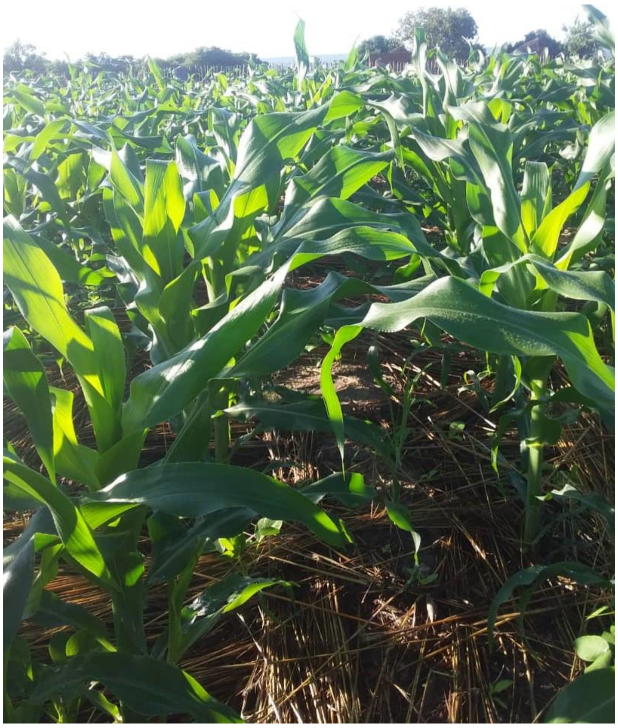
IMPACT OF PFUMVUDZA FARMING CONCEPT ON MAIZE PRODUCTIVITY IN ZIMBABWE



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About LFSP: The Zimbabwe Livelihoods and Food Security Programme (LFSP), Agriculture Productivity and Nutrition Component (APN) is managed by the Food and Agriculture Organisation of the United Nations (FAO), with the aim of contributing to poverty reduction through increased incomes for a target 250,000 smallholder farming households. The programme is being implemented in four provinces covering 12 districts, namely: Mutasa, Mutare, and Makoni in Manicaland; Guruve, Bindura, Mazowe and Mt Darwin in Mashonaland Central; Kwekwe, Gokwe North, Gokwe South and Shurugwi in Midlands and Zvimba in Mashonaland West provinces. FAO is in partnership with three NGO consortia led by Practical Action, Welthungerhilfe and World Vision International, two Strategic Technical partners, i.e. IAPRI for policy influence, HarvestPlus for biofortification, three Commercial Banks, 1 Wholesale Facility - the Zimbabwe Microfinance Fund (ZMF), 5 Microfinance Institutions (MFIs) and the USAID managed DCA Facility. To date, the LFSP is funded for two phases to the tune of £72.4m.

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EXECUTIVE SUMMARY

Low levels of agricultural production arising from low productivity have been the major problem facing Zimbabwean agriculture. This has devastating effects on rural livelihoods and the general well-being of the macro-economy. To address this problem, Government took a deliberate decision to introduce the Pfumvudza farming concept in the country, which the Food and Agriculture Organisation of the United Nations has been promoting in districts where the Livelihoods and Food Security Programme is being implemented. The primary objective of adopting the Pfumvudza concept is to achieve household food security and national food self-sufficiency. This study evaluated the impact of the Pfumvudza concept on maize productivity and assessed the heterogeneous impacts on maize productivity by gender of household head, field characteristics, number of Pfumvudza plots and provincial differences. To achieve the objectives, household survey data collected from three (3) Provinces (Mashonaland Central, Midlands and Manicaland) from 1118 households was used. The analysis was done at the field level for 1910 maize plots disaggregated by Pfumvudza and non-Pfumvudza fields. Propensity score matching technique was used to determine the impacts of Pfumvudza on maize productivity.

The study draws the following conclusions and recommendations;

Pfumvudza Practice enhances maize productivity

The estimations show that the Pfumvudza concept raises maize yields by over 1500 kg per ha and that practising Pfumvudza on a plot above the recommended size tends to reduce yields. This implies that intensification of inputs and management is beneficial. Therefore, farmers should be advised to keep the plots to recommended sizes to maximise the yield benefits of the farming practice to reduce labour requirements and increase optimal use of inputs resulting in higher yields. However, due to the potential area measurement errors for the maize plots, which may influence yield estimations, future studies would need to obtain actual plot measurements. Also, crop cuts in a sizeable sample of both Pfumvudza and non Pfumvudza plots should be performed to precisely measure the impacts of the practice on productivity.

Household food security objective not yet attained

Despite the pfumvudza concept raising the maize yield, the increase was insufficient to feed a family of six members for 52 weeks. Over 90 percent of households were food insecure as their maize production did not reach the 790kg estimated maize requirement to attain food security. However, to help the household attain food security, there is a need to address waterlogging problems and encourage farmers to adhere to recommended Pfumuvudza practices.

Adherence to recommended agronomic Pfumvudza practices results in higher maize yields

Regarding adherence to agronomic Pfumvudza practices, farmers who practised recommended agronomic practices got higher yields than those who partially adopted. This reinforces the urgent need to focus extension messages on the importance of adopting the complete Pfumvudza package with recommended full range of agronomic practices. In addition, the extension messages will also need to be bundled with addressing practice specific challenges that may have led to the households not utilizing some of the agronomic practices.

Waterlogging coupled with mulching reduces maize productivity

Pfumvudza plots experiencing waterlogging and mulched had lower maize yields than those experiencing no waterlogging or some non-serious waterlogging. In general, the country received normal to above normal rainfall, and the spread varied from place to place. This resulted in waterlogging in some areas as they received substantial amounts within a short space of time. Therefore, extension messages should also focus on the importance of drainage improvement of the fields to take advantage of the benefits of the Pfumvudza concept, especially in high rainfall areas. In addition, further studies regarding waterlogging as well as locations best for Pfumvudza should be explored.

While mulching and waterlogging have a combined negative effect on maize yield, mulching can increase maize productivity up to 5000kg/ha in non-water logging plots. Mulching would therefore be beneficial in a season with low rainfall. However, despite this benefit, very few farmers mulched their plots , highlighling the need to address the challenges associated with access to mulching materials and utilisation

No gendered differences in maize productivity

The insignificant gendered differential impacts imply that the small high yielding Pfumvudza plot and low input concept addresses the gender barriers of access to land, inputs and labour. It also closes the gender productivity gap as women usually have challenges accessing productive resources (inputs, land) and machinery. Furthermore, since productivity growth contributes to food security and poverty reduction, this places women at an advantage in terms of poverty reduction possibilities. Women should be encouraged to intensify their production by adopting the Pfumvudza farming concept, given that women play a critical role in ensuring household food security.

In addition, Pfumvudza plots closer to the homestead yielded higher than those further away, this helps to meet the practical gender needs of women who experience time poverty due to the triple burden.

Increasing the number of Pfumvudza fields reduces maize productivity

The study results show a negative relationship between maize productivity and the number of Pfumvudza maize plots the household managed. Thus, having multiple Pfumvudza maize plots tends to constraint farmers who are already labour-constrained. Given that farmers felt that the Pfumvudza concept was labour intensive and factors into their decision on whether they continue with the practice suggest that increasing the number of maize plots under Pfumvudza may be counterproductive. If the main objective is to enhance household food security for less endowed households, then doing a good job with one Pfumvudza maize plot would be recommended. However, given that rotation is a key component of Pfumvudza, farmers can have two pfumvudza plots, one for cereal and one for the legume.

Reduction of Government expenditure on input subsidies and food assistance

Pfumvudza input pack per household is small and hence cheaper compared to the traditional presidential input pack. If sustained, the government support of Pfumvudza will save Treasury resources on the input side, and food assistance level as most households who practice Pfumvudza will be food secure.

Development of labour-saving technologies

Pfumvudza farming should be complemented by technological developments, especially in labour-saving technologies, to reduce the burden on activities such as potholing and mulching. Furthermore, Government should consider a subsidy programme for those involved in the manufacture of appropriate technology (tools and machinery) which support the Pfumvudza farming concept.

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1. INTRODUCTION

Low levels of agricultural production arising from low productivity have been the major problem facing Zimbabwean agriculture for the past two decades. Low productivity has been recorded in most value chains, be it livestock and or crops. Poor weather conditions, including erratic rainfall and prolonged dry spells, have contributed to the situation. As a result, the food security situation in the country remains fragile. Given the importance of maize in Zimbabwe on rural livelihoods and the general well-being of the macro-economy, Government took a deliberate decision to introduce the Pfumvudza farming concept in the country, targeting maize and other crops (traditional grains, pulses, and oilseeds). In complementing Government efforts, the Food and Agriculture Organization of the United Nations (FAO) promoted the adoption of the Pfumvudza farming concept in districts where the Livelihoods and Food Security Programme (LFSP) was being implemented.

The primary objective of adopting the Pfumvudza concept is to achieve household food security and national food self-sufficiency. During the 2020/2021 agricultural season, the Government provided inputs to 1.8 million smallholder farmers under the traditional Presidential Inputs Scheme, now called the "Climate-proofed Presidential Inputs Scheme" (Ministry of Lands, Agriculture, Water and Rural Resettlement (MLAFWRR), 2021). Beneficiaries were expected to establish three (3) Pfumvudza plots during the 2020/21 agricultural season. In addition, each beneficiary was expected to receive at least 1 x 5kg of maize seed, 1 x 50kg basal dressing fertilizer, 1 x 50kg top dressing fertilizer, pesticide for fall armyworm/stalk borer control, and if located in drier parts of the country, the package included 2kg seed of cowpeas or sorghum or groundnuts plus 16 kg top dressing and 16kg basal fertilizer. Concurrently, under the LFSP districts, FAO targeted to support 50 000 smallholder farmers for the Pfumvudza inputs package. The key elements of the Pfumvudza concept are summarised in Box 1.

Given that this is the first season the Pfumvudza Concept was being promoted at such an unprecedented level with direct government support, it was prudent to carry out an impact evaluation of the Pfumvudza farming practice on productivity. The results from the impact assessment will help inform the Government and other stakeholders on how the Pfumvudza performed in the first year of widespread promotion, as well as provide information that will help improve the implementation of the program in the future.

Against this background, LFSP/IAPRI In conjunction with the MLAFWRR carried out a survey in 16 Districts in order to assess the impact of Pfumvudza on maize productivity. The survey had the following specific objectives:

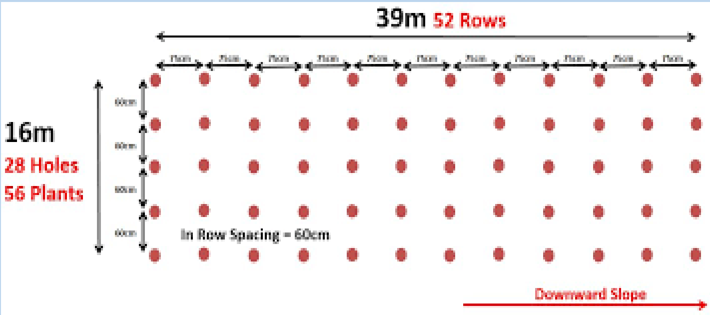
1. To assess whether it is possible to feed a family of six for a year from a Pfumvudza plot
2. To evaluate the impact of the Pfumvudza concept on crop productivity with a specific focus on maize.
3. To assess the heterogeneous impacts of the Pfumvudza concept.
4. To identify the key elements of the Pfumvudza concept important for increasing productivity.

The remainder of the study is organized as follows. Section 2 presents the data and methodology used in this study. Section 3 presents the results and discussion, and section 4 presents the conclusions and recommendations

Box 1: About Pfumvudza farming concept

The Pfumvudza Concept was developed by Foundations for Farming (FfF) and demonstrates how much land is required to feed a family of six with maize for a year (Edwards et al., 2020). The concept of Pfumvudza is a crop production intensification approach under which farmers concentrate resources (inputs and labour) on a small land unit to facilitate optimum management resulting in increased productivity through the application of conservation agriculture principles. To achieve high yields, all operations must be done to a high standard, on time, without wastage (precision farming). Using the Pfumvudza input pack, it is possible to feed a family of six for a year from a minimum maize input investment of United State Dollars (USD) 50.

Using all the FfF principles and assuming that a family would require a bucket of maize per week to provide their staple diet, fifty-six (56) cobs weighing 300 grams each are required to fill a bucket with shelled maize. If each maize plant produced at least one cob, 56 plants would be required. A row of only 16m would be required to produce a bucket of maize, with planting stations within the row spaced at 60cm and with two (2) plants per station. Fifty-two (52) rows would produce 52 buckets, which translates to 52 weeks in a year. At a row spacing of 75cm, this would give a block that is 39m long. The block measuring 16m x 39m is only one-sixteenth (1/16) of a hectare (Ha).



The critical elements for successful Pfumvudza include; Field size (16m X 39m), Minimum tillage (potholing), Plant spacing (60cm X 75cm), number of planting stations (1456), Mulching, Drainage improvements, Thinning, Weed-free field, Timely application of fertilisers (basal fertiliser (organic and/or mineral) before planting and split top dressing at 3 weeks after germination and at the start of tasselling), Timely Pest and disease control and Supplemental irrigation.

2. DATA AND METHODS

The survey was conducted in 16 Districts (10 LFSP districts and 6 non-LFSP districts) across 3 provinces, namely Mashonaland Central, Midlands and Manicaland. The selection of control districts was restricted to the three LFSP provinces to ensure geographical similarity and spatial proximity. Details about sampling and sample size are discussed below.

2.1. Sampling and sample size

A three-stage sampling strategy was employed, first at the ward level, then at the village level within the selected wards and finally at the household level within the selected villages. In the first step, treatment and control wards were identified through statistical matching based on the Zimbabwe Vulnerability Assessment Committee (ZimVAC) data collected in 2014 and 2015 and rainfall data received from Agritex.

Propensity Score Matching (PSM) was conducted to match the treated and control wards in the selected districts using the variables listed in Table 1 below. The matching enabled us to identify comparable wards (treated and controls) based on observable characteristics before LFSP and Pfumvudza interventions, contributing to the counterfactual improvement. One ward was then randomly selected per District from the list of matched wards. From the selected ward, a random sample of 7 villages was then selected.

Table A 1: Variables for matching treated wards with control wards

Ward level matching variables	
Average household size	Percentage of households with access to water from a borehole or protected well
Average household head's age	Percentage of households with draft animals
Education level for household head	Long run rainfall average coefficient of variation (CoV)
Percentage of households growing maize	

A statistical power analysis approach was employed to determine the minimum required sample size to detect the impact of the Pfumvudza farming concept on maize yield and to be able to conclude that the observed change in average maize yields would not have occurred by chance. Thus, it gave us an estimated minimum sample size for two-sample comparison of means (adopters and non-adopters of Pfumvudza farming concept).

Employing the Stata command for statistical power analysis, the minimum sample size was calculated as follows:

$$\text{sampsi } \mu_2\ \mu_1,\ p(\beta)\ r\ (n_2/n_1)\ sd1\ sd2\ alpha\ (\alpha) \quad (1)$$

Where α is the significance level set at 0.05; β is a statistical power set at 0.8, which corresponds to 80 percent power; sd1 and sd2 are expected standard deviations for the mean yields of the treatment and comparison groups set at 2.40 metric tonnes per hectare (mt/ha) and 2.68 mt/ha, respectively, based on a coefficient of variation of 0.4; μ_1- is the estimated level of mean yield for maize during the previous seasons (set at 0.6mt/ha- average national maize yield according to the second round crop and livestock assessment report of

2020); μ_2 - is the expected level of the indicator at some future date such that the quantity (μ_2 - μ_1) is the size of the magnitude of change or comparison group differences desired to be detected set at 2.4mt/ha based on the country's target to increase maize average yield to 2.4 mt/ha, a 300 percent,[1] mainly due to the promotion and government support of Pfumvudza farming concept; and r is the ratio of sample sizes of the control (n_2) and the treatment groups (n_1), set at 1. This gives a ratio of 50:50 for the control group to the treatment group to ensure a likelihood for matching in mean comparison analysis.

Populating these figures into the sampsi Stata command resulted in n_1=32 and n_2=32 per District. Meaning we needed a minimum sample of 1024 households in the 16 selected districts, 64 households per District. However, to compensate for the potential loss in observations during analysis because of trimming households that are off-support after the matching, we added an extra 10 percent (or 7 households) to each District, making the total number of sampled households 1120. This sample was large enough to offer sufficient statistical power for the identification of the expected impacts.

Ten (10) households were interviewed per village in each District, meaning the survey conducted 70 interviews in a total of 7 villages in each selected ward. However, 2 households had field-level missing information and were dropped off from the analysis leaving a sample of 1118 households. Table 2 below summarises the sample distribution by Province and District.

Table A 2: Sample Distribution by Province and District

Province/District	LFSP Districts	Total number of sampled HHs	% of households growing maize	**Average number of maize fields**
All households		1118	91.5	3
Manicaland		**350**	**92.6**	**2**
Buhera	Non-LFSP	70	88.6	2
Makoni	LFSP	70	97.1	2
Mutare	LFSP	70	94.3	2
Mutasa	LFSP	70	90.0	2
Nyanga	Non-LFSP	70	97.1	1
Mashonaland Central		**349**	**93.4**	**3**
Bindura	LFSP	70	98.6	3
Centenary	Non-LFSP	69	77.1	3
Guruve	LFSP	70	91.4	3
Mount Darwin	LFSP	70	97.1	3
Shamva	Non-LFSP	70	98.6	3
Midlands		**419**	**89.0**	**3**
Mvuma/Chirumanzu	Non-LFSP	69	100.0	3
Gokwe North	LFSP	70	98.6	3
Gokwe South	LFSP	70	90.0	3
Kwekwe	LFSP	70	94.3	2
Shurugwi	LFSP	70	67.1	3
Zvishavane	Non-LFSP	70	84.3	3

Source: LFSP/MLAFWRR Survey 2021

[1] Sihlobo W, 2020. Zimbabwe hopes to increase maize yield. The Zimbabwe Independent. Available at: https://www.theindependent.co.zw/2020/09/04/zimbabwe-hopes-to-increase-maize-yield/

2.2. Data analysis methods

To determine the impacts of Pfumvudza on maize productivity, we employed the PSM technique. This is an appropriate approach, given that the pre-intervention data is not available. Without the baseline data, a robust counterfactual needs to be reconstructed to isolate the effects of Pfumvudza from the effects of other factors (Caliendo and Sabine, 2005). Like other quasi-experimental impact evaluation approaches, the PSM method tries to mimic the randomized assignment to treatment (Pfumvudza fields) and comparison groups by choosing the comparison group with similar propensity scores (Figure 12) as those in the treatment group. By doing so, this missing data problem is solved (see Annex 1 for the PSM results). The propensity score model was specified as

$$\boldsymbol{Prob(D = 1) = \Phi(\alpha + \beta' X + \varepsilon)} \qquad (1)$$

where D is a dummy of a field being Pfumvudza or not, X is a vector of observable field characteristics deemed to affect whether a field is a Pfumvudza plot or not. Φ is a standard normal cumulative distribution function (CDF), ε is the error term, α and β are parameter and vector of parameters to be estimated. Details of PS estimation are in the appendix.

Using the matched sample, the following base equation was estimated that determines the Pfumvudza effects on the maize productivity.

$$\boldsymbol{Y = \alpha + \gamma D + \beta' X + \varepsilon} \qquad (2)$$

Where Y is the outcome variable (maize yield), and γ is the yield attributable to the Pfumvudza field (D). X is a vector of exogenous household characteristics, field characteristics, and regional factors. We incrementally included the covariates to observe the changes in the estimated yield effect whether the covariates added reduces or increases the yield effect in magnitude.

To check for the estimated results' robustness, we also estimated the Inverse Probability Weighting with Regression Adjustment (IPWRA), which specifies both an outcome and treatment probability models. An important feature of this model is double robustness which means that consistent estimates of the treatment effect can be determined even if one of the models (treatment or outcome) is miss-specified (Bang and Robins, 2005). In addition, it also addresses the confounding effects arising from selection bias, given that Pfumvudza fields were not randomly assigned. The Stata's treatment effects "teffects" IPWRA command was used to run the model. Table 3 shows the descriptive statistics of the variables used in the models.

Table A 3. Model variables descriptive statistics

Variable	N	Mean	Std. Dev.	Min	Max
Maize yield (kg/ha)	1910	2265	2428	45	15865
Pfumvudza field	1910	0.20	0.40	0	1
Average plot size (ha)	1910	0.36	0.43	0.005	4
Waterlogging major issue	1910	0.31	0.46	0	1
Waterlogging but not a major problem	1910	0.22	0.41	0	1
Distance to the field (km)	1910	0.72	1.80	0.02	60

Index of sequential Pfumvudza practices	1910	0.84	1.06	0	5
Number of Pfumvudza fields	1910	0.58	1.03	0	7
Beneficiary of Pfumvudza package	1910	0.86	0.35	0	1
Female head with no male adult	1910	0.13	0.33	0	1
Female head with male adult	1910	0.13	0.34	0	1
Adult equivalent	1910	4.11	1.69	0.74	10.76
Head with primary education	1910	0.38	0.49	0	1
Head with secondary education	1910	0.51	0.50	0	1
Head with post-secondary education	1910	0.05	0.22	0	1
Mashonaland central	1910	0.30	0.46	0	1
Midlands	1910	0.42	0.49	0	1
LFSP district	1910	0.65	0.48	0	1

Source: Authors calculations

2.3. Classification of Pfumvudza plot

During the survey, farmers were asked to indicate whether the maize plot was a Pfumvudza plot or not. The data showed that out of the 1910 maize plots, farmers categorized 942 plots as Pfumvudza plots (Table 3). However, farmers characterized even larger plots than the recommended size of 1/16 ha as Pfumvudza plots just because they had potholed the plot. However, out of the 942 plots that farmers classified as Pfumvudza plots, only 383 plots met the criteria of the definition of the Foundation for Farming concept plot size (Table 4**Error! Reference source not found.**).

Table A 4. Categories of maize plots by size and type

Maize plot size	Was this a Pfumvudza plot?		Total
	Yes	Not	
All maize fields	942	968	1,910
Pfumvudza field per FfF	383	6	389
Maize fields with planting basins			
0.0625-0.125 ha	104	13	117
0.125-0.1875ha	162	14	176
Greater than 0.1875ha	293	13	306
Maize fields with other tillage methods			
Field size same as Pfumvudza field	0	191	191
0.0625-0.125 ha	0	87	87
0.125-0.1875ha)	0	173	173
Greater than 0.1875	0	471	471

Following this classification, Pfumvudza plots were 383 (20%) out of 1910 maize plots (**Error! Reference source not found.**). Maize plots that were non-Pfumvudza but the plot size was the same as Pfumvudza plots were 191 (10%), and 1330 (70%) were larger non-Pfumvudza plots.

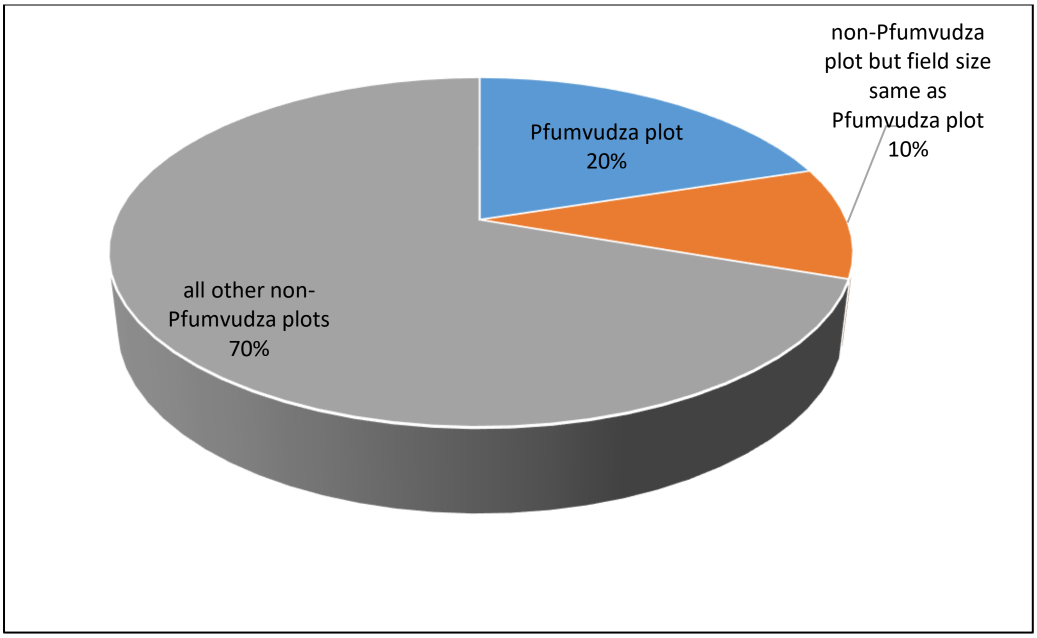


Figure 1. Categories of maize plots by type
Source: LFSP/MLAFWRR Survey 2021

Table 5 shows the distribution of households practising Pfumvudza by District. Results show that, out of all the sampled households, less than a third practised Pfumvudza. However, the proportion of households was highest in Midlands and lowest in Mashonaland Central. Generally, LFSP districts had more households practising Pfumvudza than non-LFSP districts. Among those that practised Pfumvudza, they had more than one Pfumvudza maize field on average.

Table A 5. Distribution of Households practising Pfumvudza among maize growers by District

District	Total number of sampled HHs	% of households growing maize	% of households practising Pfumvudza	Average number of Pfumvudza maize field
All households	1118	91.5	25.5	2
Manicaland	**350**	**92.6**	**17.3**	**2**
Buhera	70	88.6	29.0	1
Makoni	70	97.1	47.1	2
Mutare	70	94.3	37.9	2
Mutasa	70	90.0	9.5	2
Nyanga	70	97.1	1.5	1
Mashonaland Central	**349**	**93.4**	**25.1**	**2**
Bindura	70	98.6	29.0	2
Centenary	69	77.1	7.4	1
Guruve	70	91.4	26.6	2
Mount Darwin	70	97.1	20.6	2
Shamva	70	98.6	1.4	1
Midlands	**419**	**89.0**	**33.0**	**1**
Mvuma/Chirumanzu	69	100.0	29.0	1
Gokwe North	70	98.6	33.3	2
Gokwe South	70	90.0	19.0	1
Kwekwe	70	94.3	31.8	1
Shurugwi	70	67.1	51.1	2
Zvishavane	70	84.3	39.0	1

Source: LFSP/MLAFWRR Survey 2021

3. RESULTS AND DISCUSSIONS

As a prelude to econometric estimation, we first present the descriptive statistics from the bivariable analysis. This mainly involved generating average values for plot-level maize yields, including relevant disaggregation (e.g. plot size, plot characteristics, Pfumvudza practices, gender, and location). The last part of the results delves into the farmer's perception and access to information about the Pfumvudza practices.

3.1. Inverse field-size and productivity relationship

Results in **Error! Reference source not found.** and Table 6 shows that the size of the plot matters irrespective of the type of plot (Pfumvudza or non-Pfumvudza) as smaller fields out-performed larger maize plots. This conforms to the inverse field-size and productivity relationship (see Larson, Otsuka, Matsumoto, and Kilic, 2014; Ali and Deininger, 2015). However, the average yields of the Pfumvudza plots were 316 Kg more than any other smaller non-Pfumvudza maize plots (Table 6).

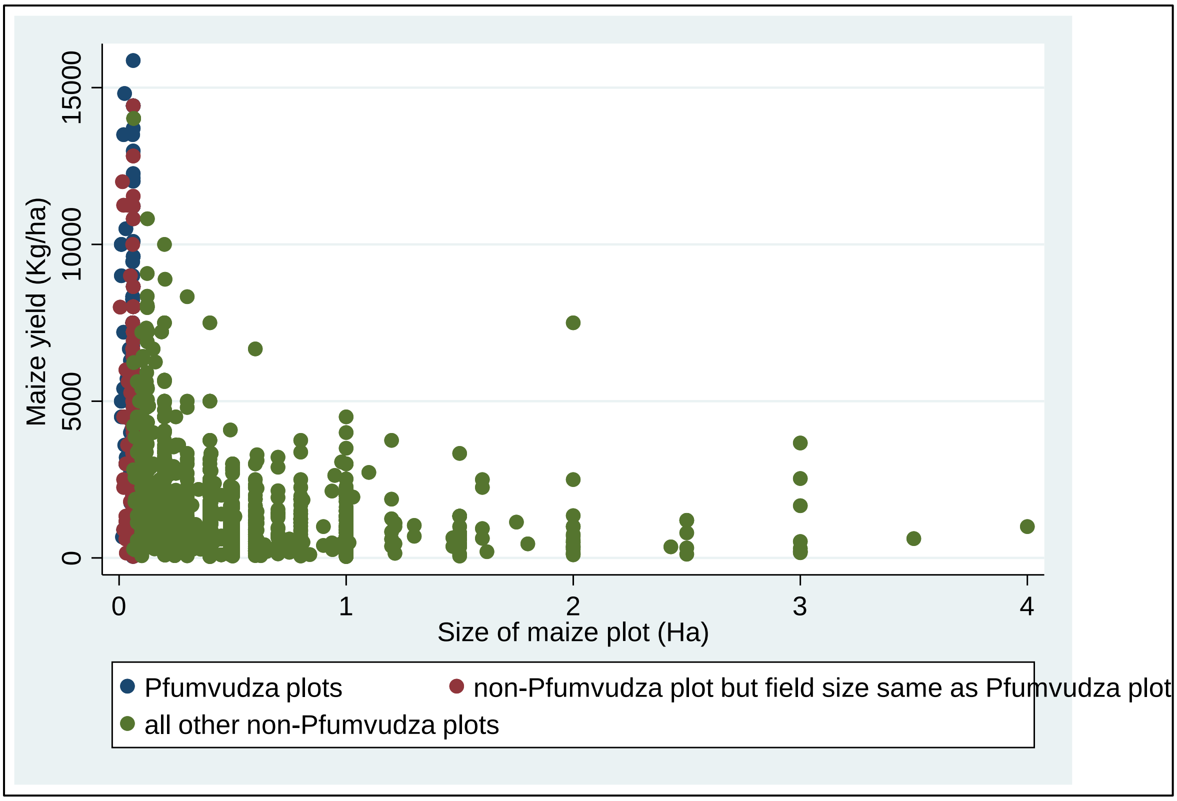


Figure 2. Distribution of maize yields by plot type
Source: LFSP/MLAFWRR Survey 2021

Table A 6. Maize yields by field type and field size

Maize field type	Count	Maize yield kg/ha				
		Mean	Percentile 25	Median	Percentile 75	Percentile 90
All maize fields	1,910	2,265	667	1,401	3,000	5,273
Pfumvudza plot	383	4,190	1,603	3,606	5,409	8,333
Non-Pfumvudza plot but field size same as Pfumvudza plot	197	3,874	1,603	3,205	5,409	8,000
All other non-Pfumvudza plots	1,330	1,473	500	1,058	1,815	3,150

Source: Authors Calculations

3.2. Descriptive Statistics

In this section, we present some key bivariate descriptive statistics with respect to Pfumvudza and non-Pfumvudza plots in terms of household demographic characteristics, Pfumvudza practices and regional differences.

3.2.1. Demographic characteristics

Household demographic summary statistics are presented in Tables 7 and 8. In general, there were more maize plots within the male-headed households than female-headed households. However, comparison within each gender group across the plot type show that a higher percent of male-headed households had non-Pfumvudza larger plots than Pfumvudza plots, while the reverse was true for female-headed households with male adult members. Conversely, a higher percentage of female heads with no male adult members had smaller non-Pfumvudza plots.

Table A 7. Household demographic characteristics by field type

	Type of plot			
	All maize plots	Pfumvudza plots	Non-Pfumvudza small plot	Non-Pfumvudza larger plots
Number of fields	1,910	383	197	1,330
Household Headship (%)				
Male headed households	74	70[a]	68[a]	76[b]
Female headed households	26	30[a]	32[a]	24[b]
Female head with male adults household members	13	15[a]	14[ab]	12[b]
Female head with no male adults household members	13	15[a]	17[a]	12[b]
Education Level (%)				
HH Head with primary education	38	39	39	38
HH head with Form 1 to 4 education	51	50	50	51
HH head with post-secondary education	5	5	4	6
Household size				
Adult equivalent	4	4	4	4

Rows with the same superscript letter are not significantly different at the 5% level
Male adult is defined as those aged 18 years and above

With respect to maize productivity, the Pfumvudza plots had higher yields than non-Pfumvudza plots across all the household attributes (Table 8) even though the yields between Pfumvudza and non-Pfumvudza small plots were statistically comparable. Even within households, comparison of yield differences showed significant differences between Pfumvudza plots (4337kg/ha) and non-Pfumvudza large plots fields (1284 kg/ha).

Table A 8. Maize productivity by household characteristics and field type

		Average maize yields (Kg/ha)			
	n	All plots	Pfumvudza plots	Non-Pfumvudza small plot	Non-Pfumvudza larger plots
All fields	1,910	2,265	4,190[a]	3,874[a]	1,330[b]
Household Headship					
Male headed households	1,416	2,233	4,254[a]	4,032[a]	1,459[b]
Female headed households	494	2,357	4,040[a]	3530[a]	1517[b]
Female head with male adults in household	252	2,538	4,558[a]	3520[b]	1634[c]
Female head with no male adults in household	242	2,169	3,549[a]	3,544[a]	1,394[b]
Education Level					
HH Head with primary education	729	2,139	3,637[a]	3,308[a]	1,512[b]

HH head with Form 1 to 4 education	970	2,322	4,381[a]	4,190[a]	1,468[b]
HH head with post-secondary education	100	2,657	6,668[a]	4,683[b]	1,489c
Quartiles of adult equivalent					
Q 1 (below 2.9)	469	2,300	3,827[a]	3,914[a]	1,647[b]
Q 2 (2.9 to 4.0)	468	2,032	3,342[a]	3,262[a]	1,519[b]
Q 3 (4.0 to 5.2)	483	2,284	4,560[a]	3,974[a]	1,321[b]
Q 4 (5.2 to 10.8)	469	2,443	4,840[a]	4,401[a]	1,394[b]

Rows with the same superscript letter are not significantly different at the 5% level

The bivariate results for education and maize yields within households practising Pfumvudza seem to suggest a positive correlation between the education level of the household head and the level of productivity. Thus, households headed by more educated heads had higher maize yields for their Pfumvudza plots compared to those with lower education. For example, maize yields were 3,637 kg/ha for households headed by heads with primary education compared to 4,381 kg/ha for households with heads with secondary education and 6,668 kg/ha for those headed by heads with post-secondary education. These differences suggest that education helps to understand the concept better. On the other hand, maize yield differences for non-Pfumvudza plots do not differ by the education level of the head of household suggesting that education does not matter because non-Pfumvudza is a routinized farming concept.

3.2.2. Plot characteristics

3.2.2.1. Distance of plot from the homestead

Table 9 shows that, on average, Pfumvudza plots were closer to the homestead than non-Pfumvudza plots, 0.5 km compared to 0.6 km (non-Pfumvudza small plots) and 0.8 km (non-Pfumvudza large plots). A closer look at the location of plots by distance quartiles confirms the conclusion that most of the Pfumvudza fields were located within the radius of 200m from the homestead, 64 percent with another 21 percent within 800 metres.

In terms of maize yields, the results show significant differences between Pfumvudza and non-Pfumvudza large plots across all the distances quartiles, with Q1 being closest to the homestead and Q4 being furthest from the homestead. However, wee do not see a clear pattern in yield differences by quartiles of distance within each plot type, especially for the first three quartiles. This is because the average distances for the first quartile to the third quartile were within a kilometre. However, maize yields across all the first three quartiles are larger than average yields in the fourth quartile (furthest plots from the homestead). For example, the average maize yields for Pfumvudza plots within 100 metres from the homestead had higher yields compared to plots within 900m or more from the homestead, 4312 kg/ha compared to 3578 kg/ha, respectively. The differences may be attributed to the degree of management and attention given to the plots closer to the homestead than those not closer to where the family lives. This hypothesis is tested in the econometrics section.

Table A 9. Maize productivity by distance of plot from the homestead

			Average maize yields (Kg/ha)		
	n	All plots	Pfumvudza plots	Non-Pfumvudza small plot	Non-Pfumvudza larger plots
Number of fields		1,910	383	197	1,330
Average distance to the maize field		0.8	0.5[a]	0.6[c]	0.8[b]
% of plots within each quartiles of distance to plot					
Q 1 (below 0.08Km) (%)		40	55[a]	37[b]	37[b]
Q 2 (0.1 to 0.2Km) (%)		15	9[a]	13[ab]	16[b]
Q 3 (0.2 to 0.9Km) (%)		24	21[a]	29[b]	24[ab]
Q 4 (0.9 to 60Km) (%)		21	15[a]	21[b]	23[b]
Maize Yield					
All fields	1,884	2,265	4,242		
Quartiles of distance to field					
Q 1 (below 0.08Km) (Kg/ha)	759	2,567	4,312[a]	4,037[a]	1,583[b]
Q 2 (0.1 to 0.2Km) (Kg/ha)	275	2,099	3,918[a]	4,134[a]	1,542[b]
Q 3 (0.2 to 0.8Km) (Kg/ha)	450	2,324	4,421[a]	3,727[a]	1,549[b]
Q 4 (0.9 to 60Km) (Kg/ha)	400	1,780	3,578[a]	3,624[a]	1,175[b]

3.2.2.2. Waterlogging

Figure 3 shows the percentage of Pfumvudza plots that were reported to have experienced waterlogging. Waterlogging was a ma
jor problem in about 20 percent of the Pfumvudza plots, whilst 34 percent of the plots, waterlogging was not a major problem.

In terms of maize yields, the results in Table 10 show that the plots reported having experienced major waterlogging issues had much lower maize yield than those with no water logging issues and/or waterlogging was reported not to be a major problem. For example, the average maize yield was 5260 kg/ha on plots where waterlogging was not a major issue compared to 3108 kg/ha in plots reported major waterlogging issues. The difference is equally higher when we consider the field experiencing no water logging at all, 4,525 kg/ha compared to 3108kh/ha.

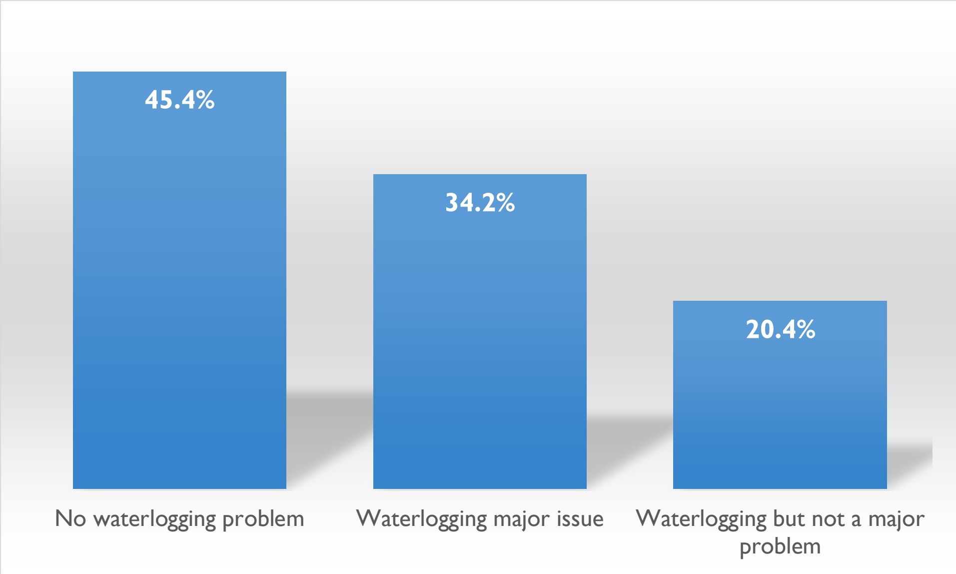


Figure 3. Pfumvudza plots experiencing waterlogging

Table A 10. Maize productivity and waterlogging on Pfumvudza plots

	Yes	No	t-test	sig
	Maize productivity (Kg/Ha)			
No waterlogging problem	4,525	3,911	-1.917	**
Waterlogging major issue	3,108	4,752	-1.9165	***
Waterlogging but not a major problem	5,260	3,916	-3.431	***

*** p<0.01, ** p<0.05, * p<0.1

3.2.3. Pfumvudza practices

As stated in the introduction, the critical elements of the Pfumvudza concept include plot size (16m X 39m), minimum tillage (potholing), plant spacing (60cm X 75cm), number of planting stations (1456), mulching, thinning, weed-free field, timely application of fertilisers and lime and timely pest and disease control. Following the classification of the Pfumvudza plot in section 2.2.1, all the Pfumvudza plots met the recommended plot size and were potholed, hence these two practices are not discussed in this section. Other practices not discussed include number of planting stations, weed-free field, and timely pest and disease control. The information on these aspects were not captured in the survey.

The results in Figure 4 show that, recommended planting spacing of 75cmX60cm was the most (95 percent) adopted Pfumvudza practices followed by thinning. Lime application was the least adopted practice. At least 35 percent of the plots were mulched despite mulching being one of the major challenges for farmers.

Another aspect of the Pfumvudza concept is the sequential adoption of Pfumvudza practices as recommended by the FfF. Considering all the recommended practices, we computed an index of Pfumvudza practices as the summation of the adopted practices as per the recommended sequence. The practices included in the computation of the index were planting spacing of 75cmX60cm, application of lime and basal fertilizer before planting, mulching the field, thinning the field after germination and applying top dressing 3-4 weeks after planting. Findings in Figure 5 show a declining proportion of plots on which the Pfumvudza concept was religiously followed. This suggests that the majority of the farmers did not apply the full range of Pfumvudza practices.

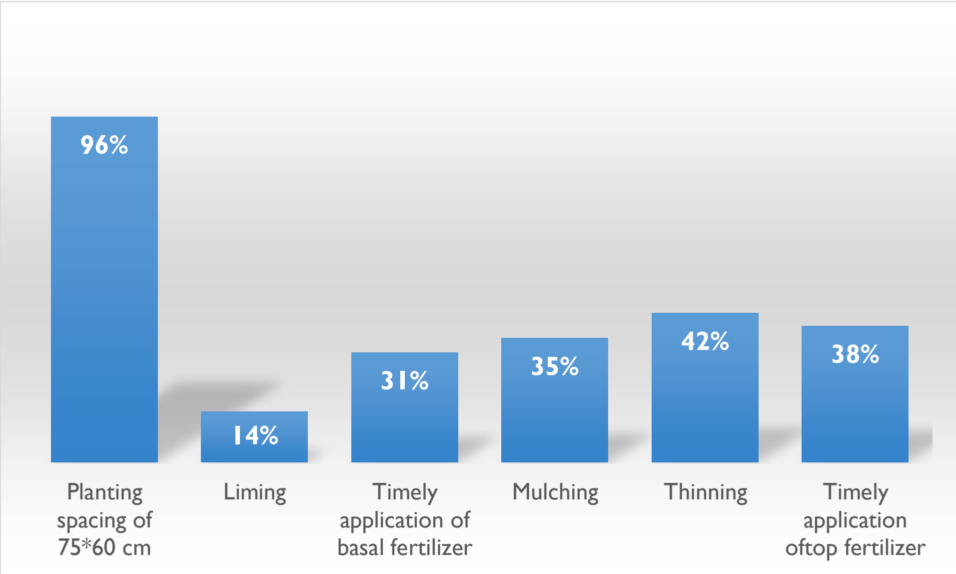


Figure 4. Adoption of individual Pfumvudza practices

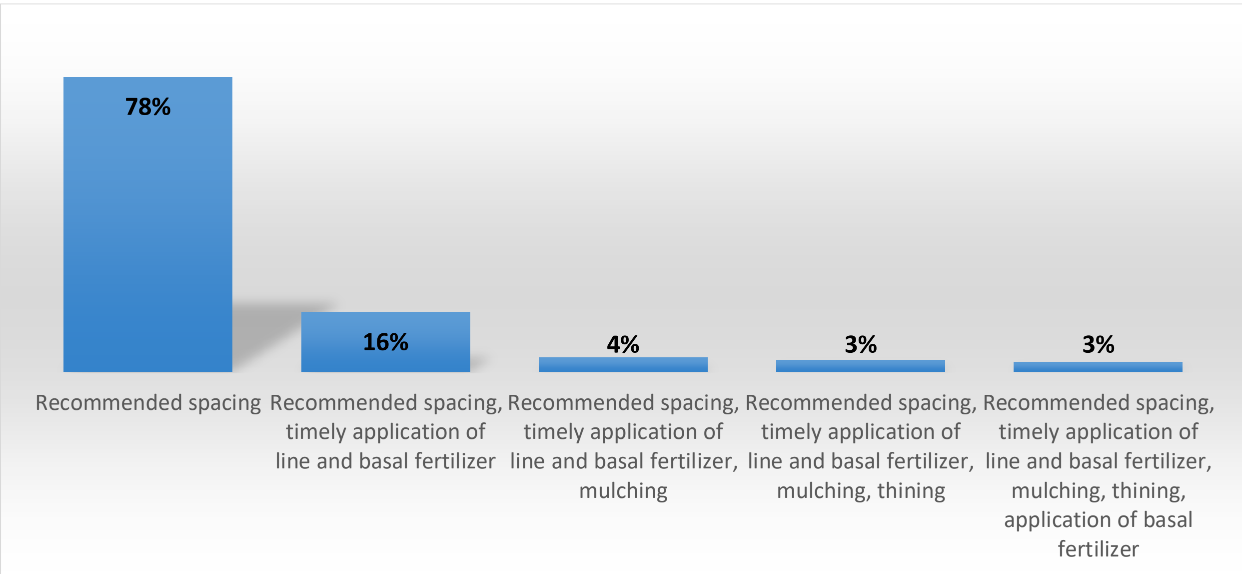


Figure 5. Sequential adoption of Pfumvudza practices

Regarding yield differences with respect to Pfumvudza practices, Table 11 shows higher yields on Pfumvudza plots where the practices were applied though the yields were significantly high on plots that were limed. While adopting any Pfumvudza practices can give high yields, the yields are even more when the practices are sequentially adopted as a complete package (Table 11).

Table A 11. Maize productivity by Pfumvudza practices on Pfumvudza plots

	Yes	No	t-test	sig
Pfumvudza practices	Maize yields (Kg/ha)			
Planting spacing of 75*60cm	4,171	6,634	0.561	
Liming	5,172	4,029	-2.5056	***
Timely application of basal fertilizer	4,390	4,103	-0.816	
Mulching	4,390	4,084	-0.907	
Thinning	4,425	4,023	-1.240	
Timely application of top dressing fertilizer	4,443	4,035	-1.238	
Sequential adoption of practices				
Recommended spacing	4,172	4,635	0.5601	
Recommended spacing, timely application of lime/basal fertilizer	4,553	3,971	-1.7665	*
Recommended spacing, timely application of lime/basal fertilizer, mulching	5,199	4,013	-2.6596	***
Recommended spacing, timely application of lime/basal fertilizer, mulching, thinning	6,135	4,054	-3.253	***

*** p<0.01, ** p<0.05, * p<0.1

3.2.4. Regional differences

The proportion of Pfumvudza plots compared to non-Pfumvudza plots was highest in Midlands province and lowest in Mashonaland Central province (Figure 6). With regard to benefiting from the Pfumvudza package, Figure 7 shows that almost all the Pfumvudza plots received the input pack. It is also interesting to note that even the non-Pfumvudza plots benefited from the Pfumvudza input pack.

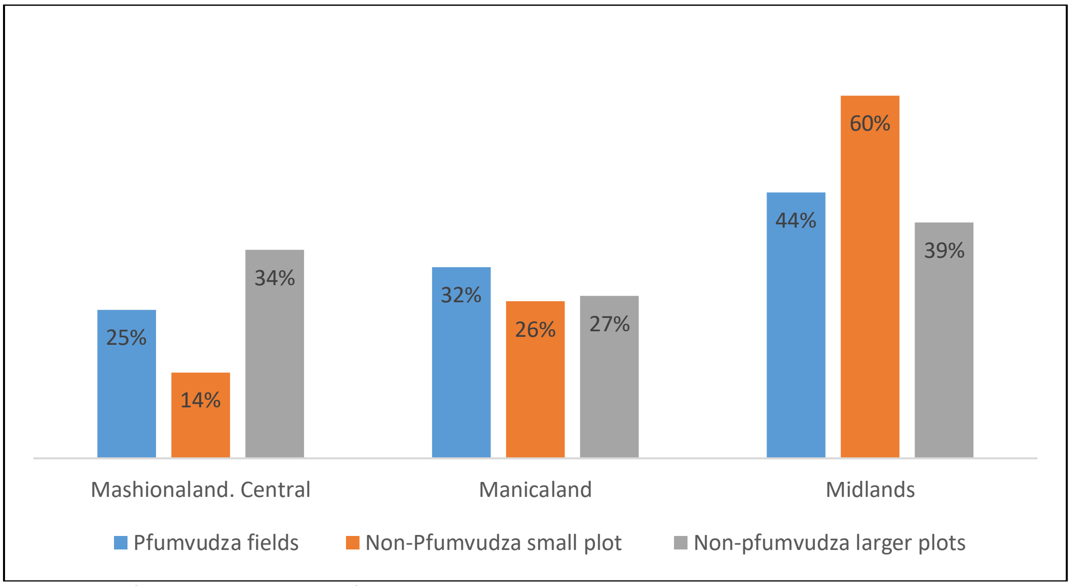


Figure 6. Pfumvudza vs non Pfumvudza plots by province

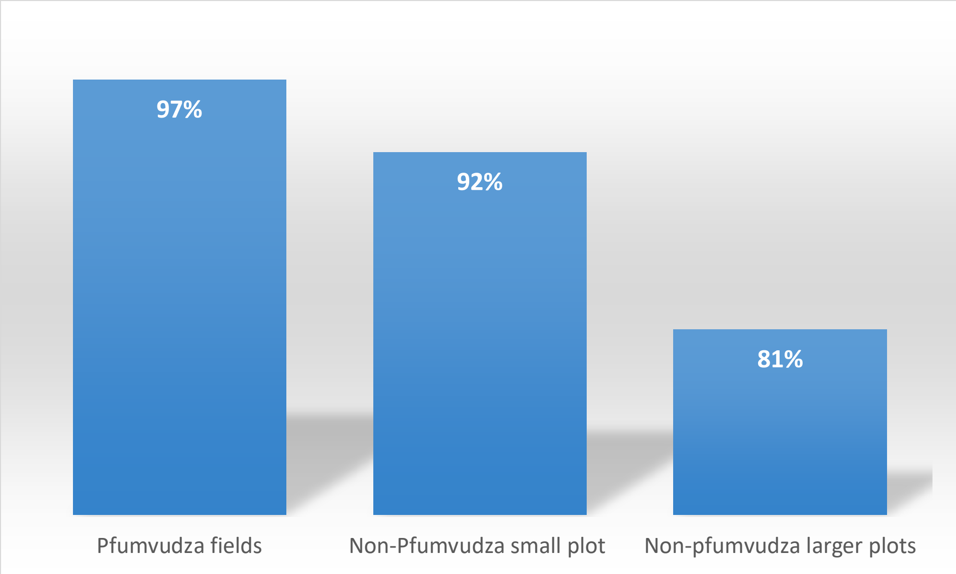


Figure 7. Beneficiaries of Pfumvudza package by plot type

In terms of maize yields, Table 12 shows significant maize yield differences between Pfumvudza plots and non-Pfumvudza plots across all the provinces, LFSP and non-LFSP districts as well as beneficiaries of the Pfumvudza package. Within the Pfumvudza plot type, the average maize yields were highest in Mashonaland Central, followed by Midlands and least in Manicaland. Given that the number of direct LFSP beneficiaries within the sample was too small for any statistical analysis, we only focused on comparing LFSP districts versus non LFSP Districts. Overall, there is a 235kg/ha difference in yield between LFSP and Non-LFSP districts. Whether this difference is statistically significant or not is tested in the econometric section. Based on descriptive analysis, the yield difference could be associated with plot characteristics as more than half of the plots in non-LFSP districts were prone to flooding compared to 44 percent plots in LFSP districts. Lime application and thinning could have contributed to the yield difference. Close to a third of plots in LFSP districts were thinned compared to less than 20 percent in Non-LFSP districts.

Table A 12. Maize productivity by province

		Average maize yield (Kg/Ha)			
	n	All plots	Pfumvudza plots	Non-Pfumvudza small plot	Non-Pfumvudza larger plots
All plots	1,910	2,265	4,190^{a}	3,874^{a}	1,330^{b}
Mashonaland Central	579	2,738	5,612^{a}	5,036^{a}	2,621^{b}
Manicaland	528	1,917	3,632^{a}	2,943^{b}	1,197^{c}
Midlands	803	2,154	3,796^{a}	4,001^{a}	1,199^{b}
LFSP district	1,247	2,347	4,150^{a}	3,998^{a}	1,403^{b}
Non-LFSP districts	663	2,112	4,329 ^{a}	3,592^{b}	1,582^{c}
LFSP beneficiaries	21	3,035	5,527^{a}	5,404^{a}	1,529^{b}
Beneficiary of Pfumvudza package	1,639	2,431	4,254^{a}	3,950^{b}	1,551^{c}
Non beneficiary	274	1,277	2,199^{a}	2,90^{b}	1,130^{c}

Rows with the same superscript letter are not significantly different at the 5% level

3.2.5. Can a Pfumvudza plot feed a family of six for a year?

According to the FfF, an average rural family with six members can consume a 20-litre bucket of maize per week, translating into 52 buckets per year. Filling this bucket requires 56 decent sized maize cobs. Assuming an average grain weight of 15.2kg per bucket, the total harvest from a Pfumvudza plot would be 790kg.

This section compares the maize production (total kilograms produced) between the FfF expected production from a Pfumvudza plot and those obtained in the survey sample. Table 13 shows that, on average, the total maize production from a Pfumvudza plot was 255 kilograms compared to 790kg kilograms per FfF. This is 67.7 percent lower than the FfF expected yield. The median production is is 225 kilograms. Thus, 50 percent of the households produced at least 225 kilograms from their Pfumvudza plots, production that is 71.5 percent less than the expected yield per FfF. On the other hand, only 2 percent (or 8 of the sampled households) reported harvesting 790kg or more than the average expected production from their Pfumvudza plot (Figure 8). Although the country produced enough maize grain on aggregate, the total production per Pfumvudza plot questions the ability of vulnerable households with six members or more to meet their households' cereal needs. Therefore, it is important to focus attention on raising household plot productivity per FfF model of 52 buckets for each 1/16 ha plot.

Table A 13. Comparison of average maize production with Foundation for Farming expected production per Pfumvudza plot

	Maize production (kgs)					
	Count	**mean**	**Median**	**Percentile 25**	**Percentile 75**	**Percentile 90**
Foundation for Farming expected production		790	-	-	-	-
Pfumvudza plots	383	242	225	100	315	450

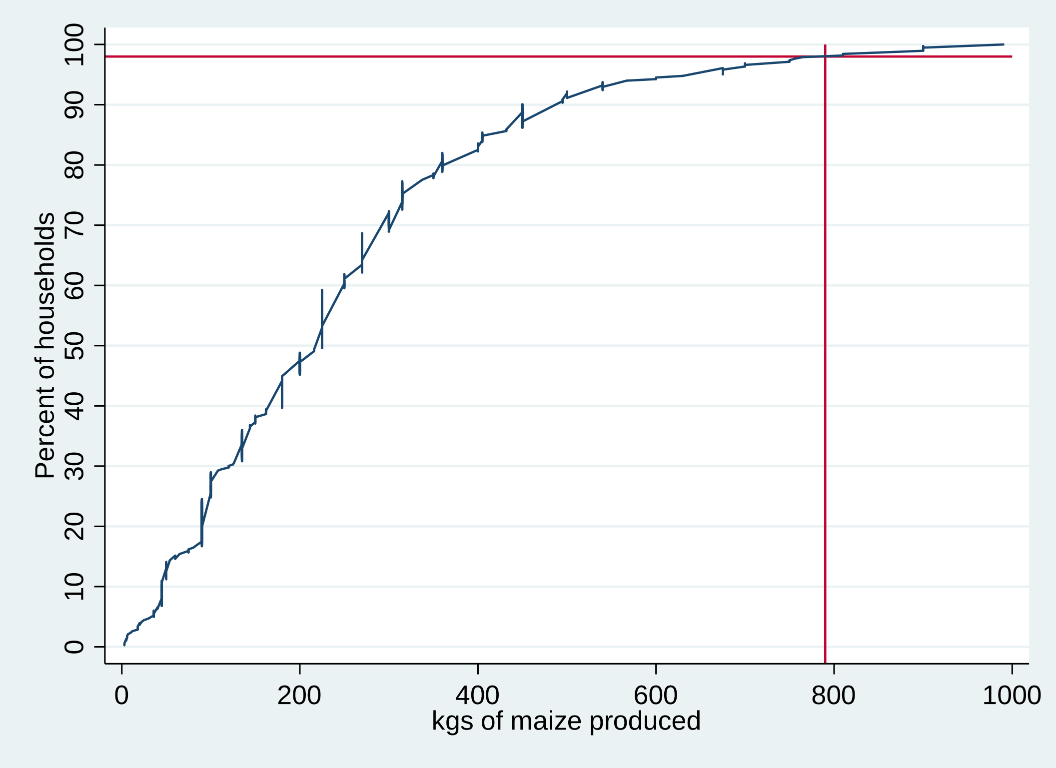


Figure 8. Percent of households producing 790kg of maize on a Pfumvudza plot

The findings in Figure 8 suggested that many households were still food insecure, and more effort is needed to increase the level of maize production as per the FtF concept. Where should this effort be directed if we are to realize the food security objective? Ideally, a detailed analysis of the 2% of households could precisely address this question. However, the sample was too small to provide any meaningful statistical analysis.

As an alternative, we attempt to understand the factors contributing to increased production by dividing households into three categories based on their production level. That is, households who produced less than 263kg (a third of 790kg); those who produced between 263 and 526kg and those who produced more than 526kg (above two-thirds of 790kg). Based on these categories, the factors that were likely to push a household in any one of the production level categories were analysed using a multinomial logit. Two models were estimated. Model I includes the Pfumvudza practices index, while model 2 includes the individual practices. [2] . To help with the interprentations of the results, the relative risk ratios (rrr) were estimated. If the rrr is greater than one, then the variable increases the probability of being in that group is high. Conversely, if the rrr is less than one, then the variable reduces the likelihood of being in that group relative to the baseoutcome.

The results presented in Table 14 presents the factors associated with the likelihood of being in one maize production level group. The factors likely to reduce maize production include waterlogging, distance to the plot and being in Manicaland. In contrast, post-education level of household head, the availability of household labour proxied by adult equivalent, recommended spacing, mulching and being in Mashonaland are associated with higher maize

[2] https://www.stata.com/manuals/rmlogit.pdf

production. These factors also came out from the maize productivity estimation (next section), where we discuss them in detail.

Table A 14. Factors associated with different maize production levels

	Reference Group 1- Households(HH) producing less than 263kg of maize			
	1		2	
	Group 2-HH producing 263-526kg	Group 3-HH producing above 526kg	Group2	Group 3
	Relative risk ratios			
Plot characteristics				
Waterlogging a major issue (=1)	0.621	0.415	0.538*	0.364
	(0.217)	(0.327)	(0.184)	(0.306)
Waterlogging but not a major problem (=1)	1.962*	3.974*	2.335**	4.883*
	(0.694)	(3.296)	(0.880)	(4.346)
Log distance to field (km)	0.472**	0.114**	0.483**	0.147**
	(0.158)	(0.103)	(0.164)	(0.135)
Pfumvudza practices				
number of Pfumvudza plots	1.115	0.888	1.062	0.849
	(0.122)	(0.150)	(0.130)	(0.143)
index of sequential Pfumvudza practices	1.152	1.348		
	(0.135)	(0.269)		
Pfumvudza recommended planting spacing (=1)			9.337**	4.449
			(9.950)	(5.697)
Applied basal fertilizer on time (=1)			0.694	1.090
			(0.198)	(0.513)
Used lime (=1)			0.893	1.466
			(0.339)	(0.892)
Mulching (=1)			1.764*	2.159
			(0.515)	(1.119)
Thinning (=1)			1.305	1.269
			(0.353)	(0.619)
Applied top fertilizer on time (=1)			1.582	2.201
			(0.444)	(1.239)
Household characteristics				
Female head with no male adults in HH (=1)	0.439*	0.824	0.472	0.917
	(0.208)	(0.785)	(0.224)	(0.916)
Female head with male adults in HH (=1)	1.537	2.032	1.256	1.762
	(0.526)	(1.385)	(0.441)	(1.174)
Adult equivalent	1.042	1.383**	1.022	1.324**
	(0.0892)	(0.187)	(0.0892)	(0.187)
HH Head with primary education	1.187	1.301	1.395	1.816
	(0.684)	(1.430)	(0.892)	(2.073)
HH head with Form 1 to 4 education	1.972	3.442	2.372	5.191
	(1.130)	(3.833)	(1.553)	(5.943)
HH head with post-secondary education	8.619**	34.57**	9.747**	50.91***
	(7.419)	(50.43)	(9.173)	(75.11)
Provincial dummies				
Mashonaland Central	2.276**	7.622**	2.999***	9.890**
	(0.824)	(6.260)	(1.157)	(9.241)
Manicaland	0.728	0.284	0.579	0.206*
	(0.237)	(0.245)	(0.199)	(0.190)
Constant	0.191**	0.00688***	0.0198***	0.00106***
	(0.141)	(0.0114)	(0.0262)	(0.00224)
Observations	382	382	382	382

Robust standard errors -eform in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Notes: The baseoutcome is group 1 (households producing less than 263kg of maize; Group 2 produced 263-526kg and Group 3 produced above 526kg.

3.3. Econometric Results

The impact of Pfumvudza on maize yields was estimated using PSM. We checked for the robustness of the results using the IPWR and Ordinary Least Squares on the unmatched sample. Results are robust across different specifications. See Table A-2and Table A-3 in annexe 2 for the results of the alternative specifications. The discussion in this section focuses mainly on the variable Pfumvudza plot (=1), whose coefficient reflects the impact of the Pfumvudza on maize yield compared to non-Pfumvudza fields. A number of models are estimated, Models 1 to 4 are models without interactions, whilst the remaining models have interactions terms to analyse differential impacts by some factors hypothesized to enhance or curtail the impacts of Pfumvudza.

3.3.1 Impact of Pfumvudza on maize productivity

The four impact estimation models (columns 1 to 4) consistently show that Pfumvudza fields had higher yields than non-Pfumvudza fields (Table 15). Using results in Model 3 and 4, where we control for other covariates that may contribute to differences in maize yields, the results consistently show that the Pfumvudza plots yield above 1,500 kilograms more maize than non-Pfumvudza fields ceteris paribus. This implies that intensification of inputs and management pays off, supporting FfF assertion that a household can plant a small field of maize and produce more and enhance their food security. Also, the Pfumvudza farming practice may be more appropriate for subsistence households who are land constrained and struggle to become household food secure by overspreading their effort and inputs on slightly larger areas. This is substantiated by the reduction in yields as the plot size cultivated increases.

Other factors that significantly contributed to increased yields include, benefiting from the Pfumvudza input package, sequential implementation of Pfumvudza practices, availability of household labour proxied by adult equivalent. Acquiring post-secondary education did also increase maize productivity, all else equal. On the other hand, waterlogging, distance to maize plot, mulching significantly reduced the maize yields. However, we determine the differential effects of these parameters on maize yields in the next section

Table A 15. Impact of Pfumvudza on maize productivity – PSM

	Dependent Variable = Maize Yield (Kg/ha)							
LABELS	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Pfumvudza field (=1)	**1,685.8*** **	**1,634.9*** **	**1,524.2*** **	**1,516.5*** **	**1,719.5*** **	**1,860.7*** **	**1,632.6** **	**2,327.3*** **
	(172.8)	(173.6)	(175.2)	(176.3)	(369.6)	(387.6)	(654.1)	(623.5)
Field characteristics								
Plot size (ha)	-1,140.1***	-1,095.2***	-979.0***	-925.8***	-1,176.1***	-1,103.1***	-971.9***	-888.9***
	(127.8)	(129.1)	(129.9)	(131.6)	(127.1)	(129.3)	(127.8)	(130.9)
No water logging (reference)								
Waterlogging a major issue (=1)	-694.0***	-808.6***	-720.0***	-805.7***	-655.3***	-625.8***	-685.2***	-638.1***
	(130.9)	(117.2)	(129.8)	(117.3)	(145.8)	(132.3)	(142.9)	(131.6)
Waterlogging but not a major problem (=1)	244.0*	121.0	234.5*	124.5	-7.2	-13.9	1.1	-1.3
	(138.5)	(130.0)	(137.4)	(130.1)	(151.0)	(143.7)	(148.1)	(142.5)
Log distance to field (km)	-273.4**	-296.7***	-275.4**	-304.0***	-184.5	-207.4*	-182.5	-213.9*
	(111.7)	(113.5)	(110.9)	(113.1)	(118.6)	(121.6)	(116.5)	(120.0)
Pfumvudza practices								
number of Pfumvudza plots	31.8	77.7	38.3	72.0	2.8	88.6	-5.1	67.6
	(63.2)	(64.4)	(62.9)	(64.4)	(63.4)	(64.7)	(63.0)	(64.8)
Beneficiary of Pfumvudza package (= 1)	499.1***	303.4**	387.5**	220.9	548.5***	331.8**	433.3***	252.9*
	(150.8)	(150.8)	(152.5)	(153.6)	(149.6)	(150.6)	(149.9)	(152.5)
index of sequential Pfumvudza practices	234.8***	220.0***			236.1***	189.0***		
	(51.8)	(51.2)			(57.9)	(57.6)		
Pfumvudza recommended planting spacing (=1)			724.7***	669.3***			870.2***	789.0***
			(122.5)	(123.3)			(124.2)	(126.5)
Applied basal fertilizer on time (=1)			207.1*	209.0*			298.6**	262.6**
			(110.3)	(111.2)			(121.9)	(124.4)
Used lime (=1)			-158.9	60.1			-413.3**	-248.0
			(169.2)	(166.8)			(192.7)	(193.4)
Mulching (=1)			-146.4	-342.2***			-327.8**	-542.7***
			(121.6)	(119.8)			(138.8)	(138.3)
Thinning (=1)			307.9**	310.0**			370.8***	322.5**
			(119.9)	(121.9)			(140.6)	(144.9)
Applied top fertilizer on time (=1)			288.2***	154.1			244.6**	110.6
			(104.6)	(103.6)			(115.1)	(115.9)
Household characteristics								
Household head headship								
Male headed households (reference)								

Female head with no male adults in HH (=1)	-113.7	-243.9	-97.8	-235.8	12.1	-108.7	54.1	-76.2
	(161.7)	(162.5)	(160.9)	(161.8)	(180.2)	(182.8)	(178.0)	(181.3)
Female head with male adults in HH (=1)	197.6	231.1	177.7	226.0	147.0	175.5	165.8	213.7
	(149.7)	(151.5)	(148.8)	(150.8)	(165.9)	(169.2)	(163.3)	(167.3)
Adult equivalent	73.2**	82.0***	67.0**	74.4**	65.8**	75.4**	48.2	56.7*
	(30.8)	(31.1)	(30.8)	(31.1)	(30.5)	(31.0)	(30.3)	(30.9)
Education level of HH head								
No education (reference)								
HH Head with primary education	72.4	-25.4	-23.7	-117.3	26.2	-65.9	25.5	-74.0
	(219.3)	(221.6)	(218.1)	(220.8)	(216.7)	(220.9)	(213.8)	(218.8)
HH head with Form 1 to 4 education	148.7	92.7	39.0	1.0	113.1	61.4	105.6	70.9
	(220.0)	(222.8)	(219.2)	(222.3)	(217.4)	(222.1)	(215.0)	(220.5)
HH head with post-secondary education	709.1**	659.8**	612.0**	603.6*	715.4**	638.3**	658.9**	630.6**
	(308.9)	(313.1)	(306.6)	(311.1)	(305.0)	(311.7)	(299.5)	(307.4)
Provincial dummies								
Manicaland (reference)								
Mashonaland Central	852.7***		909.2***		670.7***		739.5***	
	(139.9)		(144.3)		(152.8)		(155.4)	
Midlands	710.5***		831.3***		877.6***		1,023.1***	
	(130.4)		(136.8)		(147.8)		(153.5)	
LFSP district		-68.1		-62.5		-48.2		-9.6
		(108.1)		(108.4)		(116.5)		(116.9)
Interactions								
Pfumvudza* female-headed with no male adults members					-428.1	-579.1	-577.1*	-711.2**
					(352.2)	(354.3)	(349.8)	(356.0)
Pfumvudza* female-headed with male adults members					130.9	217.6	-52.5	77.2
					(348.7)	(356.6)	(345.5)	(354.5)
Pfumvudza* log of distance to field					-628.6**	-662.8**	-482.9	-536.2*
					(315.4)	(323.2)	(312.8)	(322.6)
Pfumvudza* waterlogging a major problem					48.7	-826.0***	-116.2	-897.8***
					(317.7)	(283.3)	(315.4)	(286.9)
Pfumvudza* water logging not a major problem					1,542.9***	670.8**	1,614.8***	788.2**
					(356.9)	(334.1)	(354.9)	(338.0)
Pfumvudza*index of Pfumvudza					-83.9	118.3		
					(125.0)	(124.2)		
Pfumvudza*correct spacing							-828.1	-1,045.3*

							(566.6)	(585.5)
Pfumvudza*basal fertilizer							-558.1**	-314.2
							(263.0)	(267.1)
Pfumvudza*lime							780.7**	1,234.6***
							(376.0)	(371.3)
Pfumvudza*mulching							1,011.0***	944.6***
							(271.9)	(270.2)
Pfumvudza*thinning							-171.0	69.8
							(262.5)	(267.9)
Pfumvudza*top fertilizer							610.4**	456.4*
							(261.6)	(256.9)
Pfumvudza*Mashonaland					1,356.3***		1,644.1***	
					(357.6)		(375.8)	
Pfumvudza*Midland					-724.6**		-500.9	
					(297.7)		(311.6)	
Pfumvudza*LFSP district						-15.5		-43.1
						(300.2)		(299.6)
Constant	949.8***	1,816.3***	709.4**	1,687.2***	983.6***	1,790.7***	646.6**	1,581.8***
	(310.6)	(303.5)	(313.7)	(303.9)	(312.7)	(305.0)	(313.5)	(304.4)
Observations	1,866	1,866	1,866	1,866	1,866	1,866	1,866	1,866
Adjusted R-squared	0.261	0.243	0.276	0.256	0.282	0.252	0.311	0.276

Standard errors in parentheses;*** p<0.01, ** p<0.05, * p<0.1

3.3.2 Heterogenous impact of Pfumvudza on maize productivity

The following results are based on the predicted estimates from the econometric model 7 of the matched sample. Pairwise comparisons of maize yields across different attributes were made within each field type. We used Stata's "margins" post estimation command to predict the maize yields from the fitted model.

3.3.2.1 Does gender of household head matter?

Traditionally, in developing countries, grain yields are lower on land managed by women than those on men-managed fields (Gebre et al., 2021). The gender productivity gap is often attributed to unequal access to productivity-enhancing technologies and resources such as improved tillage methods, irrigation facilities, fertilizers and improved seeds which are thinly spread on larger fields (Burke and Jayne, 2021; Njuki et al., 2014; Giordano, and de Fraiture, 2014). Thus, the Pfumvudza concept presents a better solution as it is a low input sustainable agricultural practice.

The estimated gendered differential yields indicate that the gender of the household head and the household composition does not matter. Though the yields on the Pfumvudza plots are lower for female-headed households with no male adult members, the results are not statistically different from the yields of other gendered household types Table 16. This implies that intensification can contribute to closing the gender yield gap and improve the food security of vulnerable households such as female-headed households.

Table A 16. Gendered differential impact of Pfumvudza

Field type	Household headship		
	Male-headed	Female-headed with no male adults	Female-headed with male adults
Pfumvudza field	3,933[a]	3,410[a]	4,047[a]
Non- Pfumvudza field	1,946[a]	2,000[ab]	2,112[b]

Yields within each field type with the same superscript letter are not significantly different at the 5% level

3.3.2.2 Does Provincial differences matter?

Climate variability, such as low rainfall and recurrent droughts, have devastating effects on agricultural productivity (Schlenker and Lobell, 2010; Knox et al., 2012). Therefore, Pfumvudza is recommended for drier regions or areas prone to periods of moisture stress during the growing season, as planting basins and mulching help conserve moisture. Hence, of the three provinces, Midlands may be best suited for the widespread adoption of the Pfumvudza practice compared to most areas in Mashonaland Central and Manicaland provinces. Nevertheless, the 2020/2021 agricultural season was characterized by good rainfall across the country. Hence, the provincial maize yield differences may be masked by productivity attributed to good rains. Therefore, the results presented in Table 17 should be interpreted with this caveat in mind. Ideally, analysis based on the agro-ecological zones could have been more informing, however, due to data limitations, the discussion of results can only be done at provincial level. Future studies need no consider doing collecting data across different agro-ecological zones.

In general, the results in Table 17 show that Pfumvudza plots out-performed non-Pfumvudza plots across all provinces. However, within the Pfumvudza plots, Mashonaland Central tops the list with higher estimated yields on the Pfumvudza field compared to the other two provinces. The 2020 crop assessment report also showed higher yields in Mashonaland than in other provinces (MLAWRR, 2020). On the other hand, the yield differences between Manicaland and Midlands are not statistically different.

The results also show that there are no significant differences between LFSP and Non-LFSP districts. The plausible explanation for this observation could be attributed to the Government's nationwide rollout of the concept when this study was conducted. Thus both non-LFSP Districts and LFSP Districts benefited from the programme. There could have been differences for direct LFSP beneficiaries, but as mentioned earlier, it was not possible to analyse the differences between LFSP direct beneficiaries and non-LFSP beneficiaries because of the small number of beneficiaries in the final sample. This was because the sampling procedures assumed that most of the farmers and households in LFSP districts were in one way or the other benefiting from the implementation of the Zimbabwe Livelihood Food Security Programme in those districts.

Table A 17. Provincial differential impact of Pfumvudza

	Province			LFSP vs Non LFSP Districts	
Field type	Mashonaland central	Manicaland	Midlands	LFSP Districts	Non-LFSP Districts
Pfumvudza field	5,321^{d}	3,460^{b}	2,937^{bc}	3,798	3,850
Non-Pfumvudza field	2,058^{a}	2,342^{a}	1,319^{b}	1,987	1,977

Yields with the same superscript letter are not significantly different at the 5% level

3.3.2.3 Does waterlogging affect maize yields?

Waterlogging is one of the critical constraints to crop production, especially in high rainfall areas. This is because the ability of soil to provide an optimum medium of plant growth is impeded (Manik et al., 2019). Table 18 shows lower yields when waterlogging is a major problem, even on Pfumvudza plots. This implies that some aspects of the Pfumvudza concept, such as mulching, which are water-conserving practices may not be appropriate in higher rainfall areas. The combined effect of mulching and waterlogging on a Pfumvudza plot shows a significantly lower yield when water logging is a major issue (Table 19). Otherwise, mulching has the potential to increase the yields up to 5000kg/ha if water logging is addressed. However, the results in Figure 4 showed that farmers did mulching only on 35% of plots stressing the need to address the mulching challenges.

Table A 18. Waterlogging differential impact of Pfumvudza

	Experienced water logging in the field		
Field type	No waterlogging	Yes, a major issue	Yes, not a major issue
Pfumvudza field	4,113^{a}	2,577^{b}	4,899^{c}
Non- Pfumvudza field	2,175^{a}	1,536^{b}	2,174^{a}

Yields with the same superscript letter are not significantly different at the 5% level

Table A 19. Combined effects of mulching and waterlogging on a Pfumvudza plot

	Experienced water logging as a major issue		
	No waterlogging	Yes, a major issue	Yes, not a major issue
Mulching	4,412[a]	2,876[b]	5,199[c]

Yields with the same superscript letter are not significantly different at the 5% level

3.3.2.4 Does distance from the homestead affect maize yields?

The PSM results in Table 15 shows that the interaction term on the distance variable and Pfumvudza field is negative and statistically significant. Meaning the further the plot is from the homestead, the lower the yields. Figure 9 shows the differential impacts of maize yields by distance from the homestead. These results support the bivariate findings in section 3.2.3 that showed that distance of the field had an impact on productivity. This is likely to be linked to the increased attention and management associated with the proximity of the maize plot to the homestead. Given that the Pfumvudza plot is only 1/16 of a hectare, it is recommended that the plot has to be located closer to the homestead to enable increased attention and management. Closer plots are also sensitive to the practical needs of the women who are triply burdened.

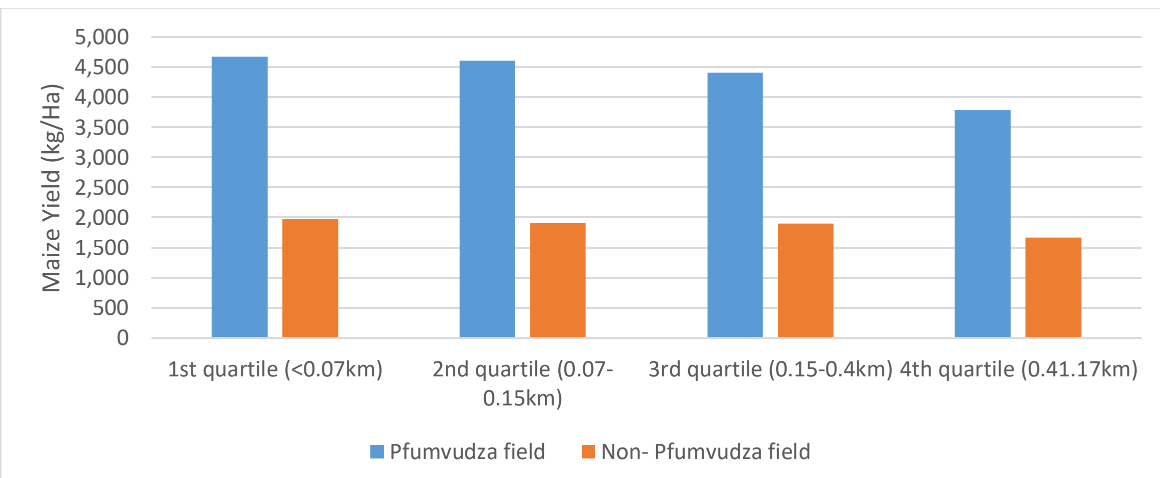


Figure 9. Distance of field from homestead and maize yields
Source: Authors calculations from PSM Model, Table 15

3.3.2.5 Does the number of Pfumvudza plots affect the maize yields?

During the 2020/2021 agricultural season, the Government of Zimbabwe promoted the Pfumvudza programme through the Presidential Input Support Scheme (MLAWRR, 2021). In particular, the Government provided 1.8 million rural households with inputs to establish 3 Pfumvudza plots. In addition, the data shows that households adopted the Pfumvudza practices even on plots larger than the recommended Pfumvudza plot size. Therefore, it was important for us to test whether the number of Pfumvudza maize plots per household affected the average maize yields.

The negative and statistically significant coefficient of the interaction term on the number of maize plots and plots being Pfumvudza in the PSM results (Table 15) implies that the more plots a household has, the lower the yields ceteris paribus. Figure 10 shows the differential impacts of maize yields by the number of cultivated Pfumvudza plots. Having multiple Pfumvudza maize plots have a negative effect on maize yields (Figure 10). Therefore, having multiple Pfumvudza maize plots is likely to result in compromised agronomic management practices due to increased management and sparse deployment of resources. However, for crop rotation's sake, farmers can have at least two Pfumvudza plots, one for cereal and another for legumes.

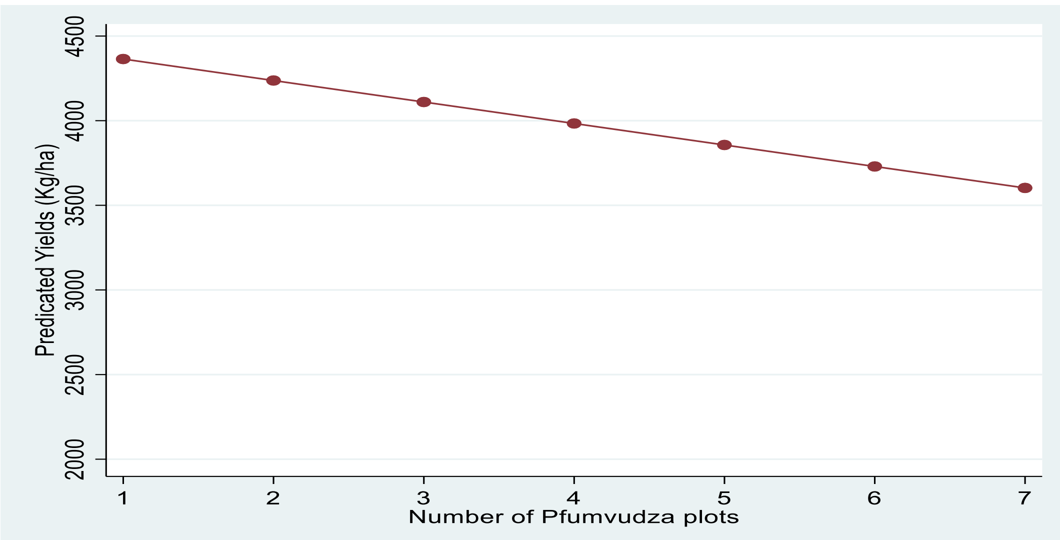


Figure 10. Differential yield of number of Pfumvudza fields
Source: Authors calculations from PSM Model, Table 15

3.3.3 Farmers' perceptions regarding Pfumvudza concept

The previous section has shown that intensification pays though there is a need to do more to achieve the food security objective. But why would farmers not adopt the Pfumvudza concept? This section highlights the farmer's perceptions regarding the Pfumvudza concept and the factors that need to be considered to enhance the adoption of the concept. When farmers were asked to rate their experience with the Pfumvudza Concept during the 2020/21 agricultural season, most of those who had practised Pfumvudza were satisfied (Figure 11), and 98 percent of the households indicated that they were likely to continue practising Pfumvudza in next farming season. They cited higher yields as the main reason for continuing with the practice, with 19.4 percent indicating that they would continue practising Pfumvudza because of efficient use of inputs (Figure 12). However, those who were likely to discontinue were of the view that the practice is labour intensive (65 percent), whilst 15 percent of the households indicated that the practice was not suitable for the disadvantaged groups because of the prerequisites such as potholing which is a labour-intensive activity (Figure 13)

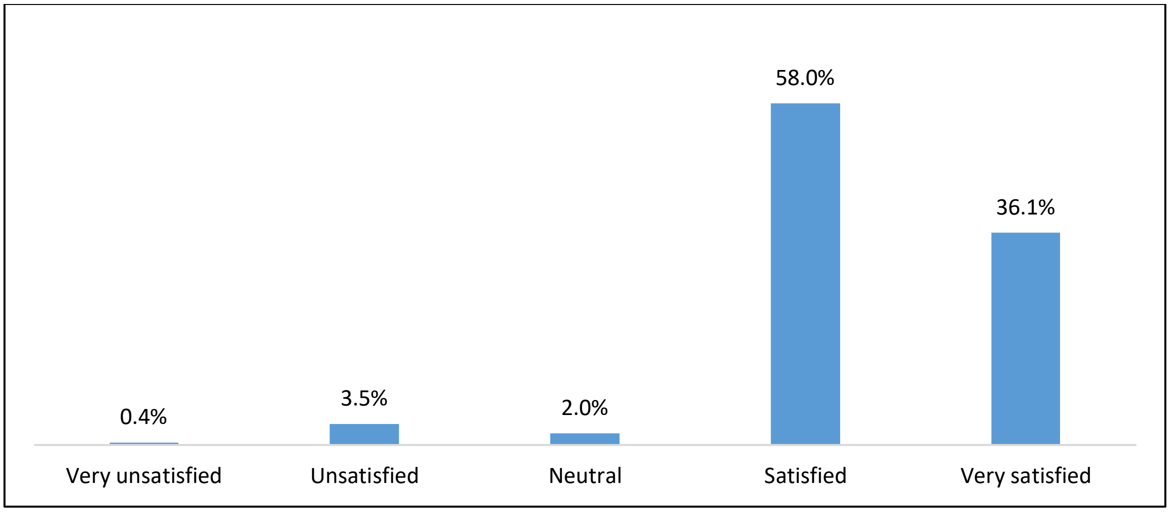


Figure 11. Rating of the experience with Pfumvudza concept

Source: LFSP/MLAFWRR Survey 2021

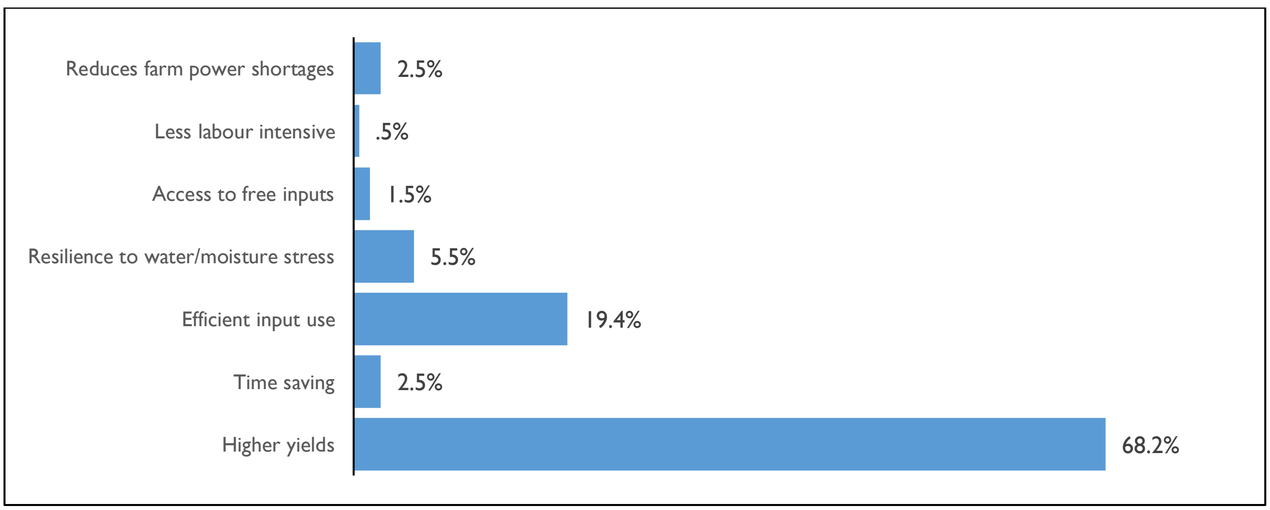


Figure 12 Reasons for continuing with the Pfumvudza practices

Source: LFSP/MLAFWRR Survey 2021

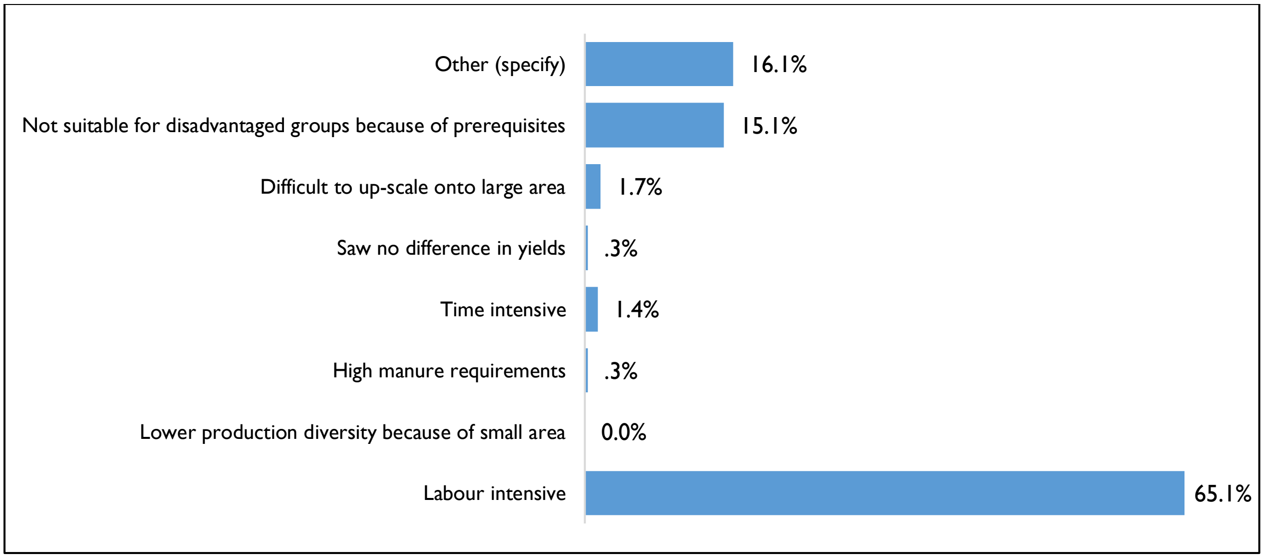


Figure 13. Reasons for discontinuing the Pfumvudza practice

Source: LFSP/MLAFWRR Survey 2021

3.3.4 Access to information about Pfumvudza concept

Access to information is key to changing any negative perception about the technology and increasing uptake. This section outlines the key sources of information about Pfumvudza concept and the means through which farmers accessed the information. Over 90 percent of households had received information or advice about the Pfumvudza concept, and the government agencies were the key source of information (Figure 14). In addition, over half of the households received the advice through demonstrations plots (Figure 15), with close to 80 percent learning about the Pfumvudza concept in the 2020/21 agricultural season, suggesting that most sampled households were implementing the concept for the first time.

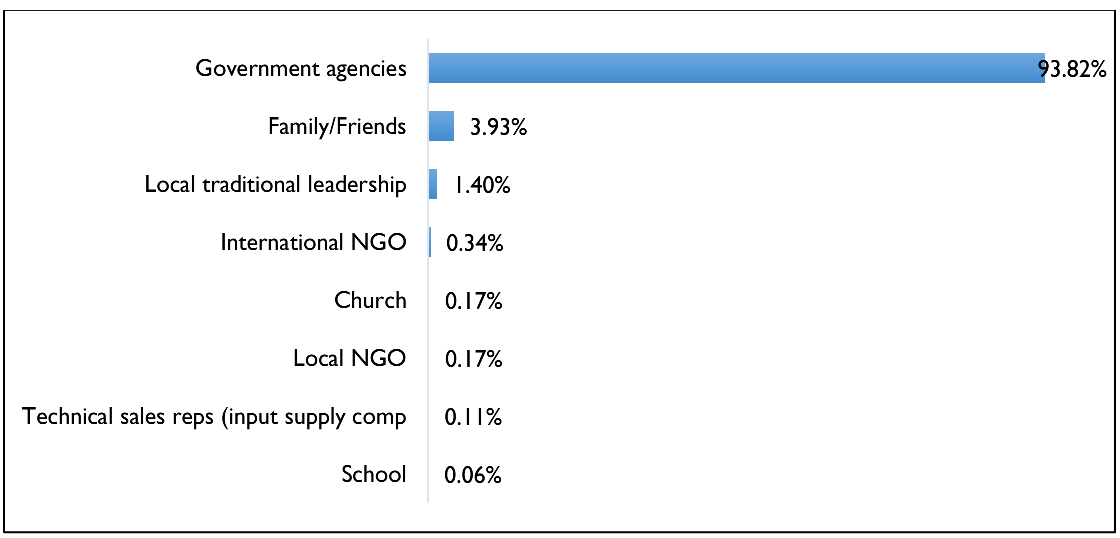


Figure 14. Most important supplier of information about Pfumvudza concept

Source: LFSP/MLAFWRR Survey 2021

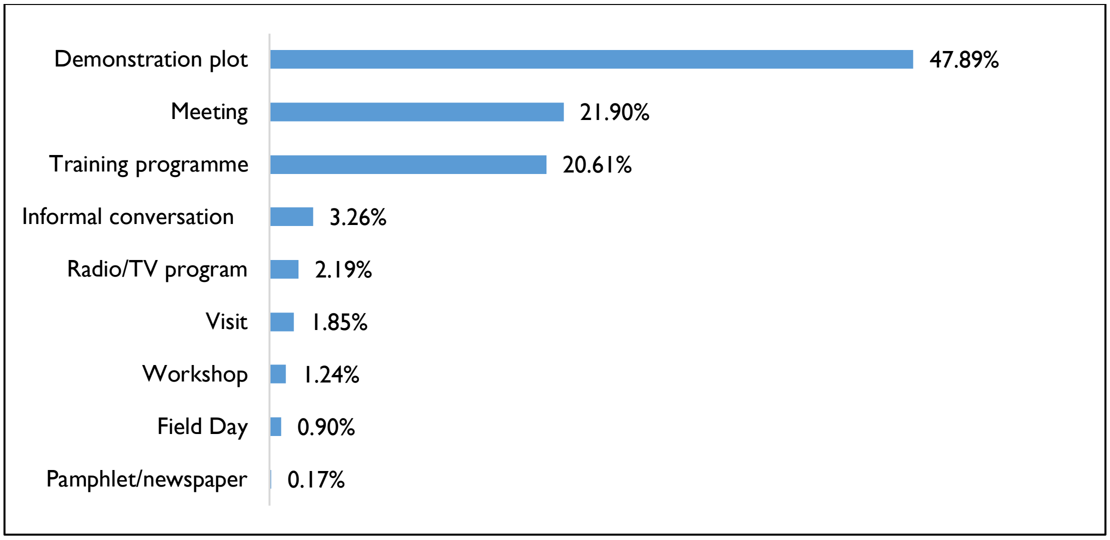


Figure 15. Most important supplier of information about Pfumvudza concept
Source: LFSP/MLAFWRR Survey 2021

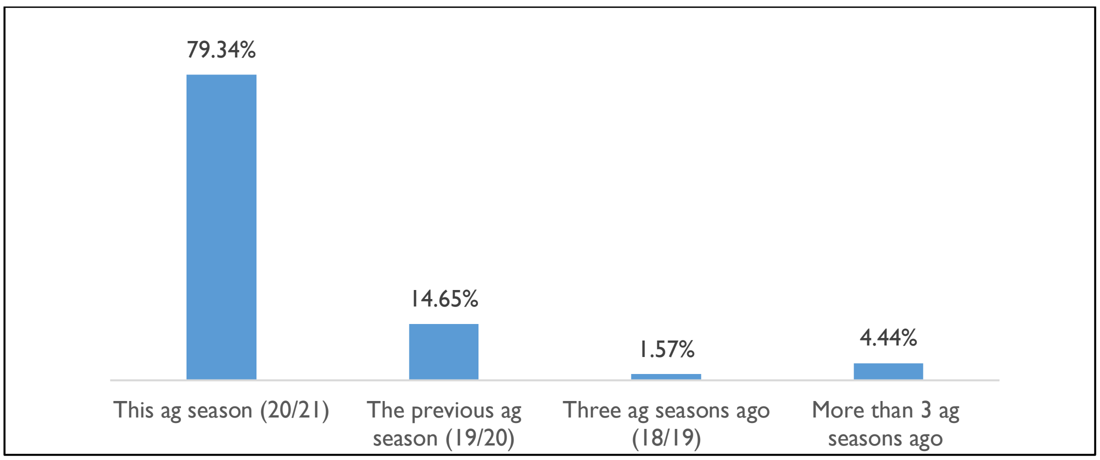


Figure 16. First time households learnt about Pfumvudza concept
Source: LFSP/MLAFWRR Survey 2021

3.3.5 Does Treasury save resources from supporting Pfumvudza farming?

Pfumvudza farming programme is wholly funded by Treasury. The quantity of inputs provided for a Pfumvudza plot are as indicated in the table below:

Table A 20. Pfumvudza farming concept and Non-Pfumvudza farming input pack

Type of input	Pfumvudza Plot (kg)	Non-Pfumvudza (kg)	Ave. Cost
Maize seed	2	10	US$3 per Kg
Basal fertilizer	16	50	US$36 per 50kg
Top dressing	16	50	US$32 per 50 kg

Source: MLAFWRR, 2021

Pfumvudza plot total input cost is on average US$26.48 while past government input subsidy was to the tune of US$98.00. Thus, the promotion of Pfumvudza plots saves Government US$71.52. Furthermore, there is also potential for additional saving as households will be food secure, and no support will be provided in the form of food rations/food assistance.

4. CONCLUSIONS AND RECOMMENDATIONS

This study evaluated the impact of the Pfumvudza concept on maize productivity and assessed the heterogeneous impacts on maize productivity by gender of household head, field characteristics, number of Pfumvudza plots and province. The study draws the following conclusions and recommendations using the field level data collected from 1910 maize fields and disaggregated by Pfumvudza and non-Pfumvudza fields.

Pfumvudza Practices enhances maize productivity

The estimations show that the Pfumvudza concept raises maize yields by over 1500 kg per ha and that practising Pfumvudza on plot sizes above the recommended size tends to reduce yields. This implies that intensification of inputs and management is beneficial. Therefore, farmers should be advised to keep the plots to recommended sizes to maximise the yield benefits of the concept. On the other hand, farmers should be discouraged from adopting the practices on larger plots because this would lead to increased labour requirements as well as less than optimal use of inputs and sparse management.

Household food security objective not yet attained

Despite the increase in the maize yields, this was insufficient to address the food insecurity problem. The majority of households produced less than 790kg a production which would feed a family of six members for the whole year. To ensure that farmers attain the food security objective of the Pfumuvudza concept, more work is needed to address problems associated with waterlogging, mulching and labour and encourage farmers to adhere to recommended Pfumuvudza practices.

No gendered differences in maize productivity

The insignificant gendered differential impacts imply that the small high yielding Pfumvudza plot and low input concept addresses the gender barriers of access to land, inputs and labour and closes the gender productivity gap as women usually have challenges accessing productive resources(inputs, land) and machinery. Furthermore, since productivity growth contributes to food security and poverty reduction, this places women at an advantage in terms of poverty reduction possibilities. Thus, there is a need to encourage more women to intensify their production by adopting the Pfumvudza farming concept, given that women play a critical role in ensuring household food security. Also, the finding on higher yields on the plots closer to the homestead meets the practical gender needs of women who experience time poverty due to many household care work demands.

Waterlogging coupled with mulching reduces maize productivity

Pfumvudza plots experiencing waterlogging and mulched had lower maize yields than those experiencing no waterlogging or some non-serious waterlogging. Therefore, extension messages should also focus on the importance of drainage improvement of the fields to take advantage of the benefits of the Pfumvudza concept, especially in high rainfall areas. Further studies regarding waterlogging as well as locations best for Pfumvudza should be explored.

While mulching and waterlogging have a combined negative effect on maize yield, mulching can increase the yields up to 5000kg/ha in non-water logging plots. However, despite this benefit, very few farmers did mulching, stressing the need to address the challenges of accessing mulching materials and utilisation.

Increasing the number of maize Pfumvudza plots reduces maize productivity

The study results show a negative relationship between maize productivity and the number of Pfumvudza maize plots the household was managing. Thus, having multiple Pfumvudza plots tends to constraint farmers who are already labour-constrained. Given that farmers felt that the Pfumvudza concept was labour intensive and factors into their decision on whether they continue with the practice suggest that households may need to concentrate on one maize field as recommended by the Foundations for Farming. If the main objective is to enhance household food security for less endowed households, then doing a good job with one Pfumvudza maize plot would be recommended more especially that majority of the households were below the minimum threshold of 790kg required to feed a family of six members . In addition, the government subsidy for this programme would be able to reach many more farmers. However, given that crop rotation is one of the Pfumvudza tenets, we recommend two Pfumvudza plots per household, one for cereal and another one for legumes to cater for crop rotational requirements.

Adherence to recommended agronomic Pfumvudza practices results in higher maize yields

In terms of adherence to agronomic Pfumvudza practices, farmers who practised recommended agronomic practices got higher yields than those who partially adopted the practices. Evidence shows that the yield gap between the agronomic practices adopted is significantly high. Therefore, there is a need for more extension services on the importance of adopting a full range of agronomic practices. This will also need to be bundled with addressing practice specific challenges that may have led to the households not utilizing some of the agronomic practices such as mulching, liming, thinning and recommended timing of fertilizer application.

Resource saving by Treasury

Capital outlay by Treasury is reduced when supporting Pfumvudza farming concept than non Pfumvudza farming. There is potential for further saving by not providing food aid to communities who are likely to be food secure.

Development of labour-saving technologies

Pfumvudza farming should be complemented by technological developments, especially in labour-saving technologies, to reduce the burden on activities such as pot holing and mulching. Furthermore, Government should consider a subsidy programme for those involved in the manufacture of tools and machinery which support the Pfumvudza farming concept.

Suggestions for further research

Due to the potential area measurement errors for the maize plots, which may influence yield estimations, future studies would need to obtain actual plot measurements as well as perform crop cuts in a sizeable sample of both Pfumvudza and non Pfumvudza plots to be able to measure the impacts of the practice on productivity precisely.

In addition, the impacts of Pfumvudza farming practice in this study were measured using one year of data and done in areas receiving relatively good rainfall. This limits the conclusions we can draw from the econometrics analysis as discussed in the methods section. The Pfumvudza concept was mainly designed to help households cope with drier conditions; hence impacts of this concept during a good rainfall season may be spurious. Future studies need to broaden the geographic coverage to include drier regions to access the farming practice's efficacy fully. Studies targeting different agro-ecological zones would help inform the performance of Pfumvudza under different conditions and offer realistic recommendations. Therefore, it is recommended that a module to assess the impacts of Pfumvudza be included in future crop and livestock assessment nationwide surveys.

There is a need to conduct a study to determine the maximum number of Pfumvudza maize plots that a given household can handle without reducing productivity. This should take into account the availability of labour in the household.

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5. ANNEX

Annex

Propensity Score Estimation
Field characteristics were used to match comparable fields among the non-Pfumvudza fields to Pfumvudza fields. The variables included distance to the field, whether the field was in wetland or not and whether the field was prone to soil erosion or flash flooding. We also controlled for the total land size that the household cultivated in the estimation of propensity scores. Finally, the PS was estimated using the logistic function in Stata.

Assessing the quality of the matching process ***Error! Reference source not found.*** Figure A-1 shows the distribution of propensity scores between the Pfumvudza and non-Pfumvudza fields. The common support requirement for the PSM estimation was satisfied as there was sufficient overlap in the distribution of the PS of both the Pfumvudza and non-Pfumvudza fields. This condition was satisfied within the region of common support [0.03502452, 0.29642524], i.e. ($0 \leq PS \leq 1$). The balancing property was equally satisfied, as shown by the balancing tests for the covariates in Table A-1 panel A. The results of the balancing tests were generated with **psmatch2** and **pstest** in Stata. The idea is that there should be no association between treatment status and each covariate once the observations have been weighted by one and the odds ratio for treatment and control households, respectively. The PS balancing test results confirm the existence of strong bias for two covariates (distance and total area cultivated) which was eliminated after matching. Also, a likelihood ratio joint test for all covariates reinforces the quality of matching as it was highly insignificant after matching (Table A-1 panel B). The results imply that the PSM was, thus, successful in eliminating the hidden bias due to observed effects.

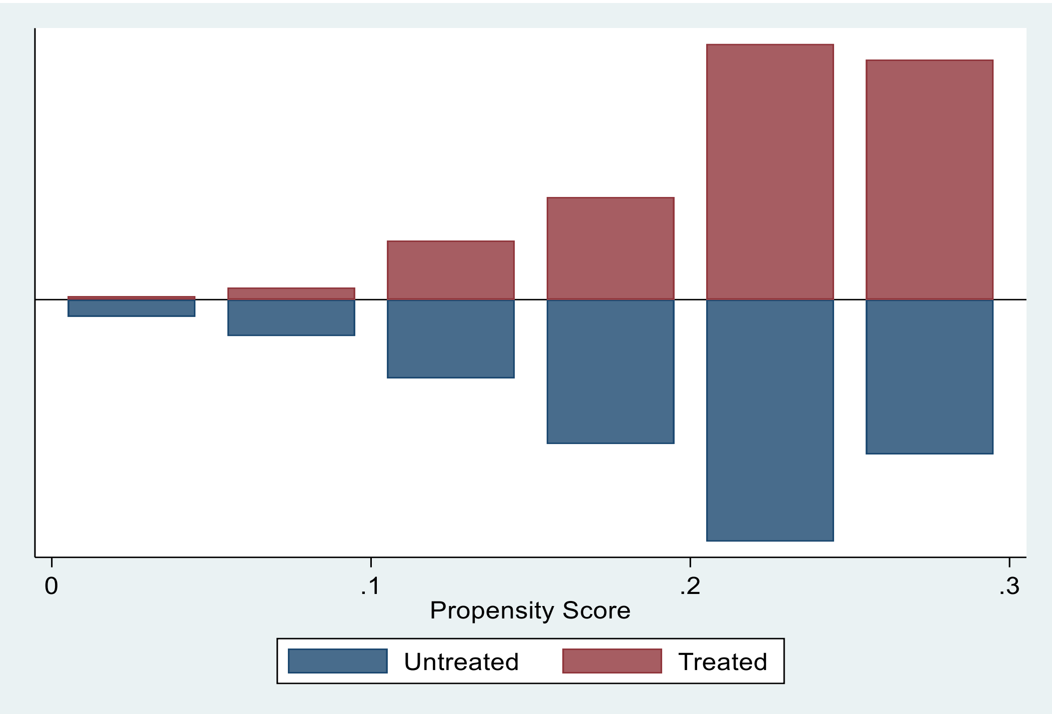

Figure A 1. Distribution of propensity scores

Table A- 1 Balancing t-tests

Panel A

Variable	Unmatched Matched	Mean Treated	Mean Control	%bias	%reduct |Bias|	t-test t	t-test p>t	V(T)/ V(C)
Total land cultivated	U	1.198	1.643	-30.6		-4.89	0.000	0.48*
	M	1.198	1.288	-6.2	79.7	-1.07	0.285	0.98
Distance to maize field	U	0.469	0.787	-21.2		-3.10	0.002	0.15*
	M	0.469	0.424	3.0	85.7	0.88	0.380	1.23*
Field in a wetland area	U	0.103	0.105	-0.5		-0.09	0.931	.
	M	0.103	0.127	-7.6	-1432.8	-1.01	0.311	.
Field prone to soil erosion and/or flash flooding	U	0.478	0.467	2.2		0.39	0.697	.
	M	0.478	0.553	-15.0	-575.0	-2.09	0.037	.

* If variance ratio outside [0.82; 1.22] for U and [0.82; 1.22] for Matched

Panel B

Sample	Ps R2	LR Chi2	p>chi2	MeanBias	MedBias	B	R	%Var
Unmatched	0.024	46.57	0.000	13.6	11.7	34.4*	0.26*	100
Matched	0.007	7.57	0.109	8	6.9	19.8	1.03	50

* if B>25%, R outside [0.5

Table A- 2. Impact of Pfumvudza on maize productivity - Unmatched sample

	Dependent Variable = Maize Yield (Kg/ha)							
LABELS	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Pfumvudza field (=1)	**1,689.7*** **	**1,638.7*** **	**1,529.2*** **	**1,522.6*** **	**1,717.4*** **	**1,866.7*** **	**1,621.1** **	**2,321.7*** **
	(172.0)	(172.8)	(174.4)	(175.5)	(367.9)	(385.9)	(651.3)	(621.0)
Field characteristics								
Plot size (ha)	-1,127.8***	-1,086.8***	-971.5***	-924.7***	-1,164.6***	-1,094.6***	-967.4***	-889.1***
	(125.7)	(126.9)	(127.6)	(129.3)	(124.9)	(127.2)	(125.5)	(128.6)
No water logging (reference)								
Waterlogging a major issue (=1)	-689.3***	-801.5***	-717.5***	-803.3***	-649.7***	-618.8***	-682.2***	-636.7***
	(129.7)	(116.0)	(128.6)	(116.2)	(144.3)	(130.8)	(141.5)	(130.2)
Waterlogging but not a major problem (=1)	241.9*	120.9	236.5*	127.3	-5.5	-12.8	8.6	3.8
	(137.4)	(129.1)	(136.4)	(129.2)	(149.8)	(142.7)	(147.0)	(141.6)
Log distance to field (km)	-290.1***	-314.4***	-291.5***	-319.1***	-206.9*	-229.5*	-205.1*	-234.4**
	(108.4)	(110.0)	(107.7)	(109.6)	(114.7)	(117.3)	(112.6)	(115.9)
Pfumvudza practices								
number of Pfumvudza plots	30.8	76.0	37.7	71.3	2.1	87.5	-5.2	67.7
	(63.0)	(64.1)	(62.7)	(64.1)	(63.2)	(64.4)	(62.8)	(64.5)
Beneficiary of Pfumvudza package (= 1)	494.8***	298.9**	394.3***	228.1	550.4***	331.6**	449.2***	265.3*
	(148.4)	(148.6)	(149.9)	(151.3)	(147.3)	(148.5)	(147.4)	(150.2)
index of sequential Pfumvudza practices	233.4***	217.5***			233.9***	185.8***		
	(51.5)	(51.0)			(57.5)	(57.3)		
Pfumvudza recommended planting spacing (=1)			718.1***	657.7***			860.1***	774.8***
			(121.5)	(122.3)			(123.1)	(125.4)
Applied basal fertilizer on time (=1)			198.4*	199.2*			280.9**	245.9**
			(108.6)	(109.4)			(119.8)	(122.2)
Used lime (=1)			-159.4	60.5			-415.2**	-248.0
			(168.5)	(166.2)			(191.9)	(192.7)
Mulching (=1)			-145.1	-342.1***			-322.0**	-539.1***
			(120.8)	(119.0)			(137.8)	(137.3)

Thinning (=1)			305.6***	307.6**			362.0***	315.9**
			(118.3)	(120.5)			(138.1)	(142.7)
Applied top fertilizer on time (=1)			293.9***	163.7			253.6**	124.9
			(103.7)	(102.9)			(113.9)	(114.9)
Household characteristics								
Household head headship								
Male headed households (reference)								
Female head with no male adults in HH (=1)	-113.7	-242.9	-98.9	-236.8	11.4	-108.1	53.9	-76.1
	(160.8)	(161.7)	(160.1)	(161.1)	(179.3)	(182.0)	(177.2)	(180.6)
Female head with male adults in HH (=1)	196.9	231.2	176.7	225.9	145.5	175.3	165.1	214.4
	(149.0)	(150.9)	(148.2)	(150.2)	(165.2)	(168.5)	(162.6)	(166.6)
Adult equivalent	73.2**	82.5***	66.8**	74.4**	65.5**	75.4**	47.7	56.3*
	(30.6)	(30.8)	(30.5)	(30.8)	(30.3)	(30.8)	(30.0)	(30.7)
Education level of HH head								
No education (reference)								
HH Head with primary education	72.1	-26.3	-22.9	-116.3	25.6	-66.4	26.2	-72.9
	(218.3)	(220.6)	(217.1)	(219.9)	(215.8)	(220.0)	(212.9)	(218.0)
HH head with Form 1 to 4 education	147.1	91.6	39.5	1.7	112.7	61.1	107.8	72.3
	(219.1)	(221.9)	(218.3)	(221.4)	(216.5)	(221.2)	(214.2)	(219.7)
HH head with post-secondary education	732.9**	685.5**	608.6**	597.0**	723.8**	652.8**	634.9**	610.6**
	(300.9)	(304.7)	(299.1)	(303.3)	(297.1)	(303.3)	(292.3)	(299.8)
Provincial dummies								
Manicaland (reference)								
Mashonaland Central	854.1***		913.0***		673.4***		746.2***	
	(138.8)		(143.1)		(151.4)		(154.0)	
Midlands	714.5***		835.0***		880.8***		1,025.1***	
	(129.4)		(135.7)		(146.5)		(152.1)	
LFSP district		-53.1		-52.3		-32.5		0.6
		(107.0)		(107.3)		(115.2)		(115.7)
Interactions								
Pfumvudza* female-headed					-427.4	-578.7	-578.6*	-713.0**

with no male adults members								
					(350.8)	(352.9)	(348.4)	(354.7)
Pfumvudza* female-headed with male adults members					132.6	218.5	-53.8	74.6
					(347.2)	(355.2)	(344.1)	(353.2)
Pfumvudza* log of distance to field					-606.3*	-641.3**	-458.9	-514.4
					(312.8)	(320.5)	(310.3)	(320.1)
Pfumvudza* waterlogging a major problem					43.2	-833.3***	-119.4	-899.1***
					(316.0)	(281.8)	(313.8)	(285.4)
Pfumvudza* water logging not a major problem					1,540.7***	668.3**	1,608.7***	784.3**
					(355.3)	(332.7)	(353.4)	(336.6)
Pfumvudza*index of Pfumvudza					-81.7	121.5		
					(124.5)	(123.7)		
Pfumvudza*correct spacing							-816.8	-1,030.0*
							(564.4)	(583.3)
Pfumvudza*basal fertilizer							-542.1**	-298.9
							(261.5)	(265.6)
Pfumvudza*lime							783.9**	1,235.5***
							(374.6)	(369.9)
Pfumvudza*mulching							1,006.3***	941.6***
							(270.7)	(269.1)
Pfumvudza*thinning							-161.8	76.8
							(260.5)	(266.0)
Pfumvudza*top fertilizer							601.0**	441.5*
							(260.3)	(255.7)
Pfumvudza*Mashonaland					1,354.1***		1,638.0***	
					(355.9)		(374.1)	
Pfumvudza*Midland					-728.4**		-501.3	
					(296.2)		(310.0)	
Pfumvudza*LFSP district						-30.6		-54.1
						(298.8)		(298.3)
Constant	955.5***	1,812.7***	707.9**	1,681.6***	986.2***	1,786.1***	641.7**	1,575.9***
	(308.3)	(302.0)	(311.4)	(302.3)	(310.3)	(303.4)	(311.2)	(302.9)

Observations	1,884	1,884	1,884	1,884	1,884	1,884	1,884	1,884
Adjusted R-squared	0.263	0.245	0.277	0.257	0.284	0.253	0.312	0.276

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table A- 3. Impact of Pfumvudza on maize productivity – Inverse Probability Weighting Regression (IPWR)

	(1)	(2)
ATET	1,418.3***	1,405.2***
	(250.0)	(251.7)
Predicated mean yield (Non-Pfumvudza field)	2,765.6***	2,778.7***
	(199.1)	(200.0)
Yield mean effect (Non-Pfumvudza field)		
Field characteristics		
No water logging (reference)		
Waterlogging a major issue (=1)	-771.6***	-764.3***
	(129.2)	(110.7)
Waterlogging but not a major problem (=1)	30.9	13.8
	(146.7)	(154.2)
Log distance to field (km)	-300.9***	-352.9***
	(104.9)	(107.9)
Number of Pfumvudza plots	172.3*	225.6**
	(96.5)	(98.2)
Beneficiary of Pfumvudza package	393.5***	237.2**
	(121.4)	(117.4)
Pfumvudza practices		
Pfumvudza recommended planting spacing (=1)	1,106.3***	997.9***
	(135.9)	(130.8)
Applied basal fertilizer on time (=1)	429.6***	408.7***
	(118.0)	(118.8)
Used lime (=1)	-426.1**	-271.0
	(168.0)	(173.3)
Mulching (=1)	-287.4**	-448.9***
	(144.3)	(143.3)
Thinning (=1)	345.7**	305.2*
	(152.1)	(161.3)
Applied top fertilizer on time (=1)	198.8*	75.9
	(105.5)	(108.5)
Household characteristics		
Household head headship		
Male headed households (reference)		
Female head with no male adults in HH (=1)	146.8	42.3
	(152.6)	(155.9)
Female head with male adults in HH (=1)	372.0*	417.8**
	(203.1)	(211.2)
Adult equivalent	18.1	33.8
	(33.0)	(34.9)
Education level of HH head		
No education (reference)		
HH Head with primary education	244.2	183.0
	(209.6)	(217.0)
HH head with Form 1 to 4 education	241.9	230.4
	(208.1)	(217.3)
HH head with post-secondary education	371.2	407.0
	(260.2)	(268.2)
Provincial dummies		
Manicaland (reference)		
Mashonaland Central	695.1***	
	(131.8)	
Midlands	909.1***	

	(156.5)	
LFSP District		9.0
		(118.1)
Number of Pfumvudza fields		
Constant	189.5	1,011.4***
	(303.7)	(288.9)
Yield mean effect (Pfumvudza field)		
Field characteristics		
No water logging (reference)		
Waterlogging a major issue (=1)	-679.3*	-1,558.3***
	(364.6)	(320.1)
Waterlogging but not a major problem (=1)	1,421.0***	514.1
	(493.0)	(465.2)
Log distance to field (km)	-750.4**	-838.4**
	(332.5)	(362.7)
Number of Pfumvudza plots	-238.0**	-131.7
	(121.1)	(118.7)
Beneficiary of Pfumvudza package	1,652.9***	1,284.6***
	(438.7)	(404.2)
Index of Pfumvudza practices		
Pfumvudza recommended planting spacing (=1)	48.3	-239.6
	(861.3)	(909.0)
Applied basal fertilizer on time (=1)	-182.2	39.3
	(329.5)	(344.9)
Used lime (=1)	123.0	865.0*
	(465.1)	(453.3)
Mulching (=1)	528.2	280.6
	(323.7)	(331.1)
Thinning (=1)	228.9	433.3
	(307.1)	(322.4)
Applied top fertilizer on time (=1)	836.1**	584.2*
	(335.1)	(311.2)
Household characteristics		
Household head headship		
Male headed households (reference)	-144.7	-508.6
Female head with no male adults in HH (=1)	(407.6)	(403.8)
	263.8	442.5
Female head with male adults in HH (=1)	(420.4)	(445.2)
	161.0*	117.7
Adult equivalent	(93.5)	(101.0)
Education level of HH head		
No education (reference)	-262.8	-447.0
HH Head with primary education	(696.3)	(647.0)
	326.8	205.9
HH head with Form 1 to 4 education	(713.5)	(675.1)
	2,706.2**	2,389.7**
HH head with post-secondary education	(1,084.1)	(1,054.5)
Provincial dummies		
Manicaland (reference)		
Mashonaland Central	2,522.9***	
	(508.7)	
Midlands	298.4	
	(397.5)	

LFSP District		-6.1
		(441.1)
Constant	994.0	2,969.3**
	(1,338.6)	(1,177.8)
Treatment mean effect (Pfumvudza field)		
Distance to maize field	-0.1***	-0.1***
	(0.0)	(0.0)
Field in a wetland area	0.1	0.1
	(0.1)	(0.1)
Field prone to soil erosion and/or flash flooding	0.1	0.1
	(0.1)	(0.1)
Constant	-0.6***	-0.6***
	(0.1)	(0.1)
Total number of observations	1,884	1,884
Number of non-Pfumvudza fields	1502	1502
Number of Pfumvudza fields	382	382

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1