An Approach for Enhancing the Adoption Rate of Pfumvudza Farming on Maize Production in Gwanda District

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ABSTRACT

This study assessed approaches to enhance the adoption rate of Pfumvudza farming among smallholder farmers in Gwanda district. Descriptive statistics were used to analyze the adoption rate. The sample consisted of 538 smallholder communal farmers selected through stratified random sampling across all 24 wards in Gwanda district. Results showed 126 adopters and 412 non-adopters, giving an adoption rate of 23.42% and a non-adoption rate of 76.58%. Data were analyzed using STATA version 13. Multicollinearity was tested using the Variance Inflation Factor (VIF), with results below 5 indicating its absence. A logit regression identified the number of plots and household size as factors determining adoption. Propensity Score Matching was used to assess the impact of Pfumvudza farming on household food security. The Average Treatment Effect results indicated that adopters achieved 48% higher food security than non-adopters. Additionally, adopters obtained 888 kg per hectare more maize yield than non-adopters. Capacity building, training, and government support were identified as key strategies to enhance adoption. The study recommends the adoption of Pfumvudza farming by smallholder farmers.

Key words: Adoption rate, communal farmers, food security, Pfumvudza farming, smallholder farmers

INTRODUCTION

Conservation Agriculture (CA) has been increasingly promoted as a strategy to address food insecurity, particularly in Sub-Saharan Africa [21]. CA is defined by three core principles: minimum mechanical soil disturbance, permanent organic soil cover, and diversified crop rotations or associations, including legumes [21]. It was designed to mitigate the impacts of climate change on agriculture, with the goal of boosting productivity and increasing resilience to climate-induced challenges [23]. Many studies have explored factors influencing farmers' adoption of new technologies [4], though adoption can occur in various forms—partial, discontinued, or resumed [9]—and may happen suddenly due to changing circumstances rather than through gradual diffusion [12]. There has also been growing interest in social networks and farmer-to-farmer extension as alternatives to traditional public-sector approaches [58].

However, the labor-intensive nature of CA often discourages farmers from continuing its practice [63]. In response, Foundations for Farming developed Pfumvudza, an intervention aimed at reducing labor demands in field preparation and mulch collection while providing necessary inputs. As highlighted by [20], the primary goal is for a family to feed itself. This approach simplifies CA principles, making it accessible and sustainable for smallholders.

The Government of Zimbabwe introduced the Pfumvudza program during the 2020/21 cropping season to improve maize production and food security [46]. It is based on three core principles: minimum soil disturbance, mulching, and specific spacing (60 cm × 75 cm) [47]. Despite its potential, the adoption rate of agricultural technologies remains low in general [3]. This study therefore investigates approaches to enhance the adoption rate of Pfumvudza farming among smallholder maize farmers in Gwanda district.

Adoption refers to the decision to use a new practice, while adoption rate measures its prevalence among a target group. Although Pfumvudza is widely practiced in Zimbabwe, its adoption rate is not well documented. This study aims to provide data on the adoption rate of Pfumvudza for maize production in Gwanda district and identify strategies to enhance it.

Research objectives

General objective

To design an approach for enhancing adoption rate of Pfumvudza farming by smallholder farmers on maize production in Gwanda district.

B. Specific objectives

i) To analyze the adoption rate of Pfumvudza farming on maize production in Gwanda district.

ii) To assess factors that determine the adoption of Pfumvudza farming on maize production in Gwanda district

iii) To assess the impact of Pfumvudza farming adoption on household food security.

iv) To identify strategies for enhancing the adoption of Pfumvudza farming by smallholder farmers.

MATERIAL AND METHODS

The study is based on a cross-sectional survey of the 2023/2024 farming season of Gwanda rural district in Zimbabwe. The researcher uses, formular postulated by Yamane [62] to calculate sample size. The study has four hypotheses which make use of different methods of analysis within a certain framework of analysis. The study seeks to assess how the government led Pfumvudza Program has impacted household's food security and at the same time looking into the determines that influences household's participation into the program and the rate of participation. As well finding strategies that enhance the adopt of Pfumvudza adoption on maize production by small holder farmers.

The first specific hypothesis raised was that the adoption rate of Pfumvudza farming on maize production in Gwanda district. To test this hypothesis so as to address the question of what is the adoption rate of Pfumvudza farming on maize production in Gwanda district. Descriptive statistics was used to calculate adoption rate.

The second objective of the study is to assess factors that determine the adoption of Pfumvudza farm the study uses a binomial logit model to analyses factors that determine the adoption of Pfumvudza farming on maize production in Gwanda district. This method has been used by several authors to study household decision to adopt to new technologies [56], [5], [25], [2], [39]; Researchers who looked into household's decisions to adopt or dis-adopt conservation agriculture and in climate change adaption studies, [52].

The dependent variable in this study is a dichotomous, that is, households' decision to participate or not to participate in the Pfumvudza Program, this makes the Binary Logit more appropriate as it considers the relationships between a binary dependent variable and a set of explanatory variables, [49] The binary logit model in this case is appropriate because it considers the relationship between a binary dependent variable and a set of independent variables.

Binary Logistics regression models are used during the prediction of categorical dependent variables with an explanatory variable or a set of explanatory variables, [33]. The model uses the Maximum Likelihood (ML) program during the selection of the coefficient estimates that maximizes the log of the probability of observing the particular set of values of the dependent variable in the sample for a given set of explanatory values, [33].

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The Logit model is specified as:

$P\ (Y_i=1|X_i)\ =F\ (X_i\ \beta_i)$ [1]

Where: *P is the probability that Y = (0, 1); Y_i =dependent variable; Xi =independent variables; β_i= the regression coefficient; F (.) is the density function for logistic distribution of the model*

By transforming the probability (Y) in (1) into log odds the model takes the following expression:

$\text{Logit (P)} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n + u_i$ [2]

The empirical binary logit to be estimated consist of 5 covariates that will be regressed against the dependent variable. The study specific model is expressed in its implicit form as follows:

$Y=f\ (X_1, X_2, X_3, X_4, X_5,)$

The model variables and their justification for use in the study were guided by previous studies on adoption and dis-adoption of CA technologies, [34]; [52]; [49].

Where Y is the adoption status (1= farmers who adopted, 0= farmers who did not adopt;

X1 is yield;

X2 is cattle ownership (number of cattle)

X3 is household size8

X4); household head gender (1=male,0=female)

X5 is number of plots

The third objective of the study was to assess the impact of Pfumvudza farming adoption on house hold food security. The study uses propensity score matching to assess the impact of Pfumvudza farming adoption on house hold food security. This method was first proposed in [55]. The participants in a project are matched with non-participants from a larger survey. In this case, the counterfactual is the matched comparison group. Each program participant is paired with one or more non-participants that are similar based on observable characteristics. It assumes that, conditional on the set of observables, there is no selection bias based on unobserved heterogeneity.

However, steps of running a propensity score matching were done as follows: Firstly, logit regression, secondly P-score summary and lastly average treatment effect [6]; [30]. Prior to non- parametrically estimating the impact of scores required specification justifying that a household had been included in the adoption. It was noted in [10] that the idea of matching is to compare a beneficiary with one or more beneficiary who are similar in terms of a set of observed characteristics. This requires predicting the propensity scores for each individual using logit or probit model. In this study, the researcher used a logit model to predict the probability that a household participates in the food security program, in this model, household characteristics are included as regressors.

Before presenting the Average Treatment Effect estimates, the researcher shows the results of the first stage logit model and check for the quality of matching. The logit regression is used to compute the propensity score used for matching method. The objective of this selection model is not to explain the of Pfumvudza farming as exactly as possible but to form a basis for eliminating the observed and non-observed differences between treated and non-treated in the matching procedure [27].

RESULTS AND DISCUSSION

Results for objective one

The adoption rate results, was calculated using number of adopters divided by the sample population or number of possible adopters. The results are presented with respect to gender in percent. Below is table shows the adoption rate of Pfumvudza farming in Gwanda district.

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Table 1. Contingency table showing adoption rate of Pfumvudza farming on maize production in Gwanda district, Zimbabwe 2023/2024 season

Adoption status	Percentage of female adoption rate	Percentage of male adoption rate	Total percentage of adoption rate	P-value (Pr)	Pearson chi2(1)
Adopt	24.26%	22.77%	23.42%	0.687	0.1623
Non adopt	75.74%	77.23%	76.58%		
Total	100%	100%	100%		

Source: survey data

Table 1. above shows that chi-square (□2) value is (0.1623). It measures the difference between observed and expected frequencies. A small (□2) value indicates that frequences are close to expected frequences. Also, p-value (Pr) is (0.687), it is the probability of observing the test statistics (□2) under the null hypothesis. P> 0.05 indicates failure to reject the null hypothesis. Where the null hypothesis state that there is no significant association between household head sex and adoption.

Therefore, the Pearson chi-square test (□2 = 0.1623, p= 0.687) suggest that no significant association between household sex and adoption. The adoption rates are largely similar across female headed (57/235= 24.3%) and male-headed households (69/303 =22.8%). The difference in adoption is not statistically significant. This analysis indicates that household head sex does not significantly influence adoption decisions. No significant differences rates of fertilizer use by male- and female- farmer in Ghana in [17]. Similarly, in [8] and [26] found that the gender of the household head has no significant effect on the adoption and intensity of use of chemical fertilizer in Zimbabwe and Kenya, respectively.

The adoption rate of Pfumvudza farming was calculated as percentage of sampled smallholder farmers practicing Pfumvudza farming on maize production over the total number of smallholder farmers used in the study. The study established that 23.42% of the smallholder farmers in Gwanda district adopted Pfumvudza farming. This was also hypothesized that the adoption rate is too low in Gwanda district. This was also supported in [29] on their study determinants of adoption and dis-adoption of minimum tillage by cotton farmers in eastern Zambia. Their adoption rate was 24%. Their results came out after combining data from survey and semi structured interviews, they examine farmers motivations for adopting CA and determinants of adopting and dis adoption of hand hoe and oxen drawn minimum tillage. On their study the adoption rates were relatively low that is 12% of cotton area and 20% of maize area. They argued that farmers are interested in adopting minimum tillage but the available minimum tillage technologies do not match their resource endowments. Labor constrains limits use of hand hoe basins while equipment costs limit oxen ripping machines. In [18], on their study, Agricultural technology adoption for smallholder small grain farmers in Zimbabwe, their results showed that 56% of the sample were non-adopters while 44% were adopters. In this study, most of the adopters were from Hwange (26.4%) followed by Chiredzi and Binga with 24.8% each and Matobo had the least (24%). On Conservation Agriculture few farmers (30%) in Binga are adopting CA. Respondents through focus group discussion highlighted that it is difficult to practice CA as it requires a lot of labor.

Apart from that, the rate of adoption theory state that adoption takes place over time with innovation going through a slow gradual period followed by dramatic and rapid growth and then a gradual stabilization and finally decline [1]. Therefore, the researcher is highly expecting that in Gwanda District the Pfumvudza adoption rate will increase with time. Also, in [11] on their study factors influencing the adoption of conservation agriculture practices among smallholder farmers in Mozambique, find out that 44.6% of smallholder farmers adopted one or more of the Conservation Agriculture (CA) practices, and 55.4% did not. It was also clear that most farmers did not adopt all components CA. These results signify a low adoption rate on new farming method (CA).

In [53] on their study the intensity of conservation agriculture by smallholder farmers in Zimbabwe also postulated that across the four years of the panel, smallholder farmers commonly used between four and seven

CA components with a mean of five and median of six components. On average, only 7.4% of farmers used all eight techniques in any given year, whereas 16.6% did not apply any of the components in any given year, as the farmers reverted to the plough. The proportion of farmers using the full package declined after 2009 just as donor support declined. Indications of a high-intensity of adoption are that more than half of the farmers used more than five components in any given year. Few of the farmers (23%) used fewer than three techniques, which is indicative of low levels of adoption intensity.

Conclusively, the researcher's results indicate that there is a lower significate level of adoption rate of Pfumvudza farming on maize production in Gwanda district, therefore there is need for interested parties together with government to find working solutions to address the barriers.

Results for objective two; To assess factors that determine the adoption of Pfumvudza farming on maize production in Gwanda district.

Firstly, the researcher presents binary model diagnostic test results which are multicollinearity test using VIF. In order to test if the model was a good model for the empirical analysis diagnostic test should be conducted by [31].

Multicollinearity test

The researcher test for model assumption, run multiple linear regression followed by VIF test for multicollinearity. This is because one should run multiple linear regression first before VIF. Table 2 below shows the VIF test results for multicollinearity.

Table 2. VIF test for multicollinearity

Mean VIF	1.34

Source: survey data

The results on table 2 above shows that there is no presence of multicollinearity. After conducting the test, the results did not indicate any presence of multicollinearity within the model. Multicollinearity occur when two or more predictor variables in regression model are highly corelated, making it difficult to determine the individual effect of each variable on the outcome. Mean VIF is 1.34, if there is presence of multicollinearity VIF will be greater than 5 hence if its less than 5, it means no multicollinearity. Therefore, the results tested for model diagnostic test allows the researcher proceeds to run the binary logit regression test.

Binary logistic results

Factors which determine the adoption of Pfumvudza farming are number of plots, number of cattle, household size, household head sex, and maize yield. These factors were analyzed using the binary logit regression on STATA 13 software. Below is table 3 showing the binary logit regression results.

Table 3 binary logistic results

Variables (Adopt / non adopt)	**Coefficient**	**Significant level (p<0.1*, 0.05** & 0.01***)**
Number of cattle	.0044717	0.919
number of plots	7.216128	0.000***
Household head gender	-.1415281	0.820
Household size	-1.27441	0.019**
Maize yield (th)	.0842635	0.828

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NB, Number of observations = 538, LR chi2(5) = 494.12, Prob > chi2 = 0.0000, Log likelihood = -45.77301& Pseudo R2 = 0.8437.

Source: survey data

From the logit regression results shown on table 3 above, adjusted R-squared is 84%, which means the model is explained by 84% of the variation in the dependent variable. R- squared of 84% shows that the model was correctly specified. An adjusted R- squared of 84% indicates that the model explains approximately 84% of the variation in the dependent variable (adopt/non adopt) after accounting for the number of predictors and sample size. The model has a high explanatory power, capturing about 84% of the variation in the outcome variable. The remaining 16% of the variation is unexplained by the model, possibly due to omitted variables, measurement error and fluctuations.

The model's signification probability chi-square is 0.0000, this means that the data model is a good fit to the data and the probability of observing the data (or more extreme) assuming that the model is true. Log likelihood is (-45.77301) is a measure of how well the logit regression model fits the data, a lower likelihood indicates better fit. Log likelihood with larger negative values indicates poor fit while smaller negative values indicate good fit but values close to zero indicate excellent fit. According to [33] log likelihood helps during the selection of the coefficient estimates it maximizes the log of probability of observing the particular set of values of the dependent variables in the samples for a given set of explanatory values. Therefore, a log likelihood of (-45.77301) means the logit regression model fits the data.

Apart from that, factors which determine the adoption of Pfumvudza which are significant are as follows, number of plots is significant at 1% confidence interval, its p- value is (0.000), it is highly statistically significant. This suggest that number of plots is also one of the factors that determine the adoption of Pfumvudza farming by smallholder farmers in Gwanda district.

Number of plots has a positive coefficient of (7.216128) and is statistically significant at 1 %, therefore rate of adoption increases or is greater as the number of plots increase. If a farmer has more plots, it means a farmer is likely going to adopt Pfumvudza farming on maize production. Farmers with more plots are more likely to adopt Pfumvudza farming possibly due to economies of scale or greater resources. All in all, it indicates an increase in number of plots is associated with a higher likelihood of adoption. This was also supported in [43], on their study factors influencing adoption of conservation agriculture done in Swaziland. Their research findings were that adopters had more land than non-adopters.

Household size, is also another factor which determine the adoption of Pfumvudza farming and it is significant at 5 % with a p- value of (0.019) and a negative coefficient of (-1. 27441). This was also supported, in [34] on factors affecting adoption and intensity of conservation agriculture techniques applied by smallholders in Masvingo district, Zimbabwe; in [49] on their study sustainable agriculture and food security in Africa, postulated that the consumption pressure as a result of a large household size may result in diversion to off-farm activities to generate more income therefore limiting chances of adopting. In [53] on their study the intensity of adoption of conservation agriculture by smallholder farmers in Zimbabwe find out that household size as a measure of family labor has a negative impact on adoption intensity, contrary to expectation. In [53] used a man day equivalents rather than total household size to measure access to labor, but this failed to reverse the sign of the estimated coefficient This means that household size is one of the factors which determine the adoption of Pfumvudza farming by smallholder farmers in Gwanda district. Despite Pfumvudza farming being a high labor requirement, family with a bigger size see it not worth to spend more of their time digging hole on a small plot rather to work on large area using moldboard plough. Therefore, an increase in household size is less likely lead to the adoption of Pfumvudza farming by smallholder farmers in Gwanda district. Also, increase in household size, will lead to other members engaging on off farm activities to bring food on the table. Especially in Gwanda district, other family members are into gold mining and vending.

Conclusively, the researcher finds out that, number of plots and household size are the most factors which determine the adoption of Pfumvudza farming. Also, number of plots are positively influencing adoption of

Pfumvudza while household size is negatively influencing the adoption of Pfumvudza farming. These factors were also supported by different researchers.

Results for objective 3; to access the impact of Pfumvudza adoption on household food security.

The study uses propensity score matching to assess the impact of Pfumvudza farming adoption on household food security. Steps of running a propensity score matching were done as follows: firstly, logit regression, secondly P -score summary and lastly average treatment effect [6]; [30]. Yield per kg was calculated using descriptive statistics. Below is the table showing the p -score matching results.

Table 4. Propensity score matching

Observation	536
Mean p score	23

Source: survey data

Number of observations were 536, p score variable represents the propensity score, which is a measure of the probability of being treated (adopting Pfumvudza farming) based on observed characteristics. The mean p score is approximately 0.23, indicating that, on average, the probability of adoption is around 23%. In the context of propensity score matching, the p score is used to match treated and control units based on their observed characteristics, to estimate the treatment effect. Below are the average treatment effect results

Table 5. Treatment effect estimation of impact of adopting Pfumvudza on selected outcomes

Non adopters	412
Adopters	126
Average treatment effect (ATE)	.4813433
Average treatment effect treated (ATET)	.3387097
Maize yield	888.54
Z	0.000

Source: survey data

The Average treatment effect on table 5 above represents the difference in food security outcomes between adopters and non-adopters, accounting for the observed covariates. The results show Pfumvudza had a positive and significant impact of maize yield and food security. The impact on food security was significant. The magnitude of the impact on maize yield was quite marked, at 888 kg per ha. This means that, on average a farmer who practiced Pfumvudza achieved maize yield per ha that were 888kg higher than a comparable farmer who did not practice Pfumvudza. In [57] carried out a research study on the Impact of CA on productivity and food security, 488 farmers were used as the sample size. The propensity score-matching approach CA was used and had a positive impact on maize grain yield. In [57] also find out that CA have a positive impact on maize grain yield (ATT= 473 kg per ha). This means that, on average adopters tend to have better food security outcome than non-adopters after controlling for the observed covariates. The 48% food security was acquired by adopters which is above food security acquired by non-adopters.

A research study on the potential impact of the adoption of soil and water conservation technologies on household food security in the Chinyanja Triangle using 312 households was done by [37]. Propensity Score Matching results shows CA has a significant impact on cereal consumption. Impact of CSA on household income and asset

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accumulation among smallholder farmers in Kenya was done by [51]. A sample size of 433 households was used and the Propensity Score Matching (PSM), adoption results show that significantly enhances household income which, in turn, improves household asset accumulation.

Table 6. Frequence distribution for food security status

Access to food	Non adopter	Adopters	Total
Food insecure	350	47	397
Food secure	62	79	141

Source: survey data

The table 6 above shows that of the total sample of 538 farmers, 350 who are non-adopters were food insecure while 47 of the adopters were also food insecure. However ,62 where food secure for the non-adopters and 79 adopters were food secure. Therefore, this shows that even if the overall numbers of adopters were very low but there where food secure most of them than non-adopters. The is strong association between adoption and food security status. Adopters are more likely to be food secure compared to non-adopters.it was also postulated in [43] that if farmers had inadequate food, that did not influence the adoption of conservation agriculture.

Results for objective four: Strategies for enhancing the adoption of Pfumvudza farming by smallholder farmers.

See figure 1 below showing the mean distribution summary of strategies which enhance the adoption of Pfumvudza farming by smallholder farmers.

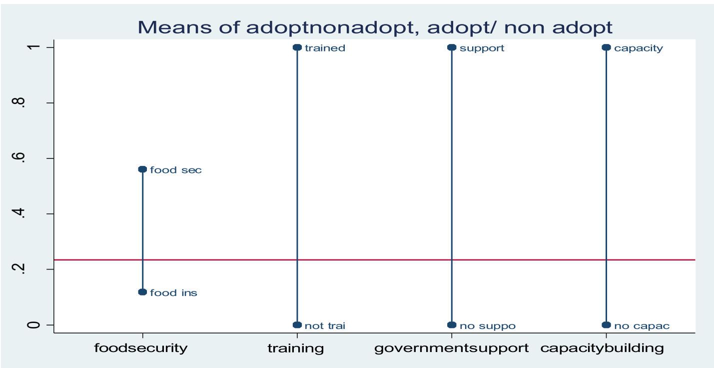

Figure 1: mean distribution of strategies for enhancin gpfumvudza adoption

Source; survey data

These results indicates that training among other strategies is essential for the adoption of Pfumvudza farming. According to [47], also postulated that it is possible to feeding a family from such a small area of land (Pfumvudza plot) but it requires training to ensure success. Training programs, led by extension agents and experts, educates farmers on the benefits and implementation of Pfumvudza farming techniques such as mulching, crop rotation and minimum tillage [44]. From the mean distribution graph above, it shows that most of the smallholder farmers who did not adopt, are food insecure and they did not receive training, government support and capacity building.

The government of Zimbabwe has established a policy framework that supports the adoption of Pfumvudza farming. Capacity building initiatives are aligned with the framework, ensuring that farmers receive training and support that is consistent with national policies [28]. Also, government support comes through provision of extension services, which is critical for capacity building. Extension agents work closely with farmers, providing

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training, guidance and support to ensure the successful adoption of Pfumvudza practices [44]. Government of Zimbabwe offers input support such as seeds, fertilizer and lime to ensure that benefits

Strategies which enhance the adoption of Pfumvudza farming at different levels.

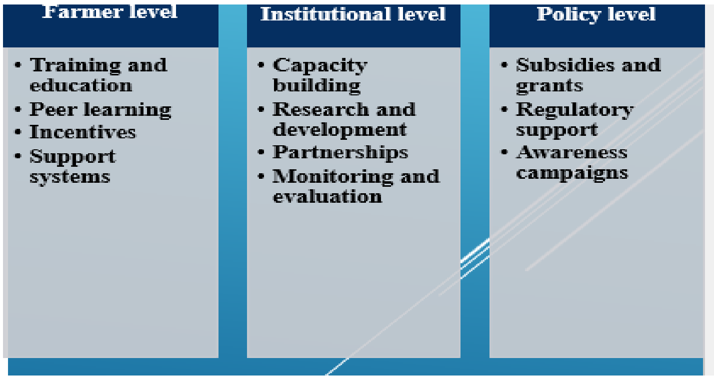

Figure 2; strategies which enhance the adoption of Pfumvudza at different levels.

Source; survey data

See figure 2 above showing the strategies which enhance the adoption of Pfumvudza at different levels. Policy strategies include regulatory support, awareness campaign and offering of grants and subsidies. These policy strategies enhance the adoption rate of Pfumvudza concept hence increase maize yield leading to an improve on farmers food security status.

Conclusively capacity building plays a vital role in enabling the adoption of Pfumvudza farming and government support. Through the provision of training, extension service and inputs support, capacity building initiatives empower farmers to usefully implement Pfumvudza farming thereby improve their food security status.

CONCLUSION

This study analyzed approaches to enhance the adoption of Pfumvudza farming among smallholder maize farmers in Gwanda district. The adoption rate was low (23.42%), influenced positively by the number of plots and negatively by household size. Pfumvudza adoption significantly improved food security and maize yield. Key strategies to enhance adoption include training, capacity building, and government support. These findings emphasize the need for coordinated efforts to promote Pfumvudza as a viable approach to improving food security and agricultural productivity.

In [47], also postulated that it is possible to feeding a family from such a small area of land (Pfumvudza plot) but it requires training to ensure success. Researcher results shows that adoption rate of Pfumvudza farming is very low about 23 % in Gwanda district. Factors such number of plots and household size determine the adoption of Pfumvudza farming.

There is a strong association between adoption status and food security status. Adopters are more likely to be food secure (64.0% of adopters are food secure) compared to non-adopters (26.5% of the non-adopters are food secure). Also, nonadopters are more likely to be food insecure (76.6% of the non-adopters are food insecure) compared to adopters (35.7% of the adopters are food insecure). Being food secure increases the likelihood of adoption, while being mildly food insecure decreases it. Smallholder farmers, who adopt Pfumvudza farming are less likely to experience food insecurity but more likely to experience food secure. In [43] also postulated that if farmers had inadequate food, that did not influence the adoption of conservation agriculture.

Conclusively, the results suggest that adoption is associated with improved food security and that adopters are more likely to be food secure compared to non-adopters. Also, Pfumvudza farming on maize production in Gwanda district have a positive impact on food security.

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Ethical Approval

This study did not obtain any ethical approval from any institution but ethical approval was obtained from participants before data collection

Data availability

Data used for this research is available, below.

Conflict of interest

The researchers do not have any conflict of interest.

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