food and nutrition security outcomes (HDDS, CSI, consumption of vegetables and fruit, and proteins), we estimate the following equation:

$$Y_i = \alpha + \beta_i X_i + \gamma W_i + \mu_i \quad (1)$$

where Y_i represents the food and nutrition security outcomes (HDDS, CSI, consumption of vegetables and fruit, and proteins); X_i is a vector of covariate variables specified in Table 1. The variable W_i is an indicator for WUA membership; β_i denote the parameters of the estimated coefficients of the controls and μ_i is the error term. Estimates of the parameter γ give the relationship between WUA membership and food security outcomes. We hypothesis that WUA membership is positively associated with HDDS, consumption of vegetables and fruit, and proteins but negatively associated with CSI (i.e. $0 < \gamma > 0$)

Assuming WUA membership is exogenous, the ordinary least squares (OLS) regression framework could be used to estimate the relationship between WUA membership and food security. However, WUA membership is an endogenous household decision due to self-selection. Therefore, not controlling for the endogeneity may likely result in a biased and inconsistent estimate of γ using the OLS. Previous research (Mojo et al., 2016; Garcia et al., 2020; [17,18,33,57]) accounted for the endogeneity of group membership using propensity score matching (PSM), which generates a comparable counterfactual of group membership and matches farmers in the two groups. As a selection-on-observables estimator, it conditions on observable factors, thereby reducing bias associated with those observable characteristics. Despite this, PSM can still produce biased results when the propensity score model is mis-specified (Robins et al., 2007; Wooldridge, 2007). Possible strategies to overcome this challenge are the doubly robust estimators such as the Inverse Probability Weighting Regression Adjustment (IPWRA) and Inverse Probability Weighting (IPW). IPWRA combines the weighting estimator (Inverse probability weighting) and regression adjustment (RA) to produce consistent and unbiased effect estimates. Being doubly robust, they produce consistent estimates when the treatment or the outcome model is correctly specified (Wooldridge, 2010 [58–60]; Zheng and Ma, 2021; [17,18,33,57,61–63]).

Based on this, the study uses weighting and doubly robust estimators to establish the relationship between WUA membership and food security. Nevertheless, we also estimate some OLS models for the basis of comparison. For the weighting and doubly robust estimators, our outcome and treatment models are represented as:

$$Y_i = f(M_{i,} + \gamma) + \varepsilon_i \tag{2}$$

$$Pr(M_i = 1, 0) = H(X_{i,}\ \beta) + v_i \tag{3}$$

The same notations are used in Eq. (1). Despite their robustness to misspecifications, doubly robust estimators only control for observed differences between WUA and non-WUA members. However, some unobserved characteristics may drive membership in WUA and food security formation, leading to some endogeneity concerns.

5. Results and discussion

5.1. WUA membership and food and nutrition security

The baseline results establishing the link between WUA membership and food and nutrition security outcomes are reported in Table 3. The OLS results show that WUA membership is associated with a 0.421 increase in HDDS (column 1) and 1.293 decline in CSI (column 2). In addition, WUA membership is positively associated with an increase in the consumption of vegetable and fruits and the consumption of protein by GHS11 (US$0.90) and GHS13 (US$1.06), respectively. The results highlight the important role of social capital in enhancing food security within a developing country context. Beyond the WUA variable, we observed that HDDS is significantly influenced by marital status, farm size, access to credit, and migration status. CSI is significantly determined by access to extension services, farm size, access to credit, remittance, and migrant status. In addition, consumption of fruits and vegetables is significantly influenced by access to extension services and remittance while consumption of protein is significantly influenced by farm size, credit access, and remittance (see Fig. 1).

Despite the insightful findings on the role of WUA membership, OLS is likely to result in bias estimate due to endogeneity in WUA membership. Given this, we focused on the IPWRA which controls endogeneity based on selection on observables. Our study did not explore instrumental variable estimation due to the difficulty in establishing a credible instrument that satisfies the exclusion restriction condition. The study presents the results of the weighting and doubly robust estimators in this section. The relationship between WUA membership and food and nutrition security is based on the weighting and doubly robust estimators (Table 4). To use these estimators, two critical assumptions must be satisfied: the balancing and overlap assumptions. To verify if we have achieved the balance after our weighting procedure, Imbens and Wooldridge (2009) overidentification test was conducted. Based on the Chi square test statistics as shown in the results (Tables 4 and 5), we conclude that our weighting samples are balanced. Additionally, we calculate the normalized differences for each of our explanatory variables and found them to be relatively small (see Table A1 in the appendix). Furthermore, the variance ratios are close to 1 for all control variables in the model. With respect to the overlap condition, none of our observations have a probability below and above the 0 and 1 thresholds, indicating the overlap condition has been satisfied (Fig. 2). The boxplot further shows that before matching, there was a significant difference between WUA and non-WUA members but after the matching, the two categories are similar indicating that the balancing condition is satisfied (Fig. 3).

The study revealed that WUA membership is significantly associated with food and nutrition security across the weighting and doubly robust specifications. Consistent with the study *a prior* expectation, WUA membership is associated with a 1.004 decline in CSI (Table 4). The findings imply that WUA membership may provide members with the resources, knowledge, and social support needed to maintain or improve food security. The study's finding is consistent with Guyalo and Ifa [33] who found that agricultural cooperative (AC) significantly reduces food insecurity status of member households. ICA and ILO [64] indicate that AC uniquely affects the livelihoods of poor households, smallholder farmers, and communities that depend on traditional farming systems with poor technology, low capital, weak institutions, and poor infrastructure. The result suggests that membership in cooperatives have the capacity to increase agricultural production, income, welfare, food security, and improve services at the lowest possible cost by enhancing synergy and economies of scale [33,65].

Table 5 also show that WUA membership is positively associated with dietary outcomes (HDDS, fruit and vegetables, and protein rich food). We found that WUA membership is positively associated with

Table 3
OLS estimates of food and nutrition security.

Variables	(1)	(2)	(3)	(4)
	HDDS	CSI	Vegetable and Fruit	Protein
WUA	0.421[b]	−1.293[a]	10.868[a]	13.321[a]
	(0.185)	(0.462)	(3.593)	(4.493)
Age	0.008	0.023	−0.173	−0.186
	(0.010)	(0.024)	(0.186)	(0.231)
Farming experience	0.001	−0.035	0.202	0.096
	(0.010)	(0.025)	(0.188)	(0.249)
Marital status	0.566[b]	0.202	−0.763	−3.408
	(0.274)	(0.601)	(4.589)	(5.835)
Sex	0.199	−0.642	−4.862	4.133
	(0.222)	(0.564)	(4.876)	(6.204)
Education	0.130	0.454	5.303	1.275
	(0.185)	(0.452)	(3.643)	(4.456)
Nativity	−0.389	−1.149	−8.107	−12.116
	(0.321)	(0.895)	(7.746)	(8.973)
Access to extension service	0.012	1.249[a]	−7.081[b]	−4.458
	(0.158)	(0.429)	(3.289)	(4.350)
Land ownership	−0.023	0.804	4.265	6.652
	(0.187)	(0.505)	(3.543)	(5.112)
Farm size	0.125[a]	−0.688[a]	1.273	3.408[a]
	(0.041)	(0.097)	(0.845)	(1.024)
Credit access	−0.335[b]	1.131[a]	−2.926	−12.928[a]
	(0.160)	(0.437)	(3.287)	(4.149)
Asset Aspiration gap	0.202	0.416	0.851	3.195
	(0.378)	(1.000)	(8.329)	(9.898)
Remittance	0.167	0.947[b]	9.002[b]	13.167[a]
	(0.170)	(0.464)	(3.519)	(4.569)
Migrant	0.288[c]	0.798[c]	1.154	−2.918
	(0.159)	(0.410)	(3.169)	(4.142)
Participate in SI and DII	0.003	−0.517	0.206	−0.584
	(0.171)	(0.463)	(3.925)	(4.801)
Constant	7.836[a]	10.959[a]	50.124[a]	56.716[a]
	(0.707)	(1.742)	(13.768)	(16.434)
Observations	820	819	820	820
R-squared	0.047	0.102	0.035	0.047

[a] $p < 0.01$.
[b] $p < 0.05$, and.
[c] $p < 0.1$.

Table 4
Weighting and doubly robust estimates of CSI.

	CSI	
	IPW	IPWRA
WUA (1 = Yes)	−1.004[a]	−1.004[a]
	(0.530)	(0.530)
Chi square (χ^2)	15.682	15.682
p-value	0.404	0.404
Other controls	Yes	Yes
Observation	812	812

Notes: Robust standard errors are in parentheses. Additional controls are specified in Table 1.
[a] $p < 0.1$.

Table 5
Weighting and doubly robust estimates of HDDS, Vegetable and Fruit, and Protein.

	HDDS		Vegetable and Fruit		Protein	
	IPW	IPWRA	IPW	IPWRA	IPW	IPWRA
WUA (1 = Yes)	0.710[a]	0.710[a]	8.103[b]	8.103[b]	11.457[b]	11.457[b]
	(0.212)	(0.212)	(3.931)	(3.931)	(4.604)	(4.604)
Chi square (χ^2)	16.019	16.019	16.019	16.019	16.019	16.019
p-value	0.381	0.381	0.381	0.381	0.381	0.381
Other controls	Yes	Yes	Yes	Yes	Yes	Yes
Observation	813	813	813	813	813	813

Notes: Robust standard errors are in parentheses. Additional controls are specified in Table 1.
[a] $p < 0.01$, and.
[b] $p < 0.05$.

0.71 increase in HDDS, GHS8.10 (US$0.66) increase in fruit and vegetables consumption, and GHS11.46 (US$0.94) increase in consumption of protein rich food. The result is consistent across both IPW and IPWRA estimates indicating the robustness of our findings. The positive association may be due to WUA members' access to irrigation, water management resources and enhanced social capital which could lead to increased agricultural diversification and productivity. Aligning with study findings, Guyalo and Ifa [33] showed that agricultural cooperatives have a statistically significant positive impact on the food security status of households. A study by Christian et al. [34] also indicated that most (93 %) members reported that agricultural cooperatives contributed positively to their livelihoods. Additionally, the result is consistent with Owusu-Sekyere et al. [26] findings that participation in the IMT scheme can enhance rice yields by 39.56 % and net farm returns by 24.52 % in Ghana, which translates into increasing dietary outcomes. Ma et al [57] found that agri-value participation improves vegetable farmers' welfare. They further indicated that participation in the agri-value chain significantly increases household income and consumption expenditure by about 22 % and 40 %, respectively. Zeweld et al. [65] found that cooperative participation positively affects household food security.

5.2. Stochastic dominance results

The stochastic dominance analysis (SDA) is limited to matched farm households based on their propensity score of participation, whose distribution and region of common support ranges from 0.0195 to 0.9997 (Fig. 4). We also dropped households outside the region of common support. The good overlap between the density distribution of propensity scores for WUA members and non-members validates the use of PSM and the basis for comparison using the SDA. The cumulative distribution functions (CDFs) for HDDS, CSI, consumption of fruit and vegetables, and proteins for WUA members and non-members are shown in Fig. 5. The results suggest that HDDS, CSI, consumption of fruit and vegetables, and protein-rich foods of WUA members stochastically dominate those of non-WUA members. We found that HDDS and CSI of WUA members stochastically dominate those of non-members at HDDS below 12 and a CSI below 23, respectively. Additionally, the result indicates that the consumption of fruit and vegetables, and protein-rich foods of WUA members stochastically dominate those of non-members at scores below GHS100 (US$8.18) and GHS113 (US$9.24). Nevertheless, the consumption of fruit and vegetables, and protein-rich foods score of above GHS100 (US$8.18) and GHS200 (US$16.25) indicates the CDFs of WUA members and non-members are almost the same. The nonparametric Kolmogorov–Smirnov test for first-order stochastic dominance further illustrates that the CDFs of WUA members stochastically dominate those of non-members for HDDS, CSI fruit and vegetables, and proteins at a 1 % level of significance. Based on the findings, we conclude that conditional on observed characteristics, there is a

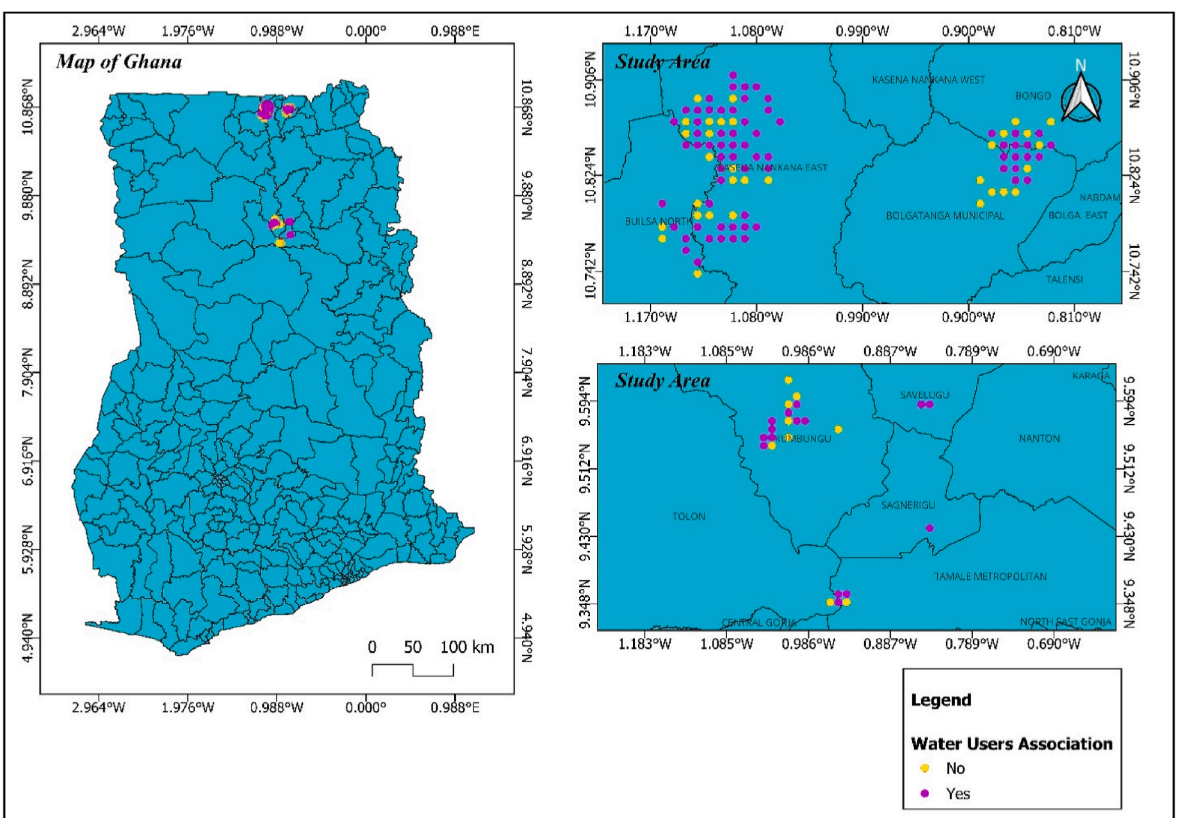


Fig. 1. Administrative map of the study area.

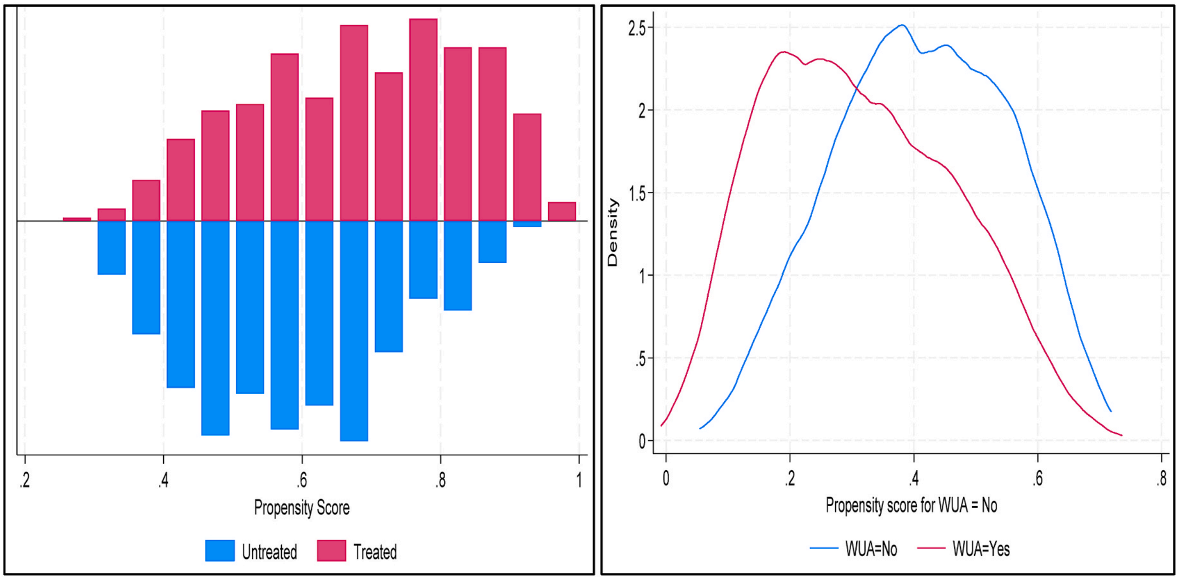


Fig. 2. Propensity score density distribution and common support region for WUA membership.

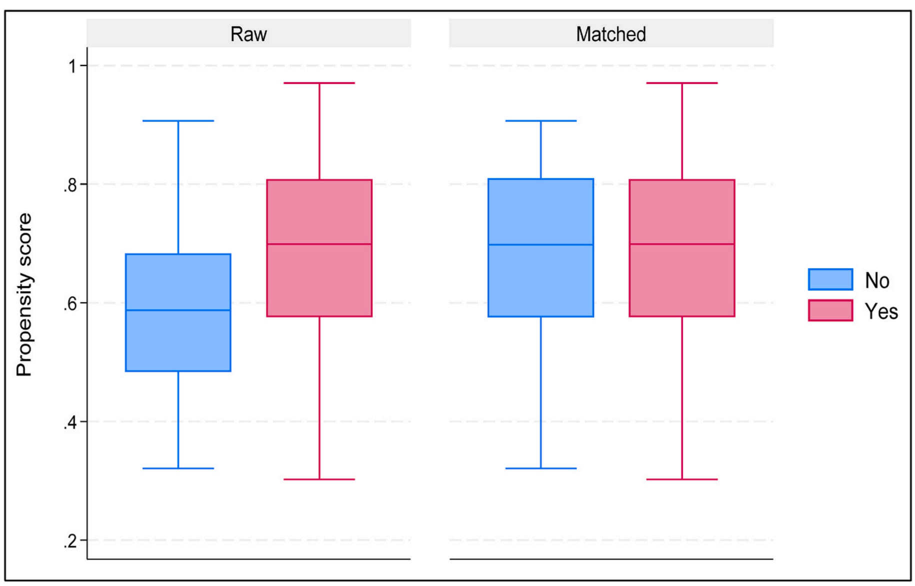


Fig. 3. Propensity score of balancing box plot for WUA membership.

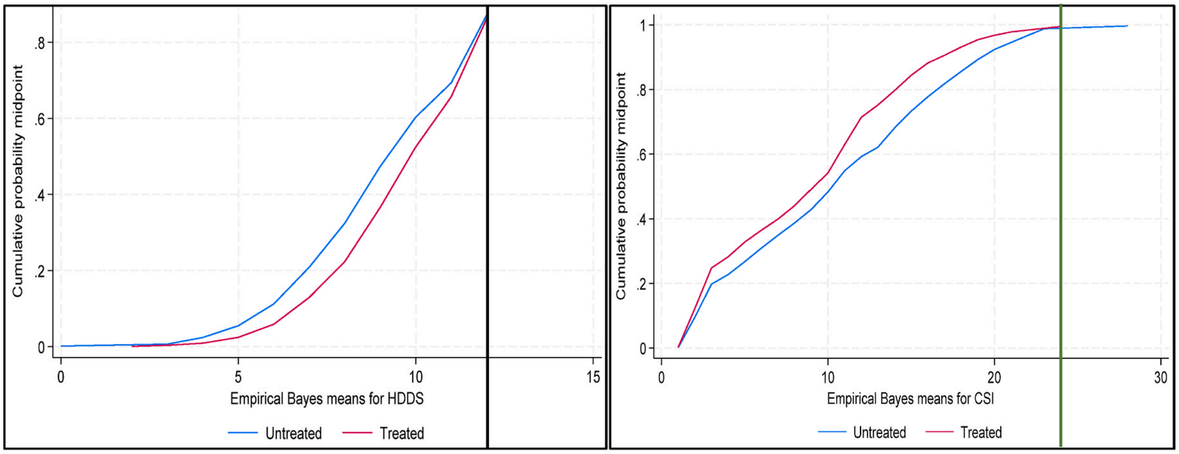
higher probability that WUA members, on average, will have higher food and nutrition security than non-members.

6. Conclusion and policy implications

Most studies in developed and developing countries have focused on social capital as institutional instrument for supporting smallholder farmers and contributing to poverty alleviation and food security. However, the relationship between WUA membership and food security is less explored, thus creating a knowledge gap. Considering that cooperative association are formed by interactions in group, this paper makes an empirical contribution in addressing the paucity of information regarding the role of WUA membership and food security of households using a cross-sectional data obtained from 820 rice farm households in northern Ghana. We employed different estimation strategies including OLS and weighting and doubly robust estimators to establish the relationship between WUA membership and food security.

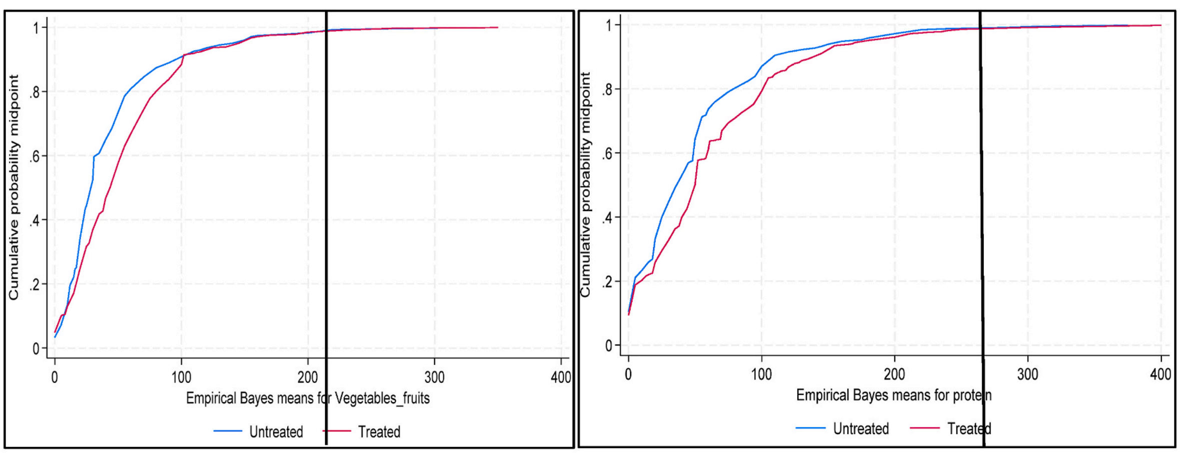
The results indicate that participation in the WUA is significantly influenced by factors such as age, marital status, access to extension services, participation in SI and DII, farm size, and the asset aspiration gap. This suggests that when establishing sustainable WUAs in northern Ghana, these factors should be carefully considered in the selection process to encourage higher participation rates. Starting with basic descriptive statistics and mean comparisons and progressing to estimators that account for several confounding factors, our results reveal a positive association between WUA membership and food security. The finding is robust across model that controls for observables and several endogeneity-corrected models.

The study's main findings suggest three key policy implications. First, given the positive association between WUA membership and food security, irrigation scheme managers, development partners, government agencies, and policymakers should actively encourage smallholder farmer involvement in WUA schemes. These cooperatives can increase members' agricultural productivity, income, welfare, and food security while improving service delivery at low costs by fostering synergy, economies of scale, and vital social networks for accessing technologies,



(a) Cumulative distribution for HDDS (b) Cumulative distribution for CSI

Fig. 4. CDF of HDDS (a) and CSI (b) for WUA and non-WUA membership.



(c) Consumption of vegetables and fruits (d) Consumption score of protein

Fig. 5. CDF of consumption vegetables and fruits (a) and protein (b) for WUA and non-WUA membership.

information, and inputs. Second, a policy to create equal employment opportunities across various sectors is essential. This aligns with Ghana's "Planting for Food and Jobs" initiative, which aims to generate employment through crop cultivation, export-driven production, greenhouse development, mechanization services, and livestock rearing. Sustaining this and the "One-Village-One-Dam" policy can support year-round agricultural production and drive progress toward SDG Goal 2, eradicating hunger. Finally, WUA participation can promote climate-resilient practices, such as water conservation and sustainable intensification. Policies supporting WUA training in climate-smart irrigation, soil management, and crop diversification would enhance farmers' adaptability to climate change which is an essential factor for long-term food security. We acknowledge two limitations of our analysis that may be important for future research. First, our findings are specific to rural contexts in developing countries and should be interpreted with caution when considering broader generalizations. Second, due to the cross-sectional nature of our dataset, our estimates should be viewed as correlations rather than indicative of causal relationships.

CRediT authorship contribution statement

Mustapha M. Suraj: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Formal analysis, Data curation, Conceptualization. **Edward Martey:** Writing – review & editing, Visualization, Validation, Supervision, Methodology, Formal analysis, Data curation, Conceptualization. **John K.M. Kuwornu:** Writing – review & editing, Visualization, Validation, Supervision, Methodology. **Emmanuel K. Apiors:** Visualization, Validation, Data curation, Conceptualization. **Francis H. Kemeze:** Visualization, Validation, Data curation, Conceptualization. **Prince M. Etwire:** Writing – review & editing, Visualization, Validation, Methodology, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix

Table A1
Balancing test

	Standardized differences		Variance ratio	
	Raw	Weighted	Raw	Weighted
Age of household head (years)	−0.134	0.043	0.942	1.019
Farming experience (years)	−0.084	0.041	0.920	0.992
Marital status (1 = married)	0.159	0.028	0.719	0.937
Sex of household head (1 = male)	−0.029	0.062	1.045	0.914
Formal education (1 = yes)	0.067	0.065	0.984	0.986
Native (1 = yes)	0.084	0.025	0.731	0.905
Access to extension services (1 = yes)	0.416	0.105	1.069	0.985
Ownership of land (1 = yes)	−0.054	0.044	0.931	1.065
Farm size (hectares)	0.318	0.020	1.388	0.750
Access to credit (1 = yes)	0.078	0.041	1.053	1.027
Asset aspirations gap (proportion)	−0.235	−0.056	1.545	1.206
Receive remittances (1 = yes)	−0.005	−0.060	0.995	0.960
Migrant household members (1 = yes)	0.200	0.093	0.995	0.989
Participate in SI and DII (1 = yes)	0.362	0.077	1.506	1.062

Data availability

Data will be made available on request.

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