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Soil conservation and governmental policies in tropical areas: Does aid worsen the incentives for arresting erosion?

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Abstract

This paper focuses on how farmers respond with respect to the adoption of soil conservation measures to governmental agricultural policies aiming at supporting smallholders. A simple micro-economic framework was chosen to undertake an analysis of farmer choices among three activities; farming, adoption of soil conservation measures and off-farm work. The model shows that governments have to be cautious when designing support measures if improved resource management is a policy goal. In the design of such measures, attention has to be paid both to (1) the distribution in land quality, and (2) the distribution in the net returns from adopting soil conservation measures.

1. Introduction

During recent decades there has been increasing awareness of the problem of land degradation. Soil erosion is now considered to be widespread, causing substantial losses both of productivity and soil, especially in sub-Saharan countries (Lal, 1987). The reason for the poor performance of agriculture in many low-income countries is believed to be partly the deterioration of the resource base. In some regions this constitutes a major hindrance to rural development and a threat against future livelihood (Timberlake, 1985).

As a consequence, planners, researchers and policy makers have focused attention on the importance of soil conservation. Many resources have been applied in the rural sector of many less developed economies to arrest erosion. The fact that governments care for the resource management of land suggests a divergence between private and social objectives concerning optimal soil conservation[1]. In the literature, the major reasons for the divergence are explained by different planning horizons and discount rates (McConnel, 1983; Griffin and Stoll, 1986). Furthermore, the off-site consequences of soil erosion may cause externalities, resulting in excessive rates of soil loss.

This paper presents an analysis of the effects on the resource management of land from different aid policies. Keeping in mind the considerable amount of resources allocated to the rural sector in some less developed economies to improve living conditions and increase production,

[1] Several authors have developed dynamic optimisation models, presenting socially optimal paths of soil loss (McConnel, 1983; Barrett, 1991; Grepperud, 1993).

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analyses of this kind are important. To be able to design optimal aid regimes, some key questions have to be addressed. How do farmers respond to different agricultural supporting policies introduced by governmental or private agencies? Under what conditions is aid effective in promoting soil conservation? Furthermore, do soil conservation supportive programmes necessarily strengthen the incentives for arresting soil erosion?

Several articles stress the importance of the role of governments in initiating and strengthening the resource management of land, both in providing infrastructure, extension services and credit facilities (see e.g. Lele and Stone, 1989; Barbier, 1992). Attention has also been paid to the role of agricultural prices and whether price liberalisations improve the incentives for erosion control (Lipton, 1987; Barrett, 1991; LaFrance, 1992). Less focus, however has been given to issues which focus upon the consequences of different agricultural assistance programmes.

The model examined was inspired by the work of Southgate and Pearce (1987) and Southgate (1990), who studied the effects on trade-offs between soil conservation and land clearing from changes in marketing costs and agricultural prices. The land clearing option (expanding agricultural frontiers) present in their work is here replaced by opportunities to engage in non-agricultural activities outside the farm. Furthermore, the area of cultivable land is given and each household is to decide how to allocate its labour between on-farm activities (cultivation and soil conservation) and off-farm activities.

This analysis allows for land productivity being unevenly distributed across a holding. Small farmers in the tropics are often confronted with complex and heterogeneous environments (see Bellon and Taylor, 1993 and references therein) and land fragmentation is a common feature of many regions. A single farmer often cultivates crops on various plots that may even be located in different ecological zones (Dejene, 1989). In the Ethiopian highlands the average holding consists of three separate plots of land, and over 98% of cultivated land is farmed on scattered individually held plots, while only 1–2% is farmed on larger consolidated blocks (Constable, 1984). In areas of Sahel, peasants possess and use different plots of land located at varying heights along rivers. In the Andes and the Himalayan region, there is spatial diversification of farm plots across heterogeneous agroclimates (Platteau, 1991)[2]. Furthermore, the susceptibility of land to erosion may differ owing to variation in gradient and slopes. Hence, parts of a holding are expected to be more eroded than other parts. Such factors suggest differences in the productivity of land even for smallholdings, a feature relatively neglected in economic research.

This paper shows a possible conflict between those objectives governments may have for the rural sector. Aid which improves agricultural production, efficiency and living conditions may cause a withdrawal of resources devoted to soil conservation. This again points to a conflict between increased immediate agricultural production and production in the long term. Giving less priority to soil conservation today will create future income losses through degradation of the soil base and increase the dependency of smallholders on future assistance. The analysis also yields insight into the design of soil conservation programmes. Making soil conservation less resource demanding for farmers will, under certain conditions, not be an efficient strategy for improved resource management. Instead, the analysis advocates assistance programmes where aid is conditional upon the provision of resources devoted to soil conservation.

Section 2 describes typical characteristics of applied soil conservation measures in developing countries. In Section 3 the analytical model is described, and the policy analysis is presented in Section 4. Finally, Section 5 concludes.

2. Soil conservation measures

The purpose of this section is to motivate the way the costs associated with the implementation

[2] Platteau (1991) considers access to a variety of lands of different quality, location and soil characteristics as a risk management strategy.

of soil conservation measures are introduced in the forthcoming model. There are many ways of conserving soil and the actual method applied differs both across regions and households, but all measures are beneficial in that they improve the productivity of land by arresting erosion, thus increasing future production per unit of land. Another feature of soil conservation measures (SCM) is that their implementation involves costs. The magnitude of these costs varies, depending on which measure is chosen and on soils, topography, crops and effectiveness in implementation. In general the costs associated with SCM can be classified into two groups: (a) costs in terms of reduced current output levels; (b) costs in terms of input use.

Fallowing has been an important way to maintain soil fertility and arrest erosion throughout history, and is still widely practised in tropical agriculture. Leaving land fallow for a period of time for grass and bushes to grow allows the fertility of the soil to be regenerated. The period of time for which land is left fallow differs widely, and depends on fertility and the regenerative capacity of land. Fallowing is the most typical example of a SCM which takes up productive land in the period of time they are implemented. However, fallowing may also involve input use since soils are often supplied with organic matter, such as mulch, dung or crop residues.

Structural conservation measures such as terracing, bunding, and construction of ditches, waterways and drainage, are for some areas observed to be a traditional way of increasing the future productivity of land (Westphal, 1975). On a larger scale, such conservation measures have mainly been adopted by farmers during recent decades, often in response to the promotion of agricultural expertise. These measures focus mainly on reducing the slope of the land, to increase water infiltration and reduce run-off, hence counteracting soil and water losses from the land. Structural soil conservation measures may be viewed as a long-term investment leading to a permanent improvement of land productivity (Blaikie and Brookfield, 1987). Planting of trees as windbreaks on cultivated land to protect the soil, or avoiding tillage close to contours, result in less area available for crops and also a need for increased input use in that they limit the ability to manoeuvre farming equipment.

3. The model

The analysis presented below considers a household which decides how to allocate its labour between on-farm activities (cultivation and soil conservation) on a given amount of land with well defined property rights. In particular, changes in the areas allocated to farming and implementation of soil conservation measures in response to three different support policies are analysed. It is assumed that each household faces possibilities in providing additional income beyond that coming from on-farm activities. Such off-farm activities could be to collect wood, to set up a small enterprise in the local market (e.g. a mill, a shop, a petrol pump), or to work for neighbouring farming units. Furthermore, the short-term costs and the long-term benefits from adopting soil conservation measures are taken into account. Their implementation is assumed to involve costs both in terms of immediate income losses and because of input use, as outlined in Section 2.

The model is deterministic in the sense that future prices and benefits are known to the farmer, and it is only focused on decisions made during a simple period of time. Land adopted for SCM may of course be adopted again in later periods, but this is a future decision for each farmer, and not considered here.

Total units of land, L, is given. Eq. (1) states that the sum of both farmed land (L_1) and land adopted for SCM (L_2) cannot exceed the given area of land

$$L_1 + L_2 \leqslant L \tag{1}$$

where

$$L_1 = \frac{N_1}{A}$$

and

$$L_2 = \frac{N_2}{B}$$

N_1 and N_2 are respectively the number of labour units allocated to farming and soil conservation. A is the number of labour units necessary to farm one unit of land and B the labour units necessary to implement conservation measures on one unit of land. These labour intensities are assumed constant in each period of time, and can be interpreted as optimal effort of labour per unit of land[3]. It is simplest to think of labour as the only input[4], but the size of A may also depend on farming practices, soils and climate and the farming 'technology' each household possesses, such as machinery, draft-animals (oxen), tillage methods (hoe or plough). B will depend on both technology and which SCM are actually applied.

The production function in farmed land is defined as $f(N_1/A)$. Land is assumed to be ranked according to land productivity, consequently yielding a concave production function in land allocated to farming: $f'(N_1/A) > 0$, $f''(N_1/A) \leqslant 0$. The net benefit function in land exposed to SCM is defined as $X(N_2/B)$. This function incorporates the future returns from adopting an area of land to SCM, when farmed for all subsequent periods. Hence, the farmer pays attention to the future return from land adopted to soil conservation measures. Subtracted from these benefits is the value of future income from production if no conservation measures are applied[5]. Since land is ranked according to productivity, it is not obvious what happens to the marginal net benefit from adopting additional (less fertile) land under SCM. In general, the marginal returns will differ over the actual conservation practices adopted. However, the marginal returns per unit of land exposed to soil conservation is most likely decreasing as less fertile lands are brought under erosion-control techniques. The following assumptions are made concerning the net benefit function from adopting SCM: $X'(N_2/B) > 0$, $X''(N_2/B) \leqslant 0$.

The average return from off-farm work is $H(N_3)$, which is assumed constant in N_3: $H'(N_3) > 0$, $H''(N_3) = 0$[6]. The opportunity cost of labour, $G(N)$, is assumed to be strictly convex in labour: $G'(N) > 0$, $G''(N) < 0$.

The objective of the farmer is in each period to maximise the discounted future net returns with respect to labour allocated to farming (N_1), to SCM (N_2) and to off-farm activities (N_3), subject to the constraint of a given area of land (1). This yields the following concave programming problem

$$\Omega = Pf'\left(\frac{N_1}{A}\right) + \delta PX\left(\frac{N_2}{B}\right) + H(N_3) - G(N_1 + N_2 + N_3) - \lambda\left(\frac{N_1}{A} + \frac{N_2}{B} \leqslant L\right) \quad (2)$$

Where δ is the farmer's discount rate between income today and future income, and P is the output price. The first order conditions are as follows

$$\frac{\partial\Omega}{\partial N_1} = \frac{1}{A}Pf'\left(\frac{N_1^*}{A}\right) - G'(N^*) - \lambda\frac{1}{A} \leqslant 0 \; (=0 \text{ if } N_1^* > 0) \quad (3)$$

$$\frac{\partial\Omega}{\partial N_2} = \frac{1}{B}\delta PX'\left(\frac{N_2^*}{B}\right) - G'(N^*) - \lambda\frac{1}{B} \leqslant 0 \; (=0 \text{ if } N_2^* > 0) \quad (4)$$

$$\frac{\partial\Omega}{\partial N_3} = H'(N_3^*) - G'(N^*) \leqslant 0 \; (=0 \text{ if } N_3^* > 0) \quad (5)$$

$\lambda = 0$ or $L_1 + L_2 = L$

Ω is concave in all endogenous variables, ensuring that the Kuhn–Tucker conditions of a

[3] In some situations the adoption of soil conservation measures may affect future labour intensities of both farming and soil conservation activities. Such changes are here assumed to be included in the net benefit function, presented below.

[4] For sub-Saharan smallholders the input use is limited, consisting of seeds from previous crops, perhaps draft animal power and labour. Furthermore, smallholders have limited access to agricultural chemicals, machinery and credit.

[5] In the case of structural conservation measures, the maintenance costs of structures are also subtracted.

[6] A more realistic assumption would probably be to assume decreasing returns of scale in labour devoted to off-farm work. Such an assumption would, however, complicate the forthcoming analysis without changing the main conclusions.

global optimum are fulfilled. In the forthcoming analysis I will focus on the case with interior solutions for all three endogenous variables and with land as a binding constraint[7]. The implication of these assumptions is that all land possessed by a household is both cultivated and adopted for SCM. Furthermore, the net returns from cultivating or conserving the least productive unit of land are assumed higher than engaging in off-farm work. If more land was available, additional units of labour would be allocated from off-farm work to the more beneficial on-farm activities. This case is meant to describe a situation with land scarcity, which seems to be relevant for many developing countries. The fact that there are many members of each household (and a rapidly growing population) leaves each farm with many hands, while cultivable land has become increasingly scarce.

Under these assumptions it follows immediately from Eqs. (3), (4) and (5) that

$$\frac{1}{A}Pf'\left(\frac{N_1^*}{A}\right) - G'(N^*) = \frac{1}{A}\lambda \tag{6}$$

$$\frac{1}{B}\delta PX'\left(\frac{N_2^*}{B}\right) - G'(N^*) = \frac{1}{B}\lambda \tag{7}$$

The first term on the left side of both equations is the marginal return from increasing labour devoted to cultivation and labour devoted to soil conservation. From these are subtracted the marginal opportunity cost of labour. This again will in optimum equal the value of being endowed with the amount of labour which makes possible one unit increase in labour for each of the on-farm activities.

The shadow value of land (λ) is defined as the increase in net returns from being endowed with one additional unit of land. From Eqs. (6) and (7) an expression for this shadow value in optimum is derived.

$$\lambda = Pf'\left(\frac{N_1^*}{A}\right) - AG'(N^*)$$
$$= \delta PX'\left(\frac{N_2^*}{B}\right) - BG'(N^*) \tag{8}$$

Eq. (8) says that λ is equal to the marginal increase in net returns from cultivation or adopting SCM to a unit of land, from which is subtracted the accompanying change in the opportunity cost of labour which is needed to cover an additional unit of land with each of the on-farm activities. It is further noticed that only when farming and soil conservation activities have the same labour intensity, will the marginal return from farming land equal the marginal net return from conserving land, in optimum. For all other situations they differ in order to adjust for differences in labour intensities.

By inserting Eqs. (1) and (4) into Eq. (3), the first order conditions turn out as follows

$$\frac{1}{A}Pf'\left(\frac{N_1^*}{A}\right) - \frac{1}{A}\delta PX'\left(L - \frac{N_1^*}{A}\right)$$
$$- G'\left[N_1 + B\left(L - \frac{N_1}{A}\right) + N_3\right]\left(1 - \frac{B}{A}\right) = 0 \tag{9}$$

$$H'(N_3^*) - G'(N^*) = 0 \tag{10}$$

The first term of Eq. (9) is the marginal value of allocating one additional unit of labour into farming (N_1). This term consists of the marginal productivity of land multiplied both by output price (P) and the increase in farmed land ($1/A$) that goes with an additional unit of labour devoted to farming. The second term represents costs, in that a marginal increase in labour devoted to farming takes up land ($1/A$) otherwise adopted for soil conservation, hence causing a future loss. The third term is a cost or a benefit, depending on whether farming is less or more labour intensive than soil conservation. For a marginal increase in labour devoted to farming,

[7] Since this paper focuses on changes in the area receiving soil conservation measures as a result of different support policies, it is convenient to consider an initial situation where soil conservation is taking place. Furthermore, it is difficult to think of situations where no land is farmed.

there will be a marginal gain in 'saved' labour units needed to farm and conserve all land, if $B > A$. Consequently, the optimal allocation is to devote labour to farming until the marginal return equals marginal costs. Eq. (10) simply states that the marginal income from allocating one additional unit of labour to off-farm activities has to equal the marginal opportunity cost of the same increment in labour.

4. Policy analysis

The second part of the paper discusses how different ways of supporting a household may influence its allocation of labour among on-farm and off-farm activities. In this framework the following three support policies are considered: (i) farming supportive programmes; (ii) conservation supportive programmes; (iii) off-farm supportive programmes.

By a farming supportive programme is meant governmental or non-governmental programmes which are labour-saving in terms of cultivation, represented in this model by a reduction in A. Many of the instruments that governments possess and often adopt to support the rural sector, do involve some type of improvement in the farming system. These range from the provision of inputs such as improved seeds, fertilisers and tillage tools to extension services, providing farmers with information on how to farm more efficiently. A wider interpretation may also be given to A, that of all labour needed both to farm a unit of land and to bring products to a market (marketing costs). Reductions in A may then represent measures facilitating transport to markets, such as road construction.

By a conservation supportive programme is meant programmes which are labour saving in terms of the adoption of SCM. Agencies may provide farmers with both tools and labour to build terraces, bundles and drainage channels. In cases where the use of organic fertilisers is adopted, all measures taken to provide farmers with dung, crop-residues and mulch may be said to be in this category. Organic fertilisers have an alternative use as fodder (crop residues) and as an energy source (dung), and increased supplies of energy and fodder cause a reduction in the labour intensity of erosion control. In this analysis, all such measures are represented by a negative shift in B.

Off-farm supportive programmes may be regarded as all measures that increase the returns from engaging in off-farm activities. For instance, programmes supporting women in their production of goods for the local market, e.g. handcrafts, or by improving wages for labour employed in infrastructure development or agricultural production on large-scale farming units, e.g. plantations or industrial agriculture. All such policies are represented by a positive shift in the average return from off-farm activities.

To study how the endogenous variables (N_1, N_2 and N_3) are influenced by changes in A, B and $H(N_3)$, Eqs. (9) and (10) are differentiated and solved using Cramer's rule.

4.1. Farming supportive programmes (FSP)

An increase in A generates the following changes in N_1, N_2 and N_3

$$\frac{\partial N_1}{\partial A} = \frac{\frac{1}{A}Pf'(*) + \frac{1}{A}\frac{N_1}{A}Pf''(*) - \frac{1}{A}P\delta X''(*)\frac{N_1}{A} + \frac{B}{A}G'(*)}{\frac{1}{A}P[f''(*) + \delta X''(*)]} \tag{11}$$

$$\frac{\partial N_2}{\partial A} = -\frac{\left[\frac{1}{A}Pf'(*) - \frac{1}{A}\delta PX'(*) + \frac{B}{A}G'(*)\right]}{\frac{1}{B}P[f''(*) + \delta X''(*)]} \tag{12}$$

$$\frac{\partial N_3}{\partial A} = -\frac{N_1}{A} - \frac{\left(1 - \frac{B}{A}\right)G'(*)}{\frac{1}{A}P[f''(*) + \delta X''(*)]} \tag{13}$$

If farming becomes less labour-intensive, there are several effects influencing a household's decisions in its allocation of labour. The first two terms in the numerator of Eq. (11) represent two opposing effects on N_1 through the production function. From the first term it follows that if less labour-units are needed to farm a unit of land, then for a marginal increase in labour, a larger area of land is farmed. This effect constitutes a gain for the farmer, thus encouraging an increase in N_1 (land expanding effect). The second term represents a contradicting effect; for every level of effort devoted to farming, a less labour-intensive farming practice means that more (less productive) lands are brought into cultivation, leaving the farmer with lower marginal returns from engaging in farming, inducing the farmer to reduce the amount of labour devoted to farming (productivity falling effect).

The next two terms represent costs for the farmer in terms of ousted conserved land, brought about by a marginal increase in labour devoted to farming. For a lower value of A, the costs associated with a marginal increase in labour devoted to farming rise, since more land previously adopted for SCM will now be ousted. If in addition there are decreasing returns to scale in adopting SCM on less fertile land, the ousting of conserved land leaves the farmer with a lower marginal net gain from these activities. Both these effects increase the costs associated with devoting more labour to farming, hence inducing the farmer to reduce the application of this type of labour.

The last term may be said to represent a 'substitution' effect. For less labour-intensive farming practices, farming becomes relatively beneficial compared with soil conservation, hence encouraging the use of more labour in farming and less in soil conservation.

4.1.1. Labour devoted to farming (N_1)

To study how a governmental policy which make farming less labour intensive affects the direction and magnitude of the allocation of labour to farming, a rearrangement of Eq. (11) is undertaken. By using Eq. (8) and

$$\epsilon = El_{N_1/A} f'\left(\frac{N_1}{A}\right) = \frac{f''(*)}{f'(*)}\left(\frac{N_1}{A}\right) \tag{14}$$

Eq. (11) is rewritten as

$$\frac{\partial N_1}{\partial A} = \frac{\frac{1}{A}Pf'(*)[1+\epsilon] - \frac{1}{A}\lambda + \frac{1}{A}\delta P X''(*)\frac{N_1}{A}}{\frac{1}{A}[Pf''(*) + \delta X''(*)]} \tag{15}$$

The opposing effects on N_1 through the production function are now represented in the first term of the numerator of Eq. (15). Their overall effect on N_1 depends crucially on whether the elasticity of the marginal productivity of land with respect to farmed land (ϵ), is less or greater than -1. The second term in Eq. (15) also represents two opposing effects; the substitution effect (encouraging more use of labour in farming) and the increase in costs that follows from more conserved land being ousted for a lower value of A. Adding these effects yields an expression equal to the shadow value of land. Consequently, their total effect is always positive as long as land is a binding constraint, meaning that the substitution effect is always dominated. The third term is the second cost effect working through the net benefit function from adopting SCM which, ceteris paribus, induces the farmer to devote less labour to farming, when farming becomes less labour intensive.

From Eq. (15) it is now possible to arrive at some conclusions as to what happens to labour devoted to farming after the introduction of FSP. Consider the case where there is constant returns to scale in soil conservation and where $f''(N_1/A)$ approaches zero (which implies that ϵ approaches zero)[8]. Using Eq. (6) it is now easily observed that the numerator of Eq. (15) approaches $G'(N)$. Hence, Eq. (15) turns out negative, saying that labour devoted to farming will increase as a consequence of FSP. The assumptions have simplified Eq. (15) in two ways. The farmer no longer faces the 'productivity falling' effect from increasing labour devoted to farming. Furthermore, soil conservation will no longer take place on land with decreasing marginal returns from the adoption of SCM. The only cost associated with improved farming systems is the accompanying increase in the ousting of conserved land. This effect though is dominated by the effects which pull in the opposite direction. It is also

[8] Assuming constant returns to scale in both farming and soil conservation will yield corner solutions. The on-farm activity with the highest rate of return adjusted for differences in labour intensities would be preferred for all land.

noticed from the denominator of Eq. (15) that as both $f''(N_1/A)$ and $X''(N_2/B)$ approach zero, the change in labour devoted to farming from a decrease in A increases in strength.

Consider the case where there is an uneven distribution in productivity of land (ϵ is low in absolute terms) and decreasing returns to scale in area adopted to SCM. For this situation the conclusion will be modified. The increase in labour devoted to farming will be weakened and could even go in the opposite direction. This is due to the introduction of the two additional costs compared with the earlier situation. This result is seen from Eq. (15), since the elasticity (ϵ) becomes more negative as the distribution in land quality becomes more uneven. If the elasticity becomes elastic ($\epsilon < -1$), the first term of the numerator turns out negative, meaning that the 'land expanding' effect is dominated by the 'productivity falling' effect. For this situation all three terms in the denominator of Eq. (15) induce the farmer to reduce the amount of labour devoted to farming in response to improved farming systems. This effect is true even if there is constant returns to scale in the net benefits from adopting SCM. Finally, observe that a higher shadow value of land promotes a stronger withdrawal of labour devoted to farming in response to less labour-intensive farming.

4.1.2. Labour devoted to the implementation of SCM (N_2)

Using Eqs. (11) and (9), Eq. (12) may be written in the following two ways

$$\frac{\partial N_2}{\partial A} = \frac{B}{A}\left[\frac{N_1}{A} - \frac{\partial N_1}{\partial A}\right] = -\frac{G'(*)}{\frac{1}{B}P[f''(*) + \delta X''(*)]} > 0 \qquad (16)$$

From Eq. (16), it can be observed that labour devoted to SCM always decreases if farming becomes less labour intensive. An FSP means that less labour units are needed to cover all land with farming and conservation activities. In addition, the application of SCM has become relatively more resource-demanding than farming, thus inducing the farmer to substitute labour units from soil conservation activities to farming activities. Both effects encourage less use of labour devoted to soil conservation. As a consequence, a policy which is beneficial in terms of improving the conditions for undertaking farming will oust an area of land under soil conservation and consequently increase the area of land under farming. This effect is valid independent of how reductions in A affect labour devoted to farming, but as seen from Eq. (16), the magnitude of this effect depends crucially on $\partial N_1/\partial A$.

The withdrawal of labour devoted to arrest erosion in response to an FSP is strongest for holdings with (1) an even distribution in land productivity (ϵ close to zero) and (2) constant net returns from adopting SCM. For holdings with a more uneven distribution both in land quality and in the returns from adopting SCM, the decrease in area under the adoption of SCM is to some extent modified. The reason for this is that decreasing returns to scale both in production and soil conservation make the marginal costs associated with increasing labour devoted to farming larger than would be the case with constant returns to scale in both activities.

To conclude, an FSP is expected to oust more land adopted to SCM for holdings which possess an area of land with uniform land quality, than for those with a more uneven distribution in land quality. The implications of these results could be that for consolidated farms, where there are fewer reasons to suspect large differences in soils and slope, a FSP might oust more land adopted to SCM than would be the case for fragmented holdings or holdings with parts of their holding more eroded than other parts.

4.1.3. Labour devoted to off-farm activities (N_3)

Using Eq. (16), Eq. (13) can be written in the following two ways

$$\frac{\partial N_3}{\partial A} = -\frac{\partial N_1}{\partial A}\left(1 - \frac{B}{A}\right) - \frac{B}{A}\frac{N_1}{A} = -\frac{\partial N_1}{\partial A} - \frac{\partial N_2}{\partial A} \qquad (17)$$

From Eq. (17) it can be observed that both the direction and the magnitude of the effect on N_3 for a decrease in A, depend on how the same decrease affects labour devoted to farming and soil conservation. If labour devoted to both on-farm activities decreases, a farmer will increase labour effort in off-farm activities.

It follows from Eq. (17) that even if labour devoted to farming increases after the introduction of an FSP, N_3 will still increase as long as soil conservation is more labour intensive than farming ($B > A$). If the opposite is the case ($A > B$) and labour devoted to farming increases strongly in response to improved farming systems, N_3 may well decrease. For this situation, relatively few labour units are rendered from the decrease in labour devoted to soil conservation, since labour devoted to farming increases in response to a reduced A. To cover all arable land with the optimal amount of both on-farm activities, a transfer of labour units from off-farm activities to on-farm activities may be preferable. In seems most plausible that a farming supportive programme tends to induce the farmer to employ more resources in off-farm activities, since less effort in general is needed to cover all arable land with production and conservation activities.

To sum up, FSPs have malign effects on the incentives for households to undertake soil conservation. Improved farming systems may cause a withdrawal of labour allocated to the adoption of SCM, which implies less land under conservation and more land under farming. The ousting of conserved land is most alarming for holdings with an uniform distribution in land quality, and where the net returns from adopting SCM is constant. Consequently, the disincentives for arresting erosion are modified for holdings possessing a more uneven distribution of land quality and for areas where the net returns from adopting SCM decrease in poorer soils.

The analysis stresses that 'traditional' FSPs are in conflict with objectives aiming to encourage farmers to increase their effort in soil conservation. Agricultural policies in less developed countries have often had a character of being farming supportive, e.g. by introducing new and more efficient ways of farming. It is shown that a consequence of such policies may be accelerated erosion, since the introduction of such supportive programmes increases the costs of keeping labour in soil conservation activities.

4.2. Conservation supportive programmes (CSP)

Similar procedures as above yield

$$\frac{\partial N_1}{\partial B} = \frac{A}{B}\left[\frac{N_2}{B} - \frac{\partial N_2}{\partial B}\right] > 0 \tag{18}$$

$$\frac{\partial N_2}{\partial B} = \frac{\frac{1}{B}\delta P X'(*)[1+\gamma] - \frac{1}{B}\lambda + \frac{1}{B}Pf''(*)\frac{N_2}{B}}{\frac{1}{B}P[f''(*) + \delta X''(*)]} \tag{19}$$

$$\frac{\partial N_3}{\partial B} = -\left[1 - \frac{A}{B}\right]\frac{\partial N_2}{\partial B} - \frac{A}{B}\frac{N_2}{B} = -\frac{\partial N_1}{\partial B} - \frac{\partial N_2}{\partial B} \tag{20}$$

where

$$\gamma = El_{N_2/B} X'\left(\frac{N_2}{B}\right) = \frac{X''(*)}{X'(*)}\frac{N_2}{B} \tag{21}$$

Eq. (18) is uniquely positive (for proof see Appendix 1) and says that labour allocated to farming will be reduced as a response to CSP, thus the area under farming will experience a decline. Since land is given, such a policy will increase area under erosion-control techniques. The effectiveness of CSP in promoting incentives for arresting erosion will, however, depend on both the distribution in land quality and the distribution in the returns from adopting SCM. This is seen by studying Eq. (19). All effects identified in Eq. (11) are also present here. The only difference is that the opposing effects which formerly took place via the production function, are now present in the net benefit function from adopting SCM. The effects of the production function now represent costs in terms of ousted farmed land, and both are now pulling in the same direction.

The elasticity of the marginal change in the net benefit function from adopting soil conservation measures (γ) is crucial for the net effect from the two opposing effects working through the net benefit function in Eq. (19). By assuming constant returns to scale in farmed land [$f''(N_1/A) = 0$] and let $X''(N_2/B)$ approach zero (which implies that γ approaches zero) and using Eq. (7) it is easily seen that the numerator of Eq. (19) approaches $G'(N)$. Consequently, Eq. (19) turns out negative which means that the allocation of labour devoted to soil conservation will increase in response to a CSP. As land quality and the net benefits from adopting SCM become more unevenly distributed, this increase is modified and it may even be reversed.

From Eq. (20) it is seen that as with a FSP, a CSP will in general cause an increase in the amount of labour allocated to off-farm activities. This is a result of on-farm activities becoming less labour demanding for the household, since the labour intensity of soil conservation is reduced. It is only when soil conservation is less resource demanding than farming ($B < A$), and labour devoted to soil conservation increases strongly in response to a CSP, that labour devoted to off-farm activities may decline. The results suggest that CSP are most efficient for holdings where both land quality and the net returns from adopting SCM are uniformly distributed over land and less efficient for hilly and fragmented holdings.

4.3. Off-farm supportive programmes (OSP)

To analyse the effects of governmental support for off-farm activities, a constant, α, is multiplied to the average return function from engaging in off-farm activities in problem (2). By increasing α, the household receives a higher average return for off-farm work. The changes in labour allocation are as follows

$$\frac{\partial N_1}{\partial \alpha} = \frac{[A-B]\frac{1}{B}H'(N_3)}{\frac{1}{A}\frac{1}{B}P[f''(*) + \delta X''(*)]} \tag{22}$$

$$\frac{\partial N_2}{\partial \alpha} = -\frac{[A-B]\frac{1}{A}H'(N_3)}{\frac{1}{A}\frac{1}{B}P[f''(*) + \delta X''(*)]} \tag{23}$$

$$\frac{\partial N_3}{\partial \alpha} = \frac{H'(N_3)}{G''(*)} - \frac{[A-B]^2}{\frac{1}{A}P[f''(*) + X''(*)]} > 0 \tag{24}$$

It follows from Eqs. (22) and (23) that the direction of the change in labour devoted to farming and soil conservation depends crucially on which on-farm activity is most labour intensive. Furthermore, the direction of change is always opposite for the two activities. If farming is more labour intensive than soil conservation ($A > B$), labour devoted to farming will decrease while labour devoted to erosion control will increase. If farming is less labour intensive than soil conservation, the effects go the opposite way.

By adding Eqs. (22) and (23) it follows that OSP always causes a reduction in the total amount of labour allocated to on-farm activities (see Appendix 2). After the introduction of a OSP, off-farm work becomes relatively more beneficial to a household than on-farm activities. In response, a household will seek to substitute labour from the most labour intensive on-farm activity to the least labour intensive. In this way, more labour units are rendered in order to be able to transfer more effort into off-farm activities. There are two effects present here, both working in the same direction. First, the total supply of labour units from the household increases since the marginal returns from engaging in off-farm activities have increased compared with the marginal opportunity cost of labour. Secondly, the result of making off-farm activities relatively beneficial compared with both farming and soil conservation, induces the household to substitute from the most to the least labour intensive on-farm activity, in order to render labour units which again are applied to off-farm activities.

Implications from the analysis undertaken suggest that supporting rural households by increasing the average returns from activities outside their holdings, may yield distortive incentives with respect to the adoption of SCM. For a farmer practising relatively resource-demanding SCM ($B > A$), such a policy causes an increase in labour devoted to farming, while labour adopted to conservation decreases. For farmers practising SCM which are less labour intensive than farming, the effect will be the opposite, so that more land will be set aside for the adoption of SCM and less for cultivation.

5. Conclusion

The analysis yields insight for the design of supportive programmes in relation to environmental degradation and resource management. The results emphasise the need for private and governmental agencies to be cautious when they are implementing supportive programmes in favour of the agricultural sector, in less developed economies. This is especially the case for holdings where land is scarce and where soil conservation measures applied involve costs in terms of taking up productive farmed land. In particular, attention should be paid to the distribution of both land quality and the net returns from adopting soil conservation measures, before designing an effective aid regime.

Policies which aim at improving living conditions for smallholders may create disincentives in arresting soil erosion. Farming supportive programmes and off-farm supportive programmes may be beneficial only in the shorter term, since such aid may induce land managers to give less priority to the application of SCM. In the long term, the consequences may be accelerated erosion, and lower returns from cultivating land. For farming supportive programmes, such malign side-effects are most likely for farms which possess a uniform land quality. Off-farm supportive programmes will discourage smallholders from adopting SCM for those practising very labour intensive conservation measures, such as structural conservation measures. In this perspective, aid does worsen the incentives for arresting erosion. The fundamental reason for such undesired effects is that the relative costs of keeping labour in soil conservation activities increase in response to such policies.

A further implication is that improvements in erosion control techniques may not be very effective in promoting further adoption of SCM. This is true for holdings which possess land with an uneven land quality and where the net benefits from adopting SCM decrease in poorer soils. For such holdings there are relatively high costs associated with replacing farmed land by a temporary adoption of SCM.

There may be more efficient ways to promote soil conservation and at the same time achieve an improvement in the living conditions of smallholders. One alternative may be to construct support regimes which directly encourage farmers to oust farmed land and apply erosion control measures, e.g. making aid conditional on the number of land units which are actually under conservation practices. Such a policy would strengthen the economic incentives for an improved resource management. Another approach would be to introduce farming practices which yield higher net returns than those they are replacing and at the same time improve the conservation of soil. The identification of such 'win-win' strategies may be very resource-demanding, since detailed information both on farming practices, soil characteristics and climate may be needed.

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Appendix 1: Proof of $\partial N_1/\partial B > 0$

Eq. (18) may be written as

$$\frac{\partial N_1}{\partial B} = \frac{\frac{1}{B}\delta PX'(*) - \frac{1}{B}Pf'(*) + \frac{A}{B}G'(*)}{\frac{1}{B}P[f''(*) + \delta X''(*)]} \tag{A1}$$

Using Eq. (9) multiplied to A/B, Eq. (A1) equals

$$\frac{\partial N_2}{\partial B} = -\frac{G'(*)}{\frac{1}{B}P[f''(*) + \delta X''(*)]} > 0 \tag{A2}$$

Appendix 2: Proof of $\partial N_1/\partial \alpha + \partial N_2/\partial \alpha < 0$

$$\frac{\partial N_1}{\partial \alpha} + \frac{\partial N_2}{\partial \alpha} = \frac{(A-B)^2 H'(*)}{P[f''(*) + X''(*)]} < 0 \tag{A3}$$

References

Barbier, E.B., 1992. The farm-level economics of soil conservation: The uplands of Java. Land Econ., 66: 199–211.

Barrett, S., 1991. Optimal soil conservation and the reform of agricultural pricing policies. J. Dev. Econ., 36: 167–187.

Bellon, M.R. and Taylor, J.E., 1993. 'Folk' soil taxonomy and the partial adoption of new seed varieties. Econ. Dev. Cult. Change, 41: 763–786.

Blaikie, P. and Brookfield, H., 1987. Land Degradation and Society. Methuen, New York.

Constable, M., 1984. Resources for rural development in Ethiopia. Ethiopian highland reclamation study. Working Pap. 17, FAO/MoA, Rome.

Dejene, A., 1989. Environment, Famine, and Politics in Ethiopia. NORAD, Oslo.

Grepperud, S., 1993. Soil conservation and agricultural prices. Memo. No. 17, Department of Economics, University of Oslo.

Griffin, R.S. and Stoll, J.R., 1986. Evolutionary processes in soil conservation policy. Land Econ., 60: 30–39.

LaFrance, J.T., 1992. Do higher commodity prices lead to more or less soil conservation. Aust. J. Agric. Econ., 36: 57–82.

Lal, R., 1987. Effects of soil erosion on crop productivity. Crit. Rev. Plant Sci., 5: 303–307.

Lele, U. and Stone, S.W., 1989. Population pressure, the environment and agricultural intensification. Variations on the Boserup Hypothesis. MADIA Pap. 4, World Bank, Washington, DC.

Lipton, M., 1987. Limits of price policy for agriculture: Which way for the World Bank?. Pol. Dev. Rev., 5: 197–215.

McConnel, K.E., 1983. An economic model of soil conservation. Am. J. Agric. Econ., 65: 83–89.

Platteau, J.P., 1991. Traditional systems of social security and hunger insurance: Past achievements and modern challenges. In: E. Ahmad et al. (Editors), Social Security in Developing Countries. Clarendon Press, Oxford.

Southgate, D., 1990. The causes of land degradation along 'spontaneously' expanding agricultural frontiers in the Third World. Land Econ., 66: 93–101.

Southgate, D. and Pearce, D., 1987. Natural resource degradation in developing countries: A causal analysis of agricultural colonisation. Discuss. Pap. 87-26, Department of Economics, University College London.

Southgate, D. and Pearce, D., 1988. Agricultural colonization and environmental degradation in frontier developing countries. Environ. Dep. Work. Pap. No. 9, The World Bank, Washington, DC.

Timberlake, L., 1985. Africa in Crisis: The Causes, the Cures of Environmental Bankruptcy. Earthscan, London.

Westphal, E., 1975. Agricultural systems in Ethiopia. Center for Agricultural Publishing and Documentation,Wageningen.