Does land tenure security matter for investment in soil and water conservation? Evidence from Kenya

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Abstract

This paper investigates the impact of tenure security and other factors on investment in soil and water conservation (SWC) in Kenya. Factor analysis, step-wise regression and reduced form model approaches are used to explain the willingness, likelihood and intensity of adoption of SWC investments. The results confirm the importance of tenure security and development domain dimensions in determining the likelihood and intensity of adoption and suggest that to ensure land tenure policy is pro-SWC/environment, it is important to consider whether household plots are owned, rented out or rented in. The impact of household assets implies a poverty environment link. Similar factors affect the decision whether or not to invest in SWC and also the level of investment. The results suggest the need for region specific SWC practices and for broad policies that provide incentives for environmental conservation and poverty reduction.

Keywords: soil and water conservation; tenure security; development domains; factor analysis

Cet article étudie l'impact de la sécurité de la tenure et autres facteurs sur l'investissement dans la conservation des eaux et des sols (SWC en anglais), au Kenya. L'analyse factorielle, la régression progressive, les approches se servant du modèle de la forme réduite sont utilisées pour expliquer la volonté, la vraisemblance et l'intensité de l'adoption des investissements SWC. Les résultats confirment l'importance de la sécurité de la tenure, et les dimensions du domaine de développement lorsque l'on détermine la vraisemblance et l'intensité de l'adoption. Ils suggèrent également que pour faire en sorte que la politique de régime foncier soit en faveur de la SWC/environnement, il est important de considérer si les familles possèdent, louent ou louent à, leurs parcelles de terre. L'impact des biens ménagers laisse supposer un rapport avec la pauvreté. Des facteurs similaires affectent la décision de savoir s'il faut ou ne faut pas investir dans la SWC ; à noter également le niveau de l'investissement. Les résultats suggèrent la nécessité de pratiques SWC pour des régions

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spécifiques et de vastes politiques capables d'entraîner une motivation en matière de protection de l'environnement et de réduction de la pauvreté.

Mots-clés : *conservation des eaux et des sols ; sécurité de la tenure ; domaines de développement ; analyse factorielle*

1. Introduction

There is a great deal of literature on the impact of land rights on investment in soil and water conservation (SWC) in developing countries. However, divergent views abound on the causal relationship between the two. Some studies argue that if property rights are both durable and assured, this could have two effects that would lead to increased investment: first, households would perceive the greater security of receiving the full benefits of long-term investments in land improvement and, second, secure land rights might help them obtain investment loans from potential lenders (Besley, 1995). It is, however, difficult to separate out the two effects. Some studies show that well-defined, durable and assured property rights may be a necessary, but not sufficient, condition to have access to finance (Carter & Olinto, 2003). Others advocate for privatization of land, on the premise that farmers' incentives to invest in technologies are inhibited because indigenous property right institutions give them weak tenure security and their lack of land titles makes it hard for them to obtain credit (Kabubo-Mariara, 2004, 2007).

There are three reasons why secure land tenure might increase farmers' willingness to invest in SWC measures. First, if they feel more secure in their right or ability to use their land in the long run, they will be more willing to make investments with high sunk costs (Demsetz, 1967; Li et al., 1998; Shiferaw & Holden, 1999; Place & Otsuka, 2000; Deininger & Jin, 2002; Jacoby et al., 2002; Gebremedhin & Swinton, 2003). Second, if land markets exist and farmers can freely dispose of their land, the added value of SWC investments can be made liquid and farmers can then realize the return to those investments without having to wait the full gestation period of the investment. This is an important consideration because when time horizons are relatively short there are high subjective discount rates and myopic time preference (Besley, 1995; Platteau, 1996, 2000). Third is the collateral effect: if farmers have more secure land titles, it will be easier for them to use their land as collateral to gain access to the necessary credit for SWC investments.

Some studies, however, have shown that tenure security is not important for land conservation (Migot-Adholla et al., 1994; Pinckney & Kimuyu, 1994), while others suggest that highly individualized rights to land are more important for long-term than short-term investments (Gebremedhin & Swinton, 2003). The main reason for these different findings is the definition of land rights and the methodological approach used. There is a range of definitions – full security of tenure, transferability, a continuum of expected rights and modes of land acquisition (Kabubo-Mariara et al., 2006). To overcome arbitrariness in the choice of indicators of tenure security, some studies have used factor analysis[1] to derive measures of tenure from existing information on various aspects of security (Kruseman et al., 2006). Besides the difficulty of defining and measuring property rights and tenure security there are

[1] Factor analysis is a methodology used to uncover the latent structure of a set of variables. It attempts to explain the correlations between variables in terms of underlying factors that are not directly observable and thus reduces the number of variables.

also theoretical and empirical difficulties. And on top of this, researchers have different reasons for studying the relationship between property rights and technology adoption and each reason may have different implications for the methodology and results (Kabubo-Mariara, 2004, 2007).

In addressing some of the above difficulties, this study makes three contributions to the literature on the impact of tenure security and other factors on investment in SWC in Africa. Firstly, while the literature suggests that the choice of indicators of tenure security is often arbitrary, owing to the difficulties discussed above, this study used factor analysis to generate these indicators and so overcome this arbitrariness, as it also did for indicators of soil quality and topographical factors. Secondly, it used rich data (geographical coverage and variables). We collected data on all forms of land rights and key SWC strategies adopted by farmers in our sample, which allowed us to analyze the determinants of the willingness to adopt, the actual adoption and the intensity of adoption of SWC. Thirdly, and most importantly, the paper introduces a methodological innovation: a nested error correction approach, where residuals from binary models and from factor analysis applied to binomial model results are used in multinomial and Tobit models to explain adoption and the level of conservation.

The rest of the paper is organized as follows . Section 2 describes the study site and the data and Section 3 the conceptual framework and methodology, Section 4 presents the results, and Section 5 concludes.

2. Study site and data

This study is based on data collected from a sample of 457 households in November and December 2004. The National Sample Survey and Evaluation Program (NASSEP) IV of the Central Bureau of Statistics, Ministry of Planning and National Development, Kenya, was used as the sampling frame for the field survey, a multi-stage sample procedure that used a mixture of purposive, stratified and random sampling methods to arrive at the final sample. In the first stage, study districts were selected on the basis of differences in poverty, population density, terrain and tenure security. In the second, administrative divisions were selected in each of the three districts, on the basis of agro-ecological diversity. In the third, locations and sub-locations were selected, also on the basis of agro-ecological diversity. In the fourth, sample points (clusters) from the NASSEP frame were selected on the basis of the total number of clusters within a sub-location and the number of households in each cluster. In the fifth and final stage, the desired number of households was selected from each cluster. To arrive at the total number of households actually visited, we took a self-weighting probability sample from each cluster in a district, making a total of 457 households from the three districts (151, 188 and 151 from Murang'a, Maragua and Narok Districts respectively). In addition to the household survey, a community questionnaire was administered to selected key informants in each cluster to collect information on markets and village level characteristics.

3. Methodology

3.1 Conceptual framework

The analytical framework used in this paper draws from the theories of induced technical and institutional innovations in agriculture, which state that with evolution in development domain[2] dimensions and technology, households adapt appropriate technologies to local circumstances and explain changing land management and SWC systems in terms of changing microeconomic incentives facing farmers because of changes in relative factor and institutional endowments (Boserup, 1965; Kabubo-Mariara, 2005; Pender, Ehui & Place, 2006). The evolutionary land rights theory is based on the same premise (Platteau, 1996, 2000).

The paper's framework also uses the farm household model, which assumes that households take into account the external environmental and socioeconomic constraints in their production activities. The model can be summarized in a number of basic equations that are a slight expansion of the original model (Singh et al., 1986). The first is a utility (u) function, which is a function of a vector of consumption goods (c), leisure (l) and household characteristics (h). The inclusion of SWC technology would imply a longer time (t) horizon, which requires the inclusion of a subjective time preference as a discount rate (r) comparable to the general formulation of optimal control models (Bulte & Van Soest, 1999). If we let F denote the cumulative distribution function of states of nature that captures the inherent risk and uncertainty of rural livelihood systems in terms of prices, weather and in some cases tenure (see for instance Kruseman, 2000), the household utility function can be defined as:

$$u = \int\int u(c,l,h)e^{-rt}\,dt\,dF \qquad (1)$$

Utility is maximized subject to a cash income constraint (equation 2), where c^m and c^a are vectors of market purchased and household produced consumption commodities respectively, q is a vector of commodities produced by the household, p^m and p^a are vectors of market and farm-gate commodity prices respectively, p^b is a vector of input prices related to material inputs x, w^i and w^o are vectors of factor prices (including wage rates and land rents) for hiring in or renting out production factors (f^i and f^o respectively) and $y*$ is exogenous income:

$$p^m c^m = p^a\left(q - c^a\right) - p^b x - w^i f^i + w^o f^o + y^* \qquad (2)$$

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[2] 'Development domains' are the agricultural potential, market access, population density and institutional setting of a locality.

The household faces a production constraint (q) reflected by a technology function that depicts the relationship between inputs (x, f^i, f^0) and outputs (q) conditional on farm characteristics z , soil quality s and technology level k . That is:

$$q = q(x, f^i + f^0, z, k, s) \quad (3)$$

The agricultural household model can be solved in two ways: by estimating a structural model, or by estimating reduced form equations. The latter is considered more appropriate because of difficulties of identification (Singh et al., 1986; Kruseman, 2000).

3.2 Empirical model specification

From the above framework, the basic model of interest is the adoption of SWC investments. This can be derived from the first order condition of the production maximization behavior of the agricultural household. Drawing from the literature, we hypothesize that adoption of SWC investments may be influenced by three sets of factors, at farm, household and village level.

Farm factors are natural capital (topography, quantity and quality of land) and household characteristics (physical assets and human capital). These factors promote intensive farming and more productive use of inputs. Tenure security regulates land management decisions. Population density could exert a negative Malthusian effect, but could also intensify the use of factor inputs and induce innovations in agriculture. Village characteristics include participation in organizations and access to programs and services such as extension, which broaden household access to information about technologies. Access to markets and infrastructure determines the comparative advantage of a location by affecting the costs and risks of SWC investments and related outcomes (Kabubo-Mariara, 2007). The SWC model can thus be specified as:

$$SWC_j = swc(z, h, v) + \varepsilon_1 \quad (4)$$

where j refers to the plot, z is a vector of farm characteristics, h is a vector of household characteristics and v is a vector of village characteristics, including quantifiable institutional arrangements at village level. Other development domain dimensions such as agricultural potential fall under z. ε is a stochastic disturbance term. Some of the institutional factors captured in v (such as the presence of village groups and the willingness to invest in SWC) are potentially endogenous. To solve the endogeneity problem, the best solution would be instrumental variables (IV) estimation. In the absence of suitable instruments, one alternative is to use a step-wise error correction approach. This involves the use of predicted values or residuals of the potentially endogenous variables as instrumental variables to estimate the truly endogenous variables (Nkonya et al., 2004; Kabubo-Mariara et al., 2006; Pender & Gebremedhin, 2006). The resulting equation allows estimation of the direct and indirect effects of exogenous variables on the dependent variable and also eliminates potential endogeneity bias (Benin, 2006). We take this approach in this paper. In the first step, we explain membership and participation in village institutions, including extension services. In the second step, we use their residuals to explain general willingness to invest in SWC. In the final step, we use the residuals of this willingness to invest to explain actual adoption of SWC.

On the basis of the theory and the literature, membership of a household in village institutions (*GRP*) can be expressed as:

$$GRP = grp(z, h, v) + \varepsilon_2 \tag{5a}$$

We also analyze the impact of listening to extension services on general matters (*EXT*) and on natural resource management (*NRM*) on adoption of SWC. The willingness to listen to extension services (= 1 if household received any extension service) can be specified as:

$$EXT = ext(z, h, v) + \varepsilon_3 \tag{5b}$$

$$NRM = nrm(z, h, v) + \varepsilon_4 \tag{5c}$$

In this study, the willingness to invest is considered for investments made up to five years ago. If the household made no investments in the past five years, the investment is set to zero. Past investments (INV_{t-1}) are SWC investments made more than five years ago. Given membership and participation in village institutions, the willingness to invest in SWC at household level (INV_{hh}) depends on other household, farm and village characteristics. The residual terms of each of the equations (5a) to (5c) are orthogonal to the other independent variables in the willingness to invest equation.[3] The truly independent variables capture the sum of the direct and indirect effects, while the residual terms capture the effect of the endogenous variables (Kabubo-Mariara et al., 2006).

The willingness to invest at household can therefore be specified as:

$$INV_{hh} = inv(z, h, v, GRP^{\varepsilon}, EXT^{\varepsilon}, NRM^{\varepsilon}, INV_{t-1}) + \mu_1 \tag{6}$$

[3] The predicted residuals are not necessarily independent from the error term of the equation in which the endogenous variable appears as explanatory variables. If they are truly dependent this estimation approach will yield biased estimators, but the bias will be quite small. Since the residuals are error correction models (ECM), this approach is more efficient than using the truly endogenous variables in the SWC model.

where the superscript ε over a variable denotes that the variable is a residual. However, we note that the equations from which residuals are derived are a set of identical equations. Membership in special interest groups and access to extension services are related and therefore should have correlated variances. Methods such as seemingly unrelated regression cannot be applied with probit models, but we can find a common variance factor by applying factor analysis to the residuals of each of the probit results for each equation (5a–5c). Since all the models are identical, the residuals will be uncorrelated with the set of explanatory variables. From factor analysis, the unrotated factors with eigenvalues greater than 1 provide us with a measure of a common variance for the residuals (for more details on factor analysis see Kaiser, 1958; Kabubo-Mariara et al., 2006; Kruseman et al., 2006). This can be included in the final estimation model of the willingness to invest in SWC. In the empirical analysis, the factor analysis loads on two factors: willingness to listen to extension in general (γ_{EXT}) and membership in special village institutions (γ_{GPR}). These two factors are then used in estimating the final model of the willingness to invest at the household level.

Equation (6) therefore becomes:

$$INV_{hh} = inv(z, h, v, \gamma_{EXT}, \gamma_{GRP}) + \mu_2 \qquad (7)$$

To capture the effect of membership in interest groups, willingness to listen to extension and the willingness to invest in SWC, we enter the residual terms of probit equations (5a), (5b) and (7) into equation (4). The final estimating equation becomes:

$$SWC = swc\left(z, h, v, GRP^{\varepsilon}, EXT^{\varepsilon}, INV_{hh}{}^{\varepsilon}\right) + \mu_3 \qquad (8)$$

where INV^{ε}_{hh} refers to the residual of the willingness to invest at the household level and all other variables are as defined earlier. The relationships modeled above are illustrated in Figure 1.

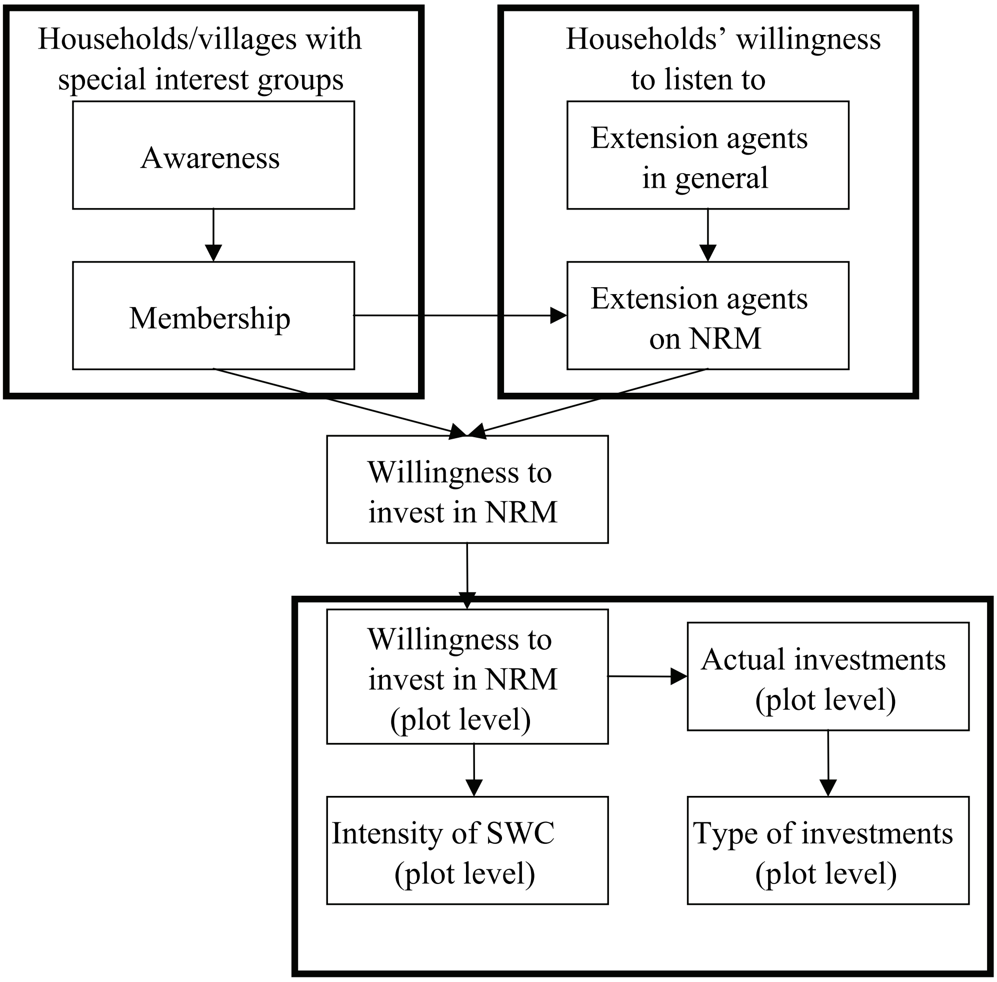

Figure 1: Link between village institutions and investment in SWC

Equation (8) is based on actual investments made by a household. We limit the analysis to plots that have had investments in the last two seasons. The analysis is based on four main types of investment: grass strips, mulching, tree planting and terracing. We further categorize these into permanent and seasonal investments, depending on how they were adopted. The multinomial logit method is therefore used to explain the adoption of SWC investments (equation 8). For intensity of SWC, we apply the Tobit regression because some plots have no investment.[4] The dependent variable is obtained by a count of all SWC investments per plot.

3.3 Estimation issues

The types of investment that we consider in this paper are determined by the same set of factors. It is therefore important to investigate for any possible correlation between the

[4] It is important to qualify this by explaining that what we estimate in this paper are no ordinary multinomial/Tobit models: they are error corrected models derived in three stages, as explained earlier. Nested in each final regression are binomial models and factor analysis variables from binomial models.

adoption decisions. This is done in several steps. First, we run probit models for each of the adoption decisions. Second, we derive residuals from each investment regression equation and examine the relationship between investment decisions by carrying out a factor analysis on the residuals from each equation. The results of the factor analysis show that there is only one factor in which residuals for more long-term SWC investments, such as permanent investments in soil fertility and tree planting, are significantly present. We refer to this unique factor as the 'speed of regenerating chemical fertility' because higher levels of regenerating soil fertility characterize these long-term investments. This is further supported by factor loadings based on varimax rotation.[5] The results of the factor analysis support our intuition that different types of SWC investment are explained by similar explanatory variables.

4. Results and discussion

4.1 Descriptive statistics

The analysis in this paper is based on data for 684 plots collected from 457 households. We collected data on the types of improvement, the number of SWC structures, when the household made the investment and whether or not any SWC strategy had been abandoned. The data shows that 70% of all households were willing to take up SWC strategies, and every household had either at least one SWC strategy in place and one previous SWC strategy. The three most frequently observed investments were grass strips, terraces, tree planting and mulching, and 33% of the investments were current (Table 1).

Table 1: Summary statistics on investments in land management

	Number of plots	Share of plots
Type of investment		
Grass strips	230	0.34
Tree planting	103	0.15
Terraces	119	0.18
Mulching	62	0.09
Other investments	170	0.25
Period of investment		
Last year	229	0.33
Last five years	189	0.28
More than five years ago	203	0.30
Already on land upon acquisition	64	0.09
Total number	684	1.00

The study collected data on all aspects of tenure security, looking at mode of acquisition and expected land rights on all plots owned, used or rented/lent out by the household. When looking at mode of acquisition we investigated how, when and for how long the plot had been held by the household; when looking at expected land rights we investigated the farmers'

[5] The results are available from the authors on request.

perception of these rights (Kabubo-Mariara et al., 2006). We also investigated rental arrangements and land rights on rented out and lent out land. The data shows that 71% of the plots were owned by the household, 22% were rented in and 7% were rented out.[6] More than half the plots had been inherited by the household. On average they had been owned for more than 18 years, though 5% had been owned for more than 50 years. Forty-six percent were registered to the household headship and 31% to other relatives. Factor analysis was used to filter out the key elements of tenure security for empirical estimation. Five factors were retained: (1) own farmland, (2) plots owned by the extended family, (3) plots for which other relatives have to give permission to transfer, (4) rented out land, and (5) rental conditions of plots that were either rented or lent with or without permission.

The soil characteristics considered were type, depth, slope, fertility, workability and texture. More than half the plots were slightly to steeply sloped and 22% were flat. The workability in 60% of the plots was easy and almost half had fine soils. Only 14% had coarse soils. The average soil depth was 22.5 cm, though the respondents perceived the soil to be generally infertile. Final variables related to soil quality and topographical factors were constructed using factor analysis. Except for depth of soil, which was unique, all categories of soil quality variables were retained in the factor analysis and were therefore used as explanatory variables for the SWC model. Three topographical factors were obtained from the factor analysis: flatness, moderate slope and undulating terrain.

Market access was based on information about distance, mode of travel and travel time and cost from the village to markets. The factor analysis for market access was limited to four factors: distance to local market, all-weather roads, public transport and nearest town. Only one factor covering almost 75% of the variation in the distance to market was retained.

4.2 Regression results

4.2.1 Determinants of adoption of soil and water conservation investments

The key task of this paper was to test the role of tenure security and household, farm and community characteristics on the adoption of SWC investments at the plot level. We also analyze the determinants of adoption of permanent and seasonal investments. The multinomial logit regression results are presented in Table 2. Since we are interested in both the direct and indirect effects, we retain all variables in the regression models, irrespective of whether they are significant or not.

Impact of household characteristics and assets

The regression results suggest that most household characteristics do not matter much in influencing the adoption decision. While this result is not uncommon in the literature (see for instance Gebremedhin & Swinton, 2003), in our study it could be because our models capture both direct and indirect effects of the explanatory factors. However, age exhibits an inverted U-shaped relationship with mulching and all seasonal investments, suggesting that life cycle affects the investment decision. Younger farmers may have more energy to engage in labor intensive conservation practices but after some threshold the likelihood of adoption declines.

[6] 'Rented in' plots are plots that the household has rented from others for cultivation. 'Rented out' plots are plots that the household has rented/leased/lent out to other households.

Presence of children younger than five years is negatively correlated with adoption of terraces. Given that terracing is labor intensive, the result implies that the presence of young children diverts labor from conservation activities to childcare. However, the presence of older children (aged six to 16 years) is positively correlated with permanent investment decisions, suggesting that they provide additional labor inputs for SWC. Another important finding is that the number of adult females in a household is positively correlated with tree planting, but negatively correlated with adoption of grass strips. The significant positive impact on tree planting suggests the importance of female labor in the adoption of SWC investments. Male labor seems to matter more for mulching than for other investments.

Household assets are captured by a vector of variables: lagged values of farm equipment and livestock wealth, plot size and existing conservation assets (permanent SWC investments). Farm equipment is positively correlated with all permanent improvements except mulching and suggests the role of capital and wealth in the adoption of SWC investments. Livestock wealth is also positively correlated with SWC improvements but is only significant for mulching, terracing and all permanent investments. This suggests that crop and livestock farming are complementary activities. The results for household wealth are consistent with studies that argue for an interlinked connection where tenure and wealth are jointly responsible for investments in SWC.

Table 2: Regression results for adoption of soil and water conservation

	Multinomial logit				Probit		Tobit
Variable	Grass strips	Mulching	Tree planting	Terracing	Permanent investments	Seasonal investments	Investment count
Household characteristics and assets							
Female head	-0.9987	-0.6955	0.3755	0.7284	0.0516	0.0042	0.0966
	[0.9221]	[0.8096]	[0.4781]	[0.7944]	[0.22]	[0.02]	[0.23]
Age of household head	-0.0375	0.2602*	-0.005	0.1359	-0.0389	0.0576	-0.003
	[0.0634]	[0.1492]	[0.0727]	[0.1366]	[1.54]	[1.70]*	[0.03]
Age of household head squared	0.0004	-0.0029*	-0.0002	-0.0014	0.0003	-0.0005	-0.0001
	[0.0005]	[0.0015]	[0.0007]	[0.0013]	[1.18]	[1.69]*	[0.00]
Children younger than 5 years	0.4837	-0.132	-0.4168**	0.2707	0.0215	-0.0401	0.0174
	[0.3058]	[0.3126]	[0.2123]	[0.3231]	[0.23]	[0.47]	[0.09]
Children 6 to 16 years	-0.2113	0.1258	0.1272	0.0076	0.1809	-0.0126	0.1208**
	[0.1987]	[0.1641]	[0.1151]	[0.1953]	[3.51]***	[0.26]	[0.05]
Number of adult women	-1.3196**	0.2857	0.4083*	-0.4571	0.0637	0.0517	0.0581
	[0.5813]	[0.2998]	[0.2286]	[0.3901]	[0.59]	[0.54]	[0.10]
Number of adult men	-0.3054	0.6354**	-0.0882	-0.0496	0.0175	-0.0151	0.0313
	[0.3883]	[0.3023]	[0.2103]	[0.3324]	[0.18]	[0.18]	[0.09]
Head’s years of schooling	-0.0012	0.0006	0.0098	0.064	0.0432	-0.0061	0.0129
	[0.0785]	[0.0711]	[0.0431]	[0.0744]	[2.07]**	[0.33]	[0.02]
Maasai tribe dummy	-0.0322	26.5614**	-0.7693	-0.7697	-0.1434	-0.4022	-0.3417
	[0.0000]	[12.1404]	[1.0265]	[1.7532]	[0.30]	[0.79]	[0.48]
Log-lagged value of livestock	0.228	0.4903*	0.2514	0.8258***	0.2697	0.0348	0.0619
	[0.2723]	[0.2559]	[0.1688]	[0.2947]	[3.45]***	[0.49]	[0.06]
Log-lagged value of farm equipment	0.3770*	-0.3433**	0.2506*	0.1513	0.1063	0.0414	0.2229***
	[0.2047]	[0.1738]	[0.1296]	[0.2041]	[1.79]*	[0.77]	[0.08]
Plot area (farm size)	0.0167	-0.0114	0.0128	0.0196	0.0103	0.0061	0.0150**
	[0.0639]	[0.0535]	[0.0195]	[0.0332]	[1.35]	[0.85]	[0.01]
Distance to plot	-0.0454*	-0.0263	-0.061***	-0.0397	-0.0174	-0.0229	-0.0099**
	[0.0262]	[0.0204]	[0.0212]	[0.0280]	[2.97]***	[2.62]***	[0.00]
Previous SWC structures	-1.6919***	-0.5818**	-2.567***	-2.595***	-0.7971	-0.6483	-1.0887***
	[0.4206]	[0.2956]	[0.3110]	[0.4405]	[7.71]***	[7.01]***	[0.10]

Village characteristics							
Number of institutions present	4.0518	-10.45***	-4.7212*	-8.8659	-0.0072	0.1363	-0.0625
	[4.5502]	[3.5605]	[2.8163]	[5.9752]	[0.01]	[0.26]	[0.50]
Presence of men's groups	0.5202	-2.0400**	-1.1608*	-2.0616	-0.1052	0.1092	-0.0309
	[1.0816]	[0.8261]	[0.6700]	[1.4162]	[0.86]	[0.90]	[0.12]
Presence of income generating	2.2967	-6.287***	-3.1350*	1.1871	-0.0597	0.0123	-0.1441
groups	[0.0000]	[2.2135]	[1.8180]	[6.7421]	[0.22]	[0.04]	[0.27]
Presence of village committees	1.0098	-2.2371**	-1.3093	-1.8976**	0.0364	0.0855	0.0125
	[1.0045]	[0.9280]	[0.8249]	[0.8485]	[0.30]	[0.69]	[0.12]
Presence of safety net and	4.5877***	10.8899**	0.3319	9.1242*	-0.2211	-0.0478	-0.1235
NRM groups	[1.1475]	[4.4174]	[1.1270]	[5.4123]	[0.49]	[0.10]	[0.45]
Population density	-0.0021	0.0004	0.0031*	-0.0014	-0.0001	0.0002	0.0001
	[0.0028]	[0.0023]	[0.0018]	[0.0028]	[0.17]	[0.24]	[0.00]
Market access	0.929	-0.5641	0.9358*	-1.7459	0.0071	0.0689	-0.0908
	[1.1503]	[0.8514]	[0.5652]	[1.4326]	[0.03]	[0.32]	[0.22]
Murang'a district dummy	0.5333	0.3779	1.0358**	1.7961**	0.6544	0.1561	0.8461***
	[0.7948]	[0.6867]	[0.4766]	[0.8231]	[2.86]***	[0.78]	[0.21]
Narok district dummy	-25.3897	-64.5219	-14.1706*	-33.8008*	-1.1159	-0.4541	-1.4038
	[0.0000]	[0.0000]	[7.7250]	[19.1127]	[0.62]	[0.24]	[1.79]
Tenure security and related factors							
Land registered in head/ spouse	0.1301	0.8368**	0.8364***	1.8769***	0.4048	0.1902	0.4392***
	[0.2405]	[0.3789]	[0.1696]	[0.4878]	[4.88]***	[2.81]***	[0.08]
Family land registered in	-0.017	-0.2709	0.2884*	0.6288**	0.0556	-0.0138	0.0151
extended family	[0.2550]	[0.2867]	[0.1560]	[0.2796]	[0.77]	[0.21]	[0.07]
Right to sell family land with	-0.1437	0.5308***	0.4653***	0.2491	0.0214	0.1267	0.1392**
permission	[0.3445]	[0.1899]	[0.1374]	[0.2656]	[0.32]	[2.10]**	[0.06]
Rented out land	-0.7917	-1.9115	-0.773***	-1.0753	-0.2892	-0.2268	-0.3656***
	[0.6791]	[1.3010]	[0.2731]	[0.8946]	[2.53]**	[2.55]**	[0.10]
Lent out land	-0.0147	-0.4321	-0.3061	-0.6362**	-0.1977	-0.1443	-0.2053***
	[0.4051]	[0.3824]	[0.1873]	[0.3056]	[2.43]**	[1.97]**	[0.08]
Soil quality and topography							
Moderate vs fine texture	-0.1387	-0.3786	-0.0887	-1.079***	-0.3143	-0.1473	-0.3570***
	[0.2701]	[0.2548]	[0.1663]	[0.3190]	[3.89]***	[2.10]**	[0.08]
Coarse soils	0.0819	0.4120*	0.1857	-1.3082*	-0.0365	0.0566	-0.0268
	[0.3541]	[0.2237]	[0.1658]	[0.7173]	[0.46]	[0.78]	[0.08]
Soil depth	0.0036	0.0917***	0.0403	0.055	0.0436	0.0068	0.0413***
	[0.0435]	[0.0315]	[0.0287]	[0.0439]	[3.70]***	[0.60]	[0.01]
Red vs black soils	-0.5992*	-0.7147**	-0.3355*	-0.235	-0.0719	-0.1752	-0.2244***
	[0.3109]	[0.3143]	[0.1766]	[0.2776]	[0.78]	[2.29]**	[0.08]
Very fertile soils	0.0203	-0.2202	0.1641	-0.3455	0.0104	0.0284	0.0791
	[0.4190]	[0.4208]	[0.1737]	[0.2939]	[0.12]	[0.38]	[0.08]
Fertile to averagely fertile	-0.3253	-0.3808	-0.2134	-0.268	-0.1639	-0.0132	-0.1481**
	[0.2505]	[0.2511]	[0.1665]	[0.2760]	[2.07]**	[0.19]	[0.08]
Poor soils	-0.3024	0.2107	-0.0316	0.2133	0.051	-0.0124	0.0487
	[0.2766]	[0.1886]	[0.1495]	[0.2423]	[0.73]	[0.19]	[0.07]
Steep slope	-0.088	-0.5005*	-0.0834	-0.3764	-0.1357	-0.0618	0.0264
	[0.2406]	[0.2657]	[0.1490]	[0.2596]	[1.67]*	[0.96]	[0.07]
Moderate slope	0.7495***	0.6743***	0.7864***	0.6587**	0.3745	0.1415	0.3982***
	[0.2565]	[0.2089]	[0.1677]	[0.2754]	[5.27]***	[2.11]**	[0.07]
Flatness of slope	-0.1376	-0.1928	-0.518***	-0.1725	-0.1646	-0.1193	-0.1391*
	[0.2295]	[0.2751]	[0.1725]	[0.2513]	[2.16]**	[1.77]*	[0.07]
Undulating terrain	-0.4741	0.3722*	0.2639*	-0.0957	-0.0345	0.1553	0.0973
	[0.3674]	[0.2174]	[0.1414]	[0.2195]	[0.48]	[2.60]***	[0.07]
Error correction terms (residuals)							
Listened to extension services	0.8453*	-0.1501	0.21	-0.511	0.1619	0.0035	0.0918
	[0.4504]	[0.3416]	[0.2493]	[0.4430]	[1.39]	[0.03]	[0.11]
Membership in village	-0.1798	-0.3787	-0.2086	-0.1812	-0.1009	-0.1052	-0.0571
institutions	[0.3229]	[0.2828]	[0.2014]	[0.3228]	[1.09]	[1.25]	[0.09]
Willingness to invest in SWC	1.1700**	1.6760***	1.5308***	2.5784***	1.0285	0.2304	0.9692***

	[0.4864]	[0.4756]	[0.3153]	[0.5852]	[6.94]***	[1.89]*	[0.14]
Constant					-1.6391	-2.1832	-1.2329
					[1.53]	[1.96]*	[1.10]
Number of plots	684				684	684	684
LR $chi^2(42)$	1400.59***				169.1***	137.11***	236.58***
Log-likelihood	-400.466				-226.84	-273.99	-538.12
Pseudo R2	0.6361				0.2715	0.2001	0.1802

Standard errors in parentheses, ** p<0.01, ** p<0.05, * p<0.1

Plot size increases the likelihood of adoption of all investments except mulching. The impact of plot size on all technologies, including permanent and seasonal SWC investments, is, however, insignificant. This perhaps implies that factor markets are not efficient enough to allow large farmers to hire labor in sufficient quantities for conservation. Distance to plot is inversely correlated with the adoption of all SWC technologies, implying that conservation is more likely to be adopted on home plots than on distant ones. The literature suggests that the transaction costs of traveling to plots will determine the types of conservation measure used on them (Gebremedhin & Swinton, 2003), such that distant or very scattered plots are more likely to be developed with less expensive SWC investments. Existing SWC assets on a plot are inversely correlated with the probability of making new investments. This implies that additional investments are more likely to be made on plots without any prior land improvements.

Impact of village level institutions

The presence of men's groups, village committees and safety net and natural resource management groups favors the adoption of grass strips, mulching and terracing. Income generation groups and village committees, however, seem to divert resources from mulching and tree planting and are negatively correlated with adoption of these investments. Population density and market access are positively correlated with tree planting, which suggests the importance of development domain dimensions in the adoption of SWC investments. The two district dummies suggest that location is an important determinant of the decision to adopt some SWC. There is a higher probability of adoption if a household is located in Murang'a rather than Maragua District, particularly for tree planting, terracing and all permanent investments. The likelihood of adoption is lower in Narok District but the coefficients are insignificant except for tree planting and terracing. Given the diversity of agro-ecology in the three districts, we conclude that the impact of district dummies reflects the unobserved relative importance of different development domains.

Impact of tenure security

The impact of tenure security factors is captured by five variables representing different kinds of land rights: land the family owns, land the household can sell or bequeath with or without permission, land registered in the family name, land rented out, and land rented/leased/lent out without permission. In this study, the first three variables represent the strongest rights to land. The coefficients of these variables exhibit positive and significant coefficients for most adoption models, suggesting the importance of tenure security in the adoption of SWC investments. The results further show that weak security of tenure will discourage investment in SWC, particularly long-term investments such as grass strips, terracing and tree planting. The differences in coefficients for permanent and seasonal investments support the finding that tenure security favors long-term rather than short-term conservation investments (Gebremedhin & Swinton, 2003). Given the types of land rights question that were put to respondents, the results suggest that to ensure that land tenure policy is pro-environment it is important to consider whether household plots are owned, rented out or rented in.

Impact of soil quality and topography

The results suggest that soil quality and topography have a variety of effects on the adoption of SWC investments. Moderate to fine soils are inversely and significantly correlated with the probability of adopting all permanent and seasonal investments, particularly terracing. Course and very fertile soils encourage the adoption of mulching, but discourage terracing, while there is less likelihood of investment in SWC on red than on black soils. Fertile soils seem to discourage all forms of SWC investments, particularly permanent investments. Soil depth is, however, positively correlated with most investments and is significant for mulching and all permanent investments. Moderate slopes favor the adoption of all forms of SWC investments. Undulating terrain is positively correlated with the adoption of mulching, tree planting and all seasonal investments. Conversely, very steep slopes and flat land lower the probability of adopting all SWC investments, probably because the former make it expensive to install and maintain investments, and the latter is unlikely to experience much erosion and therefore no conservation measures may be needed.

Impact of error correction terms

We include three error correction residuals in the SWC equation: listening to agricultural extension services in general, membership in village institutions and the willingness to invest in SWC. The residual of the willingness to listen to extension services is positively and significantly correlated with adoption of grass strips. The residual of the willingness to invest exhibits a large positive significant impact on all investment decisions. The results suggest the importance of providing incentives for SWC.

4.2.2 Determinants of the intensity of SWC investments

The results for the intensity of SWC are presented in the last two columns of Table 2. The presence of children aged six to 16 years is the only household characteristic that seems to matter for intensity of adoption. The results further suggest that although development domain dimensions (village institutions, population density and market access on intensity of adoption) may matter for some individual investment decisions, they may not be sufficient conditions for intensity of conservation. Of the three districts, Murang'a has the highest rate of adoption and Narok the lowest.

The results further show that tenure security variables determine how much to invest in SWC. Soil quality and topography also matter, and the results are comparable to those of adoption. Plot size is positively correlated with the number of actual investment structures, but the reverse is observed for distance to plot. Previously owned farm equipment has a positive significant effect on intensity. The permanent SWC investments not made in the past year but still functional are inversely related to the intensity of conservation, implying that most investment structures are seasonal rather than permanent. The residual for willingness to invest in SWC is positively correlated with the intensity of conservation, supporting earlier findings that willingness to invest boosts participation in SWC.

When we compare the intensity of adoption with the adoption of seasonal and permanent investments, the results suggest that in some cases intensity of adoption is determined by the same set of factors that influence the decision to invest. The results also suggest, however, that plot size favors intensity of adoption rather than the actual adoption decision. On the other hand, population density and market access favor the adoption decision. Village institutions also exhibit more significant effects on the adoption decision than on intensity of adoption.

5. Conclusion

This paper investigates the impact of tenure security and development domain dimensions on the adoption of SWC investments in Kenya. The analysis is based on plot level data for a sample of 457 households collected from three districts in Kenya in November and December 2004. We estimate multinomial logit models for the adoption of various SWC technologies and probit models for seasonal and permanent technologies. We use the Tobit regression method to explain the intensity of adoption and a step-wise regression method to derive residuals of village level institutional variables and willingness to invest in SWC. The residuals are used as error correction models to control for partial endogeneity of respective variables. The truly exogenous variables capture the sum of the direct and indirect effects, while the residual terms capture the effect of the endogenous variables. We use factor analysis to generate variables for tenure security, soil quality, topography, institutional presence and market access.

The paper makes three major contributions that are an advance on the previous literature: it avoids the usual arbitrariness in selecting variables for tenure security and other factors by using factor analysis to select the most important measures of the variables of interest; it is based on a relatively rich data set, since the survey collected data on all aspects of land tenure and adoption of SWC investments; and it uses a nested error correction approach to explain both the adoption decision and the intensity of adoption. Residuals predicted from binomial models are used in multinomial and Tobit models as predictors of adoption and level of conservation.

The results indicate the importance of tenure security in determining the choice and intensity of SWC investments, and the importance of household assets, farm characteristics (soils and topography) and presence of village institutions and development domain dimensions (market access and population density) in the adoption of SWC investments. Soil quality and topography, as well as location (agro-ecological diversity), are particularly important determinants of investment in SWC. These results suggest that the use of appropriate productivity increasing technologies must consider the soil quality and topography and their effect on land degradation. The findings on village institutions highlight the importance of institutional presence in encouraging the adoption of technology. The impact of household assets on investment in SWC implies a poverty-environment link because households that are poor in assets are less likely to invest in SWC.

The results of this study suggest the need for policies that improve security of tenure as a way of promoting long-term SWC investments. It is recognized in Kenya that land conservation policy and laws have not been effective in generating environmentally sound land use practices and thus need to be strengthened. It is also apparent from the results that policies aimed at environmental conservation need to be location specific. In addition, given this study's strong support for the existence of a poverty-environment link, there is need for broad policies that provide incentives for environmental conservation and poverty reduction in Kenya.

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