ANALYSIS OF FACTORS INFLUENCING THE ADOPTION OF INTEGRATED SOIL NUTRIENT MANAGEMENT TECHNOLOGY IN WESTERN KENYA

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ABSTRACT
Declining soil fertility is one of the major causes of the current low land productivity, food insecurity and high levels of poverty in western Kenya. The concern for soil fertility depletion has led to many attempts to develop and popularize integrated soil nutrient management (INM) practices to restore soil fertility and improve productivity. The main components of INM are inorganic fertilizers, animal manure, composts and green manures. Adoption of INM practices appears to be an appropriate strategy for improving the poor soil fertility in western Kenya, yet the levels of adoption are not known and factors influencing the adoption are not clearly understood. Therefore, the objectives of this study were to assess adoption levels of INM components singularly and combined use of organic plus inorganic resources; identify and understand factors that determine the adoption patterns. Data were collected from a random sample of 331 households in Vihiga and Siaya Districts using a questionnaire and analysed by descriptive statistics and logit models. Results show that animal manure was the most widely applied soil management practice. Only about a quarter of the households applied combinations of organic and inorganic fertilizers. The determinants of adoption of INM practices varied by the practices surveyed. The adoption was mainly influenced by farmers’ characteristics, farm characteristics and institutional factors. This study recommends that creation of alternative sources of income in rural areas such as improvement in small-non-farm businesses, increased Government investment in education, extension services and infrastructure as well as targeting of different INM components to the farmers with suitable characteristics could spur adoption of INM practices.

Keywords: Adoption, integrated soil nutrient management, western Kenya

INTRODUCTION
Smallholder farming in western Kenya is mainly constrained by widespread soil nutrient mining, which undermines the ability of many agrarian households to produce enough yields 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). Sanchez et al. (2002) reported that the average net mining from the soils in western Kenya were 42 kg nitrogen ha⁻¹, 3 kg phosphorous ha⁻¹ and 29 kg Potassium ha⁻¹. These figures represent a balance between nutrient inflows and outflows and are a basis of argument that future growth in agriculture in the region depends primarily on improved land management. This is because nutrient balances have been widely used as sustainability indicators (Shepherd and Soule, 1998).
The concern for soil nutrient mining and the attendant declining food 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. The attempts have been carried out by the World Agroforestry Centre (WAC) and the Tropical Soil Fertility and Biology programme (TSBF) in collaboration with Kenya Agricultural Research Institute (KARI), Kenya Forestry Research Institute (KEFRI), the Ministry of Agriculture (MOA) and other agencies (Rao et al. 1998). Much emphasis has been devoted to integrated soil fertility management (ISFM) approach. ISFM refers to making best use of inherent soil nutrient stocks, locally available soil amendments, and inorganic fertilizers to increase land productivity, whilst maintaining or enhancing soil fertility and improving efficiency of nutrient and water use (Vanlauwe, et. al. 2002; 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 in-organic sources of plant nutrients (Vanlauwe, et. al. 2002).

The rationale behind INM is that it enables farmers to manipulate the organic and inorganic nutrient stocks judiciously and efficiently to save nutrients from being lost or to add nutrients to the farming systems (Chianu and Tsujii, 2005). INM is a package with several components such as inorganic fertilizers, animal manure, crop residues, crop rotation, compost and green manures. 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 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. Therefore, the adoption question hinges on factors affecting adoption of a combination of inorganic fertilizers and organic fertilizers.

Adoption of INM practices appears to be an appropriate strategy for improving the poor soil fertility in western Kenya yet the levels of adoption of INM components either singularly or in combination are not known and drivers and barriers of the adoption are not clearly understood. Much research has focussed on technical aspects of INM without consideration of determinants of the adoption of INM. Moreover, much of the adoption studies in soil fertility management that have examined determinants of farmers’ decisions to adopt soil fertility enhancing technologies have focused on adoption of a single technology. In a few studies that have analysed more than one technology (e.g., Bonabana, et al. 2006; Marenya and Barret, 2007), the analytical methods applied did not permit analysis of integrated analysis of the technologies. Such analyses have not provided the big picture on adoption of INM components. Therefore, the objectives of this study were to assess adoption levels of INM components singularly and combined use of organic plus inorganic resources; identify and understand factors that determine the adoption patterns.

METHODOLOGY
The study area
Data for this study were obtained through a survey conducted in Vihiga\(^1\) and Siaya districts between January and August 2007. Vihiga is one of the eight districts in Western Province, whilst Siaya is one of the 12 districts in Nyanza Province. Vast of the study area 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 per year, which permits 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 input–low output farming. The farming system incorporates crops and livestock. Maize and beans are the most common crops. Recent studies found that soil nutrient balances are seriously in deficit (Jaetzold et al. 2005). With declining soil fertility and build up of *Striga hermonthica*, a parasitic weed of many cereals increases, the net effect has been the decline in production of crops and food shortages in the region, which has the potential to produce enough food for its increasing population. The yields of most crops are 2-5 times lower than the potential. The yield of maize, the staple food crop, for example, is generally less than one ton per hectare in a season compared to six tons per ha obtainable from on-farm research trials (Jaetzold et al. 2005). Thus, enhancement of soil fertility is an impetus for improved agricultural productivity and poverty alleviation in western Kenya. The study districts were selected because both experience low soil fertility, high poverty levels and INM technology was introduced in the districts. In contrast, districts differ in agricultural potential, farming systems, population densities and culture.

**Sampling design and data collection**

To achieve a fair representation of the population of reference 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\(_1\)) and the second one consisted of low potential (LM\(_1\) to LM\(_3\)). The former comprised Vihiga district and the later comprised Siaya district. In the first stage, all sublocations in each stratum were listed as per the 1999 population census (CBS, 2001) and these formed the sampling frame. In the second stage, lists specifying all households in each selected sub-location were constructed with help of local administrators, from which a random sample of 331 households were sampled for the study.

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 questionnaire administration collected the data through face-to-face interviews. Either the head of the selected households--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, farm management

\(^1\) Vihiga district was in the year 2007 sub-divided into three districts: Emuhaya (Emuhaya and Luanda divisions), Hamisi (Tiriki East and Tiriki West divisions) and Vihiga (Sabatia and Vihiga divisions).
practices, especially adoption of soil fertility management technologies, access to
different institutions to improve agriculture such as extension, markets, and credit,
membership in local groups and organizations, and attitudes towards efficacy of selected
soil management practices on improving crop productivity.

Conceptual framework
The conceptual framework for adoption of a technology is built on assumption of
expected utility that would be maximized if probability of adoption were one (Rahm
and Huffman, 1984). Households will adopt an INM practices singularly or in
combinations if the expected value of benefits from technology use 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-sustainability and improvements to the environment.

It is assumed that the individual facing technology alternatives maximizes the
expected utility derived from the choice made. If \( Y_i \) is defined as the situation where
the individual chooses the technology and \( Y_i = 0 \) otherwise, then it follows that
adoption=1 if \( Y_i^1 > Y_i^0 \) occurs and \( Y_i = 0 \), if adoption does not occur. Thus, when
farmers adopt a technology, it indicates that perception of net benefits is greater than
zero. Farmer’s perception of net benefits and adoption of a technology is determined
by interactive effects of household socio economic characteristics, resource
availability, physical characteristics of the land and institutional factors (Mbaga-
Semgalawe and Folmer 2000). It is important to understand the relationship between
these factors and the process of adoption of INM technology to improve its adoption
for sustainable land management.

Empirical model
Three statistical functional forms available to analyze binary choice problems such as to
adopt or not adopt a technology are linear probability model (LPM), logit and probit
models. LPM is popular because it is theoretically simple, thus without theoretical
guidance to the contrary, people prefer assuming the simplest case (Aldrich and Nelson,
1984). The LPM typically uses the Ordinary Least Squares (OLS) estimator for
making predictions and is thus 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 only a
few values of the dependent variable (Madalla, 1993). In addition, OLS estimates can
produce predictions that can lie outside of the [0, 1] range imposed by the laws of
probability), which cannot thus be interpreted as probabilities in dichotomous choice
adoption models, resulting arbitrary defining of outcomes which are less than 0 or
greater than 1 (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 (e.g., Agresti, 1996; Tiwari et al. 2008). These
models use the method of Maximum Likelihood Estimation (MLE) to give unbiased
and efficient estimates of the probability that the dependent variable will take on the
discrete or dichotomous values (Amemiya, 1981). The method of 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) 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 computer programmes as well as personal preferences and experiences. For this study, Logit model was used because the dependent variables (adopt or not-adopt) INM practices singularly or a combination of inorganic and organic are dichotomous and independent variables are continuous, categorical and dummy. Moreover, logit model is computationally simpler and the author is more familiar with it.

Following (Agresti, 1996), the functional form of logit model was specified as (1):

\[
\ln \frac{P_x}{1-P_x} = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \ldots + \beta_k x_{ki} \tag{1}
\]

Where, the subscript \(i\) is the \(i^{th}\) observation in the sample, \(P_x\) 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 \((1-P_x)\) is the probability of non-adoption. \(\beta_0\) is the intercept term, and \(\beta_1, \beta_2, \ldots, \beta_k\) are the coefficients of the independent variables \(X_1, X_2, \ldots, X_k\).

As indicated in equation (1) the coefficients are compared with the probability of an event occurring or not occurring and bounded between 0 and 1. Thus, the dependent variable becomes the natural logarithm of the odds when a positive choice is made. The odds predicted probability of the independent variables indicates the influence of these variables on the likelihood of adoption of a given INM practice if other variables remain the same. Hence, if the estimated values of these variables are positive and significant, it implies that the farmers with higher values for these variables are more likely to adopt improved soil conservation technology. The Logit models were estimated by a maximum likelihood method using Statistical/Data analysis (STATA) computer software.

**Dependent variables**

There are difficulties in defining adoption of a package of interrelated technologies such as integrated pest management (IPM) and INM. Tiwari et al (2008), for example, defined an adopter as a farmer who had adopted at least one improved soil conservation technology, either as recommended by extension workers or with some modification. This definition did not take into consideration the concept of integration. For this study, an adopter was defined as a household that had applied an \(i^{th}\) INM practice either singularly or organic/inorganic combinations at least once before 2006 long rain season and again applied 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.

**Independent variables**
The choice of appropriate independent variables to reflect the complex farm household adoption decisions is problematic 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 of 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:

Table 1. Explanatory variables for logit models

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description and units of measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percpn</td>
<td>Perception of extent of soil depletion (0= no problem 5=very severe).</td>
</tr>
<tr>
<td>Educ</td>
<td>1=Highest education level is at least secondary (dummy)</td>
</tr>
<tr>
<td>Age</td>
<td>Age of household head (years)</td>
</tr>
<tr>
<td>Gender</td>
<td>1= male headed household (dummy )</td>
</tr>
<tr>
<td>Fampersn</td>
<td>Farm size per man equivalent (ha/person)</td>
</tr>
<tr>
<td>Lsu</td>
<td>Livestock units</td>
</tr>
<tr>
<td>Offincome</td>
<td>1=Off-farm income is main source of income (dummy)</td>
</tr>
<tr>
<td>Labour</td>
<td>Ratio of farm worker to household size (Ratio)</td>
</tr>
<tr>
<td>Lackfood</td>
<td>1= Sufficient own food supply in 12 months prior to study</td>
</tr>
<tr>
<td>District</td>
<td>1=Farm located in Vihiga district (dummy)</td>
</tr>
<tr>
<td>Distomkt</td>
<td>Distance from homestead (km) major market (km)</td>
</tr>
<tr>
<td>Grpmemb</td>
<td>1=Household member belonged to group (dummy)</td>
</tr>
<tr>
<td>Extensn</td>
<td>1=household had any agricultural assistance within 5 years</td>
</tr>
<tr>
<td>Grphetro</td>
<td>Heterogeneity of the three most important groups (%)</td>
</tr>
</tbody>
</table>

The extent of farmers’ perception of soil fertility or soil erosion problems (Percpn) has been frequently found to be positively correlated with the adoption of soil conservation practices (e.g. Mbaga-Semgalawe and Folmer 2000; Solís et al. 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. It was 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.

Most researchers believe a priori that education of the household head (Educ) is positively related to technology adoption. However, as pointed out by Rahm and Huffman (1984), the effect of education level may not always be consistent with the expectations and could be ambiguous depending greatly on circumstances. Many studies report that education has a positive impact in the adoption of improved natural resource conservation technologies (e.g., Mbaga-Semgalawe and Folmer 2000), a few have found education to be negatively related to adoption (Gould et al. 1989) and others have found it insignificant (e.g., Shiferaw and Holden, 1998). Education was measured as years of formal schooling of the household head. Because the surveyed technologies are knowledge-intensive, higher education is expected to increase probability of the adoption of the single INM practices and their combinations,
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. Previous research reveals that young people exhibit a lower risk aversion and being at an earlier stage of a life cycle, are more likely to adopt new technologies that have long lags between investments and yield of benefits (Featherstone and Goodwin, 1993). In contrast, older people are thought to be reluctant to change their old ways of doing things. The influence of age was analysed from perspectives of risk aversion rather than time lag (planning horizon) because the technologies under the study yield benefits in a relatively short-term. Therefore, because the use of inorganic fertilizers and its combination of inorganic and inorganic fertilizers is a relatively new phenomenon, age of the household head is expected to be negatively associated with the adoptions. However, age is expected to be positively correlated with the relatively traditional practices such as manure and compost, which they are used to.

The roles of women verses men in decisions to adopt technologies (Gender) have been frequently considered in adoption studies. Most studies show mixed evidence regarding the different roles men and women play in technology adoption. There is a growing body of empirical evidence showing that men in the developing countries have a higher access to resources that facilitate adoption, therefore giving them a greater capacity to adopt capital-intensive technologies like inorganic fertilizers (Kaliba et al. 1997) than women. Gender is a dummy variable indexing the sex of the household head who is the implicit key decision-maker for the household. Male-headed households are expected to have higher probability of the adoption of inorganic fertilizers and combinations than women do.

Farm per capita (farmperson) has been used in a number of analyses as a proxy for population pressure (e.g., Shiferaw and Holden, 1998). Its effect on probability of adoption is difficult to determine a priori.

Livestock may increase availability of manure, which may be applied to the soil to increase soil fertility. However, specialization on livestock rather than cropping may reduce investment in crops in terms of soil management (Shiferaw and Holden, 1998). In this study livestock, ownership was assumed to increase availability of manure and hypothesized that ownership of cattle increases likelihood of adoption of manure and its integration with inorganic fertilizers.

Income from off-farm labour (Officome) may compensate for missing and imperfect credit markets by providing ready cash for input purchases as well as for other household needs thus increasing probability of adoption. In addition, off-farm income may increase the ability of households to bear the risk associated with technology adoption. Off-farm income has been found to be positively (e.g. Fuglie, 1999), negatively (e.g. Swinton, 2000) associated with adoption of soil conservation measures. Access to off-farm income 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 (inorganic fertilizers) 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.
Households suffering chronic food shortages (Lack food) have been negatively associated with the adoption some technologies (Tchale et al.2004). This is because such households often lack financial resources to purchase the requisite inputs.

Most studies agree that labour scarcity (Labour) is often an operative constraint in farming systems. The effect of the labour availability often depends on whether the new technology is labour saving or labour using. Some new technologies reduce the need for labour, whereas others increase it. When facing labour shortages, farmers may be less likely to adopt labour increasing technologies and the converse would apply to adopt labour saving technologies (Feder, et.1985). Batz, et. al. (2003) found that Kenyan dairy farmers, who face labour shortages, were unlikely to adopt dairy technologies that require more labour. Labour availability was measured as the proportion of household members who contribute to farm work. The practices studied here are labour intensive and high availability of labour whether household or hired labour is hypothesized increase probability of the adoption of all the studied INM practices.

Location of the farm (District) often introduces some bit of noise as it captures other differences including local infrastructures, culture, market opportunities and farm physiographical factors, which can vary within a short distance, as well as the fact that INM technologies were not uniformly introduced to all communities at the same time. Location variable was constructed as a dummy and it was hypothesized that high agriculturally potential area (Vihiga) would be positively associated with the adoption of inorganic fertilizers and negatively correlated with the adoption of manure, compost and their combinations with inorganic fertilizers.

Distance from homestead to the major market (Distomkt) is a major proxy for access to market. Living at a greater distance from the major market can reduce the expected profitability of a new technology and creates a barrier associated with limited information about distant marketing outlets, and increased transaction costs (Alene, et. al 2008). DISTOMKT is hypothesized to be negatively correlated with the adoption of inorganic fertilizers, and combined application of organic and inorganic resources.

A number of adoption studies have shown the significance of extension education (Extensn) on adoption of land-improving technologies (Pattanayak et al. 2003). Information is important for adoption of complex innovations such as Integrated Pest management (IPM) and INM (Bonabona et al, 2006). Access to extension is indexed as a dummy denoting whether or not the household access to extension services within five years prior to the study. This variable was hypothesised to be positively associated with the adoption of the relatively ‘new’ practices such as inorganic fertilizers and a combination of inorganic with organic fertilizers.

Membership in groups (Grpmemb) 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. Some studies have shown membership in a cooperative or producer organizations was positively correlated with the adoption decision and the extent of adoption (Swinton, 2000). This is because farmers in local groups are likely to be in contact with research, and development agencies, who offer an opportunity for
farmers to learn and share information on agricultural production and marketing, hence more likely to adopt innovations than those who do not. In addition, some financial institutions may be prepared to lend credit to farmers only when they are in groups or cooperatives. Group membership denotes whether any household member belonged to any group. In addition, group heterogeneity (Grphetro), an index computed based on nine criteria: neighbourhood, kin group, occupation, economic status, religion, gender, age, level of education and political orientation was also considered. 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 to adoption all the studied practices, whilst the effect of group heterogeneity is difficult to determine a priori.

RESULTS AND DISCUSSION

Socioeconomic and demographic characteristics of sample households
The key socioeconomic profiles of the sample households are presented in Table 2. Over 81% of the households were male-headed and the mean age of the household heads was 52 years. The mean education level was 7 years. Nearly 80% of the households suffered food shortages, whilst 90% of the households had members in social groups.

Table 2. Descriptive statistics of key socio-economic variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percpn</td>
<td>3.3</td>
<td>1.4</td>
<td>1.0</td>
<td>6.0</td>
</tr>
<tr>
<td>Educ</td>
<td>7.3</td>
<td>3.9</td>
<td>0.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Age</td>
<td>51.7</td>
<td>13.8</td>
<td>19.0</td>
<td>86.0</td>
</tr>
<tr>
<td>Gender</td>
<td>0.8</td>
<td>0.4</td>
<td>0.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Hiredlab</td>
<td>0.6</td>
<td>0.5</td>
<td>0.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Lsu</td>
<td>2.2</td>
<td>2.3</td>
<td>0.0</td>
<td>22.4</td>
</tr>
<tr>
<td>Lackfood</td>
<td>0.8</td>
<td>0.4</td>
<td>0.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Fampersn</td>
<td>0.5</td>
<td>0.6</td>
<td>0.0</td>
<td>5.0</td>
</tr>
<tr>
<td>District</td>
<td>0.5</td>
<td>0.5</td>
<td>0.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Distomkt</td>
<td>2.9</td>
<td>3.5</td>
<td>0.0</td>
<td>22.0</td>
</tr>
<tr>
<td>Grpmemb</td>
<td>0.9</td>
<td>0.3</td>
<td>0.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Grphetro</td>
<td>21.7</td>
<td>16.4</td>
<td>0.0</td>
<td>85.7</td>
</tr>
<tr>
<td>Extensn</td>
<td>0.6</td>
<td>0.5</td>
<td>0.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Source: Household survey

Adoption 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 3). Animal manure was preferred because of low cost of its access and high prices of inorganic fertilizers. Although 69 % of the households kept livestock, the amounts of manure applied was low, on average 1.5 tons/ha compared to 5 tons per ha recommended for most crops (FURP, 1994). This could be because the farmers kept a few livestock due to feed shortage occasioned by land scarcity resulting in low production of manure.
Table 3. Adoption of soil fertility management practices in western Kenya

<table>
<thead>
<tr>
<th>Soil management practice</th>
<th>%</th>
<th>% reporting</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>9.1</td>
<td></td>
</tr>
<tr>
<td>Inorganic</td>
<td>17.5</td>
<td></td>
</tr>
<tr>
<td>Manure</td>
<td>34.7</td>
<td></td>
</tr>
<tr>
<td>Compost</td>
<td>12.3</td>
<td></td>
</tr>
<tr>
<td>Inorganic +organic fertilizer</td>
<td>26.4</td>
<td></td>
</tr>
</tbody>
</table>

Source: Household survey, 2007

About 18% of the households used inorganic fertilizers alone. The amounts of inorganic fertilizer nutrients applied were relatively low, averaging 14.9 kg ha\(^{-1}\). Waithaka et al. (2006), similarly found that farmers in Vihiga district on average applied 10.7 kg of fertilizer per ha, which is much lower than the already low Kenyan average of 46 kg ha\(^{-1}\) against the recommended rates of 60 kg P and 60 kg N ha\(^{-1}\) (FURP, 1994). Odendo, et al. (2006) reports that the major deterrent to adoption of purchased inputs is lack of credit and cash as well as low profitability and high risk. 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) and animal manure was the main organic fertilizer.

Adoption of green manure was examined in relation to growing of plants mainly, 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 sampled households practised it. None of the farmers who adopted green manure used it singularly, hence not reported on the Table 1. This finding is consistent with earlier similar studies. For example, Onduru et al. (2002) reported that 7% of the farmers in Eastern Kenya applied green manure for soil fertility management. In the case of western Kenya, Odendo et al. (2000) reported that only 10% of the farmers adopted green manure. The dismal adoption in western Kenya 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.

The results confirm the findings of earlier adoption studies, which have repeatedly shown 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 (Smale et. al. 1995). Thus, different households have different adoption patterns of a given technological package. Some households combined organic and inorganic fertilizers, whilst other did not.

**Determinants of the adoption of selected components of INM**

The explanatory variables were tested for multicollinearity using Variance Inflation Factor (VIF). The VIF was 8.7. The rule of thumb is that if VIF is more than 10, then
multicollinearity exists (Madalla, 1993). Therefore, multicollinearity not found to be a problem to this analysis. The Chi-square value shows that the parameters included in the models taken together are significantly different from zero at 1%-significance level, suggesting the robustness of the model. The model results (Table 4) confirm the a priori expectation that farmers’ choice of INM practices is determined by the interaction of several factors. The signs of most the 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.

Table 4. Results of logit models for the adoption of INM practices

<table>
<thead>
<tr>
<th>Variable</th>
<th>Inorganic fertilizer</th>
<th>Manure</th>
<th>Compost</th>
<th>INM&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percpn</td>
<td>-0.291 (0.113)**</td>
<td>0.207 (0.095)</td>
<td>0.172 (0.102)</td>
<td>0.115 (0.101)</td>
</tr>
<tr>
<td>Educ</td>
<td>0.569 (0.280)**</td>
<td>0.456 (0.282)</td>
<td>-0.059 (0.283)</td>
<td>0.569 (0.309)*</td>
</tr>
<tr>
<td>age</td>
<td>-0.038 (0.011)**</td>
<td>-0.009 (0.010)</td>
<td>-0.010 (0.010)</td>
<td>-0.001 (0.010)</td>
</tr>
<tr>
<td>Gender</td>
<td>0.597 (0.401)</td>
<td>0.211 (0.337)</td>
<td>0.004 (0.341)</td>
<td>0.172 (0.346)</td>
</tr>
<tr>
<td>Officome</td>
<td>1.003 (0.320)**</td>
<td>0.386 (0.263)</td>
<td>0.277 (0.275)</td>
<td>0.071 (0.274)</td>
</tr>
<tr>
<td>Labour</td>
<td>0.086 (0.052)*</td>
<td>0.678 (0.361)**</td>
<td>0.323 (0.341)</td>
<td>0.134 (0.146)</td>
</tr>
<tr>
<td>Lsu</td>
<td>-0.125 (0.110)</td>
<td>0.086 (0.057)</td>
<td>0.006 (0.067)</td>
<td>0.119 (0.060)**</td>
</tr>
<tr>
<td>Lackfood</td>
<td>-0.887 (0.369)**</td>
<td>-0.055 (0.347)</td>
<td>-0.056 (0.343)</td>
<td>-0.241 (0.360)</td>
</tr>
<tr>
<td>Fampersn</td>
<td>-0.040 (0.285)</td>
<td>-0.663 (0.232)**</td>
<td>-0.320 (0.265)</td>
<td>-0.740 (0.302)**</td>
</tr>
<tr>
<td>district</td>
<td>1.073 (0.312)**</td>
<td>0.579 (0.260)**</td>
<td>-0.040 (0.254)</td>
<td>0.819 (0.284)**</td>
</tr>
<tr>
<td>distomkt</td>
<td>-0.076 (0.044)*</td>
<td>-0.048 (0.035)</td>
<td>-0.119 (0.057)</td>
<td>-0.099 (0.055) **</td>
</tr>
<tr>
<td>Grpmemb</td>
<td>0.992 (0.549)*</td>
<td>1.480 (0.541)**</td>
<td>0.287 (0.499)</td>
<td>0.143 (0.585)</td>
</tr>
<tr>
<td>Grphetro</td>
<td>0.001 (0.010)</td>
<td>0.016 (0.008)**</td>
<td>0.032 (0.011)</td>
<td>0.004 (0.009) ***</td>
</tr>
<tr>
<td>Extensn</td>
<td>0.538 (0.295)*</td>
<td>0.280 (0.251)</td>
<td>0.039 (0.265)</td>
<td>0.097 (0.269)</td>
</tr>
<tr>
<td>Constant</td>
<td>2.059 (1.024)**</td>
<td>0.252 (0.949)</td>
<td>-0.080 (0.898)</td>
<td>-0.878 (0.935)</td>
</tr>
</tbody>
</table>

Log likelihood Wald $\chi^2$ Prob $>\chi^2$ Pseudo R
-172.21 58.47 0.0000 0.1870
-203.25 40.95 0.0001 0.1124
-194.36 20.83 0.076 0.063
-184.084 26.74 0.013 0.000

Notes: Values in parenthesis are standard errors; df means degrees of freedom
*, **, and *** indicate significant at 0.1., 0.05 and 0.01 respectively
<sup>a</sup>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.

Farmers who expressed high severity of soil fertility depletion on their farms (Percpn) seem to have a lower probability of adopting inorganic fertilizers (p<0.01) and higher probability of adopting compost (p<0.1) (Table 4). The results suggest that farmers who perceive higher severity of soil depletion problem are those who do not apply inorganic fertilizers. In the case of inorganic fertilizers, this finding contrasts similar
earlier studies (e.g. Mbaga-Semgalawe and Folmer, 2000; Soils et al. 2007), which suggest that environmental awareness is an important precondition for adopting conservation technologies. However, the case of compost, it supports earlier findings (e.g., Soils et al. 2007).

Education of household head (EDUC) was positively associated with adoption of inorganic fertilizers (P<0.05) and combination of inorganic with organic resources (P<0.1). This suggests the use of inorganic fertilizers and INM is knowledge-based and thus those with higher education have the high probability of adopting them. The finding is similar to those of Mbaga-Semgalawe and Folmer (2000) who report that education had positive impact in the adoption of improved natural resource conservation technologies but contrasts other studies (e.g., Gould et al. 1989) which found education to be negatively related to adoption.

Consistent with some earlier studies (e.g., Rogers 1995), age of the household head (Age) was negatively associated with the adoption of inorganic fertilizers (p<0.01). This could be related to elderly farmers’ risk aversion to new practices or lack of resources by the elderly to invest in soil fertility management practices.

Total livestock units owned by the household (Lsu) has the expected positive and significant effect on adoption of a combination of organic and inorganic fertilizers, suggesting that animal manure generated from own livestock is important for integration of inorganic and organic resources. Marenya and Barret (2007) similarly show that livestock units owned was positively associated with the adoption of manure and inorganic fertilizers in western Kenya. Such complementary between livestock and crop enterprises as means of generating synergistic production relationships has been reported (e.g., Kristjanson, et al. 2005).

Presence of 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 is the most expensive of the studies 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 corroborates the findings of Fuglie (1999), but contrasts findings of Swinton (2000).

The coefficient for the district where the farm is located (District) positively and significantly correlated to 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). This differential adoption could be associated with high-expected returns in the high potential area compared to low potential area. 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. Whilst some studies have observed a positive correlation (e.g. Gould et al., 1989), others have revealed negative correlations (e.g. Fuglie, 1999). This particular finding requires further investigation to understand
better other location-specific factors that determine farmers’ adoption of INM practices.

Per capita farm size (Farmperson) seems to be negatively and significantly associated with the probability of adoption of manure (P<0.01) and combination of inorganic fertilizer plus 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 ratio of household members who provide farm labour (Labour) was significantly and positively associated with probability of adopting inorganic fertilizers and manure. The results are consistent with the assertion that household labour is a major constraint to the adoption of technologies, particularly labour intensive technologies 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 applying the inputs. Household labour is the most important source of labour supply for smallholder households, given that low incomes constrain financial liquidity for hiring labour. Moreover, there is moral hazard problems 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 adoption of INM practices.

Consistent with previous studies (e.g., Tchale et al.2004), this study reveals that chronic food shortages (Lack food) was negatively and significantly associated with the adoption of inorganic fertilizers (p<0.05). This is plausible because households with lower food security index lack financial resources to purchase farm inputs, especially inorganic fertilizers and are for most part of the year preoccupied with survival or coping mechanisms and have less time to manage their own farms. Again, since application of INM requires some inorganic fertilizers, it is also plausible that households that cannot afford inorganic fertilizers cannot practice INM.

Distance to the major market (Distomkt) was negatively associated 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 the 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, especially on transport in order to purchase the inputs or sale the output. 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 coefficient on adoption of inorganic fertilizer in western Kenya.

Membership in social groups (Grpmemb) had positively and significantly influenced the adoption of inorganic fertilizers (p<0.1) and manure (p<0.01). The influence of group memberships in western Kenya could be transmitted by groups enabling members to be exposed to information on improved technologies rather than assisting the farmers to buy the inputs. This is so because groups in western Kenya rarely provide credit for agricultural input purchase. Some other analyses have similarly
reported a positive influence of group membership on the adoption of soil management technologies (e.g. Swinton, 2000; Nkamleu, 2007). Nkamleu (2007) found that group membership had a positive effect on adoption of organic and inorganic fertilizers separately and in combinations in Cameroon. In addition, heterogeneity of the groups (grphetro) had a positive and significant influence on adoption of manure and compost. The results could imply that though the groups could be heterogeneous, the discussions amongst members focus on only indigenous soil management inputs. Mwakubo et al. (2004), 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 and significant effect on the adoption of inorganic fertilizer (p<0.1). The results suggest that households do not have sufficient information on the use of inorganic fertilizers. This finding is consistent with the theory that human capital formation increases the probability of technology adoption (Rogers, 1995) and previous studies (e.g., Abdulai and Huffman, 2005).

**CONCLUSIONS AND RECOMMENDATIONS**

Animal manure was the most widely applied soil management practice. About 35% of the households applied animal manure alone, whilst 18% of the households used inorganic fertilizers alone. However, the amounts of manure and inorganic fertilizer applied were lower than the recommended rates. Only about a quarter of the households applied combinations of organic and inorganic fertilizers. Green manure was not popular in the study area as only 8% of the sampled households practised it. None of the farmers who adopted green manure used it singularly.

The determinants of adoption of INM practices varied by the practices surveyed. However, the adoptions were mainly influenced by farmer characteristics, including perception of soil fertility depletion as well as age and education of household head. Farm characteristics include total livestock units, off-farm income, and location of the farm, per capita farm size, labor availability, and food shortages. The other set of factors were institutional, including the adoption were distance to market, membership in social groups and access to extension services. This study recommends that creation of alternative sources of income in rural areas such as improvement in small-non-farm businesses, increased Government investment in education, extension services and infrastructure as well as targeting of different INM components to the farmers with suitable characteristics could spur adoption of INM practices.

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