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RESEARCH

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Determinants of smallholder membership in farmers' groups in the pigeon pea-based farming system in Uganda

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Abstract

Background Membership in farmers' group (FGs) is an important social aspect of agricultural development. Little is known about the relative importance and benefits from participation in FGs in Uganda, specifically for pigeon pea smallholders in northern Uganda.

Methods We conducted a cross-sectional survey with 257 smallholders to examine the factors that motivate farmer's group membership and its influence on pigeon pea yield and technical efficiency (TE) in northern Uganda. We applied the Stochastic Production Frontier (SPF) model and complementary models to assess membership impact on pigeon pea yield and TE determinants, respectively. TE is defined as the degree to which smallholders use the minimum feasible farm inputs to produce a given level of pigeon pea grain.

Results Results show that FG members were generally older and more experienced, and had better access to extension services (76%) and credit (43%) compared to non-members. Smallholders' age, access to agricultural training, extension services, and the distance travelled to market centres were statistically significant ($p < 0.05$), thus limiting the likelihood of FG membership. TE for both groups was low and quite similar, at 63% and 59% for members and non-members, respectively, implying that both groups did not use the available farm resources to maximize pigeon pea yield.

Conclusion Our results confirm that FG membership enhances smallholder's access to extension, agricultural training services and credit. For northern Uganda, the study provides recommendations for increased government investment in the human, financial and physical capacity of extension agents as a strategy for rural development and improved livelihoods. In addition, policy incentives can encourage farmers to seek membership in farmers' groups and related associations.

Keywords Smallholders, Farmers' groups, Pigeon pea, Efficiency, Uganda

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Introduction

It is widely acknowledged that smallholders' membership in collective action initiatives can contribute to better access to markets, supply and production inputs as well increased bargaining power (Wossen et al. 2017; Wouterse and Faye 2020). In Uganda, like many other sub-Saharan Africa (SSA) countries, collective action through Farmers' Groups (FGs) is often implemented and supported by both governmental and non-governmental organizations (NGOs) at different administrative levels

(Meier zu Selhausen 2016; Ekepu et al. 2017). Despite all collective action efforts, smallholders, especially in northern Uganda, continue to be challenged by poverty, low crop yields, decreasing soil fertility, low mechanization, high pest and disease pressure as well as increasing impacts of climate change (Vanlauwe et al. 2019). Relatedly, Uganda's population is increasing and projected to exceed 100 million by 2050 (Vollset et al. 2020), implying an increasing demand for food (World Bank 2016; Uganda Bureau of Statistics 2020).

Farmers' Groups are fundamental instruments for agricultural transformation in developing countries (Ingutia 2021). The motivation of smallholders to seek membership in FGs is, however, is determined by several socio-economic and institutional factors and the individual perception of their expected benefits against the costs (Bizikova et al. 2020). FG membership benefits can be manifold, from expected better access to (often subsidized) farm inputs, extension, credit, and price information, to socio-economic and political pressure and power (Abdul-Rahaman and Abdulai 2018; Francesconi and Wouterse 2021). Moreover, the impact of such groups is lacking to support policy for sustainable rural development (Bizikova et al. 2020).

Ainembabazi et al. (2017) illustrated that FG membership can be an important mechanism for improving farm productivity of smallholders in East Africa's Great Lakes Region through improved technical efficiency (TE) in input use. Further, Abdul-Rahaman and Abdulai (2018) identified collective action mediated by FGs in Ghana as an important strategy to increase TE and improve rice yields of smallholders. For smallholders in Zimbabwe, Mujeyi et al. (2020) reported an increase in social capital and information exchange as a result of participation in FGs. To the best of our knowledge, there is no empirical evidence on the impact of FGs on crop yield and TE for pigeon pea smallholders in northern Uganda. Pigeon pea (*Cajanus cajan* [L.] Millspaugh) is a semi-perennial, multi-purpose legume that provides plant-based protein, with up to 38% protein content (Nassary et al. 2020), fodder and firewood for smallholders in northern Uganda. It is particularly important for the poor smallholder households in the tropics and sub-tropics, including Asia and Africa (Fuller et al. 2019). Further, pigeon pea is an affordable organic alternative for soil fertility improvement (Nord et al. 2020), as it can reduce the amount of mineral fertilizers by up to 50% without compromising soil productivity (Chimonyo et al. 2019). This makes it an important legume towards supporting smallholder livelihoods and attaining sustainable intensification.

We examine the factors that influence smallholder's membership decisions and its influence on pigeon pea yield and TE in northern Uganda. We define TE as the degree to which smallholders use the minimum feasible farm inputs (such as land, seed, labour and pesticides), to produce the maximum pigeon pea yield. We use propensity score matching (PSM) to account for selection bias due to non-random decisions by smallholders' membership to FGs. Many studies have used methods that do not account for potential selection bias (Kwabena Nyarko et al. 2022). In addition, we also used pigeon pea as the case study crop as it has received limited funding for research and development (Duncan et al. 2018). Despite the prominent importance of FGs in agricultural technology adoption, not much research has been done to understand the factors that motivate or demotivate farmers to seek membership in such groups. This study denotes "farmers' groups" as formal or informal village-level groups organized around shared objectives with the purpose of supporting smallholders to pursue their collective and individual interests (Bizikova et al. 2020).

Socio-economic characteristics (such as gender, age, education level attained, family size), access-related/institutional factors (access to credit and market information) are highlighted as some of the motivations to group membership, and have received some attention in research. In Nigeria, Olagunju et al. (2021) found consistently higher technical efficiency for group members compared to non-members using a survey dataset of maize smallholder farmers. Ekepu et al. (2017) found that gender and access to extension significantly influenced participation in farmer associations in Uganda's Soroti District. Similarly, Mwaura (2014) reported that membership to FGs throughout Uganda had a positive impact on banana and cassava yields, but negative effects on sweet potatoes, beans and maize yield.

Farmers' groups in northern Uganda

Northern Uganda is a predominantly agrarian-based region (MAAIF 2010, 2017), with over 70% of the population directly dependent on subsistence agriculture (Uganda Bureau of Statistics 2020). After 20 years conflict (1986–2006) in northern Uganda (Manor 2007), multiple governmental and NGO development programs aimed to improve smallholder livelihoods and increase agricultural productivity in the region (Wallace 2016). The support of smallholders' collective efforts in the region was, and remains a central component in many of these programs (MAAIF 2010).

In 2001, the Ugandan government launched the National Agricultural Advisory Services (NAADS), as a semi-autonomous body under the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF), with an objective of promoting agriculture through farm input provision via FGs (Wallace 2016; MAAIF 2017). The expectation was that FGs formed 'bottom-up' at the village level would lead to the formation of farmer associations at higher administrative levels (Kampmann and Kirui 2021). The focus of FGs was on a few selected crop/livestock enterprises for which they had competitive advantage (Wallace 2016). For some FGs, collective bulking and marketing is common, especially for cereals, and also provide price and market information to members. NAADS to some extent supported FGs by providing advisory and technical services and farm inputs (AfranaaKwapong and Nkonya 2015). Smallholder's entry to FGs is non-random and some seek membership in more than one FG depending on their need (s) and funding availability.

The effectiveness of FGs in northern Uganda in the last 20 years has been dependent on the level of advisory services and the provision of farm-input from the NAADS (Uganda Bureau of Statistics 2020). The success of the NAADS was and is still contested (AfranaaKwapong and Nkonya 2015). Apart from the comparatively low numbers of extension agents, there were also challenges such as the lack of participation from smallholders and poor group governance (AfranaaKwapong and Nkonya 2015; Wallace 2016). NGOs, for example Africa 2000 Network (A2N), Plan International, Techno-Serve and ZOA-Uganda, also supported FGs (Ekepu et al. 2017). Most FGs focus on cash crops like cotton, sesame, sunflower, and maize. Legumes like pigeon pea were rarely selected as main crop enterprises, despite their great importance for smallholders' livelihoods. In northern Uganda, there exist 162 FGs in Lira District, and 72 each in Pader and Kitgum Districts, respectively, with group memberships ranging between 10 and 50 smallholders (https://ugandafarmers.guide). However, smallholders remain challenged with inadequate information worsened by low literacy rates, low access to productive inputs and low technological know-how, among others.

Conceptual framework

The conceptual framework that was used to describe what factors motivate (or demotivate) pigeon pea growing smallholders in northern Uganda to participate in FGs and thereafter specify the general Stochastic Production Frontier (SPF) model is shown in Fig. 1. The decision for FG membership is binary (Fig. 1). We include household's access, and plot-level variables for the estimation of the factors influencing membership decision. Smallholders' age, farming experience, and education as well as household family size (as a proxy for family labour) were included as variables building on Ainembabazi et al. (2017), Nakazi et al. (2017) and Agole et al. (2021). Access to extension, price and market information, and agricultural training were included as dummy variables (1 = yes, 0 = no). We also

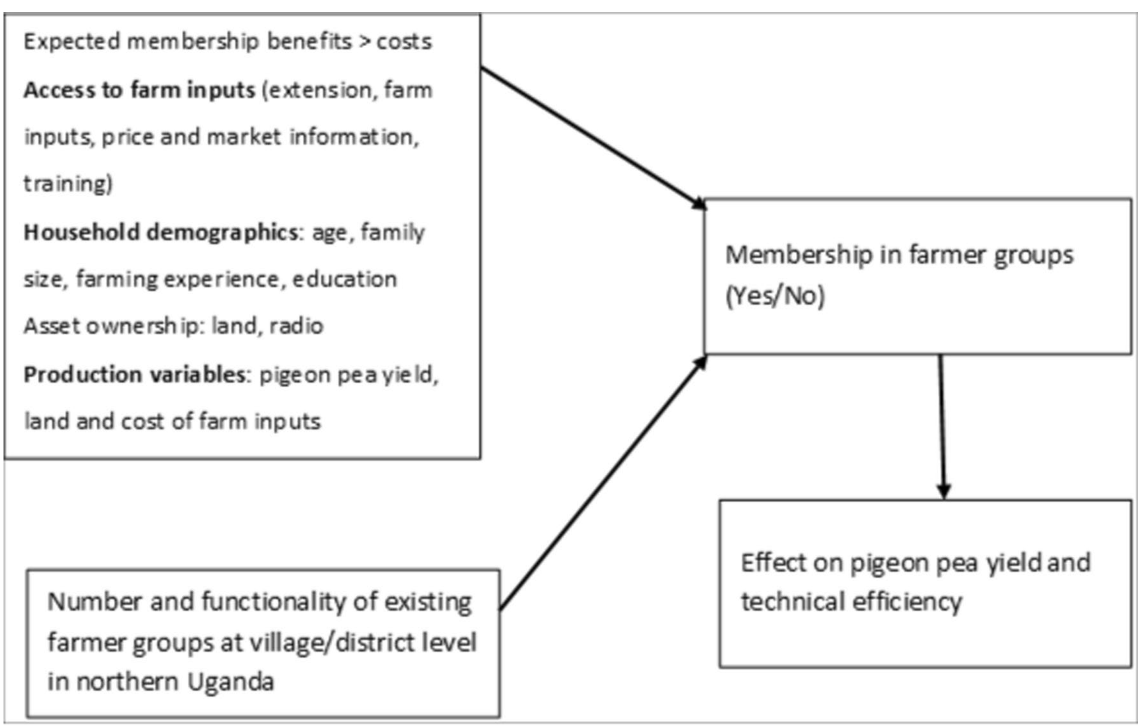

Fig. 1 Schematic representation of factors influencing smallholders' decision to participate in FGs and the influence on pigeon pea yield and technical efficiency

include land and radio ownership as continuous variables (Abdul-Rahaman and Abdulai 2020). We hypothesise that a farmer's decision for group membership is influenced by access-related factors, for example access to credit, training, extension and market information, and that these directly have an impact on pigeon pea yield and technical efficiency.

The binary probit model

Since membership in FGs is binary, it is explained with binary outcome models (Verbeek 2004), such as the probit model. The ordinary least squares (OLS) model was not sufficient in modeling factors influencing FG participation (Maddala 1986). Given the non-randomness of the decision to participate in FGs (Fig. 1), several factors influence the decision. Following Abdul-Rahaman and Abdulai (2018), we take the likelihood for FG membership as the difference between the benefits of participation; G_B^*, and the expected losses; G_L^*. Group membership increases if expected benefits overweigh the costs involved, i.e. $G_i^* = G_B^* - G_L^* > 0$. However, what is observed is FG membership, with G_i^* being a latent variable that is unobservable. G_i^* as a function of observable characteristics in a latent variable structure as;

$$G_i^* = \gamma Z_i + \omega_i + G_i = 1[G_i^* > 0] \tag{1}$$

where G_i is a group membership indicator, taking 1 if a farmer participates in any FG, and zero otherwise. γ is the error term with zero mean and variance σ^2, and Z_i is a vector of observable farm and household characteristics believed to influence the decision for membership in FGs. Therefore, the membership likelihood in any FG is specified as below;

$$Pr(G_i = 1) = PrPr\left(G_i^* > 0\right) = PrPr(\omega_i > -Z_i\gamma) = 1 - F(-Z_i\gamma) \tag{2}$$

where F is the cumulative distribution function for ω_i.

The stochastic production Frontier model

We hypothesize that pigeon pea yield increased if smallholders had FG membership. We therefore used the SPF model to estimate how membership affected yield. The model is specified as follow;

$$Y_{ij} = f(X, G_B) + \varepsilon_i, \varepsilon_i = v_{ij} - u_{ij} \tag{3}$$

where Y_{ij} the yield of the ith smallholder, X represents is a vector of inputs and explanatory variables, G_B is a dummy variable that captures the effect of group participation. v_{ij} is a two-sided error term and u_{ij} denotes the one-sided error term capturing efficiency. The subscript j refers to G_B for smallholders who are members in the jth group and G_L for non-members. Due to the non-random/voluntary nature for joining FGs, selection bias arises due to observed and unobserved smallholder traits. We address the bias when estimating the SPF model to obtain unbiased and consistent yield and TE estimates (Bravo-Ureta et al. 2012). Smallholders face technical inefficiencies because of differing production opportunities given their different specific resource endowments in terms of capital, infrastructure and other physical, economic and environmental characteristics (O'Donnell et al. 2008). We determine separate frontiers across FG members and non-members to account for TE differences across two groups.

Accounting for selection bias in the SPF model

Lai (2015) acknowledge sample selection bias in the SPF model and used different approaches to estimate TE. Solis et al. (2006) applied the Switching Regression Approach (SRA) to SPF to analyse TE levels for smallholders in El Salvador and Honduras under two different levels of adoption of soil conservation measures. They found potential selection bias for high- and low-level adopters and separate SPFs, selection bias was corrected for in each group. Likewise Mayen et al. (2010) addressed self-selection in FGs by using PSM to compare organic and conventional farms in the United States. They report small differences between organic and conventional farms when TE was measured against the appropriate technology. However, they only corrected for biases stemming from observed variables and nothing for the unobserved covariates.

We use the Cobb–Douglas (CD) function to estimate the propensity scores. PSM is often used to evaluate the impact of a binary treatment variable (Ruben and Fort 2012). Subsequently, we correct for selection bias for both the observed and unobserved factors for the estimation of production function and TE. We follow Greene (2010) to deal with biases from unobserved factors, for example, smallholder's motivation and managerial ability. The model is an improvement to Heckman's self-selection specification for the linear regression model and assumes that the unobserved characteristics in the selection equation are correlated with the noise in the SPF model (Bravo-Ureta et al. 2012). The model is specified as below;

Sample selection model:

$$G_i = 1[Z_i\gamma + \omega_i > 0], \omega_i \sim N[0,1] \tag{4}$$

SPF:

$$y_i = \beta' x_i + \varepsilon_i, \varepsilon_i \, N[0, \sigma_\varepsilon^2] \tag{5}$$

$$(y_i, x_i) \text{ observed only when } G_i = 1 \tag{6}$$

Error structure;

$$\begin{aligned}&\varepsilon_i = v_{ij} - u_{ij},\\ &u_i = |\sigma_u U_i| = \sigma_u |U_i|, \text{ where } U_i\ N[o, 1]\\ &v_i = \sigma_v V_i, \text{ where } V_i \text{ N}[0, 1]\\ &\omega_i, v_i N_2[(0, 1), (1, \rho\sigma_v, \sigma_v^2)],\end{aligned} \tag{7}$$

where G_i is a binary dependent variable taking on 1 for FG membership and zero for non-membership, y is the output (pigeon pea yield), Z is a vector of covariates in the sample selection model and x is a vector of inputs for the production frontier model. The parameters to be estimated are γ and β whereas the error structure corresponds to the errors in the SPF model. The parameter ρ indicates the presence or absence of selection bias associated with the unobserved variables (Greene 2010). Therefore, we first estimate the sample selection SPF model for group members and repeat for non-members, in which case the dependent variable G_i in the selection equation is reversed, i.e., G_i equals one for the non-participants and zero for the group participants (Greene 2010).

Specification of the empirical model

Membership in FGs is usually non-random; we therefore use a PSM approach to cater for selection bias (Dehejia and Wahba 2002; Caliendo and Kopeinig 2005) to show that the PSM estimator provided low bias especially using cross-sectional datasets, like in our case. Caliendo and Kopeinig (2005) illustrate the several matching criteria used in PSM; including nearest neighbour matching (NNM), caliper matching, kernel matching, and stratification and interval matching. For this study, we employed both the NNM and kernel matching algorithm (Caliendo and Kopeinig 2005; Abdul-Rahaman and Abdulai 2018).

The SPF model was estimated with correction for selection bias after the matching procedure. We first modelled smallholder's membership decisions using the probit model, which is described by a criterion function and expressed as a function of exogenous smallholder factors that influence FG membership;

$$G_i = \gamma_0 + \sum_{j=1}^{13} \gamma Z_{ij} + \omega_i \tag{8}$$

where G_i is the binary variable assigned to a value of 1 for members, and 0 for non-members, γ is a vector of unknown parameters to be estimated, and ω is the error term distributed as N $(0,\sigma^2)$. Z represents the variables as highlighted in the conceptual framework and used in the model.

When smallholders join FGs, the chances of accessing extension services and credit normally increase (Abdul-Rahaman and Abdulai 2018). This was related to endogeneity, which is addressed by employing a two-stage control function approach as outlined in Wooldridge (2015). Radio ownership is used as a proxy variable for access to information on prices and market opportunities, which we first estimated separately in the probit model following Ainembabazi et al. (2017). We assumed that smallholders who own a radio have better access to information compared to those without a radio. The proxy indicator is expected to influence access to information on prices and market opportunities but not influence group membership.

In the second stage, the observed predicted residuals of access to price and market information were incorporated into the group membership probit model. This approach has been used in collective action research, for example by Abdul-Rahaman and Abdulai (2018) in Ghana who used distance to credit sources and the status of farm roads as control variables to credit and extension access, respectively.

Lastly, we evaluated the two most commonly used functional forms in efficiency studies; the CD and Translog (TL) models (Becker and Ichino 2002; Bravo-Ureta et al. 2020). We used a log likelihood ratio test to reject the TL model in favor of the CD model at 5% level of significance. The CD model is specified as below;

$$In(Y_i) = \beta_o + \sum_{j=1}^{5} \beta_j ln X_{ji} + \sum_{k=1}^{8} \delta_k D_{ki} + v_i - u_i, \quad if G_i = 1 \tag{9}$$

where Y_i denotes pigeon pea yield, i, X_{ji} is the quantity of the jth input; D are the dummy variables; β and δ are unknown parameters to be estimated; v and u are the elements of the error term, ε. The dependent variable in the CD model is pigeon pea yield for the harvests of 2019 in kilogram (kg). The covariates are production function inputs, namely pigeon pea yield, the dependent variable (YIELD), acreage (HECT), proportion of seed bought (SEED) and pesticides (PESTIC), as well as soil fertility perception (SFERT). To determine the effects on TE, we employed alternative models, i.e., the logit, probit, and complementary log–log regression for the second estimation stage (Abdulai and Abdulai 2017).

Methodology

Description of the study area

Data were collected from Lira, Pader and Kitgum districts in northern Uganda between September and December 2019. The districts were selected as they are pigeon pea hotspots in Uganda (Hillocks et al. 2000). The region is characterized by a semi-arid climate, unimodal rainfall and rain-fed subsistence agriculture (Kaweesa et al. 2018; Shikuku 2019). It is the poorest region of Uganda, with 33% of the population living below the poverty line (World Bank 2016). Food insecurity is widespread, partly due to the effects of the two decades of civil war in northern Uganda between 1986 and 2006 (Kaweesa et al. 2018). Similarly, Wallace (2016) reported that 59% of the households in northern Uganda consumed only one meal per day. Smallholders keep some livestock (goats, sheep, cattle and chicken) for additional income, domestic use, draught power and manure (Kristjanson et al. 2012). The population density of Lira, Pader and Kitgum districts is 301, 54 and 51 people/km^2, respectively (Uganda Bureau of Statistics 2020).

Northern Uganda is prone to climate change compared to other parts of Uganda (Akongo et al. 2017). The soil type are ferralsols and nutrient-depleted (Apanovich and Lenssen 2018), with a high demand for P and K (Yost and Eswaran 1990). The complexity of challenges faced by smallholders in northern Uganda calls for context-specific empirical research to contribute to better livelihoods and improved food security.

Sampling and data analysis

A baseline study including informal discussions with agricultural extension workers and researchers at the Zonal Agricultural Research and Development Institute (Ngetta-ZARDI) in Ngetta sub-county, Lira district, guided selection of the study districts. Three districts were purposively selected following a multi-stage approach (from district to sub-county and then villages), and based on pigeon pea production statistics per district. In the second sampling stage, two sub-counties were selected per district, and in each sub-county, three villages (18 villages in total) were selected following a simple random sampling.

The study employed a quantitative approach that involved use of a pre-tested semi-structured questionnaire to interview 257 pigeon pea smallholders using a Computer Assisted Personal Interview (CAPI) Kobo-collect toolbox (Gravlee 2002). The questionnaire included sections on household characteristics, pigeon pea production, marketing and consumption attributes, farm endowments, as well as challenges and opportunities regarding pigeon pea production. The interviews were held in the *Langi* and *Acholi* languages by trained enumerators, and took between 30 and 40 minutes. All sampled smallholders had grown pigeon pea for at least two consecutive years. Data was analysed using STATA statistical package version 15.1 (StataCorp 2017). Mean and standard deviation were used to present descriptive statistics, and the probit, CD function, and PSM techniques to assess FG membership, yield, TE and its determinants, respectively.

Results

Descriptive statistics

Out of the 257 sampled smallholders, 61% were FG members (Table 1). There were slightly more FG members in Kitgum district (55), compared to Lira (51) and Pader (52). FG members were older (43 compared to 40 years), but the two groups had the same level of education (5 years), comparable years of farming experience (22 years for FG members compared to 21 for non-FG members) and the same household size (about seven members in both groups).

Interestingly, FG members allocated slightly less land for pigeon pea production (0.7 ha) than non-members (0.9 ha). However, FG members harvested slightly higher average yield (336 kg ha^{-1}) than non-members (311 kg ha^{-1}). Likewise, the use of pesticides was similar for both groups, with an approximate cost of US$ 2.3 and 2.2 per season for members and non-members, respectively.

Factors influencing smallholder`s decision for FG membership

To assess factors that influenced membership in FGs, we use a probit model and its co-efficients (1) and marginal effects (2) estimates are presented in Table 2. The log likelihood χ^2 was 29.5 with 15 degrees of freedom, and prob > χ^2 was 0.014 indicating that the model was statistically significant. Age of the household head, access to agricultural training, access to extension services, access to price and market information and distance to markets significantly correlated with smallholder's decision for FG membership.

Age of the household head (AGE), access to agricultural training (TRNG), and extension services (EXT) and distance to market centre (DIST), measured as distance to input and output centre, significantly correlated with FG membership, meaning that a unit increase in age increased the probability of smallholder FG membership by 3.4%. The probability of smallholder's membership in FGs increased significantly with access to credit (CRDT) (by 8.5%). Increasing distance to the nearest market centre (DIST) significantly decreased the likelihood of membership in FGs, suggesting that smallholders in very remote locations rarely participated in FGs, possibly due to poor infrastructure and less governmental and NGO engagement. Formal education (EDU) for group members did not influence the decision to participate in FGs.

Estimates of the SPF model

Results of the SPF model are presented in Table S1 for both the conventional and the sample selection models. The pooled sample estimates showed FG members and

Table 1 Descriptive statistics for overall sample, FG members and non-members in Lira, Pader and Kitgum districts in northern Uganda

VariableVariables	Code	Description	Pooled sample (n = 257)	Mean (SD) Members (n = 158)	Mean (SD) Non-members (n = 99)
Group membership		1 = member, 0 = non-member	–	0.61	0.39
Age	AGE	Age of smallholder in complete years	41.5 (13.4)	43 (13.1)	40 (13.8)
Education level	EDU	Complete years in school	5.3 (3.4)	5.2 (3.4)	5.3 (3.3)
Family size	FSIZE	Household size (number)	6.96 (2.8)	6.9 (2.8)	6.9 (2.9)
Farming experience	FEXP	Number of years in farming	21.5 (13.6)	22 (13.3)	20.6 (14.2)
Access to;					
Extension services	EXT	1 = access to extension services, 0 = no	0.7 (0.5)	0.76 (0.43)	0.59 (0.49)
Radio ownership	RADIO	1 = household owned a radio, 0 = no	0.5 (0.5)	0.5 (0.4)	0.5 (0.5)
Credit	CRDT	1 = have access to credit, 0 = no	0.4 (0.5)	0.46 (0.5)	0.38 (0.49)
Agricultural training	TRNG	1 = received agricultural training, 0 = no	0.5 (0.5)	0.5 (0.5)	0.48 (0.5)
Price and market information	PRICE	1 = have access to price and market information, 0 = no	0.374 (0.485)	0.41 (0.039)	0.32 (0.047)
Land owned	LAND	Total land owned in hectares	2.6 (2.8)	2.7 (2.8)	2.5 (2.8)
Pigeon pea variety planted	VARIETY	1 = improved variety, 0 = no	0.05 (0.2)	0.06 (0.24)	0.03 (0.17)
Distance to nearest market Center	DIST	Distance to market center in kilometer	1.4 (2.2)	1.3 (2.1)	1.59 (2.4)
Lira	LIRA	1 = location is lira district, 0 = no	0.32 (0.5)	0.31 (0.5)	0.33 (0.5)
Pader	PADE	1 = location is Pader district, 0 = no	0.35 (0.5)	0.33 (0.5)	0.42 (0.5)
Kitgum	KITG	1 = location is Kitgum district, 0 = no	0.33 (0.5)	0.35 (0.5)	0.25 (0.4)
Variables for the SPF model					
Pigeon pea yield	YIELD	Total yield of pigeon pea harvested in 2019 (in kg ha^{-1})	326 (341)	336 (272)	311 (334)
Pigeon pea acreage	HECT	Land used for pigeon pea for 2019 (in ha)	0.8 (1.1)	0.7 (0.9)	0.9 (1.3)
Proportion of pigeon pea seed bought (input)	SEED	Proportion of seed bought during for 2019 (percentage)	24.1 (41.5)	24 (41)	23.6 (42)
Pesticide cost	PESTIC	Cost of pesticides/chemicals used for 2019 (in USD)	2.3 (3.99)	2.3 (4.15)	2.2 (3.75)
Perception of soil fertility status for legume plots	SFERT	1 = fertile, 0 = not fertile	0.96 (0.2)	0.97 (0.16)	0.93 (0.26)

SD is Standard Deviation, reference period is 2019 (harvest from September to December). I US$ = 3,679 Uganda shilling (Bank of Uganda, November-2019)

non-members with and without selection correction. Whereas the conventional model accounted for only observable characteristics, the sample selection model corrected for both observables and unobservable biases. The dependent variable is pigeon pea yield (YIELD) for 2019 and the explanatory variables in the production function and inefficiency determinants. The log-likelihood ratio test led to rejection of the null hypothesis of homogenous technology for group participants and non-participants at 5% for the conventional and sample selection models, matched ($LR = 22.78$, $\chi^2 = 0.030$, $df = 11$).

The null hypothesis test of no TE ($lambda = 0$) was rejected in all cases for FG members and non-members, showing that TE contributed to pigeon pea yield differences between the two groups. The evidence for selection bias on the unobserved attributes justified why we used the sample selection model for members and non-members and the TE estimates and scores from the conventional SPF model were biased and inconsistent (Bravo-Ureta et al. 2012; Abdul-Rahaman and Abdulai 2018).

The partial production elasticities measure the percentage contribution of each input to percentage change in yield. These were positive for FG participants, apart from use of improved pigeon pea varieties. The reported partial elasticities for members and non-members in the sample selection model were lower compared to those in the conventional model,

Table 2 Results of the probit model for factors influencing farmers' group membership for smallholders in Lira, Pader and Kitgum Districts, northern Uganda

Variables	1 Probit Coefficients (SE)	2 Marginal effects Coefficients (SE)
AGE	0.089** (0.039)	0.034** (0.015)
EDU	– 0.019 (0.029)	– 0.007 (0.011)
FEXP	– 0.003 (0.013)	– 0.001 (0.005)
FSIZE	– 0.048 (0.033)	– 0.018 (0.013)
TRNG	– 83.34** (33.33)	– 0.102** (0.045)
EXT	83.83** (33.32)	0.337** (0.260)
PRICE	0.310* (0.182)	0.116 (0.066)
CRDT	0.227 (0.179)	0.085 (0.067)
DIST	– 0.078** (0.039)	– 0.029** (0.015)
VARIETY	0.173 (0.426)	0.064 (0.152)
RADIO	0.055 (0.180)	0.021 (0.068)
LAND	0.013 (0.012)	0.005 (0.005)
LIRA	– 0.230 (0.228)	– 0.088 (0.088)
PRICE residual	920.6** (368.3)	348.85** (139.41)
Constant	– 480.3** (191.5)	
Log likelihood	– 156.57	
LR χ^2 (15)	29.48	
Prob > χ^2	0.0140	
Number of Observations	257	

, and * represent significance at 5% and 1% levels respectively; Standard Error (SE) in parentheses

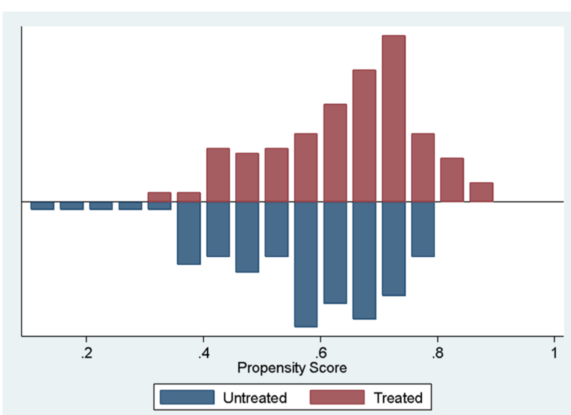

Fig. 2 Distribution of propensity scores for group members (treated) and non-members (Untreated) in the common support region

suggesting that sample selection bias overestimated partial elasticities (Villano et al. 2015). For group members, the elasticities of location and education were positive and significant, illustrating the positive impact on pigeon pea yield. FG members consistently had higher TE compared to non-members (Fig. 2).

Measuring technical efficiency

To determine factors that affect smallholder's TE, we used alternative models, i.e., logit, probit and complementary log–log regression for the second estimation stage and later tested for the appropriate functional form (Abdulai and Abdulai 2017). The average TE for group members was 63% compared to 59% for non-members. None of the two groups maximized pigeon pea production given the available resources. The results showed that pigeon pea production was constrained by low access to extension, price and market information, distance to nearest market, and the low formal educational level of the smallholders.

Discussion

In this study, we used binary probit model and complementary models to determine the factors that influence smallholders' membership to FGs and TE for pigeon pea, respectively. We used a cross-sectional survey with 257 pigeon pea smallholders in the Lira, Pader and Kitgum districts of northern Uganda, out of which 61% were FG members. As hypothesized, we found several factors that influenced smallholders' decision FG membership. Specifically, access-related factors such as access to agricultural training, extensions services, and price and market information had a significant effect on smallholders' probability to be members in FGs (Table 2).

What motivates and influences membership to FGs?

Our results show that about 37% of the smallholders had access to agricultural credit (Table 1). With about 10% smallholders' access to formal credit (from banks and/or micro-finance institutions), this remains generally low in rural northern Uganda (Uganda Bureau of Statistics 2020). Smallholders mentioned their main sources of credit to include Village Savings and Credit Associations (VSLAs), locally known as '*bol li-cup*'. Similarly, 46% of FG members had better access to agricultural credit (CRDT) compared to non-members (38%) (Table 1). In addition, 45% of smallholders mentioned borrowing and saving as the main motivation for seeking FG membership (Fig. 3), pointing to the enormous need of financial credit. Such credit is used for farm input purchase, for example fertilizer, hybrid seed, herbicides, and pesticides. Similar results were reported by Wossen et al. (2017) and Olagunju et al. (2021) for smallholders in Nigeria. Modalities to access

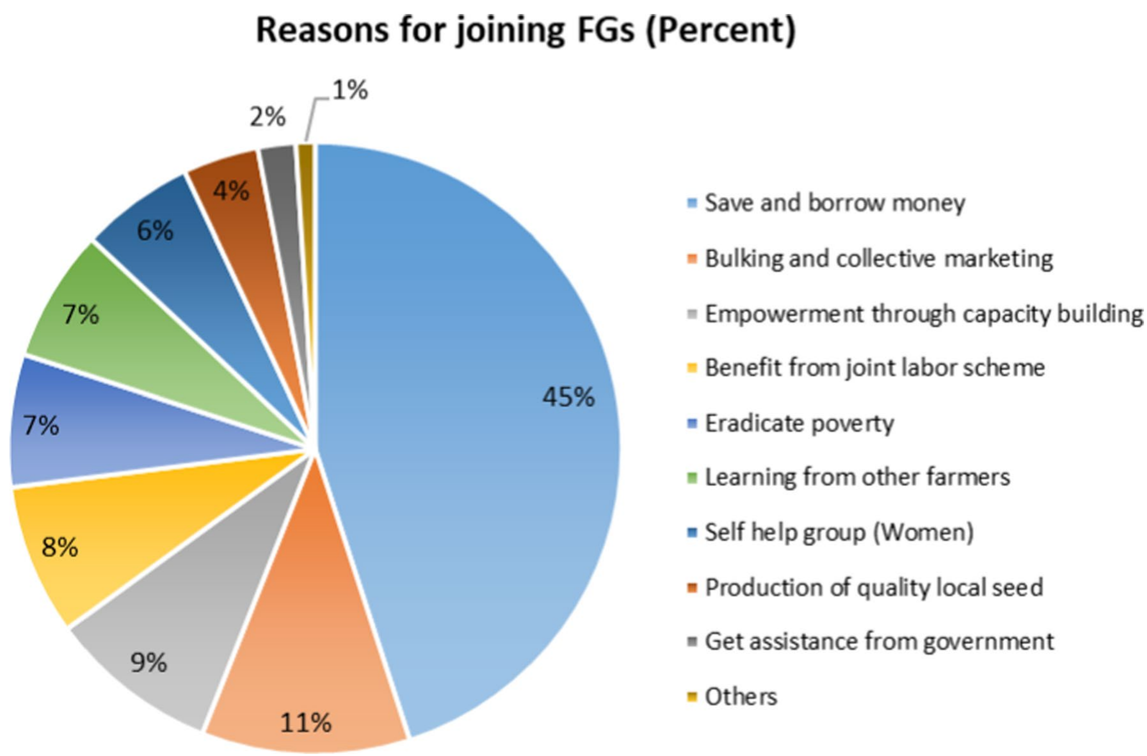

Fig. 3 Reasons for joining farmers' groups by smallholders in northern Uganda

commercial banks are limited since banks are usually located far from smallholders' reach, and farmers often lack collateral requirements, such as formal land titles, to secure credit from banks (Akudugu 2016). Therefore, approaches to improve the borrowing and saving structures in northern Uganda can go a long way in improving credit accessibility of smallholder farmers.

FGs accumulate funds through membership fees (around US$ 3 per person per year) as entry and registration fees. For example, the *"Jingkomi Local Seed Business Group"* in Kitgum District has a membership of over 70% women, whose main goal is to extend access to both formal and informal credit to smallholders through, for example, low-interest loans that can accelerate credit access among smallholders.

About 9% smallholders joined FGs to benefit from training and extension opportunities (Fig. 3). Extension services are majorly received from government extension agents, and include agricultural training and advisory (for example by NAADS). Our results showed that an increase in access to extension (EXT) increased the likelihood of FG membership by 34%. This implies that FG members accessed and benefited more from extension providers compared to non-members. Similar results from Ghana show a positive and significant effect of smallholders' membership on access to extension (Ma and Abdulai 2016). However, despite governments' effort to provide extension in northern Uganda, there are only about 5–8 extension agents per over 100,000 farmers, a low ratio compared to other regions of the country (AfranaaKwapong and Nkonya 2015). Similarly, the information provided by extension agents sometimes doesn't meet smallholders' needs, as reported from Ethiopia by Leta et al. (2020). Overall, strengthening the extension system, particularly through training and incentives to work in remote areas, can be a step toward revitalizing the role of FGs in northern Uganda.

About 11% of FG members joined groups to benefit from collective bulking and marketing of agricultural produce. Agricultural marketing is still challenged by several factors especially in northern Uganda; for instance, 75% of northern Uganda is rural, often with hard-to-reach villages due to poor road connectivity (Uganda Bureau of Statistics 2014). The few existing roads are impassable, worsened by occasioned flooding (Akongo et al. 2017). This implies limited access to markets where smallholders can sell their produce and purchase agricultural inputs. As a proxy for market access, the distance to the nearest market centre (DIST) was positive and significant in influencing smallholders' FG membership. Smallholders who live remotely rarely held membership in FGs since most of the meetings and activities are centrally located, such as at the parish or sub-county office. Similarly, only 37% of smallholder accessed price and market information (PRICE) from media, neighbors, and extension agents, which further limits produce marketing in northern Uganda. Similar findings illustrate that FG membership improved smallholders' market access and income in SSA (Bizikova et al. 2020). Opportunities to improve market access through road rehabilitation, and setting up grain aggregation centres are thus recommended.

The average education level in the three study districts was 5.3 years, which is low, and is partly attributed to the low school enrolment rate of about 4.5% in the northern region there, compared to an average of 12% for central Uganda (Ssentanda and Asiimwe 2020). Similarly, our results show that education level did not significantly influence FG membership (Table 2). Government efforts to improve literacy rates such as the Universal Primary Education (UPE) and Universal Secondary Education (USE) launched in 1997 and 2007, respectively, have not largely benefited northern Uganda (World Bank 2016; Uganda Bureau of Statistics 2020). The 20 year conflict (1986 to 2006) prevented many children (who are now adults) to go to school, and left many educational facilities vandalized, with many girls forced into early marriage and y motherhood (Baines and Gauvin 2014). In contrast, Mojo et al. (2017) and Olagunju et al. (2021) found that formal education significantly and positively influenced cooperative membership in Ethiopia and Nigeria, respectively. To overcome illiteracy challenges, the provision of agricultural-related training in local languages can contribute to improving smallholder literacy and ultimately livelihoods.

Options to improve TE and pigeon pea yield

The average TE for FG members was 63% compared to 59% for non-members, an indication that all sampled pigeon pea smallholders were not producing efficiently (Fig. 2). This implies that there is a pigeon pea production gap, and FG members and non-members can increase production by 37% and 41%, respectively. The factors affecting TE are presented in Table S2, with education level of the household head, access to extension and proportion of seed bought showing positive and significant effects on TE. This confirms the notion that smallholders rarely maximize efficiency since they often face multiple production-related constraints. For example, Okello et al. (2019) reported 78% as the mean TE for rice farmers in northern Uganda, with a potential to increase efficiency by 22%.

Important to note is that FG members and non-members lived in the same locality and villages, implying likely spill-over effects between the two groups. Pigeon pea yield (YIELD) was low, with 336 and 311 kg ha^{-1} for members and non-members, respectively (Table 1). About 24% of smallholders bought pigeon pea seed at planting, suggesting that 76% of smallholders used home-saved local pigeon pea varieties, locally known as *Apio-Elina, Apena,* and *Adong.* Yet, local varieties are relatively low yielding and prone to pests and diseases (Kaoneka et al. 2016; Manyasa et al. 2009). Similarly, Milne et al. (2015) found that 78% of smallholders in Tanzania planted low yielding local pigeon pea varieties. Smallholders expressed their desire to plant improved pigeon pea varieties, but were constrained by the high cost of seed at about US$ 2 per kg. The low access and high price of improved pigeon pea varieties in northern Uganda is also attributed to remoteness and the poor road network connecting to agro-dealers (Sikora et al. 2019; Atube et al. 2021). Consequently, the involvement of private market players can improve linkages to stabilize markets in northern Uganda.

There are a multitude of NGOs and community- based organisations that are operational in northern Uganda over the years focussing on the post-war rehabilitation of the region. Such organizations provide training and agricultural support to smallholders, in addition to the traditional government advisory system (NAADS, and Operation Wealth Creation–OWC). Smallholders reported benefiting from NGOs such as Techno-serve and World Vision that have provided agricultural training to FGs since 2010, i.e., post-conflict. Shikuku (2019) found that smallholder training can lead to substantial positive changes in farm management and crop yields, and farmers who receive training act as agents to train non-members, leading to knowledge diffusion through social learning and change. Smallholders reported participation in 'demonstration-plots' and farmer field school processes for uptake of agricultural innovations. For example, pigeon pea mother-trials hosted at the ZARDI in Ngetta, in Lira district in 2019 showcased several agricultural innovations such as land preparation, row planting and intercropping approaches. With such trainings, smallholders are equipped with Good Agronomic Practices (GAPs) pertinent for crop yield improvement.

Smallholders in Lira district had a 9% lower likelihood for FG membership, compared to farmers located in Pader and Kitgum districts (Table S1). This is perhaps due to the higher remoteness of smallholders in Lira district, and hence a reluctance to join FGs compared to the ones in Pader and Kitgum districts. The distance to FG meeting locations, in most cases parish and sub-county offices, plays a critical role in attending to FG activities as many of the activities are centrally located. Relatedly, Abdul-Rahaman and Abdulai (2018) reported that location of the smallholder plays a critical role in FG membership in

Ghana by increasing or decreasing access to group meetings and trainings. Therefore, options for decentralizing meeting locations, such as holding village meetings, are deemed necessary to boost FG membership.

The study had some limitations including; the use of cross-sectional data that is usually faced with selection bias, which we try to overcome by use of the PSM analysis. Additionally, data collection during the COVID-19 era was challenging due to the strict conditions put forward by the government of Uganda to mitigate the spread of the pandemic.

Conclusions

This study contributes to understanding FG membership as an important social component to agricultural transformation and development in rural Uganda. FGs are important for smallholders to improved access to credit, collective marketing, and extension and market information. However, our results confirm that the success of smallholders FGs membership in northern Uganda is largely limited by access-related factors, further exacerbated by low educational level, small land size used for crop production, and minimal or no access of external production inputs. On average, we found that both members and non-members did not produce efficiently (TE), implying that smallholders continue to face challenges with production input access and use, and a need for improved and better access to external production inputs such as seed, fertilizer and agricultural training. We recommend more efforts in training of extension agents and better incentives to engage with smallholders in northern Uganda as approaches to strengthen the extension system. Extension is often delivered in English, but we recommend localized extension materials in *Langi* and *Acholi* in its delivery, and also in written documents. For northern Uganda, which is particularly challenged by numerous historic, socio-economic and environmental problems, we suggest more commitment from the government to create an enabling environment for the operation and existence of FGs.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s43170-024-00281-8.

Additional file 1.

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Author contributions
DBN: Conceptualization, methodology, formal analysis, writing-original draft. TS: Conceptualization, writing-review and editing, supervision, project management. CB: Conceptualization, writing-review and editing, supervision, funding acquisition, project management.

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Availability of data and materials
The data presented in this study are available on request from the corresponding author.

Declarations

Ethics approval and consent to participate
The study was conducted and approved by the Ethics Committee for the Centre for Development Research (ZEF), and in Uganda approved by the Institutional Review Board of Makerere University, School of Social Sciences and the Uganda National Council for Science and Technology (UNCST)-(Protocol code SS 5196), Uganda. Informed consent was obtained from all subjects involved in this study.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no conflict of interest.

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