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Understanding Adoption of Soil and Water Conservation Techniques: The role of new owners

Remco H. Oostendorp
VU University Amsterdam
Tinbergen Institute
CSAE, University of Oxford
roostendorp@feweb.vu.nl

Fred Zaal
Royal Tropical Institute, Amsterdam
AISSR, University of Amsterdam
f.zaal@kit.nl

UNIVERSITY OF OXFORD
Centre for the Study of African Economies
Department of Economics · University of Oxford · Manor Road Building · Oxford OX1 3UQ
T: +44 (0)1865 271084 · F: +44 (0)1865 281447 · E: csae.enquiries@economics.ox.ac.uk · W: www.csae.ox.ac.uk

Abstract

This paper analyzes the adoption behavior of small holder farmers using comparable plot-level duration data for Kenya and The Philippines. We find that adoption behavior is strongly linked to the process of land ownership transfer. This relationship is found both for data from Kenya and The Philippines and is robust to the inclusion of unobserved village, household, plot and time effects. While previous studies on adoption using duration or panel data have focused on the role of various changing village- and household-level factors, no previous adoption study has emphasized the crucial role of land ownership changes.

Keywords: Soil and water conservation, Land ownership, Duration analysis, Kenya, The Philippines

1. Land acquisition and adoption: Introduction

An impressive number of studies have analyzed the adoption behavior of new or existing technologies by smallholder farmers in developing countries. An equally impressive number of possible determinants of adoption has been suggested by these studies, including technology characteristics (performance, risk, complexity, appropriateness), farmers' attitudes towards risk, adoption costs, availability of capital (cash resources and access to credit; natural, human and social resources), labor availability and land tenure (Feder *et al.* 1985, Sunding and Zilberman 2001, Batz *et al.* 2007).

Adoption behavior is undoubtedly a complex, multidimensional issue and different, but not mutually exclusive, theoretical frameworks have been developed to identify possible factors affecting adoption behavior. Adesina and Zinnah (1993) have defined three main paradigms, namely the economic constraint paradigm, the innovation-diffusion-adoption paradigm and the adopter perception paradigm. While the economic constraint paradigm emphasizes the factors that affect the profitability or utility of innovations, the innovation-diffusion-adoption paradigm emphasizes the key role of access to information to understand the process of technology adoption. The adopter perception paradigm in turn emphasizes the important role of attitudes and perception in the decision-making process of smallholder farmers.

As a consequence, empirical studies typically include a variety of factors that reflect not only the economic benefits and costs of technology adoption, but often also the knowledge (awareness) and perceptions of the farm household (e.g. Shiferaw and Holden 1998). Empirical studies are typically multilevel analyses and include variables that are measured at the plot, the household and the village (or even higher) level. Nevertheless, it has been noted that these empirical models often lack explanatory power, despite their long lists of explanatory variables

(Abadi Ghadim and Pannell 1999). For instance in a study on the adoption of soil and water conservation measures by farmers in Kenya, it was found that the predictive accuracy of a fully specified logit model including multiple plot, household and village characteristics was only somewhat higher than that achieved by a logit model with village dummies only (e.g. 78% versus 74% accuracy for the adoption of terraces) (Oostendorp and Zaal 2009).

A possible reason for the lack of explanatory power is that the vast majority of studies aiming to explain innovation adoption are limited to cross-sectional data and analysis techniques that cannot accommodate time-dependent variables (D'Emden *et al*. 2006). The adoption decision often was made in the past depending on past circumstances and expectations, while cross-sectional studies analyze the relationship between currently observed farming techniques (which is the outcome of past adoption decisions) with current circumstances. Therefore dynamic analyses based on panel data or duration data can be expected to generate important additional insights in the actual adoption process. These data sets however are rare as they require substantial time investment and few studies exist that use panel or duration data for rural environments in Africa (Dzuda 2001, Zaal and Oostendorp 2002, Gebremedhin *et al*. 2003).

This paper contributes to the literature on adoption of soil and water conservation techniques as follows. First, it analyzes the adoption behavior of smallholder farmers using comparable duration data for Kenya and The Philippines, derived from an international research project using a common framework. The availability of comparable data across two very different agro-climatic zones (semi-arid and humid tropics) is unique and allows for a comparative analysis of the drivers of adoption. Second, the paper shows that adoption behavior is strongly linked with the process of land ownership transfer, where plots of new owners are much more likely to be farmed with new techniques than plots of existing owners. Also the relationship between land ownership changes and adoption behavior is robust to the inclusion of unobserved village, household, plot and time effects. While previous studies on adoption using panel or duration data have focused on the role of (changing) village- and household-level factors, no previous study has emphasized the crucial role of land ownership changes, that is, a combined household-plot factor for adoption. Third, and finally, the paper speculates why ownership changes are important for adoption behavior and argues that the three existing paradigms of adoption (economic constraint paradigm, the innovation-diffusion-adoption paradigm and the adopter perception paradigm) do not consider the importance of the 'churning' of owners in the process of adoption. Also the policy implications from this insight are discussed.

The organization of the paper is as follows. In section 2 we describe the study areas and data for our study on adoption behavior of smallholder farmers in Kenya and The Philippines. In section 3 we present a descriptive duration analysis of soil and water conservation to show the presence of a strong correlation between land ownership changes and adoption behavior both in Kenya and The Philippines. Section 4 applies a regression analysis to analyze whether this relationship between ownership changes and adoption behavior is spurious and reflects unobserved heterogeneity at the village, household, plot or period level (omitted variable bias). Section 5 concludes with a discussion of the implications of the findings for our paradigmatic understanding of adoption behavior and the implications for policy.

2. Adoption by farmers in Kenya and The Philippines: Study sites and evidence

The data for this study derive from a research project on 'Agricultural Transition towards Sustainable Tropical Land Use' in Kenya, Benin, Cameroon and The Philippines between 1998 and 2001. The main impetus of the study was the 'miracle of Machakos' as described and identified by Mortimore, Gichuki and Tiffen in their book *More People, Less Erosion* (Tiffen *et* al. 1994). The miracle entailed a massive transition from a disaster area characterized by overpopulation, soil erosion and poverty into an area where food output per capita tripled and soil erosion virtually stopped in spite of a tripling of the population in the dry areas, and even a quintupling in the more humid high-potential areas. While Tiffen *et al.* (1994) emphasized a Boserupean-type transition in the wake of increasing population pressures, the research program showed that variables such as distance to major urban markets and windfall profits from the coffee boom in the late 1970s were at least as important in explaining the investment in the quality of land in Machakos as population growth (Zaal and Oostendorp 2002).

While macro drivers were found to be of importance, it was also observed that adoption of innovations in land management varies enormously across households and plots even within a specified village (Oostendorp and Zaal 2009). This suggests that macro-conditions and regional variables in themselves are not sufficient to explain adoption. Households differ in the degree to which they are integrated in the market and consequently their sensitivity to external shocks and policy drivers (such as droughts and market price fluctuations). Hence, household and even plot-specific factors should play an important role in explaining adoption behavior and information on many of these factors were also collected within the research program. Although data for four countries were collected within the research program, only data for Kenya and The Philippines can be used in this paper because the data for Benin and Cameroun do not include information on the exact timing of the adoption of soil and water conservation techniques in the past.

The data for Kenya were collected in the Districts of Machakos and Kitui. While Tiffen *et al*. (1994) focused on the District of Machakos only, the District of Kitui was added for comparative study and to test for the external validity of the research findings from Machakos. In order to reduce variability along ecological dimensions, the study was restricted to the areas located within a similar ecological zone, namely AEZ 4 (Jätzold and Schmidt 1982). AEZ 4 can be characterized as an intermediate zone between sub-humid and semi-arid conditions (around 115-145 growing days). Eight villages were selected within the AEZ 4 zones of the two Districts, stratified by population density (relatively low versus relatively high density sub-locations within the Districts, the lowest level for which data are available), and distance to the market (Nairobi) in travel time (far away versus close to the market measured in minutes by public transport). Within the villages a random selection of 25 households was made from a list of households available after consultation with the village council and headman. In all, 193 households were interviewed in Kenya. All household members available were enumerated. Of all plots, whether rented, owned, borrowed or rented out, key data were collected (a total of 484 plots).

The sampling procedure for The Philippines was broadly similar to that employed in Kenya. Four villages were selected along a gradient of distance to the major market of Manila, with a total straight length of about 250 km. Also, the variable of density of the population was taken into account, avoiding a correlation between distance from the main market and population density. Within each village, approximately 25 randomly selected households were interviewed, and a total of 104 households in the survey. The survey instrument was virtually identical to the one implemented in Kenya, except for the use of local concepts and with some adaptations to the questions to take into account local conditions. In terms of number of plots, the survey covered 235 plots that were managed by the surveyed households.

The economic and ecological conditions in the study area in The Philippines are in many ways different from those found in Kenya. Though the altitude is practically the same as in Kenya, the major climatic conditions differ considerably. The Philippines are characterized by humid and warm conditions, favoring tropical rainforest rather than savanna and dryland forests as found in the study area in Kenya.

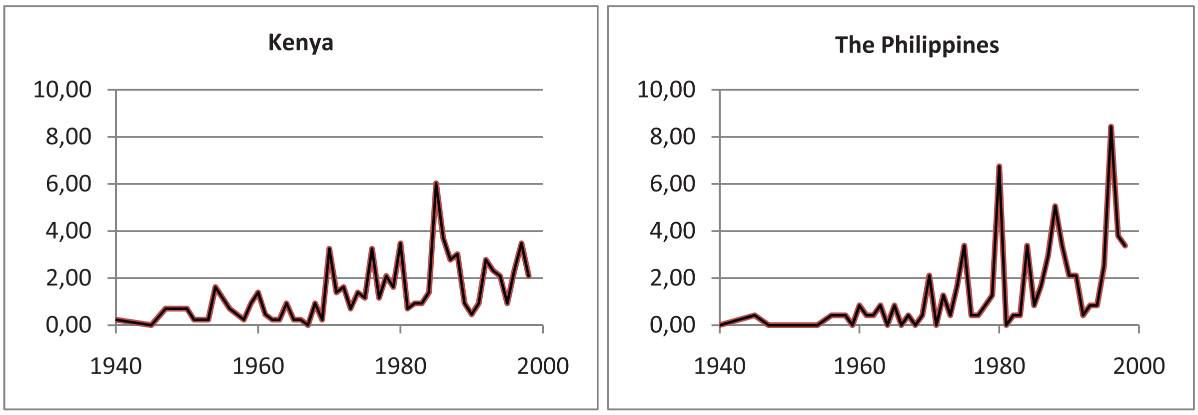
The next table reports the plot-level adoption rates for the most frequently reported soil and water conservation techniques by the households in the survey for both Kenya and The Philippines. The table shows that for Kenya terracing is the most commonly used conservation technique, with 66 per cent of the plots being terraced. The next most frequently used technique is manuring, on 47 per cent of the plots. The other conservation techniques are only used on a small minority of the plots. For The Philippines the most frequently used soil and water conservation technique is agroforestry (32% of the plots), followed by cover crops (27%), contour plowing (19%), contour bunds (17%) and terracing (12%).

Table 1. Adoption rates of soil and water conservation techniques across villages, 1999.

Kenya							
Village	Terraces	Manure	Artificial Fertiliser	Grass strips	Grassed terrace border	Green manure and compost	Trash lines
Kisaki	0.77	0.62	0.23	0.21	0.39	0.04	0.01
Musoka	0.69	0.59	0.22	0.16	0.10	0.08	0.08
Ngalalia	0.79	0.60	0.51	0.16	0.09	0.19	0.09
Ngumo	0.69	0.34	0.13	0.05	0.05	0.10	0.00
Mwanyani	0.58	0.37	0.05	0.27	0.00	0.03	0.07
Kitungati	0.43	0.19	0.00	0.02	0.08	0.00	0.09
Utwiini	0.30	0.30	0.03	0.00	0.09	0.06	0.45
Kyondoni	0.70	0.58	0.00	0.17	0.00	0.04	0.06
Total	0.66	0.47	0.19	0.14	0.11	0.08	0.08
The Philippines							
	Agro-forestry	Cover crops	Contour plowing	Contour bunds	Terracing	Re-forestation	Irrigation channel
Balete	0.16	0.09	0.21	0.59	0.07	0.00	0.12
Kapatalan	0.71	0.54	0.00	0.00	0.03	0.11	0.06
Quibal	0.06	0.06	0.46	0.00	0.09	0.01	0.00
Villa Florentino	0.51	0.50	0.01	0.10	0.25	0.14	0.08
Total	0.32	0.27	0.19	0.17	0.12	0.06	0.06

The average adoption rates reported in the table hide significant variation across village, households and even plots. Many adoption studies have attempted to identify the drivers of adoption behavior by exploiting cross-sectional variation in adoption rates with cross-sectional variation in village, household and plot characteristics (e.g. Bekele and Drake 2003, Gebremedhin and Scott 2003, Tenge *et al.* 2004, Anley *et al*. 2007). However, as noted above, such empirical models tend to have weak explanatory power (Abadi-Ghadim and Pannell 1999, Oostendorp and Zaal 2009). Therefore it is useful to exploit another type of variation hidden in the table, namely variation across time. Figure 1 shows the first year at which adoption took place on a plot for a number of important soil and water conservation techniques in Kenya and The Philippines. We focus on techniques which involve significant investments and for which retrospective information is available on the first year of adoption, namely terracing in Kenya, and terraces, contour bunds and agroforestry (including reforestation) in The Philippines.

Figure 1. Year of first adoption of technique, Kenya and The Philippines (percent of plots)



Clearly the adoption rates are not uniform across time, and earlier analysis for the Kenya data has successfully linked this time variation to changes in population pressure, cash crop (coffee) prices and rainfall (Zaal and Oostendorp 2002). A number of other studies have also linked the timing of adoption to time-varying village and household factors (e.g. D'Emden et al. 2006). These studies form an important advance over the previous cross section studies of adoption behavior taking into account that adoption depends on particular circumstances at a particular point in time.

In this paper we will further exploit the time dimension of adoption behavior by focusing on a combined household-plot characteristic that has received virtually no attention in the literature so far, namely plot ownership changes. In the next sections we will show that around the time of plot ownership change, there is a frenzy of adoption activity that cannot be explained away by (unobserved) village, household, plot or time factors (see below).

First, however, we need to discuss a data measurement issue, namely the possibility of recall bias with respect to the timing of ownership transfer and adoption. Farmers have been asked for each plot the 'year of acquisition' and 'first year of construction' of a particular soil and water conservation measure. This may create different types of recall bias. First, the responses may have a tendency of 'heaping', that is, they may be linked to five or ten year periods. We therefore calculated the Whipple Index which measures the degree of heaping (Table 2).[1] The Whipple Index suggests that there is indeed heaping in the responses for the first year of acquisition of the plot – the number of responses ending on zero and five is respectively 36 and 28% higher than one would expect in the absence of any heaping in Kenya and The Philippines. Heaping is also observed for the year of first use of technique on the plot. This suggests that there is indeed some recall bias in the data. In particularly, heaping in both the year of acquisition and first year of construction of a technique will result in too many instances

[1] The Whipple Index is defined as (# ending on zero/five)/(total #) x 5 x 100%. A Whipple Index of 100 implies no heaping, and an index of 150 implies that there are 50% more responses ending on zeroes and fives than without any heaping (Shryock and Siegel 1976).

where the farmer reports acquisition and first construction in the same year.[2] This would suggest too much adoption at the time of acquisition and this bias should be taken into account when analyzing the results. However this should not change our conclusion about high adoption activity in the first five years after acquisition, and also in the regression analysis we will look at periods longer than one year since the time of adoption. Moreover, this recall bias would create a stronger link between land ownership transfer and adoption behavior for plots acquired in the early decades (such as the 1970s) relatively to the recent decades (such as the 1990s), but actually an equally strong link is found across the different decades (see figure 5).

Table 2. Whipple Index

	Kenya	**The Philippines**
Year of acquisition of plot	136	128
Year of first use of technique on plot		
Terracing	128	172
Contour bunds		67
Irrigation channel		117
Agroforestry		176

A second type of recall bias may arise from the fact that (some) farmers may have reported the same year for the first construction of a technique as for the year of acquisition in case the technique was already present at the time of plot ownership transfer. In other words, they may have reported adoption under a previous owner as their own adoption. We can verify this possibility by looking at available information on the identity of the person who decided on the construction of the soil and water conservation technique. In most cases the decision was taken by the (late) husband and/or wife, and we can assume that construction did indeed take place *after* the plot was acquired. In case there is missing information on the identity of the adopter or

[2] E.g. if the year of acquisition is 1971 and the year of first use of terracing is 1972, the responses may heap onto '1970'.

the adoption was decided on by the parent, adoption may already have taken place before the time of acquisition. In these latter cases we exclude these plots from the analysis (18 respectively 5% of the plots in Kenya and The Philippines).[3]

Another type of bias would occur if farmers report the *re*construction or *maintenance* of existing soil and water conservation as first construction of a technique on a plot. In other words, adoption may already have taken place before the time of plot ownership change, and the new owner reconstructs or maintains these earlier structures. This possibility cannot be excluded especially as only the current rather than previous owners of a plot were interviewed. However, we will show later that the reported adoption pattern is not different between plots that were and that were not cultivated at the time of acquisition (section 5). While some of the uncultivated fields are in fallow and some of these fallow plots may have previously adopted soil and water conservation techniques, the vast majority of the uncultivated fields are unlikely to have previously adopted techniques as they were not in fallow but used for permanent grazing, bush or forest land (69%). Given that the adoption behavior is not any different on the uncultivated from the cultivated fields, the evidence that adoption behavior is strongly linked with the process of land ownership transfer cannot be explained by recall error resulting from adoption that has taken place before the time of acquisition.

3. The dynamics of adoption at the plot level: Duration analysis for Kenya and The Philippines

With the above discussion in mind, the descriptive analysis of this section will show that a significant part of the adoption takes place within a few years after a change in land ownership.

[3] The exclusion of these plots from the analysis does not actually affect the results in any significant way.

This finding holds across different decades and also for ownership changes due to inheritances as well as land purchases. It also holds for both farmers in Kenya and in The Philippines. In the subsequent section we will also show that this relationship is not spurious, in the sense that it cannot be attributed to the omission of unobserved village, household, plot or time factors.

A dynamic analysis of adoption involves a 'duration' or 'transition' or 'survival' analysis (e.g. Cameron and Trivedi 2005). Each plot is in two possible 'states', namely 'no adoption' and 'adoption' and undergoes a 'transition' if it moves from one state to another state. We are interested in the transition from the state 'no adoption' to the state 'adoption', and the time ('duration' or 'spell' length) it takes before adoption occurs on a plot. The literature on duration or transition or survival analysis is quite large and has been applied in many fields, such as engineering, biostatistics and social sciences. Also in economics there are many applications of duration analysis, for instance on the average length of an unemployment spell or the duration of strikes. There are also a limited number of applications of duration analysis in the literature on soil and water conservation, such as Dzuda (2001), Burton et al. (2003) and D'Emden et al. (2006). These studies do suggest that adoption is a dynamic process and therefore that time-dependent economic and environmental variables do affect the adoption decision. Of particular relevance is the study of Dzuda (2001) on farmers' adoption behavior in Zimbabwe, who noted that adoption is more likely in the first five years of the 'management life' of the farmer, and we will return to this study later on.

In order to do a more formal analysis, we introduce a number of basic concepts as used in duration analysis. Let the duration that no adoption takes place on a plot be given by T. A central concept in duration analysis is the 'survivor function' S(t), which gives the probability that no adoption has taken place on a plot by time t:

$$S(t) = \Pr[T > t]$$

The survivor function is monotonically declining from one to zero. If adoption takes place on all plots, then $S(\infty) = 0$. If adoption will not take place on all plots, then $S(\infty) > 0$. It can also be shown that the area under the survivor function gives the mean duration of a plot before adoption takes place.

Because we can only observe the current and past state of a plot, the data are 'right-censored', in the sense that we observe the state of a plot from time 0 until the censoring time 1998 (the final year before the survey). On some plots, measures will have been adopted by the time of the survey ('completed spells'), but on other plots no adoption will have taken place and all we know is that there may be adoption at some point in the future ('censored spells').

The survivor function can therefore not be observed but can be estimated from duration data. If there is no censoring, the obvious estimator of the survivor function $\hat{S}(t)$ is given by the number of plots that have no adoption yet by t, divided by the total number of plots. However, with right-censoring, this will give a biased estimate of the survivor function because we no longer can observe all transitions. The Kaplan-Meier estimator of the survivor function provides a nonparametric and consistent estimate of the underlying survivor function in the presence of right-censoring.[4]

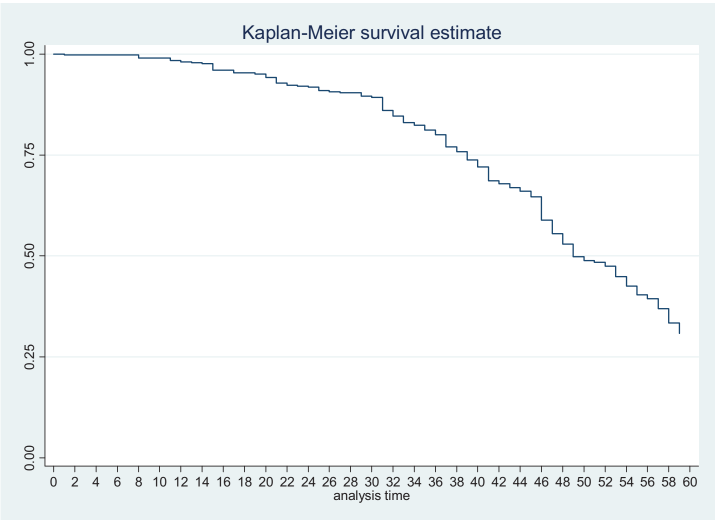
For Kenya we focus the duration analysis on terracing, as we do not have (retrospective) information on the adoption of other soil and water conservation techniques by farmers in Kenya in the past. For farmers in The Philippines we do have retrospective information on the adoption

[4] However, it assumes that the censoring process is independent of the adoption process. The regression analysis in section 4 will test for the robustness of the results when controlling for observable and unobservable factors not taken into account in the descriptive analysis presented here.

of terracing, contour bunds, and agroforestry/reforestation (at least 0.25 ha or more planted area) and the analysis will focus on adoption of these soil and water conservation techniques.[5]

For each plot we know the time of first adoption (if any), and Figure 2 shows the estimated Kaplan-Meier estimator that a plot has not been terraced in Kenya so far. We choose as starting point 1939 because the first plots were terraced in 1940. Interestingly, the survivor function is concave, reflecting the fact that the probability that a plot is not yet terraced increasingly falls over time.

Figure 2. Kaplan-Meier survival estimates for all plots for Kenya, 1939-98

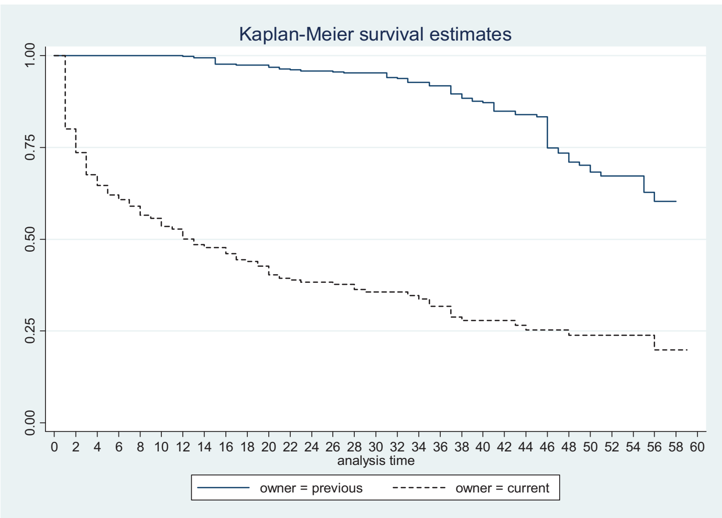


In Figure 3 we will now distinguish between two types of plots, namely plots that are owned by the farmer who also owns the plot at the time of the survey (in 1999), and plots that are owned by a previous owner. This introduces additional right-censoring in the data, because a plot might

[5] Also retrospective information on the timing of irrigation facilities is available but no information on the identity of the adopter. Hence, to avoid possible recall bias (see section 2), we do not focus on the adoption of irrigation facilities. However we note that irrigation facilities are often constructed in combination with terraces and contour bunds and therefore can be expected to have a similar adoption time pattern.

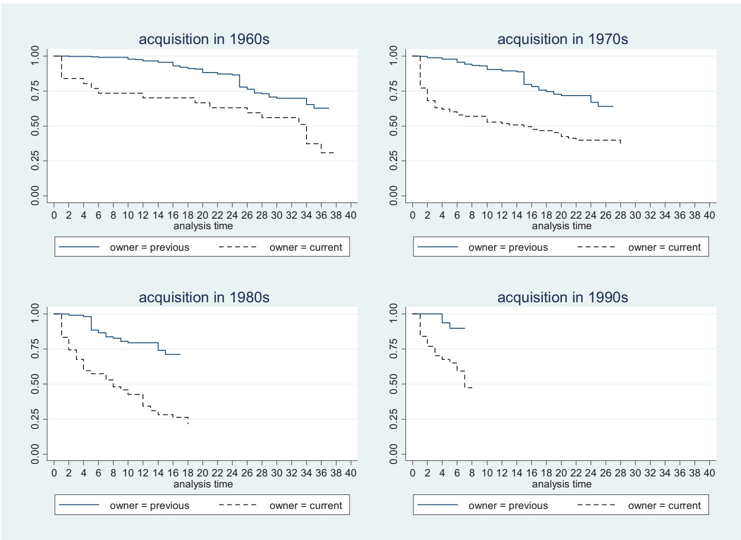
change ownership from a previous to a current owner before 1999. Figure 3 shows the Kaplan-Meier estimates for the survivor functions for both types of plots. Note that the time is different for both types of plot. For plots under previous ownership it is the time since 1939, while for plots under current ownership it is the time since the ownership change. There are two remarkable findings. First, plots under current ownership are much more likely to have been terraced at any point in time. Second, the survivor function for plots under previous ownership is still concave, while the survivor function for plots under current ownership is convex. This convexity is particularly strong in the first years after ownership but appears to continue afterwards as well. This suggests that the probability that a plot is terraced increasingly falls over time and that the highest probability of terracing is found in the first years after ownership change.

Figure 3. Kaplan-Meier survival estimates by acquisition for Kenya, 1939-98



One may argue that the above findings reflect a time effect, in the sense that in recent decades the plots tend to be under current ownership, while in past decades plots were predominantly owned by previous owners. We therefore also estimated both survivor functions for the last four decades separately, for plots under previous ownership and plots that have been acquired in a given decade (figure 4). The survivor function for plots under current ownership is convex for each of the decades, reflecting once again the significant activity in terracing right after ownership change. In particular, about 16–23 per cent of the plots are terraced within one year of the ownership change,6 23–43 per cent are terraced within five years,[7] and for the 1980s and 1990s 53–56 per cent are terraced within ten years.[8] The corresponding percentages for plots that are under previous ownership are 0 per cent for the first year, 1–12 per cent within five years[9] and 2–21 per cent within ten years.[10]

Figure 4. Kaplan-Meier survival estimates by decade and acquisition for Kenya, 1939-98



Although the above results are rather striking and suggest that soil and water conservation adoption and land ownership transfer are closely related, there may be two important concerns.

[6] By decade: 1960s: 16%, 1970s: 23%, 1980s: 17% and 1990s (till 1998): 16%.
[7] By decade: 1960s: 23%, 1970s: 40%, 1980s: 43% and 1990s (till 1998): 35%.
[8] By decade: 1980s: 56% and 1990s (till 1998): 53%.
[9] By decade: 1960s: 1%, 1970s: 2%, 1980s: 12% and 1990s (till 1998): 10%.
[10] By decade: 1960s: 2%, 1970s: 10%, 1980s: 21% and 1990s (till 1997): 10%.

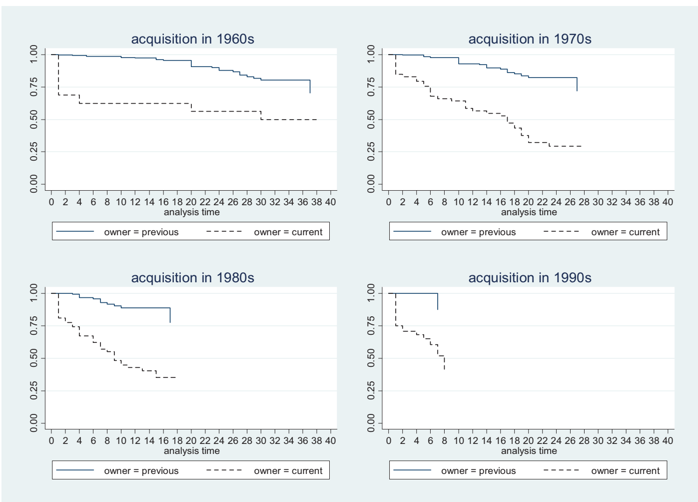
First one may question the internal validity of the results, c.q. whether the relationship is causal or spurious. In the next section we will use regression analysis to test whether the relationship is still present, once we control for possible omitted factors that vary across villages, households, plots and time.

Second one may question the external validity of the results, c.q. whether a similar relationship between land ownership transfer and adoption also holds across different contexts such as various agro-climatic zones. Because we have internationally comparable data for The Philippines, we can test the external validity of the results across both a semi-arid area (Kenya) and a humid tropical area (The Philippines) and for different types of adoption (terraces in Kenya versus terraces, contour bunds, and/or agroforestry (at least 0.25 ha or more of planted area) in The Philippines).

We note that there are obvious differences in agricultural practices between Kenya and The Philippines. The dominant crops are different - short cycle maize and beans in Kenya together with cash crops such as coffee, versus rice and maize and a large variety of tree crops in The Philippines. This means that costs and benefits of the farming system in which land management measures are introduced differ as well and thus the relative burden on the farmer's budget. But above all, these land management measures themselves have different cost structures over time. Terracing takes place in both research areas for various reasons (water and fertility management). However, whereas in Kenya investments are mostly directed towards terraces, trash lines and vegetated strips, in The Philippines terraces and contour bunds are often constructed in combination with irrigation facilities. This means that the total costs of the conversion is higher than that of terracing or bund construction alone in that country; lengths of pipes and drains are also part of the process. Other measures are not so very different in terms of level and timing of costs. Contour bunds, grass strips and even lower terraces (in the lower slope) in Kenya can be implemented at a much lower pace, using available labor, than the more costly irrigated terraces. And trees in The Philippines, another important measure, can also be introduced at a lower pace.

The next figure is the same as figure 4 above but now for The Philippines. The starting point for The Philippines is 1944 because the first plots received terraces, contour bunds, and/or agroforestry in 1945. The result is remarkable and strikingly similar – also for The Philippines we find that the adoption is concentrated in the period just after the ownership transfer. In The Philippines about 15–31 per cent of the plots are terraced within one year of the ownership change,[11] 25–37 per cent are terraced within five years,[12] and for the 1980s and 1990s 55–58 per cent are terraced within ten years.[13] The corresponding percentages for plots that are under previous ownership are 0 per cent for the first year, 1–3 per cent within five years[14] and 2–12 per cent within ten years.[15]

Figure 5. Kaplan-Meier survival estimates by decade and acquisition for The Philippines, 1944-98



[11] By decade: 1960s: 31%, 1970s: 15%, 1980s: 19% and 1990s (till 1998): 25%.
[12] By decade: 1960s: 37%, 1970s: 25%, 1980s: 33% and 1990s (till 1998): 35%.
[13] By decade: 1980s: 55% and 1990s (till 1998): 58%.
[14] By decade: 1960s: 1%, 1970s: 2%, 1980s: 3% and 1990s (till 1998): 0%.
[15] By decade: 1960s: 2%, 1970s: 7%, 1980s: 11% and 1990s (till 1997): 12%.

We have also checked whether the survivor function is different for plots that change ownership through inheritance, purchases or, for The Philippines, through new occupation / squatting. We do not find this to be the case - for both countries new owners are much more likely to invest in their land, especially in the early period after acquisition, irrespective of the acquisition mode.

4. Land acquisition and adoption: A spurious relationship?

The above duration analysis suggests a strong link between land acquisition and the adoption of SWC techniques. However, the analysis has been descriptive and the correlation between land acquisition and innovation may reflect other factors that have not been taken into account so far, such as changes in cash crop and input prices, weather conditions, population pressure, and infrastructure, as well as factors operating at the household or plot-level, such as (age and gender) composition of the household and soil and fertility conditions of the plot. In this section we therefore explore whether the correlation between land acquisition and innovation is spurious, which would mean that innovations are not more likely to occur after the acquisition of land, once we control for other possible factors.

A previous study has shown that the pattern of adoption of terraces in Kenya has been strongly affected by the distance of a village to major urban markets, coffee prices, village-level population density and the occurrence of droughts at the district level (Zaal and Oostendorp 2002). In case any or each of these variables also affects the pattern of land acquisition, these factors may be able to explain the observed correlation between land acquisition and adoption in the foregoing duration analysis (omitted variable bias).

In order to investigate this possibility, we estimate a linear probability model (LPM) to explain terracing as a function of land acquisition and village (or district)-level variables:

$$y_{vhpt} = \alpha + T_{pt}\beta + X_{vt}\gamma + \mu_v + \mu_h + \mu_p + \mu_t + \varepsilon_{vhpt}$$

where y_{vhpt} is a dummy variable equal to one if plot *p* used by household *h* in village *v* has been terraced in period *t*, T_{pt} is a variable measuring the time since acquisition for plot *p* in period *t*, X_{vt} is a vector of village (or district)-level characteristics. The terms μ_v, μ_h, μ_p and μ_t are village, household, plot and period effects and ε_{vhpt} is an idiosyncratic error term. The village, household, plot and period effects (as well as interactions of these effects) will be included in some of the regressions to control for possible omitted variable bias due to the presence of unobserved village, household, plot and period effects that are correlated with the variable of interest, T_{pt}. They are also included to control (to the extent possible) for sample selectivity bias as the linear probability model is estimated on the sample of plots under current ownership (because the time since acquisition is unknown for plots under previous owners) and which were not terraced yet at the time of acquisition.

We estimate a LPM rather than a limited dependent variable model (such as logit or probit) because LPMs are far more tractable and flexible in the handling of unobserved heterogeneity (Janvry, A. De et al. 2006). Moreover, a LPM does not need to assume a distribution for the error terms unlike a limited dependent variable model. Angrist and Pischke (2009; 107) have shown that in practice the marginal effects estimated with LPMs are typically quite similar to those derived from nonlinear probability models.

In column (1) of Table 3 we report the results of a LPM for whether a plot has been terraced as a function of the time since the plot was acquired in Kenya. The regression includes village fixed effects to control for the effect of unobserved village-level heterogeneity on terracing activity. Standard errors are corrected for clustering by year. The variable indicating the time since acquisition, T_{pt}, is measured by a number of dummy variables in column (1), namely whether the plot was acquired 0-1 year ago, 2-5 years ago, 6-10 years ago or 11-20 years ago (more than 20 years ago is the omitted category).

Table 3. LPM regression analysis of whether a plot is terraced in any given year in Kenya (t-values in parentheses).[a]

Variable	(1)	(2)	(3)	(4)
Time since acquisition (dummies)				
0-1 year	**0.141**	**0.159**	**0.156**	**0.146**
	(9.34)	(8.19)	(12.6)	(2.78)
2-5 years	**0.030**	**0.042**	**0.042**	**0.042**
	(2.55)	(2.82)	(3.73)	(4.10)
6-10 years	0.010	**0.019**	**0.018**	**0.018**
	(1.18)	(1.82)	(1.60)	(1.78)
11-20 years	0.006	0.006	0.007	0.009
	(0.66)	(0.71)	(0.69)	(1.01)
Density		-0.00003	-0.0002	
		(0.30)	(1.59)	
GDP per capita (10^{-3})		-0.0004		
		(0.03)		
Price coffee/maize		0.0001		
		(0.09)		
Drought in Machakos		0.001	-0.014	
		(0.09)	(0.86)	
Drought in Kitui		**0.026**	0.007	
		(2.76)	(0.47)	
Village effects	Yes	Yes	Yes	No
Year effect	No[b]	No[b]	Yes	No
Village x year effects	No	No	No	Yes
Number of observations	4439	3283	3283	4439
Goodness of fit (p-value)[1]	0.00	0.00	0.00	0.00

[a] Coefficients which are significant at 10% or lower level are in bold. [b] Standard errors are clustered by year.

The coefficient for the time dummies for 0-1 and 2-5 years since acquisition are 0.14 respectively 0.03 and highly significant, while the coefficients for the other time dummies are insignificant and close to zero. This suggests that terracing has a 14% higher probability within one year of acquisition, after controlling for unobserved village-level effects.

In column (2) we include village- and district-level variables to capture the impact of population density, GDP per capita, the relative price of coffee versus maize, and drought on terracing. We have annual data available for these variables for the period from 1965. Population density is measured at the level of the sub-location in which the village is located (population per km^2). GDP per capita is measured in constant market prices (in 1965 prices). The relative price variable is given by the ratio of the national producer price of green coffee and white maize. The drought variables are dummy variables and measured at the district level. Because there are two rainy seasons and farmers may be able to survive one bad season, a drought year has been defined as a year in which there is a rainy season with a severe drought and a preceding rainy season also with a severe drought. A severe drought is defined as a rainy season with a drought index less than or equal to -0.8 (DI≤-0.8, see Tiffen et al., 1994, chapter 3).

None of the village- and district-level variables are significant except for the dummy variable for drought in Kitui. This seems to be in contradiction with the findings in Zaal and Oostendorp (2002, Table 7) where population density, GDP per capita, and the relative price of coffee were found to have an impact on the adoption of terracing. The reason for this discrepancy is that the regressions in Table 3 are estimated only for the plots under current ownership while Zaal and Oostendorp (2002) include also the plots under previous ownership (for which the time since acquisition is unknown). Because there is a strong correlation between whether a plot is under current ownership and the village- and district-level variables, the estimated coefficients for these village- and district-level variables are biased in regression 2 in Table 3.[16] It would be very interesting to analyze whether there is a causal relationship between

[16] In principle we could try to correct for possible sample selectivity bias using a Heckman-type sample selection model explaining the timing of current ownership. We have not done so, however, because of the difficulty in determining an appropriate exclusion restriction as well as the absence of household-specific information at the time of plot transfers. Instead we control for sample selectivity to the extent

village- and district level variables and land acquisition (which in turn may affect land terracing), but we lack the data on the historic land acquisitions before the plot was ultimately acquired by the current owner. But even then the relationship between the village- and district-level variables and land acquisition may still be spurious, and could reflect the influence of (correlated) omitted factors at the household or plot level (such as the age composition of the households).

Most importantly within the context of this study, however, the coefficients for the variables measuring the time since acquisition are virtually unaffected by the inclusion of these village- and district-level variables. Hence, omitted variable bias related to the omission of these variables does not seem to explain the correlation between land acquisition and innovation.[17]

However, the observed correlation between land acquisition and terracing may also be the result of other sources of omitted variable bias. We explore three further sources of this bias, namely (1) unobserved time effects, (2) unobserved household effects, and (3) unobserved plot effects. In column (3) of Table 3 we include year effects in the regression to control for any year-varying factor that may have affected the adoption of terracing. The year effects therefore capture the impact of GDP per capita and relative price of coffee/maize (which have been dropped from the regression) but also the impact of any other variable which varies across time. The results show that the coefficients for the variables measuring the time since acquisition are almost unaffected, both in terms of size and significance.

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possible by testing for the robustness of the results with and without the inclusion of various unobserved village, household, plot, and period effects (as well as interactions of these effects) (see next footnote).

[17] One may argue that the coefficients for the variables measuring time since acquisition are also biased because of the sample selectivity problem. However, even if we control for unobserved village, household, plot, and period effects (as well as interactions of these effects) (compare the various regressions in Tables 3 and 4), these coefficients are barely affected. Given that these unobserved fixed effects will control for sample selectivity (at least to some extent), we would expect the coefficients for the variables measuring time since acquisition to vary across regressions with and without various fixed effects in the presence of sample selectivity bias. This is not the case however.

Another possibility is that the adoption of terraces has been affected by factors that vary over time and across villages. For instance, villages may have benefitted from specific project interventions at specific moments in time.[18] In order to allow for possible omitted variable bias due to such factors that may have varied over time and across villages, we have also included village x year interaction terms in the regression (column 4 of Table 3). Once again, we find that the inclusion of these additional effects does not explain the observed correlation between land acquisition and terracing – plots which have been acquired recently are much more likely to be terraced than other plots.

In Table 4 we investigate whether the correlation between land acquisition and terracing may actually be due to omitted household and plot characteristics. For instance older households may be more likely to transfer land to the next generation and to have sufficient savings to invest in new terraces. Or plots that have been acquired recently may be of lower quality and also require more investments in soil and water conservation. Household characteristics do vary over time and therefore we include household fixed effects interacted with year fixed effects. We also include plot fixed effects to control for unobserved heterogeneity across plots.[19] However, most of the plots have been acquired in the past decades and relatively few plots have been acquired more than 25 years ago. As a result, estimations including household x year and plot fixed effects showed an erratic relationship between the time since acquisition and terracing for the entire sample including plots which were acquired up to 63 years ago (not reported).

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[18] This has indeed happened in the relevant period in the districts of Machakos and Kitui. However, available intervention data does only report whether there has been a project or not and therefore does not show sufficient variation to identify such an intervention effect (Zaal and Oostendorp 2002).

[19] In principle we can identify these fixed effects because for each period we know whether a plot has been terraced (this creates variation across time for a given plot) and many households have multiple plots (this creates variation across plots for a given household at a given time).

For this reason we first re-estimated the last column of Table 3 but now only for plots which were acquired at most 25 years ago. Column 1 in Table 4 shows that the results are very similar and do not depend on the inclusion of plots that were acquired more than 25 years ago (14.8% of the sample). In column 2 we have included the household x year and plot fixed effects. Column 2 still shows the same time pattern of adoption – plots that have been acquired very recently have a much higher probability of being terraced. However, the coefficients for the time dummies are no longer significant because of the reduction in degrees of freedom.

The above findings therefore show that the observed correlation between land acquisition and terracing is robust and cannot be explained by omitted village effects, time effects, household effects, and/or plot effects. Specifically, plots have about a 14% higher probability of being terraced within one year of acquisition. This is an important finding because explanatory variables in static adoption models often are able to explain only a small part of the actual adoption behavior. The analysis shows that the dynamic pattern of adoption within the context of land acquisition is an important missing component for our understanding of adoption behavior.

One may also wonder whether the results are specific for Kenya or whether they also apply to The Philippines . We therefore also report the results for the regressions with village, year, household and plot effects for The Philippines (columns 3-4 in Table 4). Because most of the plots have been acquired in the past two decades and relatively few plots have been acquired more than 15 years ago (16.2% of plots), we limited the sample accordingly. Similar to Kenya, we find that plots in The Philippines are much more likely to be invested in the period right after land acquisition. It is remarkable to see the similarity in results for columns (1) (Kenya) and (3) (The Philippines) in Table 4. However, after we also include household x year and plot effects in the regression (column 4), the results for The Philippines suggest an even stronger link between land acquisition and investment than in Kenya (column 2) but similarly the time dummies are no longer significant.

Table 4. LPM regression analysis of whether a plot is terraced in any given year in Kenya and The Philippines (t-values in parentheses). Controlling for household and plot effects. *

	Kenya		The Philippines	
Variable	(1)	(2)	(3)	(4)
Time since acquisition (dummies)				
0-1 year	**0.141**	0.187	**0.137**	0.415
	(8.72)	(0.61)	(6.15)	(0.97)
2-5 years	**0.047**	-0.023	**0.035**	0.104
	(3.13)	(0.08)	(1.69)	(0.28)
6-10 years	0.025	-0.002	0.015	0.096
	(1.65)	(0.01)	(0.075)	(0.47)
11-20 years	0.014	0.004		
	(1.02)	(0.02)		
Village x year effects	Yes	No	Yes	No
Household x year effects	No	Yes	No	Yes
Plot effects	No	Yes	No	Yes
Number of observations	3581	1418	1438	659
Goodness of fit (p-value)[1]	0.00	0.00	0.00	0.00

[*] Coefficients which are significant at 10% or lower level are in bold.

5. Land acquisition and adoption: Interpreting the results

The above duration-based plot-level analysis of adoption shows that plot ownership change is a very important predictor of adoption behavior. This is an interesting combination of a plot- and household-level characteristic, not a characteristic of the plot or the owner of household separately. This seems to be a trigger in the adoption process, possibly together with other driving forces providing background pressure on land managers to adopt the innovation.

The literature on soil and water conservation techniques has so far ignored this relationship between plot ownership changes and innovation. The only exception we are aware of is a study by Dzuda (2001), focusing on the time it takes by farmers to adopt soil and water conservation techniques in Zimbabwe. Applying duration analysis, the Dzuda study finds that a farmer is more likely to adopt SWC in the first five years of his management life, which is in line with our conclusion that management and ownership are tightly related. However, the study does not develop nor discuss any theory on why farmers are more likely to adopt in the beginning of their management life.

The question is then how the decision to adopt innovation is linked with a change of ownership. The above analysis shows that land ownership change has an impact on adoption behavior, even after controlling for omitted village, household, plot and time effects. So even if change in ownership is related to other factors, the change in ownership appears to have an independent and direct impact on adoption behavior that cannot be 'explained away' by these other factors. Most importantly, we find that adoption on plots that have recently been acquired is much more likely than for other plots in the *same* household at the *same* point in time, even after controlling for (time-invariant) plot characteristics (columns 2 and 4 in Table 4). This suggests that the acquisition of a plot affects the adoption behavior independently from the characteristics of the plot and household (and other higher-level factors).

Adoption behavior is often understood within the economic constraint paradigm, where farmers will adopt when the profitability (or utility) of adoption outweighs that of non-adoption. For instance, higher output prices or more secure tenure rights may make investments in land more profitable and/or secure and therefore stimulate adoption (Pagiola 1996). While input and output prices tend to affect all plots equally, the tenure status of different plots utilized by a household may vary. In particular it has been noted that farmers may have an incentive to adopt good stewardship practices in order to strengthen their land tenure rights. For both Kenya and

The Philippines, however, we did not observe that the adoption pattern was any different across secure and insecure plots.

Another explanation based on the economic paradigm derives from the possible presence of decision-making or adjustment costs. Before a farmer starts cultivating a plot of land, he or she has to decide on the cropping pattern as well as cultivation technique (including the use of SWC techniques) depending on the current and expected market conditions. If this decision-making process is costly, if only because of the opportunity cost of time and effort, then one can argue that a farmer will focus most of this decision-making effort on new rather than existing plots, because for the latter plots he or she can implement the existing cropping and cultivation pattern. Therefore it would be rational for a farmer to consider (and possibly adopt) any soil and water conservation technique right at the beginning of the management cycle of the new plot, as part of a newly developed management strategy (a fixed cost). This is especially the case if there are also adjustment costs to changing the management strategy for existing plots, for instance if it involves the uprooting of existing tree crops and/or the removal of existing soil and water conservation structures.

We have no direct evidence on the actual decision-making process by the farmers and are unable to verify the importance of decision-making cum adjustment costs directly. However, if these costs underlie (part of) the correlation between land acquisition and adoption, then we would expect this correlation to be the highest for plots that were uncultivated at the time of acquisition. We can test for this implication by including an interaction term of the time acquisition variable $\mathrm{T_{pt}}$ with a dummy variable $\mathrm{D_n}$ equal to one if the plot was not cultivated at the time of acquisition:

$$y_{vhpt} = \alpha + T_{pt}\beta + T_{pt}D_n\beta_n + X_{vt}\gamma + \mu_v + \mu_h + \mu_p + \mu_t + \varepsilon_{vhpt}$$

If the estimated coefficient β_n for this interaction term is significantly negative, then adoption is even more concentrated in the early period of acquisition for plots that were uncultivated at the time of acquisition. A plot is being classified as not cultivated at the time of acquisition if it was used for private or communal grazing, private fallow or if it was bush or forest land (43.1% of plots). We include village x year effects rather than household x year and plot effects in the regression (cf. column 1 versus column 2 in Table 4), because the results are similar but the regressions with household x year and plot effects suffer from low degrees of freedom and therefore lack of significance.

Column 1 in Table 5 reports the results for Kenya. The interaction terms are individually and jointly insignificant at 10% suggesting that the adoption pattern following acquisition does not depend on whether the plot was or was not cultivated at the time of acquisition. Also we do not find significant interaction terms ($\beta_n \neq 0$) if we include household x year and plot effects (not reported). We have also run the same tests for The Philippines where 54.2% of the plots are uncultivated at the time of acquisition (column 2). The results also suggest that that time pattern of investment is not different across plots that were and were not cultivated at the time of acquisition (the coefficients are jointly insignificant at a 10% significance level (p-value 0.39)).

Also the innovation-diffusion-adoption paradigm focusing on the role of information in the process of technology adoption appears to be unable to explain why adoption is much more likely on recently acquired plots than on other plots in the same household at the same point in time. The adopter-perception paradigm emphasizing the role of attitude and perception in the adoption process also does not provide an obvious explanation. Actually, if a farmer learns about the quality of the land only after the plot ownership transfer, then one may expect *less* adoption in the first few years as the farmer is forming an expectation of the returns to investment on the new plot.[20]

Table 5. LPM regression analysis of whether a plot is terraced in any given year in Kenya and The Philippines (t-values in parentheses). Interaction terms with plot utilization at time of acquisition. *

	Kenya	The Philippines
Variable	(1)	(2)
Time since acquisition (dummies)		
0-1 year	**0.130**	**0.112**
	(5.67)	(4.08)
2-5 years	**0.048**	0.030
	(2.25)	(1.23)
6-10 years	0.022	0.021
	(1.02)	(0.87)
11-20 years	0.004	
	(0.17)	
* Plot not utilized (dummy)		
0-1 year	0.022	0.046
	(0.67)	(1.06)
2-5 years	-0.011	0.008
	(0.38)	(0.20)
6-10 years	-0.001	-0.020
	(0.03)	(0.48)
11-20 years	0.020	
	(0.68)	
Plot not utilized (dummy)	-0.021	0.040
	(0.81)	(1.19)
Village x year effects	Yes	Yes
Number of observations	3555	1438
F-test $\beta_n = 0$ (p-value)**	0.58	0.39
Goodness of fit (p-value)[1]	0.00	0.00

* Coefficients which are significant at 10% or lower level are in bold. ** F-test for the joint significance of the interaction terms.

Therefore we would like to consider another possible mechanism for understanding the link between plot-level acquisition and plot-level adoption which is derived from the increasingly important paradigm of ‘behavioral economics’. Behavioral economics is concerned

[20] Also this would be especially the case for purchased plots but we find a similar adoption pattern for these plots as for inherited plots.

with the limits of economic rationality and includes social, cognitive and emotional factors in the analysis of economic phenomena (Thaler 1994). Although behavioral economics focuses on many anomalies of economic behavior (when viewed from the neoclassical perspective), the recent discussion of the importance of 'nudging' may provide a possible explanation for our observed relationship between land ownership change and innovation (Thaler and Sunstein 2008).

Nudging has been recently introduced in the literature on farmer adoption by Duflo, Kremer and Robinson (2009). They note that many farmers in Western Kenya fail to take advantage of apparently profitable fertilizer investments and show that small, time-limited discounts on the costs of acquiring fertilizer (through free delivery) just after the harvest increases fertilizer use strongly. Later discounts, on the other hand, have a much smaller impact. They explain this finding by assuming that farmers are stochastically present-biased and not fully sophisticated about this bias and therefore small nudges in the form of carefully timed discounts allows present-biased farmers to commit themselves to future fertilizer use.

Similarly land ownership changes may function as a 'nudge' for farmers. As pointed out in behavioral economics, people do not like to change and are not particularly fond of making decisions in the first place (Thaler and Sunstein 2008). However, when farmers are faced with new plots, inherited or purchased or otherwise acquired, they automatically face the choice what to do with the land. Plots which may have been in the family for years may become suddenly the focus of decision-making right after a new owner takes possession of the plot. Farmers may actually start implementing new techniques on the plots, something the family may have wanted to do for many years but which simply had not been done yet. Naturally, after a number of years the decision-making focus on the plot will be reduced again and the intensified adoption activity will peter out. The above analysis suggests that the window of heightened activity is primarily within the first year of plot acquisition, with possibly some additional activity in the 2-5 years after acquisition. The nudge of land ownership transfers works, but only for a few years.

If nudging is important, then adoption-friendly economic incentives are necessary but not sufficient for stimulating adoption. Many farmers have been shown not to adopt profitable techniques in spite of the underlying favorable economic fundamentals. Heavy subsidies may be necessary to induce these 'irrational' farmers to adopt new techniques but this may induce over-investment by 'rational' farmers. More subtle nudges, on the other hand, may be necessary to reinforce the underlying economic fundamentals.

One policy option would therefore be to make land ownership transfers more frequent, for instance by reinforcing tenure rights, improving access to credit for land purchases, and making land transfers (titling processes) cheaper. Smaller plots will also facilitate land ownership transfers. In this respect one may think also about the influence of (land) inheritance systems. If the land is subdivided between all brothers or all children rather than inherited by the eldest son (primogeniture), this will further stimulate land ownership transfers. Another option would be to design specific nudges to commit farmers to the adoption of better techniques. Duflo et al. (2009) show that nudges right after the completion of the seasonal cultivation cycle (the harvest) when farmers have money to invest are most effective. The cycle of decision-making for terracing appears to be annual rather than seasonal in Kenya –the period after the long rains season (March-May) and before the short rains season (October-February) is typically used for land improvement activities. Similarly for The Philippines we find that the decision-cycle for terraces/ contour bunds/ agroforestry appears to be annual. This suggests that nudges should be applied annually, right before when land improvement activities typically start taking place.

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