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# Does Rural Labor Markets Affect Soil Conservation? Case Study of Kilimanjaro, Tanzania

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**Abstract:** This study takes on the debate on whether or not increased off-farm employment compromises the adoption and the intensity of adopting some labor intensive soil conserving technologies. The research first presents a theoretical framework of household adoption of soil conserving technologies in the presence of imperfect labor markets. Theoretically, it is shown then the overall effect is indeterminate. The study goes a step further by taking a case study of Kilimanjaro region in Tanzania and finds evidence that household participation in off-farm employment compromised soil conservation. Households supplying labor off-farm are generally associated with reduced adoption of terraces, hedgerows and cut-offs. The negative impact of supplying labor off-farm can be moderately cushioned when households also hire labor to work on the construction or maintenance of soil conserving structures. However, it is shown that hired labor is not a perfect substitute for households' own labor and does not fully off-set the effect of a household's off-farm labor supply.

**Key words:** Soil conservation, off-farm employment, rural labor markets, Tanzania

## INTRODUCTION

Recent literature on Tanzania has stressed the importance of rural labor markets, which mainly take the form of off-farm employment, on the welfare of the household and showed that the labor allocation decision between farm and off-farm employment is consistent with the objective of household utility maximization (Mduma, 2006). However, one of the questions that have to be answered is whether or not household's participation in off-farm employment affects the adoption and intensity of some labor intensive soil conserving methods. If the increase in off-farm employment deviates labor away from soil conservation, then the problem of degradation of agricultural land may, in the long run, jeopardize the resource base and ultimately the capacity of rural households to maintain self-sufficiency in food supplies (Yesuf, 2004).

Yesuf (2004) argues that, coupled with imperfections in rural labor markets, participation in off-farm activities is likely to constrain the adoption of labor intensive soil conserving technologies, because such technologies entail additional labor requirements whose return is in the distant future. Other empirical studies (Rola and Coxhead, 2001; Regmi, 1997) show that the choice of technology that will release or tie up labor in the farm, or will conserve or erode the soil, also depends on the household's labor endowment in relation to the functioning of rural labor markets. Although the results in Rola and Coxhead (2001) and Regmi (1997) are mixed, there was evidence that off-farm employment discourages labor intensive soil conserving technologies, despite the government campaigns for these techologies.

In this research, the question of whether there is trade-off between off-farm employment and the adoption of labor intensive soil conserving technologies is investigated. The study takes Kilimanjaro region, in Tanzania, as a case study. For this region, it has been argued that poor incentives and low profitability in the agricultural sector, particularly as a result of the collapse of the coffee economy, have caused the reallocation of labor to off-farm employment (Semgalawe, 1998; Semgalawe and Folmer, 2000; URT, 2002). Furthermore, the choice of Kilimanjaro is motivated by the fact that in recent years, households in Kilimanjaro have shifted from growing coffee to growing maize, beans and a variety of vegetables (URT, 2002); the later crops are generally considered soil erosive (Rola and Coxhead, 2001). As a result of this shift, the recent Regional Socio-economic Profile for Kilimanjaro agues that sustainable agricultural development remains an elusive goal, particularly on the mountain slopes, where soil degradation of agricultural land continues to pose a serious threat to the future production potential (URT, 2002). Thus, the policy question to be addressed is whether participation in off-farm employment opportunities has environmental effects in form of reducing the adoption of soil conservation practices. In this context, it is important to understand the interactions between the decision to participate in off-farm employment and agricultural land-use decisions, particularly household investment in labor intensive soil conservation methods on the mountainous plots.

## DESCRIPTIONS OF THE STUDY REGION

The data used in this chapter comes from a survey which the author conducted in the Kilimanjaro, one of the highland and mountainous areas of northern Tanzania. The survey was conducted using a structured questionnaire which was administered to the head of the households between August and December 2003. The main cash crops in the study region are coffee, which is grown in plantations as well as by smallholders. Cardamon, sisal, cotton, sunflower and groundnuts are now gaining ground as the importance of coffee declines. Important food crops are bananas, maize and beans. Other food crops include, cassava, millet, sorghum, potatoes, fruits and vegetables and various pulses grown for regional consumption and for export to other regions and East Africa as whole (URT, 2002).

Despite some irrigation farming, a large part of farming is rain-fed, thus seasonal rainfall distribution greatly influences agricultural practices. The region receives two rain seasons per year: the heavy rain season is from April to May and a light rain season is from September to November. Between these two rain seasons are two dry seasons, a major one in December to January and a minor one in July to August. However, there is marked variation in the amount of rainfall according to altitude and the direction of the mountain slopes. The mean annual rainfall varies from 500 mm in the lowlands to over 2,000 mm in mountainous areas (over 1,600 m above sea level). The temperature also varies greatly according to altitude.

Kilimanjaro region is comprised of four ecological zones based on altitude, soils and climate. According to Fernandes *et al.* (1985), the soils in the region fall into four major groups. These are (a) Humic nitosols and associated humic andosols; (b) Chromic cambisols and associated eutric cambisols; (c) Orchric andosols and associated chromic cambisols and vitric andosols; and (d) Mollic andosols and associated eutric nitosols. Thus, the agro-ecological include, the peak of Kilimanjaro Mountain, which is between 1,800-5,895 m above sea level, highlands (between 1,100 and 1,800 m above sea level), intermediate (between 900 and 1100 m above sea level) and Lowland Plains zone (below 900 m) (URT, 2002).

Fernandes *et al.* (1985) argue that, soil in Kilimanjaro region is generally fertile, but the major limitation is the steep slopes which prevent mechanization and require substantial erosion control measures. Thus, there has been a strong campaign, both from the regional government and central government as well as from non-governmental organizations, to encourage people in the region to adopt various soil conservation measures. Among the soil conserving technologies that households have been encouraged are: (1) bench terraces, which involve breaking a long slope into a series of shorter level sections to slow run off; (2) bound terraces, which involve a line of earth or stones - depending on availability of stones - placed along a contour; (3) cut-off, or waterways, or water-drains, which are built to divert part of or all of the water from plots (into different water courses, normally to the area which is considered safe disposal); (4) hedgerows, which is basically an agro-forestry system in which hedgerows of nitrogen-fixing trees or shrubs are planted very closely together and food or cash crops are grown in the alleys. Despite these campaigns, URT(2002) argues that soil degradation is one of the more severe environmental problems in the region.

## SOIL CONSERVATION UNDER IMPERFECT LABOR MARKETS: A THEORETICAL MODEL

Most of the literature on soil conservation considers soil conservation problems as an optimal control problem, involving both inter-temporal and intra-temporal trade-offs (Barbier, 1990; Rola and Coxhead, 2001; Yesuf, 2004). The model advanced here is based on the work of Clarke (1992), which was later modified by Rola and Coxhead (2001). We also subscribe to Yesuf (2004) in the way market imperfections are introduced into the theoretical model.

Suppose that household labor endowment must be allocated between current crop production, soil-conserving investment and off-farm employment. Notation wise, $\bar{L}$, $L_p$, $L_c$, $L_m$ let be household's labor endowment, labor used in the current production on the farm, labor used for installing and maintaining soil conserving structures and hired in/out labor (including off-farm labor), respectively. In this setting, $L_m$ is the balancing item in the household's labor constraints at each time period. If the farm household's initial endowment of labor, $\bar{L}$ is lower than labor employed in the current on-farm production ($L_p$) plus labor use for conservation activities ($L_c$), then the household hires in $L_m$ units of labor from the rural labor market; otherwise the household hires out the surplus labor (off-farm employment). Thus the labor constraint of the household can be written as in Eq. 1.

$$L_p + L_c = \bar{L} + L_m \tag{1}$$

To capture the imperfections in rural labor markets, we assumed that the household incurs some transaction costs (C) whenever participating in rural labor markets as a seller. The transaction cost function is assumed to be quasi convex in quantity of labor supplied off-farm; implying that it becomes more difficult to get further off-farm jobs (increasing marginal costs). (Note also that this assumption is needed to ensure that the Hamiltonian function is concave in the control variables so that the maximum principle condition is sufficient for maximization.) The cost of participating in the rural labor market is presented in Eq. 2.

$$C = C(L_m; \Omega) \tag{2}$$

where $\Omega$ captures all cost shifters such as spatial factors, which determine the position of the cost curve in the C-$L_m$ space. For simplicity, it is further assumed that there are no fixed costs for participating in rural labor markets such that $L_m = 0 \Rightarrow C(L_m;\Omega) = 0$. As in Jeong and Townsend (2002), it is supposed that participation in off-farm employment is rewarded $\omega$ as off-farm wage rate or imputed wage from self-employment. However, potential off-farm participants adjust this wage rate by a parameter $\rho \in [0,1]$, which reflects the expected match of the participant's skills and ability with those skills and abilities demanded in the local labor market. This assumption is necessary to captures some aspects of the observed rural open unemployment in Tanzania and Kilimanjaro region in particular.

As in Barbier (1990), the farm production technology is specified in a general functional form F (Q, $L_p$; $\Theta$, where the input Q is soil quality; $L_p$, as defined earlier, is on-farm labor allocated to the current production process and $\Theta$ summarizes all other relevant inputs including land quantity. F(.) is assumed to be a twice differentiable, strictly concave function. Further, we assume that labor input to current crop production is complementary to soil quality, (i.e., $\frac{\partial^2 F}{\partial Q \partial L_p} > 0$) which implies that an increase in the quantity of one raises the marginal productivity of the other.

Before we introduce dynamics to the model, we define the following notation. Let $\gamma \in \mathbb{R}_+$ denote soil quality-depleting characteristics of farm production and let $\eta$ denote the parameter that governs the rate of natural increase in soil quality in the absence of human intervention (Barbier, 1990). To make sure that the system is bounded (i.e., the increase takes place at a decreasing rate and will converge to a certain constant), it is assumed that $\eta \in (0, 1)$. In other words: in uninterrupted state, soil quality will eventually reach a steady state. Likewise, we have assumed $\gamma$ to be non-negative so that we eventually get a well behaved Hamiltonian function. The non-negativity assumption on $\gamma$ is plausible in that without any other (conservation) effort, all current farm production will not enhance soil quality. In other words, even when the plot is under such crops as legumes, which could potentially increase soil fertility, continuous cultivation without other intervention will eventually lead to a deterioration of soil quality.

Given this notation, we assume that soil quality Q (t) at time t depends on the current farm production process, summarized by $-\gamma F(Q(t), L_p(t), \Theta(t))$ and on the effect of soil conserving investments (I(t) ) which, for simplicity, includes only labor input $L_c(t)$. However, unlike in Rola and Coxhead (2001), the marginal product of labor used in soil conservation is not necessarily constant, but depends on the function $I(t) = I(L_c(t))$, which is assumed to be concave (the assumption which allows for a diminishing marginal product of labor used in soil conservation). From this discussion, the dynamics of soil quality is given by the state Eq. 3, where $Q_0$ is an appropriate initial condition constant.

$$\dot{Q}(t) = I(L_c(t)) - \eta Q(t) - \gamma F(Q(t), L_p(t), \Theta(t)) \qquad Q(0) = Q_0 \tag{3}$$

It is one again assumed that at the end of the planning horizon, the household gets benefit from the scrap value (the salvage value) of the land. This is a plausible assumption since the bequest motive induces the households to leave reasonably valuable land to their offspring under the customary laws of land holding in Tanzania and particularly, Kilimanjaro region. In principle, the salvage value of the land should be a function of the tenure system and the soil quality at end of the planning horizon. However, we assume a homogeneous tenure status across all households under customary laws; therefore the only variable relevant in the terminal value is soil quality. Given this assumption, when expressed in present value terms, the scrap value at the end of the planning period is $S(Q_T, T)e^{-\delta T}$; where $\delta$ is the rate of time discount and is assumed to be constant over time.

In this optimal control problem, the objective of the household is to choose the allocation of labor to current production, investment in soil conservation and the level of off-farm employment which maximizes the discounted value of returns to the combined farm and off-farm activities, plus the value of the land which is to be passed to the next generation. To formulate this optimization problem, we define $p_a$, vector of unit prices of produced agricultural output and $p_\theta$, the vector of unit prices of purchased current inputs. Thus, subject to the labor constraint given in Eq. 1, the transaction costs given in Eq. 2 and the state equation of soil given in Eq. 3, the household problem is the optimal control problem given in Eq. 4.

$$\max_{L^p, L^c, \Theta} \int_0^T [p_a F(Q, L_p; \Theta) + \rho\omega[\bar{L} - L_p(t) - L_c(t)] - \rho C([\bar{L} - L_p(t) - L_c(t)]; \Omega) - p_\theta \Theta] e^{-\delta t} dt + S(Q_T, T) e^{-\delta T} \quad (4)$$

This problem can be solved using the current-value Hamiltonian given in Eq. 5, where κ (t) is the co-state variable or shadow price of soil quality at time t.

$$\begin{aligned} H = \; & p_a[F(Q(t), L_p(t); \Theta(t))] + \rho\omega[\bar{L} - L_p(t) - L_c(t)] \\ & -\rho C([\bar{L} - L_p(t) - L_c(t)]; \Omega(t)) \\ & - p_\theta \Theta(t) + \kappa(t)[I(L_c(t)) - \eta Q(t) \\ & -\gamma F(Q(t), L_c(t), \Theta(t))] \end{aligned} \quad (5)$$

Other equations have been suppressed for the interest of space (can be obtained from the author upon request), but what can deduce from the maximum principal conditions is that along the optimal path, $L_p$, $L_c$, $L_m$ should be chosen in such a way as to maximize the total benefits in each period. For the maximum principle conditions and the transversality condition to be sufficient for a global maximum, it is required that the Hamiltonian be concave in all the control variables $L_p$, $L_c$, $L_m$ and the costate variable κ for all t. These requirements are always met given the assumptions we made about the functions and parameters of the model (the concavity of the production function and soil investment function, the convexity of the transaction cost function and the non-negativity of the parameters that govern degradation due to the production process).

From these conditions, we can further deduce an optimal allocation of labor in production and conservation activities, which takes into account imperfections in labor markets. The presence of the effect of labor allocated to soil conservation in the marginal product for labor can be used to show the broad indirect effects of factors that influence/are linked to soil conservation investment. On this we find that:

$$\frac{\partial I}{\partial L^c} = \frac{\gamma F_{pl} \rho(\omega - \partial C / \partial L_c)}{p_a F_{lp} - \rho(\omega - \partial C / \partial L_c)} \quad (6)$$

Equation 6 shows that the marginal contribution of labor allocated to soil conservation at the optimal path is a function of output prices, input prices, wage rate and labor market characteristics. What Eq. 6 shows is that there are various channels through which adoption and intensity of soil conserving technologies can be linked to household participation in off-farm employment. Some of the effects are direct through the reduction of labor supply for conservation, as involvement in off-farm employment may take labor directly away from conservation activities and may weaken soil conservation efforts. The magnitude of these effects will generally depend on the extent to which hired labor is an imperfect substitute for household labor and on the importance of search and monitoring costs associated with hired labor. Other indirect effects of participation in off-farm activities arise through the provision of off-farm incomes. Rola and Coxhead (2001) argue that off-farm income may affect soil conservation decisions by providing resources for soil conservation (hired labor) as the liquidity constraint is relaxed. Moreover, the liquidity effects of participation in off-farm activities may also reduce the individual discount rate which in turn triggers long-term investment decisions like soil conservation. Generally however, the effects of participation in off-farm activities are complicated and an overall effect is theoretically indeterminate.

## EMPIRICAL MODEL

To introduce the empirical model, emendable to econometrics techniques, we note that the marginal product of the labor allocated to the conservation of soil can easily be linked to the adoption and intensity of adoption, such as the number of terraces, hedgerows and waterways/drains in a given plot size. From the assumption of strict concavity of the soil conserving investment function, the marginal function $\partial I/\partial L_c$ in Eq. 6 will approach positive infinity as adoption approaches zero. Likewise, the marginal function approaches zero as the intensity of adoption becomes sufficiently large. Thus, since we do not observe a marginal value, we can safely replace it with a total function which reflects the existing state of soil conservation investment in that it covers both adoption and the intensity of adoption (e.g., the number of terraces, hedgerows and waterways/drains in a give plot size).

Table 1: Selected Regrossor in Used to explain the adoption and intensity of Adoption of Labor intensive soil conserving technologies

| Regressor | Definition |
|---|---|
| Age | Age of the household head (years) |
| Sex of the head of household | = 1 if the head of the household is males, 0 if female |
| Household size | The number of able-bodied persons in the household aged 18 and over. |
| Education of the head of household | Used three dummies for primary, secondary and above secondary education levels (no-formal education taken as reference category) |
| Off-farm wage | = 1 if off-farm employment was for wage; 0 otherwise |
| Secondary occupation | = 1 if the secondary occupation of the head of household is off-farm; 0 otherwise |
| Plot ownership | = 1 if the plot was declared to belong to the female member of the household; 0 otherwise. Permanent worker = 1 if the household has at least one permanent worker and 0 otherwise |
| Daily worker | = 1 if the household has hired daily workers |

Other studies of this nature use a dichotomous dependent variable model to analyze the adoption of these technologies. We think this is not adequate, as it does not take into account the intensity of adoption. Thus, this study aims at a model that will reflect both adoption and intensity of adoption of these technologies as measured by counting the number of soil conserving structures in a plot. As the nature of these variables suggests, Ordinary Least Squares (OLS) could have been used, but the preponderance of zeros and small and discrete values of the dependent variable posed econometric problems. These econometric problems can be circumvented by using Poisson regression (Greene, 2003). Furthermore, due to the anticipated endogenieity in the decision to participate in off-farm employment and adopting soil conserving measures, we use endogenous regime switching Poisson specification (Kozumi, 2002).

The dependent variables are the number of terraces, number hedgerows and the number of cut-offs for draining water in a unit of land area. Regressors include household and labor market characteristics as well as plot characteristics. To control for the plot characteristics, we included variables such as soil depth, slope of the plot and erosion type. The other regressors are as summarized in Table 1. Using $\chi^2$ and regression based test of over-dispersion in Poisson model, the model was observed to fit the data reasonably well. The results of the estimation and their policy implications are discussed in the next section.

## RESULTS AND IMPLICATIONS

This section presents the results of the endogenous regime switching Poisson regression model of the adoption and intensity of soil conserving technologies in the Kilimanjaro region. Regime switch is significant in the adoption of cut-off waterway/drains (at 5%), terraces (at 1%) and hedgerows (at 1%). For testing the overall fit of the models, the null hypothesis that all coefficients are zero is rejected for all three equations at a 1% significance level. Table 2 summarizes the main results of this study.

This study reveals that participation in off-farm employment as a secondary activity has significant negative effects on the adoption and intensity of the three soil conserving technologies considered in this study, namely terraces, hedgerows and waterway/drains. The coefficient for the participation in off-farm activities is significant at 1% for the terraces and waterways/drains equations and it is significant at 5% for the case of the hedgerows equation. The effect is substantial for the case of terraces and is least in the case of hedgerows. Since in the hierarchy of labor intensity, terrace technology ranks first and hedgerows rank last, these results imply that households are quite sensitive to the type of soil conservation technology, given the opportunities to work off-farm.

Note however, that for those whose main employment is off-farm the results are mixed. For terraces, participation in the off-farm wage employment and self-employment as the main activities have positive and significant effects. For hedgerow, participation in off-farm wage and off-farm self employment have a negative sign but only participation in the off-farm wage employment is significant. For waterways/drains, the effect of the participation in wage employment is not significant; but again: self-employment as the main activity has a negative and significant effect.

These mixed results could be explained by noting that most of those who reported that off-farm activities were their main activities are relatively well-off people in rural areas (NBS, 2002). For wage employment, this category is mainly composed by permanent employees of the government and few non-governmental organizations (e.g., school teachers and rural medial assistants). For the self-employment category, these are relatively well-off business people (in the rural context). Given their social status in rural areas, it is very likely that most advocates of soil conservation would target them, in order for them to be role models for others. Since one of the most important components of the soil conserving technologies in the study site (and northern highlands of Tanzania, in general) is terrace technology (Semgalawe, 1998; Semugalawe and Folmer, 2000), this

Table 2: Estimated Coefficients of the determinants of adoption and intensity of terraces, hedgerows and cut-offs

| | Terrace | | Hedgerows | | Cut-offs | |
|---|---|---|---|---|---|---|
| Variable | Coef. | p-value | Coef. | p-value | Coef. | p-value |
| Age | 28.332 | 0.00 | 49.153 | 0.00 | 10.618 | 0.07 |
| Square of age | -3.786 | 0.00 | -6.429 | 0.00 | -1.455 | 0.06 |
| Sex | -0.033 | 0.92 | 0.226 | 0.34 | 1.546 | 0.00 |
| Household size | 0.281 | 0.00 | 0.035 | 0.39 | 0.000 | 0.99 |
| Primary education | -0.711 | 0.27 | -1.428 | 0.00 | -0.846 | 0.01 |
| Secondary education | 0.924 | 0.00 | 0.002 | 0.99 | -0.781 | 0.00 |
| Education above secondary | -1.085 | 0.00 | -0.462 | 0.07 | 0.273 | 0.30 |
| Off-farm wage employment (against off-farm self employment) | 3.416 | 0.00 | -1.644 | 0.02 | 0.289 | 0.53 |
| Secondary occupation | 1.743 | 0.00 | -0.064 | 0.79 | -1.471 | 0.00 |
| Participate in off-farm employment (when farming is the main activity) | -4.644 | 0.00 | -0.984 | 0.04 | -2.606 | 0.00 |
| Plot ownership | -0.661 | 0.02 | 0.917 | 0.00 | 0.222 | 0.29 |
| Permanent worker | 0.177 | 0.63 | 1.418 | 0.00 | -0.323 | 0.14 |
| Daily worker | -1.941 | 0.00 | -0.835 | 0.00 | -0.773 | 0.00 |
| Constant term | -60.237 | 0.00 | -98.038 | 0.00 | -22.055 | 0.05 |

explains the observed positive association of soil conservation and off-farm activities as the main activities.

Turning to the effect of hired labor, the study shows that the presence of permanent workers in households has a positive and significant effect on the adoption of hedgerows and waterways/drains. However, its effect is not significant for the case of terraces. The use of hired daily labor, however, has a negative and significant effect on the adoption and intensity of all three soil conserving technologies considered here. This could be explained by the fact that hired daily labor is used as a short run household strategy of trying to cope with the acute demand for labor during peak periods. At this time, it is likely that priority is given to activities such as weeding (on time) and harvesting (on time) and not on matters of long term returns such as soil conservation. The reason is that failure to meet this seasonal labor demand has immediate effects such as the destruction of the crops by pests, but the effects of postponing soil conservation measures will only be discerned after a long time. Generally, therefore, our results suggest that hired labor, particularly daily labor, does not fully compensate for labor supplied to off-farm employment. Thus, policies that increase off-farm employment without increasing fallow or agro-forestry practices could potentially leave soil degradation unchecked. These results however, should be interpreted with caution because they are based on the assumption that the households' hired labor pattern has remained relatively stable (at least for the last five years of the recall period). Thus, our results are indicative but a firm conclusion about the substitutability between household labor and hired labor in soil conservation will need a study that tracks changes occurring in the adoption cycle.

Education has mixed results in that the adoption and intensity of terraces is not significantly affected by the education level of those who have not completed primary school. Education increases the adoption and intensity for those who just completed primary school, but is again negatively affected by secondary school education or higher. Adoption and intensity of hedgerow is negatively affected by not having completed primary school, but the other two education levels do not have significant impacts. Likewise, adoption and intensity of waterways/drains is negatively affected by education up to primary level and the secondary education level has no significant effects. These mixed results could be explained by observing that education variables have heavy impact on off-farm employment, thus capturing the negative effects off-farm employment has on the adoption and intensity of soil conserving technologies. In this case, we think that the model fails to discriminate between the effects of education and the effects of participating in off-farm employment.

The results also show that the adoption and intensity of terraces is lower in plots owned by female members of the household as compared to the reference group, which are plots that are owned by the husbands or son(s). However, plots claimed to belong to the female members of the household have more hedgerows when compared to the reference group. The difference is not significant for the case of waterways/drains. This could be due to the fact that women, in general, have a lot to take care of (for example child care and other household chore) and fail to meet the labor demands of such highly labor intensive soil conserving technologies like terracing.

## CONCLUSIONS

This study has investigated the effect of household participation in off-farm activities on the adoption and intensity of three soil conserving technologies, namely terraces, hedgerows and waterways/drains in the Kilimanjaro region. Since participation in off-farm activities is likely to be endogenous to the adoption and intensity of these technologies, we estimated the endogenous regression model of count data.

The results of this analysis revealed that participation in off-farm activities is generally associated with a decline in the adoption of the three technologies investigated and the intensity of the adoption. However, the negative impact of participating in off-farm activities is, in some instances, cushioned by the increased hired labor which works in constructing or maintaining these soil conserving structures.

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