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RESEARCH ARTICLE

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Determinants of sorghum adoption and land allocation intensity in the smallholder sector of semi-arid Zimbabwe

Joseph P. Musara[1,2], Lovemore Musemwa[1], Munyaradzi Mutenje[3], Abbyssinia Mushunje[4] and Charles Pfukwa[5]

[1]Bindura University of Science Education, Dept. Agricultural Economics, Education and Extension, P. Bag 1020, Bindura, Zimbabwe. [2]Women's University in Africa, Dept. Agribusiness Management, P.O. Box GD 32, Greendale, Harare, Zimbabwe. [3]CIMMYT, Southern Africa Regional Office, P.O Box MP 154, Mount Pleasant, Harare, Zimbabwe. [4]University of Fort Hare, Dept. Agricultural Economics, P. Bag X1314, Alice 5700, Republic of South Africa. [5]Bindura University of Science Education, Faculty of Social Sciences and Humanities, P. Bag 1020, Bindura, Zimbabwe.

Abstract

Sorghum is important for sustainability of smallholder farmers' subsistence, social and economic livelihoods in semi-arid and arid environments of Southern Africa. However, production of the crop has been on the decline in the smallholder communities of semi-arid Zimbabwe. The study examines factors affecting smallholder farmers' inclination towards producing sorghum and allocating differential land proportions towards the crop. The paper uses a double hurdle estimation approach with cross-sectional survey data from 380 small holder sorghum farmers in the Mid Zambezi region. Frequency of contact with relatives, duration of receiving subsidies and the number of groups to which household members belonged had a robust influence (p<0.01) on the adoption decision. Market frequency, availability of storage facilities and the number of buyers in the market significantly (p<0.01) influenced the land allocation decision. Variables influencing the two decisions are not necessarily the same showing independence in the decisions. However, information flow from networks and conditions of market platforms remain important variables in the two decisions. It is important to decentralise sorghum markets, strengthen local networks of kinships and increase the scope of inclusive and responsive formal extension delivery systems. Storage facilities can also be developed in partnership with private players to allow for sales during market windows which generates higher returns for the small holder sorghum farmers.

Additional keywords: double hurdle; sorghum systems; smallholder farmer; semi-arid; networking.

Abbreviations used: CDF (Cumulative distribution function); FGD (Focus Group Discussion); GMB (Grain Marketing Board); LDF (Logistic Distribution Function); LZ-TFCA (Lower Zambezi Trans-Frontier Conservation Area); SADC (Southern African Development Community); VIF (Variance Inflation Factor).

Authors' contributions: Design: JPM, LM, MM. Data search: JPM, LM, MM and CP. Data analysis: JPM, MM, LM and AM. All authors conceived the experiments, read and approved the final manuscript.

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Correspondence should be addressed to Joseph P. Musara: jpmusara@gmail.com

Introduction

Agriculture remains an integral sub-sector for economic development prospects in Southern Africa (Scoones *et al*., 2011). The choice of appropriate enterprises has been identified as a key determinant that has compromised the success of agricultural value chains. Sorghum (*Sorghum bicolor* (L.) Moench) production once dominated crop mixes in arid and semi-arid areas of Africa (Taylor, 2003). In Zimbabwe, the crop was integral in strengthening local kinship networks and as a safety net for drought resilience and food and income insecurity mitigation (Mukarumbwa & Mushunje, 2010). Zimbabwe has the potential to retain its 'bread basket'[1] status in Southern Africa if appropriate enterprise choices and land allocation decisions which accommodate 'orphan crops' such as sorghum are made at all scales. In the 1990s, smallholder farmers

[1] From around 1980 to 1995, Zimbabwe was the major agricultural hub in Southern Africa. In the Southern African Development Community (SADC) arrangement, the country is tasked to sustain food security in the region due to its comparative advantage of vast arable land and a vibrant human capital base.

contributed on average 50-70% of total national agricultural throughput. These gains have however significantly been reversed in the past one and half decades due to multiple hurdles key among them weak inter and intra networks between and among value chain actors, underperforming local markets and skewed government support across crop enterprises (Cai *et al.*, 2014; Mutami, 2015).

There is evidence that the main disincentive for intensive cereal crop production is low and variable market prices especially soon after harvesting and/or in good harvest years (Sultan *et al.*, 2013). For example in Zimbabwe following the persistent effective price declines in sorghum, the area under the crop declined by 20% from 327,000 ha in the 2009/10 season to 273,000 ha in the 2010/11 season (Mujeyi, 2013). In an effort to redress this, since the 2013/14 farming season, the Grain Marketing Board (GMB) buys the grain from farmers at a favourable government supported market price of 390 US$/ton. Since the marketing of grain has been liberalised a number of private buyers also participate in the markets and they are also mandated to buy at the same price. However, due to weak marketing monitoring structures in Zimbabwe, the latter scenario rarely prevails and traders always buy at below this price. Given the higher gazetted price, if there was proper implementation of policy, this should rationally have encouraged farmers to shift towards sorghum which performs well under the climatic conditions. A realistic scenario driven by the mismatch between policy proclamation and implementation as depicted in Fig. 1 shows that the temporal price elasticity of sorghum supply has been declining as the market price increased. This further inspires the study as it seeks to explore how other variables besides the price could be included in intervention strategies to break the present paradox using experiences from small-scale farmers in the Mid Zambezi Valley of Zimbabwe.

There is scope to redress the current lack of proclivity for sorghum by small holder farmers if balanced and accommodative structural and institutional reforms are adopted and sustained (Adegbola *et al.*, 2013). In Zimbabwe, a maize (*Zea mays* L.) dominated and biased interventionist philosophy benefits from direct and indirect subsidy programs, extension systems and market liberalisation policies which are introduced through various development models (Rukuni *et al.*, 2006). Historically, sorghum was important for food, nutrition and income among most households in arid and semi-arid areas of Zimbabwe given its ability to withstand adverse weather conditions of low rainfall and high temperatures. The crop accounted for on average 40% of land after maize which took up about 50% (Mutami, 2015). Sorghum has however been sidelined from mainstream livelihood strategies and in recent years its production has declined with the crop accounting for about 15% of the total cropped land in the smallholder sector of Zimbabwe. There is therefore increased demand for new and robust strategies which encourage smallholder farmers' participation in sorghum production and increased land allocation towards the crop. Farmer organisations, government agents and private players have singly or collaboratively made efforts to facilitate this revolution but making informed enterprise choices and land allocation decisions remain a major challenge in the smallholder sector (Sarris & Morrison, 2010).

In arid and semi-arid regions of Southern Africa, cotton (*Gossypium herbaceum* L.) emerged as a major cash income source and displaced traditional cereal crops such as sorghum which were mainly produced as climate resilience and adaptation strategies

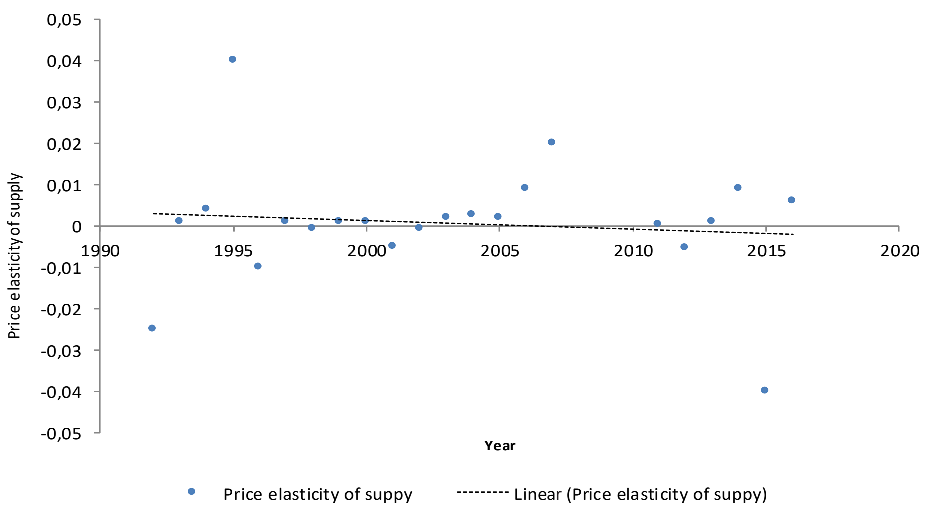

Figure 1. Annual trends in sorghum price elasticities of supply in Zimbabwe.

without much scope for generating adequate income from limited marketing channels (Masuka, 2012). The dispensation incentivised a competitive environment which encouraged private players to support cotton value chain activities. As reported by Coulibaly *et al*. (2014), the challenge is that in recent years there has been a generalised global decline in cotton prices and Zimbabwe has not been spared. This has negatively twisted the platform for farmers' dependency on the '*white gold*' and in response, the number of contractors has also dwindled and cotton is also disappearing from the production arena. There is however space for sorghum to make a comeback in the livelihood options matrix for the small holder farmers since it has potential multiple uses for food, nutrition and income (Sultan *et al*., 2013). Additionally, the crop has competitive productivity ability due to its tolerance to unfavourable climates where temperatures are high, rainfall is variable, poorly distributed and usually below average. Munyati *et al*. (2013) allude that in Zimbabwe, these positives can be blended together with the recently announced government supported price to encourage uptake and intensification of sorghum production.

In Tanzania for example, Rohrbach & Kiriwaggulu (2007) report that the commercialisation of sorghum has been made possible by vibrant seed systems and generalised affordable input price patterns. The same model has been reported by Hamukwala *et al*. (2012) to be successful in Zambia. In Zimbabwe, sorghum however continues to disappear from mainstream production decisions because *e.g*. limited varietal improvements were nurtured due to the crop's open pollinated nature which dis-incentivised seed houses from investing in research and development. Matshe (2009) also notes that biased support matrices weakened structures for most cereal enterprises with the exception of maize which remains a supported '*strategic*'[2] crop, justified by the food security argument. In Zimbabwe, government support is almost exclusively channelled towards maize while private players offer contracts for inputs, extension and a guaranteed market to the so called '*cash crop*' farmers thereby leaving sorghum farmers to fend for themselves in both input and output markets (Mujeyi, 2013). In a study by Musara *et al*. (2018) there is evidence that in the Mid Zambezi Valley of Zimbabwe, there are limited marketing channels for small scale sorghum farmers with only about 20% of the produce sold and the rest consumed in the household.

Given the persistent low uptake of sorghum by small scale farmers in Zimbabwe, the main question is whether there is scope for shifting the livelihood lens towards sorghum production and increased land allocation towards the crop through breaking the fundamental barriers of networking arrangements, access to subsidy programs and variable market conditions. This study seeks to explore the determinants that jointly affect decisions for sorghum production and enhanced allocation of land towards the crop in arid and semi-arid areas in efforts to design strategies for possible re-embracing of the crop. This study also aims to add to the adoption and land allocation decisions knowledge base by exploring the interlinked effect of the aforementioned factors.

Methods

Description of study area

The study was conducted in the Mid-Zambezi Valley of Zimbabwe which stretches along Kanyemba at the Zambezi River in the North to the Muzengezi River near Mahuwe in the East. Specifically, Mbire district (Fig. 2), which is located in Mashonaland Central Province and the youngest district in Zimbabwe with 17 administrative wards was selected for the study. The district has a population of 82.380 inhabitants and a density of 17.54/km^2 which is increasing at an average of 1.09/year. There is a balanced composition of males and females in the area with a 50% representation in the active 15-64 years category. Mbire district is located at -16°09'32" S and 30°34'21" E. The area lies at an average elevation of 373 m and is semi-arid receiving below average and erratic rainfall coupled with high temperatures.

Temperatures in the area average 30^{o}C with annual rainfall ranging from 350 to 550 mm. Water scarcity is experienced in the long dry season from April to October. Availability of water improves in the wet season stretching from November to March. Despite poor soils, erratic rainfall and crop destruction by wildlife, households in the Mid Zambezi Valley still depend on agriculture for subsistence and cash income. Cotton dominates livelihood options alongside sorghum and soyabean (*Glycine max* (L.) Merr). Livestock rearing is also practiced in the area mainly with goats and cattle. The region is a blend of Korekore, Chikunda, Doma and immigrant Karanga ethnic communities. Doma communities are nomadic hunters and Karanga accumulate cattle and use modern agricultural technologies (Baudron *et al*., 2012). These cultural dimensions can have a significant influence on multiple crop production decisions by the households.

[2] In Zimbabwe, maize is the staple crop across all geo-political spaces and scale and therefore accounts for the greater component of the total arable land.

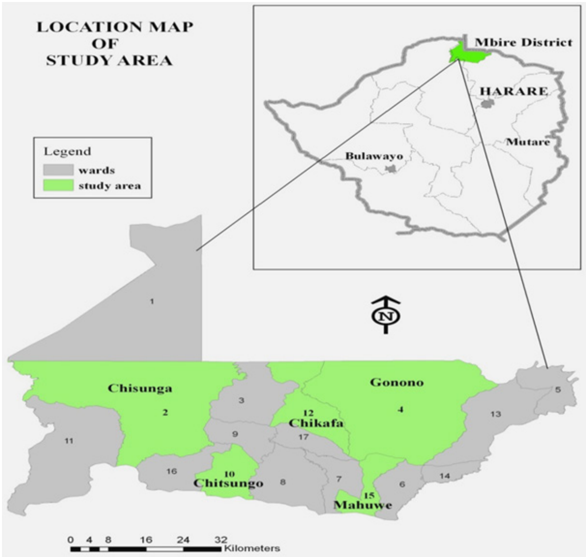

Figure 2. Location of the study area (Zimbabwe).

Data collection procedures

The area was selected purposively as it is a major sorghum producing zone in the Lower Zambezi Trans-Frontier Conservation Area (LZ-TFCA). The population was made up of small scale farming households. Five Wards namely Chisunga (Angwa), Mahuwe, Gonono, Chikafa and Chitsungo were purposively selected. The first four are dominant sorghum producing areas. Gonono and Chikafa are close to the border with Mozambique and their inclusion offers an opportunity to understand decisions in communities with mixed cultures and relations. Mahuwe is centrally located while Chisunga (Angwa) is at the periphery of the Mid Zambezi Region. Chitsungo is a unique Ward were sorghum production is minimal. This inspired its inclusion in the sample so as to understand the hurdles faced by potential sorghum farmers who can benefit from networking with others in dominant sorghum producing wards. Three hundred and eighty farmers were proportionately[3] selected at random from the Wards in April 2016. Data on networks, subsidy access and market conditions were collected using a structured questionnaire and triangulation was done using Focus Group Discussions (FGDs) and key informant interviews.

Conceptualising constrained sorghum production and land allocation decisions

The study is guided by the neo-classical economic theory and aims to isolate the determinants of household sorghum uptake and enhanced land allocation towards the crop in arid and semi-arid areas of Zimbabwe. We define and measure the adoption status of a farmer as a dummy representing whether or not the farmer produced sorghum during the period under review. The intensity of land allocation was measured as the percentage of total cropped land allocated towards sorghum during the season. The study concurs with Ortmann & King (2007) that smallholder farming communities of Southern Africa are characterised by information gaps, weak and biased support and market imperfections. These factors manifest in risky environments in which farmers operate thereby presenting pressure on resource allocation decisions (Di Falco & Bulte, 2013). This is especially so when the primary factor, land is itself also limiting. In similar studies, different forms of the rationality based expected utility model have been used to explain the processes of crop choices as influenced by the utility maximisation rationale subject to a number of constraints (Kreitler *et al*., 2014). Given that in smallholder farming communities of Zimbabwe, household decision making is multi-faceted, centralised and mainly subsistence oriented, this entails simultaneously making decisions regarding whether to produce and the scale of production. The study therefore conceptualises sorghum adoption and the associated land allocation decisions towards the crop within the random utility framework Ragasa (2012) and Kreitler *et al*. (2014) with multiple covariates induced by networking, access to subsidies and variability in market parameters. The rationality assumption that unconstrained households in arid and semi-arid farming zones decide to adopt and allocate

[3] There was variability in farmer populations across the wards and representative proportions were selected from each ward.

more land towards sorghum is herein made. In the guiding framework presented in Fig. 3, assuming that the adoption of sorghum in land allocation decisions generates utility, then proclivity for the enterprise may be directly derived from the demand function.

Farmers in arid and semi-arid regions of Zimbabwe may have positive desired demand for sorghum production and increased land allocation towards the crop but may be constrained in one way or the other (Oduol & Mithöfer, 2014; Maina *et al*., 2015; Shiferaw *et al*., 2015). The study formalizes the theoretical production model based on the demand function and as guided by Hassan *et al*. (2016) assumes that rationally, a household (*h*) will likely take up sorghum if the expected utility for the positive state (U_{h1}) is greater than for the negative state (U_{h0}). We let the difference between these utility states be denoted by A^d. Because these utilities are not observable, they can therefore be estimated as a dummy function of observable elements denoted by A^{d*} and expressed as:

$$A^{d*} = \beta Z_h + \mu_h \quad (1)$$

where A^{d*}= binary latent indicator variable of the adoption and enhanced land allocation states, Z_h=a vector of exogenous variables, β = the parameter vector to be estimated, and μ = the stochastic error term assumed to be normally distributed.

The farmer's demand which we hypothesise to influence the positive decision is therefore summarised as:

$$A^d{}_h = \begin{cases} 1 & if\ E(U_{h1} - U_{h0}) \geq 0 \Leftrightarrow \beta Z_h \geq -\mu_h \\ 0 & if\ E(U_{h1} - U_{h0}) < 0 \Leftrightarrow \beta Z_h < -\mu_h \end{cases} \quad (2)$$

where $A^d{}_h$ = binary observed indicator variable.

Equation (2) stipulates the conditional acceptance or rejection decision based on the utility variations for the two possible positive (1) and negative (0) states.

Networking also allows decision making units to evaluate land allocation options and objectively assess the relative expected net gains. If the decision maker's information level from networking with friends, relatives and other extension agents is greater than the threshold level needed to make choices, then they can be considered to be at least aware of the practice (Aldana *et al*., 2011). Additionally, with smallholder farmers, access to subsidies and market inconsistency hurdles such as prices and distance to the market may also affect their effective decision making regardless of access to information about the innovation (Brown & Kshirsagar, 2015). As such, we are cautious to note that a small scale farmer with positive desired demand may not necessarily allocate land towards sorghum due to either or all of the aforementioned determinants. Sorghum

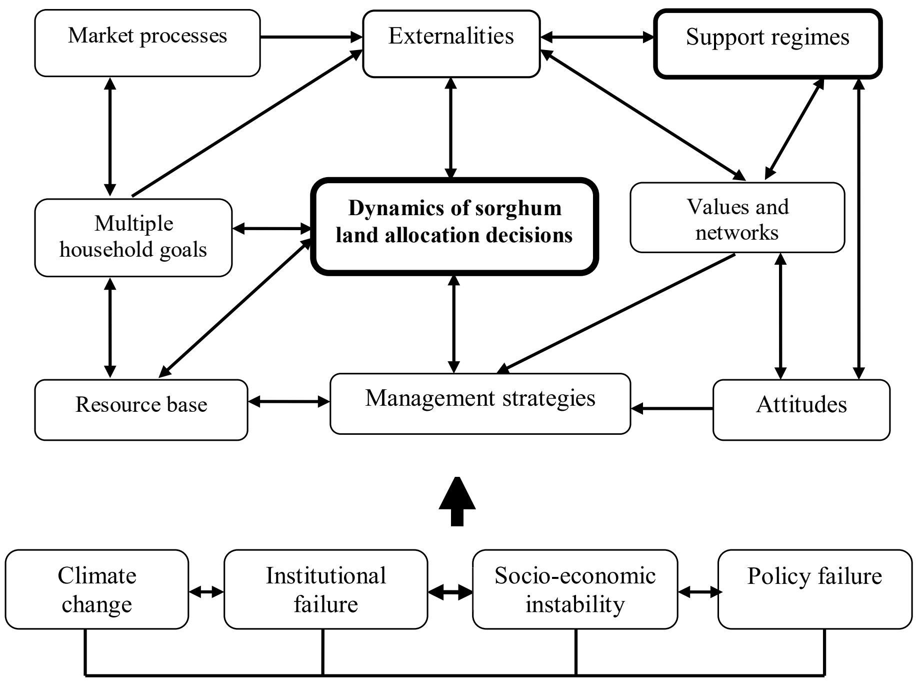

Figure 3. Conceptual framework for dynamics of sorghum production and associated land allocation. *Source:* Adapted from Tefera *et al.* (2012), Di Falco & Bulte (2013) and Shiferaw *et al.* (2015).

production and enhanced land allocation can only take place when a number of factors as presented above are simultaneously satisfied (Shiferaw *et al.*, 2015). Observing a state of land allocation towards sorghum occurs when specific thresholds in the farmer's decision making process have been passed. Literature and observations in the study area guided the choice of variables which were included in the models as in Table 1.

Empirical model for estimating sorghum adoption and associated land allocation decisions

Adoption studies have been dominated by binary regression modelling such as probit, tobit and logit. The underlying assumption of these models is that farmers have full information regarding the innovation and are not resource constrained (Amare *et al.*, 2012). This is not true for smallholder farmers in Zimbabwe

Table 1. Variables list and associated descriptive statistics.

	Variable	Variable description	Units	Summary statistics	
				Mean	St. Dev.
Dependent variables					
Production		Whether a farmer produced sorghum during the season (yes=1, 0 otherwise)	dummy	0.382	0.486
Intensity		Percentage of total cropped land allocated to sorghum in hectares	number	26.084	36.209
Independent variables					
Networks	extfreq	Frequency of contact with extension agents per month during the season	number	7.550	2.140
	lclrel	Number of relatives who reside in the respondent's village	number	2.761	2.958
	extrel	Number of relatives who reside outside the respondent's village	number	1.621	2.491
	ethnic	Whether household is originally from Ward (yes=1, 0 otherwise)	dummy	0.663	0.473
	freqloc	Frequency of contact with local relatives in a month	number	45.35	77.51
	freqext	Frequency of contact with external relatives in a month	number	7.402	23.091
	ngroup	Number of groups to which household members belong	number	1.295	1.203
Aid	infoaid	Number of information sources about aid	number	2.000	0.477
	aidbenfcr	Number of household members who are aid beneficiaries	number	2.303	1.254
	numaidsc	Number of aid sources household members are aware of	number	1.034	0.769
	durtnaid	Number of years household members have been receiving aid	number	2.152	2.638
	aidvalue	Total market value of aid accessed during the season	US$	8.60	19.41
Markets	mktdist	Average walking distance to the main market	minutes	76.51	46.55
	transcst	Costs of transporting produce to the market	US$	29.81	48.95
	mktfreq	Frequency of using the main market during the season	number	23.068	12.516
	pymntspd	Time taken for payment to sail through after a sale has been made	months	1.855	1.064
	numbuy	Number of buyers farmer directly interacts with in main market	number	0.487	0.683
	weightprc	Average weighted market price during previous season	US$/kg	24.06	10.22
	mktinfo	Number of information sources about markets	number	3.000	0.512
Demographic	age	Age of the household head	years	44.73	14.64
	orientation	Proportion of sorghum output consumed by the household	percent	65.32	9.142
	cropdiv	Crop diversity	number	4.00	0.124
	livediv	Livestock diversity	number	3.00	0.356
	gender	Gender of household head (male =1, 0 otherwise)	dummy	0.739	0.439
	hhldsze	Number of household members residing at the homestead during the season	number	8.389	4.957
	experience	Number of farmer's years in farming	number	15.49	10.04
	income	Total household income from farm and non-farm activities	US$	356.82	209.31
	arbland	Total amount of arable land owned by the household	hectare	4.31	1.16
	storage	Number of storage facilities owned by the farmer	number	2.000	0.275

Source: Generated by authors from 2016 sorghum survey data using STATA.

where input supply systems are poorly developed, extension delivery is not responsive to the demands of advancements in agribusiness, markets are inefficient and networks are weak or absent. Farmers must overcome a number of these hurdles before deciding on whether or not to produce sorghum, and allocate more land towards the crop. Using composite probit, tobit or logit in isolation will most likely generate inconsistent parameter estimates if applied in these contexts. To cater for the two hurdles of adoption and intensity of adoption we estimate a double hurdle model with two equations (Burke *et al*., 2015). A probit model is used for the dichotomous adoption decision because of its post estimation convenience since the distribution is assumed to be approximately normal. Probit also uses a cumulative distribution function (CDF) which captures more detail. Using logit would assume a logistic distribution function (LDF). We however accept that the outcomes of the predicted probabilities for these two maximum likelihood estimation approaches are similar. A censored tobit model is then applied to the second hurdle of land allocation intensity.

For any farmer, *i*, the unobserved (latent) demand D^*), is modelled as:

$$D_i^* = \beta' X_i + \mu_i \tag{3}$$

where X = the vector which captures determinants of the demand function, β= the parameter vector, and μ= a normal variate with mean 0 and variance σ_μ.

Following this argument, the observed demand can therefore be computed as an index function:

$$D_i = \begin{cases} 1 & if\ D_i^* > 0 \\ 0 & if\ D_i^* \leq 0 \end{cases} \tag{4}$$

The farmer will only demand the sorghum enterprise if the utility from the positive mode (U_{d1}) outweighs that of the negative condition (U_{d0}).

$$P(D_1) = \Pr(U_{d1} > U_{d0}) \tag{5}$$

We then manipulated the condition presented in equation (5) without loss of generality by allowing the variance (σ^2) of the error term to be unrestricted, and have a conditional probability given a set of covariates:

$$\Pr(D_i^* > 0 \mid X_i) = \Pr(D_i = 1 \mid X_i) = \Pr(\mu_i > \beta' X_i) = \\ = \Pr(\frac{\mu_i}{\sigma} > \frac{-\beta' X_i}{\sigma}) = \Phi(\frac{-\beta' X_i}{\sigma}) \tag{6}$$

The latent (unobserved) variable is also called the index which is related to the error term in that for there to be observed probability for a farmer to demand sorghum, then the error term should be large enough to produce an index greater than one. Since maximum likelihood estimators are probabilistic and starting again with the adoption decision and making inference to intensity of adoption, we used the log-likelihood function as:

$$L(\beta \mid d) = \prod_i [\Phi(\beta' X_i)]^{d_i} [1 - \Phi(\beta' X_i)]^{(1-d_i)} \tag{7}$$

The latent variables underlying a farmer's decision to produce and intensify sorghum production are then modelled as in (8) and (9) respectively:

Hurdle One (Adoption decision):

$$A_i^* = \theta' z_i + \varphi_i \tag{8}$$

To untangle the effects of the first hurdle of deciding whether or not to produce sorghum (A_i^*) that is the adoption decision, the study uses a probit model. It has been shown that the parameter estimates for a probit and logit could differ quite a lot between the models, but the marginal effects are very similar. As such the former is selected for convenience and preference.

Hurdle Two (Enhanced land allocation decision):

$$I_i^* = \alpha' g_i + \omega_i \tag{9}$$

Following Shiferaw *et al*. (2015)'s argument on effectiveness of tobit in censored datasets, we confidently used a censored tobit model to explain the behaviour of the intensity variable I_i^* as the second hurdle in the decision making process.

From equations (8) and (9): z and g are vectors of variables that affect adoption and intensity of adoption decisions respectively; θ and α are the corresponding parameter vectors; and ø and ω are normally distributed random variates with mean 0 and variance 1.

The latent variable models presented above show the reality encountered in practice that farmers' preferences cannot be observed. The observed demand (D_i) is characterised by the interaction of equations (8) and (9). In various forms of the hurdle framework, there is consensus that it is not worthwhile to assume dependency between the two equation clusters (Burke *et al*., 2015; Shiferaw *et al*., 2015). Literature shows that there is no statistical justification which exists to assume such relationships and this creates a basis for assuming that sorghum production and enhanced land allocation hurdle equations are mutually exclusive[4].

[4] Results for the two models also validate this assumption since determinants of the adoption decision are not necessarily the same as for the land allocation decision.

To test for potential collinearity in the independent variables, we subjected them to a Variance Inflation Factor (VIF) test (Murray *et al*., 2012).

Results and discussion

A descriptive presentation of production status can be found in Table 2 and distribution summaries of major sorghum varieties grown are in Table 3. Gonono has the largest number (81%) of sorghum producers while Chitsungo has the least (14%). The main variety grown across all the five Wards is 'Silla' followed by 'Macia'. The other three are '*emerging varieties*'[5] and are still to be widely accepted by the communities. Results of the probit regression for the adoption hurdle and a truncated tobit regression for the intensity hurdle are in Table 4. All the VIF values for the exogenous variables included in the model are less than 10 and ranged from 1.11 to 3.85 with a mean of 1.60 showing absence of collinearity.

The number of groups to which family members subscribe have significant influence on the sorghum production decision. This can be attributed to information diversity and sharing practices in various group platforms beyond the family structures. Family members will then aggregate and digest this information to make more informed and unbiased decisions on the most appropriate enterprise. This is in agreement with Langyintuo & Mekuria (2008) and McMichael & Shipworth (2013) who also observed positive neighbourhood effects on adoption decisions. This approach significantly reduces tranaaction costs of searching for information.

Payment period also significantly affects sorghum adoption decisions. During FGDs it was noted that longer time lags between a transaction and a payment discourage production. Since these small scale farmers heavily depend on agriculture for livelihood and have limited income sources, the incentive of instant payments can trigger increased sorghum production. Musara *et al*. (2018) also reported the negative relationship between payment time and the decision to market sorghum in semi-arid Zimbabwe.

Information about subsidy sources and the duration household members have been receiving subsidies exhibited positive and significant relationships with sorghum production. Deliberations during FGDs and key informant interviews indicated that reduced costs incentivise adoption of supported enterprises since farmers enjoy convenient and timely production, higher yields and favourable marketing margins. In Mali, Coulibaly *et al*. (2014) also reported increased production participation and perfomance by sorghum farmers who had access to complete subsidy packages. The subsidies grease the input acquisition process and may also be extended to output markets where depots are brought closer to farmers so as to reduce transport costs.

Table 2. Household sorghum production status across sampled wards.

Ward[a]	Sample size	Sorghum growers (%)	Sorghum non-growers (%)
Angwa (2)	80	34	66
Chikafa (12)	70	30	70
Chitsungo (10)	50	14	86
Gonono (4)	79	81	19
Mahuwe (15)	101	26	74
Total sample	**380**		

[a] Ward number in parenthesis. *Source:* Field survey 2016.

Table 3. Major varieties grown by households in the sampled wards.

Ward[a]	Variety and associated respondents (%)				
	'Chibuku'	'Kandevha'	'Kanzvonzvo'	'Macia'	'Silla'
Angwa (2)	11	15	7	48	19
Chikafa (12)	5	13	10	24	48
Chitsungo (10)	0	14	43	14	29
Gonono (4)	5	8	6	33	48
Mahuwe (15)	4	8	3	35	50
Total sample	**6**	**10**	**8**	**34**	**42**

[a] Ward number in parenthesis. *Source:* Field survey 2016.

[5] Given the limitation of seed access from the formal markets, farmers have developed their own seed varieties over time from cross pollination of existing varieties.

Table 4. Estimation of double-hurdle model. Standard error for each estimate is placed in parenthesis.

Variable	1st hurdle (Adoption) *Dependent variable: Farmer's status in production of sorghum*		2nd hurdle (Adoption intensity) *Dependent variable: Farmer's intensity of sorghum production*	
	Coefficient	***p*-value**	**Coefficient**	***p*-value**
Network attributes				
extfreq	2.042*** (0.647)	0.007	1.971** (0.857)	0.021
lclrel	-0.198 (0.197)	0.316	-2.302*** (0.763)	0.003
freqloc	-0.238* (0.105)	0.065	-0.142** (0.021)	0.042
ethnic	1.546 (1.402)	0.270	9.597* (5.464)	0.079
extrel	0-.371 (0.271)	0.171	-0.478 (1.083)	0.659
freqext	0.016 (0.015)	0.274	0.318** (0.165)	0.050
ngroup	1.638** (0.767)	0.033	2.448 (2.148)	0.254
Aid attributes				
infoaid	1.656* (0.892)	0.064	2.776 (3.833)	0.469
aidbenfcr	0.376 (0.261)	0.150	2.784* (1.479)	0.060
numaidsc	0.664 (0.532)	0.212	5.633** (2.550)	0.027
durtnaid	2.998*** (0.985)	0.002	1.766 (1.128)	0.117
aidvalue	0.061 (0.014)	0.968	0.112* (0.104)	0.061
Market attributes				
mktdist	-0.19*** (0.0123)	0.006	-0.074** (0.063)	0.027
transcst	-0.18* (0.016)	0.059	0.069 (0.072)	0.332
mktfreq	0.199** (0.047)	0.035	0.466*** (0.153)	0.002
pymntspd	-0.122** (0.295)	0.044	-2.074 (1.787)	0.246
numbuy	0.572 (0.543)	0.292	13.85*** (3.811)	0.0003
mktinfo	1.807 (1.235)	0.143	2.069 (6.436)	0.159
weightprc	0.27 (0.029)	0.139	0.213*** (0.186)	0.009
Demographic attributes				
age	-0.108*** (0.043)	0.008	0.042 (0.143)	0.771
gender	0.513 (0.718)	0.475	-2.233 (4.355)	0.608
hhldsze	-0.362** (0.185)	0.047	1.074 (0.838)	0.199
experience	0.103** (0.038)	0.033	0.414* (0.239)	0.084
income	0.138 (0.029)	0.522	0.146** (0.01)	0.022
arbland	0.453 (0.306)	0.139	0.237** (1.799)	0.048
storage	0.698 (0.225)	0.334	1.176*** (0.839)	0.001

***; ** and * indicate *p*-values significant at 1%, 5% and 10% levels respectively. *Source:* Generated by authors from 2016 sorghum survey data using STATA.

The estimated coefficient of household size was negative and significant at the 5% level. With labour intensive agricultural production systems, larger household sizes would be favourable since they imply more labour available and hence higher chances of adoption. Sorghum does not necessarily follow the same trends since most agronomic processes do not require much labour. Additionally, sorghum yield levels are low and cannot be an incentive enough for the large households. This conflicts with Josephson *et al*. (2014) who reported limitation in livelihood options with large households as one prime driver of extreme and continuous poverty in arid rural areas thus demanding production of drought tolerant crops such as sorghum.

Farmer's age had the expected negative and significant influence on the chances of sorghum production at the 1% level. This concurs with Manda *et al*. (2016) who highlighted that with increase in age, farmers tend to shun some crop enterprises for less risky cropping systems which have lower transaction costs and favourable support. In the present case sorghum has no reliable markets and is vulnerable to pests such as qualea birds which need constant monitoring thus increasing the chances of crop failure. Additionally, FGDs deliberations indicated that processing sorghum grain can also be a challenge in these economically constrained environments thus exerting additional burden on the elderly. Mafuru *et al*. (2007) weigh in and argue that being older creates an experience based conservative feeling which can stall adoption.

The second hurdle model shows that once farmers have decided to produce sorghum, different factors influence their decision to allocate more land towards the crop. As the number of aid sources and aid beneficiaries in the household increase, chances of allocating more land towards sorghum also increase due to the higher value of accessed aid packages. This tallies with observations by Ricker-Gilbert *et al*. (2011) and Mabiso *et al*. (2014) who reported that well targeted aid programs can be useful for expansion in agricultural activities in resource constrained environments such as semi-arid areas of Zimbabwe. During FGDs and key informant interviews, stakeholders were of the perspective that appropriate subsidies open avenues for commercial and market driven agribusiness. Shiferaw *et al*. (2015) however suggest that subsidy programs can induce market imperfections and therefore need to be correctly structured and monitored. The same can be said for the current study were policy implimentation still remains weak.

As expected, the number of buyers with whom the farmer interacts has a positive and significant estimated coefficient. The variable is an indicator of the efficient functioning of markets and as such is expected to significantly affect the decisions by farmers to intensify sorghum production. Higher numbers of buyers usually imply lower chances of price related risks and other forms of administrative exploitation for the farmers. Tefera *et al*. (2012) also report the sensitivity of farmers' selection of sorghum to the relative market inefficiency caused government policy which created barriers to entry for private players.

Weighted average market price had the expected positive and significant influence on the land allocation decision. Surprisingly the variable did not significantly influence the adoption decision. Given the limited market channels available for the farmers, they are more of price takers with very little bargaining power (Musara *et al*., 2018). The traders pay them on average 240 US$/ton against the gazzetted government price of 390 US$/ton. As such, the farmers do not necessarily consider the prevailing market prices when making the adoption decision. However, on the other hand, based on the opportunity cost principle, the variable has widely been reported to significantly affect the decisions by farmers as to whether they should allocate more land towards a given crop or not. Higher producer prices usually imply higher margins which are favourable performance indicators to farmers (Coulibaly *et al*., 2014).

Total household income had the expected positive and significant effect on the intensity of land allocation towards sorghum. On average, well-to-do farmers are more likely to access inputs and penetrate rewarding markets (Maina *et al*., 2015). From FGDs, it was noted that the reinforcing effect, where allocating more land towards sorghum increases the income gains, and in turn also increasing the likelihood of further increases in land allocated towards the crop prevails. The same arguments can also be made for the landholding variable which has a positive and significant effect on the land allocation decision.

Postharvest handling accounts for over 60% of the losses experienced by smallholder sorghum farmers (Mukarumbwa & Mushunje, 2010). The adequacy of storage facilities has a positive and significant estimated coefficient. This implies that as storage becomes a limiting factor, chances of increased land allocation towards sorghum are also reduced. FGDs deliberations showed that farmers become more concerned with the higher losses which will be incurred if the output levels from sorghum increase beyond the holding capacity of the storage facilities at their disposals.

Frequency of contacts with relatives in the locality has negative and significant estimated coefficient. The more farmers are exposed to localized networks, the less likely they are to produce sorghum and allocate more land towards the crop. Kinship networks have however been reported by Bale *et al*. (2013) to have a positive effect on technology adoption decisions. The same observation was made by Di Falco & Bulte (2013) in their study on adoption of risk mitigating strategies. However, discussions during FGDs show that the reverse scenario may be attributed to the negatively oriented conservative tendencies that diffuse within relatives and friends with respect to the benefits of sorghum production. These negative perceptions are perpetually reinforced in family structures thereby reducing the likelihood of sorghum production. Musara *et al*. (2018) also reports that the decision to market surplus sorghum is negatively influenced by the number of local relatives. This observation can also reinforce localised marketing tendencies reported in the same study.

Linkage to markets can catalyse rural agricultural development prospects. The frequency of visiting the market is another significant determinant of sorghum production and intensity of land allocation towards the crop. Farmers who frequent the market platforms have higher chances of capitalizing on market window opportunities as and when they arise. Escobal *et al*. (2015) notes that these farmers are usually the first to identify market opportunities and the chances of being affected by consequences of market failure are reduced. The platforms also act as additional information sources which can influence a farmer's decision.

Extension capacitates farmers with requisite skills and knowledge on sustainable production practices (Rukuni *et al*., 2006; Hassan *et al*., 2016). It avails up to date information on production practices, market prices and benefits of commercializing farming. As expected, the estimated coefficient for frequency of contact with extension agents was positive and significant. Farmers who have more interactions with the agents have a higher chance of producing and intensifying sorghum production since extension programs have accepted sorghum as an important cereal for food and income security (Kerr, 2014). This concurs with Amare *et al*. (2012), who in Tanzania observed a positive impact of extension in influencing increased uptake and utilisation of agricultural technologies.

Distance to the market negatively influenced both the adoption and intensity of land allocation decisions. Due to the time and expenses associated with travelling to the market, as the market distance increases, there are higher chances that farmers will opt not to take the risks and choose alternative enterprises. This is in agreement with Birachi *et al*. (2013). Evidence from FGDs and observations were that in most cases rewarding markets were located away from production hubs and rarely did their agents make purchases at the farm gate.

Most farmers had on average 15 years farming experience and as per prior expectations, duration in agricultural production activities has a positive and significant estimated coefficient for both models. This determinant influences the farmers' decision to produce and intensify sorghum production as rooted in their dependency on farming over long periods of time as a livelihood strategy (Rukuni *et al*., 2006). Experience in production creates the ability of farmers to obtain, process and use information relevant to commercialising sorghum production. FGDs showed that experience has tendencies of generating confidence among farmers leading to higher proclivity to venturing into sorghum as a source of food and income. The same patterns were reported by Amare *et al*. (2012) in a maize-pigeonpea intensification study in Tanzania.

Variables including proportion of sorghum output consumed, crop diversity and livestock diversity which cater for the farm type and farm orientation were included in the analysis but since they were insignificant in determining the outcome of both decisions, they were later dropped from the analysis (see Table S1 [suppl]).

In summary, using a double hurdle framework with probit and censored tobit models, the study uses cross sectional data collected in April 2016 from 380 small scale sorghum farmers in the Mid Zambezi Valley of Zimbabwe to examine determinants of sorghum production and enhanced land allocation towards the crop. Frequency of contact with local relatives, number of groups to which household members belonged, duration of receiving subsidies, age of the household head and household size had a significant influence on the adoption decision. A different set of variables including number of local relatives, ethnicity, frequency of contact with external relatives, number of subsidy sources, number of subsidy beneficiaries, market access frequency and number of buyers significantly influenced the land allocation decision. However information flow from networks and conditions of market platforms remain important variables in the two decisions. As opposed to the much held view that a rational farmer who adopts sorghum production will naturally allocate more land towards the crop, the two decision pathways are influenced by a different set of variables. This shows independence in these two decisions. For example, based on evidence from the study, for a farmer to intensify sorghum production, there has to be favourable market prices. However, the variable is not important to influence the initial adoption decision. As such, the current government effort to support sorghum through a favourable producer price must not be the entry intervention, but instead, there should be efforts to enhance the appetite for extension agents to inform farmers on sorghum best practices and the associated long term benefits of taking up the crop.

The primary barrier of access to production factors need to be broken so that farmers are placed in the proximity of input markets. There is need to develop subsidy strategies which do not only provide short-term benefits but instead capacitate the farmers in the long run. Holistic and complementary support regimes with production and marketing should be developed and sustained if farmers are to move from the current non-intensified production levels which leave little volumes for the markets. An immediate option is to provide contract arrangements for sorghum across different commodity value chain nodes so that farmers can adopt the crop, intensify and reliably supply adequate volumes to the market. Aggregately, the broader policy space should transform systems where ideologies for rural agricultural development initiatives in arid and semi-arid regions of Zimbabwe need to migrate towards re-accepting sorghum as a potential option for reducing household food security risks and potentially earn income. This must not entirely be anchored on manipulation of producer prices which are placed at the terminal end of the cycle but also providing adequate resources for the initial uptake process. This should offer multiple interfaces and options thereby generating rewards from low cost production, favourable prices and binding mutually beneficial relationships. Information is also another ingredient to success of the sorghum value chain. However, in the present case, the supported gazetted producer price needs to be universally implemented across all markets since it is not the prevailing price across all marketing channels. As such, the study recommends that there is need to strengthen local networks starting at household level and cascading to the extended family. This should facilitate generation and dissemination of up to date and acceptable information about the enterprise as well as strengthening bargaining power in markets. Naturally, this is expected to incorporate sorghum related discussions on the mainstream kinship based extension platforms and beyond. The hope is that the crop, upon being adopted and allocated a significant share of land can then be transformed into a commercial enterprise which can generate higher margins for the farmers and other stakeholders along the value chain alike. It therefore becomes important to catalyse the adoption process with sorghum by re-training extension agents hoping for the multiplier effect to spill over to increased allocation of land towards the crop. Going forward, there is need to also include and relook at more time lags with the price variable more comprehensively capture the time effect of price on the adoption and enhanced land allocation decisions.

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