Farmer groups and inorganic fertiliser use among smallholders in rural South Africa

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Smallholder farmers in developing countries are characterised by low uptake of improved farm inputs and weak links to markets. Among other reasons, the high transaction costs that these smallholder farmers incur, as a result of their location in remote areas, inadequate information and missing credit markets, inhibit them from participating in both input and output markets. Organising farmers into groups has been suggested as a potential mechanism for reducing transaction costs. Accordingly, farmer groups have been preferred channels for smallholder farmer support in South Africa, both by the government and donors. However, the impact of these groups on smallholder outcomes such as technology adoption is largely unknown. We investigated the extent to which membership in farmer groups influences the use of improved farm inputs such as inorganic fertiliser among smallholder farmers in South Africa. A sample of 984 households was analysed using the propensity score matching method. Group membership was found to play a positive role in inorganic fertiliser use with a 14% higher chance of inorganic fertiliser use among group members. Among fertiliser users, group members used 170 kg more inorganic fertiliser than did non-members. Further analysis indicated that the effect of group membership on inorganic fertiliser use was heterogeneous among group members. The results suggest that farmer groups play a positive role in the use of improved farm inputs in South Africa. For greater effectiveness of group membership, policymakers should target the less educated, increase the assets of the poor and improve access to extension and information.

Significance:

- The impact of farmer groups on smallholder outcomes such as technology adoption is largely unknown.
- Farmer groups were found to play a positive role in the adoption of agricultural technologies such as inorganic fertilisers.
- Effect of group membership on inorganic fertiliser adoption was heterogeneous among group members.
- Variables that should be targeted for greater effectiveness of collective action were identified.

Introduction

Smallholder farming plays an important role in the livelihoods of the poor in the developing world, in general, and in sub-Saharan Africa in particular. However, smallholder farmers face several constraints that have limited the effectiveness of their farming activities in alleviating the rural poverty and food insecurity challenges. They are often located in remote areas with poor infrastructure, inadequate information and imperfect or missing credit markets, which results in higher transaction costs.[1-5] The higher transaction costs reduce their incentives for participation in both agricultural output and input markets. Moreover, these farmers are poorly endowed with assets and lack adequate access to government support services such as extension and training, which are important in alleviating the effects of high transaction costs.[6-8]

Thus, the smallholder farmers in sub-Saharan Africa are characterised by low uptake of improved farm inputs and weak links to output markets.[9-12] For example, whereas the average intensity of inorganic fertiliser use in Latin America and Asia is about 100 kg/ha, it is below 10 kg/ha in sub-Saharan Africa.[9,13,14] In South Africa, the average inorganic fertiliser application rates of smallholders are significantly below the recommended levels for the respective agro-ecological regions in the country, and are too low and ineffective to sustain crop and soil fertility.[15,16] There is therefore a need for mechanisms to address the challenges that smallholders face to enhance their market participation as well as increase their modern technology adoption rates to ensure that they benefit from these technological advancements.

Several studies have indicated that organising farmers into groups can play a significant role in reducing transaction costs and increasing farmers' market participation and input use.[2,4,5,7,8,17] Farmer groups can provide a variety of services that are key for market access, input use and improved welfare.[4] For instance, buying inputs or selling outputs collectively results in economies of scale, which reduces transportation and transaction costs and increases bargaining power (resulting in favourable prices).[17] Governments and development agencies all over the developing world are placing considerable emphasis on using collective action as a means of effectively linking smallholders with input and output markets.[4,18-22]

The South African government has also been actively promoting collective action through groups among the smallholder farmers.[15,23,24] For example, Output 5 of Outcome 7 of the government's outcomes approach aimed to, among other targets, have at least 30% of smallholder farmers organised into producers' associations or marketing co-operatives by 2014.[24] These farmer groups are expected to give collective power in negotiations for inputs and marketing, thus enhancing the institutional environment for poverty reduction and sustainable and inclusive growth in the rural areas.[24] Farmer groups are also the preferred channel through which most non-governmental organisations (NGOs) and donors reach and support the poor with their food security and poverty reduction interventions in the rural areas. Hence, several farmer groups and cooperatives have been formed in the smallholder sector. While some of the groups focus on one purpose (e.g. marketing), most of these groups are multi-purpose: helping the farmers access information, secure inputs as well as sell their produce.[15]

Membership in these groups enables pooling of resources, sharing of information as well as collective bargaining, thereby increasing the participation of the smallholder farmers in both the input and output markets. The government as well as NGOs often give free and/or subsidised inputs, credit or training through these farmer groups. While organising farmers into groups may make service provision by government and NGOs easier in many respects, its impact on the farmers themselves is mixed.[4,25] Literature is available on the impact of farmer groups in the output markets, and the results, although somewhat mixed, suggest a positive role of collective action on output market participation.[2,21,26-28] However, few studies, such as Abebaw and Haile[7] have focused on the groups' potential role in improving the adoption of modern technologies. While studies such as Abebaw and Haile[7] are relevant, these studies should not be generalised because technology adoption is context specific.[29,30]

In this study, we investigated the extent to which membership in farmer groups influences inorganic fertiliser use among smallholder farmers in the KwaZulu-Natal (KZN) Province of South Africa, using the propensity score matching technique. This study contributes to the literature in three ways. First, while previous technology adoption studies either failed to include group membership in their models, or did not control for its potential endogeneity in the models, as noted in Abebaw and Haile[7], we controlled for potential endogeneity issues using propensity score matching. Propensity score matching pairs group members and non-members who have similar observable characteristics to control for endogeneity problems that arise from observable variables. Second, we did not assume that group membership has homogenous effects, but also investigated the heterogeneous effects of group membership on fertiliser use. That is, we asked: who is likely to benefit more from being a member of a group? This aspect is important for evidence-based policy and for better targeting of interventions meant to increase modern technology use among smallholder farmers.

Thirdly, we focused on smallholder farmers in KZN. To our knowledge, few studies on this subject, if any, have been done in South Africa in general and KZN in particular. We focused on KZN because smallholder farming is very important in the province, as most rural-based people are employed or self-employed in this sector. According to StatsSA[31], more than 28% of the households in KZN are directly involved in agriculture. The high unemployment rate (33%) in the province, especially among the youth (42%), has resulted in a number of household members who fail to secure employment in urban areas, returning to rural areas to engage in smallholder farming, among other economic activities.[31] The other motivation for selecting KZN as the study area was that, even though it has a huge potential in agriculture owing to good, reliable rainfall (more than 1 000 mm a year), smallholder farmers have failed to tap into this potential because of, among other reasons, their use of rudimentary and out-of-date farming methods.[32] According to KZN-DAE[32], the agricultural output could be increased significantly if modern farming practices were adopted and the natural resources optimally managed for agriculture.

Research methodology

Theoretical framework and selection of variables

Group membership was analysed as a choice problem within a random utility framework[33], following previous literature[2,7,17,34]. According to the random utility theory, a farmer decides to be a group member if the expected utility from group membership (U_i^M) is greater than that of non-membership (U_i), i.e. a farmer chooses group membership if the expected net utility (U_i^M -U_i^N) is greater than zero. The unobserved net utility can be expressed as a function of observable elements in the following latent variable model:

$$U_i^* = \beta Z_i + \varepsilon_i, U_i = 1 \text{ if } U_i^* > 0 \quad \text{Equation 1}$$

where U_i is a binary indicator variable that equals 1 for household *i* in case of group membership and 0 otherwise; β is a vector of parameters to be estimated; Z_i is a vector of household and farm characteristics; and ε_i is an error term.

Group membership is associated with potential costs (membership fees, time, etc.) and benefits (better access to information, inputs, collective bargaining, etc.), which may be perceived differently by different households.[2,17] Individual comparative advantage plays an important role in the choice of whether or not to join a group.[2] Farmers incur different transaction costs because of heterogeneities in household resource endowments and access to information, which results in different market behaviour.[1,2,35,36] The selection of variables into the group membership decision model was based on previous literature.[2,7,26,27,37] Table 1 presents the variables that were considered. These variables include personal details of household head and household characteristics (age, gender, education level, employment status, etc.), wealth and asset endowment (land size, livestock size, income, asset values, etc.), access to support services (extension, credit, training, information, etc.), infrastructural and/institutional support (irrigation, distance to the nearest all-weather road, location/district, etc.).

Table 1: Variables and their descriptions

Variable code	Variable name and description
Outcome variable	
FERTUSE	Fertiliser adoption (1=adopter, 0=non-adopter)
FERTKG	Amount of fertiliser used (kg)
Treatment variable	
GROUP	Farmer group membership (1=yes, 0=no)
Independent variable	
AGE	Age (years)
GENDER	Gender (1=male, 0=female)
MARRIED	Marital status (1=married, 0=unmarried)
EDUCAT	Education level (years)
HHSIZE	Household size (number of people)
LAND	Land size (ha)
TLU	Livestock size (TLUs)
ASSETS	Value of household assets (ZAR)
TOTINC	Annual total household income (ZAR)
EXTENSION	Access to extension (1=yes, 0=no)
INFORM	Number of information sources
CREDIT	Access to credit (1=yes, 0=no)
TRAINING	Access to agricultural training (1=yes, 0=no)
ROADDIST	Distance to the nearest all-weather road (km)
FARMEXP	Farming experience (years)
IRRIGAT	Access to water for irrigation purposes (1=yes, 0=no)
EMPLOYED	Off-farm employment (1=yes, 0=no)
BUSINESS	Ownership of small non-farm business (1=yes, 0=no)
HGWALA	District 1 (1=Harry Gwala, 0=otherwise)
UMZINYAT	District 2 (1=Umzinyathi, 0=otherwise)
UTHUKELA	District 3 (1=Uthukela, 0=otherwise)
UMKHANYA	District 4 (1=Umkhanyakude, 0=otherwise)

Personal characteristics of the household heads such as age, gender, marital status and education level determine group membership by influencing the opportunity cost of time and attitudes towards collective action.[2,7,38] The outcome variables considered were the decision to use inorganic fertilisers and the amount used. The amount of fertiliser used applies to the adopters only, as the non-adopters do not have these figures.

Data

Data were collected from 984 farming households drawn from four districts in KZN. The survey was conducted using a multistage sampling technique. First, 4 districts were purposely chosen out of the 11 districts in the province. The four districts selected were Harry Gwala, Umzinyathi, Umkhanyakude and Uthukela. These districts have a significant number of rural households engaged in farming activities. Second, one local municipality was randomly selected for each district: the Ubuhlebezwe local municipality in the Harry Gwala district; the Msinga local municipality in the Umzinyathi district; the Jozini local municipality in the Umkhanyakude district; and the Imbabazane local municipality in the Uthukela district.

Third, a total of 984 rural households were randomly selected from the four local municipalities. The list of farming households was obtained from the respective local offices of KZN's Department of Agriculture. No stratification was done according to group membership (or any other variable), giving an equal chance for both group members and non-members to be included. The total sample comprised 411 households from Ubuhlebezwe, 239 from Msinga, 143 from Jozini and 191 from Imbabazane. The number of households sampled was not proportional to the population sizes of the respective local municipalities, but was proportional to the number of farming households, as received from the local Department of Agriculture.

The data were collected during the months of October and November 2014 using a structured questionnaire. The questionnaire was administered by experienced enumerators who spoke the local IsiZulu language. These enumerators were trained before the survey. Questionnaire pre-testing, involving 15 rural households, was also done. The ambiguities or difficulties with regard to question wording were noted and remedied during questionnaire pre-testing. The questionnaire included household demographics and socio-economic characteristics; income and wealth endowment; institutional support services; membership in farmer organisations; and inorganic fertiliser use. The data on the use of chemical fertilisers refer to agricultural season prior to the survey, i.e. the 2013/2014 season. All procedures performed in the study were approved by the Human and Social Sciences Research Ethics Committee of the University of KwaZulu-Natal (reference number HSS/0027/015D). Informed consent of the study subjects was obtained and the principles of the 1964 Helsinki declaration were adhered to.

Propensity score matching

To investigate the impact of group membership on inorganic fertiliser adoption, we used the propensity score matching (PSM) method. This non-experimental approach is adopted because group membership is non-random, as an individual household decides to join a group voluntarily. As such, households which are group members might systematically differ from non-members in several socio-economic observable characteristics that may have a direct effect on inorganic fertiliser use. To the extent that group and non-members are different, simply computing the difference between the mean values of the outcome variable of interest of the two categories gives biased results. PSM identifies non-members of groups that are similar to members in their observable characteristics, and comparisons are made in the region of common support. Compared to estimates based on full samples, the impact estimates based on matched samples are less biased and more reliable.[39,40]

To apply PSM in this study, we assumed that our outcome of interest is the amount of inorganic fertiliser used. Further, we assumed that the amount of inorganic fertiliser used by group member *i* is Y_{1i}. The amount of inorganic fertiliser used by a non-member is then assumed to be Y_{0i}. G_i denotes group membership by household *i*, which can take two values: namely $G_i = 1$ if the household is a group member and $G_i = 0$ if the household is a non-member. Our interest was to evaluate the impact of group membership on those households that are group members. The focus is on estimating the average treatment effect on the treated (ATT), the expected treatment effect over the sample of group members, which is estimated as follows:

$$ATT = E[\Delta_i | G_i = 1] = E[Y_{1i,t} | G_i = 1] - E[Y_{0i,t} | G_i = 1] \qquad \text{Equation 2}$$

where $E[\Delta | G_i = 1]$ is the expected treatment effect; $E[Y_{i1} | G_i = 1]$ is the amount of inorganic fertiliser used by the group members; and $E[Y_{i0} | G_i = 1]$ is the amount of inorganic fertiliser that would have been used by group members had they not been group members. The ATT captures the change in the amount of fertiliser (outcome) realised by households which are group members subject to their group membership status.

The fundamental evaluation problem is that of missing data.[41] This is because the amount of inorganic fertiliser for the group members, had they not been group members, cannot be observed. Similarly, the amount of inorganic fertiliser used by the non-member households, had they been group members, cannot be observed. In other words, the treatment indicator takes either one or zero, but not both. The PSM procedure was used to generate the missing data.[42-46] PSM can estimate the causal group membership impact as the difference between the amount of fertiliser used for the group members and what would have been the case if these members had not joined groups. Estimating the propensity score, which is simply the probability that a household is a group member, is a crucial step in using matching as an evaluation strategy. The logit model was used to generate the propensity scores as follows:

$$p(Z_i) = Prob(G_i = 1 | Z_i) \qquad \text{Equation 3}$$

where $p(Z_i)$ is the propensity score; G_i is group membership; and Z_i are the observed household socio-economic characteristics affecting group membership.

According to Becker and Ichino[47], an estimate of the propensity score is not enough to estimate the average treatment effect on the treated (ATT), because the probability of observing two units with exactly the same value of the propensity score is, in principle, zero. Various matching algorithms have been proposed in the literature to determine the region of common support. The most widely used are the nearest-neighbour matching, radius matching, Kernel matching and stratification matching.[41,47-49]

A matching estimator is considered good if, on the one hand, it does not eliminate too many of the original observations from the final analysis, while, on the other hand, it yields statistically equal covariate means for households in the treatment and control groups.[7,50] The nearest-neighbour matching and Kernel matching are reported in this study. The nearest neighbour was chosen because it is generally used in practice because of its ease of implementation, while Kernel matching is a recently developed technique that is gaining popularity in non-experimental literature.[41] The balancing property was selected in estimating the propensity scores. The use of the balancing property ensures that a comparison group is constructed with observable characteristics distributed equivalently across quintiles in both the treatment and comparison groups.[41]

In constructing the matching estimates, the common support was imposed. The treatment observations with weak common support were dropped, as inferences can be made about causality only in the area of common support.[48] All the standard errors were bootstrapped with 1000 repetitions, as suggested by Smith and Todd[41]. The sensitivity of the estimated average adoption effects to hidden bias was tested using the Rosenbaum bounds sensitivity test.[51] This test indicates how strongly an unobservable variable must influence the selection process to undermine or reverse the findings based on matching on observables.[51-53] Previous studies on group membership impacts such as Abebaw and Haile[7], Cunguara and Darnhofer[54] and Tilahun et al.[34] have used the same approach to test for hidden bias in impact estimates. We focused on positive self-selection in search for evidence for overestimation of ATT, even though the Rosenbaum procedure provides bounds to both positive and negative self-selection.

The estimation of ATT assumes a homogenous treatment effect among the group members. However, as explained in previous studies,[7,40,54,55] the treatment effects are not the same for all the different socio-economic groups within the same treatment group. To investigate the extent to which the treatment effect on fertiliser adoption varies within group members, ordinary least squares regression of the household-level treatment effect on some background characteristics of the group members was estimated.

Results and discussion

Descriptive statistics

Table 2 presents the descriptive statistics of the interviewed households according to group membership status. The table shows that 414 of the sampled households were group members, representing over 42% of the sample. Discussion with the group members indicated that most of these groups have not yet been formally registered, although there is a government effort to ensure that these groups are formally registered as cooperatives. The group members indicated that the groups render several services to their members, such as dissemination of price or market information, collective purchasing of input, output market access, credit and savings, training and information/experience sharing. Some of the benefits of group membership, according to the farmers, is that groups make it easier to access government or NGO support, as these bodies prefer to disseminate extension information, inputs and other forms of support to groups over individuals. The high proportion of smallholders who are members of farmer groups implies that the government's drive to ensure that at least 30% of smallholders are members of groups may have been achieved in the study area. However, the process of formal registration is ongoing.

Table 2 shows that group members were more educated, had bigger households and were wealthier (in terms of land, livestock, assets and income) than the non-members. Table 2 also suggests that group members have better access to support services such as extension, information and credit. The non-farm business owners and those with more farming experience were less likely to be group members. Most sampled households in Uthukela and Umkhanyakude districts were members of the various farmer groups.

Table 2 also shows that inorganic fertiliser use is significantly different between group members (59%) and non-members (53%). Among the fertiliser users, the table indicates that the group members applied nearly

Table 2: Descriptive statistics of sample households according to group membership status

Variable	Means			*t*-test (X^2 tests)
	Pooled sample (*n*=984)	Group members (*n*=414)	Non-members (*n*=570)	
FERTUSE	0.56	0.59	0.53	3.86**
FERTKG[a]	245.40	357.21	172.85	4.37***
AGE	56.11	56.31	55.96	0.42
GENDER	0.47	0.50	0.44	4.46**
EDUCAT	4.67	4.95	4.47	1.78*
HHSIZE	7.04	7.70	6.56	4.98***
LAND	1.93	2.50	1.52	3.44***
TLU	3.53	4.95	2.49	2.18**
ASSETS	82 105.38	88 178.31	77 694.52	4.20***
TOTINC	46 757.43	51 581.08	43 253.93	3.97***
EXTENSION	0.57	0.68	0.49	35.38***
INFORM	2.28	2.65	2.01	9.37***
CREDIT	0.36	0.40	0.32	6.79***
TRAINING	0.41	0.57	0.30	76.63
ROADDIST	17.75	17.28	18.01	-0.31
FARMEXP	18.70	16.25	20.47	4.98***
IRRIGAT	0.46	0.48	0.45	0.86
EMPLOYED	0.20	0.19	0.21	0.22
BUSINESS	0.08	0.11	0.06	5.97**
HGWALA	0.42	0.17	0.60	180.60
UMZINYAT	0.24	0.26	0.23	0.94
UTHUKELA	0.19	0.28	0.13	35.79***
UMKHANYA	0.15	0.29	0.04	120.20***

[a]*Indicates the 554 farmers who used inorganic fertilisers.*

*Significant at the *10%, **5% or ***1% level.*

double the fertiliser quantities applied by the non-members. The box-and-whisker plots in Figure 1 also show that group members used higher quantities of fertiliser than non-members, and that there were relatively higher variations in the fertiliser quantities used among group members than among non-group members. Figure 2 presents the plots showing the quantity of fertiliser used by farmers according to group status and district. Again, the figure shows higher levels of fertiliser use and variations among group members across all districts, with the exception of the Umzinyathi district. However, at this stage, the results should not be used to make inferences regarding the impacts of groups on improved agricultural technology adoption as confounding factors have not been controlled for, which is done through the econometric model later.

Determinants of group membership and estimation of the propensity scores

The logit model was estimated to investigate the factors associated with membership in farmer groups and compute the propensity scores. The results are presented in Table 3. The estimated model fits the data reasonably well as the likelihood ratio X^2 is statistically significant at the 1% level and the model correctly predicts 80% of the sample observations. Most of the variables in Table 3 have the expected signs. The results indicate that group membership is significantly associated with a household's demographic and socio-economic characteristics as well as access to support services.

Table 3 shows that, consistent with previous literature[2,7,27], age is associated with increasing chances of group membership. An additional year is associated with an increase of 0.4% in the likelihood of group membership. This implies that older farmers are more inclined towards working as groups while the younger prefer working as individuals. The reason is that older farmers would have developed more contacts and trust, and have more positive attitudes to group membership than younger farmers. The insignificant coefficient of gender suggests no bias in group membership. This is in contrast to past studies[2,7] which have indicated that female-headed households are less likely to join groups

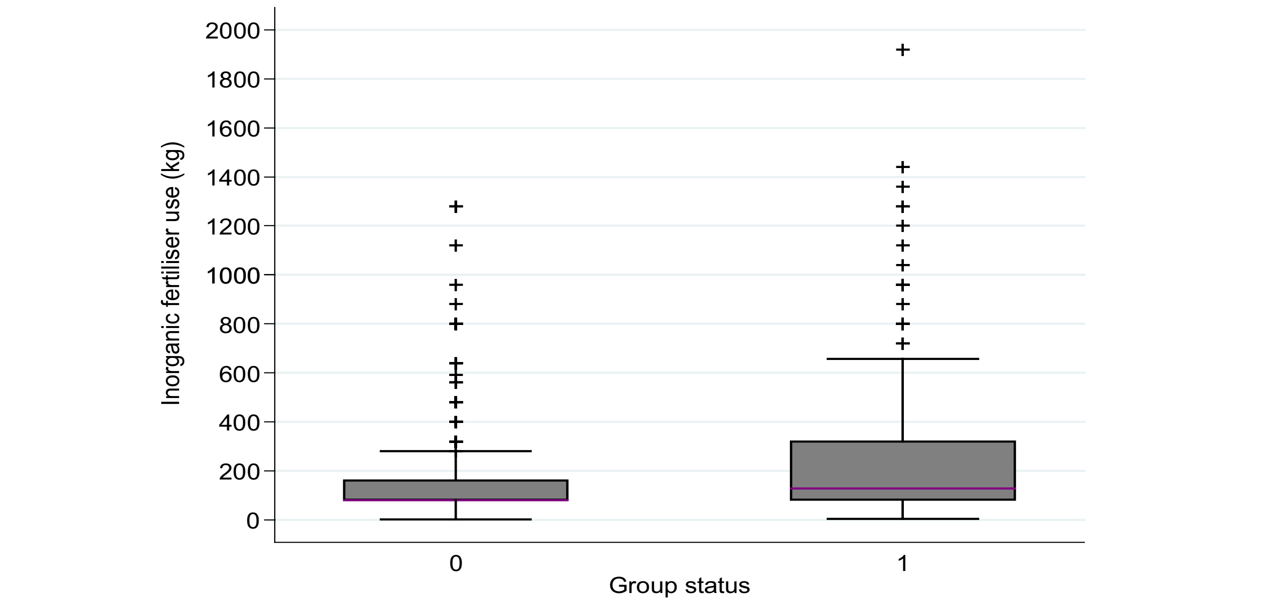

Figure 1: Box-and-whisker plots showing the quantity of fertiliser used by farmers according to group status: 0 indicates non-members and 1 indicates group members.

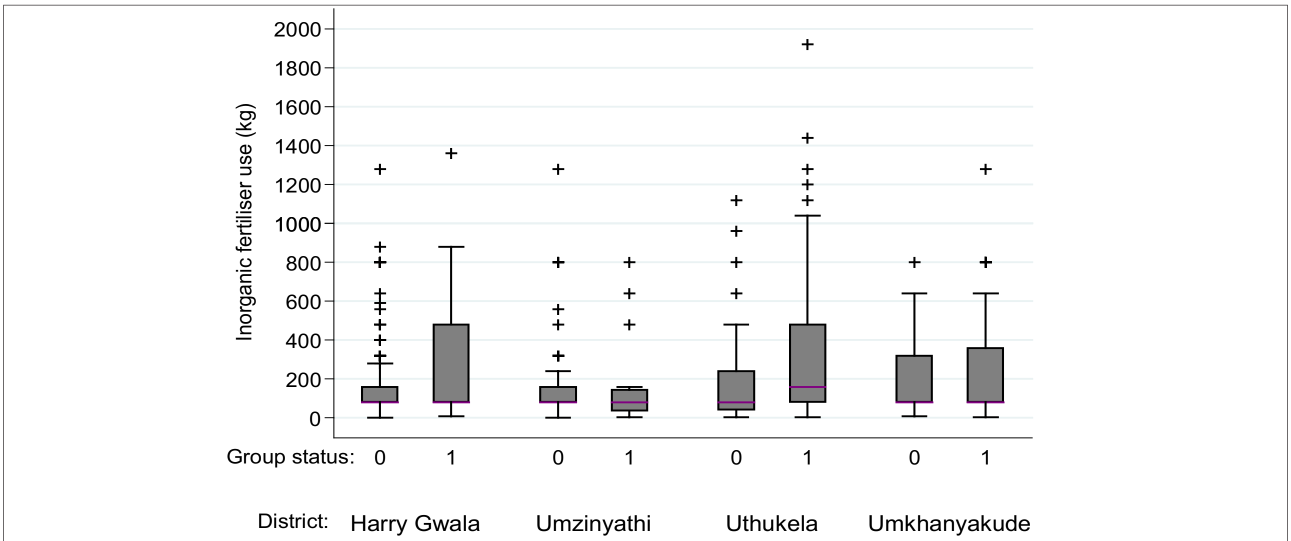

Figure 2: Box-and-whisker plots showing the quantity of fertiliser used by farmers according to district and group status: 0 indicates non-members and 1 indicates group members.

Table 3: Factors determining farmer group membership: logit model results

Variable	Coefficients		Marginal effects	
	Value	Standard error	Value	Standard error
AGE	0.028***	0.008	0.004***	0.001
GENDER	-0.169	0.196	-0.025	0.029
MARRIED	0.269	0.184	0.040	0.028
HHSIZE	0.045*	0.025	0.007*	0.004
EDUCAT	0.039*	0.022	0.006*	0.003
LAND	0.364***	0.085	0.055***	0.012
TLU	-0.014	0.014	-0.002	0.002
ASSETS[a]	0.224*	0.126	0.033*	0.019
INCOME[a]	0.267*	0.149	0.040*	0.022
EXTENSION	0.275**	0.113	0.041**	0.020
INFORM	0.375***	0.082	0.056***	0.012
CREDIT	0.204	0.176	0.030	0.026
TRAINING	1.067***	0.186	0.159***	0.026
ROADDIST	-0.010***	0.002	-0.002***	0.000
FARMEXP	-0.026***	0.007	-0.004***	0.001
IRRIGAT	0.115***	0.016	0.017***	0.006
EMPLOYED	-0.208	0.243	-0.031	0.036
BUSINESS	0.921***	0.334	0.138***	0.049
HGWALA	-2.063***	0.251	-0.308***	0.032
UTHUKELA	0.025	0.269	0.004	0.040
UMKHANYA	1.789***	0.352	0.267***	0.049
_CONSTANT	-8.119	1.922		
Pseudo R^2	0.332			
Likelihood ratio X^2	249.59***			
% predicted correctly	0.80			

[a]Assets and income values were logged.

*Significant at the *10%, **5% or ***1% level.*

than male-headed households because women face higher opportunity costs of time as a result of family responsibilities in addition to farming, reducing their incentives for group membership.

In line with studies such as Bernard and Spielman's[26] and Fischer and Qaim's[2], the results indicate that household size is positively associated with group membership. Presumably, bigger households are more likely to participate in groups as a consequence of labour availability. Education, as a proxy of human capital, is also positively associated with participating in groups because the more educated are more likely to understand and interpret information better, which will result in them facing lower transaction costs and benefiting more from the group membership. Table 3 shows that increasing land size is positively correlated with membership in farmer groups. An increase of 1 ha is associated with an increased chance of group membership of 5.5%. The net benefits of farmer group membership increase with increasing farm size, possibly because bigger farms signify increased agricultural production potential. As membership costs are usually fixed, farmers who produce more are likely to benefit more from the groups.

The same pattern also applies to other proxies of physical and financial capital such as asset values, income, irrigation access and ownership of non-farm micro-businesses. The positive relationship between physical as well as financial capital and group membership has been shown by several past empirical studies.[2,7,17,26,27,34,56] The reason is that gains from participation in farmer groups are larger if a household owns complementary assets that enhance successful cooperation.

Access to support services such as extension, information services and training are associated with increased likelihood of group membership. Such services ease access to relevant information about the benefits of group membership. This is in line with previous literature.[7,34] In South Africa, extension officers have been in the forefront of promoting group formation as the government prefers working with farmer groups. As such, extension officers are likely to influence the farmers they contact to form groups. Training also increases the chance of group membership by close to 16%. A counterintuitive result in Table 3 is that distance to the nearest all-weather road has a significant and negative effect on group membership. One would have expected that farmers furthest from all-weather roads are more likely to join groups to alleviate transportation costs. A plausible explanation is that farmers in isolated areas do not have access to enough information about the benefits of group membership. This is unfortunate, as these are the farmers who would benefit the most from group membership (Table 7).

Farming experience is associated with decreasing chances of group membership. This suggests that experienced farmers would have developed enough individual capacity such that they prefer to work as individuals. The results also show location effects as district dummies, which were included to account for unobserved agro-climatic, institutional, market access and socioeconomic heterogeneities among the sample districts, were significant. In comparison to farmers located in the Umzinyathi district, farmers in Harry Gwala were less likely to participate in groups, while those in Umkhanyakude were more likely to participate. In summary, the logit results show that group participation was biased towards the educated, the relatively wealthier households and households with access to support services such as extension, training and information. Previous studies have also reported that the poor and uneducated tend to be excluded from membership in farmer groups.[7,26]

Impact of group membership on inorganic fertiliser use

The PSM method was employed to estimate the impact of group membership on the probability and level of inorganic fertiliser use. Table 4 shows the impact of group membership on fertiliser use probability. The impacts are estimated using both nearest-neighbour and kernel matching to ensure robustness.

Table 4: Impact of group membership on the probability of inorganic fertiliser use

Matching method	Number of households		ATT	*t*-test
	Treatment	Control		
Nearest neighbour	414	158	0.140 (0.063)	2.210**
Kernel matching	414	461	0.148 (0.052)	2.849***

*Significant at the **5% or ***1% level.*

Table 4 shows that both the matching estimators yield similar results and that group membership has a positive and statistically significant effect on the probability of inorganic fertiliser use. The results indicate that the fertiliser use rate would be 14% lower if the farmers had not participated in farmer groups. The Rosenbaum bounds sensitivity analysis showed that the conclusion would change at a bounds statistic (Γ) of 2.35. This implies that the results are only sensitive to a hidden bias that would more than double the odds of being a group member. Therefore, it is concluded that the results are not very sensitive to hidden bias, because it would require more than 130% of bias to reverse the conclusion.

Table 5 shows the impact of group membership on fertiliser use level. The table shows that the fertiliser use level would have been between 134 kg and 168 kg lower had farmers not joined farmer groups, indicating the positive role that farmer groups play in fertiliser use. Rosenbaum bounds test showed that the conclusion would change at $\Gamma = 4.35$, implying that the results are not very sensitive to hidden bias because it would require more than 300% of bias to reverse the conclusion.

Table 5: Impact of farmer group membership on inorganic fertiliser use level

Matching method	Number of households		ATT	*t*-test
	Treatment	Control		
Nearest neighbour	218	88	167.41 (52.95)	3.161***
Kernel matching	218	288	134.23 (49.60)	2.706***

*Significant at the ***1% level.*

To further evaluate the reliability of the above reported estimates, the balancing tests based on nearest neighbour were done and the results are presented in Table 6. The table shows that, after matching, both group members and non-members have characteristics that are statistically similar. The test for equality of the two group means shows that there is no statistically significant difference between members and non-members after matching. This contrasts with the unmatched sample presented in Table 2 which indicated statistically significant differences in several covariates between the two groups. The standardised differences (% bias) for the mean values of all the covariates between members and non-members are below 20%, implying that the balancing requirement is adequately satisfied.[57]

Table 6: Test of matching quality

Variable	Means		% Bias	% Reduction |bias|	*p*-value of equality of mean
	Members	Non-members			
AGE	56.31	55.60	5.4	-99.8	0.42
EDUCAT	4.95	5.14	-2.4	68.3	0.50
HHSIZE	7.70	7.71	-4.6	59.6	0.97
LAND	2.50	3.14	-13.5	68.7	0.23
TLU	4.95	4.18	4.1	68.8	0.57
ASSETS[a]	11.25	11.31	-9	66	0.11
TOTINC[a]	10.65	10.60	7.9	46	0.24
EXTENSION	0.68	0.71	-7.5	81	0.26
INFORM	2.65	2.74	-8.7	85.7	0.19
CREDIT	0.40	0.36	9.1	46	0.20
TRAINING	0.57	0.53	10.1	82.6	0.16
ROADDIST	17.28	17.83	-1.4	31.7	0.84
FARMEXP	16.25	15.60	5	84.5	0.43
IRRIGAT	0.48	0.44	7.3	-21.6	0.30
EMPLOYED	0.19	0.16	8.5	-181.2	0.20
BUSINESS	0.11	0.10	2.6	83.2	0.73
HGWALA	0.17	0.17	0	100	1.00
UTHUKELA	0.28	0.30	-4.3	88.9	0.59
UMKHANYA	0.29	0.29	0	100	1.00

[a]Assets and income values were logged.

Impact heterogeneity

To investigate the extent to which the treatment effect on fertiliser adoption differs among group members, the ordinary least squares regression was estimated and results are presented in Table 7. The table shows that the impact of group membership is not the same among members. The results show that group membership increases inorganic fertiliser use more for the less educated than for those with more education. This is, as explained by Abebaw and Haile[7], an important result as the poorly educated are less likely to adopt improved farm inputs as a result of their limited ability to understand and interpret new information on technologies. The impact is also larger for those with smaller household sizes and those households with more land and assets and fewer livestock. This result suggests that group membership benefits the richer more than it does the poorer.

Table 7: Heterogeneous fertiliser use impacts among group members

Variable	Coefficient	Standard error
AGE	-0.001	0.002
GENDER	-0.039	0.053
MARRIED	-0.015	0.051
EDUCAT	-0.012*	0.006
HHSIZE	-0.013**	0.006
LAND	0.025***	0.008
TLU	-0.004**	0.002
ASSETS	0.097***	0.036
INCOME	0.052	0.038
EXTENSION	0.090*	0.055
INFORM	0.043*	0.022
CREDIT	0.043	0.048
TRAINING	-0.067	0.048
ROADDIST	0.002***	0.001
FARMEXP	0.006***	0.002
IRRIGAT	0.156***	0.047
EMPLOYED	-0.073	0.073
BUSINESS	0.275***	0.091
HGWALA	0.047	0.076
UTHUKELA	0.344***	0.067
UMKHANYA	-0.117*	0.070
_CONS	-1.335	0.529
N	414	
F	6.16***	
R^2	0.248	

*Significant at the *10%, **5% or ***1% level.*

The farmers with access to extension and information would benefit more from farmer groups, as would farmers with access to irrigation. The results also suggest that the impact of farmer groups on inorganic fertiliser adoption is larger for experienced farmers, farmers located further from all-weather roads and owners of small, non-farm businesses. The greater impact of group membership for the farmers further away from all-weather roads suggests that groups contribute towards alleviating the transaction costs that these isolated farmers face. The fact that gender is not significant suggests that the impact of farmer groups on fertiliser adoption is the same for both male and female farmers, indicating no gender bias.

Conclusions and policy implications

The South African government has identified increased smallholder productivity and commercialisation as an integral part of the strategy for stimulating rural economic development and reducing poverty. The government has also invested considerable effort in organising smallholder farmers into groups to establish an enabling institutional environment for agricultural intensification and achieving sustainable, inclusive and better growth in the sector. Limited research has investigated the role of these farmer groups in improving the adoption of modern farm inputs. We investigated the impact of groups on the use of inorganic fertilisers using cross-sectional data from 984 households and the PSM technique.

The empirical results indicate that participation in farmer groups significantly and positively influences fertiliser use. Group membership improves the average fertiliser application rate by about 14%, and the fertiliser use level by 134–168 kg. The Rosenbaum bounds tests indicate the impact estimates obtained using the PSM approach were robust to hidden bias. The results also show greater group membership impact for the less educated, the wealthier (more land and assets), the irrigators, those with access to extension and information and those located further from all-weather roads. The findings suggest that the government's strategy of organising farmers into groups for improved smallholder production activities should continue, as groups raise the demand for improved farm inputs such as inorganic fertilisers. For greater effectiveness of membership of groups in improving modern technology adoption among smallholders, policymakers should target the less educated, increase the assets of the poor and improve access to extension and information.

Authors' contributions

S.S. was responsible for conceptualisation, methodology, data collection, data analysis, and writing the initial draft and revisions. M.M. was responsible for the methodology and critically reviewing the writing and revisions.

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