Policy instruments for sustainable land management: the case of highland smallholders in Ethiopia

Bekele Shiferaw*, Stein T. Holden

Agricultural University of Norway, Department of Economics and Social Sciences, P.O. Box 5033, 1432 Ås, Norway

Abstract

Degradation of land continues to pose a threat to future food production potential in many developing economies. Various approaches, mainly based on command-and-control policies, have been tried (with limited success) in the past to encourage adoption of erosion-control practices by farm households. High transactions costs and negative distributional impacts on the welfare of the poor limit the usefulness of standards and taxes for soil and water conservation. One innovative approach is the use of interlinked contracts which create positive incentives for land conservation. This study analyses the social efficiency of such policies for erosion-control in the Ethiopian highlands using a non-separable farm household model. Incentive contracts linked with conservation seem to be promising approaches for sustainable resource use in poor rural economies. This may suggest that conservation programs should give greater consideration to better fine-tuning and mix of policies that help achieve both economic and environmental objectives. © 2000 Elsevier Science B.V. All rights reserved.

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1. Introduction

The problem of land degradation and loss of food production potential in poor rural economies with fast growing populations has received increasing attention in recent years (Southgate, 1988; Anderson and Thampapilai, 1990; Scherr and Yadav, 1996). Soil and water conservation (SWC) has, therefore, become an area for public intervention. Lack of knowledge about appropriate instruments, however, hinders progress in implementing SWC programs in many developing

countries. Appropriate institutions and policy instruments that efficiently internalize land degradation externalities are urgently needed in many countries suffering from deterioration of their resource base.

In a world without transaction costs, farming practices and conservation investments undertaken by individual farmers also maximize the discounted value of social net returns in land use. Thus, government intervention, on efficiency grounds, is not needed. The necessary conditions for the social efficiency of private land use require that markets are perfectly competitive and that prices of all resources relevant for the well-being of all individuals reflect their social scarcity values. However, rural economies in LDCs are often far from being competitive, and

* Corresponding author. Tel.: +47-649-8600;
fax: +47-649-48655.
E-mail address: bekele.shiferaw@ios.nlh.no (B. Shiferaw)

face pervasive impediments (high transactions costs and imperfect information) and weak enabling conditions (incomplete property rights) (Hoff et al., 1993). Covariate risk also contributes to pervasive market imperfections. The divergence between private and social paths of soil use in LDCs may be attributed to imperfect information, high transactions costs, imperfect insurance and capital markets, incomplete property rights, and misguided government policies.

The interlinkages between poverty, population growth, and environmental degradation further complicate and reinforce the potential impact of market imperfections. Smallholders may, therefore, base their land use and investment decisions on distorted signals, which may prevent the resource use pattern from emulating the socially optimal path (McConnell, 1983; Shiferaw, 1997). Soil conservation investments that would increase social efficiency may, therefore, fail to be undertaken by individual users, and excessive degradation of land may ensue, as is reported in several case studies (e.g. FAO, 1986). However, from the efficiency perspective, the existence of market imperfections per se is not a sufficient condition for government intervention into market processes. The efficient level of land conservation that equates marginal social benefits and costs of abating degradation can result in a soil erosion level either lower or higher than the natural rate of regeneration. Thus, the mere existence of the land degradation externality does not necessitate policy intervention (Kirby and Blyth, 1987). The likelihood of a policy failure (inefficient intervention) and a net social welfare loss further strengthens this point. Hence, an economic efficiency justification for augmenting the 'invisible hand' mechanism with a 'visible hand' approach requires evaluation of social costs and benefits of interventions and demonstrating a possible net gain to society from implementing proposed interventions. Intervention in soil conservation is, therefore, justified when the net social benefit of intervention is shown to be positive.

Public policy instruments for sustainable land use include regulatory, economic, and advisory approaches (OECD, 1994). The economic incentives approach, based on voluntary behavior of resource users, is likely to be more successful than a coercive or regulatory approach (Chisholm, 1987; Panayotou,

1993). The non-point nature of the soil erosion externality and the high cost of monitoring individual levels of input use, make first-best policies difficult to implement. Thus, in countries like the US, soil conservation policy emphasizes an approach based on cooperative behavior in response to positive incentives (Reichelderfer and Kramer, 1993). In LDCs, regulatory standards and user charges on degrading inputs or soil loss are even more difficult to implement due to weak regulatory capability, scarcity of information, high transactions costs, and adverse distributional impacts on poor smallholders.

The purpose of this paper is to evaluate the role of various policy instruments for soil conservation and examine the rationale for public intervention into the market mechanism. Emphasis is given to incentive contracts, like cross-compliance and cost-sharing policies, which are also expected to offer positive distributional benefits to poor farmers. Moreover, the role of output pricing policies related to the erosivity of the crops is also examined. The rest of the paper is organized as follows. Section 2 presents the conceptual framework. A review of the agricultural sector and the land degradation problem in Ethiopia is presented in Section 3. Section 4 outlines the analytical methods. Results are discussed in Section 5. We summarize in the final section highlighting implications for conservation policy.

2. Conceptual framework

2.1. The economic incentives approach to soil conservation

Once the existence of a socially excessive level of land degradation is known, governments may resort to various policy instruments for mitigating or internalizing externalities. Some policy instruments specify quantity standards on the level of emission of the externality that cannot be exceeded by generators of that externality. These types of command-and-control regulations entail inflexible limits or technological requirements and stipulate a range of penalties for non-compliance. In contrast, the economic incentives approach utilizes market-based instruments designed to modify the behavior of the generators of the exter-

nality through their effect on the prices of resource inputs used in economic activities. [1]

The economic incentives approach to soil conservation may use a range of policy instruments. Provision of secure land rights, price support and reduction of export taxes to less erosive crops, resource pricing, input taxes (subsidies), and credit subsidies are some examples (OECD, 1994). Secure land rights help extend the planning horizon of the poor and vest with the land user the benefits of investments in land improvement and conservation (Panayotou, 1993). Secure rights to land may serve as collateral and improve access to capital credit. Besides, macro-policies, like devaluation of overvalued exchange rates and interest rate adjustments, can be used. Interlinking program benefits with preferred land management practices is a useful approach particularly when the instrument itself (e.g. fertilizer subsidies) tends to substitute for resource conservation.

The effect of a general increase or decrease in commodity prices on soil and water conservation is unclear (LaFrance, 1992; Pagiola, 1996). It has been argued that depressing agricultural prices may reduce profitability of farming and discourage land-improving investments, whilst increasing commodity prices through its effect of raising farm returns may encourage cultivation of marginal lands (Southgate, 1988). It may also be argued that in the presence of a suitable land use policy and where rights to land are clearly defined, increased profitability of farming through higher prices may make conservation more attractive to the farmer. The impact of price changes on land management also depends whether the conserving input has beneficial or adverse impacts on yields (Shiferaw, 1997). Changes in relative prices, however, can have predictable impacts depending on the crops and inputs that are promoted or discouraged and the farmers' ability to respond to such price changes. A rise in the profitability of less erosive crops relative to more erosive crops can, for example, be expected to encourage soil-conserving land use and cropping patterns, and conversely (Southgate, 1988; Panayotou, 1993).

The Pigouvian approach to internalizing externalities calls for taxes on degrading inputs and subsidies on conserving inputs in proportion to the marginal external damages or benefits resulting from the use of each input (Baumol and Oates, 1988). In the first best case, this requires information on the level of use of each type of input on each land type. Thus, governments prefer taxing the use of degrading inputs or subsidizing conserving inputs. When farmers have sufficient economic incentives to adopt soil-conserving practices on profitability grounds, the best policy is not provision of subsidies, rather removal of constraints that deter adoption. When significant off-site effects of soil erosion exist, conservation subsidies may be justified although on-site effects may be minimal.

The choice of policy instruments for resource conservation may depend on environmental effectiveness, costs of contracting, monitoring and enforcement, distributional effects, conformity with other policies and political preferences. The suitability of policy instruments may, therefore, be examined in relation to the ecological, economic and institutional setting (OECD, 1994). Owing to informational inadequacies and prohibitive costs of monitoring the activities of smallholders and enforcement of standards, the regulatory approach may, for example, have limited relevance for soil conservation policy. A mix of regulatory and economic incentives approaches may, however, prove to be useful (see Section 2.2). However, interlinked contracts may be inferior to general instruments like pricing policies in cases where administrative and enforcement costs are high. When local enforcement potential is large, cross-compliance policies may also be very effective. For example, past soil conservation programs in Ethiopia used a mix of coercive and incentives approaches. Farmers were forced to keep erosion-control methods once installed through food-for-work incentives. Enforcement was possible mainly due to strong local state power since peasant associations were entrusted with overseeing compliance.

However, designing a suitable subsidy scheme presents several incentive and targeting problems (Chisholm, 1987; Lutz et al., 1994). Production subsidies for inputs with significant external effects may artificially boost profitability of activities using these inputs and encourage resource depletion and degra-

dation. Conservation subsidies may create perverse incentives to farmers to increase rates of soil erosion to qualify for subsidies or encourage planting on marginal lands made profitable through subsidies. Subsidies may also modify farmer behavior only as long as they continue to be paid. This implies that subsidies may have to be paid for maintenance as well. Therefore, a subsidy scheme should be designed carefully, and often entails a heavy strain on the economies of poor countries unless external assistance is made available.

2.2. Cross-compliance approaches

One mechanism to create economic incentives for conservation is based on interlinked compliance strategies that employ a mix of regulatory and incentives approaches based on voluntary behavior and positive economic incentives (Holden and Shanmugaratnam, 1995). Cross-compliance (interlinkage) means that conservation objectives are linked to access for a vital input (e.g. irrigation water) or access to certain farm program benefits is made contingent upon installing erosion-control practices on erodible lands.

Cross-compliance policies for resource conservation under peasant farming may offer some advantages. First, whilst direct subsidies for productive inputs may distort price signals and erode the incentive to economize scarce resources, subsidies linked to conservation can help mitigate the land degradation externality. Removal of input subsidies through adjustment programs and currency devaluation may also raise prices (e.g. fertilizer) and encourage soil mining and diminish household welfare. However, production subsidies linked to conservation can protect both the environment and the welfare of the poor. Subsidies for productive inputs linked to conservation can enable poor households to comply with conservation requirements without adverse impacts on their welfare, especially when the latter do not provide quick benefits. The increased production through such subsidies may boost national food security that may also benefit the urban poor and rural net buyers through lower prices. In food deficit countries, like Ethiopia, increased production can also contribute to self-sufficiency and reduce food imports. If improvements in efficiency, environmental quality,

and equity can be achieved, such policies represent a win-win-win strategy. Second, where asymmetric information and transactions costs lead to market failures, despite differing distributional impacts, interlinked contracts may result in more efficient outcomes than could be achieved through isolated transactions (Bose, 1993; Hoff et al., 1993). When the regulating agency lacks full information on plot-specific erosion levels, on-site and off-site effects, and profitability of conservation technologies, interlinking of different markets may be second-best institutional innovations to achieve environmental targets through effective use of scarce information.

3. Agriculture and land degradation in Ethiopia

By all accounts, agriculture is the predominant sector of the economy. The sector is primarily dependent on smallholder farming. Smallholders cultivating fragmented micro-holdings produce more than 90% of the annual agricultural output. Despite its pivotal role, the performance of the sector has remained largely unsatisfactory. Food self-sufficiency remains to be an unattained objective. Between 1979 and 1980 and 1993 and 1994 food production grew by 0.5% per year while population grew by 3%, implying a per capita food production decline of 2.5% (Zegeye and Habtewold, 1995). Another serious concern coupled with the stagnation of the sector has been the degradation of the resource base mainly due to soil erosion (FAO, 1986). The problem of degradation of the soil stock and loss of production potential is severe in the highlands that harbor 88 and 75% of the human and livestock populations, and constitute 95% of the cultivated lands. FAO (1986) estimates that 50% of the highlands are significantly eroded, of which 25% are seriously eroded, and 4% have reached a point of no return. Hence, soil erosion induced productivity decline is estimated to average 2.2% per annum from that of the 1985 level. Estimated annual rates of soil erosion on croplands at national level average 42 t/ha (Hurni, 1993). In a country with a fast growing population vulnerable to frequent famines, loss of food production potential is a concern not only for future generations but also for the present generation of Ethiopians.

The stagnation of the agricultural sector and degradation of the resource base can be attributed to several

interrelated factors: misguided policies and neglect of the sector, technological stagnation, weak institutional support, insecure land rights, high population pressure, drought, political instability, and frequent wars (Shiferaw and Holden, 1997). Consistent with the general neglect of the agricultural sector in development theory, policy support to the sector prior to 1974 was very poor. Some of the reforms that followed the 1974 revolution, like 'land to the tiller', were later liquidated by misguided policies and ardent socialist orientation. Until the late 1980s, fertilizer and output marketing remained under state control while producers were forced to supply at prices fixed below the free market level. Credit supply, input distribution, output marketing, and extension were mainly targeted towards cooperatives and state farms which jointly accounted no more than 10% of the agricultural produce. Excessive surplus extraction and discriminatory policies discouraged private smallholder production and land-improving investments.

Coupled with disabling polices, the land reform of 1975 also failed to provide impetus to boost production and enhance sustainable land use. Although the reform policy enabled many landless farmers to gain access to land, the state ownership of land and the insecurity of usufruct rights hindered consummating the reform. Land still remains under state ownership while farmers only possess use rights. Land cannot be sold nor mortgaged. Moreover, rural infrastructure is poorly developed, agricultural research is rudimentary, and profitable production and conservation technologies are largely unavailable. Information on erosion-productivity relations or control measures is scanty and unavailable to farmers. Formal credit is available only for short-term loans for fertilizer, while long-term loans for investment (e.g. in land or livestock) are lacking.

We use data from our detailed survey of 120 farm households in Ada district, East Shewa zone in 1994/1995. The production system in the area is typical of the general mixed crop-livestock system in the highlands. Average production activities are reported in Table 1. Although soil erosion is a problem mainly on erodible uplands, proposed erosion control methods are not used. Less effective traditional practices like drainage furrows, waterways, and cut-off drains are used together with crop rotations where farmers perceive the threat of soil erosion. Short-term renting

Table 1
Smallholder production activities and estimated user costs of soil erosion in Ada district

Crop production (kert)[a]			
Crops	Upland	Lowland	Total area
Teff	3.24	2.38	5.62
Wheat	0.51	0.43	0.94
Barley	0.16	–	0.16
Pulses[b]	0.77	0.97	1.74
Total	4.67	3.78	8.46
Estimated marginal user costs (Birr per ton of eroded soil)[c]			
$\rho = 0.54$	2.5	1.0	
$\rho = 0.20$	6.75	2.7	
$\rho = 0.10$	13.5	5.4	
$\rho = 0.05$	27.0	10.8	

[a] Kert is the local unit of land measurement. The average from a sample of 20 plots measured during the survey indicates that a kert is about 0.3 ha.

[b] Pulses include field peas, faba beans and lentils on uplands, and chickpeas and rough peas on lowland soils.

[c] Birr is the Ethiopian currency. In 1994, US$ 1 ≅ 6 Birr. The current rate is about 1 US$ to 8 Birr.

of land is common although such practices often lack legal basis. Limited formal credit is available for fertilizer at a rate of 12%, but informal rates may be as high as 100%.

4. Analytical methods

Farm households' land use and conservation decisions are shaped by several factors: the policy environment, institutional arrangements, population pressure, asset endowments, household characteristics, access to new technologies, biophysical conditions, and opportunities for off-farm employment (Reardon and Vosti, 1992; Shiferaw and Holden, 1998, 1999). When consumption preferences and household characteristics condition production and investment decisions, a farm household approach is needed to study land use and investment decisions of smallholders.

This study develops a non-separable farm household model based on linear programming to investigate the role of alternative policy instruments for soil

conserving land use. [2] The model identifies a production plan which maximizes annual net returns defined as current net returns less the present value of future income loss caused by land productivity decline due to soil erosion (on-site user costs) subject to various farm-level resource supply and behavioral constraints. The condensed structure of the LP model is given in Table 2. The model includes crop production activities on two land types (upland and lowland) with three levels of fertilizer use, two technological options (improved and traditional varieties), and two land management options (with and without conservation) and livestock production, sale and consumption activities. Labor use activities (leisure, on-farm, off-farm, and hiring options) were defined seasonally, and activities for crop sale and consumption were included. The constraints included limits on 'owned' and rented land, labor (including leisure), oxen power, subsistence needs, animal feed requirements, restrictions on credit, crop rotations, and cash income.

Soil erosion levels for each production activity on two land types and two management options were estimated using the modified Universal Soil Loss Equation (USLE) adapted for Ethiopian conditions (Hurni, 1985). Actual measurements were used to generate values for the slope length and slope gradient factors. The effect of soil erosion on productivity was estimated econometrically based on time series data. [3] The marginal user costs of soil (discounted perpetual productivity losses per unit of eroded soil) were assessed on levels of gross erosion from the two land types (see Table 1). The optimized value thus maximizes the returns to farming and non-farming activities less the user cost of current soil erosion. Activity budgets and resource supplies were specified for household groups with a pair of oxen, which better reflects average conditions in the area.

The cross-compliance policies analyzed include differing levels of input subsidies (for fertilizer, improved seeds, and a mix of fertilizer and improved seeds) offered only when upland cereals are grown on land treated with conservation. When the incentive contract (linked to conservation) makes production on conserved land profitable, the household uses subsidized inputs and installs conservation structures on some of the land while traditional practices and unsubsidized inputs may continue to be used on the remaining land. The cost-sharing policies considered were differing subsidies per unit of labor used for installing conservation structures (soil-stone bunds) on erodible slopes. The incentive contracts were specified at varying levels per unit of labor used in conservation activities. The cost shares were computed as a share of the total discounted cost of construction and maintenance of structures. Since soil conservation is often undertaken during the slack period (January–May), labor costs are computed using the shadow value of labor during this period.

In addition to mitigating soil erosion, conservation structures may affect the yield path positively and/or negatively. For example, conservation may improve certain soil properties (e.g. improve water holding capacity) or raise relative returns to intensification (e.g. fertilizer use). It may also take 10–20% of the productive land out of production or increase pest incidence (e.g. rats and weeds) by providing a suitable habitat within the cropland. When initial yields with conservation are lower, a long time lag may be involved until conservation provides higher yields. The net effect of these additional positive and negative influences depends on the type of technology and local biophysical conditions. Since farmers in our surveys expressed both concerns, two stylized scenarios are developed to capture the differential effects of conservation: (a) short-term yields with conservation are 20% less (Case I) and (b) short-term yields with conservation are unaffected due to conservation (Case II). Therefore, subsidies are specified for cases where conservation does not offer immediate benefits to the smallholder. However, subsidies may still be needed even if yields are initially higher but not sufficient to cover the full cost of conservation. Our focus is, however, on evaluation of policies that may be used to increase adoption of existing conservation technologies, which do not seem to provide such short-term benefits.

The model was first solved using user costs estimated based on the farmers' average real rate of discount (discrete time) of 54%. The latter was estimated

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[2] The mathematical set up of the model is available from the authors upon request. The full description of the model is given in Shiferaw (1997).

[3] The translog production function for teff (major crop) indicated a productivity decline of 45 and 20 kg per cm of soil depth lost on upland and lowland soils, respectively. At the ongoing rate of soil erosion, this amounts to 2.8 and 0.3% productivity decline per year (Shiferaw and Holden, 1999).

Table 2
An aggregated structure of the non-separable farm household model[a]

	Produce crops	Sell crops	Consume crops	Use own seed	Buy seed	Buy fertilizer/animal feed	Hire in/out land	Soil erosion	Family labor on farm	Family labor off-farm	Labor hiring	Leisure	Keep breeding stock and oxen	Sell livestock	Consume livestock	Income	Relation	RHS
Objective	+C				−C	−C	−/+C	−C		+C	−C		+/−C	+C				MAX
Land	1						−/+1										≤	B
Soil erosion	+A							−1									=	0
Income identity	+C				−C	−C	−/+C	−C		+C	−C		+/−C	+C		−1	=	F
Labor on-farm	+A								−1		−1		+A				=	0
Family labor supply									1	1	1						≤	B
Leisure demand												1				−β	≥	B
Oxen power	+A												−A				≤	0
Fertilizer	+A					−1											=	0
Seed use	+A			−A	−A												≤	0
Production	−A	+A	+A	+A													≤	0
Consumption			+A												+A	−β	≥	B
Cash income		+A												+A			≥	B
Credit constraint						+A				+A							≤	B
Rotations	+/−1																≤	0
Crop residue	−A					−1							+A				≥	0

[a] The C, A, B, F and β's, respectively, represent, sets of objective function coefficients, input-output coefficients, available resource supplies or requirements, farm fixed costs, and the marginal propensity to consume estimated from a system of Engel equations. Allocation of labor and oxen power was specified over seven periods in a year.

based on hypothetical questions to elicit the present value equivalent of a future income stream. For alternative policies, the model thus determines the level of soil erosion and conservation investments endogenously using the farmers' estimated rate of discount, thereby enabling comparative efficiency analysis of the instruments for sustainable land management. This was done by computing the net present value of soil productivity loss prevented over the lifetime of conservation practices when the economic incentive is provided less the flow of any real social costs of conservation as given in Eq. (1).

$$\sum_{t=1}^{T} \Big(\lambda(E_t^i - E_t^{wi}) - [\theta(1-\gamma)(I_t + M_t) + S_t + A_t] \Big)(1+\rho)^{-t+1} \quad (1)$$

Where, E_t^i and E_t^{wi} are, respectively, soil erosion levels with and without the incentive contract, I_t is the labor requirement for installing conservation structures (hence $I_{t>1}=0$), M_t is the annual labor requirement for maintenance of structures ($M_{t=1}=0$), S_t is the cost of the subsidy in year t, A_t is annual administrative costs (assumed 10% of the subsidy cost), λ is the marginal user cost of soil erosion with the social rate of discount, θ is the shadow value of family labor, γ is the cost-share covered by the incentive contract (for the cost-sharing policy only), and ρ is the social rate of discount. The payment required in subsequent years ($S_{t>1}$) to create an incentive for the farmer to maintain structures once built through the starting economic incentive ($S_{t=1}$) was estimated by computing the income level that would equalize the flow of net benefits with conservation to that without conservation as given by:

$$S_t = \pi_t^c - \pi_t^{nc} \quad \text{for all } t > 1 \quad (2)$$

Where π_t^c and π_t^{nc} are farm profits with and without conservation, respectively. This was estimated for the major cereal (teff) grown in the area as:

$$S_t = p_t[f_t^c(x_{it}^c) - f_t^{nc}(x_{it}^{nc})] - \sum_{i=1}^{n} e_{it}(x_{it}^c - x_{it}^{nc}) \quad \text{for all } t > 1 \quad (3)$$

Where $f^c(\cdot)$ and $f^{nc}(\cdot)$ are the per hectare production functions under the two regimes, x_{it} is the use

of input i, p_t is the output price, and e_{it} the input price. The difference in the cost of production between the two land management systems is mainly the cost of conservation. Since subsistence-constrained households often face problems in deferring current consumption (Holden et al., 1998), the incentive contract is needed until the discounted net benefits of switching onto the soil-conserving practice are positive ($\pi_t^c > \pi_t^{nc}$). When conservation reduces yields by 20%, it takes up to 11 years until net benefits of conservation are positive. If all the subsidy needed from Year 2 is paid in that year, the discounted value of the subsidy (at $r=0.54$) is estimated at Birr 430 ha^{-1} of conserved land. The benefit-cost evaluation was done at differing social rates of discount ($\rho=0.05, 0.1, 0.2$) for $T=15$ years. The policy instrument is considered to improve social welfare when Eq. (1) is positive or the benefit-cost ratio is sufficiently greater than one. Finally, the effect of changing the relative prices of erosive and non-erosive crops on land use and conservation decisions was examined through a 20% decrease (increase) of the price of an erosive crop (teff) or less erosive crops (pulses), respectively.

5. Results and discussion

5.1. Effect of cross-compliance policies

The effect of cross-compliance policies for fertilizer and improved seed inputs on land use and conservation investments is presented in Table 3. When conservation reduces immediate benefits by 20%, no conservation of erodible lands occurs until about 50% of the (1993/1994) price of fertilizer is covered through the subsidy. Even at 50% subsidy, only some 20% of upland cereals (17% of the uplands) are grown on conserved land. The increase in the level of the subsidy to 75 and 90%, respectively, raises adoption of conservation to 45 and 62% of the upland area.[4] The benefit-cost ratios (BCR) for 50–90% fertilizer subsidies show that, considering the on-site effects of soil erosion alone over the 15-year period, the

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[4] The corresponding ratio of the upland area conserved is different from the cereal area conserved since fertilizer is only used for cereals (teff, wheat, and barley) and at present local improved varieties of pulses are unavailable.

Table 3
Efficiency of fertilizer and improved seed contracts linked to conservation

	Conservation 20% less productive					Conservation equally productive					
	Fertilizer subsidy (%)			Seed subsidy (%)		Fertilizer subsidy (%)			Seed subsidy (%)		
	50	75	90	90	100	10	25	50	10	25	50
Net income (Birr)	4408	4590	4718	5278	5289	4432	4598	4937	5285	5309	5436
Area conserved (kert)	0.80	2.15	2.91	0.53	0.55	0.96	3.89	4.07	0.57	1.76	3.33
Upland conserved (%)	16.5	45	62	11.6	11.9	19.5	84	85.8	11.9	38.8	66.0
Upland cereal area Conserved (%)	20.0	52.8	71.6	13.3	13.7	23.6	100	100	14.4	49.9	79.0
Soil loss (t/ha)	33.8	29.3	25.7	36.4	36.2	31.5	20.9	19.8	35.4	29.4	25.5
Total damage prevented[a] (Birr)	172	583	914	211	227	382	1352	1460	177	726	1085
Cost of the subsidy	130	449	622	90	95	7	77	196.1	3	23	81
Own installation and maintenance costs	92	246	332	61	63	182	743	776	110	336	635
Conservation costs	235	741	1017	160	167	190	828	991	113	361	724
Average costs	293	343	350	299	304	199	212	243	196	205	217
Benefit/cost[b]											
$\rho=0.05$	1.77	1.92	2.19	3.19	3.28	4.36	3.58	3.30	3.41	4.39	3.30
$\rho=0.1$	0.73	0.79	0.90	1.32	1.36	2.01	1.63	1.47	1.57	2.01	1.50
$\rho=0.2$	0.27	0.29	0.33	0.49	0.50	0.86	0.69	0.60	0.68	0.86	0.63

[a] The present value of annual yield losses prevented due to the policy instrument over the life time of conservation structures (15 years) discounted over perpetuity. For estimated marginal user costs under different rates of discount see Table 1.

[b] Total damages prevented/cost of conservation. The reported benefits and costs are only for $\rho=0.1$. For $\rho \neq 0.1$, only the final results are reported.

instrument will not increase net social benefits unless the social rate of discount is close to 5%. At the rate of discount of $\rho \geq 0.1$, the policy instrument is also unlikely to be socially profitable, even if one assumes that structures may form terraces and have a longer lifetime. Only an increase in the user costs of soil or a lowering of the social rate of discount could make the instrument a Pareto improvement. Since switching into a conserving practice lowers immediate income, it requires more than 90% subsidy before the instrument could have a significant impact on land use and investment behavior. The soil loss declines progressively from 35.6 t/ha without the subsidy to 25.7 t/ha with 90% subsidy, respectively. Since the linked fertilizer subsidy relaxes the credit constraint, the returns to the policy instrument increase with the level of the subsidy. But, more conservation also brings higher subsidy costs from the second year and hence makes social profitability difficult to attain.

When short-term yields are 20% less with conservation, an improved seed (30% higher yielding compared to traditional cultivars) subsidy for cereals is, however,

socially profitable even at $\rho=0.1$ (Table 3). When technical change allows a 30% increase in yields, a shift onto the soil-conserving practice still allows a 10% increase in yields over traditional cultivars thereby allowing adoption of conservation practices without severe impacts on meeting subsistence needs. Moreover, compared to the fertilizer subsidy, the seed subsidy has a lower average cost per area conserved. Thus, although it requires up to 90% subsidy to induce some conservation, at $\rho \leq 0.1$, both 90 and 100% seed subsides are socially efficient. In this case, a subsidy for improved seeds linked with conservation that sufficiently counteracts the yield-depressing effects of structures and induces conservation at lower cost is likely to be socially more attractive than a high cost fertilizer subsidy. However, even with the 100% seed subsidy, the level of conservation achieved in the short-term is very low. Soil loss only decreased from 38.7 t/ha without the seed subsidy to 36.2 t/ha with the 100% subsidy.

When yields are unchanged due to conservation, even a 10% fertilizer subsidy enables 24% of upland

cereals to be grown with conservation. An increase in the level of the fertilizer subsidy to 25%, brings all the upland cereals (84% of the upland area) into conservation farming. A further increase in the level of the fertilizer subsidy to 50% encourages slightly more conservation and cropping of cereals on uplands (86% conserved). Further increase in the level of the subsidy does not spur much conservation as land hiring and rotational constraints begin to be binding. Besides, the higher demand for conservation labor and the parallel increase in opportunity cost of labor as the level of the subsidy increases, reduce the marginal conservation effect of the policy instrument. However, the 10–50% fertilizer subsidies are socially efficient at $\rho = 0.1$. Soil erosion progressively declined from 35.6 t/ha without the economic incentive to 20 t/ha with the 50% fertilizer subsidy.

With a yield-neutral conservation, the improved seed subsidy will also have a comparable level of social efficiency as the fertilizer subsidy. Again this is related to the lower cost of the seed subsidy per unit of land conserved. A policy that plans to transform all cereals on uplands to conservation farming is also socially efficient at $\rho \leq 0.1$. However, the net benefits increase initially, reach a maximum between 10 and 50% levels, and start to fall thereafter. Like the fertilizer subsidy, the fall in BCR is related to the effect of cropping patterns on resulting levels of erosion, and a rise in the opportunity cost of labor in farming with the increase in the subsidy. This is observed in the form of a larger decrease in the soil erosion level from 10 to 25% subsidy compared to higher levels of the subsidy. This implies that although the area under conservation increases with the subsidy, after some level, the marginal change in soil erosion falls as erosive crops come to be grown on treated land. The policy instrument decreased soil erosion successively from 37.3 t/ha without the policy to 22.2 t/ha with the 75% seed subsidy.

The effect of a mix of fertilizer and seed subsidies is presented in Table 4. For the case of yield-decreasing conservation, a 50% seed subsidy was combined with differing levels of fertilizer subsidies. Although the 50% seed subsidy alone brought no conservation, mixing it with a fertilizer subsidy of 25, 50 and 75%, respectively, raised the upland cereal area conserved to 13.5, 99 and 100%. The first two combinations are efficient at $\rho \leq 0.1$, but the 50–50 scheme was only

marginally so. If soil conservation is a preferred social goal, a policy that enables growing of upland cereals with conservation, is socially efficient at $\rho \leq 0.1$. The rise in the profitability of farming following the increase in the subsidy raises the opportunity cost of labor used for conservation. This, coupled with growing of erosive crops on conserved land introduces decreasing returns to the subsidy. The policy instrument progressively reduced soil erosion from 38.7 t/ha without the instrument to 21 t/ha with the 50–75 seed-fertilizer subsidy.

For the case of yield-neutral conservation, a 10% fertilizer subsidy was combined with differing levels of seed subsidies. Table 3 shows that a 10% improved seed subsidy led to the adoption of conservation technology on 12% of uplands. Adding a 10% fertilizer subsidy raises adoption to about 14% of the upland area operated. Similarly, adding a 10% fertilizer subsidy over the 25 and 50% seed subsidy raises adoption, respectively, from 39 and 66% to 67 and 80% of the cultivated upland area. Thus, a 50% seed subsidy is almost equivalent to a mix of a 10% fertilizer subsidy with 25% seed subsidy. This implies that, depending on the availability of the economic incentive and the budget constraint, the fertilizer and seed contracts can be combined in different proportions without a loss in their efficiency. At $\rho \leq 0.1$, the mix of seed and fertilizer subsidies is also socially efficient. Conservation can be extended to 80% of the uplands without loss of efficiency. The BCR of the instrument seems to be increasing first and decreasing later mainly due to the differences in the erosivity of cereals and a rise in the shadow value of labor. The instrument seems to achieve highest efficiency between the 10–10 and 50–10 mix of seed-fertilizer subsidies. The incentive system reduced soil erosion successively from 37.3 t/ha without the subsidies to 23 t/ha at the 50–10 seed-fertilizer subsidy.

5.2. Effect of cost-sharing (labor subsidies)

Analytical results for the cost-sharing contract are also given in Table 4. When conservation is yield-depressing, none of the uplands would be conserved if the initial payment is less than 4 Birr/laborday (B/L). This amounts to 120% of the total discounted cost of construction and maintenance of structures.

Table 4
Efficiency of cost-sharing and a mix of improved seed and fertilizer contracts linked to conservation

	Conservation 20% less productive (I)						Conservation equally productive (II)					
	Seed and fertilizer subsidy (%)			Labor subsidy (Birr/manday)			Seed and fertilizer subsidy (%)			Labor subsidy (Birr/ manday)		
	50–25	50–50	50–75	4	7	9	10–10	25–10	50–10	1	2	3
Net income (Birr)	5274	5350	5645	5253	5285	5338	5306	5382	5557	5260	5277	5356
Area conserved (kert)	0.54	4.11	4.34	0.28	0.84	1.47	0.63	3.34	4.11	0.58	2.64	4.58
% upland conserved	11.7	84.3	86.7	6	17.2	30.3	13.7	66.6	80.4	12.7	57.7	100
Upland cereal area conserved (%)	13.5	99.2	100	6.9	20.7	36.2	17.1	79.2	100	14.7	69.7	113
Soil loss (t/ha)	37.2	21.7	21.1	37	35	32.5	35.3	25.3	23	35.2	24.7	18.2
Total damages prevented (Birr)	206	1570	1614	82	296	565	181	1103	1316	249	1211	1814
Cost of subsidy	91	717	948	75	315	660	8	70	138	21	191	497
Own installation and maintenance costs	103	783	827	0	0	0	145	763	940	90	312	375
Conservation costs	204	1572	1870	83	346	726	154	837	1091	113	522	922
Average costs	376	382	430	295	414	494	243	251	266	194	198	235
Benefit/costs												
$\rho=0.05$	2.39	2.35	2.06	2.57	2.23	2.03	2.55	2.88	2.66	4.77	5.03	4.28
$\rho=0.1$	1.01	1.00	0.86	0.99	0.86	0.78	1.17	1.32	1.21	2.21	2.32	1.97
$\rho=0.2$	0.38	0.38	0.32	0.33	0.29	0.26	0.50	0.56	0.50	0.95	1.00	0.84

Thus, the cost-sharing policy fails to induce conservation unless the contract covers more than the entire investment cost. This is because investing labor in conservation becomes unprofitable unless the incentive payment is large enough to compensate for the lower initial yields. Increase in the labor subsidy to 7 and 9 B/L raised adoption of the soil-conserving technology to 17 and 30% of the upland area, respectively. Soil erosion decreased progressively from 38 t/ha without the contract to 32 t/ha with 9 B/L (280% incentive payments). Although the area conserved increases with the incentive payment, the scheme is inefficient and efficiency falls as the public 'cost-sharing' increases.

However, with a yield-neutral conservation, even a 1 B/L subsidy (20% cost-sharing) could propel some conservation. Raising the labor subsidy to 3 B/L (60% cost-sharing) brings all uplands under conservation farming. Under the current situation where improved seeds are unavailable for all upland crops and fertilizer is used only on a few crops, the cost-sharing (labor subsidy) policy may, therefore, be an effective means of achieving a wider adoption of conservation structures. All levels of the labor subsidy are efficient at $\rho \leq 0.1$. Soil erosion declined successively from 38 t/ha without the subsidy to about 18 t/ha with a 60%

cost-sharing. The most efficient level of cost-sharing seems to be reached between 20 and 60%.

5.3. Effect of pricing policies

5.3.1. Taxing the price of an erosive crop (teff)

The incentive effect of depressing the price of an erosive but a major cash and staple crop (teff) by 20%, relative to other crops, is given in Table 5. In response to the relative price change, smallholders adjust their land use and cropping patterns. The area under teff is more than halved while the area under wheat is more than doubled, and the area of pulses increases by about 60%. Household income falls by up to 12% as a result. When the farmer begins to incorporate the user costs of current soil erosion into decision-making, teff ceases to be grown on erodible lands. Even when user costs are unaccounted for (in the basic model), soil loss decreases by 12% (5 t/ha) although bunds have not been installed on the uplands. Similarly, soil erosion decreases by 16% without adoption of bunds when user costs are accounted at high rates of discount ($r=0.54$). As more weight is given to future productivity loss, reduction in teff area alone is insufficient to mitigate erosion and adoption of conservation structures becomes necessary.

Table 5
Effect of a 20% tax on the price of an erosive crop (teff) on resource use and conservation decisions (% of the before price change)

Issues considered	Basic model (without user costs)	User costs accounted ($r=0.54$)	User costs accounted ($r=0.1$)		User costs accounted ($r=0.05$)	
	I and II[a]	I and II	I	II	I	II
Net income	89.2	89.1	88.7	88.3	88	88.3
Teff (kert)	53.3	42.9	44.2	43.6	68.4	53.7
Wheat	266.9	291.0	254.6	265.2	153.5	221.5
Barley	45.0	43.2	60.1	59.6	85.0	60.6
Pulses	167.9	176.7	203.4	77.5	128.1	153.8
Teff area upland	26.9	0.0	0.0	0.0	0.0	0.0
% upland conserved	0.0 (0)	0.0 (0)	0.0 (0)	86.7 (39)	56.4 (22)	100.0 (100)
Soil loss (t/ha)	88.5 (33.7)	84.1 (31.8)	87.8 (31.6)	96.5 (25.4)	104.1 (28)	87.7 (15.7)
Family labor supply (mandays)	103	103	100	114	93	110
Labor off- farm	150	144	139	98	191	107
Leisure	83	83	81	81	77	80
Hired labor	76	64	75	39	0.0	64
Teff marketed surplus	19	0.0	0.0	0.0	47	23
Wheat marketed surplus	501	513	373	406	174	305

[a] The scenarios analyzed are: I=Short-term yields with conservation are 20% less than conventional farming, II=Short-term yields with conservation are equal to conventional farming, and r=the household's real rate of discount used in computing the user costs. Values given in parentheses refer to actual values after the price change.

Table 6
Effect of a 20% price support for less erosive crops (pulses) on resource use and conservation decisions (% of the before price change)[a]

Issues considered	Basic model (without user costs)	User costs accounted (r=0.54)	User costs accounted (r=0.1)		User costs accounted (r=0.0.05)	
	I and II	I and II	I	II	I	II
Net income (Birr)	102.1	102.2	101.7	101.6	102.0	101.7
Teff (kert)	92.6	92.7	100.1	98.9	97.6	100.4
Wheat	133.1	131.9	98.7	103.5	105.0	98.7
Barley	77.5	74.9	102.0	99.0	95.0	100.0
Pulses	113.2	119.5	100.2	109.0	100.5	100.6
Teff area upland	88.4	88.3	107.2	105.0	88.8	101.1
% upland conserved	0.0 (0)	0.00 (0)	0.00 (0)	119 (53)	94.9 (37)	100.0 (100)
Soil loss (t/ha)	98.2 (37.4)	98.6 (37.4)	100.6 (36.2)	95.4 (25)	99.3 (26.7)	100.6 (18)
Family labor supply (mandays)	98	98	98	98	98	98
Labor off- farm	93	93	99	100	98	100
Leisure	103	103	103	103	103	102
Hired labor	105	105	114	126	106	101
Teff marketed surplus	81	84	98	95	94	100
Wheat marketed surplus	175	164	97	105	106	97

[a] For additional descriptions, see the note under Table 5.

However, the change in cropping patterns resulting from the price policy allows sizable reductions in soil erosion without much soil conservation effort.

The fall in income reduced the consumption of leisure and teff by up to 23 and 14%, respectively. Since wheat is not a substitute for teff and due to the fall in income, the consumption of wheat also decreases by up to 10%. The price policy also prompts households to be only self-sufficient in teff. Thus, wheat largely substitutes for the decline in the marketed output of teff. Although this partial analysis does not reveal the general equilibrium effects, the policy is likely to have substantial impacts on the marketing of teff and wheat. The decrease in marketed surplus of teff may have an eventual effect of driving up teff prices. The increased supply of wheat may also depress its own price. In our model, prices are exogenous and such second-round effects cannot be traced. Future research should investigate such effects in a multi-market or general equilibrium framework.

5.3.2. Supporting the price of less-erosive crops (pulses)

Table 6 presents, the incentive effect of supporting the relative price of less-erosive crops (horse beans, field peas, lentils, chick peas, and rough peas) by 20%. Pulses together account for about 20% of the cropped area. Despite the very low yields, farmers do not use

fertilizer on these crops. Pulses are often used for replenishing soil nutrients and they precede cereals in the rotation cycle. They are also mainly produced for own consumption. Thus, the responsiveness to the prices of these crops is likely to be limited. The results also indicate that, unlike the case of the teff price-tax policy, the relative increase in the profitability of pulses does not decrease the area under teff to bring a significant reduction in soil erosion. Teff planted on erodible slopes did not also show a significant decline. The area under wheat also remains about half of that under an equivalent tax on the price of teff. The pulse area also increased only marginally or remained the same. As a result, the desired effect of the price policy to stimulate soil-conserving land use and cropping pattern did not succeed. Hence, the soil erosion level remained comparable to that before the price change. Since household income showed only a slight increase, the effect on consumption was limited. Marketed surplus of teff declined by up to 20% in the basic model, but this effect disappears when user costs are considered. The overall outcome of the pulse price-support policy does not differ much from the case without the policy. The low relative prices of pulses and their low current yields limit the effectiveness of the policy.[5]

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[5] The 1993/1994 average yields (kg/kert) of teff and pulses were 280 and 200, while average prices (Birr/kg) were 2.38 and 1.60, respectively.

Under the current low productivity of pulses, a much larger pulse price support is required before significant changes in cropping patterns occur to have any notable effect on soil erosion. Thus, the pulse price-support policy did not bring a comparable change in household behavior as the teff price-tax policy.

6. Summary and policy implications

The problem of land degradation and productivity decline in countries with fast growing populations that are also suffering from poverty and malnutrition is becoming an important area for government intervention. From the viewpoint of economic efficiency alone, the mere existence of land degradation does not, however, necessitate public intervention. An economic rationale for public intervention prevails when market failures leading to socially excessive land degradation exist. Market failures, when they exist, may affect market signals and encourage socially sub-optimal land use and investment patterns. This study analyzes some policy instruments to mitigate the soil erosion externality using empirical data from Ethiopia.

Table 7
The effect of cross-compliance policies (incentive contracts linked to conservation) on soil conservation decisions as compared to subsidies unlinked to conservation

Subsidies (%)	Unlinked subsidy		Linked subsidy	
	Upland conserved (%)	Soil loss (t/ha)	Upland conserved (%)	Soil loss (t/ha)
Fertilizer subsidy I[a]				
0	0.0	35.6	0.0	35.6
25	0.0	39.4	0.0	35.6
50	0.0	37.9	16.6	33.8
75	0.0	38.0	45.0	29.3
90	0.0	37.2	62.0	25.7
Fertilizer subsidy II[b]				
0	0.0	35.6	0.0	35.6
10	0.0	38.7	19.5	31.5
25	0.0	39.3	84.0	20.9
50	0.0	38.0	85.8	19.8
Seed subsidy I				
0	0.0	38.7	0.0	38.7
90	0.0	41.5	11.6	36.4
100	0.0	41.5	11.9	36.2
Seed subsidy II				
0	6.5	37.3	6.5	37.3
10	5.5	36.6	11.9	35.4
25	3.4	36.6	38.8	29.4
50	0.0	39.5	66.0	25.5
75	0.0	42.4	83.8	22.2
Seed-fertilizer subsidy I				
50–25	0.0	39.6	11.7	36.5
50–50	0.0	36.0	84.3	21.7
50–75	0.0	36.1	86.7	21.1
Seed-fertilizer subsidy II				
10–10	2.8	36.7	13.7	35.3
25–10	0.5	37.4	66.6	25.3
50–10	0.0	42.5	80.4	23.0

[a] I=Short-term yields with conservation are 20% less than conventional farming.
[b] II=Short-term yields with conservation are equal to conventional farming.

The results show that policies that link production subsidies with soil conservation can provide opportunities for countering erosion-induced productivity declines without adverse impacts on marketed surplus of food and the welfare of the poor. Such policies may, therefore, represent improvements in efficiency, equity, and environmental quality. However, if conservation technologies significantly reduce short-term household income, fertilizer subsidies linked to conservation failed to be efficient unless the social rate of discount is less than 10%. Seed subsidies and a mix of seed and fertilizer subsidies were, however, more efficient since they enable sizable reductions in erosion damage at low cost. If the social rate of discount is as high as 20%, such economic incentives also become socially inefficient. When conservation leaves short-term benefits unchanged, cross-compliance policies for fertilizer, and a mix of seed and fertilizer subsidies linked with conservation were able to create sufficient incentives for sustainable land management and reduce erosion-induced productivity loss efficiently. The social returns to these policies, however, disappear as the rate of discount rises above 10%. Compared to unlinked subsidies, the cross-compliance approach was more effective to counter the soil erosion externality. When unlinked input subsidies are provided, the enhanced profitability of farming discourages the need to conserve the soil stock and thus conservation disappears as the subsidy increases (see Table 7).

Furthermore, at low rates of discount, the cost-sharing (labor subsidy) policy was not efficient when conservation decreases short-term yields. The cost-sharing policy was, however, more efficient when conservation is yield-neutral in the short-term. This indicates that utilizing household labor through incentive contracts, like food-for-work programs, may be an effective approach for soil conservation. This approach, also widely used in conservation programs, is likely to be effective when used to subsidize the smallholder until conservation provides positive net benefits over traditional land use. Such contracts may, however, be very costly unless they are made available through external assistance.

The efficiency of the policy instruments depends on the user cost of soil erosion, the social rate of discount, and the lifetime and productivity effects of conservation structures. An increase in the user cost, a decrease in the rate of discount, and an increase in the life of structures improve the efficiency of the policy instrument. The user costs depend on the productivity impact of soil erosion, output prices, and the social rate of discount. A decrease in soil depth and technical change raise the productivity impact of soil erosion. Increase in prices and a decrease in the discount rates also raise the user costs. Moreover, taxing the most erosive crop (teff) is more effective in abating soil erosion than supporting the prices of less erosive crops (pulses). The limited success of the latter approach was mainly due to low initial prices and low productivity of pulses. Areas for future research include empirical estimation of transaction costs associated with various policy instruments and how such costs may influence policy recommendations, exploring alternative institutional arrangements that may help reduce transactions costs, investigating how poverty may influence farmers' responsiveness to incentive contracts, and careful estimation of the user costs by land type and land use, preferably using a dynamic bio-economic household model.

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