Economic Analysis of Incentives for Soil Conservation

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Summary: Whether governments should intervene to encourage adoption of conservation measures, and if so in what way, is a complex issue. Without a clear understanding of the reasons farmers adopt particular land use practices, effective policies to encourage conservation cannot be devised. This paper uses a simple graphical model to examine the factors that drive farmers to adopt one land use practice rather than another and the role that government policies might play in encouraging farmers to adopt more conserving practices, and illustrates the results with data from semi-arid Kenya. When on-site productivity is the primary concern, farmers tend to have strong incentives to adopt conservation measures. Divergences between privately-optimal and socially-optimal conservation behavior are usually caused either by differences in the valuation of inputs and outputs, or because constraints prevent farmers from adopting otherwise profitable conservation practices. Unless these problems are addressed directly, incentive schemes are unlikely to prove effective. When off-site impacts are the primary concern, farmers have no direct incentive to take appropriate remedial actions. In such cases, a subsidy scheme may be called for. Even in such cases, close attention must be paid to price distortions and to any constraints to the adoption of conservation measures.

Concern over the consequences of land degradation for agricultural productivity and problems such as reservoir siltation has led many governments to attempt to encourage soil conservation. Some governments adopted legislation and regulations intended to prevent farmers from undertaking degrading activities or to compel them to adopt conservation practices, while others opted to subsidize the adoption of particular practices—particularly mechanical conservation structures such as terraces. The results of these efforts have often fallen far short of expectations. Land use rules have proven exceedingly difficult to enforce because of the vast spatial dispersion of agricultural activities and the often weak enforcement powers available to developing country governments. Subsidies have often succeeded in stimulating the adoption of conservation measures, but farmers frequently abandon their use—and sometimes actively destroy conservation structures—once subsidies cease (Lutz, Pagiola, and Reiche, 1994). At other times, efforts to encourage conservation have achieved only token cooperation by farmers (Enters, 1996).

This paper uses a simple graphical model to examine the elements that drive farmers to adopt one land use practice rather than another and the role that government policies might play in encouraging farmers to adopt more conserving practices. Data from Kenya are then used to illustrate the results.

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Social vs Private Analysis of Soil Conservation Problems

Designing policies that will successfully and sustainably increase conservation requires that two distinct but closely related questions be asked: what farmers will do under different conditions (a *positive* question), and what society would like farmers to do (a *normative* question).

(a) Ultimately, land use decisions are made by the farmers themselves and not by social planners or government agencies. Farmers decide how to use their land in light of their own objectives, production possibilities, and constraints. Understanding what drives individual farmers' land use decisions is a positive question, and it calls for analysis of farm-level costs and benefits valued in private terms—that is, in terms of the prices that individual farmers actually pay for inputs or receive for outputs.[2] The main difficulties here are the availability of adequate quantitative data on the technical relationships between different land use practices and long-term yields and costs of production; and understanding of the farmers' preferences and constraints.

(b) Second, one must ask what society would like farmers to do. The answer to this question is much less obvious than it might seem. Even when society has clearly articulated social goals, such as "sustainable development", it is often difficult to translate these goals into specific actions by individual land users, especially given the site-specificity of agricultural production and land degradation problems and the weakness of available data. Answering this normative question calls for analysis of national benefits and damages arising from different activities valued in social terms—that is, using the opportunity cost of goods and services to society.[3] This exercise calls for re-valuing farm-level benefits at social prices; and adding the benefits resulting from reductions in a variety of off-site damages (also valued at social prices). The main difficulties here, in addition to those already encountered in understanding farm-level conditions, are identifying and measuring the links between farm-level activities and downstream damages; and valuing the various damages.

The nature of the interventions necessary to ensure appropriate use of conservation measures—and, indeed, whether any intervention at all is necessary—will depend on the answers to these questions.

Private analysis: returns to conservation as seen by individual farmers

Land degradation occurs as a result of land use decisions. Without a better understanding of why particular land use decisions are made, appropriate policy prescriptions cannot be made. If we assume farmers are rational, their land use decisions depend on a comparison of the returns they can obtain under each practice available to them.[4] While many cultivation practices can

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2. The terms "private" and "social" analysis in this paper follow the usage of Monke and Pearson (1989). They are equivalent to the terms "financial" and "economic" analysis, respectively, used for example by Gittinger (1982).

3. For guidelines on how to estimate social prices, see Monke and Pearson (1989) or Gittinger (1982)

4. It is important to note that the use of the word 'returns' is not limited to monetary costs and benefits, but to all costs and benefits farmers derive from a given land use practice.

degrade the soil, action to slow or arrest degradation through changes in crop and management practices or through the adoption of conservation techniques is likely to be costly, either directly in terms of investment requirements or indirectly in terms of foregone production. The critical question farmers face is: do the long-term benefits of reduced degradation make these costs worth bearing?

Figure 1 depicts a stylized choice between two land use practices: a degrading practice and a conserving one. The top left panel shows the flow of net returns to individual farmers under each practice. Under the degrading practice, yields and hence returns gradually fall. Under the conserving practice, stable yields can be achieved after an initial investment.[5] It is important that all costs and benefits be included when estimating net returns under each practice. The opportunity costs of land and household labor are often omitted or under-estimated, resulting in over-estimates of returns. Some of the benefits of certain land use practices, such as crop by-products or the fact that they provide income or fodder at times when other sources are unavailable, are also often under-valued; in this case, this would lead to returns being under-estimated.

The bottom left panel shows the discounted net returns to each practice.[6] In this panel, the short-term costs and long-term benefits of adopting the conservation practice can be compared directly. If the long-term benefits exceed the short-term losses, we expect the practice to be adopted unless a constraint prevents it.[7] In a number of cases, the private benefits of switching to a conserving practice may be insufficient to justify adoption. The degrading practice may cause little damage, for example, or the conserving practice may not be a significant improvement; low prices might make the productivity improvements insufficient to justify the costs; poverty or credit constraints might prevent the required investments; insecure tenure might dissuade farmers from undertaking investments whose benefits will only be obtained in the future. Since both agro-ecologic and socio-economic conditions vary substantially, it should not be surprising that the extent of adoption can vary substantially (Pagiola, 1994).

The off-site costs that might result from each practice, such as downstream sedimentation, are not included in the private analysis. From the farmers' perspective, these costs are externalities which they will not take into account. This is not to say that farmers are ignorant of these effects (though they might be, especially if they occur far downstream), but that it's not in their personal interest to address them.

That profitability of conservation measures from the farmers' perspective is a critical factor in their adoption has been confirmed in a number of studies (Pagiola, 1994). A review of the costs

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5. This comparison between degrading and conserving practices is clearly very stylized for the purpose of illustration. In practice, conservation measures might only slow, rather than arrest, degradation. Conversely, some conserving practices might not only stop degradation but result in improvements in land conditions, thus leading to increasing returns over time. The same reasoning would apply to these cases. Likewise, the decline of returns under the degrading practice need not be linear as represented here for convenience. For ease of exposition, a model without risk or uncertainty is presented here. When production, future prices, or the effects of degradation are uncertain, the values used in the estimation should be expected values and the analysis would be a measure of individual farmers' subjective evaluation of the expected net benefits to adopting the conservation practice.

6. Since the choice of which practice to use is made by farmers in light of their own objectives and constraints, the appropriate discount rate to use is the farmers' own subjective rate of time preference.

7. The decision to adopt a given conservation measure is not a once-and-for-all decision. This analysis shows whether adoption is profitable in the current period, on the basis of all available information at this time. The decision will be re-evaluated in all subsequent periods, in light of updated information.

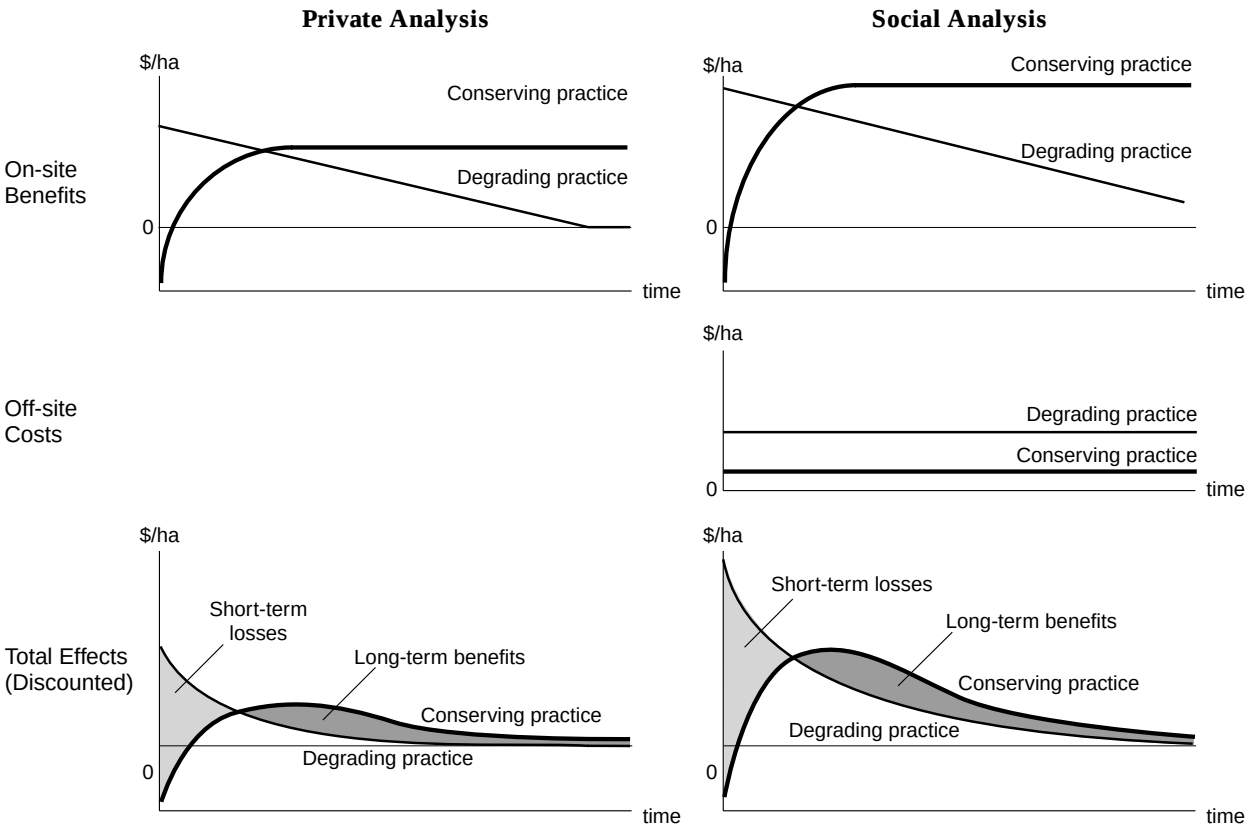


Figure 1. *Conceptual framework: Private versus social incentives to adopt conserving practices*

and benefits of soil conservation measures in six Central American and Caribbean countries, for example, found that adoption rates tended to be low in cases where conservation measures were estimated to be unprofitable from the farmers' perspective (Lutz, Pagiola, and Reiche, 1994). In some cases, low profitability was due to low rates of soil degradation, as in the case of Tierra Blanca in Costa Rica; in others, such as Patzité in Guatemala, the costs of the proposed conservation measures were too high relative to their benefits. Conversely, adoption was high in areas where profitability was estimated to be high. Similarly, in the Kitui / Machakos area of Kenya, adoption of locally-developed terraces known as *fanya juu* has been extensive; as shown below these terraces are likely to be profitable for farmers under a broad range of conditions (Pagiola, 1994; Tiffen, Mortimore, and Gichuki, 1994).

Of course, a number of other factors will affect farmers' conservation decisions, such as insecure tenure, lack of credit, and poverty. In some cases, these factors act to modify the costs and benefits as perceived by individual farmers, and so can be incorporated into the profitability analysis directly. For example, if expensive informal moneylenders are the only source of credit, the cost of investments will be higher. This can be incorporated into the analysis by adding the financing costs to the costs of adopting the conservation measure. Insecure tenure, on the other hand, means farmers cannot be sure to receive the long-term benefits of their actions, and so they will discount such future benefits more heavily. In other cases, the choices available to farmers will be limited. For example, adoption of particular practices may not be feasible due to non-availability of inputs. If fertilizers are not available, for example, farmers cannot use them to

replenish soil nutrients no matter how profitable it might be for them to do so. In such cases, the analysis might be limited to examining the choices that are, in practice, available to farmers. Often, however, it is interesting to undertake the profitability analysis as if the constraint was not present, so that the benefits of lifting that constraint can be determined.

If subsidies of any kind are received from the government for adoption of conservation practices, these subsidies would be included in the revenues from that activity when undertaking the analysis. If the subsidy is paid every year, it will shift up the entire net returns curve for the subsidized practice. If, as is more common, the subsidy is only paid for a short period, only the initial part of the net returns curve is shifted up. Likewise, the effect of indirect subsidies such as lower prices for particular inputs would be included in the analysis by using the subsidized prices in valuing the inputs.

Social analysis: returns to conservation as seen by society

The right-hand panels in Figure 1 show the equivalent social analysis of the same choice among activities. The top panel shows the on-site benefits of each activity. These might differ from those perceived by individual farmers because inputs and outputs are valued at their social opportunity cost rather than at their market values. If government policies or market failures distort observed market prices, substantial divergences can result. For example, if government policies keep the prices of agricultural commodities low, as has historically been the case in developing countries (Monke and Pearson, 1989; Schiff and Valdés, 1992), the social value of those commodities will be higher than the market price observed by farmers. Any direct subsidies paid to farmers or taxes paid by farmers—including subsidies for adoption of conservation measures or taxes imposed on the use of degrading measures—should *not* be included in this analysis, since they are transfers to farmers from the government (or vice versa in the case of a tax).

The middle panel then shows the off-site costs associated with each activity. For the purpose of illustration, the degrading practice is assumed to result in a constant level of off-site damage, for example by contributing to siltation of a reservoir, while the conserving practice results in much lower levels of off-site damage. These costs are often difficult to estimate, partly for lack of data and partly because of the difficulty of establishing clear cause-and-effect relationships when the causes tend to be distant in both space and time.

These costs and benefits are then brought together in the bottom right panel, which again shows the flow of discounted total costs and benefits, this time from society's perspective. Again, the fundamental question is whether the long-term benefits of switching from the degrading to the conserving practice are worth the short-term costs. It should not be assumed that the conservation option will always have higher social returns.[8]

8. Note that this analysis only indicates whether the *specific* conservation measure being examined is more socially profitable than the current, degrading practice. If the analysis shows this practice to be socially unprofitable, it does not mean that all conservation practices are socially unprofitable. Likewise, even if the analysis shows the proposed conservation practice to be socially profitable, it does not mean that there does not exist another conservation practice whose social profitability is even higher.

Developing appropriate responses

If the answer to the positive question of what farmers will do is the same as that to the normative question of what it would be socially optimal for them to do, then no intervention is necessary. If the answers to these two questions are not the same (that is, if privately optimal behavior differs from socially optimal behavior), then farmers will not undertake conservation at the socially optimal rate. The question of how to reconcile privately-optimal and socially-optimal conservation behavior then arises. A critical first step is to understand why the two differ.

Most developing countries have until recently had policies that discriminate heavily against agriculture. Resources have been extracted from agriculture in a variety of ways: over-valued exchange rates, protection of competing sectors, price controls, and high direct taxation. Analysis of a sample of eighteen developing countries found that transfers out of agriculture averaged 46 percent of agricultural GDP during 1960-84 (Schiff and Valdés, 1992). It has often been thought that these distortions have tended to discourage conservation (Southgate, 1994). In fact, given the wide variety of policies and of agro-economic conditions, it is difficult to predict a priori whether a given policy will tend to encourage or discourage conservation (LaFrance, 1992; Pagiola, 1996). In cases where policy-induced price distortions are the primary reason for farmers's failure to adopt socially-optimal conservation measures, however, the appropriate intervention is to remove these distortions. Doing so would be a "win-win" policy reform, in that it would improve both overall efficiency and conservation.

Since price policies can have substantial effects on incentives to adopt conservation measures, it might be thought that prices could be manipulated so as to encourage conservation. This is a very blunt instrument, however. Unless the subsidy (or tax) is narrowly targeted to apply only to inputs used in conservation activities, it is likely to affect activities far beyond its intended scope, thus imposing substantial budgetary costs and creating inefficiencies elsewhere in the economy. Moreover, if care is not taken the subsidy could actually be counterproductive from a conservation perspective as well. For example, subsidizing fertilizer might help reduce the extent of nutrient depletion in one area, but discourage farmers from adopting terraces in another because artificially cheap fertilizer provides a more profitable means of maintaining production from a private perspective.

That conservation measures be privately profitable from the farmers' perspective is a necessary condition for their adoption, but it is not sufficient. In many cases, constraints may prevent farmers from adopting conservation measures even though they are privately profitable. The main such constraints that have been identified in the literature are lack of credit, tenure insecurity (Ervin, 1986; Wachter, 1992), and poverty (Pagiola, 1995). In cases where such constraints are preventing farmers from adopting conservation practices, the appropriate intervention is to attempt to remove these constraints. Indeed, unless these constraints are removed other interventions are unlikely to succeed.

If individual land use decisions differ from socially-optimal land use decisions because there are externalities that farmers are not taking into account, then there is a rationale for payments to farmers to encourage appropriate behavior (or taxes to discourage inappropriate behavior). Assuming that a conservation measure would generate a positive externality (for example, by reducing downstream damages to reservoirs and waterways), the minimum subsidy required to induce adoption of the measure is that amount necessary to make adoption profitable for farmers. The maximum subsidy that should be paid is the amount of the downstream benefit being generated. While this is simple in theory, in practice numerous problems arise: First, it is

often extremely difficult to associate changes in costs and benefits downstream with specific changes in land use upstream. Second, the information available to planners on farmers' actual costs and benefits is usually very limited, and farmers have strong incentives to misrepresent these costs. Third, both the on-farm costs and the off-farm benefits are likely to vary substantially according to site-specific factors. Finally, since land use changes will only generate downstream benefits if they are maintained, payments to farmers must themselves be maintained over time. The common practice of paying the entire subsidy over a very short time period creates incentives for farmers to pocket the subsidy and then revert to their previous land use practices.

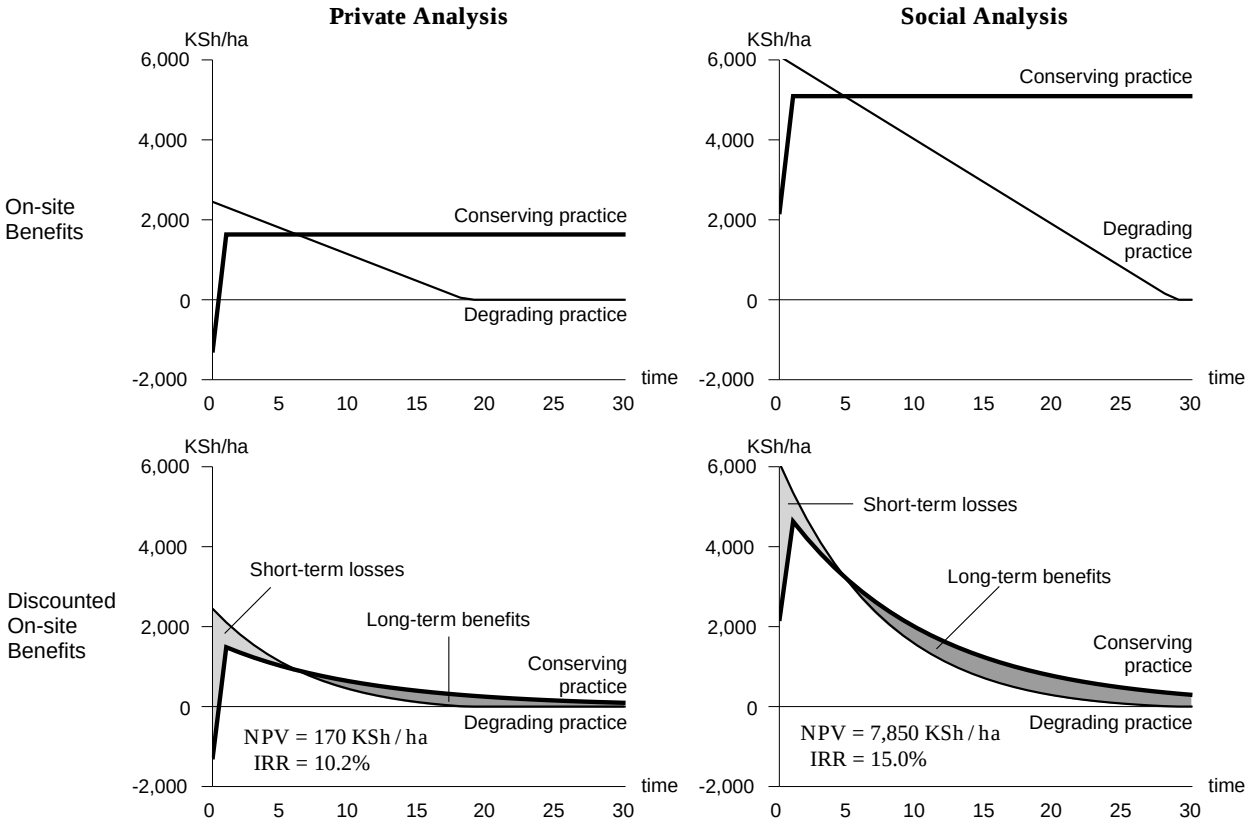
Incentives and adoption of terracing in semi-arid Kenya

Data from Kitui and Machakos districts in Eastern Kenya provide an example of the magnitude and direction of the effects of policy-induced price changes on incentives to adopt conservation measures. Agriculture in this semi-arid region is mainly subsistence-oriented, with maize the dominant food crop. Soils in the region are shallow, generally deficient in nitrogen and phosphorus, and have little organic matter. Low infiltration rates and a susceptibility to sealing make the area's soils vulnerable to erosion, particularly since the most intense rains come early in the growing season, when ground cover is poor. The recommended practice to avert this threat involves construction of terraces using a locally-developed method known as *fanya juu* (other measures such as trash lines or live barriers tend not to be viable because of the scarcity of fodder and problems with termites). Adoption of *fanya juu* terraces requires constructing and maintaining physical structures, but does not otherwise change farming practices.

Figure 2 shows the predicted benefits from adoption of *fanya juu* terraces on fields with 15 percent slopes in the Kitui / Machakos area.[9] In private terms, the adoption of *fanya juu* terraces is estimated to break even on such fields. On steeper slopes, the benefits of conservation would be higher since the damage caused by erosion would be greater; on gentler slopes, the benefits of conservation would be lower. That adoption of conservation measures is profitable from the farmer's private perspective is confirmed by their widespread adoption throughout the region even in the absence of any government support program (Pagiola, 1994; Tiffen and others, 1994). By 1985, about 85 percent of land in Machakos that required conservation work had some form of conservation on it; on the steeper slopes, this proportion was as high as 90 percent. Government support was limited to technical assistance in laying out the terraces and, occasionally, to provision of tools to women's self-help (*mwethya*) groups involved in conservation.

The right-hand panels in Figure 2 show the same analysis in social terms. The main difference here is that maize has been priced at its import parity level (adjusted for transport costs to Kitui Town) of 6 Kenya Shillings (KSh) per Kg, which is substantially higher than the price of

9. The predicted erosion rates and the resulting effects on yields are derived from data produced in long-term experiments carried out at the Katumani National Dryland Research Station in Machakos. Crop production costs area based on fieldwork carried out by the author in Kitui in 1990. Full details of the biophysical and economic model used can be found in Pagiola (1994, 1996). As is pointed out there, the model slightly under-estimates the benefits of terracing since it only partially accounts for the benefits of increased moisture conservation (the benefits of increased moisture conservation thanks to greater water storage capacity are included, but those resulting from modifying a field's slope by terracing are not). The degree of under-estimate is greatest on steep slopes and least on gentle slopes. Had better information on moisture conservation benefits been available, it would probably show that conservation investments are repaid sooner than estimated here and that they are profitable on a slightly greater range of slopes. The qualitative points made in this chapter, however, are not affected by this under-estimation.



Note: Estimates are for a field on 15% slope

Private prices are at the level observed during 1989-90 crop years; Social analysis assumes maize is priced at import parity

Source: Adapted from data in Pagiola 1994, 1996

Figure 2. *Private and social analyses of profitability of terracing in Kitui/Machakos, Kenya*

2.5KSh/Kg set by the parastatal in charge of grain marketing during the study period. At this higher price, adoption of *fanya juu* terraces would have been substantially more profitable for individual farmers, as can be seen from the higher net present value and internal rate of return. In general, price distortions of the magnitude seen here might can be expected to have quite substantial effects on the extent to which conservation measures are adopted. In this instance, however, the impact of this policy change would be rather limited, since even at distorted prices terraces were sufficiently attractive to induce widespread adoption under the conditions faced by most farmers. The main impact would be that adoption of conservation would be profitable over a broader range of slopes (Pagiola, 1996).

The social analysis in Figure 2 does not take into consideration external costs because such costs are minimal in this area, since there are few reservoirs and waterways. Had there been any external costs, would subsidies have been justified as means of abating them? In this case, the answer is most likely that they would not. As noted above, private incentives for conservation are already high enough to justify adoption on steeper slopes, where erosion is likely to be heaviest. Private returns to conservation are lower on the shallower slopes and may not justify adoption; such fields tend to produce relatively little sediment, however, so subsidies to induce farmers to adopt conservation measures would have little effect on any externalities, since they would only change conservation decisions on the fields which experience the least erosion.

That conservation should have been so broadly adopted in Kitui and Machakos without government support may seem surprising, given the substantial investments required, in terms of the actual expense of terracing and of forgone production from the reduction in effective area. Moreover, credit markets are practically non-existent in the region. Several mechanisms have allowed farmers to undertake investments in conservation despite these potential constraints. Remittances from family members working off the farm provided a source of finance, but perhaps most important, the monetary cost of terracing was reduced by the use of women's labor exchange (*mwethya*) groups. Participation in such groups allows farmers to obtain the necessary labor for terracing without requiring large cash outlays. The labor provided by *mwethya* groups, however, is neither costless nor of low opportunity cost, since reciprocal obligations of labor exchange are incurred. In a sense, farmers are borrowing labor—*mwethya* groups provide a mechanism which substitutes for the missing credit markets. Had *mwethya* groups and remittances not provided an alternative to missing credit markets, farmers might have been unable to construct *fanya juu* terraces despite their profitability. The first-best intervention in this case, however, would have been to attempt to provide alternative financing mechanisms rather than to subsidize the construction of terraces.

Land tenure constraints also do not play an important role in Kitui and Machakos. Although few farmers have title deeds, most feel secure about their tenure. Moreover, farmers expressed an unwillingness to use their land as collateral for loans, since they feared losing it should weather conditions lead to poor harvests. In this case, therefore, interventions such as land titling would have little effect on the adoption of conservation, since they would not increase either tenure security or access to credit.

This case study should only be interpreted as an illustration of farmers' incentives to adopt conservation measures. Land degradation problems tend to be extremely site-specific, so the results of might vary substantially in other cases. Even within a given area, variations in agro-ecological and socio-economic conditions can result in substantial differences in farmers' incentives to adopt conservation measures (Pagiola, 1994).

Conclusions

Whether governments should intervene to encourage adoption of conservation measures, and if so in what way, is a complex issue. Appropriate policies can only be developed on the basis of detailed information on each specific situation. There are many reasons why farmer conservation behavior might differ from socially-optimal conservation behavior. Without a clear understanding of the reasons farmers have for adopting particular land use practices, it is unlikely that an effective policy to encourage adoption of conservation measures can be devised. Farmers tend to have strong incentives to adopt conservation measures when land degradation threatens the long-term productivity of their land. When degradation is of concern primarily because of its impact on on-site productivity, divergences between privately-optimal and socially-optimal conservation behavior are usually caused either by differences in the valuation of inputs and outputs, or by the presence of constraints that prevent farmers from adopting otherwise profitable conservation practices. Unless these problems are addressed directly, any incentive scheme is unlikely to prove effective. Conversely, when degradation is of concern primarily because of its off-site impacts, farmers have no direct incentive to take appropriate remedial actions. In such cases, a subsidy scheme may be called for. Even in such cases, close attention must be paid to price distortions and to any constraints to the adoption of conservation measures. Failure to do so reduces the likelihood that appropriate incentive schemes can be devised.

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