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A cost function analysis of trade-offs within climate smart agriculture: does mulching save the cost of crop production among smallholder farmers in Uganda?

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Abstract

Climate-smart agriculture (CSA) is increasingly being promoted among scientists, policy makers and donors as an approach towards sustainably increasing agricultural productivity, building and increasing resilience of farming systems to climate change, and reduction of greenhouse gases. Successful implementation of CSA, however, depends on the ability to identify and quantify the trade-offs involved in its adoption. This study investigates the trade-offs involved in the adoption of mulching among smallholder farmers in Rakai district of Uganda. It specifically examines the effect of mulching on the expenditure shares of herbicides, pesticides, fertilizer, and labour. A translog cost function is estimated jointly with expenditure shares on these inputs using seemingly unrelated regression analysis. Results indicate a negative relationship between mulching and expenditure share on herbicides on one hand, and a positive relationship between mulching and expenditure share on pesticides, fertilizer, and labour on the other hand. The paper discusses the policy implications.Keywords: Mulching, demand for farm inputs, translog cost function, climate-smart agriculture, trade-offs

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1. Introduction

Increasing food security, enhancing farmers' adaptive capacity to climate risks, and contributing to greenhouse gas reduction is at the center stage of many policy debates, particularly in developing countries. Efforts to promote climate-smart agriculture are therefore intensifying (FAO, 2010, 2013; IFAD, 2012; World Bank, 2014). In the same vein, the urgency to develop and incorporate in national development plans policies that will help to strengthen resilience to climate variability is increasingly clear. However, any effort to increase the resilience of livelihoods and increase food security must essentially recognize the different actors, incentives and interactions between different provisioning demands for food, water, energy, materials and ecosystem services (Neufeldt et al. 2013). Such efforts must understand farmers and the different specific contexts in which they operate (Andersson and D'Souza, 2014).

In search for locally appropriate options to increasing resilience of farming systems and livelihoods to climate variability, trade-offs analysis has emerged as a powerful tool to assess suitability of agricultural innovations. A number of studies conducting ex-post analysis indicate that adoption of agricultural technologies can increase farm revenues and food security (Di Falco, 2014; Di Falco and Veronesi, 2013) but might also create trade-offs such as increased demand for agro-chemicals and labour (Teklewold et al. 2013). Other studies employ ex-ante analysis using a multi-dimensional trade-offs analysis (TOA-MD) approach to simulate both adoption rates and associated economic and environmental impacts for a population of farms (Antle and Stoorvogel, 2008; Antle et al. 2014; Valdivia et al. 2012; Claessens et al. 2012; Tui et al. 2014). Several others conduct multi-objective optimization (Naudin et al. 2015; Baudron et al. 2015) while a few others perform regression analysis (Jaleta et al. 2013; Teklewold et al. 2013).

In this study we contribute to the rapidly growing literature on trade-offs analysis of agricultural innovations by introducing a cost function approach to trade-offs analysis. We use this approach to quantify the trade-offs involved in the adoption of mulching. Our choice of mulching is motivated by the growing interest among scientists to understand the trade-offs around this practice (Valbuena et al. 2014; Naudin et al. 2014; Baudron et al. 2014; Jaleta et al. 2013). Mulching involves retention of crop residues on the farm and plays an important role to conserve soil moisture and reduce surface runoff hence erosion (Erenstein, 2003; Giller *et al.* 2009), provide soil organic matter and a carbon sink while increasing soil fertility (Holland, 2004), and shield the soil from direct solar radiation thereby reducing evapotranspiration (Erenstein, 2002).

Despite its benefits, mulching present potential trade-offs that need to be carefully weighed against the gains. The economic potential of mulching depends on the opportunity costs of retaining the mulch (Erenstein 2004). Evidence is mounting to indicate that mulching could negatively affect livestock productivity through reduced amount of crop residue available for feed (Valbuena et al. 2012; Baudron et al. 2014a, 2014b, Naudin et al. 2014 and Jaleta et al. 2013). Valbuena et al. (2012), for example, found that although in the high density[1] sites biomass production tends to be high enough to provide livestock feed while allowing part of the residues to be used as mulch, in both the medium and low density sites, the opportunity cost of using crop residues as mulch is very high. Similarly, using a multi-scale trade-off analysis, Baudron et al. (2014a) found an inverse relationship both at farm and territory level between residue retention for mulch and livestock numbers among farmers who keep livestock for traction. The relationship between mulching and livestock feed is further complicated by the fact that the demand for the limited resource for both purposes occur during the same period. That is, the value of residue as feed is higher during the dry season (Magnan et al. 2012) the same period when mulching is more beneficial because of the need to conserve moisture (Mkoga et al. 2010).

Several options have been recommended to address such trade-offs. Valbuena et al. (2012) recommends complementary research and development efforts to increase biomass production to alleviate the opportunity costs of leaving crop residues as mulch in sites with relatively high feed and fuel pressure. Baudron et al. (2014) suggest the need to intensify dairy production by promoting the use of rations that are more energy-dense than cereal residue-based rations. Similarly, Jaleta et al. (2013) recommend the need to reduce the use of crop residues as livestock feed through the introduction of alternative feed sources, better extension services on the use of crop residue as soil mulch and designing context-specific strategies and interventions.

Another important trade-off related to mulching, particularly the use of cereal residue, is N immobilization. Plot level results of simulation analysis indicate that although crop yield marginally increases with small amounts of mulch, use of sorghum residue without N fertilization will cause a decline in yield with additional amounts of mulch due to N immobilization (Baudron et al. 2014a). As cereals residues continue to be the single most important source of mulching material among smallholder farmers, it is imperative to balance the C:N ratio (Alvarez and Steinbach, 2009; Baudron *et al.* 2014a). Maintaining such a balance, while desirable, might imply extra costs to farmers to purchase nitrogenous mineral fertilizer. In SSA where most smallholder farmers lack effective

[1] Valbuena et al (2012) define i) high density as a site with higher pressure on resources but with high biomass production; ii) medium density as a site with relatively lower population and livestock densities but with lower biomass production and high pressure on land and feed; and iii) low density as a site with relatively low population and livestock densities and existence of communal feed and fuel resources but with low biomass production and over-reliance on crop residues to feed livestock during the long dry season.

demand for fertilizer and where knowledge on soil fertility management is still limited, failure to balance the C:N ratio might significantly lower yields.

Nevertheless, possibilities of creating synergies between mulching and livestock feeding exist. Naudin et al. (2014), for example, using optimization techniques argue that even when there is a strong biomass demand for fodder it could be more profitable to practice mulching on some fields and to purchase forage to compensate the biomass retention in the field. In their conclusion, the authors argue that mulching and livestock production can be compatible and even mutually beneficial especially when the pressure on biomass is less intense. Such synergies, however, can only be realized if mulching is complemented by other practices that increase biomass production (Naudin et al. 2014).

The appropriateness of mulching in the context of property rights has also been highlighted. In some parts of western Kenya, for example, neighbours culturally have the right to allow their livestock to feed freely on the sugarcane residues after harvesting (Sibanda et al. 2011). Similarly, burning of crop residues for hunting purposes is a common practice in northern Uganda (Mwongera et al. 2014). Under such circumstances, therefore, the use of residues for mulch might interfere with the cultural norms (Erenstein et al. 2012).

While previous studies on the use of crop residues for mulching provide useful insights, knowledge of the potential trade-offs associated with the practice is only partial. Trade-offs involve not only allocation of crop residues among competing purposes of mulching, feed and fuel but also the effect on demand for agricultural inputs. Economic analysis of trade-offs associated with mulching, therefore, remains limited. Although a few studies warn of the potential increase of expenditure on nitrogenous fertilizers with mulching (Baudron et al. 2014, Jaleta et al. 2013) demand for pesticides, herbicides, and labour has not been adequately investigated.

A few studies that examine effects on labour demand and herbicides do so within the wider concept of conservation agriculture (a package of technologies involving minimum soil disturbance, permanent soil cover, and crop rotation) and not specifically in relation to mulching. These studies indicate that conservation agriculture has the potential to save the cost of labour required for manual weeding as farmers substitute herbicides for labour. In such cases, it is argued that the demand for herbicides will increase with conservation agriculture. Affholder et al. (2009), however, found a reduction in labor productivity due to the relatively large amount of labour required for biomass collection and spreading on the soil when building up the straw mulch layer. The extra labor was not offset by a reduction in labour required by weeding (Affholder et al. 2009). Assessing the effectiveness of individual technologies that could be used to form packages is therefore important. Teklewold et al. (2013), for example, found that although conservation tillage, a major component of conservation agriculture, increases crop income the practice increases demand for pesticides and creates more work load to women.

In this study we quantify the responsiveness of the quantity demanded of herbicides, pesticides, fertilizer, and labour to mulching. The study is organized as follows. Section 2 explains the study methodology including the theoretical framework and econometric estimation. Section 4 presents the results. Section 5 concludes.

2.0 Study methodology

2.1 Theoretical framework

Consider a farmer whose objective is to produce output ($\boldsymbol{y}$) using different combinations of inputs ($\mathbf{x}$) and crop management practices ($\boldsymbol{z}$). Denote ($\boldsymbol{w}$) a vector of input prices; w_i is the price of i^{th} input for $i = 1, \dots, n$ inputs. The cost function in a translog form can be written as (Christensen 1975):

$$lnC^* = \alpha_0 + \sum_i \alpha_i \, lnw_i^* + \sum_i \beta_i \ln y_i + 0.5 \sum_i \sum_j \gamma_{ij} lnw_i^* \, lnw_j^* + 0.5 \sum_i \sum_j \delta_{ij} lny_i lny_j + \sum_i \sum_j \varphi_{ij} lnw_i^* \, lny_i + \sum_i \phi_i z_i + \mu \quad (1)$$

where C^* is cost, α_0, α_i, β_i, γ_{ij}, δ_{ij}, φ_i, and ϕ_i are unknown parameters to be estimated. The random term μ captures unobserved factors as well as measurement errors. By Young's theorem, $\gamma_{ij} = \gamma_{ji}$ and $\delta_{ij} = \delta_{ji}$. The cost function is linearly homogenous and non-decreasing in w. Satisfying the homogeneity condition requires that: $\sum\alpha_i$=1; $\sum\gamma_{ij}$=0; and $\sum\varphi_{ij}$=0. The translog function is flexible because specific features of technology such as returns to scale may be tested by examining the estimated model parameters. Constant returns to scale, for example, need not be assumed a priori but can be examined by testing that $\gamma_{ij} = 0$, $\delta_{ij} = 0$, and $\varphi_{ij} = 0$.

Shephard's lemma can be applied to Equation (1) to generate conditional factor demands, $x_i(w, y, z)$ obtained by taking the first derivative of the cost function with respect to w_i. Hence,

$$\frac{\partial lnC^*}{\partial lnw_i^*} = s_i = \frac{w_i^* x_i}{C^*} = \alpha_i + \sum_i \gamma_{ij} \, lnw_j^* + \sum_j \varphi_{ij} lny_i + \sum_i \phi_i \, z_i^* \quad (2)$$

The expenditure shares s_i add up to one, a condition which requires that $\sum_i \alpha_i = 1$, $\sum_j \gamma_{ij} = 0$, and $\sum_j \varphi_{ij} = 0$. Note that these are the same conditions implied by linear homogeneity of the cost function in input prices. Although this paper focuses on the factor demands, the following relations can be obtained for each output if an additional assumption of marginal cost pricing for the output is placed:

$$\frac{\partial lnC^*}{\partial lny_i} = q_i = \frac{p_i y_i}{C^*} = \beta_i + \sum_i \delta_{ij} lny_i + \sum_j \varphi_{ij} lnw_i^* + \sum_i \phi_i \, z_i^* \tag{3}$$

Where q_i is the "revenue share" equation and need not add up to one unlike the cost shares, s_i.

2.2 Econometric approach and data

In order to assess the effect of mulching on the demand for herbicides, pesticides, fertilizer, and labour, Equations (1) and (2) were jointly estimated using seemingly unrelated regression model (SUR). Two outputs were considered: maize and beans while coffee was used as the *numereire*. The price of coffee was thus used to normalize all the input prices and the cost, that is, prices were expressed as relative prices to maintain linear homogeneity of the cost function. The analysis focused on five inputs: herbicides, pesticides, fertilizer, hired labour, and seeds. However, in order to satisfy the adding up condition and to maintain the linear homogeneity requirement, the seeds share equation was dropped.

In the dual system, input prices are used rather than physical quantities. Hence, the following explanatory variables were included in the share equations: herbicide price (*lnpherb*), pesticide price (*lnppest*), fertilizer price (*lnpfert*), the price of hired labour (*lnwagerate*), quantity of maize (*lnqmaize*), and quantity of beans (*lnqbeans*). All prices and quantities are expressed in natural logarithms. A dummy variable equal to 1 if the farmer applies mulch and zero otherwise was included to capture the effect of mulching on the cost shares. In addition to the explanatory variables in the share equations, the cost equation also included interactions between input prices (e.g. *lnpherb* x *lnppest*), output quantities (e.g. *lnqbeans* x *lnqmaize*), as well as the input prices and output quantities (e.g. *lnpherb* x *lnqmaize*).

The dependent variables were defined as follows: *herbshare* is cost of herbicides divided by the total farm production expenses; *pestshare* is cost of pesticides divided by the total farm production expenses; *fertshare* is cost of fertilizer divided by the total farm production expenses; *labourshare* is cost of hired labour divided by the total farm production expenses; *seedshare* is cost of herbicides divided by the total farm production expenses. The dependent variable in the cost equation is *lncost*, the natural log of the farm production expenses.

Allen-Uzawa partial elasticities of substitution between inputs i and j were also derived from the cost function as: $\sigma_{ij} = (\gamma_{ij} + s_i . s_j)/(s_i . s_j)$ and $\sigma_{ii} = (\gamma_{ii} + s_i^2 - s_i)/(s_i^2)$. Following

Binswanger (1974) and Ray (1982), own and cross price elasticities of demand for individual inputs can be calculated as: $\eta_{ii} = s_i . \sigma_{ii}$ and $\eta_{ij} = s_j . \sigma_{ij}$, respectively.

The study uses two datasets. The first dataset was collected in 2012 as part of the IMPACTlite household survey[2] (Silvestri *et al*. 2014). The second dataset included data that were collected as part of the gender survey in 2013 (CCAFS, IFPRI, and ILRI, 2013). Both surveys were conducted in Rakai district of Uganda and involved the same households. In the gender survey, however, two senior-most members of a household (spouses) were interviewed, except for cases where only one party was available. In such a case, only the available senior-most decision-maker was interviewed. A total of 200 farmers were interviewed in the first survey while in the follow-up gender survey, 187 female and 156 male respondents were interviewed.

IMPACTlite survey included questions on household composition, crop and livestock production and marketing activities, cost of farm inputs, land allocation, and crop-livestock management practices. In addition, the survey collected data on expenditure, off-farm income, assets, and crop residues. The follow-up gender survey asked questions on awareness of different crop and land management practices including the use of crop residues as mulch, and whether the respondents had applied the practice in the previous twelve months. Respondents were also asked about the perceived benefits and disadvantages of the each practice they had implemented. Other data collected in the follow-up survey include household demographics, land tenure and ownership by gender, decision making, access to information, credit and insurance, climate shocks and perception of the risks associated with climate change, adaptation strategies, and personal values.

2.3 Study site

Located in southwestern part of the Central Region of Uganda, Rakai District is predominantly agricultural. Majority of the population living in Rakai derive their livelihoods largely from crops, livestock and natural resources. A report of the CCAFS baseline household survey conducted in 2011 indicates that farms in Rakai are diversified, with most households producing and consuming a wide range of food crops (Kyazze and Kristjanson, 2011). Two-thirds of the households sell some of the food crops they produce. Three-quarters of the households also produce a cash crop (typically coffee). Eighty percent of households have small livestock (sheep, goats, chickens or pigs), and one-fifth own cattle. Bananas, beans and maize are the most important crops grown. Most households (88%) have introduced new crop varieties. The biggest shifts have been towards higher yielding varieties, drought tolerant varieties, and disease and pest-resistant varieties.

[2]The survey tool and the data can be found at: http://dx.doi.org/10.7910/DVN/24751

The CCAFS baseline report indicates that 57% had introduced mulching. The practice is mostly done for bananas (68%). The report further indicates that 39 % had started using or had increased the use of pesticides and/or herbicides (Kyazze and Kristjanson, 2011). Similarly, 13% of the household interviewed had increased their use of chemical fertilizer. Only 5% were practicing integrated crop management while 11% had introduced integrated pest management. Taylor et al. (2011) indicate that labour shortage, pests and diseases, and declining soil fertility are major problems facing farmers in Rakai.

3.0 Results and discussion

3.1 Descriptive statistics

The summary statistics are presented in Table 1. As shown, the average age of the household head is 49 years. The household head has on average 7 years of formal education slightly lower than the maximum for a household which is 9 years. The average size of a household is 9 members. Most of the respondents (99%) are aware about the practice of leaving crop residues in the fields while 45% practice mulching. As shown in Figure 1, awareness on the use of crop residues for mulching seem to be largely from own-experience and indigenous knowledge. About 29 percent of the respondents are members of agricultural production groups present in the community.

>>Figure 1 about here>>

The four main perceived benefits of leaving crop residues in the fields are increased productivity, increased soil fertility, labour saving, and water retention (Figure 2). Except for water retention, female’s perception was higher and significantly different from male’s (p=0.01). Perceived disadvantages include increased crop management costs, unavailability of the material, increased cost of disease and pest control, and high establishment costs (Figure 3).

>>Figure 2 about here>>

>>Figure 3 about here>>

>>Table 1 about here>>

3.2 Results of regression analysis

The estimation results of the seemingly unrelated regression are presented in Table 2[3]. The test of Cobb-Douglass (i.e. that the interaction terms are equal to zero) was rejected *(F=21.06; p=0.0000)* indicating that Cobb-Douglas is not appropriate in this case. All the constraints imposed

[3] We do not present the results of highly insignificant interactions in the cost equation due to space limitations. The complete model can, however, be availed to interested readers upon request from the corresponding author.

were satisfied. The coefficient of mulching is significant in the herbicide, pesticide, and fertilizer, at 5 percent level and 10 percent level in the labour share. *Ceteris paribus*, expenditure on herbicides decreases with mulching as hypothesized. In line with conventional agronomic knowledge, mulching can play an important role to suppress weeds. This is particularly true when the mulch is applied pre-emergent. This finding suggests that farmers who practice mulching will most likely save on the cost of weeds control. The finding contradicts most studies on CA which argue that due to minimized tillage, the cost of herbicides increase as manual weed control is discouraged.

The coefficient of mulching in the pesticides share equation (0.046) indicates that the practice is not cost-saving in pest control. This can be explained in two ways: 1) Mulching can form a breeding ground for pests, consequently increasing the intensity of infestation and 2) Mulching can reduce the effectiveness of pesticides especially if the chemical is absorbed by the mulch and does not reach the pest or where it reaches the pest only in limited amount that the pest develops resistance. There is, however, need for further research into the link between mulching and pest multiplication.

>>Table 2 about here>>

Similarly, the coefficient of mulching in the expenditure share equation for fertilizer (0.026) and labour (0.175) shows that the practice increases the cost of these inputs. The main material for mulching in Rakai is maize residue. Studies such as (Palm et al., 2001; Zibilske et al., 2002) indicate that cereal residues have a wide C:N ratio and their decomposition may lead to temporary N immobilization. Under such conditions, a larger amount of N fertilizer will be needed to achieve equivalent yields as compared without mulching (Giller *et al*. 2009; Naudin *et al*. 2010). Corbeels *et al*. (2014) examine mulching within CA and finds that although mean yield was higher among CA farmers, these farmers applied on average 10 percent more fertilizer and spent 45 percent more labour time. Lahmar *et al*., (2012) argues that labour requirements for creating adequate mulch prior to the next crop can be costly for farmers. This might result in economically unattractive farming systems (Affholder *et al*. 2010)

The above results indicate that promotion of mulching can be beneficial but could also bring with it increased costs of crop management including pest control, mineral fertilizer requirement and increased demand for labour. These cash requirements can hinder adoption of mulching especially where farmers have liquidity constraints and where they lack effective demand for the inputs. Without being quick to conclude that farmers with constrained access to such inputs might be better-off not practicing mulching, it is important to understand the different contexts in which farmers operate. While in the short-term climate finance might be an appropriate option to ease the cash constraints required to successfully implement mulching, long-term success will require promotion of complementary practices. Such are practices that will help to increase soil fertility such as crop rotation and intercropping with legumes and integrated pest management. Efforts to promote complementary investment, however, must also be context-specific recognizing not also synergies but also trade-offs.

Table 3 presents Allen-Uzawa elasticities of substitution while Table 4 shows own and cross price elasticities of demand. Consistent with the theory, all own price elasticities of demand are negative. Our estimates of elasticities, however, are lower in absolute terms contrary to what would be expected in SSA hence the magnitude of the elasticities should be interpreted with caution.

>>Table 3 about here>>

>>Table 4 about here>>

4.0 Conclusion and recommendations

Climate-smart agriculture (CSA) is increasingly recognized as an important approach to sustainably increase agricultural productivity and income, build and increase resilience of farming systems towards climate change, and reducing greenhouse gas emissions. Several options have been identified, albeit at different scales and contexts. Successful implementation of CSA will, however, require a proper understanding of the trade-offs and synergies that the different options present.

This study investigates the trade-offs associated with mulching by specifically looking at the effect of the practice on the demand for factors of production. The study uses survey data to estimate a system of equations including a translog cost function and its derived factor shares. The study finds that while expenditure on herbicides reduces with mulching, the practice is associated with increased cost shares of pesticides, fertilizer, and labour. Based on the findings of this study and the literature on mulching, we conclude that mulching has the potential to increase crop productivity and crop income but also presents several economic trade-offs that need to be weighed against potential benefits. Ignoring such trade-offs might not only over-estimate the benefits associated with mulching but might also limit its successful adoption.

Efforts aiming to promote wide-scale adoption of mulching should equally focus on ways to minimize its effect on the cost of production. Promoting mulching within a package including complementary practices such as intercropping, crop rotation and integrated pest management might be useful. Such options will help to address the problem of soil fertility while contributing to pest control by breaking pest cycles. Policy should also address the labour constraints associated with mulching. One possible strategy would be to encourage participation in groups to increase social capital and boost collective action. Finally, current literature on the link between mulching and growth of weeds and pest incidence is largely anecdotal. There is thus need for future research to examine these dimensions.

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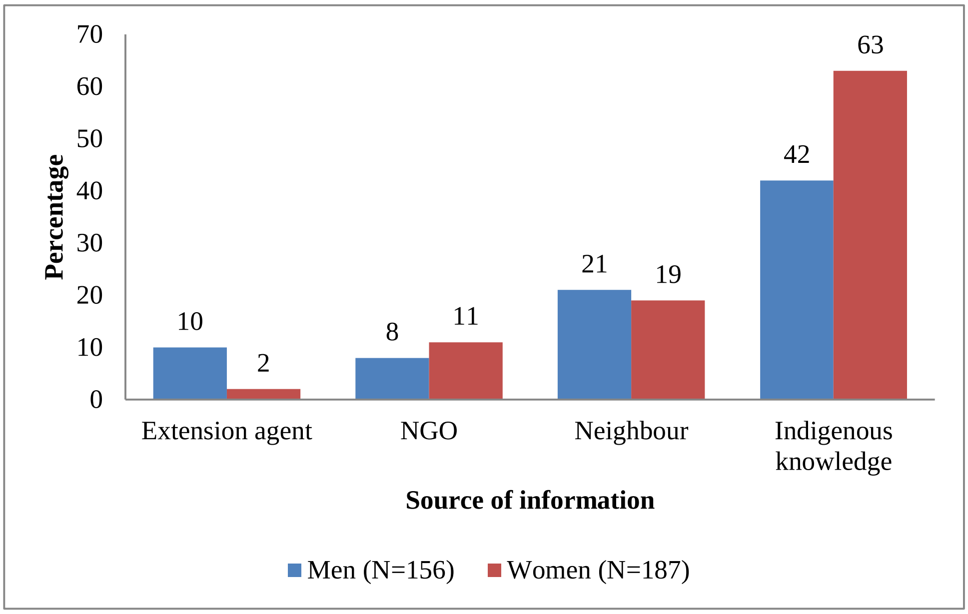

Figure 1: Sources of information on use of crop residues for mulching, percentage by gender

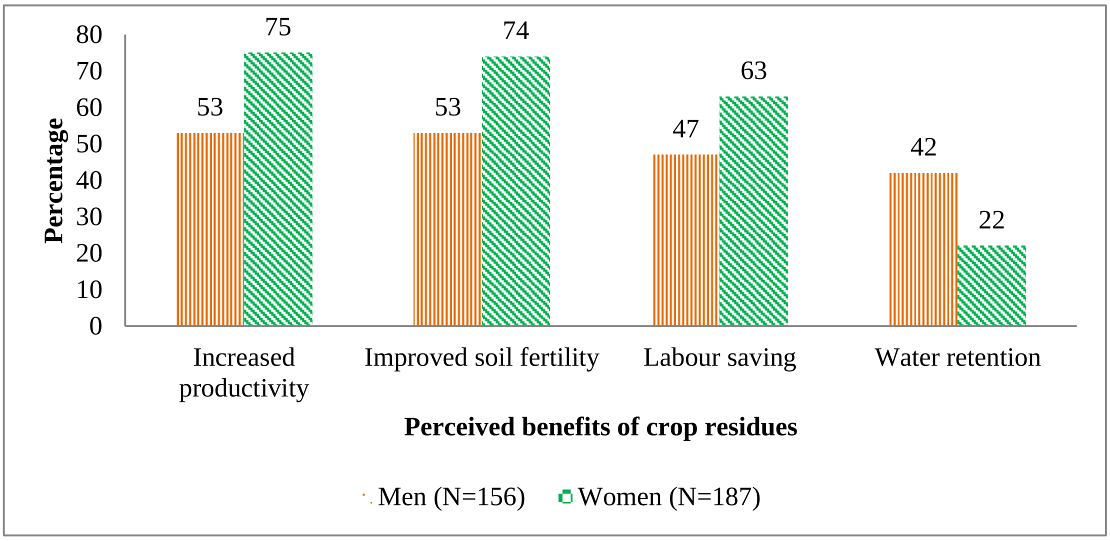

Figure 2: Farmers' perceived benefits of the use of crop residues for mulching, percentage by gender

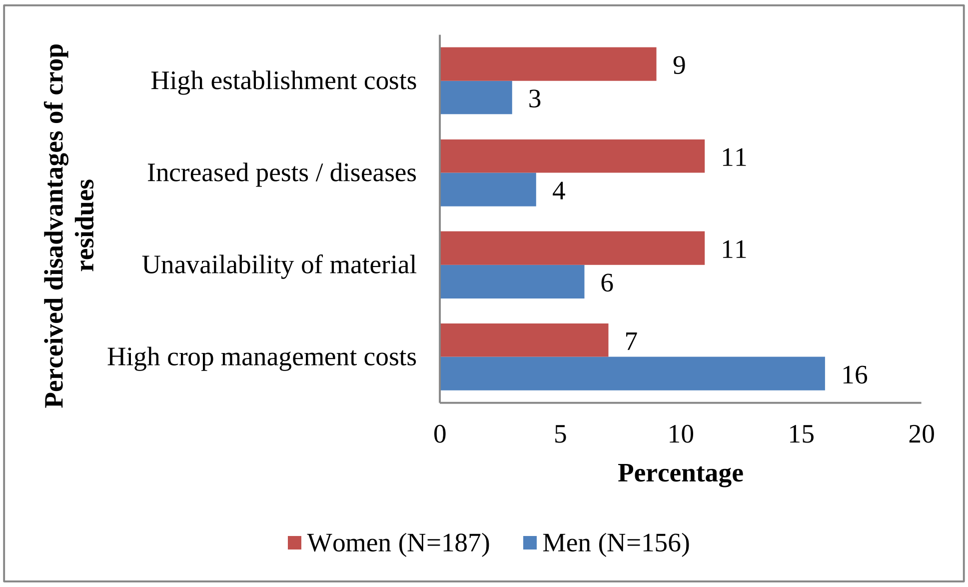

Figure 3: Perceived disadvantages of using crop residues for mulching, percentage by gender

Table 1: Summary statistics

Variable	Description	Mean	Standard deviation
P_{Herb}	Price of herbicide (UShs/L)	14109	2435.98
P_{Pest}	Price of pesticide (UShs/L)	17971	11526.11
P_{Labour}	Wage rate (UShs/day)	5766	3480.39
P_{Fert}	Price of fertilizer (UShs/kg)	2541	489.97
P_{Seed}	Price of seeds (UShs/kg)	2010	1774.94
Farmsize	Size of farm in acres	4.75	2.89
Mulching	Dummy variable (1 if yes; 0 otherwise)*	0.45	0.50
Hhsize	Number of resident members of a household	9	2.90
Agehhh	Age of the household head	49	13.92
Maxeduc	Maximum education in the household	9	3.25
Educhhh	Education of the household head	7	3.53
Grpmember	Group membership*	0.29	0.45

Source: Authors' calculations

Note: For dummy variables variables the mean is interpreted as the proportion of farmers under the category 1.

Table 2: Results of the seemingly unrelated regression model for demand estimation

Variable	lncost	Herbshare	Pestshare	Fertshare	Labourshare
lnpherb	0.124***	0.013***	-0.004**	-	-0.006
	(0.016)	(0.002)	(0.002)		(0.006)
lnppest	0.097***	-0.004**	0.017***	-0.002**	-0.009***
	(0.016)	(0.002)	(0.002)	(0.001)	(0.002)
lnpfert	0.157***	-	-0.002**	0.020***	-0.003***
	(0.015)		(0.001)	(0.002)	(0.001)
lnwagerate	0.247***	0.008***	-0.009***	-0.003***	0.008***
	(0.023)	(0.002)	(0.002)	(0.001)	(0.002)
lnherblnherb	0.013***	-	-	-	-
	(0.002)				
lnpestlnpest	0.017***	-	-	-	-
	(0.02)				
lnfertlnfert	0.020***	-	-	-	-
	(0.002)				
lnwagelnwage	0.008***	-	-	-	-
	((0.002)				
lnherblnpest	-0.004**	-	-	-	-
	(0.002)				
lnherblnwage	0.008	-	-	-	-
	(0.002)***				
lnpestlnfert	-0.002**	-	-	-	-
	(0.001)				
lnpestlnwage	-0.009	-	-	-	-
	(0.002)***				
lnfertlnwage	-0.003***	-	-	-	-
	(0.001)				
lnqmaize	0.002	0.002	-0.004***	-0.001*	-0.002
	(0.002)	(0.001)	(0.001)	(0.001)	(0.003)
lnqbeans	0.001	-0.002	-	0.001	-
	(0.001)	(0.001)		(0.001)	
lnppestlnqmaize	-0.004***	-	-	-	-
	(0.001)				
Mulching	0.008	-0.051**	0.046**	0.026**	0.175***
	(0.236)	(0.024)	(0.023)	(0.011)	(0.058)
Constant	6.465***	0.124***	0.097***	0.157***	0.247***
	(0.298)	(0.016)	(0.016)	(0.015)	(0.023)

Note: *,**,***, indicates significance at 10%, 5%, and 1% level. The figures in parentheses are standard deviations

Table 3: Allen's elasticity of substitution (mean values)

Variable	Herbicide	Pesticide	Fertilizer	Labour
Herbicide	-6.50			
Pesticide	-5.23	26.13		
Fertilizer	2.04	-10.28	61.40	
Labour	1.48	0.59	0.47	-1.63

Source: Authors' calculation

Table 4: Own and cross price elasticity of demand for inputs

Variable	Herbicide	Pesticide	Fertilizer	Labour
Herbicide	-0.60			
Pesticide	0.006	-0.38		
Fertilizer	0.04	-0.02	-0.09	
Labour	0.67	0.24	0.28	-0.33