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Full Length Research Paper

What factors influence the speed of adoption of Soil fertility management technologies? Evidence from Western Kenya

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Most adoption studies have employed cross-sectional data in a static discrete choice modelling framework to analyze why some farmers adopt technology at a certain point in time. The static approach does not consider the dynamic environment in which the adoption decision is made and thus does not incorporate the speed of adoption and the effect of time-dependent elements in explaining adoption. The adoption speed of an innovation is important in various aspects. Based on data from a survey of a random sample of 331 smallholder households in western Kenya, this study investigated determinants of time to adoption of mineral fertilizer, animal manure and compost using duration analysis. Results revealed that factors that influenced timing of the adoption varied by the practices. Whilst education level of the household head, cattle ownership, location of the farm, access to extension services, and participation in land management programmes accelerated the adoption of different practices, age of household head, relative farming experience and market liberalization retarded the adoption. Gender of household head gave mixed results. To speed up adoption of the practices requires policies that promote farmers' participation in land management programs, access to extension services and markets in addition to stratified targeting of different practices to specific locations and farmers.

Key words: Adoption, duration analysis, soil fertility, Kenya.

INTRODUCTION

Soil degradation on smallholder farms has been cited as the fundamental biophysical root cause of food insecurity and poverty in sub-Saharan Africa, where most of the people live in rural areas and derive their livelihoods from agriculture (Sanchez et al., 1997). Degradation of the soil is especially a serious problem in Kenya, where agriculture is the mainstay of the economy (GoK, 2006). In an effort to restore soil fertility and improve agricultural productivity amongst resource-poor smallholders in western Kenya, many agencies have promoted several soil fertility management practices. The key practices that have been promoted include mineral fertilizers and organic inputs such as improved fallows, animal manure, green manure, biomass transfer, compost, crop residues and crop rotation. This study focuses on the most critical practices in western Kenya which comprise mineral fertilizers and the most commonly available organic inputs: compost, green manure and animal manure.

Although technology adoption is a dynamic process, most adoption studies have employed cross-sectional data in a static discrete choice modelling framework such as logit and probit models to analyze why some farmers adopt at a certain point in time and others do not (Marenya and Barrett, 2007; Tiwari et al., 2008; Odendo et al., 2009). The static approach does not consider the

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dynamic environment in which the adoption decision is made. In particular, the approach does not incorporate the speed of adoption and the effect of time-dependent elements in explaining whether and when an individual decides to adopt.

The speed of adoption of an innovation is important in various aspects. Batz et al. (2003) observe that innovations that are adopted rapidly are more profitable than those with low rates of adoption because the benefits occur faster and the ceiling of adoption is achieved earlier, other factors remaining constant. Duration models are better able to analyze the dynamics of the adoption decision to determine not only what factors influence the probability of adoption but also time to adoption (Dadi et al., 2004; D"Emden et al., 2006; Odendo, 2009).

Despite the importance of speed of the adoption, no study in Kenya has looked into timing of the adoption of soil fertility management technologies. The length of time farmers wait before adopting a new technology is a complicated process that may be influenced by interactive effects of many factors, some of which vary with time, whilst others may not vary over time. Moreover, effects of most variables are often contradictory across technologies and study areas. Therefore, the objective of this study was to investigate determinants of the time to adoption of soil fertility management practices in western Kenya. A better understanding of the underlying dynamics can help improve strategies to speed up adoption of soil fertility management strategies.

METHODOLOGY

The study areas

The study was conducted in Vihiga and Siaya districts[1] of western Kenya (Figure 1). The two districts were chosen for the study because they have some similar and contrasting characteristics. Vihiga district covers an area of 563 km^2 (GoK, 2001) and falls between longitudes of 34° 30" and 35°, 0" East and latitude 0° and 0° 15" North. Altitude is between 1300 and 1500 m above sea-level (asl) and is dominated by rugged terrain. The major soils are dystric acrisols and humic nitosols (Jaetzold et al., 2005).

Siaya district, on the other hand, covers an area of 1523 km^2 (GoK, 2001) and lies between latitude 0° 26" to 0° 18" North and longitude 33° 58" East and 34° 33" West. Altitude is between 1140 and 1400 m (asl). Soils are predominantly ferralsols. These soils have sandy properties, underlying murram, and poor moisture retention (Jaetzold et al., 2005).

Ecologically, 95% of the total area in Vihiga district falls in the upper midland 1 (UM1) agro-ecological zone (AEZ), whilst 5%, is in the lower midland (LM1). Siaya district, however, falls in the lower midland (LM) AEZ which has lower agricultural potential than that found in Vihiga district (Jaetzold et al., 2005). Both districts, however, receive bimodal rainfall pattern that enables two cropping seasons per annum. The mean annual rainfall in Vihiga and Siaya districts are 1,800 to 2,000 mm and 800 to 1600 mm, respectively. Rainfall amounts and distribution are quite variable in Siaya district (Jaetzold et al., 2005).

Population densities and poverty levels in western Kenya are amongst the highest in Kenya. Population densities of Vihiga and Siaya districts were 886 and 325 persons per km^2, respectively (GoK, 2001); whilst poverty incidences are 57 to 60% in Vihiga district and 61 to 68% in Siaya district (GoK, 2005). The high poverty levels are mainly attributed to low productivity of the agricultural sector, which is the major source of livelihoods for most households.

Agriculture in both the study districts is characterized by low input–low output. Maize, the staple food crop, is often intercropped with beans and dominates the cropping pattern. Studies have shown that crop productivity is very low (less than one ton of maize per hectare per year) and that nutrient balances are seriously in deficit (KARI, 2007) mainly because of poor soil management (Jaetzold et al., 2005). Thus, innovative enhancement of adoption of soil fertility technologies is an impetus for improved agricultural productivity and poverty alleviation in the study areas.

Survey design and data collection

Sampling was designed to maximize on spatial coverage in order to capture variability in socio-economic and agro-ecological circumstances that span the study districts. A two stage stratified sampling procedure was applied. In the first stage, each study district formed a sampling stratum. Vihiga and Siaya districts represented high and low agricultural potential areas, respectively. All the 130 sub-locations in each stratum were listed as per the 1999 population census (GoK, 2001) to form the sampling frame. Following consultations with the Ministry of Agriculture staff and local administrators, the sub-locations were grouped into six clusters based on socio-economic and agro-ecological circumstances. From each cluster, the study sub-locations were sampled proportionate to the total number sub-locations in the cluster. In total, 25 sub-locations were sampled to represent diversity of the study districts. In the second stage, lists specifying all households in each of the selected sub-locations were constructed with the help of local administrators and agricultural extension staff from which 331 households comprising 165 and 166 from Siaya and Vihiga Districts, respectively were sampled for the study.

Data were collected between January and August 2007 by a team of five trained enumerators using a structured questionnaire which was administered through face-to-face interviews of household heads, or in their absence, household members responsible for the farm management. Variables expected to play an important role in adoption and vary with time were collected by recording one observation per household per year from the year of farm formation to the year of adoption for the adopters or to the year of the survey for non-adopters. Thus, the time-varying covariates were reported as annual averages for the appropriate year. These data were used to reconstruct a retrospective panel data set, an approach first suggested by Besley and Case (1993) as a feasible low-cost method to glean information on dynamics of adoption not obtainable from traditional cross-sectional studies. The inclusion of time-varying variables is one factor that clearly differentiates Duration models from discrete-choice models of adoption.

Empirical duration model specification

For a given household, define T as "failure" time, at which the

[1]Vihiga district was in the year 2008 sub-divided into three districts: Emuhaya, Hamisi and Vihiga, whilst Ugenya district was excised from Siaya district in 2009.

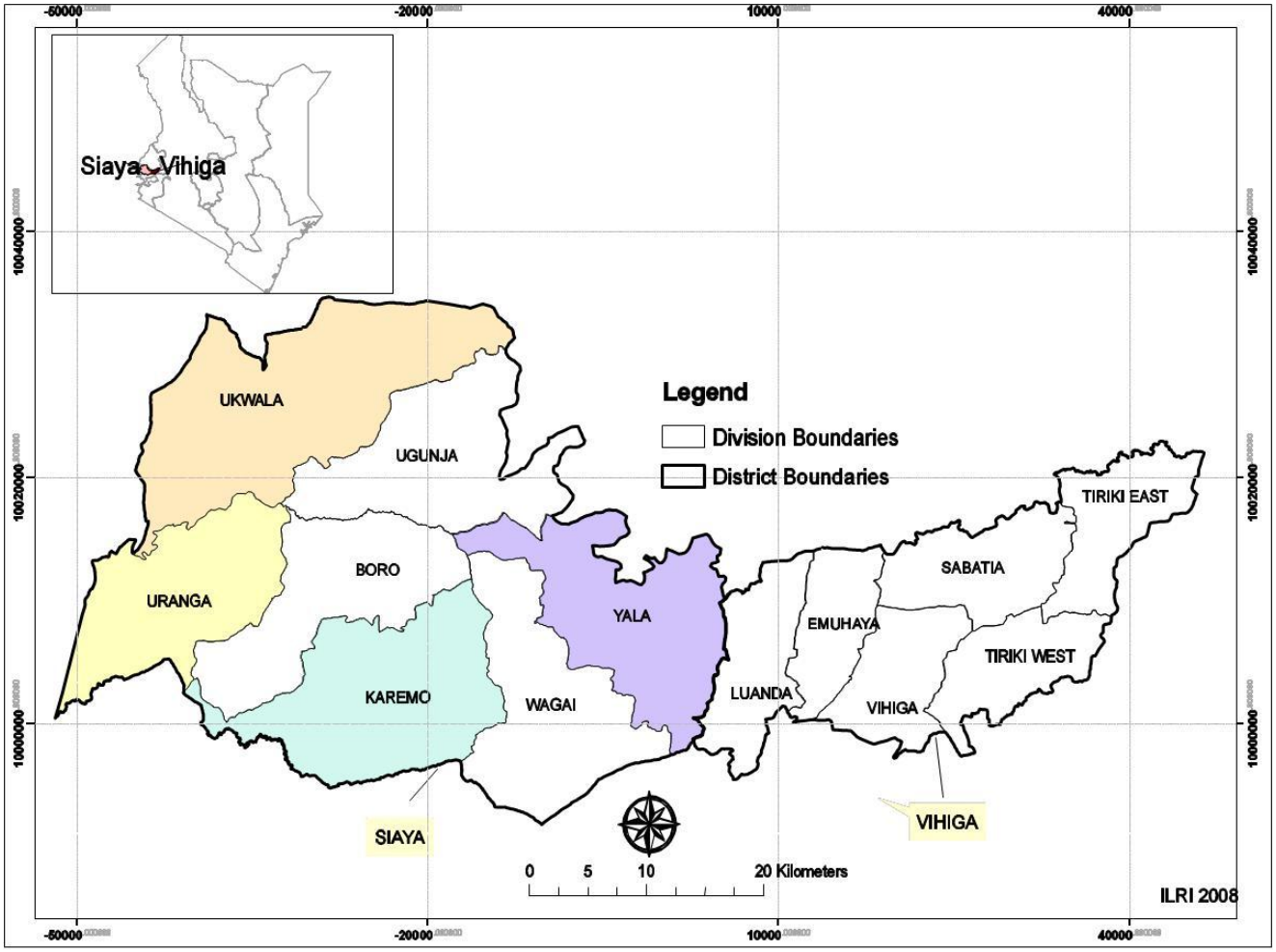

Figure 1. Geographical location of Vihiga and Siaya districts in Kenya.

household makes a transition from non-adoption to adoption state. The hazard function, $h(t)$, is the probability that the failure event (adoption) occurs in the time period between t and Δt , conditional on the fact that the adoption has not yet occurred by t :

$$h(t) = \lim_{\Delta t \to 0} \frac{\Pr(t \le T < t + \Delta t \mid T \ge t)}{\Delta t} \quad (1)$$

Following convention (Keifer, 1988), empirical model was specified as the natural log of the hazard function:

$$Inh_i(t) = \omega(t) + x_i \beta \quad (2)$$

where *i* denotes an individual household observation, t is a non-negative random variable denoting adoption time, $\omega(t)$ is the baseline hazard rate, x_i is a vector of explanatory variables, whilst β is a vector of corresponding parameters to be estimated and ε is the error term .

To estimate the hazard function $h_0(.)$ and the effect of explanatory variables on the hazard, proportional hazard rate (PH) (Baltenweck, 2000) and accelerated failure time models (AFT) (Dadi et al., 2004) approaches have been employed as the basis for parameterization. In the PH, the effect of covariates enters as a multiplicative effect on the hazard function: (1)

$$h(t; X_{it}\beta) = h(t)\exp(X_t \beta) \quad (3)$$

where $h(t)$ is the baseline hazard, X_{it} is a set of explanatory variables composed of both cross-sectional and time-dependent variables, which speed up or retard the adoption decision. (2)

However, in the case of AFT, explanatory variables are introduced in such a way that they have a direct effect on an individual"s waiting time rather than on the baseline hazard (Greene, 2003). As such, unlike the PH form, which reports variables" effect on the hazard rate, the AFT coefficients can be easily interpreted as in regular regression models and reflect the acceleration or deceleration effect on the time until the occurrence of the event of

Table 1. Description of variables used in econometric models

Variable	Description and measurement
Agehh	Age of household head (years) at time of adoption
Rfmexphh	Ratio of hh head's years of farming experience to age at first adoption
Educ	Years of formal education level of household head
Genderhh	1= male headed household at time of the adoption (dummy)
Attitude	1= Practice *i* perceived to increase yield before dummy adoption
Cwratiot	Consumers/ workers ratio at time of adoption
District	1=Farm located in Vihiga district (dummy)
Famsize	Farm size at the time of adoption t (acres)
Officomet	1=Off-farm was main income source at household formation (dummy)
Labour	Ratio of household members working on farm in year of first adoption
Grpmemb	1=Household member belongs to group at survey (dummy)
Cattle	1=owned cattle before the year of first adoption (dummy)
Distamket	Distance to the major market (km)
Mkelib	1= household formed after the year 1990 (dummy)
Extensn	1=accessed extension contacts before adoption (dummy)
Partcipn	1=participated in land management project before adoption (dummy)

interest (adoption). For more intuitively interpretable results, this study applied AFT.

Because there is no economic theory to determine the relevant functional form for empirical analysis, Kaplan-Meier estimator was used to provide graphic presentation suggesting appropriate functional forms for parametric analysis (Keifer, 1988; Dadi et al., 2004). The commonly used functional forms are exponential, Weibull, the logistic, lognormal, log logistic, and Gompertz probability distributions (Keifer, 1988; Cleves et al., 2004). Estimation of the hazard followed maximum likelihood procedures using robust estimator of variance (or White estimator) to relax the assumption of independence of observations from the same farmer (Greene, 2003).

Variables in the empirical models

Unlike discrete choice models, Duration analysis treats the length of time to adoption (or adoption spell) as the dependent variable. The start of the duration spell was set either at the year a practice was first introduced or the year a household started making farm management decisions (the potential year of first adoption), whichever was latest. The choice of explanatory variables was guided by previous studies, economic theory and the peculiar characteristics of the technologies under consideration. The specific variables hypothesized to influence the speed of adoption are presented in Table 1 and their expected direction of influence briefly discussed below.

Older farmers are likely to adopt a technology because of their accumulated knowledge, capital and experience (Abdulai and Huffman, 2005; Lapar and Pandey, 1999). However, young farmers 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; Sidibe, 2005). The surveyed soil management technologies are not long-term as each of the technology is applied and yields harvested seasonally. Therefore, this study considers age in the perspective of the risk aversion and resistance to change. The expected sign of the coefficient on age is indeterminate.

Typically, age and experience are correlated as in this sample. Farmer"s relative experience measures ratio of years of farming experience to age of household head. This variable is an indicator of household head"s involvement in farming. It is designed to better capture the effect of years of experience on speed of adoption, as it is normalized by age. The effect of relative farming experience cannot also be determined a priori.

Education enables farmers to distinguish more easily technologies whose adoption provides an opportunity for net economic gain from those that do not (Abdulai and Huffman, 2005; Rahm and Huffman, 1984). Given that time to adoption is being modeled in this study, it is significant to note that more efficient adoption decisions could result in more educated farmers adopting the technology either earlier or later.

Previous research in Africa has documented women"s lesser access to and control of critical resources, especially land, cash, labor and information (Kaliba et al., 2000; Quisumbing et al., 1995). Thus it does not appear that gender per se heavily affects adoption patterns. Rather the inherent resource inequities in ownership and control of productive resources between men and women play a big role. For soil management practices involving the use of financial resources (mineral fertilizer) and knowledge intensive (e.g. compost), it is hypothesized that male headed households are more likely to adopt the practices faster than female-headed households.

Adesina and Baidu-forson (1995) demonstrate the importance of farmers" perceptions of technology characteristics on adoption. Farmers" positive attitude of a given practice is hypothesized to hasten the adoption of the practice.

Larger farm size is associated with greater wealth, increased availability of capital, and high risk bearing ability which makes investment in conservation more feasible (Norris and Batie, 1987). Moreover, farmers operating larger farms can afford to devote part of their fields to try out the improved technology (Rahm and Huffman, 1984). It is hypothesized that large farm size increases the probability of the adoption of all the studied practices.

A higher ratio of household members who contribute to farm work is generally associated with a greater labor force available to the household for timely operation of farm activities including soil management. Due to the high labor demands for preparation and

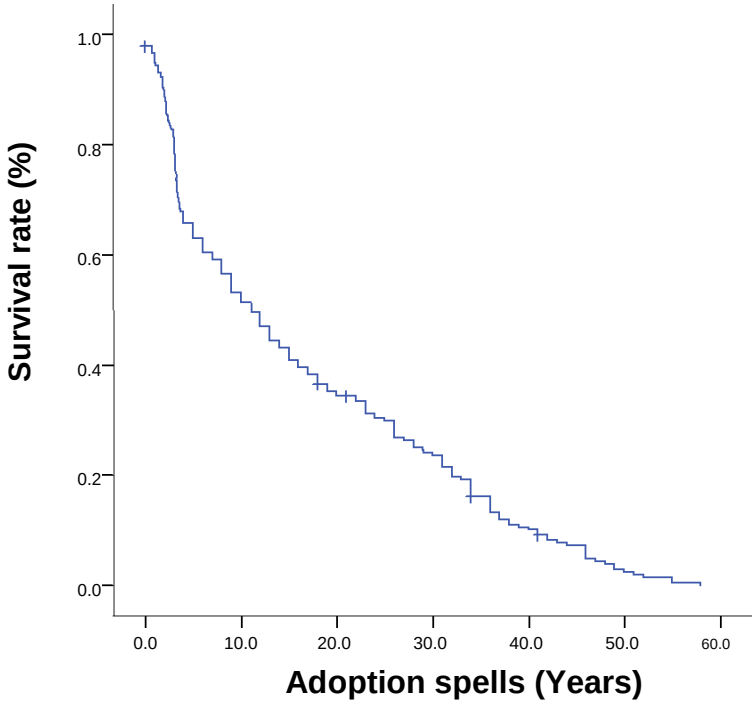

Figure 2. Kaplan-Meier survival estimate of manure adoption.

application of manure, compost and mineral nutrient sources, higher ratio of household members who contribute to farm work is hypothesized to increase the speed of the adoption of all the studied practices because of the low opportunity cost of labor in the study areas.

An increase in consumer-worker ratio raises the need to deploy household resources to cater for consumption, thus undermining accumulation of savings for investment on the farm (Shiferaw and Holden, 1998). When the ratio is greater than one it means a household has more dependants than household members who work and be productive, and vice-versa. A high consumer-worker ratio is expected to retard speed of adoption of all the studied practices.

Livestock wealth may ease cash constraints, increase availability of manure and act as a major conduit of nutrient flows on the farms through nutrient re-cycling. However, more specialization in livestock rather than cropping may reduce investment in crops. Ownership of cattle is assumed to increase availability of manure and to generate income through sales of the cattle or its products. It is thus hypothesized to accelerate adoption of manure and mineral fertilizers.

Off-farm income may compensate for missing and imperfect credit markets by providing ready cash for input purchases and could also be used to spread the risk of using improved technologies (Mathenge and Tschirley, 2007). However, off-farm income earners may decide not to invest their financial resources in soil conservation but instead invest in more profitable off-farm enterprises (Gebremedhin and Swinton, 2003; Shiferaw and Holden, 1998). Thus the effect of off-farm income is difficult to determine a priori.

Location of the farm comprises of biophysical factors associated with farm and climatic factors such as rainfall, and soils (Ervin and Ervin, 1982). It is hypothesized that farmers in high agriculturally potential areas (Vihiga district) have higher speed of technology adoption than those in low agriculturally potential areas (Siaya district).

Access to extension services and participation in land management programs may have a positive impact on farmers" access to information, managerial capabilities and productivity (Abdulahi and Huffman, 2005). Farmers" contacts with extension agents and participation in land management programs were measured prior to adoption of a particular practice to ensure that information regarding the effects of these variables was a possible cause for adoption rather than the effect of adoption. These variables are both hypothesized to speed up the adoption of composts and inorganic fertilizer, which are relatively new practices.

Membership to groups may enable farmers learn about a technology via other farmers and from other development agencies (Nkamleu, 2007). Group membership is thus expected to speed up adoption of relatively new technologies: inorganic fertilizers and compost.

Living far from the major market can reduce the expected profitability of a new technology and create a barrier associated with limited information about distant marketing outlets and increased transaction costs (Abdulahi and Huffman, 2005). Distance simply refers to physical dimension without any due attention to the quality aspects of the road. The hypothesis here is that, living at a greater distance from the major market retards speed of adoption of the practices.

In addition to capturing changing conditions through some of the above covariates expressed in time-varying form, different specifications of time at the community level are introduced in this study to describe the changes in external conditions such as market liberalization. Starting in the early 1990s, agricultural markets have been fraught with frequent problems, primarily due to market liberalization. A dummy variable representing market pre- and post

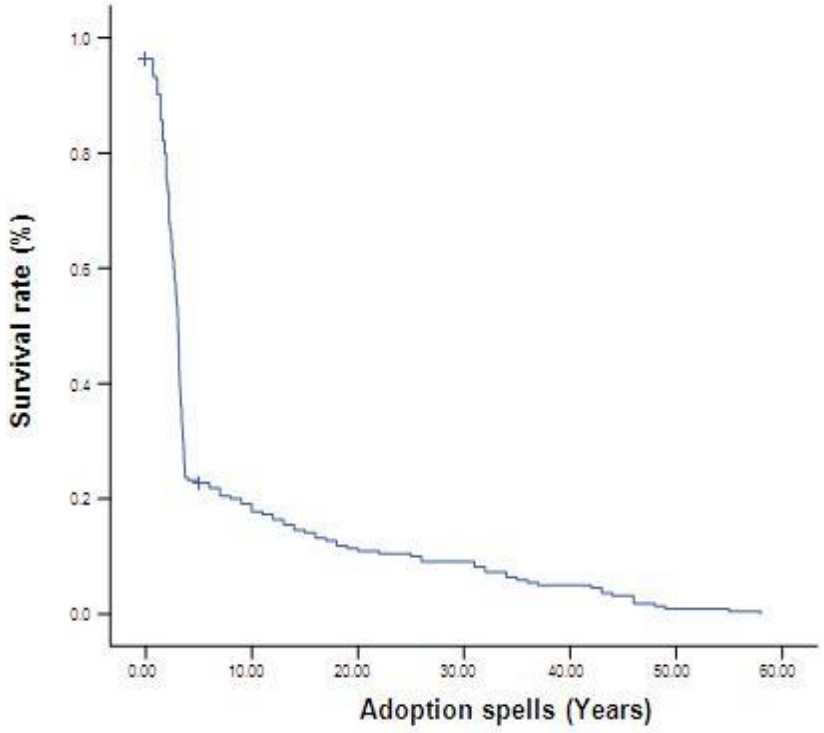

Figure 3. Kaplan-Meier survival estimate of mineral fertilizer adoption.

market liberalization periods allows for an epoch shift and it is hypothesized to retard adoption of mineral fertilizers, but hasten the adoption of compost and manure as „substitutes".

RESULTS AND DISCUSSION

Non-parametric duration analysis

Kaplan-Meier estimates of the survival functions for adoption of inorganic fertilizers and animal manure are plotted in Figures 2 and 3, respectively. Those for composts and green manure were almost identical to that of manure and are therefore not reported here. The horizontal axis shows the number of years that elapsed from the date of the introduction of a particular INM practice or year of household formation (whichever event is the latest), to the year of first adoption. A comparison of Figures 2 and 3, shows that the speed of adoption of mineral fertilizer was rapid in the early years but became more sluggish later (suggesting Weibull function), while that for animal manure was gently sloping throughout (suggesting exponential function).

Parametric duration analysis

Turning to the parametric estimation, this analysis avoided restricting to a particular distribution and initially estimated four different distributions: exponential, Weibull, Gompertz and Log Logistic including the full set of time invariant and time-varying variables listed in Table 1 and results compared. To obtain the preferred models reported here, variables in Table 1, which had z-values less than one in the models that included all variables considered relevant on *a* priori grounds, were dropped because of their insignificant effects. The Akaike information criterion (AIC) [2] was employed to further evaluate the distributions that best fitted the data for each model, that is, a model with the smallest AIC is preferred (StataCorp, 2007). The models that best fitted data were Weibull for mineral fertilizers and exponential for both manure and compost. The AICs were 528 for mineral, 485 for compost and 362 for manure.[3] The other AICs are not reported but are available on request from the corresponding author.

It is important to note that the size and significance of most variables were relatively consistent across different

[2] For parametric duration models, the AIC is defined as AIC= -2 (log likelihood) L+2 (k+c), where k equals the number of independent variables, and c is the number of model-specific distribution parameters: it is equal to one for the exponential distribution and equal to two for the Weibull and Gompertz distribution, respectively (StataCorp, 2007).

[3] Only 8% of the households reported application of green manure, hence removed from further analysis due to degree of freedom concerns.

specifications, indicating robustness of the results and conclusions drawn from the preferred specifications. A log-likelihood test [4] conducted to verify whether the coefficients of the omitted variables were jointly zero failed to reject the null hypothesis, implying that dropping variables with z-values less than unity was statistically justified.

Using the likelihood ratio test statistic to test the null hypothesis that no unobserved heterogeneity exists, that is, $H_o = 0$ versus $H_o \neq 0$ shows that *p*-values were 0.258 for manure, 1.00 for compost and 0.001 for inorganic fertilizers. The conclusion is that unobserved heterogeneity in non-adoption spells exists in the inorganic fertilizer model. The Duration model for adoption of inorganic fertilizer was thus modeled with gamma heterogeneity correction.

The adoption of the practices has been estimated independently. However, there are potentially some important issues related to integration of different practices but it is not possible to formally consider these empirically within the duration framework due lack of records from households on technology adoption patterns. Results of the preferred regression models are presented in Table 2. The results suggest that the nature of each of the studied practices is different because each model includes different sets of independent variables. The Wald statistic is significant at 1% in all the three models, implying that the association of the independent parameters with speed of the adoption of the practices is significantly different from zero. A negative coefficient reflects a shorter pre-adoption spell (the relevant variable speeds up the adoption process) and increases the probability of adoption, while a positive coefficient indicates longer pre-adoption spell and lower probability of adoption.

Age of the household head has a positive coefficient on the adoption of mineral fertilizers ($p < 0.01$), signaling that households headed by elderly people are likely to take longer time to adopt mineral fertilizers. As household heads grow older, their risk aversion increases and adapt less swiftly to a new phenomenon such as mineral fertilizer. In addition, with advance in age, the ability for the household head to participate in strenuous manual activities such as application of mineral fertilizers decline and this reduces the speed of the adoption of labor-intensive technologies. This finding is consistent with Matuschke and Qaim (2008) who found that age of household head had a significant effect on accelerating the adoption of pearl millet in India. In contrast, other studies, for example, Abdulai and Huffman (2005) found that households headed by elderly persons adopted dairy cattle faster than those headed by younger ones. This is because adoption of dairy cattle requires a significant capital investment, and because elderly household heads may have accumulated capital and may be preferred by credit institutions, both of which may make them more prepared to adopt technology faster than younger ones.

The coefficient of relative farming experience of the household head is positive with regard to adoption of mineral fertilizers, manure and compost, all at 1% signify-cance level. This denotes that relative farming experience retards the adoption of all the three practices. This result is rather surprising, as one would have expected relative farming experience to hasten the adoption. However, the result suggests that household heads with high relative farming experience took longer time to assess potential of the practices before making informed adoption decisions based on past experiences with new practices. In contrast, Edmeades et al. (2008) found that relative farming experience increased the likelihood of the adoption of different banana varieties in Uganda. The results thus suggest that the effect of relative farming experience is dependent on the type of technology under consideration.

The coefficient for education attainment of the household head is negative for mineral fertilizers model ($P < 0.01$), suggesting that an increase in household heads‟ years of schooling shortens duration of non-adoption of mineral fertilizer. The effect of education could be transmitted through off-farm income rather than knowledge-intensive requirement for its use because mineral fertilizer is a relatively simple technology that does not need high education level for farmers to use it. However, it may be argued that farmer education hastens the adoption of mineral fertilizer because better-educated farmers are able to understand the benefits of the mineral fertilizer faster. It is, however, important to note that after the initial adoption, which was the focus of this study, optimal use of chemical fertilizers requires much knowledge in understanding types of fertilizers for different crops, as well as rates, time and method of application, which require high educational attainment. Conversely, because cash income is required to purchase mineral fertilizer, household heads with higher education levels are most likely to obtain off-farm income through employment, hence hasten the adoption. The finding is consistent with Weir and Knight (2000) who reported that household heads‟ level of education hastened the timing of technology adoption, but was less critical to the question of whether or not a household ever adopts a new farm technology.

Gender of the household head stands out as an important predictor of the time to adoption of mineral fertilizers: male headed households have a high likely-hood of adopting mineral fertilizers faster than their female headed counterparts ($p < 0.05$) and manure ($p < 0.05$)

[4] The likelihood ratio test is defined as: $-2(L_\Omega - L_\omega)$, where L^Ω and L_ω are values of the log likelihood functions for the restricted and unrestricted models respectively. The number of restrictions equals the number of explanatory variables omitted. It is asymptotic χ^2 (k), where k is the number of restrictions. If the calculated χ^2 is less than the critical value of χ^2 the null hypothesis is accepted.

Table 2. Restricted hazard models for adoption of soil management practices.

Variable	Mineral fertilizer Weibull	Manure: Exponential	Compost: Exponential
Age of household head (years)	0.015 (0.008)[c]	-	0.011(0.009)
Relative farming experience (ratio)	0.026 (0.007)[c]	0.013(0.004)[c]	0.027(0.008)[c]
Education of hh head (years)	-0.046 (0.018)[c]	-	-
1= male headed households	-0.992 (0.411)[b]	1.547(0.653)[b]	-
1=Positive attitude to i^{th} practice	-0.347 (0.163)[b]	-0.677(0.195)[c]	0.326(0.170)[a]
Ratio of farm worker to hh size	-0.343 (0.295)	-0.765(0.377)[b]	-0.371(0.341)
1=main income off-farm	-0.423(0.090)[c]	-0.239(0.136)[a]	-
Consumer-worker ratio	-	-	0.627(0.039)[a]
1=Own of cattle	-	-0.518(0.194)[c]	-
1=Prior access to extension	-0.314(0.146)[b]	-	-
1=Participate in land mgt. program	-0.427 (0.157)[b]	-0.698(0.197)[c]	-
Location of farm (1=Vihiga)	-0.368 (0.156)[b]	-0.668 (0.200)[c]	-0.200(0.148)
1=Group member	0.524 (0.338)[a]	-0.942(0.541)[a]	-
Distance to major market (km)	0.026 (0.013)[b]	-0.018(0.016)	-0.023(0.016)
Market liberalization(1=after1990)	0.322 (0.148)[b]	-	0.405(0.262)[a]
Constant	1.723 (0.670)[b]	1.720(0.692)[c]	1.370(0.609)[b]
Log likelihood	-292.908	-191.806	-298.250
Wald (χ^2)	χ^2 (13) = 104.2	χ^2 (10)= 103.3	χ^2(8)= 80.8
Prob > χ^2	0.000	0.000	0.000
Log likelihood ratio test[a]	χ^2 (13)=0.626	χ^2 (10)=2.212	χ^2 (8)=1.682
Log likelihood ratio test θ=0	χ^2(0.01)=86.3 (p=0.00)	χ^2(0.01) =0.61 (p=1.00)	χ^2(0.01)=0.42 (p= 0.26)

Figures in parentheses are robust standard errors. a, b, and c indicate significant at 0.1., 0.05 and 0.01, respectively.

slower than female headed counterparts. The faster adoption of mineral fertilizers by male-headed households could be because male-headed households are relatively wealthier and control the financial resources, which could be applied to buy mineral fertilizer, unlike female-headed households. The results on mineral fertilizer corroborate the findings of Kaliba et al. (2000) on adoption of mineral fertilizers, whilst the findings on manure is consistent with the results of Burton et al. (2003), which showed that women had a higher likelihood of adopting organic farming faster than men.

Attitude of the household head on the efficacy of a given practice on increasing crop yields has a negative coefficient on the speed of the adoption of mineral fertilizers ($p<0.05$) and animal manure ($p < 0.01$) but positive coefficient on the speed of the adoption of compost ($p<0.1$), suggesting that positive attitude accelerates adoption of mineral fertilizers and manure but retards the adoption of composts.

The result suggests that the motivation to adopt a given practice is not solely driven by efficacy of the practice, but rather by other factors. Even though inorganic fertilizers are seen to have high efficacy on crop yield, there is evidence that manure would be applied instead due to its relatively low cost because it can be obtained from owned cattle. The result means that composting is expensive in terms of the labor input requirements such that even if it would appear that fertilizer is expensive, it might be relatively cost-effective when other factors are accounted for. Consistent with this study a number of studies provide evidence that attitudes are indeed important in the choice of agricultural practices (Burton et al., 2003).

Ownership of cattle at the time of farm establishment, as expected, has a negative coefficient on manure ($p < 0.01$), suggesting cattle ownership speeds up the adoption of manure. The results imply that owned cattle are the major source of manure, as market for manure seems not to be well-developed in the study area. This finding is consistent with Marenya and Barret (2007) on adoption of manure in western Kenya.

The ratio of household members who provide farm labor to total household size at the time of household formation accelerated the adoption of manure as expected. This confirms that household labor is very important for speeding up implementation of labor intensive technologies such as manure application. This is consistent with Franzel (1999) study on the adoption of improved tree fallows, which found that labor constraints had a significant impact on the adoption decision, as tree fallows are a relatively labor-intensive.

The coefficients of off-farm income as the main income

source for the household at farm establishment are negative in mineral fertilizer ($p < 0.01$) and manure ($p < 0.1$) models. The result signal that, in general and holding other factors constant, households which had off-farm income as a major source of income at the year of household formation had a higher probability of adopting manure and mineral fertilizer faster than those which did not. This is because off-farm income relaxes the cash constraints on purchase of mineral fertilizer and hiring labor. The result is consistent with Ervin and Ervin (1982) and Shiferaw and Holden (1998), which show that households with prior access to off-farm income were more likely to adopt soil management technologies.

Consumer-worker ratio has a positive coefficient on compost adoption model ($p < 0.1$), implying that a high consumer-worker ratio retards the adoption of composts. This could imply that households with a high consumer-worker ratio are dominated by young children, elderly and sick members who cannot provide labor to carry out the drudgery activities of preparing and applying composts. Shiferaw and Holden (1998) found similar results in Ethiopia where adoption of labor intensive physical soil conservation measures was lower amongst households with high consumer worker ratio.

Prior access to extension contacts had a negative coefficient in mineral fertilizer ($p<0.05$) model. This suggests that farmers who had prior contacts with extension agencies have greater likelihood of adopting mineral fertilizers faster than those without. Extension may have a positive impact on farmers‟ managerial capabilities and productivity (Abdulahi and Huffman, 2005). Farmers‟ participation in land management projects or programs has negative coefficients on the adoption of both mineral fertilizers ($p < 0.01$) and manure ($p < 0.05$), denoting that participation in programs speeds up the adoption of mineral fertilizers and manure. These findings are consistent with innovation-diffusion theory (Rogers, 1995), which postulates that innovation is communicated through certain channels over time among members of a social system and that access to information speeds up technology adoption.

The findings corroborate Abdulai and Huffman (2005) who found that prior access to extension service accelerated the adoption of dairy cattle in Tanzania. However, in a review of 31 empirical studies (Knowler and Bradshaw, 2007) participation in a state subsidy programs such as land management was significantly associated with adoption in four instances and insignificant in two instances.

The coefficient for location of the farm variable has a negative sign in the mineral fertilizer ($p < 0.05$) and manure ($p < 0.01$) models. This denotes that households located in the high agricultural potential area (Vihiga district) tend to adopt mineral fertilizer ($p < 0.05$) and manure ($p < 0.01$) faster than those located in Siaya district. The location effect appears, however, to have strongest effect on the speed of the adoption of manure, possibly because of the relatively lower costs of accessing manure compared to mineral fertilizer. This finding is consistent with Dadi et.al. (2004), who report that the speed of adoption of mineral fertilizer and herbicides was faster in a high agriculturally potential area with good infrastructure in rural Ethiopia compared to a low agricultural potential area with poor infrastructure. In the case of Vihiga district, the faster adoption of mineral fertilizer could also be attributed to small farm sizes due to high population pressure, hence need to survive on small farms by increasing productivity.

Membership in groups accelerated the adoption of manure ($p<0.01$) and retarded adoption of mineral fertilizers ($p<0.01$). This finding on mineral fertilizers is rather difficult to explain. However, because most groups in western Kenya do not provide sizeable credit to support agriculture, the effect of group membership is most likely transmitted through access to information rather than economic empowerment. Another possible explanation may be that group members share a myth that “mineral fertilizers spoil the soil”, thus reducing the speed of adoption, as farmers take long to observe whether mineral fertilizer actually spoils the soil or not before deciding to adopt. For the study, the latter explanation is more relevant than the former. The finding on mineral fertilizer is consistent with Njuki et al. (2008) who report that farmers who perceived chemical fertilizers to be bad for the soil were more likely to use other soil management options. The finding on adoption of manure is consistent with Burton et al. (2003), who found that membership in farmer associations accelerated the adoption of organic farming.

The evidence regarding the importance of distance to market in adoption decisions is also reasonably strong, the relevant coefficients being positive and significant in the mineral fertilizer ($p < 0.05$) model. The positive sign of the coefficient suggests that the farther the distance from the farm gate to the major market centre the lower the speed of farmers‟ adopting mineral fertilizers. However, distance to the major market does not significantly influence the use of manure and compost. This may reflect that these inputs are thinly traded. The finding on chemical fertilizers means that transaction costs are a significant deterrent to market participation by agricultural households and diffusion of technologies.

Empirical microeconomic evidence from Nakuru district, Kenya (Obare et al., 2003) show that farmers faced with high farm-to-market access costs or poor market access commit less land, fertilizer and machinery resources to production, but more labor and use rudimentary tools such as hoe and machete for tilling. The finding of this study is consistent with Dadi et al. (2004) who showed that distance to a major market significantly retarded the adoption of mineral fertilizer in rural Ethiopia. Considering the effect of distance to major market on adoption from

different perspectives, other studies have found that farmers in closer proximity to major markets could face very high land pressure especially if it is in urban centre, which induces them to use more land intensive production practices such as mineral fertilizers (Adesina and Chianu, 2002).

Finally, market liberalization has a positive coefficient for the mineral fertilizers ($p < 0.05$) model, indicating that advent of market liberalization retarded the adoption of mineral fertilizer. As noted by Shiferaw et al. (2008) slow adoption of mineral fertilizer seems to be associated high cost of mineral fertilizers upon liberalization and poor input-output price ratios. The results imply that the expected positive response by the private sector to fill the void left when Government withdrew from markets controls has not been fully exploited, especially western Kenya, where structural problems of poor infrastructure and lack of market institutions are prevalent, resulting in market failure. This has left a large number of smallholder farmers under subsistence production and, therefore, unable to benefit from liberalized markets. Dadi et al. (2004) found similar scenario in rural Ethiopia.

Conclusions

This study has demonstrated that duration analysis conveys information not only on why a household adopted, but also on the timing of the adoption decision, using both cross sectional and time-series data, which cannot be portrayed by static discrete choice models. The study reveals that factors that influence timing of the adoption were many and varied by soil management practices. Access to extension services, participation in land management programs, cattle ownership, education of household head and location of the farm, accelerated the initial adoption. In contrast, age, relative farming experience and market liberalization retarded the adoption. However, gender of household head gave mixed results. Speeding up adoption and diffusion of soil fertility management technologies requires the policies that promote farmers" participation in land management programs and targeting of the existing practices to households and areas with characteristics that favor their adoption, whilst generating alternative technologies that suit the other households and areas. In addition, due to market failure in rural western Kenya, smallholders" participation in the market could be improved through concerted efforts of development agencies to catalyse formation of farmer marketing groups and strengthening management capacity of the groups to engage in meaningful collective marketing. Policy actions on deployment of resources in rural areas to correct for labor market imperfections could stimulate off-farm employment for rural folks to help investment in soil fertility.

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