Participatory Evaluation of Integrated Pest and Soil Fertility Management Options Using Ordered Categorical Data Analysis

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Abstract

During participatory rural appraisals, farmers at the Lake Victoria basin of Kenya and Uganda identified *Striga*, stemborer and declining soil fertility as three major constraints to maize production To reduce food insecurity, several innovative integrated technologies to address these constraints have been developed, including push-pull (maize intercropped with *Desmodium* and surrounded by napier grass), maize-soybean and maize-crotalaria rotations, and Imazapyr-resistant (IR) maize seed coated with the herbicide. To let farmers evaluate the new technologies, 12 demonstration trials, comparing the different technologies, were established in four villages in Siaya and Vihiga districts (Western Kenya) and two villages in Busia (Uganda). These evaluations, where farmers' appreciation and feedback on the technology are captured, are an important step in technology development. During field days at the end of short rainy seasons of 2003 and 2004, 504 farmers individually observed and rated each treatment under the different cropping systems, with and without IR maize, and with and without fertilizer, with a maize continuous monocrop as control. Farmers scored each of the 16 treatments on an ordered scale of five categories: very poor, poor, average, good, and very good. The treatments were scored for each of the criteria farmers has previously determined (including yield, resistance to *Striga* and stemborer, and improvement of soil fertility). Analysis of the evaluation, using ordinal regression, show significant differences in farmers' preference by year and site. There was, however, little effect of farm and farmer characteristics such as farm size and gender of the observer. Ordinal regression of farmers' scores are not as intuitive and also bit cumbersome to use, but they have a better theoretical foundation than other methods, in particular the use of means. This paper shows how the method can be used, and concludes that, with some effort, it is a convenient way to analyse farmers' ranking of a large number of options.

Key words: farmers' preference, technologies, ordinal regression.

1. Introduction

Sub-Saharan Africa's rapid population growth, combined with a stagnating agricultural productivity, has lead to a decrease in food production per capita. It is now the only region in the world where both the number and the proportion of malnourished children has been consistently rising in recent years (Rosegrant et al., 2001). Throughout most of eastern and southern Africa maize is the dominant food staple (Byerlee and Eicher, 1997), so improving its productivity is essential to reversing this trend. Maize in the region is primarily grown by small-scale farmers, using limited inputs an almost no irrigation, resulting in average yields of only 1,200 kg/ha (FAO, 2005).

The Lake Victoria basin is characterized by a very high population pressure and small land holdings. Farmers in the area identify as the major constraints in maize production *Striga*, a parasitic weed of sorghum and maize, insect pests such as stem borers and storage pests, and declining soil fertility (De Groote et al., 2004, Odendo et al., 2001). *Striga* species, also known as witchweed, are obligatory root parasites and a serious constraint to cereal production in Western Kenya (De Groote et al., 2005). Over Africa, it affects the livelihood of approximately 100 million people and, by some estimates, causes crop damages of around US$7 billion (Berner et al., 1995). *Striga* infestations increase with continuous planting of cereals on the same plot, and with declining soil fertility that weakens the host plant and makes it more susceptible to *Striga* attack. Over the years, *Striga*-infested areas have developed very high levels of s*triga* seeds in the soil with only a few breaking dormancy each season when stimulated by crop root exudates. In Kenya, yield losses due to *Striga* range from 35-72% (Hassan et al., 1994). In Kenya, an estimated 200,000 ha of land is infested with *Striga* (76% of farmland in Western Kenya) causing an estimated crop loss valued at about US$53 million (De Groote et al., 2005).

Large maize growing areas in the developing countries also face serious problems of insect infestation, in particular stem borers. In Kenya alone, farmers estimate crop losses due to stem borers at 13.5% of their potential harvest (De Groote et al., 2004), in a country where many people live on less than US$ 1 a day. Infestations of these pests can decimate individual maize fields depriving a rural family of vital income and year's supply of their food source.

Soil fertility depletion on the other hand is increasingly being recognized as a fundamental biophysical root cause for declining food security in smallholder farms of SSA. No matter how effectively other constraints are remedied, per capita food production in Africa will continue to decline unless soil fertility depletion is effectively addressed (Sanchez et al., 1997). Declining soil fertility is a fundamental impediment to agricultural growth and a major reason for slow growth in food production in SSA and is a worldwide problem affecting 135 million hectares in Africa (Oldeman et al., 1991). Soil nutrient mining and soil fertility decline is a fact for most areas in Kenya as can be substantiated by the generally observed negative balances for N, P, and K at the farm level (Smaling et al., 2002).

To counter these major constraints in maize production in East Africa, a collaborative project was initiated in the Lake Victoria basin in 2003, by the International Centre for Insect Physiology and Ecology (ICIPE), the International Maize and Wheat Improvement Centre (CIMMYT), the Tropical Soil Biology and Fertility (TSBF) program from the International Centre for Tropical Agriculture (CIAT) and the Kenya Agricultural Research Institute (KARI). In demonstration trials, different technologies that these institutes have been developing, were jointly presented to farmers. These included push-pull (ICIPE), intercropping with legumes such as crotalaria (KARI) and soybean (TSBF), and herbicide resistant maize (CIMMYT).

2. Background

Farmer evaluation

Many of the technologies agains striga and poor soil fertility have been developed and tested before, in particular the use of inorganic fertilizer and rotations with legumes. Despite proven technical efficiency, adoption of these technologies remain very low. Three problems can be distinguished: i) proper evaluation by farmers of demonstration trials, ii) appropriate economic analysis of these trials, and iii) proper testing and evaluation by farmers on their own land. First, farmers are often invited to come and see demonstration trials, but seldom is their evaluation captured systematically and incorporated in the research and development. Secondly, proper economic analysis of the results, in particular including the cost of labor and proper analysis and discounting in a multi-period time frame, is often lacking. Consequently, similar trials (especially green manure seems to be popular) are repeated year after year, but no labor data are available to allow for proper economic analysis. Thirdly, evaluation on-farm is a major challenge to more conservative agricultural scientists. Control over the trial decreases while variation of the results increases. Harvesting the larger number of trials needed, spread over time and space in often hard to access places, can be a major headache. Finally, the organization of farmer evaluations and the collection of good data is difficult and time consuming.

In this paper we mainly focus on the first problem: using the appropriate methodology in soliciting and analyzing farmers' evaluation of new technologies. Based on literature and experience, we propose a four-step approach: i) study of the farming system, ii) defining criteria to judge new technologies, iii) scoring of new technologies using those criteria in demonstration trials, iv) selection of technologies by farmers and testing on their own farms under their own conditions. First, it is important to study a constraint within its context, as was demonstrated by the farming systems research approach. Therefore, before any evaluation, short but comprehensive reviews should be undertaken, including literature review, key informant interviews and participatory rural appraisals (PRA). The objectives of such reviews is to check if available technologies address real constraints as faced by the farmers, to review which methods have been tried before, and to conclude if the proposed technologies are likely to fit within the current farming system and policy environment. Secondly, to avoid scientists' bias, it is important that farmers themselves indicate which criteria should be used to evaluate new technologies. Third, these criteria should now be used to evaluate the technologies, using appropriate quantitative methods. Fourth, farmers should be able to test and adapt the technologies on their own fields. Step one and two are dealt with in another paper reporting on the PRAs conducted in this project. In this paper, we focus on step three: appropriate quantitative methods. In a future paper, the economic analysis of the trials will be reported.

Quantitative analysis of farmers' evaluations

A convenient and popular way of farmers' evaluation is ranking: farmers are asked to rank proposed or demonstrated technologies. Unfortunately, two major problems arise when trying to apply ranking in a systematic way. First, it is hard for farmers (and other participants), to rank more than a small number of options. Where a large number of technologies, such as new varieties or combinations of technologies (crop management, fertilizer and varieties, as in this case) are involved, ranking all options is cumbersome. The second problem is the appropriate analysis of ranking: although appropriate quantitative methods are available, they are not easy to use, and they have high requirements of the data (such as no missing values).

Because of these problems, the alternative of scoring is becoming increasingly popular. In scoring, also called rating, farmers evaluate new technologies on a limited scale, for example on a scale of five from 1 (very bad) to 5 (very good). Because of convenience, many scientists treat these scores as continuous variables, calculate the mean score for each technology, and compare means using statistical tools. Unfortunately, this type of analysis is based on assumptions that are hard to maintain, in particular that the numeric distance between scores have a meaning. For example, treating the score as a continuous variable implies the assumption that a score of 4 (very good) has twice the value of a score of 2 (bad), although this is not what the farmer said.

The theoretically correct way to treat these scores is as ordered categorical data (Coe, 2002). This approach, popular in other fields, is rarely used in agricultural research, likely because of the difficulties encountered in the analysis and interpretation. Modern software, however, makes the analysis fairly straight forwards and, as we will show, with some effort the results can be conveniently interpreted.

Conceptual framework

The basic assumption is that the choice of the respondent to assign his evaluation of a treatment in a trial in a particular ordered category, is driven by a latent y^* , influenced by a set of factors ***x*,** such that (Greene, 1991)

$$\mathbf{y}^* = \beta' \mathbf{x} + \varepsilon \ .$$

The latent variable y^* is not observed, but what we do observe is

$$
\begin{aligned}
y &= 0 \quad && if\ y^* \le \mu_1 , \\
y &= 1 \quad && if\ \mu_1 \le y^* < \mu_2 , \\
&. \\
&. \\
y &= J \quad && if\ \mu_{J-1} \le y^* .
\end{aligned}
$$

We assume the disturbance term is logistally distributed, then:

3. Methodology

Technologies tested

Participatory rural appraisals (PRAs) were conducted at the beginning of 2003 in the Lake Victoria basin of Kenya and Uganda. The objectives were to understand the farming systems, understand production constraints, gauge farmer's knowledge on the biology of the constraints, gather information on the coping strategies and select the target villages. The sites were purposely selected to represent areas where maize production is important and facing many constraints, and to allow comparison of areas with good and poor market access. In Kenya, four villages were selected in the Vihiga district, representing good market access, and four in Siaya district, representing poor market access. In Uganda, the the Busia district was selected, and two villages within the district: Angorom for good market access and Kubo West for poor access. The results of the PRAs showed that *Striga*, stemborers and declining soil fertility were the major constraint in most villages.

Four of the most affected villages in Kenya (Ngoya, Nyalgunga, Ebulonga and Ematsuli) and two in Uganda (Angorom and Kubo West) were then purposely selected for on-farm trials that started during the long rains of 2003 (April-August). Three cropping systems were used to address these major constraints: push-pull (PP), soybean-maize (SOY) rotation, and crotalaria-maize (CRT) rotation, and these strategies are compared to the control, maize monocrop (MON).

In the so-called “push-pull” strategy, maize is intercropped with desmodium and surrounded with a band of napier grass (Khan et al., 2001). Desmodium is a fertility enhancing legume that also produces semio-chemicals that trigger the germination of *Striga*, thus reducing the seed bank. It also produces a smell that repels the stemborers away from the maize. The napier grass traps the repelled stemborers. Soybean and crotalaria are legumes that improve soil fertility through nitrogen fixation. Soybean can be consumed in the household or sold for cash, while crotolaria is a green manure that is plowed under at the end of the season. Further, each of the three management strategies and the control are applied once with (+F) and once without fertilizer (-F). Moreover, two maize varieties are tested in each of the above treatments: a local variety and Imazapyr resistant (IR) maize. IR maize is resistant to the herbicide Imazapyr, and can therefore be coated with the herbicide. This low-dose seed coating provides good control of *Striga*, especially in the early growth stages when most of the damage is done (Kanampiu et al., 2002). The three cropping systems plus control, in combination with two fertilizer and two variety options, result in a total of 16 treatments.

In each of the six villages, the trial was replicated once, and the initial phase of the project went over four seasons, starting with the long rains of 2003 (April to August) until the short rains of 2004. For the push-pull treatments, the napier and desmodium were established in the first season, and maize planted in all seasons. For the treatments involving rotations, the legumes were planted during each of the long rainy seasons, and maize in each of the short rainy seasons (September to December). In the control plots maize was planted in all seasons. In Uganda, the project only obtained government permission to introduce Imazapyr- resistant (IR) maize into the trials 2004. During 2003, another improved variety was substituted for IR maize, Longwe I.

Farmer evaluations

Farmer evaluations of the trials took place at the end of each short rainy season, the season when maize was planted in all treatments. Each village followed the same procedure. During the introductory meeting, both farmers and scientists introduced themselves, and the purpose of the visit was discussed. A review of the various treatments was presented to the farmers and other participants, such as extension and NGO officers. Farmers listed and ranked the criteria they would use to evaluate the different treatments. Farmers in all villages used *Striga* resistance, stemborer resistance, soil fertility enhancement, yield, labor saving as criteria to evaluate the different treatments. The Ngoya and Nyalgunga villages also added crop vigor, fodder supply, and soil erosion reduction to the list. Farmers were also asked to give an overall evaluation score for each treatment.

Next, each farmer was supplied with an evaluation form consisting of a short section of farmers' characteristics, an evaluation table, and some final questions. Before going to the field, farmers filled in the first section, indicating their age, gender, level of education, and experience, as well as the size of their farm and the area under maize. Next, they were invited to visit the trial for the evaluation. At the site, they filled in the evaluation table, consisting of a row for each treatment and a column for each criterion they had mentioned. Farmers then scored each treatment for each criterion, according to a scale of 1 (very poor) to 5 (very good), and also gave an overall score for each treatment. Then, farmers selected the top three or four treatments they would like to try in their own fields. They were also asked to make any suggestions and, after the individual evaluations, the farmers and scientists regrouped to discuss their preference. This was also the chance for farmers to question scientists and extension staff.

This paper utilizes data collected during the farmer evaluation meetings held at the end of short rainy seasons of 2003 and 2004 for the Kenyan villages, and the short rainy season of 2004 only for Uganda villages (total of 504 farmers) (Table 1). Since the Ugandan trials did not include IR in 2003, those evaluations were excluded from the analysis.

Analysis

Scores are ordered categorical data, for which the appropriate analysis is ordinal regression (Coe, 2002). Means brings biased results since it assumes than scores are continuous numeric values. Therefore, the proportional odds regression model was used, which calculates the cumulative probabilities that a response variable Y falls in category *i* or below, for each possible *i*,where *i* refers to ordered categories. The estimate arrived at is the log odds ratio which equals to the log (odds of one treatment being high verses low/odds of another being high verses low) (Coe, 2002). The following short model was estimated: $Y_j = f(X_j)$ where Y is overall farmer evaluation, score from 1-5 of treatment X_j .Next, the effect of year, site and gender were evaluated by inserting dummy variables and cross effects with each treatment. Farm size, age and total livestock units are continuous variables and were used in regression as co-factors. Analysis using ordinal regression estimates 15 coefficients are log-odds ratios, compared to the last entry, here monocrop of local variety without fertilizer.

Finally, multilinear regression was used to estimate the relative importance of the different criteria in the overall score. The overall score of each treatment was regressed on the scores of the five criteria that were used in all sites: *Striga* resistance, stemborer resistance, soil fertility enhancement, labour saving and yield. The coefficients of each of the criteria can be interpretated as their relative importance or weight towards the overall evaluation score.

3. Results

Overall comparison of the cropping systems

In the first analysis, the ordinal regression model is run with the overall evaluation as dependent variables, and the treatments as independent variables. The estimated coefficients for the treatments represent the odds-ratio that the treatment is preferred to the baseline, here the monocropping of the local maize variety without fertilizer. To allow for differences between sites and years, these factors were included as dummy variables.

The results indicate that, overall, respondents preferred the push-pull treatments (Table 2). The estimated coefficient on Push-pull IR with fertilizer for example, was 2.62. This indicates that the treatment was 13.74 more likely to be preferred by farmers than the base, monocrop local maize variety without fertilizer. This coefficient, as all other push-pull coefficients were significant, at the 1% significant level. The sizes of the coefficients present a ranking of farmers' preference. Thus, after push-pull, maize-crotalaria was the preferred treatment, followed by maize-soybean. Preference for IR was significant in combination with push-pull and soybean rotation.

Analyzing different preferences between years and sites

Ordinal regression also allows for the analysis of diffences in appreciation between groups of respondents, or between sites and seasons, by including cross effects in the model. If a particular group is identified by a dummy variable (1=member of the target group, 0=all other respondents or control group), the coefficients of the treatments represent the log-odds ratio that the other respondents prefer that treatment to the base. The coefficients of the cross-effects then represent the log-odds ratio that the target group prefers the treatment more than the control group.

This analysis was first used to compare the years, the negative cross-effects indicate that many treatments were significantly less appreciated in 2004 than in 2003 (Table 3). The log-odds ratio for push pull with fertilizer and IR was 2.99 in 2004, but with a cross-effect of -1.05 for 2003, resulting in a log-odds ratio of only 1. 94 for 2003. Similar negative cross-effects for 2003 indicate that the push-pull technology was more appreciated in 2004 than in 2003. Similarly, the crotolaria intercrop and the IR maize monocrop were more appreciated in 2004.

Next, the differences in appreciation between sites were analyzed in a similar manner (Table 4). The coefficients in the fifth column indicate farmers' preference for the various treatments. For example, is the coefficient of push-pull with IR and fertilizer is 1.21, indicating that this treatment was 3.35 more likely to be preferred than the base treatment, in the base site (here Busia). The coefficient of the cross-effect with Vihiga and Siaya (column six and eight) show the difference of appreciation for different treatments in that site with Busia. To obtain log-odds ratio for the different sites, the coefficients of the cross-effects are added up to the coefficients for the treatments in Busio. This calculation shows that farmers in Siaya preferred push-pull more, while those in Vihiga and Busia preferred maize-soybean.

Finally, the method was used to analyze the effect of farmer characteristics on technology preference, in particular the effects of gender (Table 5) and age (Table 6) were analyzed. The results show that female participants generally rate all technologies higher, as expressed by the coefficients in column 5 in Table 5. Age had positive and significant for push-pull with IR maize. This shows that old farmers prefer push-pull combined with IR maize with and without fertilizer.

Similarly, the effect of wealth can be analyzed through estimating a cross effect with wealth indicators. Wealth was approximated by total livestock units and farm size (Table 6, columns 7 and 8). Total livestock units had little effect but negative for three push-pull treatments meaning farmers with few livestock preferred this technology. Farm size had a negative effect on the preference for push-pull technologies, indicating that the proposed technologies is indeed well appreciated by small-scale farmers.

Estimating the importance of different criteria

The overall evaluation score of the different treatments was regressed on evaluation scores of the separate selection criteria to estimate their respective weight (Table 7). The coefficients on all criteria are significantly different from zero, but differ substantially in size. By far the most important criterion is yield, with a coefficient of 0.40, meaning that when the score for yield increases by 1, the overall score increases by 0.40. Other important criteria are soil fertility enhancement (0.25), *Striga* resistance (0.13) and labor saving (0.09). Stem borer resistance, on the other hand, comes out as a relatively minor criterion (0.03).

4. Conclusions

This paper shows that, given some effort, scoring and ordinal regression are convenient ways to capture and analyze farmers' opinions and preferences for new technologies. Moreover, this method allows for further analysis of these preferences, looking at differences by sites, year, or individual and farm characteristics.

In this particular analysis of innovative new technologies; push-pull, maize soybean and maize-crotalaria are compared with monocrop. The comparison shows that there was a clear difference in technology preference between year, sites, gender and farm size. There was high preference for these technologies in year 2004. Farmer's preference was high in Siaya and female ratings were higher than males. Farm size had a negative effect on the preference for push-pull technologies while total livestock units and age had little effect.

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TABLES

Table 1: Farmer participation in trial evaluation per village by gender and season

	Vihiga (Kenya)		Siaya (Kenya)		Busia(Uganda)	
Season	F	M	F	M	F	M
Short rains 2003	29	51	37	25	26	34
Short rains 2004	66	66	93	77	18	42
Long rains 2005	148	72	73	71	24	22
Total	243	189	203	173	68	98

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Table 2**:** Overall appreciation of technologies

Components of the treatment				Coefficient
Cropping system	Treatment	Maize variety	Fertilizer	overall
Push-pull	1	IR	Yes	2.62***
	2	IR	No	2.39***
	3	Local	Yes	1.95***
	4	Local	No	2.09***
Maize-Soybean	5	IR	Yes	1.53***
	6	IR	No	0.62***
	7	Local	Yes	0.89***
	8	Local	No	0.86***
Maize-crotalaria	9	IR	Yes	1.56***
	10	IR	No	1.06***
	11	Local	Yes	1.68***
	12	Local	No	1.56***
Monocrop	13	IR	Yes	0.47***
	14	IR	No	0.46***
	15	Local	Yes	0.53***
	16	Local	No	(redundant)
Sites	Vihiga			0.17**
	Siaya			0.09
	Busia			(redundant)
Year	2003			-0.37***
	2004			(redundant)
Goodness of fit	log likelihood			3043.38
	X^2			1118.08
	N			7033

*** significant at 1%, ** significant at 5%, * significant at 10%.

Table 3**:** Appreciation of technologies by year

Components of the treatment					Estimated coefficients		
Cropping system			Maize variety	Fertilizer	2004	cross effects of 2003	2003
Push-pull		1	IR	Yes	2.99***	-1.05***	1.94
		2	IR	No	2.97***	-1.48***	1.50
		3	Local	Yes	2.23***	-0.79***	1.44
		4	Local	No	2.32***	-0.73**	1.59
Maize-Soybean		5	IR	Yes	1.47***	0.18	1.65
		6	IR	No	0.60***	0.05	0.64
		7	Local	Yes	0.79***	0.29	1.08
		8	Local	No	0.99***	-0.45*	0.54
Maize-crotalaria		9	IR	Yes	1.75***	-0.63**	1.12
		10	IR	No	0.99***	0.17	1.16
		11	Local	Yes	1.95***	-0.88***	1.07
		12	Local	No	1.76***	-0.63**	1.12
Monocrop		13	IR	Yes	0.62***	-0.53**	0.09
		14	IR	No	0.64***	-0.58**	0.06
		15	Local	Yes	0.53***	-0.01	0.52
		16	Local	No	0.00	0.00	0.00
Year	2003				0.03		
Sites	Vihiga				0.14*		
	Siaya				0.08		
Goodness of fit	log likelihood				2935.86		
	X^2				1225.59		
	N				7033.00		

*** significant at 1%, ** significant at 5%, * significant at 10%.

Table 4**:** Appreciation of technologies per site

Components of the treatment				Estimated coefficients				
Technology	Treatment	Maize variety	Fertilizer	Busia	Cross effect of Vihiga	Vihiga	Cross effect of Siaya	Sia
Push-pull	1	IR	Yes	1.21***	-0.30	1.51	1.79***	3.0
	2	IR	No	1.06***	-0.87**	1.93	1.82***	2.8
	3	Local	Yes	0.55*	-0.23	0.79	1.59***	2.1
	4	Local	No	0.11	1.56***	-1.46	1.85***	1.9
Maize-Soybean	5	IR	Yes	2.27***	-1.86***	4.14	-1.16***	1.1
	6	IR	No	1.17***	-1.57***	2.74	-1.15***	0.0
	7	Local	Yes	0.36	0.14	0.22	-0.30	0.0
	8	Local	No	1.51***	-1.17***	2.69	-1.74***	-0.
Maize-crotalaria	9	IR	Yes	-0.54*	2.15***	-2.69	1.37***	0.8
	10	IR	No	1.84***	-1.42***	3.26	-1.64***	0.2
	11	Local	Yes	-0.39	2.08***	-2.47	1.43***	1.0
	12	Local	No	1.75***	-1.17***	2.92	-0.55**	1.2
Monocrop	13	IR	Yes	0.48	-0.67**	1.15	-0.79***	-0.
	14	IR	No	2.18***	-2.74***	4.92	-2.61***	-0.
	15	Local	Yes	0.02	0.37	-0.34	-0.58**	-0.
	16	Local	No	0.00	-0.22	0.22	-1.25***	-1.
2003				-0.29				
Log likelihood				2207.71				
x2				1953.74				
N				7033.00				

*** significant at 1%, ** significant at 5%, * significant at 10%.

Table 5: Appreciation of technologies by gender

Components of the treatment				Coefficients		
Cropping system	Treatment	Maize variety	Fertilizer	Female	Cross effects of male	male
Push-pull	1	IR	Yes	3.19***	-0.98***	2.21
	2	IR	No	2.83***	-0.75***	2.08
	3	Local	Yes	2.39***	-0.74***	1.65
	4	Local	No	2.64***	-1.00***	1.64
Maize-Soybean	5	IR	Yes	1.61***	-0.15	1.46
	6	IR	No	0.58***	0.09	0.67
	7	Local	Yes	1.04***	-0.27	0.77
	8	Local	No	0.84***	0.05	0.89
Maize-crotalaria	9	IR	Yes	1.82***	-0.47**	1.34
	10	IR	No	1.02***	0.08	1.10
	11	Local	Yes	1.90***	-0.39*	1.51
	12	Local	No	1.65***	-0.16	1.49
Monocrop	13	IR	Yes	0.49***	-0.04	0.45
	14	IR	No	0.39**	0.15	0.54
	15	Local	Yes	0.50***	0.08	0.58
	16	Local	No	0.00	0.00	0.00
2003				-0.63***	0.41***	
Male				0.06		
Log likelihood				378.26		
x2				1110.90		
N				7001		

*** significant at 1%, ** significant at 5%, * significant at 10%.

Table 6: Effect of respondent characteristics

Components				Coefficients			
Cropping system	Treatment	Maize variety	Fertilizer	General	Livestock	farmsize	age
Push-pull	1	IR	Yes	2.51***	-0.01	-0.17***	0.03*
	2	IR	No	2.48***	0.01	-0.14**	0.02*
	3	Local	Yes	2.10***	-0.02	-0.16***	0.02
	4	Local	No	2.28***	-0.01	-0.15***	0.01
Maize-Soybean	5	IR	Yes	2.69***	0.00	0.03	-0.01
	6	IR	No	0.82	-0.05	0.05	0.00
	7	Local	Yes	1.25*	0.08	-0.09*	0.00
	8	Local	No	2.32***	-0.04	-0.04	-0.01
Maize-crotalaria	9	IR	Yes	1.86***	0.04	-0.22***	0.01
	10	IR	No	1.74**	-0.09	0.09*	-0.01
	11	Local	Yes	1.80**	0.00	-0.17***	0.02
	12	Local	No	3.01***	0.03	-0.06	-0.01
Monocrop	13	IR	Yes	1.08	-0.02	-0.05	0.00
	14	IR	No	1.82**	-0.08	0.07	-0.01
	15	Local	Yes	0.27	-0.03	0.05	0.01
	16	Local	No	0.00	0.00	0.00	0.00
Total livestock unit				0.04			
Farmsize				0.02			
Age				-0.01			
Log likelihood				7862.11			
x2				663.70			
N					2928	6997	4351

*** significant at 1%, ** significant at 5%, * significant at 10%.

Table 7: Decomposition by different criteria

Criteria	Coefficient	Std. Error	t	Sig.
Yield	0.40	0.01	35.65	0.00
Soil fertility enhancement	0.25	0.01	18.91	0.00
Striga resistance	0.13	0.01	12.42	0.00
Labor saving	0.09	0.01	8.21	0.00
Stemborer resistance	0.03	0.01	2.54	0.01
Constant	0.45	0.04	12.05	0.00
R^2	0.575			
N	7033			

*** significant at 1%, ** significant at 5%, * significant at 10%.