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Determinants of food security status with reference to women farmers in rural Kenya

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ABSTRACT

Food insecurity exacerbates malnutrition with irreversible consequences for children. Thus, we address the determinants of food security status with reference to women farmers, the determinants of access to irrigation technology as a critical determinant of food security and the effect of cooperatives on nutritional status. We used primary data from Kakamega, Kenya. Descriptive data analysis was applied together with regression analysis using logistic, probit and linear endogenous treatment models. Cooperative membership facilitates female farmers' access to productive resources like credit, thereby contributing to improved food security status. Though most female farmers are not members of cooperatives, the female members of cooperatives perform slightly better as determinants of food security status and are more food secure than female non-members. The limitations of cooperatives include the low percentage of farmers using irrigation and farmers' low nutritional status. Extension services positively impact irrigation, thereby calling for gender equality amongst field officers to enable communication with female farmers and for the formation of cooperatives that target women's needs. Governments, development agencies and civil societies should support cooperatives in their financial, technical and management issues to create awareness concerning family planning and offer access to credit and irrigation technology, resulting in increased food production, improved food security and nutrition status.

Introduction

Maintaining an adequate level of food security remains a crucial challenge for most rural households in developing countries, particularly in sub-Saharan Africa [42]. The Food and Agriculture Organization [16] defines food security as follows: 'When all people at all times have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life'. Drought, conflicts, poverty, and rapid population growth are the main factors exacerbating food security problems in Kenya. Large parts of Kenya are arid and semi-arid, with erratic and unreliable annual rainfall amounting to less than 500 mm, thereby contributing to the frequency and severity of droughts ([17]; FSIN, 2017).

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Agricultural production in Kenya is largely rainfed, and climate change is resulting in shorter growing seasons, culminating in crop failures and episodes of drought-related hunger and severe malnutrition, particularly amongst mothers and children, along with rampant poverty levels (Huho and Mugalavai, 2010; [43]). Malnutrition is the consequence of limited dietary intake, caused by household food insecurity, a lack of safe drinking water, a lack of knowledge concerning the basics of sanitation, poor health exacerbated by a lack of access to health facilities and a lack of alternative income sources [30].

The consequences of climate change and droughts, including rainfall variability, water scarcity, soil degradation and food insecurity, require innovative strategies to address food insecurity and malnutrition [50]. Under these circumstances, irrigation is becoming an increasingly important tool for ensuring sufficient food supplies and better livelihoods for rural populations [53,71]. Securing water to bridge dry spells and improving soil management to increase nutrient availability and the water holding capacity of the soil profile are crucial actions. Irrigation systems should be demand-based systems, with irrigation water supplementing rainwater and soil water [68].

This paper focuses on rural women, who are mostly small-scale farmers and are generally the primary providers of food and water [3]. However, such women have a limited capacity for climate change adaptation, including the ability to apply sustainable irrigation due to laws and customs that limit their rights to access and control over productive resources, including natural, physical, human, economic, social and political capital [30,38]. This includes women having only limited control of and access to irrigation technologies, attributable to different gender roles assigned to men and women, which impacts their access to and control over productive resources and the division of labour as well as their interests, knowledge and needs [5,18].

Women in Africa usually do not have access to resources or to knowledge due to social-cultural institutions that constrain women's decision-making power and their access to productive resources and the adoption of certain agricultural technologies [9,51,52]. A case in point is land near the river, which facilitates access to water to irrigate the small plots. Men in the Upper East Region of Ghana, for example, obtain water to irrigate their plots near the river, whereas the women have not been granted plots near the river and lack the right to dig into the riverbed to access water. Another case is that of Tanzania, where men have adopted drip irrigation and motor pumps technologies while women have continued practicing labour-intensive manual irrigation methods, such as hauling water with buckets [6].

Women face constraints in accessing extension services, including inappropriate extension packages and a lack of flexibility regarding their options, with timetables that are not always conducive to their daily chores. Many extension services make projections orientated towards crops traditionally grown by men, and cultural factors prohibit women from receiving training in certain cases [38].

What factors then facilitate rural women's access to productive resources, enabling them to maximise the benefits of sustainable irrigation, resulting in increased food security, improved nutritional status and better rural livelihoods? The values governing the operation of cooperatives, including equality and equity, solidarity and social responsibility, economic participation, and concern for the community [64], place cooperatives in a unique position to ensure and promote gender equality, thereby enabling women farmers to access all the productive resources, including water resources, at the disposal of the cooperatives. Nonetheless, evidence points to the underrepresentation of women in cooperatives, thereby denying them opportunities for advancement.

Studies on cooperatives and food security have reported that cooperatives have positive and significant effects on food production through the facilitation of cooperative members' access to technology and farm input and output markets [29,39,59,72]. Properly managed cooperatives offer efficient and effective high-quality services to their members and contribute to broader developmental issues, including food security, the sustainable use of natural resources (land management techniques to halt soil degradation) and sustainable irrigation practices to facilitate farming during both drought and dry seasons.

Women's key role in the provision of food and water is affected by their lack of access to irrigation technologies, and yet such a crucial role requires their deep involvement in solutions to food security problems. However, few studies have focused on sustainable irrigation using cooperatives as a platform to grant women access to both the resources required for running sustainable irrigation and the resources that complement irrigation in establishing food security. This paper fills the gap by addressing the food security status of women farmers and investigating the factors affecting food security, with sustainable irrigation as a key determinant of one potential pathway to overcoming drought challenges through a platform of cooperatives that enables women farmers to access productive resources. Based on this understanding, our central research question is as follows: What are the determinants of food security status with reference to female cooperative members versus non-members?

As its main contribution, this paper addresses the determinants of food security status with reference to women farmers and particular emphasis on inclusive sustainable irrigation as a potential channel for increasing agricultural production during drought and rainy seasons in Kenya. Women are more likely than men to be affected by severe food insecurity (FAO, 2017), thus it is crucial to help women farmers become more resilient to the effects of climate change by highlighting certain critical factors, including inclusive irrigation. Furthermore, we highlight family planning as a complement to more inclusive irrigation; otherwise, population growth defeats any efforts at establishing food security. The following sections provide a literature review, address the materials and methods, identify the key results and discuss them, and finally, offer some conclusions.

Table 1
Kenya population forecast. Source: UN Population Division (2017).

Year	Population (millions)	Yearly% change	Fertility rate	Density per Km^2
2020	53,491,697	2.52	3.77	94
2050	95,467,137	1.54	2.61	168

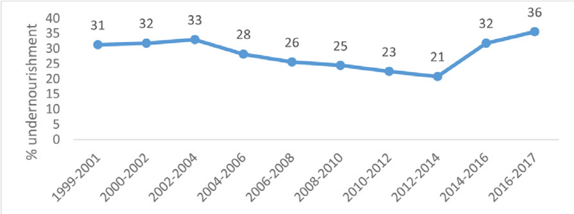

Fig. 1. Percent of undernourished people in Kenya 1999–2017. Data source: FAOSTAT.

Literature review on the link between irrigation and women farmers

The various dimensions of food security determine food security status. Therefore, the literature review section discusses population growth as one factor affecting food availability, while malnutrition is discussed as an outcome of a lack of food availability, accessibility, stability, and utilisation. Given that Kenya mostly suffers from droughts, sustainable irrigation is crucial to boosting food production, resulting in improved food availability and increased incomes that enable both food accessibility and stability, leading to better food utilisation and reduced malnutrition rates. While cooperatives have no direct impact on food security status, they indirectly increase food security through the services offered to their members.

Dimensions of food security

Food security is composed of four dimensions. The first dimension is food availability, which is determined by food production and food distribution [18,23,27]. Second, food access refers to the affordability and allocation of food; hunger and malnutrition are generally not caused so much by food scarcity as inability to access available food, usually due to poverty [22,69], low education levels and the gender of the head of household [11]. Third, food utilisation depends on food safety, access to healthcare [18,31,66], improved sanitation and water facilities, and nutrition education [30]. The fourth and final dimension is food stability, the ability to obtain food over time [11], which may be interrupted by drought, resulting in crop failure and decreased food availability [18,47].

Population growth and malnutrition

Kenya's population growth and density (Table 1) affect agricultural output in two keyways. First, they result in increased food demand, which places pressure on the food supply. This in turn leads to increases in food prices and input prices, thereby contributing to declining food production, which exacerbates food insecurity. Second, increasing food demand leads to decreases in the size of land parcels in areas with strong agricultural potential. Creating more land for cultivation through the clearance of grasslands and forests of native vegetation contributes to soil degradation and poor-quality soils, which leads to crop failures and food shortages.

Table 1 shows the alarming population forecast for Kenya, with the population nearly doubling between 2020 and 2050 if not controlled.

The prevalence of undernourishment points to low food security status [32]. The percentages of undernourished people in Kenya declined steadily until 2012, after which the rates rose dramatically (Fig. 1). This turn of events is largely due to temperature anomalies during the years 2011–2016 in the agricultural cropping area, which affected agricultural production, leading to shortages in food availability and exacerbating food prices and income losses, thereby reducing food access [13].

Sub-Saharan Africa (SSA) has one of the highest child malnutrition levels globally, and poor nutrition accounts for a large percentage of the high mortality rates amongst children under five years of age. One in six children is underweight in developing countries, and one in three children suffer from stunted growth [4]. Children attending primary often attend classes hungry in Africa [67]. In Kenya, child malnutrition rates remain high despite the government's commitment to reducing malnutrition [10,33]. Fig. 2 shows child anthropometric measures in Kenya during for the 1993–2014, indicating that nutritional status is improving. However, the number of stunted children remains high.

Studies by Victora et al. [70] and Kudzai [36] have demonstrated that malnutrition both impedes short-term child development and negatively impacts their cognitive abilities and productivity during adulthood, with substantial economic costs. In addition to the direct impact of malnutrition on cognitive function, an indirect effect also exists in the form of delayed entry into school because poorly nourished children are more likely to be retarded in motor and cognitive development. Malnourished children tend to have higher morbidity rates, contributing to high school absenteeism and dropout

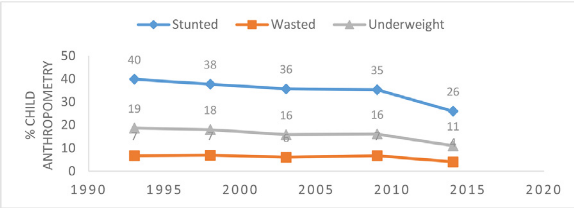

Fig. 2. Percent child anthropometry in Kenya 1993- 2014. Data source: Demographic Health Surveys.

rates. The irreversible consequences of childhood malnutrition include adults who are for the most part less physically and intellectually productive, have lower education attainment and are more vulnerable to chronic illness and disability ([30], 2019).

Sustainable irrigation

Sustainable irrigation calls for proper water management to avoid water wastage and ruining the crop plants. Underwatering or overwatering leads to soil problems, root and turf diseases, nutritional deficiencies and reduced plant yields. Irrigation water demand is determined by crop type, soil type, soil infiltration rate and irrigation method [56,60]. Women farmers can play a key role in the success of sustainable irrigation because they have substantial knowledge about water resources acquired from their important role in water management, including collecting water, using water and managing water for domestic purposes and for irrigating garden crops [12].

Rainwater harvesting irrigation systems

The United Nations classifies Kenya as a water-scarce country based on the fact it has less than 1000 m^3 per capita of renewable freshwater supplies [40,44]. Ironically, agricultural production in Kenya is largely rainfed, with climate change and droughts now exacerbating both water scarcity and food security problems in Kenya. Given that surface water is scarce and groundwater exploitation is not economically feasible, sustainable rainwater catchment systems are one of the most viable options for combating water scarcity [45]. Geographic location and available resources mostly determine the method utilised for rainwater harvesting, including reservoirs, tanks, drums, farm ponds, water pans and underground wells and dams. Mompati et al. [41], focusing on in South Africa, and Kimani et al. [35], focusing on Kenya, have reported that most of the users of rainwater harvesting irrigation systems are women; however, rainwater harvesting techniques are labour intensive, thus being burdensome to women farmers given that they are constrained by the need to perform household labour.

A drip irrigation system using rainwater harvested from rooftops is generally one of the most efficient and accessible systems for credit-constrained farmers. However, despite the efficacy of rainwater harvesting irrigation (RWHI), its success is constrained by a lack of technical standards, a lack of investment in water resources, only sporadic efforts at implementing RWHI systems and a lack of specific RWHI policies (Trincheria et al., [65]). Dawit et al. [8] found that in Ethiopia, the application of drip irrigation combined with hand-dug well water reduces labour-intensive manual irrigation, mostly practiced by women, thereby reducing women's farm workloads and enabling them to expand their plot sizes as well as increase a variety of crops grown year-round, resulting in higher crop productivity.

Crucial preconditions for designing and managing rainwater harvesting include the technical capacity of farmers and their service providers and access to professionals. Farmers need to receive relevant information on micro-irrigation practices, such as how to manage soil water needs and rainfall in a timely manner. The potential for rainwater runoff collection, crop water demand forecasts, required storage capacities and the most appropriate methods for harvesting rainwater are also factors requiring more information. Extension officers must be equipped to provide adequate rainwater harvesting services for small-scale farmers [14]. Fulfilling the preconditions for the design and management of rainwater harvesting and adoption of irrigation technologies is tied to land ownership, which is disadvantageous to women farmers given that they have poor access to land ownership and other productive resources [48].

Effects of access to irrigation on women's empowerment and food security

Water, food security, nutrition, health, and women's empowerment are all closely interlinked. A conducive environment that facilitates women farmers' adoption of irrigation water technologies would increase their chances of have reliable access to water, subsequently leading to several positive outcomes, including intensified cultivation. This in turn would lead to increased productivity throughout the year and greater availability and stability of food supplies during the dry season, enabling crop diversification in micronutrient-rich vegetables and fruits and thereby enhancing the nutrition status of crops [37]. The availability of irrigation water mitigates drought, resulting in improved the crop yields and crop quality and potentially promoting food security.

Extended growing seasons owing to the availability of irrigated water would contribute to higher crop yields and higher crop value, helping women generate more income. Securing access to a water supply benefits more than just crops (sanita-

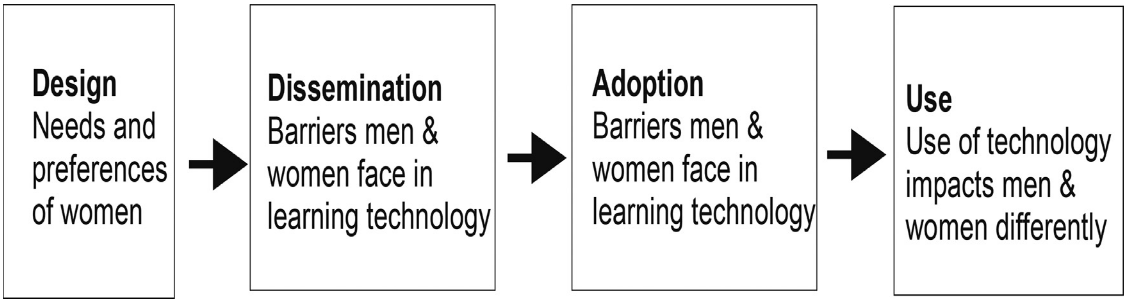

Fig. 3. Irrigation technology uptake processes. Source: Theis et al. (2018) .

tion, hygiene, livestock). Irrigation water improves family health and reduces the burden placed on women to care for the sick and engage in collecting water; hence, it leaves women with more time to engage in income-generating activities [54].

Inclusive irrigation technology that benefits women in crop production activities

The process of creating inclusive irrigation technology that benefits women must account for gender and social issues at four critical stages by considering the following factors, as indicated in Fig. 3.

The first stage involves designing irrigation technologies that can be installed near the homestead to support women's water collection role in a way that serves multiple purposes, including domestic use, livestock watering and irrigation. Issues concerning irrigation technology, such as labour requirements, the social acceptability of its use and upfront and operational costs, should be considered from the viewpoint of women [37].

The second stage has to do with effectively disseminating information concerning new technologies in a way that can reach women through such networks as farmer groups, women community leaders and community health workers. The third stage involves taking into consideration gender differences when adopting, for example, new irrigation technologies. A majority of small-scale farmers, particularly women, have not complemented unpredictable rainwater with new irrigation technologies due to constraints in accessing credit, appropriate technologies and farm input and output markets to invest in irrigation equipment [46,63].

The final stage involves noting that the use of irrigation technology impacts men and women differently in terms of workload, the power to decide where the technology is used, i.e., on whose plots of land, and control over the income generated from irrigated production. There is a need to secure women's land and water tenure to ensure that benefits are accessible after a new technology is adopted. Crops traditionally managed by women may potentially be appropriated by men when they become more profitable under irrigation [63]. The absence of a family workforce may not favour adopting certain sustainable irrigation decisions given the cost of hiring labourers to irrigate crops. None of the four stages is single-handedly responsible for women's exclusion from the adoption of new technology. Each contributes to creating small-scale irrigation work for women, starting from the design, dissemination, adoption, and use of the technology.

Role of the cooperatives

Women are less likely to access or benefit from irrigation interventions due to numerous constraints. By virtue of their principles, cooperatives can promote women's inclusion and participation by facilitating their access to productive resources and by training them in sustainable irrigation technologies. Cooperatives may offer a range of services, including adult education for illiterate women, essential information on family planning to counteract rising population numbers, nutrition education, empowering women in decision-making and offering extension services. Most rural cooperatives do not offer any of these services to their members because of unskilled management, a lack of capital, corrupt practices, and a lack of commitment of both members and management [29,39].

Conceptual framework for food security status with reference to women farmers

Fig. 4 presents a conceptual framework for food security status with reference to women farmers. It indicates that due to institutional constraints, women lack access to productive resources like irrigation technology, resulting in low crop yields and food insecurity. However, the cooperatives can help women gain access to such productive resources as irrigation technology, with the result being higher yields and greater food security.

Materials and methods

Description of study areas

Since the survey covers agricultural yields, it was conducted in October 2018 to coincide with the harvesting season (September and October) in the sub-counties of Navakholo (Esumeiya Ward) and Lurambi (Butsotso Central Ward), in

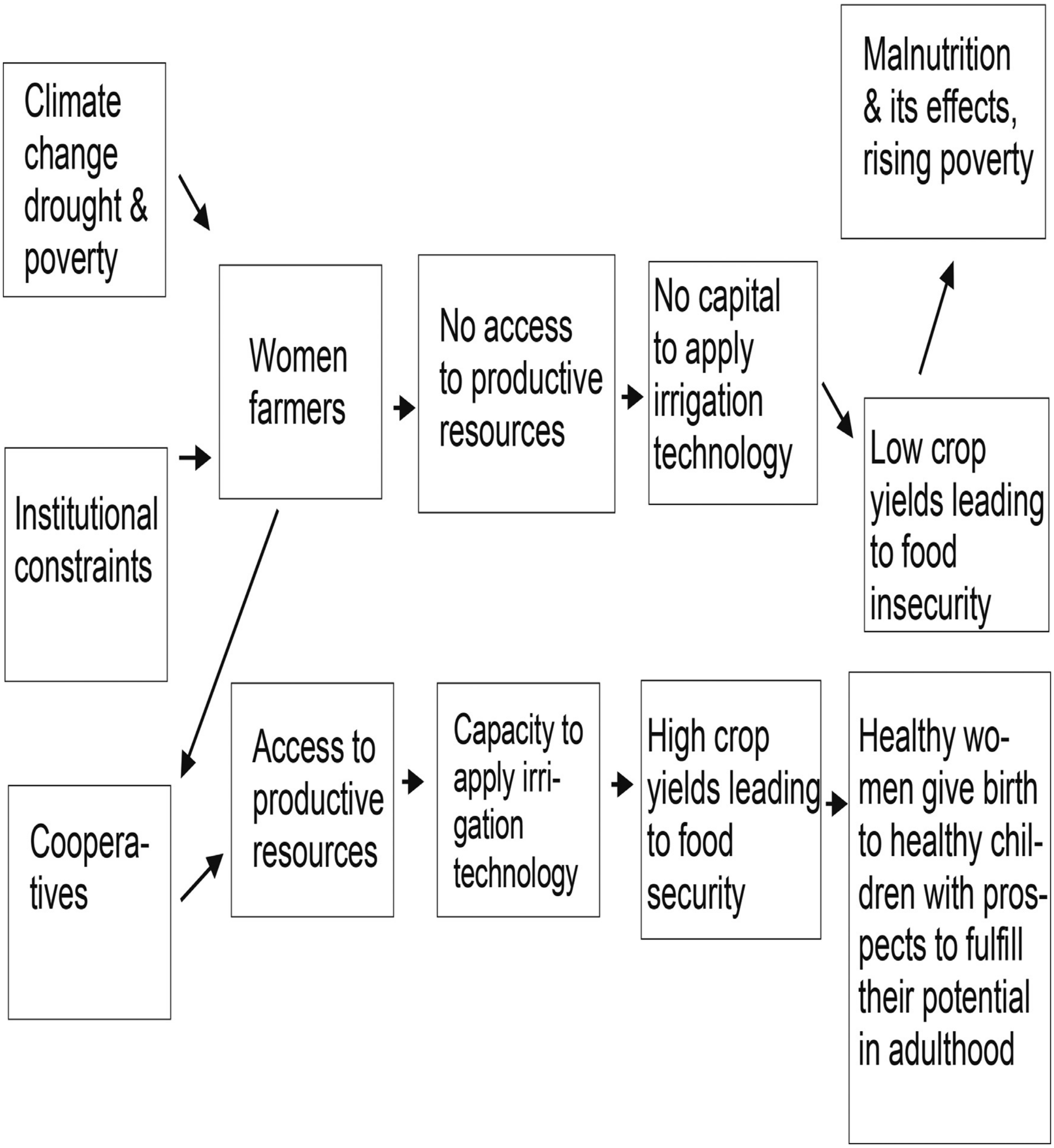

Fig. 4. Conceptual framework for food security status with reference to women farmers .

Kakamega County, Kenya. Both Lurambi and Navakholo belong to the upper-medium ecological zone. Butsotso Central lies between latitude 0º21'13" N and longitude 34º41'52" E, while the land area is 48.8 km^2 with a population of 25 744; Esumeiya lies between latitude 0º19'50" N and longitude 34º39'30" E, while the land area is 48.4 km^2 with a population of 25 352. Small-scale subsistence farming is the main livelihood, carried out on land parcels averaging 0.6 hectares in size; the crops include maize, beans, bananas, sugarcane, sweet potatoes, fruits and vegetables, and minimal livestock farming is also practiced, mainly with dairy cattle and poultry [62]. Numerous, mostly informal, farmer groups exist, with poor sustainability measures and no funds. Fig. 5 provides a map of the study area — Navakholo (Esumeyia) and Lurambi (Butsotso).

Sampling and data collection

Purposeful sampling was applied when selecting the study areas due to their geographical locations and accessibility. Butsotso Central is situated next to the municipality of Kakamega, presumably giving farmers easy access to input and output markets as well as extension services. On the other hand, Esumeiya is in the interior of the county, further away from both input and output markets. The study areas experience food insecurity because crops are grown only during the

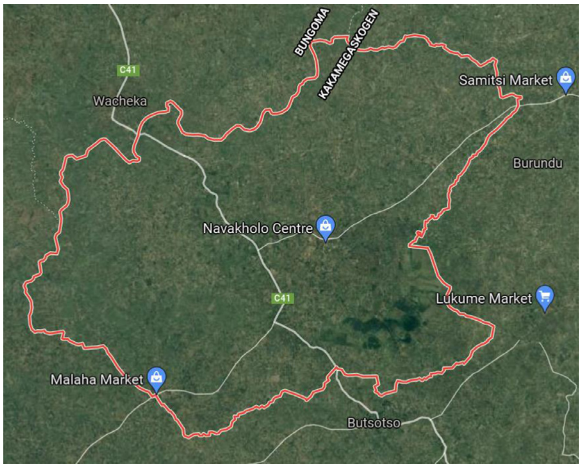

Fig. 5. The map of study area- Navakholo (Esumeyia) and Lurambi (Butsotso).

rainy season, with farmers lacking access to irrigation during the dry season. To the best of our knowledge, we are the first researchers to study both sites. The author who travelled to the survey areas speaks the local language of the regions, an advantage when interacting with the farmers.

Proportional sampling was used to randomly sample rural, small-scale women farmers who were members of cooperatives. The sampling was based on a list of all multipurpose cooperatives in both study areas and the number of women per group. A total of 347 smallholder farmers, 137 of whom were cooperative members and 210 of whom were not, were randomly selected and interviewed (female farmers were our target group, though male farmers responded to the questions in some households) using pre-tested structured questionnaires. In addition, leaders of the respective cooperatives were also interviewed. The total of smallholder farmers (347), and the respective numbers of those who were either members or non-members of the cooperatives in the areas under study, fits the general guidelines of including at least 30 observations. The data collection process focused on farm and household characteristics, production and marketing activities, health, nutritional status, and food security issues. The field survey was conducted with the help of trained research assistants.

Data analysis

Statistical tools employed during the study include descriptive statistics (Excel data analysis), dietary diversity measures and econometric analysis with the help of the STATA software package. Descriptive statistics summarise the socio-economic characteristics of households in the study area. Food security status is based on primary data collected using a household dietary diversity score (HDDS) questionnaire focusing on 12 food groups (cereals, roots and tubers, vegetables, fruits, meat and poultry, eggs, fish and seafood, pulses/legumes/nuts, milk and milk products, oils/fats, sugar/honey, and miscellaneous). The HDDS tool counts the food groups that a household has consumed over the preceding 24 h [61], but we replaced the 24-hour period with per-week recall adapted to the respondents' circumstances.

The HDDS indicator reflects the economic ability of a household to access a variety of foods and the food security of a household [15,25]. A multi-country analysis by Ruel [55] implies that household-level dietary diversity is strongly associated with per capita consumption (a proxy for income) and energy availability. This suggests that HDDS is a useful indicator of household food security [19,55,58]. We therefore used HDDS to categorise respondents into food-secure and food-insecure groups.

Each food group (1–12) was assigned a value of either 1 or 0, depending on whether or not the food had been consumed within the past week. The HDDS variable is calculated for each household by totalling the food groups consumed. The average HDDS indicator is the sum of HDDS divided by the number of households. We followed Swindale and Bilinsky [61] in determining food-insecure households by calculating the average diversity amongst the 33% of households with the greatest diversity. Our findings indicate that food-insecure households consume less than four food groups per week.

Model

Logistic regression is used to estimate the factors affecting food security status based on several independent variables, including cooperative membership (1=member; 0=non-member) and household characteristics. To minimise any biases that may arise by simply comparing members and non-members, we used Fisher's exact test and the Mann-Whitney U test to account for any statistically significant differences between the two groups. The probit model is applied in econometric regressions to the determinants of access to irrigation with respect to boosting food security status.

The logistic regression model provides a framework for detecting the likelihood of a household being food secure or insecure and examines the factors influencing the odds ratio for household food status. The odds ratio is the ratio of the probability that a household has sufficient daily rations for its members to be food secure (P_i) in relation to the probability of a household not having enough daily rations, i.e., being food insecure (1- P_i). The logistic model of the relationship between the household food security status variable (FSS) and its explanatory variables is specified as follows:

$$In\ [\ P_i/(1-P_i)\ ] = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_6 d_i \tag{1}$$

where i denotes the i th observation in the sample, P is the outcome probability, β_0 is the intercept term and $\beta_{1,}\ \beta_2 \ldots \ldots \beta_6$ are coefficients associated with each explanatory variable $X_{1,}\ X_2 \ldots \ldots X_6$. The estimated coefficients do not directly indicate the effect of change in the corresponding explanatory variables on the probability (P) of the outcome occurring. Rather, the coefficients reflect the effect of individual explanatory variables on the odds ratio of the dependant variable (household food security status).

P = dependant variable – food security status
X_1 = Information on family planning
X_2 = Farming is profitable
X_3 = Farm size in hectares
X_4 = Improved water source
X_5 = Female member of cooperative
X_6 = Market information
d_i = Butsotso Central $d = 1$ Esumeiya $d = 0$

When estimating the treatment effects, selection bias arises due to the treated group (cooperative members) differing from the non-treated group (non-members) for reasons other than treatment status. We used linear regression with an endogenous treatment model [73], which allowed for a specific correlation structure between the unobserved reasons affecting the treated group (cooperative members) and the unobserved reasons affecting the potential outcome (food security status). The estimation was performed using a maximum likelihood estimator.

The endogenous treatment regression model consists of an equation for outcome y_j and an equation for endogenous treatment $t_{j,}$

$$y_j = X_j\beta + \delta t_j + \epsilon_j\ t_j = \begin{pmatrix} 1, & \text{if } w_j\ \gamma\ +\ u_j\ >\ 0 \\ 0, & otherwise \end{pmatrix}, \tag{2}$$

where x_j are covariates used to model the outcome, w_j are the covariates used to model the treatment assignment and the error terms ϵ_j and u_j are a bivariate normal with a mean of zero and a covariance matrix of

$$\begin{bmatrix} \sigma^2 & \rho^\sigma \\ \rho^\sigma & 1 \end{bmatrix} \tag{3}$$

The covariates x_j and w_j are unrelated to the error terms, suggesting they are exogenous.

Descriptive statistics

Table 2 defines the variables and presents the summary statistics.

Results and discussion

We begin by presenting comparisons between cooperative members and non-members.

Descriptive statistics of cooperative members vs. non-members

Table 3 compares the determinants and indicators of food security status amongst cooperative members and non-members. Our null hypothesis was that the determinants and indicators of food security status would be the same for both the cooperative member and non-member categories. We used Fisher's exact test to test whether the differences were statistically significant. Differences between the two groups were statistically significant at $p< 0.05$ level for certain variables, including improved access to water source, housing quality, weekly milk intake, percentage of female farmers, years of education and family planning information. We rejected the null hypothesis at a significance level of 0.05 (independent samples, Mann-Whitney U Test).

Fig. 6 compares the percentages of members and non-members based on child nutrition information and shows that only 23% of non-members are aware of the benefits of exclusive breastfeeding compared to 51% of cooperative members.

Table 4 compares diversified food intake and the number of food intakes per week amongst children and youths from cooperative member and non-member households. Our null hypothesis was that the distribution of food security would be the same across the different categories for cooperative members and non-members. We used the Fisher's exact test to account for any for statistically significant differences. We rejected the null hypothesis at a significance level of 0.05 (independent samples, Mann-Whitney U Test).

Table 2
Variable definition and summary statistics.

Variable	Definition	Mean	Std. Dev
Food security status	1–4, food insecure if < 4 food groups consumed per week	149	0.93
Female cooperative member	1 if farmer participates in farmer group, 0 otherwise	0.31	0.46
Respondent gender	1 if female, 0 otherwise	41.95	14.65
Farm size	Farm size in hectares	1.50	1.13
Irrigation	1 if farm is under irrigation, 0 otherwise	0.18	0.38
Farming profitability	1 if farming is profitable, 0 otherwise	0.58	0.94
Food safety storage	% of households with knowledge on food storage	34.35	23.71
Extension visit	1 if receives extension visit, 0 otherwise	0.41	0.49
Non-farm business	1 if does non-farm business, 0 otherwise	0.56	0.50
Solar panels	1 if has solar panels, 0 otherwise	0.38	0.48
Info on family planning	1 if has received info on family planning, 0 otherwise	0.42	0.34
Access to credit	1 if access to credit after joining cooperative, 0 otherwise	0.32	0.47
Weekly milk intake	Number of times of milk intake per week	3.38	2.92
Vegetables & fruit	Number of times of veg & fruit intake per week	3.08	2.10
Employ workers	1 if employs workers, 0 otherwise	0.42	0.49
Market information	1 if receives market info, 0 otherwise	0.45	0.75
Water source	1 if has access to improved water source	0.55	0.49
Kakamega Central	1 if from Kakamega Central, 0 otherwise	0.41	0.49
Navakholo	1 if from Navakholo, 0 otherwise	0.59	0.49

Note: a household with less than 4 food groups is considered food insecure (more information see section 3.3).

Table 3
Determinants & indicators of food security status amongst cooperative members and non-members.

	Cooperative members	Non-members	Pearson's Chi2 P value	Fishers's exact
Food security status	1.78	1.31	0.084	0.083
Food safety storage	38.75	31.20	0.084	0.085
Improved water source	0.65	0.49	0.003	0.004
Improved sanitation	0.70	0.56	0.104	0.132
Poor shelter	0.53	0.72	0.002	0.003
Weekly milk intake	4.29	2.71	0.000	0.000
Weekly vegetables & fruit intake	3.51	2.81	-	-
Female farmers	0.83	0.60	0.000	0.000
Farming is profitable	0.61	0.56	0.839	0.829
Average household size	4.98	5.07	0.652	0.646
Average respondent age	41.58	42.19	-	-
Years of education	7.54	7.48	0.057	0.054
Information family planning	0.50	0.37	0.001	0.001
Farm size in hectares	1.48	1.51	0.833	0.854
Irrigation technology	0.23	0.15	0.497	0.549

Note: Each subscript letter denotes a subset of cooperative member categories whose column proportions do not differ significantly from each other at the 0.05 level.

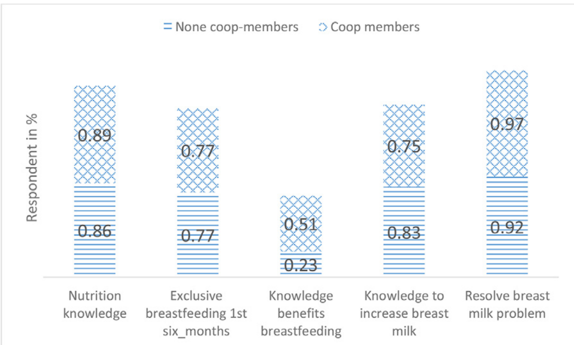

Fig. 6. Percentages of those with knowledge about child (0–6 months) nutrition.

Regression results

Table 5a presents logistic regression estimates of factors affecting food security status with reference to female cooperative members versus non-members. We found that households with information on family planning have 24 times the odds of experiencing increases in food security status compared to households without family planning information, and this difference was statistically significant at $p<0.01$.

Table 4
Diversified food intake by cooperative and non-members (%) & number of times consumed weekly (Children & youths 1–18 yrs.).

Types of food intake weekly			**No. Of times of food intake weekly**			
variable	%non-members	%Cooperative members	Non-members	Cooperative members	Pearson's Chi2 P value	Fishers's exact
Roots tubers	0.11	0.19	1.00	0.80	0.160	0.100
Legume & nuts	0.19	0.13	1.14	1.00	0.101	0.065
Infant milk	0.19	0.16	2.20	2.14	0.068	0.027
Meat cuts	0.19	0.10	1.43	1.17	0.343	0.344
Grains	0.21	0.33	1.67	1.27	0.080	0.050
Fish	0.30	0.13	1.30	0.71	0.461	0.456
Eggs	0.41	0.35	1.17	1.18	0.136	0.114
Local vegetables	0.85	0.77	1.64	1.89	0.086	0.072
Ripe fruits	0.89	0.74	1.75	1.96	0.066	0.056
Milk products	0.89	0.91	1.71	1.72	0.095	0.068

Note: Each subscript letter denotes a subset of cooperative member categories whose column proportions do not differ significantly from each other at the 0.05 level.
The null hypothesis is that the distribution of food security is the same across categories of cooperative members and non-members. The null hypothesis is rejected at the significance level of 0.05.

Table 5
a. Logistic regression of factors affecting food security status in the context of female cooperative members.

Variable	Odds ratio	Z Value	pvalue
Constant	0.164	−2.18**	0.029
Info on family planning	24.276	4.32***	0.000
Farming profitability	10.588	4.24***	0.000
Farm size in hectares	1.588	2.05**	0.041
Improved water source	10.343	3.84***	0.000
Female cooperative member	1.900	1.01*	0.312
Market information	4.886	1.98**	0.048
Average household size	1.247	1.89**	0.059
Respondent age	0.978	−1.43*	0.153
Butsotso Central (Fixed Eff.)	0.764	−0.54	0.593
Pseudo R2	0.54		
Number of observations 347			
b. Linear regression endogenous treatment with food security as the outcome & female cooperative member as the treated group			
Variable	Maximum likelihood Coefficients	Z Value	p Value
Food security (outcome) Constant	0.224	3.79***	0.000
Info on family planning	0.387	7.86***	0.000
Farming profitability	0.032	1.94**	0.052
Improved water source	0.137	4.21***	0.026
Female cooperative member	0.201	4.48***	0.000
Market information	0.098	4.76***	0.000
Average household size	0.006	0.77	0.441
Respondent age	−0.001	−0.14	0.889
Butsotso Central	−0.094	−2.91**	0.004
Female cooperative member(treated)			
Constant	−1.653	−8.37***	0.000
Farm size in hectares	−0.094	−1.21*	0.225
Access to credit	2.295	12.07***	0.000
Improved water source	0.237	1.27*	0.205
Butsotso Central (Fixed eff.)	0.518	2.80***	0.005
Athrho	−0.424	−3.56	0.000
Insigma	−1.261	−31.83	0.000
Rho	−0.400		
Sigma	0.283		
Lambda	−0.113		
Number of observations	347		
Wald test of indep. eqns. (rho=0): chi2(1) = 12.69 Prob > chi2=0.0004			

Note: *, **, *** represent significance at the 10%, 5%, and 1% levels respectively.
Note: *, **, *** represent significance at the 10%, 5%, and 1% levels respectively. Food security is the dependant variable.

The estimate for farming profitability is a proxy for (1) food availability because farmers are encouraged to farm when profitable and for (2) income level because farmers' incomes increase with higher food production. The 'improved water source' estimate is a proxy for irrigation technology. Access to an improved water source enables year-round crop production, leading to higher crop productivity, higher incomes, greater food security and lower undernourishment levels. Households with access to improved water sources have ten times better food security than households without access to an improved water source. Sustainable irrigation can therefore be considered a critical factor for increasing agricultural production.

Table 6
Determinants of access to irrigation technology.

Variable	Probit		Marginal effects	
	Coefficients	Std. error	Coefficients	Std. error
Constant	−2.11***	0.285		
Employ workers	0.658***	0.209	0.143***	0.048
Solar panels	0.489**	0.205	0.105**	0.046
Extension visit	0.482**	0.212	0.102**	0.046
Non-farm business	0.481**	0.229	0.094**	0.042
Respondent gender	−0.568**	0.245	−0.116**	0.049
Improved water source	0.450**	0.213	0.089**	0.042
Female cooperative member	0.360*	0.244	0.079*	0.056
Butsotso Central	0.068	0.199	0.139	0.041
PseudoR^2		0.24		
LR χ^2 (8)	72.66			
Number of observations	305			

Note: *, **, *** represent significance at the 10%, 5%, and 1% levels respectively.

Conventional treatment effects estimators require a conditional independence assumption, implying that unobserved variables do not affect the treatment assignment or outcome. However, as noted in section 3.4, selection bias may arise due to cooperative members being more likely or able to increase their food security status than non-members due to reasons (unobserved variables) other than treatment status. Selection bias may arise because food-secure households are more likely cooperative members than non-members, leading to reverse causality issues. The unobserved variables may affect both the treatment a person receives and the outcome, posing endogeneity problems that lead to inaccurate estimates. Endogenous treatment estimators address such cases. To eliminate the effects of selection bias, we therefore applied linear regression with endogenous treatment effects to estimate the average treatment effects (ATE), which constitute the mean difference between the treated (cooperative members) and control groups (non-members). Thus, Table 5b estimates the ATE for female cooperative members as a treated variable on food security (the outcome) with the help of a maximum likelihood estimator.

Table 5b indicates that the statistical significance of the estimates for female cooperative members and market information have increased, while information on family planning and improved water source have not changed as a result of maximum likelihood compared to the logistic regression estimator. On the other hand, the section on female cooperative members as the treated (selection) group suggests that the estimate for credit access confirms the theory that a lack of collateral constrains women from accessing credit facilities. Joining a cooperative facilitates access to credit through collateralised loans with peer-supported guarantees of group lending. Access to credit enables farmers to procure production inputs, such as farm equipment, fertiliser, and chemicals, along with payments for labour expenses. We found that households with credit access have 2.3 times the odds of increasing their food security status than households without credit access, and this difference is statistically significant at $p<0.01$.

The likelihood ratio test at the footer of Table 5b indicates that we can reject the null hypothesis regarding a lack of correlation between treatment assignment errors and outcome errors. The estimated correlation between treatment assignment errors and the outcome is −0.400 (rho). The negative relationship indicates that the unobserved variables that reduce food security tend to occur with unobserved variables that reduce female cooperative membership. Since we fit a linear regression model that does not include interactions with treatment variables and other covariates, the estimated ATE of being a cooperative member is simply the coefficient of a female cooperative member in the main equation, which is 0.201. The coefficient for Lambda (hazard) is statistically significant at a 5% significance level. This confirms the relevance of the maximum likelihood for assessing the impact of cooperatives on household food security status.

Table 6 presents estimates of the determinants of access to irrigation technology as a key determinant of food security.

Marginal effects are computed to allow for a better interpretation of the results [24]. The parameter estimates are jointly significant at 0.01%, as revealed by the chi-square test statistic, (LR χ^2 (8) = 72.66. We found that access to irrigation requires hiring laborers, as the predicted probability of accessing irrigation is 0.143 times higher for households that hire workers than for those that do not hire them, as revealed by the marginal effects in Table 6. The cost of hiring laborers may be a constraint to women farmers because they mostly have limited financial resources. Being a cooperative member resolves this problem, as members can join forces when irrigating their lands. Solar panels increase access to irrigation, particularly for remote farmers without access to electricity or fuel. The predicted probability of accessing irrigation is 0.105 times higher for farmers with solar panels than for those without solar panels.

The 'respondent gender' estimate shows a negative significant impact on accessing irrigation because women generally face barriers in accessing water and technologies and require their husbands' permission to invest in irrigation [46]. Furthermore, culture dictates the irrigation methods suitable for women. Table 6 shows that the 'extension visit' estimate is statistically significant and that extension services, including technical advice and training, raise awareness about the advantages of agricultural technologies, thereby boosting farmers' desire to access irrigation.

Discussion

This paper has explored the determinants of food security status with reference to female members of cooperatives compared to those who are not members. The results concur with the findings presented in other studies. Our descriptive analysis of the differences between whether or not women are members of a cooperative as a determinant of food security status point to statistically significant variables, including improved access to a water source, housing quality, weekly milk intake, percentage of female farmers, years of education and family planning information. These results are similar to those provided by Nkomoki et al. [49], who found that group membership increases the prospects of household food security. When women farmers are members of cooperatives, it facilitates their access to productive resources, such as credit [46,63] and labour [48], thereby enabling them to access irrigation technology.

The comparison of diversified food intake and the number of food intakes per week amongst children and youths from cooperative member and non-member households established that the consumption of legumes and nuts, infant milk, grains, local vegetables, ripe fruits and milk products is statistically significant. Children and youths from cooperative member households are more likely to have a larger number of diverse food intakes per week compared to their peers from non-member households. This contrasts with the findings of Fischer and Qaim [20], who posited no significant differences between the diversified dietary intakes of youths and children from cooperative member households and non-member households.

While the platforms provided by cooperatives boost the agricultural productivity of their members, leading to greater food security, the lack of female farmers who are members of cooperatives is a constraint on their performance. Olagunju et al. [28] have provided supported for the former observation by stating that members of agricultural cooperatives in rural Nigeria demonstrate higher levels of technical efficiency than do non-members. Consequently, they stress that policy incentives should offer financial and technical support to agricultural cooperatives. Abate et al. [1] agree that agricultural cooperatives enhance members' efficiency by facilitating access to productive inputs and extension services, resulting in increased agricultural productivity and food security. Cishe and Shisanya [7] in turn have found that although agricultural cooperatives are potential drivers of food security, employment, and income in rural households in South Africa, agricultural cooperative members are ill-equipped to manage the day-to-day functions of cooperatives, and therefore, are not capitalising on all the benefits that cooperatives have to offer, including low prices for farm inputs and high prices for farm outputs.

Irrigation technology is a critical determinant of food security. Ransford et al. [53] has noted the extent to which irrigation is a crucial tool for ensuring food security, thus this paper highlights the need for creating an enabling environment to facilitate women farmers' access to irrigation technology. Likewise, a previous study by Laia [37] reinforces our recommendations that women farmers' adoption of irrigation water technologies enables crop production even during dry seasons, leading to crop diversity and food security. In a broader geographical study, Fredriksson and Kumar [21] have reported a negative association between ancestral irrigation and female farmers' agricultural productivity in Africa and India. However, our findings show that sustainable irrigation clearly has a positive effect on food security. Dawit et al. [8] found that in Ethiopia, drip irrigation combined with dug well water is a laboursaving device, thereby giving women more time to be engaged in other productive activities.

Since water scarcity issues are interconnected with food insecurity, thereby exacerbating malnutrition status. Sera et al. [57] reviewed the evolution of scales to measure water and food security and recommend conducting joint interventions with respect to water management practices and food security, which would lead to increased access to water and result in improved food security status. Kehinde and Kehinde [34] endorse the fact that programmes aiming at food security interventions for rural households must acknowledge the important roles of cooperative membership and access to credit in improving food security status. We conclude that the cooperative membership of female farmers, better family planning and improved access to water resources will strengthen food security, as evidenced by the significant coefficients in our results. The indirect significant positive effects of cooperatives on food security have also been reported in studies, including Shumeta and D'Haese [59], Woldegebrial et al. [72], Mhembwe and Dube [39], and Ingutia and Sumelius [29]. The estimate that family planning will have a positive impact on food security status is in line with the findings presented by Hall et al. [26], who noted that projected population growth will be a leading cause of food insecurity and widespread undernourishment across Africa in 2050. Moreover, future scenarios, including the effects of climate change, still find population growth to be the dominant driver of change.

Conclusion

This study began by seeking an answer to the following question: What are the determinants of food security status with reference to female cooperative members versus non-members? Cooperatives indirectly determine food security status by facilitating women farmers' ability to access productive resources. Therefore, we examined the effect of cooperatives on nutritional status through the lens of diversified dietary intake. Given that irrigation technology is a crucial determinant of food security status, we investigated the determinants of access to irrigation technology. The work was performed using primary data from 347 smallholders from the wards of Esumeiya and Butsotso Central in Kakamega County, Kenya. We used logistic, probit and linear regression with endogenous treatment models.

After eliminating the effects of selection bias, we combined female membership in cooperatives, access to credit, improved water sources and farm size as means for women to improve their food security. The results show that irrigation technology and access to credit are crucial determinants of food security status. Other determinants of food security status include market information, farming profitability, information on family planning, average household size and respondent age. Table 6 shows that the significant determinants of access to irrigation technology included improved water sources, female cooperative membership, extension visits, solar panels, employ workers and non-farm businesses.

Despite the fact that only a small number of female farmers who are members of cooperatives, the results indicate that cooperative members perform slightly better with respect to the determinants of food security and are more food secure than non-members. Being a member of a farmer cooperative facilitates female farmers' access to vital resources, including credit, information on family planning, improved water sources, market information, extension visits and profitable farming, all of which contribute to the probability of improving their food security status. Although the percentage of farmers using irrigation technology is generally quite low, households with access to water are more likely to increase their food security. Access to credit and water are important determinants for women farmers joining cooperatives (cooperative membership positively affects water management) because women farmers generally face constraints in accessing credit and water for irrigation. Female cooperative member farmers are twice as likely to be food secure than female non-member farmers. We thus conclude that female cooperative membership significantly impacts food security.

These findings imply a need for the government, development agencies and civil societies to provide financial, technical, and managerial support to cooperatives, which would help them raise awareness about family planning and offer women farmers better access to credit and irrigation technology, resulting in increased food production, improved food security and nutrition status. The formation of farmer cooperatives is chiefly facilitated by male field officers, who tend to mostly communicate with male farmers. This calls for increases in the gender equality of field officers. Group formations should target the needs of women farmers, including the numerous constraints they face in accessing productive resources and the high opportunity costs required to increase the likelihood of more women participating in cooperatives.

The solutions offered here addresses the priority area in African Union's Agenda 2063 "Women and girls empowerment" relating to goal no 17 "Full Gender Equality in All Spheres of Life" and the aspiration no 6 "An Africa Whose Development is people driven, relying on the potential offered by African People, especially its Women and Youth, and caring for Children" [2].

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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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