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AGRICULTURAL INNOVATION SYSTEM INTERVENTIONS AND TECHNOLOGY USE IN AFRICA: THE CASE OF INORGANIC FERTILIZERS IN RURAL MALAWI

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ABSTRACT

This paper highlights the factors determining the decision to use inorganic fertilizer over a five year period in a rural community in Malawi, given changing macro-level fertilizer subsidy programs and the micro-level work of agricultural research interventions that were driven by innovation system concepts. The results indicate that different factors that influence households' ability and willingness to purchase inorganic fertilizers were found to positively and significantly influence the decision to use inorganic fertilizer in varying degrees in different cropping seasons. Participation in innovative agricultural research interventions was however, found to negatively affect fertilizer use as the system of beneficiary identification was subjective and dependent upon criteria set by local traditional leaders and extension agents. The paper concludes that the current system of fertilizer coupon distribution in Malawi leads to discrimination against households that are viewed as better off. The results imply that there is the need to mainstream agricultural innovation systems concepts in all public agricultural research and extension programs, so that beneficiaries are not considered better off and hence excluded from social welfare programs to which they are entitled.

Keywords: Logistic regression modeling, Enabling Rural Innovation, Input fertilizer subsidy

INTRODUCTION

The use of Agricultural Innovation Systems (AIS) has been promoted in many African countries to implement agricultural research interventions in rural communities. It is generally acknowledged that investments in agricultural research can improve the delivery of research outputs; have the potential to enhance rural livelihoods and the adoption of improved technologies. Furthermore, evidence exists that any small improvement in the income of rural individuals, which can be brought about by the adoption and utilization of improved agricultural technologies, has the potential to bring significant improvements in rural livelihoods (Delgado, Hopkins, & Kelly, 1998; Mwabu & Thorbecke, 2004; Spielman, 2005). Despite this, the literature on adoption lacks studies that assess the role that agricultural interventions using innovation system concepts play in influencing the adoption of improved technologies, such as inorganic fertilizer and/or improved hybrid seed for agricultural production.

In view of this, the objective of this article is to assess the role that agricultural research interventions that are promoted through the innovation systems concepts play in influencing the decision to use improved agricultural technologies in rural societies within an African context. This paper highlights the varying factors determining the decision to use inorganic fertilizer over a five year period, in a rural community in Malawi. During the study period (2004/05 to 2008/09) there were substantial changes in the rural livelihood economy in the study area, but also in the fertilizer policies in the country. At the community level, the implementation of agricultural research interventions that employ agricultural innovation systems concepts, have changed the way in which participating households interact with the market and the ways in which they utilize information and knowledge. This is because innovation systems approaches enhance the use of knowledge and information hence contributing towards greater adoption of improved technologies. In terms of fertilizer policy, the country has seen a shift from a targeted fertilizer input program in which only a few members of the rural community are targeted, to a universal fertilizer subsidy program for rural producers in which all rural households have an equal chance of benefiting. The use of innovation systems approaches in Malawi has the potential to therefore enhance the ability of rural beneficiaries to effectively use and utilize the available subsidized fertilizer thus improving their livelihoods This article will contribute towards greater understanding of the role and application of agricultural innovation systems concepts and the effects that their use has on decision making processes, and technology use at the household level in rural agrarian communities in Africa.

FERTILIZER USE AND DEBATES ON FERTILIZER SUBSIDIES IN MALAWI

Fertilizer use in Malawi is essential as the majority of smallholders farmers who are land constrained, have poor soils that are depleted of essential nutrients, especially nitrogen (Snapp, 1998). Although fertilizer is not the only determinant of improved agricultural productivity (Minde, Jayne, Crawford, Iriga, & Govereh, 2008), it is one of the key ingredients needed to boost agricultural productivity, and therefore economic growth. This is especially true for Malawi as which the majority of rural households cultivate maize. This is because maize productivity, in combination with sufficient water, labour and improved seeds, is determined by the levels of soil nutrients (Minde et al., 2008). Although fertilizer is widely used within the maize based farming system in Malawi, the country has been plagued by low incomes, chronic food shortages and decreasing agricultural productivity (Dorwarld et al., 2008). And because of this, a full input fertilizer subsidy was introduced for all smallholder subsistence maize producers and tobacco growers in the 2005/06 cropping season.

The reintroduction of the full fertilizer subsidy program in Malawi led to countless debates by agricultural pundits. Proponents of the subsidy program state that the resultant increased staple food commodity production has led to improved rural livelihoods (Department of International Development [DFID], 2007; Dorward, 2007). Skeptics, however, point out that the macroeconomic fall out and the budgetary implication of the input subsidy program far outweighs any livelihood improvements that may accrue to either producers or consumers (Morris *et al.*, 2007). Furthermore, the skeptics stipulate that any gains in livelihood outcomes are offset by decreased staple food commodity prices and the weakening and displacement of the private sector input markets and networks (Minde, Kelly, Kopicki, & Byerlee, 2008; Ricker-Gilbert & Jayne, 2008). In addition the program lacks a clear exit strategy to ensure financial manageability and easy political adjustment (World Bank, 2009).

Recent empirical evidence exists to support both of these arguments as some evidence exists which demonstrate that the subsidy program has led to improved livelihood outcomes and food security (Chirwa, 2010; Rickert-Gilbert & Jayne, 2008).

However, other evidence shows that the budgetary burdens of the input fertilizer subsidy program led to reductions in allocation of funding for other public activities (Dorward et al., 2008 cited by Minde et al., 2008, pp.9-10).

All the arguments pertaining to the reintroduction of the fertilizer subsidy in Malawi are unsubstantiated due to the lack of robust empirical evidence. Although numerous studies on the impacts of input subsidies have been previously conducted (Harrigan, 1988; Kherallah, Delgado, Gabre-Madhin, Minot, & Johnson, 2000; Minot, Kherallah, & Berry, 2000); the rural economy in which input subsidies are currently being implemented is far more complicated, and differs from the rural economy in which the majority of these studies were conducted. These changes are the result of many factors, but the most relevant is the prevailing agricultural research paradigm that is driven by innovation systems concepts, which is geared, at not merely bringing technologies to end users, but also ensuring that end users are part and parcel of the research process. In Africa, this has manifested itself in continent-wide agreed upon policies and practices which recognize the need to empower end users in the agricultural research process and to change both the practice of agricultural extension and research to make them less linear and more inclusive (Forum For Agricultural Research in Africa, 2009) As such end users have become more involved in problem identification, technology development, and are enabled to access and utilize knowledge and information more effectively. This is achieved by strategies, which include increasing a smallholder farmer's capacity to conduct research and on-farm experimentation, and linking them to input and output markets. This changes the dynamics of the complex rural household economy, as well as, household level thought processes and decision making. It leads to greater exposure and vulnerability of smallholder farmers to market forces and dependence on the market, for both incomes and staple food, thus making rural producers more vulnerable to macroeconomic shocks, changing the way in which fertilizer subsidies affect them.

STUDY METHODOLOGY

Study area and data collection

Primary data was collected from Katundulu, Mphamba and Kango communities in Ukwe Extension Planning Area (EPA) in Lilongwe Agriculture Development Division (LADD) in Lilongwe district in the Central region of Malawi. Katundulu and Mphamba villages are in communities where agricultural research interventions were implemented using Agricultural Innovation Systems concepts. Kango village is in a community in which Agricultural Innovation Systems concepts have never been used to implement any research interventions. Purposive random sampling was hence used to select a total of 100 farming households who had participated in the agricultural research intervention that was driven by agricultural innovation systems concepts from Katundulu and Mphamba villages; while simple random sampling was used to select 101 farming households from Kango village.

A semi-structured questionnaire was used to gather quantitative data pertaining to crop production and marketing; fertilizer use and perceptions of the fertilizer subsidy program; seed acquisition and costs; livestock ownership and marketing; labour availability; income sources; human capital; accessibility and availability of public capital; asset ownership as well as general household characteristics. A semi-structured questionnaire was used as it is an effective tool for minimizing bias and random error (Fowler, 1998).

Logistic regression model of fertilizer use

A logistic regression model of fertilizer use was estimated in order to determine the factors that determine fertilizer use in the study area. Separate models were estimated for a five year period from the 2004/05 cropping season to the 2008/09 cropping season. Fertilizer use was modeled as a dichotomous dependant variable taking the following form (Gujurati, 1992, p. 423):

$$\ln(P_i/1-P_i) = \beta_0 + \beta_1 X_1 + ... + \beta_{19} X_{19} + e$$

Where:

P_i	is the probability of using fertilizer (0= No did not use, 1= Yes, used fertilizer)
β_0	is the intercept
β_1 to β_{19}	are the parameter estimates
X_1 to X_{19}	are the independent variables
e	is the error term

Model estimation was influenced by the hypothesis that a households' decision to use or not to use inorganic fertilizer is influenced by three main underlying factors. These are the potential profitability to the household of using fertilizer, the willingness and the ability of the household to purchase fertilizer (Morris et al., 2007). According to Morris et al. (2007) a household's potential profitability from using fertilizer is determined by the responsiveness of the crop on which fertilizer is applied, the prices of fertilizer on the market, and the prices of both substitutes and complements as well as the output prices. Furthermore, the ability of a household to purchase fertilizer is determined by the household's purchasing power which is determined by different factors, including the availability of cash or credit and the proximity of the household to the point of sale of fertilizer and access to subsidized fertilizer.

Lastly, the willingness of a household to purchase fertilizer is determined by the household's perceptions of profitability, and this is shaped by the household's level of knowledge and skills of fertilizer technologies and their capacity to evaluate the potential gains from fertilizer use. Thus, participation in agricultural research interventions that are driven by innovation systems concepts has been included in the model, as it enhances the use of knowledge and contributes towards increasing adoption of technologies. This is because interventions driven by innovation systems concepts bridge farmers information and skills gaps which constraint adoption and effective utilization of improved technologies (Rajalahti, 2009).

Hence, the following variables, participation in innovation system interventions, and other additional independent variables were included in modeling fertilizer determinants in this study, as they shape and affect either positively or negatively a household's willingness and ability to buy fertilizer as well as the potential profitability of using inorganic fertilizer:

X_1 = Sex of the household head (0= male, 1= female)

X_2 = Age of the household head (years)

X_3 = Age of the spouse (years)

X_4 = Educational attainment of the household head (years of schooling)

X_5 = Educational attainment of the spouse (years of schooling)

X_6 = Household size (number of people residing in household)

X_7 = Frequency of contact with extension agent (0=low, 1=medium, 2=high)

X_8 = Ownership of a wetland (0= no wetland, 1= yes, owns a wetland)

X_9 = Total farm size (hectares)

X_{10} = Number of separate farm plots owned by household)

X_{11} = Ownership of livestock (0= no livestock 1= yes, owns livestock)

X_{12} = Access to credit (0=no access to credit, 1= yes, has access to credit)

X_{13} = Type of household (0= resource constrained, 1= intermediate resource endowed household 2=high resource endowed household)

X_{14} = Access to coupons for subsidized fertilizer (0= no, did not receive coupon, 1= yes, received coupon)

X_{15} = Distance to nearest Tarmac road (kilometers)

X_{16} = Participation in innovation intervention (0= no participation, 1= yes, participated)

X_{17} = Membership into a farmer group (0= no membership, 1=yes, at least one household member has membership in one farmer group)

X_{18} = Access to remittances (0= no, did not receive remittances 1= yes, receives remittances)

X_{19} = Engagement in another occupation (0= no other occupation, 1= yes, other occupation apart from farming

SOCIO-ECONOMIC CHARACTERIZATION OF SAMPLED HOUSEHOLDS

This section presents the characteristics of sampled households pertaining to farming, fertilizer use patterns and human capital for greater contextual understanding of the study area and the results of the logistic model of fertilizer use.

Farming characteristics

All sampled households in the study area are in a maize based farming system, in which maize is grown as the main food crop in combination with different legumes and cash crops. Crops grown in the study area with maize included groundnuts (*Apios Americana*), beans (*Phaseolus vulgaris*), sweet potatoes (*Ipomoea batatas*), soy bean (*Glycine max*) and cow peas (*Vigna unguiculata*). Tobacco was found to be the only non-edible cash crop cultivated in the area. Other cash crops that are widely cultivated in other parts of the country, such as cotton and paprika, were not found in the study area. The study further found that the majority of households (58.3%) owned livestock, such as pigs, chickens and goats. Other livestock owned by the households in smaller numbers included draught animals, such as oxen and donkeys; other types of poultry, such as ducks, guinea fowls and turkeys; and other livestock, such as sheep, dairy cattle, rabbits, and hamsters.

Table 1: Farming characteristics of sampled households

Farming characteristics			
	Intervention	**Counterfactual**	**F-Value**
Average number of separate farm plots	3.1	2.2	0.217***
Average land holding size (ha)	1.72	1.23	0.218**
% of households with a wetland	94.1	56.4	304.1***
% of household owning livestock	85.0	42.6	15.33**
% of households receiving remittances	13.9	10.9	1.641
% of households who have access to credit	12.9	7.9	5.412

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level

From Table 1 above, it can be seen that on average households in the intervention had more access to farm land than households in the counterfactual. This is demonstrated by statistically significant differences in the land holding size, the number of separate farm plots and the ownership of a wetland for winter cultivation between the intervention and counterfactual. On average, the intervention had more separate farm plots (3.1) and more households owning a wetland (94.1%) as opposed to the counterfactual where households had fewer numbers of separate farm plots (2.2) and fewer numbers of households owning a wetland (56.4%). Differences in accessing credit and remittances were not statistically significant between the two communities.

Fertilizer use patterns

The majority of households in the intervention use inorganic fertilizers on their farms as compared to the households in the counterfactual. Seen in Table 2 below, the differences between households using and not using inorganic fertilizer are highly statistically significant for the 2004/05, 2005/06 and 2006/07 agricultural seasons but less significant for the 2007/08 and 2008/09 agricultural season. For the intervention, at least 60% of all households have been using inorganic fertilizers on an annual basis since the 2004/05 season. In the counterfactual, it is only in the 2007/08 agricultural season that the percentage of household using inorganic fertilizers neared 60%.

Table 2: Fertilizer use patterns amongst sampled households

Fertilizer use patterns			
	Intervention	**Counterfactual**	**F-Value**
% of household using fertilizer in 2004/05	59.0	31.7	6.97***
% of household using fertilizer in 2005/06	68.0	36.6	4.065***
% of household using fertilizer in 2006/07	72.0	45.5	21.00***
% of household using fertilizer in 2007/08	80.0	58.4	42.60**
% of household using fertilizer in 2008/09	83.0	69.3	21.95*

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level

Further analysis shows that the amount of inorganic fertilizer applied by households in the intervention and those in the counterfactual differed significantly in the 2004/05, 2005/06 and 2006/07 agricultural seasons at the 1%, 5% and 10% confidence levels respectively. Table 3 below further shows that in more recent years the differences in the amounts of inorganic fertilizers applied in the 2007/08 and 2008/09 cropping seasons are non-significant between the intervention and counterfactual.

Table 3: Impact of the ERI intervention on fertilizer use patterns

Fertilizer use patterns (no. of 50kg bags)	Intervention		Counterfactual		Effect
	Mean	Standard Deviation	Mean	Standard Deviation	
2004/05	1.24	1.85	0.567	1.55	0.679***
2005/06	1.38	1.87	0.624	1.12	0.761**
2006/07	1.50	1.88	0.858	1.38	0.644*
2007/08	1.68	1.97	1.38	3.39	0.297
2008/09	1.95	2.49	1.77	6.18	0.171

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level

This can be attributed to the increased availability of fertilizer due to the implementation of the full fertilizer subsidy program in the country. The implementation of a subsidy for fertilizer increased the availability and accessibility of inorganic fertilizer throughout the rural areas of the country hence increasing the opportunity for all farmers to access inorganic fertilizer

Human capital characteristics

Further analysis demonstrates that there are more household heads in the intervention community with some level of formal education (84.2%) than in the counterfactual (74.5%) and this difference is statistically significant. The differences in the level of educational attainment of the spouses in the two communities were however found to be insignificant (Table 4).

The majority of households in the counterfactual (81.2%) stated that they had frequent contact with a public extension agent as compared to households in the intervention (52.6%) and this difference was found to be highly statistically significant. This was the case, despite the fact that on average counterfactual households were significantly further from the extension officers' houses and offices (20 km), as compared to the intervention households (7.5 km). The differences in the average distances from the extension officer's house and office between the intervention and counterfactual were statistically significant, implying that intervention households were in general much closer to an extension officer's house or office compared to any household in the counterfactual.

Table 4: Human capital characteristics of sampled households

Human capital characteristics			
	Intervention	**Counterfactual**	**F-Value**
% of household head with some formal education	84.2	75.8	3.12*
% of spouses with some formal education	74.4	80.5	1.27
% of respondents who have contact with extension agent at least once a year	52.6	81.2	21.78***
Average distance from extension office/house in km	7.5	20	403.7***
% of households that are members of more than one farmer group	5.9	4.0	1.683
% of household heads that are members of farmer groups	26.7	27.7	1.100
% of spouses that are members of farmer groups	6.3	4.5	3.86

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level

In addition it can be seen that there is no statistically significant differences between the counterfactual and intervention in terms of membership into farmer groups for either the household heads or the spouses.

RESULTS OF THE LOGISTIC REGRESSION MODEL OF FERTILIZER USE

The estimated logistic regression models for the 2004/05 and 2005/06 cropping seasons correctly predicted 52.7% and 53.3% of the variation in the model of fertilizer use in the study area. In the 2006/07, 2007/08 and 2008/09 cropping seasons, the estimated logistic models correctly predicted 65.3%, 72.5% and 79.6% of the variation in fertilizer use in the study area. The robustness of the last three models can be attributed to that respondents were better able to recall information from these cropping seasons than from the first two cropping seasons as the information is not recorded, but recalled from memory. Hence, the lack of accuracy of information from past cropping seasons was a factor that reduced the robustness of the estimated models, and therefore its predictive abilities. All the models estimated are, however, good estimates of fertilizer use for each of the cropping seasons under study as the chi-square static for each of the estimated models is highly statistically significant at the 1% confidence level and the Hosmer-Lemeshow (H-L) static for each of the models is above 0.05 and shows non-significance.

Table 5 below presents the results of the five logistic regression models estimated for the five cropping seasons. The odds ratio provides the probability of a household using fertilizer over the probability of not using fertilizer in a given cropping season. From the estimated model for the 2004/05 season, it can be seen that the number of separate farm plots, access to credit, distance from the tarmac road and access to a fertilizer package under the targeted input program were factors that were found to significantly influence the use of inorganic fertilizers.

In addition, the odds in favor of using inorganic fertilizer increased by a factor of 1.529 for farmers who had more separate farm plots; it increased by 3.139 for farmers who had access to credit, and it increased by 2.016 for farmers who lived closer to a tarmac road. Access to a fertilizer package from the targeted input program was, however, by far the most important factor in positively influencing fertilizer use as it increased the odds of using fertilizer by a factor of 7.467 in the 2004/05 season. Further analysis, however, shows an unexpected result, in that participation in an agricultural research intervention that used innovation systems concepts reduced the probability of using fertilizer in the 2004/05 season.

In the 2005/06 cropping season educational attainment of the spouse, the land holding size and access to credit were found to significantly influence fertilizer use. Access to a coupon for subsided fertilizer was found to be highly significant in influencing fertilizer use. The odds in favor of using fertilizer increased by 1.776 for households with spouses that had higher levels of education; increased by 1.421 for households with larger land holdings; and increased by 3.927 for households that had access to credit. Access to a coupon for subsidized fertilizer increased the odds of using fertilizer in the 2005/06 cropping by a factor of 15.8862 for households that had access to a coupon.

Table 5: Results of the logistic regression model of the determinants of fertilizer use

Explanatory variables	Agricultural Cropping season 2004/05 β	Std. Error	Odds ratio	2005/06 B	Std. Error	Odds ratio	2006/07 B	Std. Error	Odds ratio
Constant	-6.457	6.025		-5.779	6.813		-8.471	2.651**	.000
Sex_HHead	-1.329	2.831		-1.140	3.167				
Age_HHead	.036	.032		.034	.034				
Age_spouse	-.007	.037		-.027	.040		.053	.022*	1.055
Edu_spouse	.326	.213		.574	.263*	1.776	.566	.260*	1.761
Edu_HHhead				.079	.179				
HH_size	.153	.107		.103	.109		.058	.113	
Ext_contact	.124	.118					.079	.123	
Own_wetland	.677	.654		-.487	.653		.273	.613	
No_Plots	.425	.235*	1.529				.659	.278*	1.932
Farm_size	.122	.110		.351	.150*	1.421	.148	.132	
Own_LVK	.626	.477		-.080	.234		-.122	.234	
Credit	1.144	.685*	3.139	1.368	.792*	3.927	1.114	.839	
Type_HH	-.369	.369		-.370	.443		-2.259	.415	
Access_Coupn	2.010	.459***	7.467	2.764	.516***	15.862	2.291	.498***	9.888
Dist_Tarmac	.701	.325*	2.016	.541	.389		.658	.504	
Part_Intervention	-17.46	8.232*	.000	-12.576	9.817		-16.225	12.690	
Member_FO				.209	.530		-.227	.568	
Remittances	-.718	.657					.355	.781	
Other_occup							-.305	.474	
Model Chi-Square		73.74***			96.30***			74.28***	
H-L Chi-Square		13.306	ρ=.106		12.974	ρ=.113		6.567	ρ=.584
Nagelkerke R-Square		0.48			0.58			0.49	
Log Likelihood		158.75			140.03			142.31	
% corrected predicted		52.7			53.3			65.3	

Explanatory variables	Agricultural Cropping season 2007/08 β	Std. Error	Odds ratio	2008/09 β	Std. Error	Odds ratio
Constant	-8.320	3.56*	.000	-3.538	2.834	
Sex_HHead						
Age_HHead	-.044	.042				
Age_spouse	.060	.050		.017	.023	
Edu_spouse				-.105	.276	
Edu_HHhead	.315	.249		.131	.220	
HH_size				-.158	.129	
Ext_contact	.104	.138		-.154	.151	
Own_wetland	-.772	.686		.284	.657	
No_Plots	.416	.321		.495	.290*	1.641
Farm_size	.135	.140				
Own_LVK	.962	.573*	2.618	1.506	.562**	4.508
Credit	.826	.895		1.096	.986	
Type_HH	-.670	.527		-.175	.473	
Access_Coupn	2.952	.569***	19.139	2.093	.526***	8.113
Dist_Tarmac	1.478	.704*	4.384	.644	.544	
Part_Intervention	-36.967	17.671*	.000	-16.986	13.785	
Member_FO	-1.626	.682*	.197	-.909	.649	
Remittances	-1.121	.784		1.619	1.19	
Other_occup	.683	.581		-.351	.532	
Model Chi-Square		85.1***			55.92***	
H-L Chi-Square		9.194	ρ=.326		4.613	ρ=.718
Nagelkerke R-Square		0.58			0.45	
Log Likelihood		11.51			112.70	
% corrected predicted		72.5			79.60	

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level

For the 2006/07 cropping season, the model results show that the educational attainments of both the household head and spouse and the number of separate farming plots were statistically significant in influencing use of fertilizer. The odds of using fertilizer in the 2006/07 cropping season increased by a factor of 1.055 for households with heads who had higher education and by 1.761 for households in which the spouse had higher educational attainment. While fertilizer use increased by a factor of 1.932 in households with more separate plots of farm land. Access to subsidized coupons was further found to be highly statistically significant in positively influencing fertilizer use. And the odds of using fertilizer increased by a factor of 9.888 in households who accessed coupons for subsidized fertilizer in the 2006/07 cropping season.

In the 2007/08 cropping season, the results show that the ownership of livestock and the proximity to a tarred road were found to be positive and significant factors influencing fertilizer use. The odds of using fertilizer increased by a factor of 2.618 for households owing some form of livestock and by a factor of 4.384 for households who were closer to a tarred road. The results also indicate that access to coupons for subsidized fertilizer positively impacted upon fertilizer use the most with the odds of using fertilizer increasing by a factor of 19.139 for households that received a coupon. Further analysis shows that participation in the innovation intervention had a negative effect on the probability of fertilizer use implying that households that had participated in the innovation intervention were less likely to use inorganic fertilizer in the 2007/08 cropping season. From the statistical analysis it was found that participation in the innovation intervention increased farmers membership into farmer groups, hence, it is not surprising to find that membership into a farmer group in the 2007/08 cropping season also negatively affected use of inorganic fertilizer, but the effect was weak.

In the 2008/09 cropping season, the results show that the factors that impacted the use of fertilizer were the number of separate farm plots and the ownership of livestock, while access to a coupon for subsidized fertilizer was found to be a very significant factor influencing fertilizer use. The implications were that households with more separate farm plots increased their odds of using fertilizer by a factor of 1.641, while the odds of fertilizer use increased by a factor of 4.508 for households owing livestock. Receiving a coupon for subsidized fertilizer was once again found to be the greatest factor influencing fertilizer use in the 2008/09 season, as it increased the odds of fertilizer use by a factor of 8.113.

DISCUSSIONS OF THE DETERMINANTS OF FERTILIZER USE

In the last five cropping seasons, the most important factor that has positively influenced fertilizer use has been the accessibility to a coupon for subsidized fertilizer as evidenced by it being found as a very significant factor in each of the cropping seasons. This implies that households who received a coupon for subsidized fertilizer were more likely to use fertilizer than other households. Further analysis shows that the marginal effect of the use of coupons as a modality of subsidizing fertilizers for rural farmers was higher in comparison to the use of a targeted program as evidenced by the lower impact factor of the targeted program in the 2004/05 season.

The second most significant determinant of fertilizer use in the study area in the last five cropping seasons was the number of separate farm plots, as it has been found to be significant in three of the five cropping seasons. Informal interviews in the community revealed that households with more separate farm plots made more efforts to ensure that they used inorganic fertilizer in each of the separate plots that they owned. So in the long term, households with more fragmented pieces of land tended to put more effort into sourcing and using inorganic fertilizer. This was also the case for households whose land holding size when aggregated was smaller than households who had larger but more aggregated land holdings. In relation to the number of separate plots, the study finds that farm size was found to only be a significant determinant of fertilizer use in the 2005/06 cropping season and its effect in that particular cropping season was weak. This agrees with other empirical evidence which shows that the farm size does not have an effect on the probability of using fertilizer (Minot, Kherallah, & Berry, 2000) and in some instances households with small land holdings are more likely to use fertilizer than households with relatively larger land holdings (Aklilu, 1980, p. 395).

Access to credit was found to positively influence the decision to use fertilizer in the 2004/05 cropping season and 2005/06. In 2004/05 the input fertilizer subsidy program had not been universal for all rural producers, but was targeted to only productive farmers. Hence, in this cropping season, the majority of rural producers had to source fertilizer on their own. The 2005/06 cropping season was the first season in which a universal subsidy program for all rural producers was introduced. And because of this the majority of farmers still depended on credit in order to purchase fertilizer. In subsequent years, the importance of credit in the acquisition and use of inorganic fertilizer may have been offset by the high level of dependency that the full input fertilizer subsidy program created. In addition the creation of a parallel market in the rural areas fuelled by the implementation of the full fertilizer subsidy program in the 2005/06 season increased the availability of lower priced fertilizer. This parallel market was created as some beneficiaries of the fertilizer subsidy program sold their coupons to business men who engage in selling the subsidized fertilizer, which is obtained with the coupons bought from the beneficiaries at price that is higher than the subsidized fertilizer price, but lower than the prevailing fertilizer market prices.

Two factors were found to reduce the probability of fertilizer use; the membership into a farmer group and participation in the innovation intervention. Membership into a farmer group was found to reduce the likelihood of using fertilizer in the 2007/08 cropping season, but the effect was relatively weak. This finding was surprising as both theory and empirical evidence has shown that membership in farmer groups increases the probability of fertilizer use (Minot et al., 2000) as farmer groups are the main mechanism through which credit is accessed in rural areas where farmers have no other forms of collateral. However, there are other empirical studies that show that membership in farmer groups' decreases the probability of using inorganic fertilizer (Makokha, Kimani, Mwangi, Verkuiji, & Musembi, 2001).

Participation in the innovation intervention was found to significantly reduce fertilizer use in the 2004/05 and 2007/08 cropping seasons. This can be attributed to two factors. Firstly, the targeted input program in the 2004/05 cropping season and the full fertilizer subsidy program in the 2007/08 cropping season used local community and traditional leaders to select recipients for both the input programs based on perceived production capacities and welfare considerations. Farmers engaging in an intervention were therefore considered better off as they were seen to be benefiting from participation in the innovation intervention, and hence would not be as readily selected for the targeted input program or for receiving a coupon for subsidized fertilizer. Studies conducted in Malawi of the input fertilizer subsidy program by Ricker-Gilbert & Jayne (2008) have demonstrated that wealth and social networks were important factors that determined who received subsidized fertilizer. This implies that benefiting from the fertilizer input program in any of these cropping seasons was subjective and therefore inherently biased. Secondly, the Enabling Rural Innovation (ERI) intervention, in which participating households in this study engaged in, promoted livestock production and as such households had access to animal manure which they could use as an alternative to inorganic fertilizer (Bacha, Aboma, Abdissa, & De Grotte, 2001). And it is this that could explain the reason that livestock ownership is insignificant for the 2004/05, 2005/06 and 2006/07 years. It is only in the last two cropping seasons (2007/08 and 2008/09) that livestock ownership has a significant impact on fertilizer use. This implies that households with livestock were more likely to use inorganic fertilizer in the last two cropping seasons in comparison to households without livestock.

CONCLUSION AND RECOMMENDATIONS

The econometric analysis from this study has revealed that participation in an agricultural research intervention that uses innovation systems concepts and membership in farmer groups, were negatively and significantly related to fertilizer use in some cropping seasons and insignificant in others. For those years in which a negative and significant effect was found, the implications are that participating households were more likely to be discriminated against from benefiting in the fertilizer subsidy program as the distribution of vouchers for subsidized fertilizer was handled by community and traditional leaders who would discriminate against households who were deemed relatively better off and who were seen to be benefiting from other social programs in the community.

.In addition, other variables that had the potential to impact upon access to capital for purchasing fertilizer were found to be insignificant in the majority of the cropping seasons in determining fertilizer use. The implications are that other confounding factors such as accessibility and availability of fertilizer in the community may have the potential to offset the positive effects that capital has on fertilizer use. Access to credit however was found to have a strong and positive effect on fertilizer use in some cropping seasons. Implying that, households that had access to credit were more likely to use fertilizer than households that did not have access to credit.

Policy recommendations show there is the need to restructure the way in which beneficiaries of the input fertilizer subsidy program in Malawi are selected, and to consider using methods that would randomize the distribution of vouchers as this would eliminate bias thus ensuring that all eligible beneficiaries have an equal chance of benefiting from the fertilizer subsidy program. Secondly, there is the need to strengthen existing rural credit facilities as a strong and effective credit system for fertilizer maybe the only credible and feasible long term exit strategy from the input fertilizer subsidy program for Malawi. Further recommendations are that similar studies should be conducted to access the role of agricultural research interventions that are driven by agricultural innovation systems concepts in the use and adoption of other improved agricultural technologies in rural communities, in order to generate credible evidence on which effective rural development policies and agricultural research programs can be based.

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