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*Full Length Research Paper*

# Factors responsible for differences in uptake of integrated soil fertility management practices amongst smallholders in western Kenya

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**To address soil fertility depletion and the attendant low agricultural productivity in western Kenya, many attempts have been made to develop and popularize integrated soil nutrient management (INM) practices. Adoption of INM practices appears to be an appropriate strategy for restoring soil fertility, yet patterns of adoption and factors influencing the adoption process are not clearly understood. This paper evaluated adoption patterns of INM components and investigated factors that determine the adoption patterns. Data were collected from a random sample of 331 households in western Kenya using a questionnaire and analysed by descriptive statistics and binary logit model. Results show that animal manure was the most widely applied soil management practice. About 25% of the households applied combinations of organic and inorganic inputs. Determinants of the adoption of INM practices varied by the INM practices surveyed. However, education level of household head, livestock units and the district where the farm is located had statistically significant positive effects on integrated use of organic and inorganic inputs, whilst land per capita had a significant negative effect. Targeting different INM components to the farmers and areas with suitable characteristics is recommended to spur adoption of INM practices.**

**Key words:** Adoption, soil fertility, integrated soil fertility management.

## INTRODUCTION

Smallholder farming in Kenya is mainly constrained by widespread soil nutrient mining, which undermines the ability of many agrarian households to produce enough food for household subsistence needs and surplus for income generation, resulting in burgeoning poverty among most rural households (Jama et al., 1999; Marenya and Barret, 2007). The concern for soil nutrient mining and the attendant declining productivity has led to many attempts in the past two decades to develop, test, and popularize several soil fertility management technologies that could restore soil fertility and improve productivity in western Kenya, particularly in Vihiga and Siaya Districts.

These attempts have been carried out through collaboration of several research and development institutions (ICRAF, 1996; Rao et al., 1998). Much emphasis has been placed on integrated soil fertility management (ISFM) approaches. ISFM refers to making best use of inherent soil nutrient stocks, locally available soil amendments, and inorganic fertilizers to increase land productivity, whilst maintaining and enhancing soil fertility and improving efficiency of nutrient and water use (Vanlauwe, 2004; Maatman et al., 2007). Integrated Nutrient management (INM), which is the technical backbone of ISFM and the focus of this study, entails combined use of organic and inorganic sources of plant nutrients (Vanlauwe, 2004; Chianu and Tsujii, 2005).

The rationale behind INM is that it enables farmers to manipulate the organic and inorganic nutrient stocks judi-

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ciously and efficiently to save nutrients from being lost or to add nutrients to the farming systems (Chianu and Tsujii, 2005) for sustainable soil fertility management and agricultural productivity (Vanlauwe, 2004). INM is a package with several components such as inorganic fertilizers, animal manure, crop residues, crop rotation, compost and green manures (Vanlauwe, 2004; ICRAF, 1996).

It is important to note that inorganic fertilizer is at the centre of any efforts meant to resuscitate agricultural productivity in western Kenya. This is based on the argument that strategies that promote organic 'best-bet' options without integration with inorganic fertilizers are unlikely to succeed under smallholder farming systems in western Kenya because of the low effect of organic fertilizers on the inherently low soil fertility levels (Jama et al., 1999; Vanlauwe, 2004). Therefore, the adoption question hinges on factors affecting adoption of a combination of inorganic and organic inputs.

Adoption of INM practices appears to be an appropriate strategy for restoring soil fertility in western Kenya. Despite the many factors that influence technology adoption (Feder et al., 1985; Kaliba et al., 2000), much research on soil management has focussed on technical aspects of soil management without consideration of determinants of the adoption process, which are important in guiding technical research. Moreover, adoption studies on soil fertility management have mainly focused on adoption of a single technology (Franzel, 1999; Kiptot et al., 2007). A few studies have analysed uptake of more than one technology (Odendo et al., 2004; Marenya and Barret, 2007). However, the analytical methods applied have not explicitly permitted analysis of determinants of integrated uptake of organic and inorganic inputs. Thus, levels of adoption of INM components either singly or in combination are not known and determinants of the adoption are not clearly understood. The current study was intended to fill this gap by assessing adoption levels of INM components either singly or combined use of organic and inorganic resources; and investigating factors that determine the adoption patterns. The findings of this study are expected to contribute to refinement of existing adoption theories, learning new lessons and charting new directions for future research and development strategies to facilitate wide adoption of INM practices

## METHODOLOGY

### The study area

Data for this study were obtained through a survey conducted in Vihiga and Siaya districts between January and August, 2007. The study districts were selected because both experience low soil fertility, high poverty levels and INM technology was introduced in both districts. In contrast, Vihiga district falls in a relatively higher agricultural potential area and has higher human population density than Siaya district.

Most of the study areas lie in the medium elevation of 1,100 - 1,600 meters above sea level (masl). The area receives annual rainfall ranging between 1,200 and 1,800 millimetres, which permit two growing seasons. Thus, much of western Kenya is considered to have good potential for agriculture.

Farming is the main economic activity and is characterized by low external input-low output agriculture. The farming system incorporates crops and livestock. Maize and beans are the most common crops in both districts (Jaetzold et al., 2005). Past studies found that soil nutrient balances are seriously in deficit (Smaling et al., 1993). With declining soil fertility and a build up of Striga *hermonthica,* a parasitic weed of many cereals, the net effect has been decline in land productivity and food shortages in a region which has the potential to produce enough food for its increasing local population. The yields of most crops are between two and five times lower than what is potentially realizable. The yield of maize, the staple food crop, for example, is generally less than 1 t ha$^{-1}$ in a season (Jaetzold et al., 2005) compared to 6 t ha$^{-1}$ recorded from on-farm research trials (KARI, 2005). Thus, innovative enhancement of soil fertility is an impetus for improved agricultural productivity and poverty alleviation in western Kenya.

### Sampling design and data collection

To achieve a fair representation of the study population in the districts, each of the survey districts was stratified on the basis of agro- ecological zones as defined by Jaetzold and Schmidt (1983). One stratum comprised the high agricultural potential area ($UM_1$) in Vihiga district and the second one consisted of low potential ($LM_1$ to $LM_3$) in Siaya district. In the first stage, all sub-locations in each stratum were listed as per the 1999 population census (CBS, 2001) and formed the sampling frame from which 25 sub-locations were selected. In the second stage, lists specifying all households in each selected sub-location were constructed with the help of local administrators, from which between 12 and 14 households were selected per sub-location by simple random sampling. In sum 331 households were sampled and interviewed.

The survey was done in two stages. In the first stage, group discussions, key informant interviews, and field observations were used to obtain background information on the farming systems and adoption of soil management practices using a checklist. This information was used to design a structured questionnaire, which was pre-tested and used for collection of quantitative data from the sampled households during the second stage of the survey. A team of five enumerators who had earlier been trained on survey methods and questionnaire administration collected the data through face-to-face interviews. Either the heads of the selected households who are the implicit decision makers or in their absence, household members responsible for the farm management were interviewed. The questionnaire covered a wide range of issues, including personal characteristics of the household head, resource endowments of the households and farm management practices, especially adoption of soil fertility management technologies. The other data included information on access to different institutions to improve agriculture such as agricultural extension service, markets and credit, membership in local groups and organizations, and attitudes towards efficacy of selected soil management practices on improving crop productivity.

### Analytical framework

The analytical framework for adoption of a technology is built on assumption that the expected utility would be maximized if the technology is adopted, that is, if the probability of adoption were one (Rahm and Huffman, 1984). We assume that a household will adopt an INM practice singly or in combinations if the expected value of benefits from using the technology exceeds the expected value of benefits from use of current practices or not using it. Benefits are used here instead of profitability because farmers in western Kenya base their decisions on more than monetary expectations. In addition to profitability, which is affected by changes in yields and input use, other benefits may include increased productivity, food self-sufficiency and improvements to the environment.

We further assumed that a household facing technology alternatives maximizes the expected utility (U) derived from the choice made. If $U^1$ is defined as the situation where the individual chooses the technology and $U^0$ otherwise, then it follows that adoption only occurs if $U^1 > U^0$. Thus, when a household adopts a technology, it indicates that the expected net benefit is greater than zero.

Three statistical functional forms are available for analyzing binary choice problems such as to adopt or not adopt a technology. These are linear probability model (LPM), logit and probit models. LPM is popular because it is theoretically simple, thus without theoretical guidance to the contrary, researchers prefer assuming the simplest case (Aldrich and Nelson, 1984). The LPM typically uses the Ordi-nary Least Squares (OLS) estimator for making predictions. It is therefore unsuitable for limited dependent variable adoption studies in that the assumption that the error term is normally distributed does not hold for such regressions because it is impossible to have a normal distribution with limited values of the dependent variable (Maddala, 1993). In addition, OLS estimates can produce predic-tions that can lie outside the [0, 1] range imposed by the laws of probability. In dichotomous choice adoption models the predictions cannot be interpreted as probabilities (Aldrich and Nelson, 1984).

As an alternative, logit and probit models are generally used to analyse adoption studies where the dependent variable can take on a number of discrete values within utility maximization framework (Agresti, 1996; Tiwari et al. 2008). These models use the maximum likelihood estimation (MLE) procedures to give unbiased and efficient estimates of the probability that the dependent variable will take on the discrete or dichotomous values. Generally, MLE finds the function that maximizes the ability to predict the probability of the dependent variable based on what is known about the independent variables (Amemiya, 1981).

Amemiya (1981) and Agresti (1996) identify difficulties involved in selecting between probit and logit models because of statistical similarities between the two models, except that the probit model assumes a normal cumulative distribution function (thus has fatter tails) while the logit model assumes a logistic distribution of the dependent variable. Therefore, the choice between the two models revolves around convenience such as availability and flexibility of com-puter programmes as well as personal preferences and experiences. For this study, logit model was used because the dependent varia-bles (adopt or not-adopt) are dichotomous and independent variables are continuous, categorical and dummy. Moreover, logit model is computationally simpler.

Following (Agresti, 1996), the functional form of logit model was specified as:

$$In[P_x/(1-P_x)] = {}_0 + {}_i X_i + {}_2 X_2 + \ldots\ldots\ldots\ldots\ldots\ldots {}_k X_{ki}$$

Where the subscript i is the $i^{th}$ observation in the sample, Px is the probability of an event occurring for an observed set of variables $X_i$, that is, the probability that the farmer adopts an INM practice and (1-Px) is the probability of non-adoption. $\beta_o$ is the intercept term, and $\beta_1$, $\beta_2$ ……$\beta_k$ are the coefficients of the independent variables $X_1$, $X_2$...….......$X_k$. For this study, an adopter was defined as a household that had applied an $i^{th}$ INM practice either singly or organic/inorganic combinations at least once before 2006 long rain season and again applied the same during the 2006 long rain season. This was to avoid including households that were trying the practice for the first time as adopters. The dependent variables for the adoption models were, thus dummies indexing whether or not a household has adopted any component of INM or combination of organic and inorganic components.

The choice of appropriate independent variables to reflect the complex farm household adoption decisions is problematic. This is because there is no firm economic theory that dictates the choice of independent variables in adoption studies. Therefore, the choice of independent variables for the empirical model was informed by working hypotheses suggested by general economic theory and empirical findings from similar studies. The specific variables hypothesised to influence the probability of adoption of INM practices are outlined in Table 1 and their expected direction of influence briefly discussed below. The models were estimated by a maximum likelihood method using Statistical/Data analysis (STATA) computer software (Statacorp, 2007).

Farmer perception was constructed as a scale variable to reflect severity of the problem. The use of scale is more informative than dummies often used in previous studies as severity of the problem is likely to induce actions taken to alleviate it. Studies have shown that higher perception of soil erosion is associated with adoption of soil conservation practices (Shiferaw and Holden, 1998). It was, thus hypothesized that since most households rely on agriculture for their livelihoods, the extent of farmer's perception of severity of the problem would positively correlate with the adoption of inorganic fertilizers and a combination of inorganic and organic fertilizers as a quick solution to the problem.

Education level of the household head (Educ) was measured as years of formal schooling. It is often believed that higher education gives farmers the ability to perceive, interpret and respond to new information much faster than their counterparts with lower education (Rahm and Huffman, 1984; Feder et al. 1985). Because, adoption of compost and combined use of organic and inorganic soil nutrient inputs are knowledge-intensive, requiring understanding of types and quantities of different fertilizers to be combined and the procedures for proper preparation of composts, higher education is expected to have positive effect s on the adoption of these technologies.

Effect of the age of the household head (Age) in explaining technology adoption is somewhat controversial in the literature and is often an empirical question (Gould et al., 1989; Mbaga-Semgalawe and Folmer, 2000) . Older farmers, perhaps because of investing several years in a particular practice, may not want to jeopardize themselves by trying out a completely new method (Khanna, 2001). The use of inorganic fertilizers and combination of organic and inorganic fertilizers is a relatively new practice compared to manure. Age of the household head is, thus expected to be negatively associated with the adoptions. However age is expected to be positively correlated with the relatively traditional practices such as manure, which farmers are used to.

Gender of household head (Gender) is a dummy variable indexing the sex of the household head who is the implicit key decision–maker for the household. Empirical evidence shows that male-headed households in the developing countries have a higher access to resources and information that give them greater capacity to adopt technologies (Kaliba et al., 2000). Thus, male-headed households are expected to have higher probability of the adoption of inorganic fertilizers and combinations than women because of their high likelihood of access to requisite resources and information.

Farm per capita (Farmpersn) has been used in a number of analyses as a proxy for population pressure and has been shown to have mixed effect on technology adoption (Shiferaw and Holden, 1998; Alene et al., 2008).The effect of farm per capita on probability

**Table 1.** Explanatory variables for logit models.

| Variable | Description and units of measurement |
|---|---|
| Percpn | Perception of extent of soil depletion (0 = no problem 3 = very severe). |
| Educ | Years of schooling of household head |
| Age | Age of household head (years) |
| Gender | 1 = male headed household (dummy ) |
| Fampersn | Farm size per man equivalent (hectare/person) |
| TLU[a] | Tropical Livestock Units |
| Offincome | 1 = Off-farm income is main source of income (dummy) |
| Labour | Ratio of farm worker to household size |
| Food | 1 = Sufficient in own food for more than 6 months/year in past 2 years |
| District | 1 = Farm located in Vihiga district (dummy) |
| Distomkt | Distance from homestead (km) major market (km) |
| Grpmemb | 1 = Household member belonged to group (dummy) |
| Grphetro | Heterogeneity of the three most important groups (%) |
| Extensn | 1 = household had any agricultural assistance within 5 years prior to this study |

[a]One adult cattle or equivalent = 0.7 TLU, one goat or sheep = 0.1 TLU and one calf = 0.4 (Jahanke, 1982).

of adoption is, thus difficult to determine a priori.

The number of Tropical Livestock Units (TLU) is a proxy for wealth and assumed to increase availability of manure for application to the soil (Marenya and Barret, 2007). With increased manure availability, it is hypothesized that TLU has positive effect on the adoption of manure and its integration with inorganic fertilizers.

Access to off- farm income (Officome) is a dummy variable that denotes whether or not off- farm income was the main source during two crop growing seasons prior to 2006 long rain season. Because all the surveyed inputs either require cash for purchase or for hiring labour to apply the inputs, it was hypothesized that off-farm income would be positively associated with the adoption of inorganic fertilizers, manure, compost and their combinations.

Self-sufficiency in own food for more than half of the year (Food) is hypothesized to be positively associated with the adoption of all the studied practices. Without application of soil nutrients, a household in western Kenya is unlikely to be food self-sufficient due to low soil fertility on their farms. Thus, households that are food secure are likely have financial resources to purchase the requisite inputs.

Labour availability (Labour) was measured as the proportion of household members who contribute to farm work. The practices studied here are labour intensive, hence it is hypothesized that proportion of household members available to provide labour has a positive effect on the adoption of all the studied INM practices.

Location variable (District) was constructed as a dummy and it was hypothesized that households in high agriculturally potential area (Vihiga) would be positively associated with the adoption of inorganic fertilizers, manure, compost and their combinations with inorganic fertilizers. This is because of high expected returns and relatively low risk of adverse weather conditions.

Distance from homestead to the major market (Distomkt) is a major proxy for access to market. Location of the farm far from the market increases transaction costs (Abdulahi and Huffman, 2005), hence distance to the market is hypothesized to be negatively correlated with the adoption of inorganic fertilizers, and combined application of organic and inorganic resources.

Access to extension (Extensn) was indexed as a dummy denoting whether or not the household access to extension services within five years prior to the study. Because access to extension services exposes farmers to new technologies and their potential benefits (Abdulahi and Huffman, 2005), we postulate that access to extension positively affects the adoption of the relatively 'new' practices such as inorganic fertilizers and a combination of inorganic with organic fertilizers which require extra knowledge.

Group membership (Grpmemb) denotes whether any household member belonged to any group. Membership in groups may expose individuals to a wide range of ideas and sometimes afford farmers the opportunity to have better access to information, which may either cause them to form a favourable or unfavourable attitude toward an innovation (Swinton, 2000; Nkamleu, 2007). The direction of this variable is thus ambiguous.

Group heterogeneity (Grphetro) variable was computed on the basis of nine criteria: neighbourhood, kin group, occupation, economic status, religion, gender, age, level of education and political orientation. A score of 0 was assigned if the respondent believed the group was homogenous on the stated criterion and 1 if respondent believed the group was heterogeneous with regard to the criterion. The scores of at most three groups were averaged and the resulting index was re-scaled from 0 to 100, whereby 100 correspond to the highest possible value of heterogeneity. Group membership was hypothesized to be positively associated with the adoption of all the studied practices, whilst the effect of group heterogeneity is difficult to determine a priori.

## RESULTS AND DISCUSSION

### Adoption of patterns of soil fertility management practices

Of the surveyed soil nutrient sources, animal manure was the most widely applied. About 35% of the households applied animal manure alone (Table 2) . Animal manure was preferred probably because of its lower cost than inorganic fertilizers. Although 69% of the households kept livestock, the amount of manure applied were low, on

**Table 2.** Adoption of soil fertility management practices in western Kenya.

| Soil management practice | % reporting n = 331 |
|---|---|
| None | 9.1 |
| Inorganic | 17.5 |
| Manure | 34.7 |
| Compost | 12.3 |
| Inorganic +organic fertilizer | 26.4 |

Source: Authors' analysis of household survey data, 2007

average 1.5 t $ha^{-1}$ compared to 5 t $ha^{-1}$ recommended for most crops (FURP, 1994). This is probably because the farmers kept a few livestock due to feed shortage occasioned by land scarcity resulting in the production of low quantities of manure.

About 18% of the households used inorganic fertilizers alone. The amount of inorganic fertilizer nutrients applied was relatively low, averaging 14.9 kg $ha^{-1}$. Waithaka et al. (2006), similarly found that farmers in Vihiga district on average applied inorganic fertilizer rate of 10.7 kg $ha^{-1}$ ,which is much lower than the already low Kenyan average of 31 kg $ha^{-1}$ (Camara and Heinemann, 2006) against the recommended rates of 120 kg $ha^{-1}$ (FURP, 1994). Odendo et al. (2006) observed that application of inorganic fertilizers in Vihiga district was mainly limited by high costs of inorganic fertilizer and the low producer prices of most food crops. A few farmers that used inorganic fertilizers could not afford the recommended rates owing to liquidity constraints, poor access to credit and high risks associated with agricultural enterprises. Incidentally, only 22% of the surveyed households had ever obtained agricultural credit. This makes integrated application of INM practices rather difficult as inorganic fertilizer is a key ingredient for implementation of INM strategy.

About a quarter of the households applied combinations of organic and inorganic fertilizers. The main inorganic fertilizer involved was di-ammonium phosphate (DAP), whilst animal manure was the main organic input. Adoption of green manure was examined in relation to growing legumes, which are incorporated in the soil while still green to supply soil nutrients. Green manure was not popular in the study area as only 8% of the sample households practised it. None of the farmers who adopted green manure used it singly, hence not reported on the Table 1. This finding is consistent with Onduru et al. (2002) who reports that 7% of the farmers in eastern Kenya applied green manure for soil fertility management. The dismal adoption was attributed to inadequate information on its use, especially on incorporation of green manure into the soil, high labour demand at the time of planting and unavailability of seed for green manure establishment. Incidentally, only 9% of the households did not apply any of the studied soil fertility management practices.

Overall, the above results confirm the observation by Smale et al. (1995) that farmers do not adopt complete package of a technology even when extension attempts to popularize it because of capital scarcity and risk considerations. They instead adopt parts or a component of recommended technology. Thus, different households have different adoption patterns of a given technological package. Some households combined organic and inorganic fertilizers, whilst others did not.

## Determinants of the adoption of selected components of INM

Multicollinearity between the explanatory variables was tested by examining the variance inflation factor (VIF). The highest VIF was 8.7. The rule of thumb is that if VIF is more than 10, then multicollinearity exists (Maddala, 1993). Therefore multicollinearity was not found to be a problem in this study. The chi-square values show that the parameters included in the models taken together are significantly different from zero at conventional significance levels, suggesting the robustness of the models. The model results (Table 3) confirm the a priori expectation that farmers' choice of INM practices is determined by the interaction of several factors. The signs of most coefficients turned out to be consistent with the a priori expectations. However, the magnitudes and direction of influence of the parameters varied across the practices.

Farmer's perception of severity of soil fertility depletion on their farms (Percpn) has a negative significant effect on adoption of inorganic fertilizers ($p < 0.01$) and positive effect on adoption of compost ($p < 0.1$). The results suggest that farmers may perceive high soil fertility degradation, but due to situational constraints such as lack of financial resources to buy inputs and lack of technical information, they may not adopt the effective technology to reverse the problem. Instead, farmers may opt for the inputs they can easily access such as compost even if it is not very effective. In the case of inorganic fertilizers, the finding of this study contrasts similar earlier studies (Mbaga-Semgalawe and Folmer, 2000; Solis et al., 2007), which found that perception of soil degradation was an important precondition for adoption of conservation technologies. However, result on compost is in agreement with earlier findings (e.g., Solis et al*.,* 2007).

Education of household head (Educ) was positively associated with both adoption of inorganic fertilizers ($p < 0.05$) and combination of inorganic with organic resources ($p < 0.1$). This suggests that the use of inorganic fertilizers and INM are knowledge-based, thus those household heads with higher education have higher probability of adopting them. Age of the household head (Age) was negatively associated with the adoption of in-

**Table 3.** Results of logit models for the adoption of INM practices.

| Variable | Inorganic fert. | Manure | Compost | INM[a] |
|---|---|---|---|---|
| Percpn | -0.291 (0.113)*** | 0.207(0.095) | 0.172(0.102)* | 0.115 (0.101) |
| Educ | 0.569 (0.280)** | 0.456(0.282) | -0.059(0.283) | 0.569(0.309)* |
| Age | -0.038(0.011)*** | -0.009(0.010) | -0.010(0.010) | -0.001(0.010) |
| Gender | 0.597(0.401) | 0.211(0.337) | 0.004(0.341) | 0.172(0.346) |
| Officome | 1.003(0.320)*** | 0.386(0.263) | 0.277(0.275) | 0.071(0.274) |
| Labour | 0.086(0.052)* | 0.678(0.361)** | 0.332(0.341) | 0.134(0.146) |
| TLU | -0.125(0.110) | 0.086(0.057) | 0.006(0.067) | 0.119(0.060)** |
| Food | -0.887(0.369)** | -0.055(0.347) | -0.056(0.343) | -0.241(0.360) |
| Fampersn | -0.040(0.285) | -0.663(0.232)*** | -0.320(0.265) | -0.740(0.302)** |
| District | 1.073(0.312)*** | 0.579(0.260)** | -0.040(0.254) | 0.819(0.284)*** |
| Distomkt | -0.076(0.044)* | -0.048(0.035) | -0.119(0.057)** | -0.099(0.055) |
| Grpmemb | 0.992(0.549)* | 1.480(0.541)*** | 0.287(0.499) | 0.143 (0.585) |
| Grphetro | 0.001(0.010) | 0.016(0.008)** | 0.032(0.011)*** | 0.004(0.009) |
| Extensn | 0.538(0.295)* | 0.280(0.251 | 0.039(0.265) | 0.097(0.269) |
| Constant | 2.059 (1.024)** | 0.252(0.949 | -0.080(0.898) | -0.878 (0.935) |
| Log-likelihood | -172.21 | -203.25 | -194.36 | -184.084 |
| Wald $^{2}$ | 58.47 | 40.95 | 20.83 | 26.74 |
| Prob > $^{2}$ | 0.000 | 0.000 | 0.076 | 0.013 |
| Pseudo R | 0.187 | 0.112 | 0.063 | 0.142 |

Notes: Values in parenthesis are standard errors
*., **., and *** indicate significant at 0.1., 0.05 and 0.01 respectively
[a]INM means use of inorganic fertilizers with one or more of the following: animal manure, compost and green manure Variables are defined and explained in the text.

organic fertilizers. This implies that older household heads are more conservative, risk averse and do not easily learn and adopt the new innovations.

The effects of age and education are consistent with Rogers's (1995) generalizations which state that early adopters of innovations are younger and more educated. The finding also agrees with Mbaga-Semgalawe and Folmer (2000) who reported that education had a positive effect on the adoption of improved natural resource conservation technologies but contrasts other studies (Gould et al. 1989) which found education to be negatively related to adoption of soil and water conservation measures.

Tropical Livestock Units owned by the household (TLU) has the expected positive and significant effect on adoption of INM, suggesting that animal manure generated from own livestock is important for integration of inorganic and organic resources. Marenya and Barret (2007) similarly show that tropical livestock units owned by the household were positively associated with the adoption of manure and inorganic fertilizers in western Kenya. Such complementarities between livestock and crops as means of generating synergistic production relationships have also been reported by Kristjanson et al. (2005).

Off-farm income (Officome) as the main source of income was positively correlated with the adoption of inorganic fertilizers ($p < 0.01$). This is not surprising as inorganic fertilizers are the most expensive of the studied inputs, which may not be financed by low cash incomes generated from most farms. Moreover, in most rural parts of Kenya it is common for people with off-farm income to remit some cash to their family members living in the rural areas. The cash may be used for consumption and investment on the farm. The results corroborate the findings of Fuglie (1999) on adoption of conservation tillage but contrasts findings of Swinton (2000) on adoption of soil erosion control measures.

The coefficient for the district where the farm is located (District) was positive and significant on the adoption of inorganic fertilizer ($p < 0.01$), manure ($p < 0.05$) and organic- organic combinations ($p < 0.01$). The results suggest that the likelihoods of adoption of all the studied practices, except compost were significantly higher in high agricultural potential areas (Vihiga) than in low potential areas (Siaya). The differential adoption could be associated with high expected returns and low risk of applying soil nutrients in the high potential area compared to low potential area. This finding is consistent with the results of Shiferaw and Holden (1998) with regard to adoption of physical soil conservation measures in Ethiopia. The result has important implication for targeting areas where pre-conditions for adoption potential exist. With respect to location of the farm, previous research provides mixed results depending on technology under consideration.

Per capita farm size (Fampersn) was negatively associated with the probability of adoption of manure ($p < 0.01$) and combination of inorganic fertilizer and organic resources ($p < 0.05$). This result suggests that households with low per capita farm size are more likely to adopt manure and its combination with inorganic fertilizers. The result neither supports the argument that larger land holding per person associated with greater wealth and increased availability of capital, makes investment in soil fertility management more feasible nor that wealthier farmers are willing to take risk to invest in soil fertility management. Thus empirical results are not always in accord with accepted interpretation of standard economic assumptions. The results corroborate findings by Shiferaw and Holden (1998).

The ratio of household members who provide farm labour (Labour) was positively associated with probability of adopting inorganic fertilizers ($p < 0.1$) and manure ($p < 0.05$). The results are consistent with the assertions that household labour is a major constraint to the adoption of labour intensive technologies (Franzel, 1999) such as animal manure. Due to high labour demand for applying animal manure, households with a high ratio of members working on farm are likely to apply the inputs. This is because household labour is the most important source of labour supply for smallholder households, given that low incomes constrain hiring labour.

Moreover, there are moral hazards associated with hired labour calling for considerable supervision. These problems raise the real cost of household labour beyond the observed wage rate. Therefore, lack of adequate labour accompanied by inability to hire labour can seriously hamper adopton of INM practices. The result is consistent with Franzel's (1999) study in western Kenya, which found that labour constraints had a significant negative effect on the adoption of improved tree fallows, which are labour- intensive like manure use.

Consistent with previous studies (Tchale et al., 2004), this study reveals that households' food self-insufficiency (Food) was negatively and significantly associated with the adoption of inorganic fertilizers ($p < 0.05$). This is plausible because households that are food insecure are often poor and caught in a vicious cycle in their management of resources. For most part of the year they are preoccupied with survival or coping mechanisms and have less time to manage their own farms and preferably spend the little resources at their disposal to purchase food rather than farm inputs such as mineral fertilizers.

Distance to the major market (Distomkt) showed a weak association with the adoption of inorganic fertilizers ($p < 0.1$) and compost ($p < 0.1$), implying that farms located far away from the major market have lower probability of the adoption of these inputs than those closer. This could be because of the inconvenience of travelling long distances and high transaction costs such as travel costs incurred during purchase the inputs and sale of outputs. This finding is in agreement with the widely held belief that high distance to market increases transaction costs, which are deterrent to market participation of most agricultural households and diffusion of technologies. This finding is consistent with those of Alene et al. (2008), which show that distance to market had a negative and significant effect on adoption of inorganic fertilizer in western Kenya.

Membership in social groups (Grpmemb) has positive influence on the adoption of inorganic fertilizers ($p < 0.1$) and manure ($p < 0.01$). Group memberships could enable members to be exposed to information on improved technologies. Other studies have similarly reported a positive influence of group membership on the adoption soil management technologies (Swinton, 2000; Mwakubo et al., 2006). Nkamleu (2007), for example, found that group membership had positive effect on adoption of organic and inorganic fertilizers separately and in combinations in Cameroon.

Heterogeneity of the groups (Grphetro) had a positive effect on the adoption of manure and compost. The results could imply that though the groups could be heterogeneous, they transmit information on indigenous soil management inputs to the members. Mwakubo et al. (2006), however, found that group heterogeneity negatively influenced terracing intensity in semi-arid Kenya, possibly because group heterogeneity created conflicts amongst members.

Access to extension contacts (Extensn) had a positive effect on the adoption of inorganic fertilizer ($p < 0.1$), suggesting the importance of extension as a source of information and knowledge to rural farmers. This finding is consistent with the assertion that human capital formation increases the probability of technology adoption (Rogers, 1995; Abdulai and Huffman, 2005).

## Conclusions and Recommendations

Determinants of the adoption of INM practices varied by the practices surveyed. However, households located in Vihiga district, led by more educated heads and those with more tropical livestock units were more likely to adopt integrated use of organic and inorganic inputs, whilst high per capita farm size reduced the adoption. Access to off-farm income increased the likelihood of the adoption of inorganic fertilizer, a key component of INM.

Policy implications arising from the findings of this study are that different INM components should be targeted to the households with characteristics that favour their adoption. Specifically, efforts to promote inte-gration of INM practices on the smallholder farms should focus on enhancement of farmers' education and dissemination of intensive livestock management systems that support more livestock units per unit land for provision of manure. Increased investment in the rural areas to spur growth of rural economies could create off-farm employment opportunities that may help finance purchase of inorganic fertilizer. It is also important to improve access to credit for most farmers in western Kenya who face liquidity constraints to help them buy inorganic fertilizer. This study investigated factors that influence adoption of INM components at a point in time. However, since factors that influence technology adoption often change over time; future research should investigate factors that determine the adoption over time.

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