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Heterogeneous welfare effects of farmer groups in smallholder irrigation schemes in South Africa

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Abstract

This paper analyses the heterogeneous effects of membership of a farmer group on access to water, use of inorganic fertiliser, household incomes, and farm asset holdings. A sample of 401 irrigators in South Africa was analysed using propensity score matching. The study found that group membership had a positive effect on all four outcomes. Group members had an extra four days of access to water in a month, and applied at least 130 kg/ha more inorganic fertiliser, than non-group members. Group members had a higher household income per capita and more assets than non-group members. However, the result revealed a heterogeneous effect among group members, with the benefits varying according to members' socio-economic characteristics as well as internal group dynamics. The government and private donors should continue to promote the formation and organisation of farmers into groups. The role of group membership in farming outcomes can be enhanced if smaller groups are promoted. It is also crucial that strategies for promoting trust, reciprocity and group commitment be implemented for better group outcomes.

Key words: farmer groups; smallholder; heterogeneous impact; propensity score matching

1. Introduction

In many developing countries, particularly in Sub-Saharan Africa, smallholder agriculture constitutes a key vehicle to lessen poverty (Cele & Wale 2018; Phakathi & Wale 2018; Van Averbeke *et al*. 2011). In South Africa, the Department of Agriculture, Forestry and Fisheries ([DAFF] 2012) and the Department of Economic Development ([DED] 2010) aimed to pay particular attention to increasing food security, job opportunities and the effect of agriculture on the gross domestic product through expanding the commercially-oriented smallholder farming sector by 300 000 by 2020. However, the performance of the smallholder sector is still reported to be below potential because of limited access to irrigation water, low adoption of modern farming technologies (such as inorganic fertiliser), and poor access to farming equipment, among other challenges (Crawford *et al*. 2006; Morris *et al*. 2007; Cele & Wale 2018; Selejio & Lasway 2019).

Faster agricultural growth in Africa requires improving soil fertility to meet the Sustainable Development Goals, such as eradicating poverty and hunger by 2030 (Crawford *et al*. 2006; Sinyolo & Mudhara 2018b). The Sub-Saharan countries, in particular, have experienced low crop productivity because of limited use of inorganic fertiliser. The average use of inorganic fertiliser in Sub-Saharan Africa, at 8 kg per hectare, is far below the 78, 96 and 101 kg per hectare used in Latin America, East Asia and South Asia respectively (Crawford *et al*. 2006; Morris *et al*. 2007). The limited use of modern technologies such as inorganic fertilisers are due, among others, to the higher transactional costs of accessing input and output markets (Duflo *et al*. 2011; Sinyolo & Mudhara 2018b). Water insecurity is prevalent among smallholder irrigators in South Africa because of economic and physical water scarcity, which disincentivises farmers from adopting inorganic fertilisers (Cousins 2013, Sinyolo *et al*. 2014; Sharaunga & Mudhara 2016). Modern inputs such as inorganic fertilisers are costly and produce higher yields under conditions of adequate moisture. As such, farmers are more likely to invest in these technologies when they have access to secure and reliable irrigation water, which reduces the risk of crop failure and results in increased production and returns (Hussain & Hanjra 2004; Sinyolo *et al*. 2014).

Transitioning through groups offers farmers a better opportunity to overcome transaction costs and access inputs and output markets. Participating in farmer groups reduces transaction costs, as it enables the sharing of information, inputs and transportation costs. Also, farmers in groups often buy together in bulk, resulting in economies of scale and improved bargaining power. These group advantages lead to a greater likelihood of the use of inorganic fertiliser, among other inputs, improved access to water, higher productivity and better output prices, which lead to higher household incomes and asset accumulation (Nilsson 2001; Fischer & Qaim 2012; Abebaw & Haile 2013; Sinyolo & Mudhara 2018a; Bachke 2019). Several empirical studies have reported the positive effect of farmer groups on various outcomes in the smallholder sector, such as fertiliser use, crop yields, market access, incomes and poverty reduction (Abebaw & Haile 2013; Fischer & Qaim 2012; Ma & Abdulai 2016; Sinyolo & Mudhara 2018b). Abebaw and Haile (2013) reported that group members improved fertiliser adoption rate by nine to 10 percentage points compared to non-members in Ethiopia. In South Africa, Sinyolo and Mudhara (2018b) revealed that group members applied 170 kg/ha more of inorganic fertiliser, while Sinyolo and Mudhara (2018a) found that the average income per adult equivalent of group members was R3 000 more than that of non-group members. In China, Ma and Abdulai (2016) found that being a member of a group improved apple output, net returns and incomes by 5.36%, 6.06% and 4.66% respectively.

Studies have also found that the benefits of group membership vary among members, based on the groups' internal dynamics as well as the individual members' socio-economic characteristics. However, a few studies (e.g. Barham & Chitemi 2009; Sebhatu *et al*. 2021) have discussed group characteristics and internal dynamics, and how these affect the influences of groups. Often, the focus of studies is on whether a farmer belongs to a group, without investigating the characteristics of the different groups that farmers belong to. No two farmer groups are the same, as they are likely to differ in terms of group size, socio-characteristics of members, available capital assets, internal dynamics, etc., which affect the strength and success of groups (Barham & Chitemi 2009). Barham and Chitemi (2009) found that groups that were characterised by maturity, strong internal institutions, good asset bases of natural capital and male dominance had better market outcomes. Sebhatu *et al*. (2021) highlighted the importance of group total assets, membership size and occurrence of conflict among members as vital factors that influence group performance. It is difficult to monitor and enforce rules in bigger groups because of the increasing transactional cost for rule enforcement due to free-riding among members (Gezahegn *et al*. 2019). Groups dominated by males tend to be more successful because male farmers have better access to resources in rural areas due to patriarchy (Barham & Chitemi 2009; Sharaunga & Mudhara 2016; Sinyolo *et al*. 2018). Moreover, few studies in South Africa have evaluated the heterogeneous effect of group membership on various outcomes, with most focusing on one or two outcomes (e.g. Sinyolo & Mudhara 2018a, 2018b). To further understand if farmer groups are beneficial, it is vital to analyse the heterogeneous effect of group membership on various outcomes, such as access to water and fertiliser, assets holding and household income.

Our contribution in this paper therefore is to analyse the heterogeneous effect of group membership on inorganic fertiliser use, access to water, household incomes and asset holdings in four irrigation schemes (Qamata, Zanyokwe, Tugela Ferry and Mooi River) in the Eastern Cape and KwaZulu-Natal provinces of South Africa. Secondly, the study presents the characteristics and the internal dynamics (e.g. group cohesion, trust, cooperation, etc.) of the farmer groups. These provinces were chosen because they have the second- and third-largest number of irrigation schemes in South Africa, and irrigated agriculture in these areas is an important source of livelihood, given the high temperatures and low rainfall (Van Averbeke *et al*. 2011). Improving agriculture presents an opportunity to alleviate the high poverty rates in these provinces.

The paper is organised as follows: Section 2 provides a theoretical framework on collective action and random utility theory. Section 3 presents the research methodology for data collection, while Section 4 presents a discussion of propensity score matching. Section 5 gives the results and discussion. Lastly, the conclusions and policy recommendations are presented in Section 6.

2. Theoretical framework

This paper evaluates voluntary farmer choice to participate in a group based on random utility theory. It is postulated that farmers are rational agents, and their decision to be part of a group is based on individual expected utility, which should be greater than not being a member of a group (Fischer & Qaim 2012; Sinyolo *et al*. 2018a). This means that a farmer will participate in a group if the anticipated net utility is more than zero. Farmers who are group members benefit from economies of scale because they share information, transaction costs and farming equipment (Nilsson 2001; Sinyolo & Mudhara 2018a; Gezahegn *et al*. 2019). The study postulates that being a member of a group improves bargaining or negotiation power, resulting in a better collective voice. A collective voice enables farmers to fight for better access to water and access to farming equipment. Moreover, economies of scale are realised, as a group buys inputs in bulk and shares input costs, improving fertiliser adoption among farmers. Sharing of information and equipment leads to better crop management practices, which might improve households' incomes. Improved income enables a farmer to further invest in asset accumulation (Shiferaw *et al*. 2009). The cost of being a member involves joining fees and opportunity costs for meeting attendance. These costs and benefits are viewed differently by the individual farmers, influencing their choice to join a group. The latent utility function can be expressed as follows:

$Vi(\beta X_i)$, where Ui = $Vi(\beta X_i) + ui$

X_i represents farmers' exogenous socio-demographic variables (education, experience, age, gender and assets ownership), while unobservable characteristics are signified by the error term (ui). Ui is a binary indicator that is equal to 1 if the farmer is a group member and 0 if the farmer is not a group member. Choosing to be a member is represented by the probability: P $(U_i < \beta X_i)$. Therefore, the model can be estimated using a logit model.

Table 1 presents the variables that were used in the analysis. The independent variables presented are pre-treatment variables, while the outcome variables are post-treatment variables.

Table 1: Description of variables

Variable code	Variable description	Expected sign
Outcome variables		
WATER ACCESS	Number of days with access to water in last 30 days	
FERTILISER USE	Kg of fertiliser per ha	
ASSET VALUES	Holding assets value (ZAR)	
INCOME PER CAPITA	Household income per capita (ZAR)	
Treatment variable		
FARMER GROUP MEMBER	Group membership (1 = yes; 0 = no)	
Independent variables		
AGE	Age (years)	+/-
EDUC	Education level (grades)	+
SEX OF THE RESPONDENT	Gender (1 = male; 0 = female)	+
FARM_EXPERIENCE	Years of farming experience	+/-
MARRIED	Marital status (1 = married; 0 = otherwise)	+
FULL TIME FARMER	Occupation (1 = fulltime farmer; 0 = otherwise)	+
HHS	Household size (numbers)	+
TOT_HA	Land size (hectares)	+
CROP_TYPE	Type of crop grown (1 = cash crop; 0 = food crop)	+
ACCESS_EXTENSION	Farmers access to extension service (1 = yes; 0 = no)	+
ACCESS_CREDIT	Farmers access to credit (1 = yes; 0 = no)	+
GRAVITY_MODE	Mode of irrigating (1 = gravity; 0 = otherwise)	+/-
QAMATA	Scheme (1 = Qamata; 0 = otherwise)	+
ZANYOKWE	Scheme (1 = Zanyokwe; 0 = otherwise)	+
MOOI-RIVER	Scheme (1= Mooi River; 0 = otherwise)	+

To capture access to water, farmers were asked about the number of days they had uninterrupted access to water in the last 30 days. This procedure was considered reliable, because asking about the previous four weeks is regarded short enough to minimise recall problems and long enough to give some variation of the number of days that they had access to water (Sinyolo *et al*. 2018). The fertiliser was measured in kilograms per hectare, while asset holding was measured by the total value of farming assets owned by the farmer, such as a tractor, hand hoes, shovels, spades, wheelbarrow and fertiliser sprayer. Lastly, household income was calculated as the total household income annually from irrigated crops and off-farm incomes.

The independent variables specified in Table 1 were identified from the existing literature (Abebaw & Haile 2013; Sinyolo & Mudhara 2018b; Bachke 2019). There have been mixed results on the determinants of being a group member in smallholder farming. Socio-economic variables such as experience in farming, size of household, farmer’s age, marital status, gender, education, land size, access to extension service and wealth-related measures (livestock size) have been reported to be positively correlated with group membership (Ouma & Abdulai 2009; Abebaw & Haile 2013; Sinyolo & Mudhara 2018a). For example, in terms of gender, empirical results have indicated that men tend to participate and benefit more than women (Ouma & Abdulai 2009; Fischer & Qaim 2012; Sinyolo & Mudhara 2018b). This is because of inequality in access to farming assets, as patriarchal systems produce a multitude of socio-cultural bottlenecks against females, particularly in relation to land ownership (Cousins 2013; Sharaunga & Mudhara 2016). Age has often been associated positively with group membership, because older farmers benefit more from other group members’ labour supply (Ouma & Abdulai 2009; Sinyolo & Mudhara 2018b). Studies have reported that experience in farming is negatively associated with group participation, suggesting that experienced farmers acquire sufficient capacity to farm individually over time, as they have established various networks (Sinyolo & Mudhara 2018b).

3. Sampling approach and data collection methods

The data were collected using a multi-stage sampling method. Firstly, the Eastern Cape and KwaZulu-Natal provinces were purposively selected because they have the second- and third-largest irrigation schemes in South Africa. In these provinces, irrigated agriculture is the primary source of livelihood among rural farmers because of high temperatures and low precipitation (Van Averbeke *et al*. 2011; Muchara *et al*. 2014). In stage two, four irrigation schemes were purposively selected from a list of irrigation schemes in the Eastern Cape and KwaZulu-Natal provinces. The lists were obtained from the provincial departments of agriculture. After field visits to most of the schemes and informal discussions with farmers on scheme dynamics, the Qamata and Zanyokwe irrigation schemes of the Eastern Cape and Tugela and Mooi River irrigation schemes of KwaZulu-Natal were selected. Table 2 summarises the characteristics of the selected irrigation schemes (Van Averbeke *et al*. 2011; Cousins 2013; Cele & Wale 2018; Phakathi *et al*. 2021).

Table 2: Key characteristics of the selected irrigation schemes

	Tugela Ferry	Mooi River	Qamata	Zanyokwe	Average
Province	KZN	KZN	EC	EC	-
Year formed	1898	1902	1960	1983	-
Irrigable size (ha)	837	600	400	450	572
Main canal length (m)	34	25	28	-	29
Average plot size (ha)	0.2	0.4	2	3	1.4
No. of irrigators	1 500	824	350	164	710
No. of blocks	7	15	7	6	9
No. of blocks selected	7	9	6	6	7

The next sampling stage involved the selection of farmer groups in the four chosen irrigation schemes. The contact details of the group chairperson were obtained from the local extension officers in the Department of Agriculture. The total number of groups selected was 28 (Tugela Ferry – 7, Mooi River – 9, Qamata – 6, Zanyokwe – 6), and the group chairpersons were interviewed to provide group information. A list obtained from the extension officers and group chairpersons was used to select farmer group members randomly. A total of 228 group members were sampled, ensuring that at least 10% of the population was sampled from each group. Furthermore, 173 non-group members located in the same communities and irrigation schemes as the group members were randomly selected using a list obtained from the extension officers. The total sample size was 401, because it represented at least 10% of the population size.

Data were collected in 2019 by four enumerators who spoke IsiZulu and IsiXhosa, the languages spoken in KwaZulu-Natal and the Eastern Cape respectively. Structured questionnaires, focus group discussions and key informant interviews were used. The questionnaires were translated into the farmers' home languages. The enumerators were trained and the questionnaires were pretested before the survey. The questionnaire covered questions relating to socio-demographics, production and perceptions of internal group dynamics. Interviews on group information were done with the chairperson, secretary and treasurer of each group. It is important to note that our target was an irrigator responsible for the management of the farming on an irrigation plot and responsible for making farming decisions, whether or not they were the household head.

4. Propensity score matching

To investigate the influence of group membership on access to water, inorganic fertiliser use, asset holding and incomes (WFAI), propensity score matching (PSM), a widely used tool for impact valuation, was employed. PSM is used to generate a statistical contrast group based on model probability to evaluate the treatment effect of a set of exogenous factors (Nguyen 2006). This technique has been used commonly in the agricultural sector to investigate the effects of group membership on various outcomes (Fischer & Qaim 2012; Sinyolo & Mudhara 2018a, 2018b; Bachke 2019). The PSM method requires a treatment variable to be binary; therefore, group membership status was treated as a binary treatment, and non-group members as a control group. PSM is grounded in the conditional independence or confoundedness assumption, which assumes that the selected outcomes (WFAI) are independent of membership status of the farmer group, conditional on the set of observable characteristics. PSM relies on non-parametric regression methods to construct the counterfactual based on the observable pre-treatment characteristics (Baker 2000; Blundell & Costa Dias 2000).

This paper assumes that M_i represents the farmer's membership status i, where $M_i = 1$ if the farmer is a group member and $M_i = 0$ if the farmer is not a group member. If a farmer is a group member, then access to water, fertiliser, asset holding and income (WFAI) is Y_{1i}. Therefore, if the ith farmer is not a member, these outcomes (WFAI) are represented by Y_{0i}. The average treatment effect (ATE) denotes the weighted average, which tells us about the expected effect of group membership status on the selected outcomes (WFAI) for the whole population (Cobb-Clark & Crossley 2003).

$$ATE = E[\Delta i] = E[Y_{1i} - Y_{01}] \quad (1)$$

$$= E[Y_{1i} \_ Y_{0i}|M_1 = 1]Pr(M_i = 1) + E[Y_{1i} \_ Y_{0i}|M_1 = 1]Pr(M_0 = 0), \quad (2)$$

where $E[\Delta i]$ is the anticipated effect on household i; Pr is the probability of participating in a farmer group; and the other variables are as explained above. However, this paper intended to evaluate the effect of being a group member on those farmers who are group members, which is the average treatment effect on the treated (ATT). ATT represents the possible change in these outcomes (WFAI) gained by being a group member.

$$ATT = E[\Delta i|M_i = 1] = E\left[Y_{1i,t}|M_i = 1\right] - E\left[Y_{0i,t}|M_i = 1\right], \quad (3)$$

where E[Δi|Mi = 1] represents the expected treatment effect; $E\left[Y_{1i,t}|M_i = 1\right]$ denotes the selected outcome variables (WFAI); and $E\left[Y_{0i,t}|M_i = 1\right]$ is the ATT for the WFAI outcomes of the members if they were not part of a farmer group (Nguyen 2006).

In comparing group members and non-group members, survey data was used to generate scores from the population over a set of pre-treatment socio-economic variables, as shown in Table 1. The p-scores were generated based on pre-treatment covariates using recall data. Generating a propensity score (probability of being a group member) is imperative when employing matching as the valuation approach, and therefore the logit model was employed to estimate the p-scores. The likelihood of detecting binary units with precisely the identical value of the p-scores is zero. Therefore, neighbour, kernel and radius matching were used to validate the results to eliminate biased results (Becker & Ichino 2002). This is because these matching methods are not dependent on a particular functional form of the outcome; hence, they eliminate linearity imposition, multicollinearity and heteroskedasticity challenges (Nguyen 2006). Since PSM relies only on observed characteristics, we tested the sensitivity of the results to hidden bias using the Rosenbaum sensitivity test (Rosenbaum 2002; Nguyen 2006). This test indicates how strongly an unobservable variable must influence the selection process to undermine or reverse the findings based on the matching of observables.

The estimation of ATT assumes a homogenous effect among the group members. However, as explained, the treatment effects are not the same for all the different socioeconomic groups within the same treatment group. Following studies such as Verhofstadt and Maertens (2015) and Wossen *et al*. (2017), this paper used the ATT of each outcome indicator as a dependent variable. The ordinary least squares regression (OLS) was then estimated to investigate the extent to which the treatment effect varied within group members according to background characteristics.

5. Results and discussion

5.1 Descriptive statistics

Table 3 presents the farmers' socio-economic characteristics according to their membership status. The total sample size was 401, of which 57% were group members and 43% were non-group members. During the focus group discussions, extension officers elaborated that the government encouraged farmers to join farmer groups to apply for input support, and for other funding applications to be processed. The government prioritises farmers in groups because it reduces the transaction costs for offering extension support.

Table 3: Descriptive statistics of farmers based on group membership

Factors	Means			T-test
	Pooled sample (n = 401)	Group members (n = 228)	Non-group members (n = 173)	
WATER ACCESS	4.27 (0.27)	6.14 (0.41)	3.81 (0.19)	8.76***
FERTILISER USE KG/HA	126.93 (7.97)	183.16 (12.13)	52.82 (5.51)	8.84***
INCOME PER CAPITA	2 548.78 (277.76)	3 526.359 (324.63)	1 260.411 (464.32)	4.1204***
ASSETS VALUE (logged)	8.67 (0.05)	9.251 (0.06)	7.900 (0.05)	15.207***
AGE	53.69 (0.557)	53.74 (0.72)	54.82 (0.87)	0.90
SEX OF THE RESPONDENT	4.49 (0.22)	4.62 (0.29)	4.32 (0.34)	0.66
GENDER	0.33 (0.02)	0.33 (0.03)	0.32 (0.04)	0.32
FARM_EXPERIENCE	19.16 (0.54)	18.46 (0.71)	20.09 (0.84)	1.49
MARRIED	0.58 (0.02)	0.61 (0.03)	0.54 (0.04)	1.24
FULL TIME FARMER	0.89 (0.02)	0.96 (0.01)	0.81 (0.03)	4.83***
HHS	6.22 (0.15)	6.50 (0.20)	5.97 (0.23)	1.64*
TOT_HA	1.36 (0.09)	1.37 (0.13)	1.33 (0.11)	0.24
CROP-TYPE	0.74 (0.29)	0.73 (0.03)	0.75 (0.03)	0.39
ACCESS_EXTENSION	0.82 (0.01)	0.89 (0.02)	0.72 (0.03)	4.26***
ACCESS_CREDIT	0.26 (0.02)	0.32 (0.03)	0.19 (0.02)	2.93**
GRAVITY_MODE	0.85 (0.02)	0.74 (0.03)	0.99 (0.01)	7.58***
QAMATA	0.24 (0.02)	0.07 (0.02)	0.46 (0.04)	10.2**
ZANYOKWE	0.16 (0.02)	0.22 (0.03)	0.08 (0.02)	4.09***
MOOI-RIVER	0.25 (0.02)	0.29 (0.03)	0.20 (0.03)	2.23**
TUGELA FERRY	(0.34) (0.02)	(0.40) (0.03)	(0.27) (0.03)	2.89***
YEARS_FARMER-GROUP	3.12	5.44	-	

Standard errors in parentheses. Significance levels are represented by * = 10%, ** = 5% and *** = 1%

Farmers who were not group members indicated that it was harder to receive government support because the fee for joining a group hinders participation in a group. Table 3 indicates the differences in statistical significant between the two groups in all the outcome indicators (WFAI). The outcomes of group members were better than those of non-group members. On average, group members applied 183 kg/ha of inorganic fertiliser, compared to 53 kg/ha applied by non-group members. Group members had an extra two days of access to irrigation water, which is vital, given the high temperatures and persistent droughts. Moreover, group members were different to non-group members across various socio-economic characteristics, such as full-time farmer status, household size, access to extension service, etc. The results show that most smallholder farming is dominated by older and female farmers, as males tend to migrate to urban areas while women remain in rural areas to care for their children (Cousins 2013). The average number of years that group members had participated in groups was 5.44 years. The respondents were asked to provide data in relation to the situation before joining the group. While recall data may be sensitive to recall bias, the pre-treatment socio-economic variables are comparable to studies such as those by Chitsa (2014), Muchara *et al*. (2014) and Sinyolo *et al*. (2014), who collected similar data in the same irrigation schemes in the previous five to six years.

Table 4 indicates that there is a significant difference in terms of all four outcome variables between male and female farmers.

Table 4: Access to assets by gender

	Means		T-test
	Male	**Female**	
Water access	5.39	3.73	2.95***
Asset value	22 313.4	9 474.28	2.53***
Fertiliser use (kg/ha)	160.27	110.76	2.94***
Income per capita	3 809.06	1 937.31	3.19***

Significance levels are represented by * = 10%, ** = 5% and *** = 1%

Male farmers had higher levels of access to water, possessed more than twice the value of female farmers' assets, and made over 96% more income per capita. This suggests gender inequality in rural areas, as they are dominated by a patriarchal system of governance and economic management (Cousins 2013; Sharaunga & Mudhara 2016).

Table 5 displays the characteristics of the 28 groups in the four irrigation schemes.

Table 5: Group characteristics

		Zanyokwe (n = 6)	**Mooi River (n = 9)**	**Tugela Ferry (n = 7)**	**Qamata (n = 6)**	**Total (n = 28)**
Group size (number)		12	95	81	30	53
Joining fee (ZAR)		308.33	112.00	125.00	170.00	176.43
Gender composition of group members	Male	0.71	0.33	0.29	0.52	0.46
	Female	0.29	0.67	0.71	0.48	0.54
Age categories of group members	15–39	0.26	0.17	0.17	0.16	0.19
	40–49	0.35	0.20	0.21	0.21	0.24
	50–59	0.26	0.37	0.34	0.37	0.34
	Above 60	0.13	0.26	0.29	0.26	0.24
Education attainments of group members	No education	0.25	0.60	0.44	0.37	0.41
	Primary	0.29	0.17	0.33	0.35	0.30
	Secondary	0.35	0.24	0.22	0.22	0.25
	Post-secondary	0.03	0.00	0.02	0.04	0.02
Received government input	1 = yes; 0 = no	100	0.60	100	0.78	0.86
Production training	1 = yes; 0 = no	0.33	0.60	0.75	0.78	0.64
Established networks for market	1 = yes; 0 = no	0.33	0.40	0.50	0.44	0.43
Own tractor	1 = yes; 0 = no	0.83	0.40	0.63	0.56	0.61
Own harvester	1 = yes; 0 = no	0.00	0.00	0.50	0.44	0.29
Trailer	1 = yes; 0 = no	0.50	0.20	0.25	0.33	0.32

The results indicate that the average total size of the groups was 53. Zanyokwe had the smallest average group size, of 12 members, while Mooi River had the biggest group size (95). The group size corresponds with the number of beneficiaries, so that schemes such as Zanyokwe, which has a small number of beneficiaries (about 164 in total), also have small group sizes, while schemes such as Tugela and Mooi River, with more than 800 beneficiaries (Table 2), have bigger groups. Zanyokwe also had the highest joining fee, while Mooi River had the lowest joining fee. According to Markelova *et al*. (2009), an organisation's success depends on group size. Smaller group sizes come with the advantage of reducing free-riding issues and better collective action among members. However, larger groups tend to gain more from economies of scale, as they share the costs for input procurement and hiring transport for market produce, among other things (Gezahegn *et al*. 2019). The groups were dominated by women. However, this differed by province. The two irrigations schemes in KwaZulu-Natal (Tugela and Mooi River) were dominated by women, while those in the Eastern Cape (Qamata and Zanyokwe) had more men than women. A significant proportion of the groups (41%) had no education, with a tiny fraction of them having attained education beyond matric (2%). The results further indicate that the majority of these groups had received input support from the government, such as inorganic fertiliser. While groups in Zanyokwe had better access to farming equipment, the majority of groups in the other schemes did not have access to farming equipment, such as tractors, harvesters, trailers and water tanks. According to the sustainable livelihood framework, farmers cannot reap all the potential benefits without the necessary farming equipment required to make farming a success. These results indicate that the government and private donors can significantly support farmer groups with the necessary equipment required to make farming a sustainable livelihood.

The success of groups also depends on their internal group dynamics. The ability to cultivate a feeling of collective action, trust, reciprocity and commitment to group goals is dependent on the level of internal social trust, because goals that are set are fruitless if there is no trust (Ostrom & Ahn 2003; Moody & Paxton 2009). Group members were asked to rank their perceptions using a five-point Likert scale, as shown in Table 6 below. The ranking took values from one, when the farmer strongly disagreed, to five when the farmer strongly agreed. Table 6 show the results for the summary statistics of group perceptions that were considered in the study.

Table 6: Summary statistics of groups' internal dynamics in terms of farmers' perceptions of the groups

Variable	Mean
Treated fairly	2.63
Feeling of togetherness and cooperation among members	2.64
Few conflicts	2.70
Easy to talk in the group	2.62
Free to share information	2.66
Group members share responsibilities	3.47
Commitment to group goals	3.64
Trust group members	3.33
Trust group leaders	3.23
Trust competitiveness of group leaders	3.39
Group purpose is clear	3.46
Common norms within group	2.98

The results show that most farmers were neutral in their perceptions of the groups. The scores are between 2.62 and 3.47, from slightly above disagree to just above neutral. While clarity of roles was rated the highest, easiness to talk and share opinions was scored the lowest. There were also low scores for fair treatment, feelings of togetherness and cooperation, and freeness of information sharing. Trust among group members and leaders was slightly above neutral. Trust determines the level of cooperation, and group success is dependent on the level of mutual trust and commitment among members. For these groups to function more efficiently, there is a need to create an environment that is conducive for all group members to share their opinions or ideas. Promoting optimal levels of social cohesion among members is central to achieving success as a collective. The 12 variables in Table 6 were added together to generate a proxy for group cohesion. The scores were used to categorise groups into two classes of high and low group cohesion, using the 50th percentile as the cut-off.

5.2 Factors associated with group membership

Table 7 illustrates the logit model results of the factors associated with group membership. The chi-square is highly significant, at 1%, signifying that the model fits the data well, and R^2 is 0.35, which is considered good for cross-sectional data. The variance inflation factor (VIF) is 1.65, indicating limited evidence of multicollinearity, since it is less than 10 as per the rule of thumb (Gujarati 2009).

Table 7: Logit model results: factors associated with group membership

Variables	Coefficient		Marginal effect	
	Coefficient	Standard error	Coefficient	Standard error
AGE	0.015	0.015	0.002	0.002
EDUC	0.067*	0.037	0.010*	0.005
SEX OF THE RESPONDENT	0.832***	0.370	0.123***	0.053
FARM_EXPERIENCE	-0.031**	0.016	-0.005**	0.002
MARRIED	0.144	0.278	0.021	0.041
FULL-TIME FARMER	1.649***	0.540	0.243***	0.076
HHS	0.054	0.046	0.008	0.007
TOT_HA	0.415***	0.139	0.061***	0.020
CROP_TYPE	0.120	0.302	0.018	0.045
ACCESS_EXTENSION	1.222***	0.410	0.180***	0.058
ACCESS_CREDIT	0.370	0.299	0.055	0.044
GRAVITY_MODE	-4.012***	1.033	-0.592***	0.146
QAMATA	-2.790***	0.614	-0.412***	0.081
ZANYOKWE	-0.077	0.727	-0.011	0.107
MOOIRIVER	0.422	0.332	0.062	0.049
_constant	0.109	1.480		
Number of observations	401			
Pseudo R-squared	0.35			
Wald Chi-square	192.23***			
Variance inflation factor	1.65			

Significance levels are represented by * = 10%, ** = 5% and *** = 1%

In line with the views of Fischer and Qaim (2012) and Sinyolo and Mudhara (2018b), education level, which represents human capital, was positively associated with group membership. Education enables a farmer to acquire, interpret and understand the circulated knowledge better, which directly reduces transactional information costs and increases the net benefits of being a member. The variable of gender is positive, indicating that men are more likely to participate in groups than women. During the focus group discussions, women indicated that the opportunity to attend group activities was lower because they have many responsibilities, such as household chores and caring for children. Mayoux (1999) and Abebaw and Haile (2013) also revealed that women have limited opportunity to participate in co-operatives.

Consistent with Sinyolo and Mudhara (2018b), Table 7 shows that farming experience is negatively associated with being a member. One more year in farming is related to a 0.5% decline in the likelihood of group membership. This may be because more experienced farmers have acquired sufficient farming skills and established sufficient working conditions, such as better market information and input procurement, and hence prefer to work alone. As expected, Table 7 shows that being a full-time farmer is positively associated with group membership. Full-time farmers have the privilege of focusing more on agricultural farming and can participate more in group activities such as meetings and training. Along with Fischer and Qaim (2012) and Sinyolo and Mudhara (2018b), our data show that land size is positively associated with group membership. The farm size is correlated with an increased likelihood of participating in a farmer group. Owning a larger land plot improves the net benefits of access to inputs and output markets that collective action provides. Moreover, farmers who have received agricultural training are more likely to be group members because extension officers offer farmers training and might influence their decision to join a group.

Access to extension officers increases the likelihood of group membership. Farmers with access to extension officers have the privilege of gaining information on groups that are available to join and receiving extension support services. Farmers using the gravity model to extract water for their plots had a negative association with being a group member. This is because those using the gravity-fed system do not have to pay collectively for water-related fees, as do those using an electric or diesel pump. In summary, the results indicate that education, gender, full-time farmer status, total hectares of land, and access to extension and training had a significantly positive effect on farmers' voluntary decisions to be part of a group. Experience in farming and using the gravity-fed system to access water had a negative effect on group membership.

5.3 PSM results on the effect of group membership on farmers' welfare

Table 8 below present the results from matching quality between members and non-members. "Psmatch2" (nearest neighbour one) was used to test the difference before and after matching. The results show that there is no statistically significant difference between the two groups after matching. This indicates that both groups have similar characteristics, unlike what is shown in Table 3 above (unmatched sample), which indicates a statistically significant difference between the two groups in several variables. Moreover, the standardised differences (% bias) in all the mean values of the covariates between members and non-members are below 20%, implying that the balancing requirement is satisfied adequately.

Table 8: Matching test quality for covariates

	Means		% Bias	% Reduction in bias	P-value of equality of mean
Variables	**Members**	**Non-members**			
AGE	51.96	51.39	5.0	43.4	0.72
EDUC	4.59	4.65	-1.3	79.8	0.91
SEX OF THE RESPONDENT	0.30	0.32	-4.8	-47.4	0.69
FARM_EXPERIENCE	19.58	18.18	12.9	14.4	0.28
MARRIED	0.58	0.51	13.8	-10.1	0.27
FULL TIME FARMER	0.93	0.94	-2.4	94.8	0.80
HHS	6.27	6.56	-9.7	49.4	0.44
TOT_HA	1.21	1.27	-3.1	-25.1	0.79
CROP_TYPE	0.71	0.69	5.1	-29.2	0.69
ACCESS_EXTENSION	0.86	0.86	0.0	100	1.00
ACCESS_CREDIT	0.33	0.31	-3.5	88.3	0.79
GRAVITY_MODE	0.97	0.94	9.6	88.2	0.24
QAMATA	0.12	0.18	-15.3	84.5	0.17
ZANYOKWE	0.17	0.14	8.7	79.6	0.49
MOOI-RIVER	0.35	0.28	15.9	29.9	0.23

Table 9 below shows the summary of quality-matching tests for the nearest neighbour, kernel and radius-matching algorithms. The results show that, after matching, there is no statistically significant difference between the two groups. Table 9 shows that, before matching, the pseudo R-square was relatively higher, but it was very low across all the algorithms after matching, indicating that there was no systematic difference in the distribution of covariates.

Table 9: Summary of quality-matching test for selected algorithms

Algorithms	Sample	Pseudo R-squared	Wald chi-square (p-value)	Mean standardised bias	Median standardised bias
Nearest neighbour	Unmatched	0.352	192.90 (0.000)	29.1	19.2
	Matched	0.021	8.89 (0.88)	7.4	5.1
Kernel	Unmatched	0.352	192.90 (0.000)	29.1	19.2
	Matched	0.02	9.55 (0.845)	8.0	6.3
Radius	Unmatched	0.352	192.90 (0.000)	29.1	19.2
	Matched	0.01	4.95 (0.99)	4.7	3.8

Moreover, the Wald chi-square on the joint significance before matching was not rejected (p = 0.000). However, it was rejected for all selected algorithms after matching, indicating that the matching was successful between the two groups (Caliendo & Kopeinig, 2008). The mean standardised bias for all algorithms is below 20%, implying that the balancing requirement is satisfied. The relatively low pseudo R-square, low mean standardised bias and insignificance joint covariates when testing after matching indicate successful balancing of the PSM quality test. Moreover, Figure 1 below provides a visual inspection of the estimated PSM scores, indicating that the common support condition is satisfied.

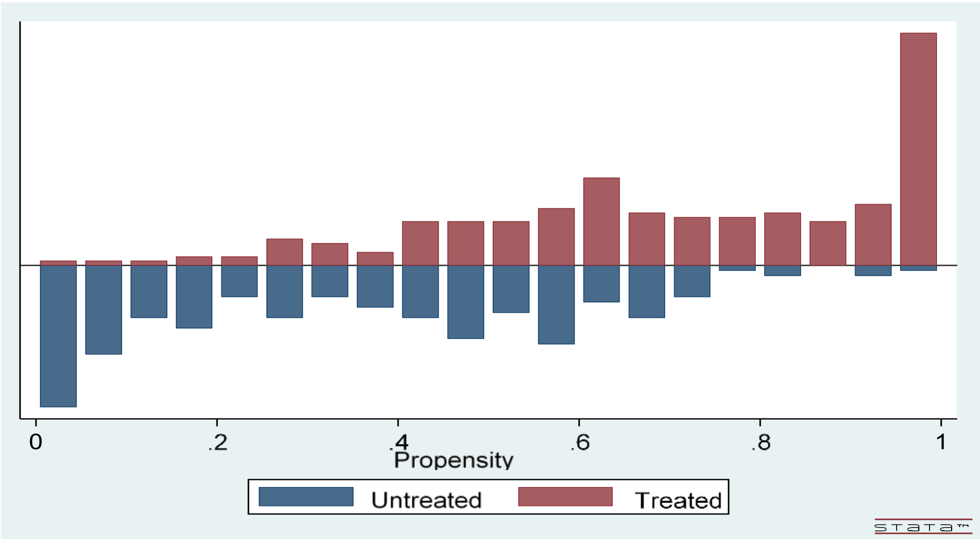

Figure 1: Propensity score distribution and common support

The PSM was then used to evaluate the effect of being a group member on access to water, fertiliser use, household income per capita and asset holding. The study used nearest neighbour, kernel, radius and stratification matching to estimate the average treatment effect on group members (Baker 2000; Nguyen 2006). The results in Table 10 show that the estimated effect values across all the outcomes are very similar, with minimal differences, implying that the estimates are robust.

Table 10: Homogenous effect of group membership on outcomes

Outcome variables	Nearest neighbour	Kernel matching	Radius matching
Water access (number of days)	4.866*** (0.604)	4.379** (0.670)	4.673*** (0.548)
Fertiliser use (kg/ha)	143.577*** (20.526)	131.276** (17.315)	140.130*** (15.539)
Asset value (logged)	1.606*** (0.229)	1.466*** (0.176)	1.412*** (0.091)
Income per capita (ZAR)	2 894.422** (472.791)	2 662.189*** (421.600)	2 791.467*** (383.491)

Significance levels are represented by * = 10%, ** = 5% and *** = 1%. Standard error values are given in brackets.

The results indicate that being a member of a group was associated with positive and statistically significant levels of access to water, fertiliser use, household income and asset holding. Furthermore, the results are consistent across the different matching algorithms. They also show that access to water would be about five days less if these farmers had not been group members. Moreover, inorganic fertiliser use would be about 131 kg/ha to 143 kg/ha less if not a group member, and this is consistent with the findings of Sinyolo and Mudhara (2018b), who reported 170 kg/ha of fertiliser usage among group members in KwaZulu-Natal. The result shows that group members earned an extra R2 662 to R2 894 income per capita annually compared to non-group members. This result is in line with Sinyolo and Mudhara (2018a), who reported that members earned about R3 000 more in KwaZulu-Natal.

To assess the sensitivity to hidden bias, the Rosenbaum sensitivity test was done after kernel matching. The Rosenbaum bounds test allows the researcher to determine how strongly an unmeasured confounding variable must affect the selection into treatment in order to change the results, which show a positive effect – as presented in Table 10. The results in Table 11 are highly insensitive to hidden bias, as it would take huge increases in the odds of treatment to change the conclusions.

Table 11: Rosenbaum bounds test for sensitivity analysis

Gamma	**Access to water (number of days)**	**Fertiliser used (kg/ha)**	**Asset holding value (ZAR)**	**Income per capita**
r	Upper bound	Upper bound	Upper bound	Upper bound
1	0.00	0.00	0.00	0.00
31	0.00	0.00	0.00	0.00
61	0.01	0.01	0.01	0.01
91	0.04	0.03	0.03	0.03
121	0.06	0.06	0.06	0.06
151	0.09	0.07	0.08	0.08
181	0.99	0.09	0.098	0.9
211	0.11	0.11	0.12	0.11

5.4 Heterogeneity of effect

Figure 2 shows how the ATT of the four outcomes vary over the estimated propensity scores. The results show that the slopes of three variables (fertiliser, income per capita and assets) were negative, indicating that the effect of group membership on outcomes decreases with the propensity of membership. The slope for water access was positive, implying that the effect of group membership on water access increases with the propensity score. The slopes of fertiliser use and water access varied more significantly than those of household incomes per capita and assets. The results imply that the effect of group membership is stronger for households with a lower propensity for joining a group.

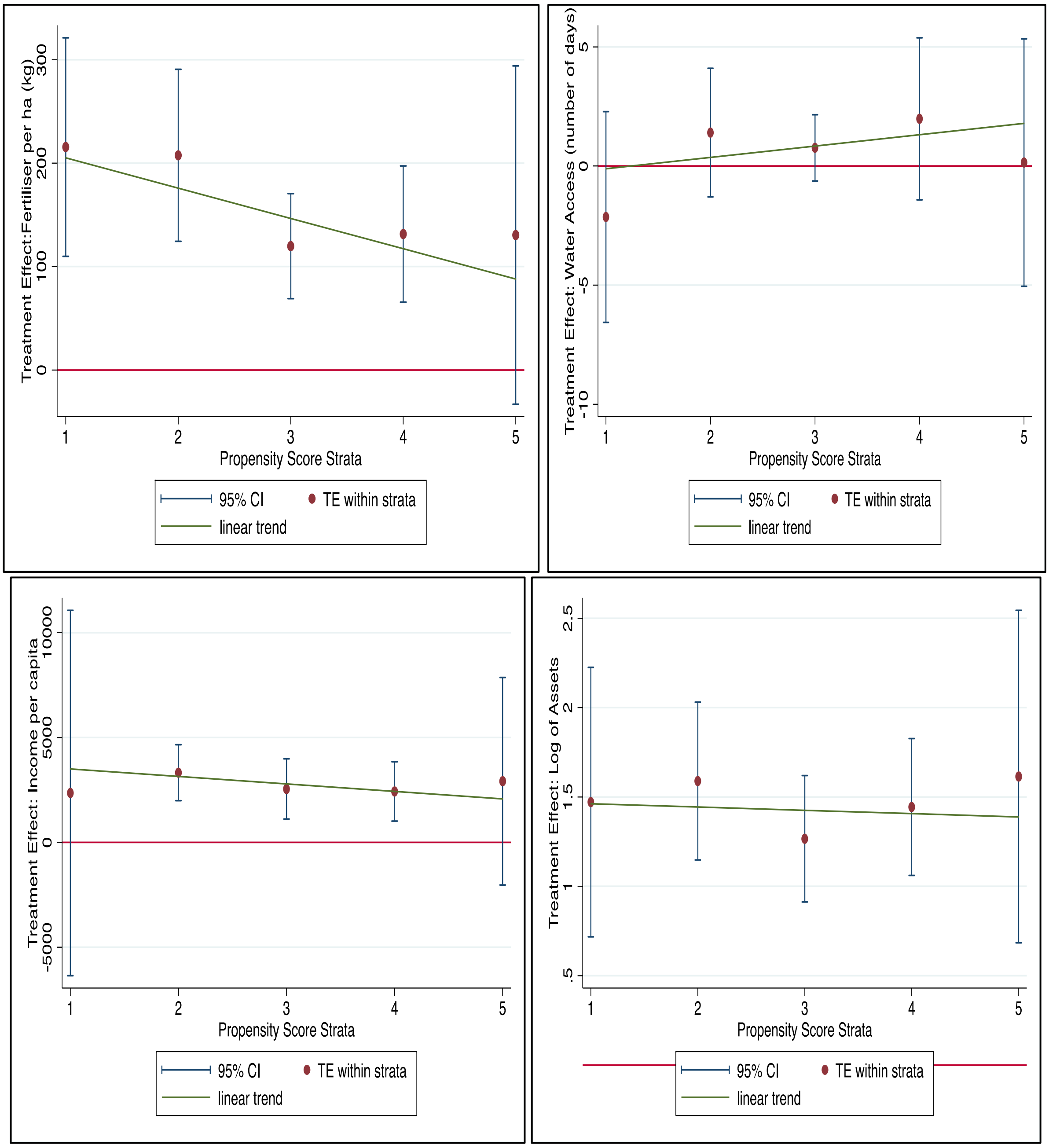

Figure 2: Heterogeneity of treatment effect over the propensity score

The study also investigated the heterogeneous effect of group membership according to socio-economic characteristics using OLS regression and ATT as the outcomes (Table 12). The results show that members with a higher level of education benefitted more from group membership than those with lower levels of education. Education enables a member to better understand and interpret information shared in groups.

Table 12: Heterogeneous effect according to socio-economic characteristics

Variables	Fertiliser use (Kg/ha)	Water access (number of days)	Income per capita (ZAR)	Logged assets value
	Coef.	Coef.	Coef.	Coef.
AGE	-0.18 (0.46)	-0.01 (0.02)	-2.89 (7.36)	0.00 (0.01)
EDUC	0.43** (1.14)	0.01 (0.04)	6.86** (18.17)	0.02** (0.01)
SEX OF THE RESPONDENT	6.64 (11.08)	0.27 (0.39)	106.59** (177.37)	0.23* (0.14)
FARM_EXPERIENCE	0.21 (0.48)	0.01 (0.02)	3.30 (7.72)	0.00 (0.01)
MARRIED	-1.22 (8.45)	-0.07 (0.30)	-18.63 (135.23)	0.06 (0.11)
FULL TIME FARMER	-6.83 (19.06)	-0.31 (0.67)	-107.59 (304.99)	-0.37 (0.24)
HHS	3.49*** (1.46)	0.12*** (0.05)	55.78*** (23.40)	0.03* (0.02)
TOT_HA	-3.55 (3.63)	-0.19 (0.13)	-56.63 (58.09)	-0.07 (0.05)
CROP_TYPE	-5.61 (8.75)	-0.22 (0.31)	-89.39 (139.97)	0.03 (0.11)
ACCESS_EXTENSION	17.00 (13.20)	0.41 (0.46)	271.04 (211.24)	0.08 (0.17)
ACCESS_CREDIT	-17.08** (8.63)	-0.63** (0.30)	-273.54** (138.05)	-0.20* (0.11)
GRAVITY_MODE	26.23*** (11.31)	1.38*** (0.40)	423.02*** (181.04)	0.74*** (0.14)
QAMATA	46.42** (21.43)	1.64*** (0.75)	740.38*** (342.92)	0.40 (0.27)
ZANYOKWE	52.20*** (20.92)	2.02*** (0.74)	833.59*** (334.75)	0.53** (0.26)
MOOI-RIVER	-3.59 (10.36)	-0.09 (0.36)	-56.73 (165.84)	-0.20 (0.13)
Constant	8.51 (34.44)	0.23 (0.21)	129.47 (551.09)	7.54*** (0.43)
R squared	0.14	0.18	0.14	0.19
Prob > F	0.009	0.000	0.0094	0.0002
Number of observations	228			

Dependent variables are the ATT of each outcome. Significance levels are represented by * = 10%, ** = 5% and *** = 1%. Standard errors are in brackets.

Male members benefitted more from membership in relation to a household's income per capita and asset holding. These results are consistent with Table 4, which indicated gender inequalities in terms of asset ownership. The results show that group members with bigger households benefitted more from membership because of the availability of a family labour supply. Farmers without access to credit benefitted more from group membership than those with access to credit. This is because group membership assists members to share costs, which benefits most those with limited access to credit. In groups, farmers can get access to financial assistance from the government and other donors. Farmers using gravity modes of irrigation benefitted more from group membership than those who rely on diesel pumps and electric pumps. Lastly, the results show that Qamata and Zanyokwe farmer groups benefitted more from farmer cooperatives.

The study further analysed heterogeneous effects according to group characteristics. Table 13 shows the ATT outcomes according to group size. The results show that the smaller groups had better outcomes than the larger groups.

Table 13: Heterogeneous effect according to group size

ATT Means	Membership of smaller groups (n = 94)	Membership of bigger groups (n = 134)	T-test
Water access (number of days)	1.49	1.14	1.28
Fertiliser use (kg/ha)	45.43	35.57	1.32
Household income per capita	725.31	567.69	1.31
Logged assets value	7.62	7.66	0.42

Table 14 shows that farmers belonging to female-dominated groups had lower outcomes than those in male-dominated groups. This is not surprising, since male farmers have better access to resources and opportunities compared to females, particularly in rural areas dominated by patriarchal systems of governance (Sharaunga & Mudhara 2016; Sinyolo *et al*. 2018).

Table 14: Heterogeneous effect according to gender composition of groups

ATT	Membership of female-dominated groups (n = 137)	Membership of male-dominated groups (n = 91)	T-test
Access to water (number of days)	1.08	1.56	1.74*
Fertiliser use (kg/ha)	34.84	46	1.84*
Household income per capita	555.93	734.68	1.49
Logged assets value	7.59	7.73	1.39

Table 15 indicates that 131 members belonged to groups in which they perceived the level of cohesion to be low.

Table 15: Heterogeneous effect according to level of group cohesion

ATT	Low cohesion (n = 131)	High cohesion (n = 97)	T-test
Water access (number of days)	1.57	1.08	1.69*
Fertiliser use (kg/ha)	47.61	34.08	1.19
Household income per capita	543.39	761.38	1.70*
Logged assets value	7.73	7.56	1.72*

Members of groups characterised by high cohesion had higher outcomes than those with less group cohesion. Group cohesion is imperative for better collective action.

6. Conclusions and policy recommendations

This paper evaluated the heterogeneous effect of group membership on access to water, fertiliser use, household incomes and asset holding in four irrigation schemes (Tugela, Mooi River, Qamata and Zanyokwe) in the KwaZulu-Natal and Eastern Cape provinces in South Africa. The study found that group membership had a positive effect on all four outcomes. Group members had an extra four days of access to water in a month, and applied at least 130 kg/ha more inorganic fertiliser, than non-group members. Group members had higher household income per capita and assets than non-group members. However, the results revealed a heterogeneous effect among group members, with the benefits varying according to members' socio-economic characteristics as well as internal group dynamics. The findings indicate that the effect of group membership was stronger for households with a lower propensity for joining a group, suggesting negative selection into group membership. Group membership was found to benefit the most those members who were men, were more educated, who did not have access to credit, and those reliant on gravity irrigation. Further analysis indicated that members in smaller groups dominated by men and characterised by high group cohesion benefited more from group membership. The findings of the study suggest that organising farmers into groups presents a promising strategy for improving access to water, the adoption of technology and reduction of poverty. The government and private donors should continue to promote the formation and organisation of farmers into groups. Moreover, policymakers should implement policies that will attract the youth into agricultural farming, as the findings indicate that older farmers dominate. The role of group membership in farming outcomes can be enhanced if smaller groups are promoted. It is also crucial that strategies to promote trust, reciprocity and group commitment be implemented for better group outcomes.

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