# The awareness and adoption of environmentally sustainable practices by agricultural cooperative members in Zambia

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***Abstract***

*As the world population is continuously growing, agricultural practices should be done sustainably to achieve food security, nutrition, and economic success. Due to the networking, economies of scale and improved access to information, collective actions and producers' cooperatives seem to be a good instrument for acquiring, sharing and promoting such practices. Therefore, the main aim of this study was to estimate the effect of cooperative membership on the awareness and adoption of environmentally sustainable practices. We purposively selected 210 members and 166 non-members of maize cooperatives in the Southern province of Zambia. To cater for both observed and unobserved bias in the study, we adopted the propensity score matching and endogenous treatment effect models. The study results confirm that cooperative membership positively influences the awareness and adoption of sustainable environmental practices used in the study but encourages the usage of synthetic fertilizers because of the government input subsidy.*

***Keywords****: Producer groups, Maize, Zambia, Propensity score matching, Endogenous treatment effect.*

## 1. Introduction

In 2015, the United Nations (UN) highlighted that, as the world population is continuously growing, agricultural practices should be done sustainably to achieve food security, nutrition, and economic success. The supply of sustainable agricultural production is expected to be on the rise because of increasing consumer sensibilities and the initiatives of governments (Saitone and Sexton, 2017). Nevertheless, there are also long-term benefits of adopting sustainable practices to smallholder farmers apart from the concerns of consumers, governments, and global organizations. Sustainable practices play a vital role in preserving the ecosystems, promoting economic stability for farms, and improving the quality of life of smallholder farmers (Kata and Kusz, 2015).

On the other hand, adopting sustainable practices in developing countries tends to be too knowledge-intensive (Wall, 2007; Giller *et al.*, 2009). The smallholder farmers may not have the knowledge or the awareness of such practices. It is, therefore, vital to find communication channels to provide smallholder farmers with the knowledge and understanding regarding the benefits associated with the adoption of sustainable practices.

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Across southern Africa, land degradation and soil erosion have been observed to be challenging for smallholder farmers due to poor farming practices, climate variability, increased precipitation, more runoff, and soil loss (Ward *et al.*, 2017). In Zambia, the vulnerability of production is mainly attributed to unreliable seasons and changing climate and the lower adoption of SAPs among the farmers in Zambia (Svitálek, 2017). There is an increase in frequency of destructive floods, as well as decline in biodiversity that is crucial to the proper functioning of ecosystems.

The nature of collective action and group organization as formalized communication networks with improved access to external services makes the agricultural cooperatives a potentially good instrument for promoting sustainable practices. It can satisfy the need to learn, adopt and exchange information, resources, and skills needed for such practices among cooperative members. The International Labor Organization also recognizes the cooperative organizational model as a tool for sustainable development and increasing well-being where economic, social, and environmental factors are inherently interdependent (Birchall, 2013). Attia *et al.* (2021), in their study related to the sustainability of the three farming systems (rainfed, irrigated, and mixed) in Tunisia, suggested that for sustainability to be achieved in dairy farms, farmers should be encouraged by the state to create and form cooperatives to enhance professional links, and encourage local exchange, flows and collective projects.

Existing literature already brings broad evidence of the positive role of cooperatives on economic performance. Cooperatives have proved a positive impact on productivity (Mojo *et al.*, 2017; Wossen *et al.*, 2017a) and farmers' income (Verhofstadt and Maertens, 2014; Mojo *et al.*, 2017; Hoken and Su, 2018). Also, cooperatives provide farmers with access to larger regional and international markets, higher prices, assets, and innovation adoption (Wollni and Zeller, 2007; Rommel *et al.*, 2013; Cechin *et al.*, 2013; Jardine *et al.*, 2014).

Agricultural cooperatives also seem vital to help farmers change their farming practices to favour adopting environmentally sustainable techniques through their close relationship with their member farmers. Studies by Abebaw and Haile (2013), Liu and Liang (2018), and Yu *et al*. (2021) show empirically the role of cooperative membership in technology and environmentally friendly practices adoption. The environmental dimension is an important dimension of social innovation of cooperatives in the Spanish olive industry, in addition to economic, cultural and technological dimensions (Parrilla-González and Ortega-Alonso, 2021). Cooperatives play a positive role in adopting farmer innovations and sustainable practices by providing extension services, participation in meetings and training of the groups, increased knowledge exchange amongst members, and a forum to discuss problems at the community level (Schulte *et al.*, 2020). Also, cooperatives act as a medium for social networking and learning where smallholder farmers can share their knowledge, know-how, and experiences with the sustainable practice, influencing other farmers' knowledge, hence adopting a sustainable environmental approach (Mutyasira *et al.*, 2018). Cooperatives act as channels and partners for knowledge transfer from governmental services, development organizations, and international donors (Wanyama, 2014; COPAC, 2018).

The promotion of SAPs in the province is done through various NGOs, farmer groups and agricultural cooperatives. The Conservation Farming Unit (CFU) is among the NGOs popularly known in Zambia for promoting conservation agriculture through the Zambian National Farmers Union (ZNFU) (Manda *et al.*, 2015; Nkomoki *et al.*, 2018). To engage cooperatives for extension and training of farmers is favourable in Zambia because the farmer input support program (FISP) by the government serves as a motivation for most farmers to join cooperatives (Donkor and Hejkrlik, 2021).

Nevertheless, studies analyzing the role of cooperatives on sustainability are still limited in the literature. The cooperative impact studies are generally limited for Zambia (e.g., Chabu, 2020; Donkor and Hejkrlik, 2021), and existing studies leave out the environmental aspects of sustainability entirely. Therefore, the main aim of this study is to analyze the impact of cooperatives on environmental sustainability within the maize supply chain in Zambia. We contribute to the literature by considering the impact of cooperatives on achieving sustainability in food supply chains by adopting counterfactual evaluation approaches. The study, therefore, demonstrates the role of cooperatives in achieving Sustainable Development Goal number 12 (sustainable production and consumption). The rest of the study is organized in the following way: section 2 reviews existing literature, section 3 presents the methodological and analytical framework, section 4 presents the study's results, and sections 5 and 6 highlights the discussion and conclusion of the study, respectively.

## 2. Cooperatives and farmers adoption of sustainable practices

Cooperatives are successful in achieving sustainability in both ends of food supply chains. The seventh principle of cooperative "concern for community" makes cooperatives to have sustainability in their "DNA" (COPAC, 2018). The concern for the needs of their members and communities encourages cooperatives to invest in sustainable, environmentally friendly practices and create awareness among their members (COPAC, 2018). Cooperatives can have a domino effect in their communities by educating their members on the importance of sustainable consumption and production. Cooperatives contribute to sustainable development's economic, social, and environmental goals because they aspire to meet members' economic progress while satisfying their socio-cultural interests and protecting the environment (Wanyama, 2014).

In developing countries, the main objectives of farmer cooperatives are to promote innovations, offer professional training, ease members' access to new technologies and equipment, and sustainable management practice among smallholder farmers (Wollni and Zeller, 2007; Ma *et al.*, 2018). Farmer cooperatives serve as intermediaries and platforms for promoting technology adoption by facilitating information exchanges between smallholder farmers and technology suppliers (universities, research institutes, agricultural extension agents, and technology companies) (Zhang *et al.*, 2020). Cruz *et al.* (2021) highlighted that Spanish researchers consider agricultural cooperatives technicians as farmers' primary source of information. Through the cooperatives, the farmers can get experiential learning, which is vital for knowledge gain and innovation adoption (Cruz *et al.*, 2021). Cooperatives understand the needs of their members and have direct contact with them, which makes cooperatives an effective channel for horizontal learning and information sharing among farmers (Thorat *et al.*, 2008). Cooperatives play the coordinator role in the service system and bridge the gap between the policy system and sustainable farm management practice (Kilelu *et al.*, 2011).

Agricultural cooperatives governance model shows positive impacts in sustainable development through transparency, participation, and cooperation with local communities, enterprises, and local and international governments (Cato, 2012; Wanyama, 2014). Knowledge and technical information sharing are more efficient due to the internal organization of the groups. Cooperatives increase the efficiency of the local strategies to reach the AES objectives among the farmers complying with the governmental legal framework (Franks, 2011). These strategies are based on the knowledge of the specific local conditions, past experiences and the decision making of the members to identify the main problems and allocate the resources in faster implementation rates than central authorities and top-down approaches (Stallman, 2011; Prager, 2015).

Collective action increases the social capital of cooperatives through face-to-face communication. The social capital in the cooperatives increases the advice, mutual support, collaboration, trust, commitment, and the willingness to comply with the rules and regulations; generating a sense of belonging to a social group and esteem their contributions are considerable valuable (Stallman, 2011; Prager, 2015). Besides, the peer-pressure mechanism inside the farmer group changes farmers' attitudes, values, and aspirations, increasing the rates of adoption and harmonization of environmental and agriculture measures and practices (Prager, 2015).

Empirical evidence suggests that agricultural cooperatives promote adopting new farming practices and technologies (Abebaw and Haile, 2013; Verhofstadt and Maertens, 2014; Wossen *et al.*, 2017b; Ma *et al.*, 2018; Ma and Abdulai, 2019; Yu *et al.*, 2021). Ma and Abdulai (2019) empirical results in China show that cooperative membership positively impacts integrating pest management (IPM) technology. Yu *et al.* (2021) opined that cooperative membership has a significant favourable influence on adopting green control techniques (ecological regulation, biological and physical control, and the scientific use of chemical pesticides) in China. Candemir *et al.* (2021) reviewed the empirical studies on the impact of cooperatives on the farm sustainability of their members. In their review, they found that cooperative contributes significantly to the adoption of sustainable environmental practices. Gonzalez (2018) confirms this in his book "Farmer's cooperatives and sustainable food systems in Europe" that cooperatives may impact farmers to adopt sustainable environmental practices and agricultural innovations. In their study in Nicaragua, Bro *et al.* (2019) found that cooperative members adopt higher rates of sustainable practices than non-members. Nkomoki *et al.* (2018) also found a significant impact of farmer groups' membership on adopting crop diversification strategy in Zambia. Ma *et al.* (2018) study found a significant influence of cooperative membership on the probability of investing in organic amendment practice. Available technical assistance increased the farmers' propensity to adopt sustainable environmental practices in the vegetable sector in Vietnam (Naziri *et al.*, 2014). Also, Ji *et al.* (2019) study in the Chinese hog industry concluded that farmers engaged in the cooperatives have significantly higher incentives to adopt safe production practices.

In conclusion, it is evident from the literature review that cooperatives have the potential to promote the adoption of sustainable practices if they function well and have sufficient information on the sustainability problem. Agricultural cooperatives contribute to adopting sustainable agricultural practices due to their core cooperative principles and values, the specific form of governance, internal structures, communication and group dynamics among members. The cooperatives' social capital and peer pressure mechanism (farmer to farmer learning experience) contributes to the successful adoption of sustainable agricultural practices as well.

## 3. Data and methods

### 3.1. *Data collection*

For our study, we used counterfactual non-experimental analytical methods with the comparison of treatment and control groups. The two target groups were smallholder farmers who are members and non-members of agricultural cooperatives. We used the multi-stage sampling technique in this study. Data were collected by first obtaining the provincial cooperative officer's list of cooperatives in the Southern province. With the help of agricultural extension agents and cooperative officers, we used purposive sampling to select four districts (Pemba, Monze, Choma, and Kalomo) with the highest concentration of cooperatives in the Southern province. The same local experts assisted us in a selection of 19 cooperatives. The selection criteria were the group activity and members' participation in meetings. We purposively selected such cooperatives to prevent us from selecting cooperatives that are dormant and exist just on paper. For the individual members, we randomly selected at least 10 members of each cooperative. Because we did not have the list of the non-members, the extension agents in the four districts assisted us by purposively interviewing the farmers in each of the communities that the cooperatives are located. The sample size for the study was 373 at the end of the data collection, with 210 cooperative members and 163 non-members. Table 1 below summarizes the number of respondents (both members and non-members) interviewed in each district.

The data was collected from July 10 to Septem-

Table 1 - Sample size estimation.

| *District* | *Number of cooperatives/ communities* | *Members interviewed* | *Non-members interviewed* |
|---|---|---|---|
| Choma | 4 | 48 | 34 |
| Kalomo | 5 | 56 | 51 |
| Monze | 5 | 57 | 33 |
| Pemba | 5 | 49 | 45 |
| Total | 19 | 210 | 163 |

Table 2 - SAPs description.

| *Variables* | *Description – if not specified otherwise, all questions related to the period of the last three years* | *Measurement* |
|---|---|---|
| *Awareness of SAPs* | | |
| Frequency of SAPs training | Number of SAP training received by farmers in the last farming period. | Number of training |
| Knowledge on SAPs | Farmers' knowledge of SAP has increased. This aimed at assessing an increase in the knowledge of the farmers on SAPs in the last three years. | 5-point ordinal scale |
| *SAPs Adoption* | | |
| *Atmospheric* | | |
| Non-use of synthetic fertilizer | Farmers have not adopted/used synthetic fertilizer in the last three years. This operationalisation does not mean that the farmers who do not use synthetic fertilizer use organic fertilizer (Bandanaa et al., 2021). | 5-point ordinal scale |
| *Land/soil dimension* | | |
| Mulching | Farmers have adopted mulching. Mulch is defined as a coating material spread over the soil surface (Kasirajan and Ngouajio, 2012; Kader et al., 2019). | 5-point ordinal scale |
| Minimum tillage | Farmers have adopted minimum tillage. The adoption of hand hoe basins, ox-drawn ripping and tractor ripping (Grabowski et al., 2016). | 5-point ordinal scale |
| Intercropping with legumes | Farmers have adopted intercropping the maize farm with legumes on the same plot of land (Nkomoki et al., 2018). | 5-point ordinal scale |
| *Biodiversity dimension* | | |
| Agroforestry | Farmers have adopted agroforestry. It is a tree-based practice for nitrogen-fixing with fast-growing shrubs or trees (Altieri et al., 2012). | 5-point ordinal scale |
| Crop rotation | Farmers have adopted crop rotation. The practice of growing different crops in succession on the same farmland mainly to preserve the productive capacity of the soil (Asseng et al. 2014; Dhaliwal et al. 2021). | 5-point ordinal scale |
| Crop diversification | Farmers have adopted crop diversification. Defined as cultivating a range of crops on the same farmland. The typical arrangement is cereals, legumes and tubers (Nkomoki et al., 2018). | 5-point ordinal scale |

ber 25, 2021, by an electronic structured questionnaire (Nestforms mobile application) through face-to-face interviews with the farmers. Data was collected on the farm, household, and institutional characteristics of farmers that potentially affect sustainability. Additional questions included farmers' awareness and training on SAPs. We also collected qualitative data from the farmers and the leaders of the cooperatives to learn how the cooperatives facilitate the SAP training inside the group and detailed experiences of farmers learning from each other in the group.

Following Bandanaa *et al.* (2021) approach, we focused on farmers' adoption of three dimensions of environmental sustainability (atmospheric, land and biodiversity). The sustainable practices were measured with a 5-point ordinal scale to capture the degree of adoption within the last three years. The awareness and adoption of SAPs were measured based on three years, with five as the highest rate of awareness and adoption and one as the lowest. We also did a transact walk on the farm of some farmers to confirm the adoption of SAPs.

Table 2 below shows the variables for farmers awareness, training on SAPs and adoption of SAPs.

### 3.2. *Empirical analysis*

Simple descriptive statistics were used to summarize the data. The impact of cooperative membership on members' awareness and adoption of sustainable agricultural practices was analyzed by adopting propensity score matching (PSM). PSM was adopted to control selection bias due to the observable characteristics between the members and non-members (Rosenbaum and Rubin, 1983).

In the first stage, propensity scores P(x) were generated from a probit regression model to show the probability of farmers to participate in the cooperative. The decision to join in cooperative was modeled under the random utility theory, denoting that farmer will choose to participate in cooperative based on the perceived utility. Under the assumption of the risk-neutral nature of farmers, their decision to participate in cooperatives may be influenced by the perceived cost and benefits they will derive from the integration strategy.

The perceived benefits of participating in cooperative can be represented by a latent variable $D_J^*$ jexpressed as a function of the observed characteristics and attributes, denoted as $Z$ in the following latent variable model:

$$D_J^* = Z_J\gamma + \varepsilon_J;\ D_J = 1\ if\ D_J^* > 0; \quad D_J = 0\ if\ D_J^* \leq 0 \qquad (1)$$

where $D_J^*$ is a dummy variable that equals 1 for cooperative membership and 0 for non-membership; $\gamma$ represents the estimated parameters. $\varepsilon$ is the error term with a mean of zero; $Z$ represents the factors that influence farmers decision to participate. The binary choice model was estimated using probit regression model.

As the second step of our analysis, we constructed a control group by matching members and non-members according to the generated propensity scores. Members and non-members whom we could not find appropriate matches were then be dropped. The impact of participation in the cooperative on the outcome variables (y) was estimated using matched observations. Empirically, ATT is represented as:

$$ATT = E_{P(X)(C=1)}\{\mathrm{E}[\mathrm{y}\ (1)|\mathrm{C}=1, \mathrm{P(x)}]| + - [\mathrm{E}\ \mathrm{y}(0)|\mathrm{C}=0, \mathrm{P(x)}] \qquad (2)$$

where y(1) and y(0) are the outcomes for those farmers in the treated (members) and control groups without treatment (non-members), respectively, while C=1 for treated farmers and C=0 for control farmers. The difference between the two outcomes refers to the treatment effect on the treated (ATT).

However, PSM has a challenge of producing biased results in the presence of misspecification in the propensity score model, according to (Robins *et al.*, 2007; Wooldridge, 2007). Therefore, to estimate the robust impact of cooperatives on economic and environmental sustainability, we employed the inverse probability-weighted adjusted regression (IPWRA), which has double robustness properties by combining regression and propensity scores methods (Robins and Rotnitzky, 1995; Wooldridge, 2007; Imbens and Wooldridge, 2009). The IPWRA model estimates the outcome and treatment model in two steps. Following the step used by Wossen *et al.* (2017a), assuming the outcome model is represented by a linear regression function in the form:

$$Y_i = \alpha_i + \theta_i x_i + \varepsilon_i \text{ for } i = [0\ 1] \qquad (3)$$

Where $y_i$ is the outcome variable of interest, $x_i$ is a set of explanatory variables; $\alpha$ and $\theta$ are parameters to be estimated; $\varepsilon$ is the error term.

Again, supposing the propensity scores are given by $p(X;\vartheta)$, propensity scores were estimated as $p(X;\hat{\vartheta})$ and then, linear regression was employed to estimate ($\alpha_0$, $\theta_0$) and ($\alpha_1$, $\theta_1$) by using inverse probability-weighted least-squares shown below:

$$\min_{\alpha_0\theta_0} \textstyle\sum_i^N (Y_i - \alpha_0 - \theta_0 X_i)/p\left(X, \hat{\vartheta}\right) \text{ if } I_i = 0 \quad (4)$$

$$\min_{\alpha_0\theta_0} \textstyle\sum_i^N (Y_i - \alpha_1 - \theta_1 X_i)\ /p\left(X, \hat{\vartheta}\right) \text{ if } I_i = 1 \quad (5)$$

The average treatment effect (ATT) was estimated as the difference between equations (4) and (3)

$$ATT = \frac{1}{N_W} \textstyle\sum_i^{N_W}\ \left[(\hat{\alpha}_1 - \hat{\alpha}_0) - \left(\hat{\theta}_1 - \hat{\theta}_0\right) X_i\right] \quad (6)$$

Where $\alpha_1$ are estimated inverse probability-weighted parameters for members of cooperatives while $\hat{\alpha}_0$ are estimated inverse probability-weighted parameters for non-members; $N_W$ represents the total number of respondents and

$I_i$ is an indicator that takes a value of 1 if farmer household is a member of cooperative and 0 if not a member.

However, the PSM and IPWRA control only observable factors that influence the participation in cooperative but not the unobservable factors such as the inner motivation of farmer to participate in the cooperative. To add further robustness to our analysis, we used the endogenous treatment regression model. The endogenous treatment regression model is a linear potential outcome model that allows for a specific correlation structure between the unobserved variables that influence the treatment and the unobservable variables that affect the possible outcomes (StataCorp, 2017). Supposing the effect for participation in cooperative is $Y_m$ and the endogenous treatment is $t_m$, the outcome equation for the endogenous regression was estimated as follows:

$$Y_m = X_m\beta + \delta t_m + \varepsilon_m, \text{ and } t_m = = \begin{cases} 1, if\ w_m\lambda + u_m > 0 \\ 0, if w_m\lambda + u_m \leq 0 \end{cases} \quad (7)$$

where $X_m$ are the covariates that affect the outcome variable and $w_m$ refers to the covariates used to model the treatment variable. The covariates $x_m$ and $w_m$ are exogenous. $\varepsilon_m$ and $u_m$ are error terms that are bivariate normal with a mean of zero, and the covariate matrix is as follows:

$$\begin{bmatrix} \sigma^2 & \rho^\sigma \\ \rho^\sigma & 1 \end{bmatrix} \quad (8)$$

The likelihood function for observation of the endogenous treatment regression model was estimated as follows:

$$lnL_C = \begin{cases} ln\phi\left\{\frac{w_m\lambda+(y_m-x_m\beta-\delta)\rho/\sigma}{\sqrt{1-\rho^2}}\right\} - \frac{1}{2}\left(\frac{y_m-x_m\beta-\delta}{\sigma}\right)^2 - \ln(\sqrt{2\pi}\sigma) & t_m = 1 \\ ln\phi\left\{\frac{-w_m\lambda-(y_m-x_m\beta-\delta)\rho/\sigma}{\sqrt{1-\rho^2}}\right\} - \frac{1}{2}\left(\frac{y_m-x_m\beta}{\sigma}\right)^2 - \ln(\sqrt{2\pi}\sigma) & t_m = 0 \end{cases} \quad (9)$$

where $\phi(.)$ is the cumulative distribution function of the standard normal distribution. The ATE estimates from the treatment regression model maximum likelihood estimation can also be used for ATT when the outcome is not conditionally independent of the treatment (StataCorp 2017). Participation in an off-farm business (off-farm income), and participation in local social group were included in the model as an instrumental variable.

## 3.3. *Description of variables*

The variables used in the probit regression mode, the PSM and the endogenous treatment regression models are highlighted in this section.

### *Dependent variables*

The dependent variable for the selection equation of the endogenous treatment regression model and the probit regression model was membership in cooperatives, measured "1" for cooperative membership and "0" for the non-members.

The outcome variables for this study were the awareness and adoption of SAPs. In this study, we have two models for the two awareness variables (frequency of SAPs training and knowledge of SAPs). For the adoption of SAPs, we have one model for the atmospheric dimension (non-use of synthetic fertilizer), three models for the land or soil dimension (mulching, minimum tillage, and intercropping with leguminous crops), and three models for the biodiversity dimension (agroforestry, crop rotation, and crop diversification).

### *Independent variables*

Based on the existing evidence in the literature (Fischer and Qaim, 2012; Abebaw and Haile, 2013; Mojo *et al.*, 2015, 2017; Wossen *et al.*, 2017b), the independent variables used in the various models in this study were age (continuous - years), gender (bivariate - 1 for males and 0 for female), marital status (bivariate - 1 for married and 0 for otherwise), years of education of the farmer (continuous - years), maize farm size (continuous - Ha), intention to benefit from input subsidy (bivariate - 1 for yes and 0 for no), years of farming experience (continuous - years), household size (continuous - number of members), access to credit (bivariate - 1 for yes and 0 for no), social groups participation such as savings groups and church (bivariate - 1 for yes and 0 for no), and farmers participation in off-farm business (continuous - off-farm income (ZK)).

# 4. Results

## 4.1. *Description of Respondents*

From Table 3, the T-test shows that comparatively, the members in the cooperative have a

Table 3 - Summary of variables.

| *Variables (N=224)* | *Members* | *Non-members* | *Mean Difference* |
|---|---|---|---|
| Age (years) | 46.87 (11.42) | 47.00 (17.03) | -0.13 |
| Education (years) | 8.51 (2.68) | 8.35 (2.56) | 0.17 |
| Maize farm size (Ha) | 2.78 (1.79) | 2.32 (2.11) | 0.46** |
| Household size (number) | 8.24 (4.38) | 7.07 (3.65) | 1.17*** |
| Farming experience (years) | 20.06 (10.66) | 17.72 (13.34) | 2.34* |
| Off-farm income (ZK) | 3892.93 (4830.19) | 4149.74 (8843.36) | -256.81 |
| Gender- Male | 67.61% | 61.96% | 5.65 |
| Access to credit- Yes | 26.20% | 19.63% | 6.57 |
| Social group- Yes | 92.38% | 70.55% | 21.83*** |
| Marital status- Married | 58.33% | 47.61% | 10.72 |
| Intention to benefit from input subsidy input subsidy- Yes | 97.14% | 17.18% | 79.96*** |
| *Note: ***, **, and * represent 1%, 5%, 10% levels of probabilities respectively. Mean difference estimated with independent sample T-test at 5% level of probability.* | | | |

bigger farm size than the non-members. The difference is statistically significant, though the farm size is still between 2-3 hectares for both groups. Also, the members have larger families and farming experience than the non-members. There are more male farmers in both the members and non-members samples as compared to the women. Most of the members and non-members do not get access to credit.

Interestingly, a majority of both the members and non-members participate in local social groups. However, the percentages of members participating in other local social groups such as savings group and church are higher than for the non-members. In terms of access to the Zambian government input subsidy (FISP system), almost all the members indicated that they intend to benefit from the input subsidy compared to the non-members. However, this is in line with the fact that the subsidy should be distributed only through cooperatives.

### 4.2. *Determinants of cooperative membership*

The goodness-of-fit tests show that the covariates selected provide a reasonable estimate of the conditional density of cooperative membership. The independent variables are jointly statistically significant with Wald $\chi2 = 306.55$, $p < 0.00$, and the pseudo R2 of 0.597 (see Table 4). Off-farm income has a significant negative influence on farmers' decisions to be cooperative members. On the other hand, participation in other social groups (e.g., church groups, savings clubs) and farmers' intention to benefit from input subsidy have a significant positive effect on cooperative membership as expected.

The PSM and IPWRA estimates indicate that the members of the cooperatives are more aware of environmentally sustainable practices than the non-members. The same estimates also show a statistically significant difference between the members and non-members based on the number of SAPs training they receive in a year, and perceived increase in knowledge about SAPs over the previous three years (Table 5).

From Table 6, we can observe that the endogenous treatment regression model for the awareness of SAPs was a good fit. The likelihood ratio tests of joint independence are significant at 1% probability levels for all models, indicating that the two equations are dependent on each other. The signs and significance of the error of correlation terms show that the covariance terms of cooperative membership are statistically significant. Endogenous treatment regression model results confirm the results of the PSM and IPWRA in terms of a statistically significant positive influence of cooperative membership on the awareness of farmers on SAPs.

Table 4 - Factors that influence cooperative membership.

| | *Group membership* | *dy/dx* |
|---|---|---|
| Age | -0.000 (0.004) | -0.000 (0.002) |
| Gender | 0.027 (0.260) | 0.011 (0.103) |
| Marital status | 0.289 (0.294) | 0.115 (0.116) |
| Household size | 0.033 (0.030) | 0.013 (0.012) |
| Education | 0.013 (0.040) | 0.005 (0.016) |
| Maize farm size | 0.061 (0.053) | 0.024 (0.021) |
| Farming experience | 0.006 (0.010) | 0.002 (0.004) |
| Access to credit | -0.046 (0.222) | -0.018 (0.089) |
| *Off-farm income* | *-0.001 (0.000)** | *-0.001 (0.000)* |
| *Social group* | *0.628 (0.295)*** | *0.244 (0.108)* |
| *Intention to benefit from input subsidy* | *2.909 (0.231)**** | *0.838 (0.029)* |
| *Constant* | *-3.000 (0.585)**** | |
| Number of obs. | 373 | |
| P-value | 0.000 | |
| Wald $\chi 2$ (10) | 305.56 | |
| Pseudo $R^2$ | 0.597 | |
| *Note: ***, **, and * represent 1%, 5%, 10% levels of probabilities respectively.* | | |

Table 5 - PSM and IPWRA estimates of SAPs awareness.

| | *Matching type* | *Members* | *Non-members* | *ATT* | *Bootstrap S.E.* | *Z* |
|---|---|---|---|---|---|---|
| Frequency of SAPs Training | Unmatched | 2.695 | 1.748 | 0.947 | 0.2 | 4.74*** |
| | Nearest neighbour | 2.699 | 1.583 | 1.117 | 0.29 | 3.76*** |
| | Radius | 2.66 | 1.763 | 0.897 | 0.21 | 4.31*** |
| | IPWRA | | | 0.881 | 0.203 | 4.33*** |
| Knowledge of SAPs | Unmatched | 3.9 | 3.3 | 0.6 | 0.16 | 3.81*** |
| | Nearest neighbour | 3.91 | 3.44 | 0.47 | 0.21 | 1.92*** |
| | Radius | 3.88 | 3.38 | 0.5 | 0.16 | 3.21*** |
| | IPWRA | | | 0.51 | 0.16 | 3.13*** |
| *Note: ***, **, and * represent 1%, 5%, 10% levels of probabilities respectively.* | | | | | | |

However, other factors influence farmers' awareness of SAPs apart from cooperative membership (see Table 6). Gender has a significant positive influence on the frequency of SAPs training. The number of years of farmer education has a significant positive effect on all the awareness indicators of SAPs.

The PSM and IPWRA estimate highlighted that the cooperative membership positively affects the use of synthetic fertilizer (negative influence on non-use of synthetic fertilizer (Table 7). It is also evident that cooperative membership significantly influences farmers' adoption of environmentally sustainable mulching land practices and intercropping with leguminous crops. However, the nearest neighbour estimates for minimum tillage are not statistically significant. Regarding the sustainable agroforestry practices, only the nearest neighbour matching shows a significant positive impact of cooperative membership on their adoption. Cooperative membership has a significant positive effect on

Table 6 - Endogenous treatment regression estimates of SAPs awareness.

| | *Group membership* | *Frequency of SAPs training* | *Knowledge of SAPs* |
|---|---|---|---|
| Age | -0.000 (0.004) | 0.000 (0.003) | 0.003 (0.002) |
| Gender | 0.027 (0.260) | 0.394 (0.253) | 0.324 (0.202)* |
| Marital status | 0.289 (0.294) | -0.575 (0.297)* | -0.150 (0.237) |
| Household size | 0.033 (0.030) | -0.014 (0.026) | -0.014 (0.021) |
| Education | 0.013 (0.040) | 0.079 (0.04)** | 0.078 (0.032)** |
| Maize farm size | 0.061 (0.053) | -0.013 (0.01) | -0.018 (0.008)** |
| Farming experience | 0.006 (0.010) | -0.041 (0.052) | -0.023 (0.041) |
| Access to credit | -0.046 (0.222) | 0.122 (0.235) | 0.274 (0.188) |
| Off-farm income | -0.001 (0.000)* | | |
| Local social group | 0.628 (0.295)** | | |
| Intention to benefit from input subsidy | 2.909 (0.231)*** | | |
| Cooperative membership | | 1.614 (0.246)*** | 1.402 (0.217)*** |
| Constant | -3.000 (0.585)*** | 1.35 (0.476)*** | 2.413 (0.381)*** |
| Athrho | | -0.590 (0.140)*** | -0.980 (0.201)*** |
| lnsigma | | 0.638 (0.038)*** | 0.414 (0.041)*** |
| Number of obs | | 373 | 373 |
| P-value | | 0.000 | 0 |
| Wald χ2 (10) | | 58.352 | 67.383 |
| LR test of indep. eqns. (rho = 0): | | chi2(1) = 21.53 Prob > chi2 = 0.000 | chi2(1) = 30.09 Prob > chi2 = 0.000 |
| *Note: ***, **, and * represent 1%, 5%, 10% levels of probabilities respectively.* | | | |

adopting crop rotation practices based on all the matching types apart from the nearest neighbour and a significant positive impact on adopting crop diversification practices based on all the matching indicators.

From the endogenous treatment regression model (Table 8), the likelihood ratio tests of joint independence are significant for all the environmentally sustainable practices apart from the intercropping with legumes model. The signs and significance of the error of correlation terms show that the covariance terms of cooperative membership are statistically significant. Self-selection did not occur in the intercropping with leguminous crops model. Cooperative membership significantly impacts farmers' adoption of all the environmentally sustainable practices (see Table 8).

In terms of the other factors, gender (male) has a significant negative influence on the non-use of synthetic fertilizer. Years of education significantly influence the adoption of intercropping with intercropping with legumes, agroforestry, and crop rotation. Farming experience has a significant adverse effect on adopting mulching and intercropping with leguminous crop practices. Household size has a significant positive impact on the non-use of synthetic fertilizer. Interestingly, access to credit has a significant negative effect on adopting mulching, minimum tillage and agroforestry practices.

## 5. Discussion

The probit regression estimates of determinants of cooperative membership indicate that off-farm income negatively influences farmers' decisions to participate in the cooperative. It suggests that farmers who have an off-farm business or obtain income from off-farm activ-

Table 7 - PSM and IPWRA estimates of SAPs adoption.

| *Atmospheric* | *Matching types* | *Members* | *Non-members* | *ATT* | *Bootstrap S.E.* | *Z* |
|---|---|---|---|---|---|---|
| Non-use of synthetic fertilizer | Unmatched | 1.56 | 1.86 | -0.30 | 0.15 | -1.99** |
| | Nearest neighbour | 1.55 | 2.01 | -0.46 | 0.24 | -1.92* |
| | Radius | 1.56 | 1.88 | -0.31 | 0.16 | -1.90* |
| | IPWRA | | | -0.32 | 0.15 | -2.15** |
| *Land* | | | | | | |
| Mulching | Unmatched | 3.12 | 2.77 | 0.35 | 0.17 | 2.12** |
| | Nearest neighbour | 3.12 | 2.47 | 0.65 | 0.28 | 2.29** |
| | Radius | 3.13 | 2.66 | 0.47 | 0.19 | 2.54*** |
| | IPWRA | | | 0.38 | 0.16 | 2.27** |
| Minimum tillage | Unmatched | 3.57 | 3.18 | 0.39 | 0.17 | 2.24** |
| | Nearest neighbour | 3.55 | 3.33 | 0.22 | 0.3 | 0.73 |
| | Radius | 3.6 | 3.2 | 0.38 | 0.18 | 2.05** |
| | IPWRA | | | 0.33 | 0.18 | 1.86* |
| Intercropping with legumes | Unmatched | 4.56 | 4.282 | 0.275 | 0.105 | 2.63*** |
| | Nearest neighbour | 4.56 | 4.14 | 0.42 | 0.2 | 2.14** |
| | Radius | 4.56 | 4.25 | 0.31 | 0.11 | 2.72*** |
| | IPWRA | | | 0.31 | 0.11 | 2.75*** |
| *Biodiversity* | | | | | | |
| Agroforestry | Unmatched | 2.91 | 2.72 | 0.19 | 0.17 | 1.08 |
| | Nearest neighbour | 2.91 | 2.15 | 0.76 | 0.29 | 2.6*** |
| | Radius | 2.9 | 2.65 | 0.26 | 0.22 | 1.17 |
| | IPWRA | | | 0.231 | 0.173 | 1.33 |
| Crop rotation | Unmatched | 4.78 | 4.53 | 0.25 | 0.08 | 3.27*** |
| | Nearest neighbour | 4.78 | 4.52 | 0.26 | 0.16 | 1.6 |
| | Radius | 4.78 | 4.54 | 0.24 | 0.09 | 2.64*** |
| | IPWRA | | | 0.23 | 0.08 | 3.05*** |
| Crop diversification | Unmatched | 4.65 | 4.27 | 0.38 | 0.1 | 3.96*** |
| | Nearest neighbour | 4.65 | 4.36 | 0.29 | 0.16 | 1.80* |
| | Radius | 4.65 | 4.33 | 0.32 | 0.09 | 3.36*** |
| | IPWRA | | | 0.33 | 0.1 | 3.43** |
| *Note: ***, **, and * represent 1%, 5%, 10% levels of probabilities respectively.* | | | | | | |

ities have diversified attention, which prevents them from participating in the meeting and other activities of cooperatives. Also, farmers who engage in off-farm business can patronize their farm inputs and do not depend on the Zambian government's input subsidy through cooperatives. The findings are consistent with similar results from other countries (Klein *et al.*, 1997; Qiao *et al.*, 2009; Matchaya, 2010; Ma and Abdulai, 2019).

Experience with participation in other social groups besides producer cooperatives, such as savings and church groups, also significantly influences farmers' decision to join cooperatives, confirming findings of other authors (Matuschke and Qaim, 2009; Conley and Udry, 2010). We

Table 8 - Endogenous treatment regression estimates of SAPs.

| | | *Atmospheric* | *Land* | | | *Biodiversity* | | |
|---|---|---|---|---|---|---|---|---|
| | Group membership | Non-use of synthetic fertilizer | Mulching | Minimum tillage | Intercropping with Legumes | Agroforestry | Crop rotation | Crop diversification |
| Age | -0.000 (0.004) | -0.003 (0.002) | 0.003 (0.002) | 0.003 (0.003) | 0.002 (0.001) | 0.002 (0.003) | 0.001 (0.001) | 0.001 (0.001) |
| Gender | 0.027 (0.260) | **-0.326 (0.194)*** | -0.126 (0.206) | -0.041 (0.221) | 0.174 (0.129) | 0.120 (0.217) | 0.097 (0.096) | 0.041 (0.123) |
| Marital status | 0.289 (0.294) | -0.044 (0.227) | 0.077 (0.241) | -0.094 (0.259) | 0.07 (0.151) | 0.020 (0.254) | -0.035 (0.1120 | 0.160 (0.144) |
| Household size | 0.033 (0.030) | **0.045 (0.020)**** | -0.013 (0.021) | -0.027 (0.023) | -0.006 (0.013) | -0.013 (0.022) | -0.005 (0.010) | 0.015 (0.013) |
| Education | 0.013 (0.040) | -0.040 (0.031) | 0.037 (0.033) | 0.043 (0.035) | **0.065 (0.02)***** | **0.098 (0.034)***** | **0.040 (0.015)***** | 0.014 (0.019) |
| Maize farm size | 0.061 (0.053) | 0.057 (0.040) | 0.010 (0.042) | 0.027 (0.045) | -0.032 (0.026) | 0.004 (0.044) | -0.015 (0.020) | 0.005 (0.025) |
| Farming experience | 0.006 (0.010) | 0.000 (0.007) | **-0.028 (0.008)***** | 0-.013 (0.008) | **-0.009 (0.005)*** | -0.002 (0.008) | -0.002 (0.004) | -0.008 (0.005) |
| Access to credit | -0.046 (0.222) | 0.078 (0.180) | **-0.420 (0.191)**** | **-0.344 (0.206)*** | 0.164 (0.120) | **-0.372 (0.202)*** | 0.129 (0.089) | 0.162 (0.114) |
| Off-farm income | **-0.001 (0.000)*** | | | | | | | |
| Local social group | **0.628 (0.295)**** | | | | | | | |
| Intention to benefit from input subsidy | **2.909 (0.231)***** | | | | | | | |
| Cooperative membership | | **-0.855 (0.230)***** | **0.732 (0.200)***** | **0.948 (0.241)***** | **0.388 (0.129)***** | **0.601 (0.210)***** | **0.395 (0.090)***** | **0.627 (0.117)***** |
| Constant | **-3.000 (0.585)***** | **2.373 (0.365)***** | **2.830 (0.386)***** | **2.923 (0.416)***** | **3.682 (0.242)***** | **1.685 (0.408)***** | **4.128 (0.180)***** | **3.788 (0.231)***** |
| Athrho | | 0.596 (0.200)*** | -0.311 (0.123)** | -0.516 (0.170)*** | -0.182 (0.130) | -0.426 (0.128)*** | -0.355 (0.112)*** | -0.532 (0.128)*** |
| Lnsigma | | 0.370 (0.039)*** | 0.431 (0.037)*** | 0.503 (0.038)*** | -0.037 (0.037) | 0.484 (0.037)*** | -0.333 (0.037)*** | -0.085 (0.038)** |
| Number of obs | | 373 | 373 | 373 | 373 | 373 | 373 | 373 |
| P-value | | 0.002 | 0.000 | 0.005 | 0.000 | 0.006 | 0.000 | 0.000 |
| Wald χ2 (10) | | 26.75 | 33.78 | 23.29 | 38.95 | 23.09 | 35.21 | 44.74 |
| LR test of indep. eqns. (rho = 0): | | chi2(1) = 11.250 Prob > chi2 = 0.0112 | chi2(1) = 6.83 Prob > chi2 = 0.009 | chi2(1) = 12.58 Prob > chi2 = 0.001 | chi2(1) = 1.92 Prob > chi2 = 0.165 | chi2(1) = 12.34 Prob > chi2 = 0.000 | chi2(1) =8.98 Prob > chi2 = 0.002 | chi2(1) =16.88 Prob > chi2 = 0.000 |

perceive such membership as a proxy for farmers' social capital, openness to working with others and willingness to adopt innovations and new technologies (Matuschke and Qaim, 2009; Fischer and Qaim, 2012). Farmers who are already members of other social groups may also understand the benefits of cooperative membership in a farmer-to-farmer learning experience.

Farmers' intention to benefit from the government input subsidy (FISP scheme) is another significant factor influencing farmers' decision to participate in agricultural cooperatives. In Zambia, the government uses agricultural cooperatives as the primary channel to distribute inputs to farmers at a subsidized price. Therefore, most farmers decide to join cooperatives because of this external motivation (Donkor and Hejkrlik, 2021).

The various matching types indicate that cooperative membership positively affects farmers' environmentally sustainable practices. Also, the linear regression with endogenous treatment effect confirms the results of the matching types. These results imply that collective actions linked to external consultancy systems are good channels for remote smallholder farmers in rural areas to access and learn environmentally sustainable practices. Through internal communication mechanisms, the cooperatives distribute information from government extension agents connected to the cooperative leaders or from various development non-governmental organizations. There is also an excellent opportunity for members to gain from the farmer-to-farmer learning experience and the social interactions organized by the cooperative. The leaders of the cooperatives are usually lead farmers and main opinion-makers in their communities. Also, attending cropping events increases the chance for farmers to know and adopt sustainable agricultural practices (D'Emden *et al.*, 2008; Ashrit and Thakur, 2021). From the qualitative interviews, the leaders of the cooperatives highlighted that the cooperatives facilitate the adoption of SAPs through the "zone system". Through the zone system, the cooperatives periodically train each zone members on SAPs. The zone system ensures consistent and effective meetings and training to understand better the topic the members are trained on. Each zone has a leader who attends training and events of SAPs organized by agricultural extension agents and the cooperative department. The leader of the zone trains the cooperative members of his area accordingly. Also, the leaders stated they invite government or non-government extension agents to their meetings to train them on good agricultural practices.

Consequently, farmers with better access to information and more frequent contact with extension services have a better perception of the importance of environmentally sustainable practices (Füsun Tatlidil *et al.*, 2009). As confirmed by other authors, the cooperative's learning experience through extension access, attending SAPs events by the cooperative leaders, and farmer-to-farmer experience serve as an excellent opportunity for the cooperative members to adopt SAPs compared to the non-members (Nkomoki *et al.*, 2018). Thus the results confirm the assertions made by Wanyama (2014) and COPAC (2018) in terms of cooperatives serving as an avenue for educating its members on the importance of sustainable production and the protection of the environment. And awareness of SAPs is an essential factor in adopting new techniques by smallholder farmers (Ashrit and Thakur, 2021).

From our results, it is evident that cooperative membership not only improves access to needed information but also positively influences the adoption of environmentally sustainable practices. The findings confirm the empirical review done by Candemir *et al*. (2021) on cooperatives and farm sustainability, demonstrating the positive impact of cooperative members on adopting environmentally sustainable practices. Nkomoki *et al.* (2018), in their study in the Southern province of Zambia about SAPs, indicated that the cooperative members adopt crop diversification strategy because they receive different inputs at a cheaper cost than non-members. Another contributing factor of cooperative membership impact on SAPs adoption is the technical support members enjoy from (or through) the cooperative, as similarly found by Naziri *et al.* (2014) and Ji *et al.* (2019).

However, the cooperative membership encouraged the use of synthetic fertilizer since only these were part of the FISP input packages that the cooperative members received from the Zambian government. From the assertion of Nkomoki *et al.* (2018), we could assume that cooperative members may use synthetic fertilizer more than the non-members because of the targeted subsidies. Another possible explanation could be linked to the income level of the members and the non-members, when the members have the financial capacity to purchase synthetic fertilizer. We tried to confirm if income plays a positive role in the adoption of synthetic fertilizer, so we analysed the asset value of the members and the non-members. However, the difference was not statistically significant.

As we learned from our models, other factors significantly influence smallholder farmers' awareness and adoption of sustainable agricultural practices apart from cooperative participation. Male gender has a significant favourable influence on the knowledge of SAPs. Our study confirms the findings of Ashrit and Thakur (2021). Male gender also has a significant negative influence on the non-use of synthetic fertilizer, indicating that male farmers are more urgent to purchase synthetic fertilizer to apply on their farms. Household size also has a significant favourable influence on the non-use of synthetic substances and crop diversification practices. In other words, a larger family size encourages the adoption of sustainable environmental practices by not applying synthetic fertilizer. It may be opinioned that households with larger family sizes in the rural setting may lack the financial capacity to purchase non-synthetic fertilizer, hence the non-use of synthetic fertilizer (Ma *et al.*, 2018).

Years of farmer education have a significant favourable influence on all the awareness measures of environmentally sustainable practices. Highly educated farmers are more enlightened about environmentally sustainable practices and their benefits to the community and productivity (Myeni *et al.*, 2019; Ashrit and Thakur, 2021). Also, years of education significantly influence adopting intercropping with leguminous crops, agroforestry, and crop rotation practices. Again, there is already extensive evidence that highly educated farmers are more knowledgeable about SAPs which increases their probability to adopt SAPs (Wossen *et al.*, 2017b; Ma and Abdulai, 2019; Myeni *et al.*, 2019; Ashrit and Thakur, 2021).

Interestingly, farming experience negatively the adoption of land sustainable practices (mulching and intercropping with leguminous crops). Nevertheless, our study is consistent with studies such as Matuschke and Qaim (2009), who revealed a similar negative influence on the intensity of adoption of hybrid wheat and pearl millet technologies. It may be assumed that experienced farmers are used to traditional farming techniques and do not want to adopt new practices. Our result contradicts studies such as Baffoe-Asare (2013) and Nkomoki *et al.* (2018), which found a significant impact of farming experience on adopting cocoa high yielding technologies and crop diversification and agroforestry, respectively.

Access to credit also has a significant negative influence on mulching, minimum tillage, and agroforestry adoption. The results are similar to the study done by (Nkomoki *et al.*, 2018) in the Southern province of Zambia. Also, Myeni *et al.* (2019) study found the negative influence of access to credit on adopting both traditional and new sustainable practices. Access to credit is a constraint in the study area (only 26% of members and 19% of non-members get access to credit).

## 6. Conclusion

The study analyzed the influence of agricultural cooperatives on smallholder farmers awareness and adoption of environmentally sustainable practices in southern Zambia. The probit regression model was used to explore the determinants of cooperative membership and assign propensity scores. The propensity score matching was used to analyze the impact of cooperative membership on smallholder farmers awareness and adoption of environmentally sustainable practices by controlling for observable bias. The linear regression with endogenous treatment effect was further used to control for unobserved bias and estimate the impact of cooperative membership on farmers awareness and adoption of environmentally sustainable practices.

The significant determinants of cooperative membership based on the probit regression model were off-farm income, local social group participation, and perceived intention to benefit from the input subsidy. Both the propensity score matching and the linear regression with endogenous treatment effect models showed that cooperative membership has a significant favourable influence on smallholder farmers awareness and the adoption of environmentally sustainable practices, even though the cooperative membership used to encourage in the past the use of synthetic fertilizer due to the design of government farmer input subsidy scheme.

We can recommend that the Zambian government and development organizations that seek to achieve environmental sustainability rely on cooperatives as the primary channel to achieve such goals. The results show that cooperatives are suitable instruments for farmers to spread the information and provide training on environmental sustainability The cooperative values such as democratic decision making, equality, local responsibility, solidarity, and interdependence also give cooperatives a unique identity and mission to impact their members to adopt SAPs. The International Cooperative Alliance (ICA) cooperative principles of education, training and information, cooperation among cooperatives and concern for the community confirm such potential. Communication and interactions within the farmers' groups are vital for the members to be aware and adopt environmentally sustainable practices, even though the members still perceive some obstacles and short-term costs of implementation. We also recommend future studies to focus on the relationship between the adoption of environmental sustainability and the economic benefits of the cooperative members.

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