Reviews

A Review of the Socio-Economic Analysis of Soil Degradation Problems for Developed and Developing Countries

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In this paper, the main socio-economic concepts and their applications in the study of soil degradation are reviewed under three broad headings: soil conservation as an input in agricultural production; topsoil as a natural resource somewhere between being renewable and nonrenewable; and the effects of dealing with common property resources. The treatment of soil conservation as an input has involved the demonstration of damage functions and a study of factors influencing the adoption of soil conservation. The study of renewability, or the lack of it, has involved the application of the concept of user costs, whilst the consideration of common property resources has concentrated on the need to minimise the divergences between social and private values. The literature is dominated by work on developed countries and also reveals the research on decision frameworks to be compartmentalised in terms of the three concepts.

1. Introduction

Socio-economic analyses of issues concerning soil degradation and conservation date back at least to the 1930s (Schickele 1935, Ciriacy-Wantrup 1938, Bunce 1942). The widespread interest in soil conservation in the United States of America (U.S.) in the 1930s (the 'Dust Bowl' era) stemmed from the intensification of agricultural production with technologies and land-use practices that subsequently were recognized as less than wise. Although many of the concepts developed in the 1930s are relevant and still used, their scope has now been broadened. For example, the basic effect of soil loss, namely reduced output, was and still is explained within the framework of production theory. Nevertheless, this framework has now been expanded to include broader public interest in environmental issues (Dickason and Piper 1983).

In this paper, the main socio-economic concepts that have been developed and applied in the context of soil degradation are reviewed. These concepts can be grouped conveniently into three broad categories. These are:

(a) the treatment of soil conservation as an input in agricultural production;

(b) the definition of topsoil as one that borders between a nonrenewable and a renewable resource; and

(c) the consideration of soil degradation and its effects within the frameworks of common property resources.

The paper is divided into four sections. The concepts and their applications are presented in the first three sections. Some implications of the review are considered in the final section.

2. Soil Conservation - An Input in Agricultural Production

The recognition of soil conservation as an input in production, leads to two further sets of concepts, namely those dealing with (a) the effect of soil con-

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Review coordinated by John Brennan.

servation on output and income; and (b) the factors influencing the adoption of soil conservation, such as technology, management practices including the use of fertilizers, education, and policy incentives.

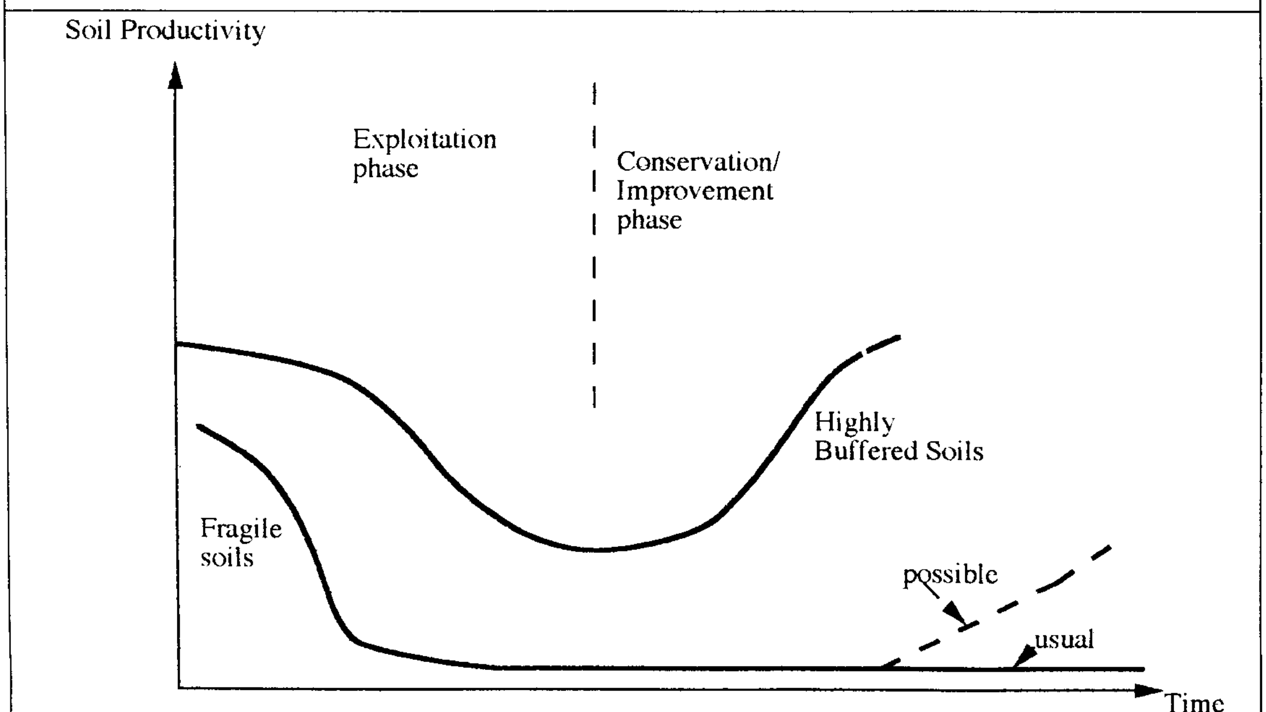
The relationship between the effect of soil conservation on output and the factors influencing the adoption of soil conservation is complex. The effect of soil conservation on output and income overtly influences the adoption of soil conservation measures. Yet, there is a distinction between these sets of concepts. The effect on output can be regarded as one that induces movement along a given demand or supply function pertaining to soil conservation. Alternatively, the factors influencing the adoption of soil conservation can be conveniently regarded as those that induce shifts in the demand or supply functions. The difficulty is in distinguishing between demand and supply, because of the absence of a clearly defined market for soil conservation. This is due to the fact that the very same firm (i.e., farm) that demands soil conservation usually has to provide it as well. The literature thus skirts the issue of supply and demand for soil conservation, and generally deals with the factors that influence the adoption of conservation measures.

The Effect of Soil Conservation on Output and Income

Perhaps the greatest concerted effort to assess the effects of soil conservation on productivity have been made in the U.S. Several of these studies have been reviewed instructively by Crosson with Stout (1983) and commented on by Frye (1987). Evidence from the rest of the world, especially the developing countries, has been sparse and usually more recent. Findings to the early 1980s have been well summarized by El-Swaify, Dangler and Armstrong (1982, pp. 60-9) and reviewed by Sfeir-Younis (1985). Given this extensive documentation of the effects of erosion, attention here is concentrated on the more constructive issue of the effects of soil conservation.

First, however, the point should be made that not all soils are 'created equal'. This idea is illustrated

Figure 1: Contrasting Profiles of Soil Productivity Over Time



in Figure 1 which contrasts the temporal experience of fragile soils typical of many tropical areas and robust soils that are more typical of temperate regions (Anderson and Thampapillai 1990). Many soils are so inherently poor that a soil improvement program is a necessary prelude to any work on improving crop yields or even of considering sustainability of production. Such considerations should be kept in mind throughout this review because the world literature on soil erosion and conservation is dominated by work on the relatively well buffered soils of North America.

To enter this North American literature, Walker (1982), Walker and Young (1986) and van Vuuren (1986) have introduced a simple production function where depth of topsoil is regarded as a surrogate for soil conservation. This is illustrated in Figure 2. If soil conservation practices are adopted to maintain soil depth at levels above OS, output will be sustained at Y. Conversely, soil loss on land with topsoil depth greater than OS will not affect the optimality of output. Productivity losses occur when land degradation results in topsoil depths below OS. Walker (1982) provided an empirical illustration of such a function for the Palouse area of the U.S. states of Washington and Idaho. The function is labelled a damage function, since it reveals the loss in output as depth of topsoil decreases. It is derived from a nonlinear regression analysis utilising time series data on crop yields and soil losses gathered by the United States Department of Agriculture. Sinden and Yapp (1987) demonstrated a similar function for New South Wales and estimated the value of annual output losses due to soil erosion to be about $A50m. An extension of this relationship to include more variables, including soil loss, size of property and percentage of arable land, is illustrated by Sinden and King (1988).

A major effect of land degradation is sustained yield reductions that are translated into income losses. These reductions develop over time, and following Bunce (1942), Walker (1982) and Walker and Young (1986) have introduced time

Figure 2: Soil Depth and Yield - An Implicit Damage Function

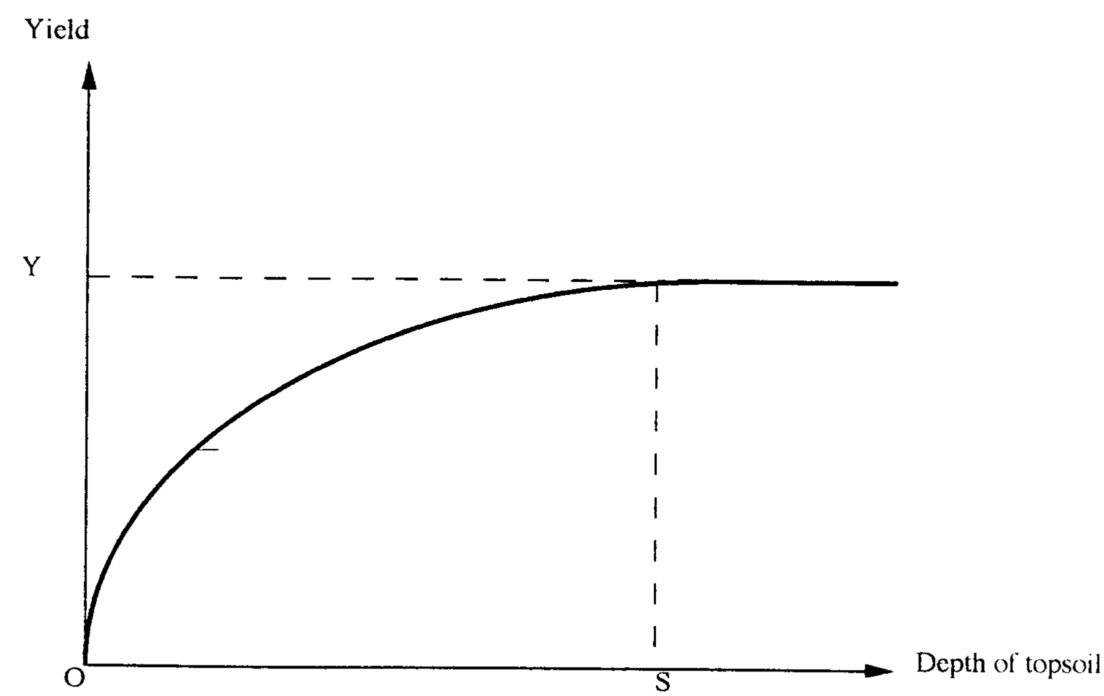
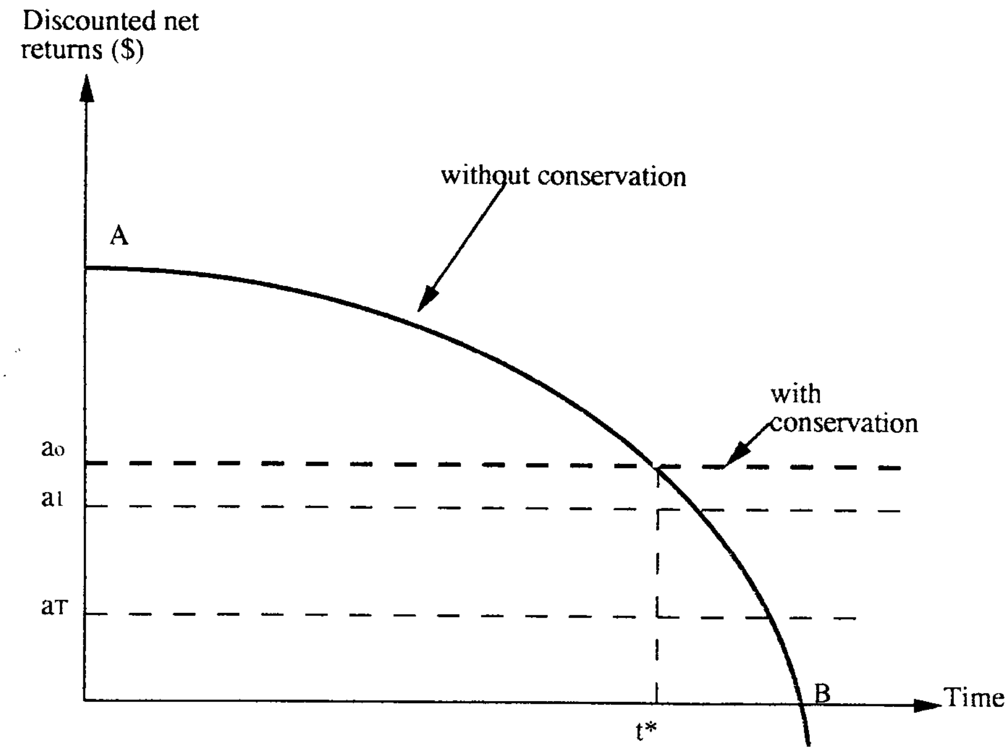


Figure 3: Net Returns With and Without Conservation Over Time



explicitly into the analysis. Bunce's treatment can be illustrated in Figure 3, where returns without soil conservation decline over time, while net returns with conservation are assumed to be constant at $\$a_0$. Further, the maintenance of net revenue at $\$a_0$ implies that soil conservation practices are carried out to maintain soil depth at levels above OS (Figure 2). The introduction of time in Figure 3 illustrates that net returns without conservation are higher than net returns with conservation until time t^*. This implies that farmers may not have a strong incentive to conserve their soils until after t^*. Walker (1982), however, showed that, for areas with relatively shallow top soils (say, a depth of 30 cm or less), conservation practices should be initiated almost immediately.

Walker (1982), following Seitz *et al.* (1979), described how soil loss is also influenced by some tillage practices. But while the use of a production (or damage) function is explicit in Walker's (1982) study, it is only implicit in others. For example, Seitz *et al.* (1979) illustrated the losses due to soil erosion within a framework of mathematical programming. A production function is implicit because the technical coefficients of the programming model are based on perceived relationships between soil loss by using two sets of models - one where no restrictions are placed on soil loss and another where soil loss is restricted to specified levels. The restrictions are based on the adoption of a package of conservation practices. The difference in the value of the optimized objective functions of the two models (with restriction minus without), is an indicator of the loss in income from failure to conserve soil in the specified manner. However, since the relationship between soil depth and productivity is not explicit, these models are likely to understate the extent of income losses from not adopting soil conservation measures. For example, the study by Seitz *et al.* revealed that net benefits without conservation would exceed those with conservation for at least 40 to 60 years, depending on the rate of discount used.

Analogous implicit use of production functions in the analysis of soil conservation decisions has been popular with agricultural economists (for example, Wade and Heady 1977, Osteen and Seitz 1978, Burt 1981, Kramer, McSweeney and Stavros 1983, McSweeney and Kramer 1986b). Although such analysts employ the concept of soil conservation as an input to production, the dominant concept that they adopt belongs more to one of the other categories mentioned above, and hence these studies are considered here under other headings.

Regardless of whether or not a production function is incorporated explicitly, all the published studies involving the use of production functions appear to be confined to developed countries, and display the following two characteristics:

(a) The annual rates of soil loss for lands of different types and different use are estimated from detailed survey data, the application of the universal soil loss equation (USLE) (Wischmeier and Smith 1978) or both. The application of the USLE involves the estimation of specific parameters that define the physical properties of the soil and the environment. To use it in contexts outside of the U.S. requires considerable faith that may well not be justified (if the Australian experience can be generalised, Edwards and Charman 1980) or be cost effective, given the information costs involved in application (Chisholm and Dumsday 1987).

(b) The added expenses due to soil conservation practices are incorporated into well defined farm budgets enabling the estimation of the changes in net income following the adoption of soil conservation (Arch 1987).

Factors Influencing the Adoption of Soil Conservation

Some factors influencing the adoption of soil conservation are directly related to monetary income, while others are governed by nonmarket forces and unpriced values. The former are considered here first.

Net returns and access to credit

It can be hypothesized that farmers are likely to adopt profitable soil conservation decisions if they either have sufficient funds of their own or have access to credit. Blase (1960) employed a statistical model in which off-farm income and the ability to borrow were found to be variables significantly correlated with reductions in soil loss. Off-farm income is interpreted as a means of overcoming financial constraints. However, the results of a later study by Ervin and Ervin (1982) dilute the importance of these variables. Others (Carlson *et al.* 1977, Earle *et al.* 1979, Sinden and King 1988) regarded farm size and farm income to be positively associated with each other and, in turn, to influence positively the adoption of soil conservation. The diversity of farm circumstances means that generalization about the private profitability of conservation measures for farmers is difficult, and farm management research to provide relevant information to farmers is an important field of applied economic analysis (Dumsday and Seitz 1985, Musgrave and Pearse 1985, Arch 1987).

Further, Veloz *et al.* (1985) have illustrated that the size of net returns depends importantly on the topographical characteristics of the locations. In their study of the Valdesia watershed in the Dominican Republic, the net returns with soil conservation were much lower than those without conservation. Seitz *et al.* (1979) established this difference in the U.S. Corn Belt at roughly $US50 per hectare. The size of such differential net returns depends directly on the length of the planning period and the discount rate, as well as topographical characteristics.

Access to credit is of special concern in the developing countries. Olayide and Falusi (1977) have raised this as an issue in the context of Nigerian soil management, although Crosson (1983) has expressed cogent scepticism at the importance of the issue, given the functioning of informal credit markets. Notwithstanding such sceptical views, Veloz (1985) have argued that many developing-country farmers would find soil conservation difficult because of their inability to borrow funds. The inaccessibility to credit is largely due to the rationing of credit to those borrowers who, relative to their less fortunate colleagues, are less likely to default on loans and who can be served at a lower cost (Gonzalez-Vega 1983). Braverman and Guasch (1986) have illustrated further that the problems of inaccessibility persist even when financial institutions have been purposefully installed to channel credit to poor farmers. The reasons are several and include (a) lack of collateral due to land tenure arrangements, (b) insufficient information regarding the ability to borrow funds, and (c) the provision of funds to wealthy farmers and nonagricultural users.

Attitudes to risk

Farmers' attitudes to risk also influence their willingness to invest in soil conservation (Kramer, McSweeney and Stavros 1983). McSweeney and Kramer (1986a) observed that farmers' receptiveness to implementing soil conservation practices depends on their beliefs about short-term and long-term net returns associated with these practices. Conservation practices, while reducing risks to the soil resource itself, will generally lead to modifications of existing farm operations and could thus create additional, presumably undesirable, uncertainties with respect to net returns. Just how these uncertainties evolve over time is still inadequately researched and understood, as explained by Shortle and Stefanou (1986), and as is clear from the defence against their criticism by McSweeney and Kramer (1986b). Dynamic extensions of the analytical frameworks for handling risk will be useful in assisting planners and others in reducing the cost of risk through diversification over time and accounting for the intertemporal stability benefits that soil conservation may bring to farming systems.

Uncertainty may be particularly worrying for farmers who operate at the margin of economic survival. There is now considerable evidence that most farmers most of the time are averse to risk whether they farm in developing countries (Dillon and Scandizzo 1978, Binswanger 1980, Hamal and Anderson 1982, Hazell 1982, O'Mara 1983, Antle 1987) or developed countries (Binswanger 1982, Pope 1982, Robinson 1982, McSweeney and Kramer 1986a). Hence McSweeney and Kramer (1986a) have argued that risk attitudes will, in principle, affect the adoption of conservation practices, especially if adoption alters the perception of risk. However, the evidence pertaining to perception of such risks remains mixed. Reicosky *et al.* (1977) have demonstrated that conservation practices such as minimum tillage reduce to some extent the risk of crop and income losses by conserving moisture and reducing labour requirements. A survey of Colombian farmers by Reinhardt (1987) supports a similar notion with respect to the perception of risk. The farmers surveyed had resisted the adoption of a 'modernization' program (which had no explicit provision for soil conservation) apparently for fear of incurring losses due to soil erosion and fertility reduction. On the other hand, Pollard, Sharp and Madison (1979) have reported that farmers in Wisconsin and Iowa believe that the adoption of reduced tillage brings increased risk of crop and income losses.

Recent U.S. studies have revealed that there is a fine, albeit somewhat blurred, line between whether risk aversion is a positive or negative factor in adopting conservation tillage practices (Williams and Johnson 1985). Klemme (1985), for instance, found that there was little difference for Midwest risk averters between conventional and reduced tillage methods for maize and soybean culture. Conventional methods were preferred if costs of soil loss were ignored, but reduced tillage became preferable when such future productivity losses were assigned (Anderson 1983). Analogous results were derived for dryland wheat farms in Utah by Helms, Bailey and Glover (1987). Their analysis encompassed participation in government price support and other programs. Reduced tillage methods were found to be dominant when adopted in conjunction with program participation. Such participation is discussed in Williams' (1988) work on incentives and support.

Kramer, McSweeney and Stavros (1983) have also suggested that farmers with high degrees of aversion to risk will follow production practices that are associated with higher incomes as well as higher rates of soil loss. Ervin and Ervin (1982) found in a multiple regression analysis that the adoption of soil conservation practices decreases as the level of risk aversion increases. Such findings are inconsistent, for example, with those of the Colombian study where the farmers were explicitly categorized as risk averse (Reinhardt 1987). The mixed nature of the evidence suggests that the role of the risk should be subject to further careful analysis. It is quite possible that risk attitudes and their implications for the adoption of soil conservation measures are more importantly associated with other factors such as wealth, education and tenure, and there may thus be identification difficulties in empirical associations observed in cross-sectional data (Norris and Batie 1987).

Length of planning horizon and the discount rate

A farmer's wealth may influence the adoption of soil conservation practices in various ways, in part through related expectations about future income. These expectations are conditioned by the farmer's planning horizon and discount rate (Solow 1974). A farmer who expects the net returns with soil conservation to be lower than those without conservation is certainly likely to postpone the adoption of soil conservation decisions. The effects of postponing the decision are illustrated in Figure 3. If the soil conservation decision is instead implemented immediately, the discounted net returns would remain constant at $\$a_0$. Alternatively, postponing the soil conservation decision by 1,...,t years would result in a corresponding set of lower (for simplicity, presumed constant) discounted net returns, $\$a_1, ..., \$a_T$. Curve AB in Figure 3 represents the decline in net income resulting from the absence of soil conservation. So, if the planning horizon is longer than t^* years in Figure 3, the farmer may be prompted to adopt the soil conservation measures immediately, because postponing the conservation decisions by each successive year results in potential future losses, namely, $\$(a_0 - a_1), ..., \$(a_0 - a_{T^*})$. Seitz *et al.* (1979), however, illustrated that the length of T is influenced by the discount rate. In their case, with zero discount rate, net returns without conservation exceed those with conservation for up to 40 years, but this period became 60 years with a discount rate of five per cent. Analogously, Walker (1982) found this period to be about 60 years with a discount rate of two per cent, but as much as nearly 200 years with a discount rate of eight per cent. Walker and Young (1986) found that the period becomes much shorter if the analysis includes the effects of technological change (which is considered below). Ervin and Ervin (1982) defined the length of the planning period as a binary variable in terms of transferring property to children and found it to be insignificant in influencing the adoption of conservation measures.

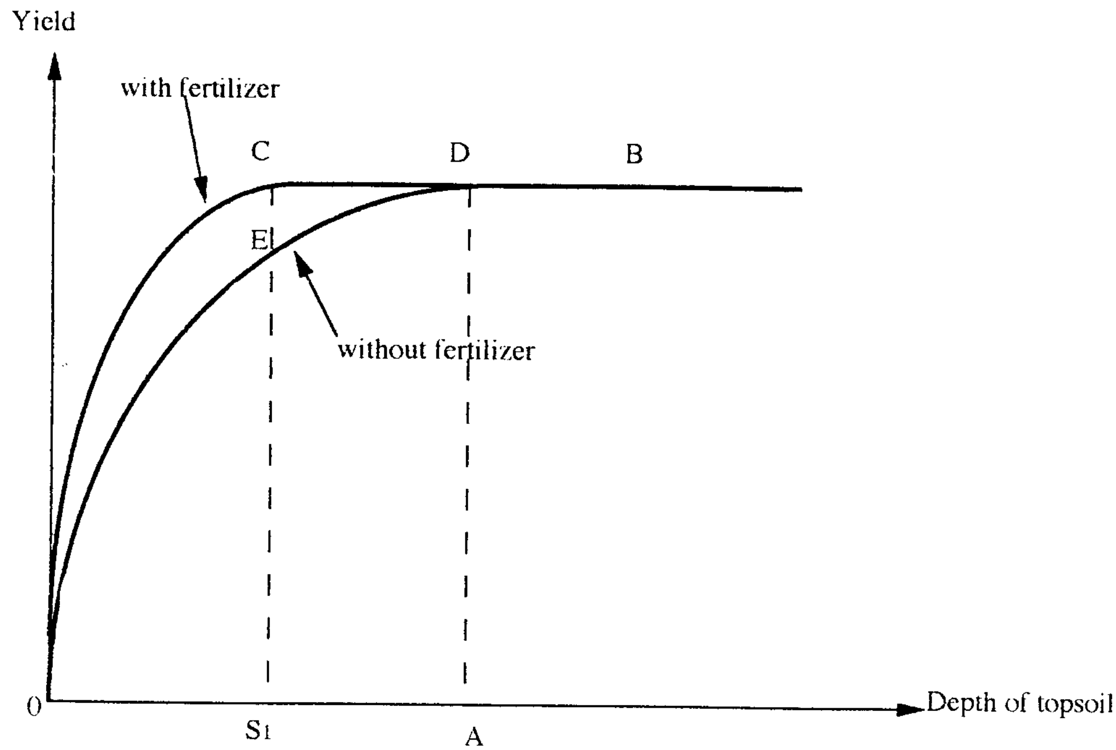
The following general inferences can be drawn:

(a) The length of time over which the net returns without conservation exceed those with conservation is often too long for the planning period to be a significant influential variable.

(b) Any such lack of influence is exacerbated by increases in the magnitude of the prevailing rate of discount.

An apparent consensus regarding developing countries is that the rate of discount is high and the length of planning horizon is short (Hufschmidt *et al.* 1983, Dasgupta and Pearce 1984, Irvin 1984, Markandya and Pearce 1988). However, the discount rate need not be high. For example, Ehui and Hertel (1989) illustrate in a study of Cote d'Ivorie that deforestation would be preferred if the discount rate were higher than eight per cent. If the effects of land degradation are perceived to be unlikely to occur in the near future, the adoption of soil conservation practices would correspondingly remain unlikely. Such effects are not, of course,

Figure 4: Effect of Fertiliser Use on the Damage Function



confined to developing countries (Chisholm and Dumsday 1987).

Production incentives and support payments

There is a growing consensus that certain government policies which directly affect farm incomes have also been instrumental in contributing to the problem of land degradation (Batie and Sappington 1986, Blyth and Kirby 1985, Ervin, Heffernan and Green 1984). Such policies include input subsidies, guaranteed prices, and income assistance programs.

Blyth and Kirby (1985) have argued that the fertilizer subsidy in Australia has hindered the adoption of management and production practices consistent with lower rates of degradation. Van Vuuren (1986) has proposed a conceptual framework to explain such observations. In Figure 4, curve OEB represents the relationship between soil depth and yield without the application of fertilizer, and OCB with fertilizer. It is evident that, with the use of fertilizer, productivity losses are delayed until soil depth is OS_1. That is, the use of fertilizer can offset to a certain extent the effect of productivity losses caused by soil loss (Dumsday 1971). However, the excessive use of fertilizer (due perhaps to its cheapened availability by way of subsidies) can have other adverse effects as well. For example, Costin and Coombs (1982) have criticized the superphosphate subsidy in Australia on the premise that this subsidy has led to the application of large quantities of superphosphate, and that such heavy application may damage the structure and reduce the overall quality of the soil. Similar concerns regarding fertilizer use in India have been raised by Singh, Singh and Bal (1987), Subba Rao, Chowdry and Venkata Reddy (1987) and Chopra (1989). Other related issues that are not connected to damaging intensity of fertilizer use, and which are not taken up here, concern the efficient management of soil nutrient levels through intertemporal fertilizer decisions (Stauber, Burt and Linse 1975, Dillon 1977, Helyar and Godden 1977, Godden and Helyar 1980, Lanzer, Paris and Williams 1987).

Input subsidies are not confined to fertilizers. Water pricing has been used as a means of encouraging land settlement and regional development. In Australia, for instance, but reflecting a widely spread phenomenon, Randall (1981) and Musgrave (1983) have argued that irrigation water is underpriced. As a result, the amount of water drawn for irrigation tends to be extravagant and contributes to the problems of erosion, sedimentation and salinity. Peck, Thomas and Williamson (1983) estimated the damage cost of soil degradation in Australia for the period 1971-81 due to irrigation to be $94 million (in 1982 prices). Nadkarni (1987) and Joshi (1987), for certain parts of India, have also illustrated the adverse effects on soil quality of excessive irrigation. It is generally agreed that, as long as water remains inexpensive, irrigators have little incentive to economise on the amount of water used and, consequently, land degradation becomes highly likely.

Governments sometimes also provide assistance for land clearing which, in turn, is often a central cause of land degradation (World Bank 1978). Hecht (1985) and Binswanger (1987) have detailed government assistance for land clearing in Brazil. Studies of such lands reveal that their quality has usually deteriorated significantly within a short time (Salati and Vose 1984, World Resources Institute 1985, Jordan 1987). Blyth and Kirby (1985) have argued that tax concessions have been instrumental in accelerating the rate of land clearing activity in Australia. Similar arguments are offered in other areas of government support as well. For instance, Freebairn (1983) has argued that drought assistance in the form of fodder subsidies encourages the retention of livestock on farms. Such unreduced livestock holding during periods of drought accelerates pasture and soil degradation. In most developed countries the so called 'farm problem' has been treated with price supports. Such supports inevitably attract additional resources into agriculture with almost inevitable implications for land degradation such as faster 'optimal' rates of soil loss, unless cross-compliance programs are introduced to balance such deleterious effects more favourably.

It is possible that the beneficial effects of the various soil conservation policies in place in the developed countries since the 1930s have been largely negated by the unintended but adverse effects of agricultural support policies. This is also true of developing countries, although to a lesser extent, in that the incentives for conservation inevitably fall far short of the incentives for production. The prevalence of inconsistencies between the two sets of policies has led to the formulation of cross-compliance policies. Various U.S. cross-compliance policies have been analyzed by Benbrook (1979), Libby (1980), Ervin, Heffernan and Green (1984) and Batie and Sappington (1986). The guiding principle behind cross-compliance is that farmers who maintain specified conservation standards would be eligible for higher benefits under the program of general agricultural support. The major objectives in cross-compliance research have been: (a) to identify the agricultural enterprises and other production incentives that require compliance with a conservation standard, and (b) to specify the limits of the conservation standard. McSweeney and Kramer (1986a) extended this principle to an examination of attitudes to risk; and concluded that cross-compliance would induce risk-averse farmers to adopt soil conservation.

A policy measure that has been recently introduced in the U.S. to prompt the protection of fragile lands is the 'conservation reserve program' (CRP). Essentially, the CRP is aimed at retiring ecologically sensitive land from production. The welfare effects of the CRP have been examined by Ervin and Dicks (1988) and these include enhanced land values (Shoemaker 1989) and reductions in downstream damages (Ribaudo 1989).

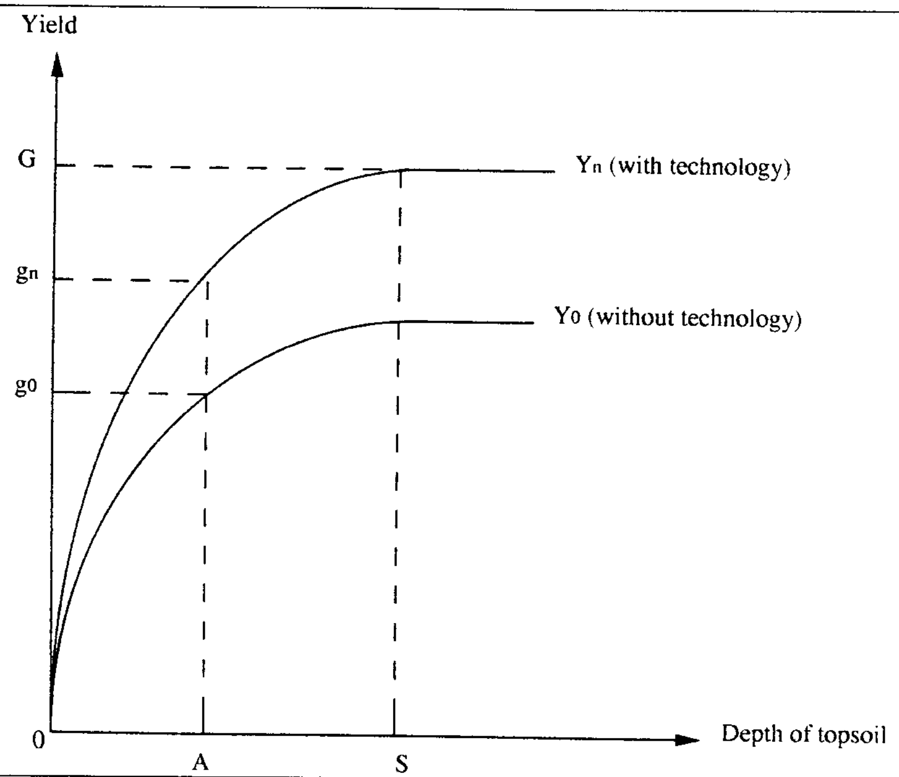
Cross-compliance and CRP policies appear to be absent in the developing countries - perhaps because there are relatively few instances of strong positive support for agriculture that can be linked to carrot-and-stick corrective policies. Given the rapid increase of various degradatory practices and the fact that quite a few developing countries do have positive protection of at least some of their agricultural producers (Binswanger and Scandizzo

1983, Byerlee and Sain 1986, World Bank 1986), promulgation of such policies could go some way to alleviate the rapid rates of soil loss caused by the clearing of forests and the intensification of production.

Technology

The effect of technology on soil conservation has been illustrated by van Vuuren (1986) and Walker and Young (1986). In Figure 5, Y_n represents the damage function with the use of technology such as modern crop varieties and, Y_0 represents the damage function without such technology. Technology has the effect of shifting the production function upwards. If technology is introduced when soil has eroded to a depth of OA, then output would increase by an amount equal to $g_n g_o$. However, the same technology on uneroded soils (or soils of depth greater than OS) would provide a yield of OG. Hence, Walker and Young (1986) argued that the loss due to erosion in the context of technology is the potential output that is sacrificed, namely Gg_o in Figure 5. The contention is that technology and soil conservation are complementary inputs and not substitutes. The non-recognition of this complementarity results in an under estimation of the benefits of soil conservation. Walker and Young (1986) examined the effect of the rate of technical progress on the timing of soil conservation decisions. The influence of technical progress appears to be severely diminished when the social rate of discount exceeds five per cent. For instance, when the discount rate is 11 per cent and the rate of technical progress is zero, net returns without conservation exceed those with conservation for a period of 62 years. With the same discount rate and the highest feasible rate of technical progress, this period reduces to 58 years. However, when the discount rate is low (say, 2 per cent) the introduction of new technology reduces this period to between 1 and 12 years. Low discount rates and high rates of technical progress would prompt the early adoption of soil conservation practices.

Figure 5: Effect of Technology on Soil Conservation



Much literature on modified technology for developing countries is concerned with the question of its appropriateness or otherwise. Most technology transferred to the developing countries was originally developed for different environments and agricultural regimes. The adoption and careless use of such technology frequently promotes land degradation (Milton and Farvar 1972, Janzen 1973). The issue of inappropriate technology has been formalized by Todaro (1977) within the framework of the 'false paradigm' model; that is, the adoption of growth strategies that have been relevant for developed countries. This false paradigm is illustrated, for the green revolution and particularly the careless use of modern cereal varieties in India, by Chaudhary, Malik and Singh (1987) and Chawala and Gill (1987). For a rather different example, Allen (1972) considered the transfer of hydro-electric technology to Colombia and argued that, given the site characteristics of the Colombian case, watershed management should have been initiated before the dam came on-line. The problem of sedimentation that emerged during the early stages of the project has rendered subsequent conservation efforts futile.

In quoting the negative effects, critics tend to lose sight of the 'big picture' of the green revolution. Had the rapid increase in productivity of modern rice and wheat not taken place in the 1960s and 70s, the destructive pressure on tropical forest lands would have been much greater and faster than has actually been the case (Anderson *et al.* 1987). The continued development of new land-saving technologies through both national and international agricultural research is the broad policy that probably has the best prospects for reducing global soil erosion and meeting intergenerational resource obligations. Meantime, many countries are environmentally benefiting from distant consequences of the green revolution that were unintended and unanticipated. An example is the move towards bush and tree crops on steep slopes of Java that was permitted by crop intensification on the lower lands, and assisted by price policy aided in turn by favourable petroleum revenues.

Education

The effect of education on attitudes to soil conservation has been examined by several authors in quite different ways. Blase (1960) related education to the ability to perceive erosion as a problem. Positive associations between soil conservation and education have also been reported by Carlson *et al.* (1977) and Earle *et al.* (1979). In a study of Nebraska farmers, Hoover and Wiitala (1980) found soil conservation measures were more common among farmers who are young as well as educated. That the young are more likely to adopt soil conservation measures than the more experienced has been also noted by Gould, Saupe and Klemme (1989). Ervin and Ervin (1982) hypothesized the adoption of soil conservation to follow a sequence of three steps, namely: (a) perception of soil erosion as a problem, (b) decision to adopt soil conservation, and (c) soil conservation effort. Education was significant at each step.

In-depth studies of the type carried out by Ervin and Ervin (1982) appear to be absent from the literature on soil management in developing countries. However, the problem has been raised by several authors (Veloz *et al.* 1985, Nadkarni 1987). Anecdotal evidence of post-project reversions to previous erosive practices and the dismal record of some extension projects suggests that the task is not easy. Active involvement rather than compulsion together with perception of personal benefit are clearly important in fostering long-term changes to attitudes and practices. A key role for governments is to transmit pertinent information on soils problems and possibilities through education generally, and through targeted extension programs.

Tenure arrangements

Eckholm (1976) and Veloz *et al.* (1985) among many observers of similar perspective have stressed that farmers' insecure or limited tenure acts as a severe disincentive for the adoption of soil conservation practices. Even should they be keen to adopt, the farmers' limited tenure tends to constrain them from acquiring the necessary credit to carry out the practices needed. Although much of the discussion concerning the role of land tenure in soil conservation tends to be speculative rather than analytical and empirical, some concrete evidence is to hand from the study of Colombian farmers by Reinhardt (1987). A majority of the farmers from the El Parmar district of Colombia refrained from participating in a modernization program supported by the government on the premise that such modernization would lead to land and environmental degradation. This attitude coincides with the fact that land ownership rather than leasing predominates in the community.

Evidence of tenure arrangements on the adoption of soil conservation practices from developed countries may have limited applicability in developing countries. Lee (1980), for instance, found no significant relationship between rates of soil loss and renting versus corporate or family ownership of land in the U.S. Blyth and Kirby (1985), however, have commented on the effect of land tenure on soil conservation in Australia. Among developed countries, Australia is almost unique in having a relatively high proportion of land under state ownership. Blyth and Kirby argued that the uncertainty regarding the renewal of land leases and the lack of full compensation for improvements carried out act as deterrents to the adoption of soil conservation. They further indicated that price controls on the disposal of leases probably serve as added disincentives for conservation. In short, although concerns for custodial management of land feature among the diverse political, economic and social reasons for the dominance of state ownership of land, the procedures adopted have often been ineffective for the efficient and sustainable management of land resources.

Focusing attention on the tenure conditions experienced by present land users does not confront the issue of the contentedness of such users with their circumstances. In many parts of the developing world, many of the most eroded or rapidly eroding landscapes are occupied by resource-poor farmers who have been forced into such areas through political, social and economic pressures and conflicts, a process that Blaikie (1985, pp. 124-30) has summarized as 'marginalization'. He has documented instructive evidence from countries as diverse as Nigeria, Zambia, Kenya, Tanzania, Nepal and India. Yet another dramatic case can be observed in the Mandarra mountains of Northern Cameroon where a disadvantaged ethnic group has retreated to and proliferated in a confined region of high erosivity and erodibility with predictable results.

Population pressures

The discussion of the influence of population pressures on land degradation is almost exclusive to the literature pertaining to developing countries. The dominant contention is that rapid increase in population leads to a greater segregation of land followed by its more intensive use as well as the clearing of virgin areas for cultivation (Repetto 1987). Both of these effects contribute to land degradation. The application of such Malthusian perspectives has remained central to the analysis of land degradation in developing countries (Eckholm 1976, Brown and Lugo 1982, Myers 1984, Nicolaides *et al.* 1983, Brown and Wolf 1984).

However, critics of the Malthusian view (Franke and Chasen 1980, Watts 1983) argue that environmental problems of the developing countries have their origins in the structural poverty of rural populations. The decision to have children is a rational response to concrete economic circumstances. The benefit-cost ratio of extra children in poor societies is high, in part because children can contribute agricultural labour or earn income in the informal economy from an early age. The contention is that curbing population pressures may not be feasible without dealing with the causes underlying rural poverty. By strong implication, the argument is that land degradation and adoption of measures to conserve soil are influenced by the causes of rural poverty.

Despite the controversies noted above, the recognition of population pressures has led to the formulation of plans that involve the displacement of people from sites where conservation programs are intended. For example, Veloz *et al.* (1985) reviewed a project proposal for soil conservation by way of afforestation involving the movement of 25 per cent of the population elsewhere. The resettlement of populations has usually been considered in the context of projects directed at objectives other than soil conservation per se, such as hydro-electricity and highway development. Further, agencies such as the World Bank have also provided funds for a limited number of resettlement projects. An issue central to resettlement is the payment of compensation for the welfare losses incurred by the evictees. However, some projects involving the resettlement of populations appear to ignore such evictee welfare losses (Parthasarathy 1987). Veloz *et al.* (1985) have stressed that an examination of the radical shifts in life styles imposed on people to be relocated is essential and that the incentives for relocation should be based on these shifts.

These generalisations from 'traditional' resettlement projects do not apply to the new breed of transmigration schemes such as those popular in Indonesia. These schemes are inspired in part by environmental concerns over the serious erosion in the steep areas of desperately crowded Java and Bali (Hudson 1986, p. 310, Repetto 1986). With such miniscule proportions of the population leaving, the small 'dent' from any positive effect in terms of reduced pressure on Javanese land resources must be modest indeed. On the other hand, however, the main ecologically negative consequences are to be found in the newly settled areas where the combination of fragile lands, untried technologies and locally inexperienced farmers can lead to rapid degradation of soils. Such matters are the subject of the (1987-88) Indonesia case study of environmental and natural resource issues by the Environment Department of the World Bank. The concerns have been reflected in progressively greater attention to environmental screening, site selection, and evaluation of projects such as, say, Transmigration II through V.

International and political pressures

Hecht (1985) has noted that land degradation in most developing countries cannot be adequately explained by population pressures or inappropriate technologies. Taking the case of the Brazilian Amazon, she argued that accelerated land degradation and lack of conservation followed strong national and international pressures which confronted the new military government in Brazil after the coup of 1964. These pressures included: (a) the need for the government to establish its legitimacy, (b) unrest in urban and rural areas, and (c) a growing deficit in the balance of payments. Thus, she held, the Amazonian development program provided a means of diverting attention from the unrest in urban areas, and of addressing the social and political problems in the rural areas as reflected in stagnant production, low rates of investment, and out-migration. Nationally, the image of legitimacy was helped because the program involved areas surrounded by border disputes. Internationally, the government was seen to be dedicated to resolving the problems of the poor.

Further incentive for degradation, in the form of the conversion of forest to pasture, came from the ready availability of credit for large-scale projects involving beef cattle enterprises (Repetto and Gillis 1988). During the period 1965-80, there had also been a significant increase in agency funding for beef cattle development. The net outcome of these various international and national pressures has been the promotion of large farms for cattle ranching over all other forms of land use (Binswanger 1987). Examples of social and political pressures of a similar vein in India have been presented by Nadkarni (1987).

3. Topsoil - A Renewable or a Non-renewable Resource

Theoretically all natural resources are renewable. However, some resources such as fossil fuel and minerals are considered nonrenewable because their rate of regeneration is spread over an extremely long time. On the other hand, resources such as biological species that regenerate fairly rapidly are considered renewable. A specific concern in the management of natural resources is that some of the so-called renewable resources are readily transformed into the category of nonrenewable resources in the event of over-exploitation or mismanagement (Howe 1979). Such a concern applies to the management of topsoil. Under natural conditions, topsoil is a renewable resource. That is, the topsoil that is lost due to natural erosive processes is largely replenished from the subsoils. Further, the rate of regeneration of topsoils can be fairly rapid, as long as the rate of soil loss falls within tolerable levels. Ciriacy-Wantrup (1968) thus defined topsoil as a renewable resource with a threshold level below which resource use renders it nonrenewable. Many of the land-use practices adopted in the developing as well as developed countries appear to be consistent with measures which transform topsoil into a nonrenewable resource.

Regardless of the resource category, with the exception of a few renewable resources, the current extraction of a natural resource implies that less of it is available for the future. This, whilst clearly evident in the case of a nonrenewable resource, may be less evident with a renewable resource. The reduction in future availability with a renewable resource could be due to either overharvesting or underharvesting both of which can lead to regeneration from a reduced stock size, or a reduction in the rate of regeneration. However with soils, McInerney's (1976, 1978, 1981) generalisation can be adopted, namely that the extraction of a natural resource in the current period imposes a reduction in consumption net benefits on the future generation. This loss in future net benefits is defined as the user cost.

The Concept of User Cost

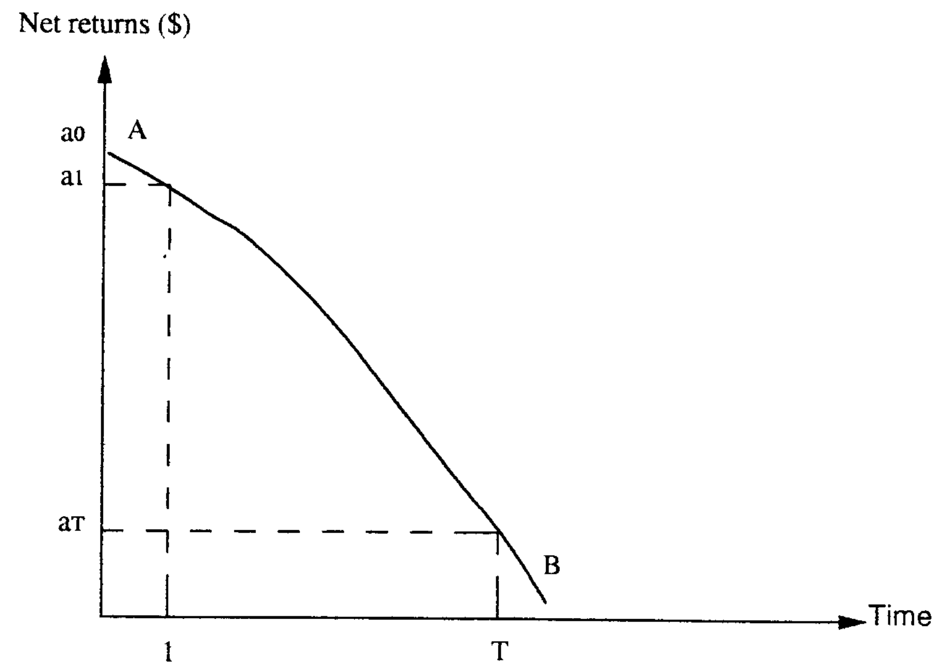
The user cost of soil exploitation is likely to be low in situations where the net returns without soil conservation exceed those with soil conservation for a substantial length of time. Seitz *et al.* (1979), Walker (1982) and Walker and Young (1986) estimated this time period for certain areas in the U.S. to range between 40 and 60 years. However, as noted earlier, this time period can be significantly reduced by technical progress (Walker and Young 1986). The relevance of the user cost concept remains high in such situations.

The user cost concept is clearly highly relevant in heavily eroded environments, where the net returns with conservation are in excess of those without conservation (Pearce and Markandya 1985, 1987). Such a case is considered in Figure 6, and user costs are defined in terms of the effects of postponing soil conservation. That is, postponing the decision imposes on the future generation an added cost, which is most likely to be higher than the current cost of conservation due to increased degradation. This added cost represents the reduction in future consumption net benefits, namely the user cost. In Figure 6, $\$a_0$ represents the constant net returns that would accrue if the soil conservation decision is adopted in the current period. Postponing the soil conservation decision by one year results in a reduced constant net return of $\$a_1$. Thus curve AB in Figure 6 represents the locus of the points of origin of the different constant net returns corresponding to different periods of postponement. Hence the user cost of postponing the soil conservation decision by one year is $\$(a_0 - a_1)$. Likewise, the user cost of postponing the conservation decision to year T is $\$(a_0 - a_T)$.

Application of User Costs

Recognition of the user cost concept implies that land use and management decisions have to be evaluated within an intertemporal framework (Pearce 1976). The basic framework of intertemporal analysis is well defined by optimal control theory, although applications are easier said than done. Burt (1981) has employed a dynamic programming framework as an approximation to an optimal control model to evaluate soil conservation strategies in the Palouse area of the U.S. Northwest. Depth of topsoil (xt) and percentage of organic matter (yt) are the state variables; and all possible

Figure 6: Definition of User Costs Using the Effects of Postponing the Conservation Decision



cropping practices (ut) are decision variables. The optimization framework is as follows:

Max G (ut, xt, yt)/(1+r)t

subject to: x(t+1) = xt - k(ut, xt, yt) and

y(t+1) = yt - h(ut, xt, yt),

where:

G(ut, xt, yt) is an annual net return function, and k(ut, xt, yt) and h(ut, xt, yt) are soil loss and organic matter loss functions, respectively, and r is the social rate of discount.

The reduction in net returns in the context of the two loss functions enables the definition of user costs. However, the reduction in net returns does not become significant due to the assumption that good cropping practices (including the use of fertilizers) can substitute for the losses in topsoil and organic matter. Hence, Burt's (1981, 1986) preferred intertemporal land use strategy involves intensive wheat production with good cultural (including fertilization) practices. However, this strategy along with several of Burt's analytical simplifications, does not find favour among critical observers such as Taylor *et al.* (1986).

McConnell (1983) has presented a control model based on the calculus of variations, where a farmer is assumed to maximize the present value of the profit stream of various enterprises plus the resale value of the farm at the end of the planning period. Both components of the objective function (profits and resale value) are defined as functions of the main constraint, namely rate of soil loss. The model enables the determination of the optimal rate of topsoil mining (erosion). However, the model solutions are based on the assumption that product prices, input costs, length of planning period and the discount rate are all known with certainty at the start of the initial year. Further, in conjunction with the inclusion of resale value, McConnell (1983) defined topsoil as a capital asset that appreciates in value when the rate of soil loss is low. This implies that an excessive increase in the user cost (namely the reduction in net returns or the value of the objective function) will be constrained through the motive of wishing to maximize resale value as well as productive earnings. He deduced that expectations of high future prices and low discount rates act as disincentives for soil erosion.

Kiker and Lynne (1986) have taken exception to some of McConnell's findings on the premise that, even over a short period, the amount of information available to farmers is limited. An implication of the evaluation by Kiker and Lynne is that the certainty assumptions in McConnell's framework should be relaxed and the framework extended to include the effects of uncertainty. On the other hand, there appears to be some justification for including resale value and soil asset appreciation in the model. This follows in part from empirical illustrations of positive relationships between soil conservation and land values (King and Sinden 1986, 1988 and Palmquist and Danielson 1989). Although the association between land values and soil conservation efforts is deemed insignificant in some studies (Ervin and Miller 1985, Gardner and Barrows 1985), it becomes significant when the method of analysis is hedonic (King and Sinden 1988).

McConnell (1983, 1986) also extended his analysis to explore the divergence between private and social values of soil erosion, and argues that there is a correspondence of private and social interests in soil conservation policy. In his response to Kiker and Lynne (1986), his further arguments are very much in the context of well-functioning U.S. farm real estate markets. These markets, especially with regard to their dependence on farmers' informed personal valuations of the many intrinsically uncertain components of farmland values, are not necessarily such reliable indicators of either changes in intrinsic worth or of the user costs of soil loss in many developing-country situations. In fact, the concerns of Kiker and Lynne (1986) over such things as the food-producing capacity bequeathed to future generations seem applicable to such situations, even if the relevance to contemporary policy debate in the U.S. may not be seen as high.

The analysis of renewability and nonrenewability in the context of developing countries has typically been more qualitative and the recognition of the user cost concept only implicit. For example, Gagdil (1987) examined a range of renewable resources (including topsoil) in Karnataka, India, and concluded that, in most range areas and croplands, the rate of topsoil loss exceeds the rate of natural regeneration. The concept of a user cost is also implicit in French's (1986) study of deforestation in Malawi. He estimated the added costs that would be imposed on the Malawian economy if land degradation is permitted to continue, and used these estimates to define a range of conservation strategies.

4. Frameworks of Common Property Resources

The Central Concepts

The traditional understanding of a common property resource (CPR) is that of free access for its utilization. Ciriacy-Wantrup and Bishop (1975) and Quiggin (1988c) have argued that the term CPR itself implies the existence of ownership and collective property rights. Ciriacy-Wantrup and Bishop (1975) have cited examples of resources that have survived centuries of utilization, despite the provision of common access, due to the presence of well-defined rules of collective ownership and utilization. Hence, the degradation of, say, a forest or a nature reserve can be regarded as a result of utilization, where common access is permitted without the complete specification of ownership rights. Hardin's (1968) somewhat misnamed 'tragedy of the commons' can be interpreted as a consequence of the collective utilization of a nonexclusive open access resource (Magrath 1988).

Hardin (1968) nominated population growth as the driving force behind the exploitation of a common resource, and offered the following explanation. When such a resource is exploited, individuals seek to maximize their utility. Further, while each individual garners the personal benefits of additional exploitation, the costs of the additional exploitation (for example, those attributable to land degradation) are shared by all users or society as a whole. There is thus substantial gain to the individual at a relatively small personal cost. Such a system prompts each person to expand individual exploitation competitively, resulting in the destruction of the resource. In essence, Hardin's (1968) tragedy of the commons is that individual rationality of wealth maximization results in collective tragedy. Clarke (1974) and others have explained that the exploitation of common resources is influenced not only by the competitive behaviour of the individuals, but also by the prevalence of high rates of discount and short planning periods.

The utilization of common resources inevitably results in the generation of externalities (Howe 1979). For instance, the collective cost imposed on society as a result of the maximization of individual exploitation of a common resource, can be defined as an intertemporal externality. That is, the collective costs of restoration and reduced consumption are borne by subsequent generations. As explained by Hardin (1968), these collective costs can also be expanded to include other externalities such as the loss of unique species and the effects of downstream sedimentation. Hence the exploitation of a common resource often results in a conflict between social and private values. Theoretical solutions are based on eliminating this conflict. Hardin (1968) has suggested population control and the privatization of the resource. The literature on welfare economics (Dasgupta and Pearce 1984, Irvin 1984) suggests the imposition of regulatory measures such as taxes and standards, and indeed the most common practice is regulation.

In terms of Hardin's solutions, the difficulties concerning population control are noted already, and the strategy of privatization is also not without considerable difficulties (Izac 1986). Hardin's solution of privatization rests on the neoclassical premise that individual resource owners will rationally manage their resources in their best uses in order to remain competitive in the market. The inherent assumption is that markets are capable of providing the signals for efficient resource use. However, given market imperfections and transaction costs, and the inability of the market to deal with externalities, privatization is likely to lead to sub-optimal strategies (Hecht 1985). Further, given the inegalitarian structure of many developing country societies, privatization is likely to restrict the access of common resources to only the privileged. This follows from Clarke's (1974) argument that privatization of a common resource could enable its exploitation by the wealthy. Further, privatization has also tended to favour the adoption of capital intensive methods that prompt exhaustion.

However, following the reasoning variously provided by Ciriacy-Wantrup and Bishop (1975), Quiggin (1988a, b, c) and Magrath (1988), the inefficiency of privatization could rest on the lack of attention afforded to the rights of collective ownership. If a common resource is collectively owned, its owners would refrain from indiscriminate exploitation, since such utilization adds neither to individual nor collective welfare. Thus a strategy of conservation could involve the development of mechanisms to endow the users of the resource with property rights. The difficulty, as Quiggin (1988b) has conceded, arises in determining who should be endowed with the ownership rights. However, if all users of the common resource can be endowed with ownership rights, then the application of a framework that regards the resource as an asset and that aims to maximize the value of the asset would result in a sustained and efficient use of the resource (Quiggin 1988c). Certainly, some of the experience in changing rights is less than encouraging from several development perspectives. Jodha (1987) has described the decline of common property resources in semi-arid India, which were traditionally used by the rural poor. When privatized, such lands have gone mainly to existing land owners, been increasingly cropped rather than grazed and have suffered rapid degradation, including soil erosion. That is, intergenerational externalities are not necessarily confined to common property resources. They can emerge with privately owned parcels of land as well. However, evidence cited earlier (for example, King and Sinden 1988, Palmquist and Danielson 1989), that soil characteristics are manifested in land values, supports the argument that property rights have a role in alleviating the soil degradation problem when markets are competitive.

Difficulties exist with the formulation of regulatory measures as well, because these measures usually rest on the feasibility of internalizing externalities. Such internalization involves, in part, the necessarily imperfect and approximate improvization of valuation methods for items that may not be exchanged in the market (Sinden and Worrell 1979).

Applications Involving CPRs and Externalities

Empirical applications involving the concepts of common resources and externalities with respect to soil conservation are limited. The applications considered herein attempt to illustrate the divergence between private and social values, and thereby deduce strategies for conservation. McConnell (1983) distinguished between private and social decisions in his optimal control model for intertemporal land-use decisions. In the model for social decisions, the profit component is replaced by economic rent. The two model solutions suggest that private and social strategies would generally coincide. However, Kiker and Lynne (1986) have indicated that McConnell's formulation is too restrictive because only soil depletion is considered and the environmental disruptions caused by soil erosion are ignored.

Veloz *et al.* (1985) employed a private as well as a social analysis to evaluate a soil conservation project in the Dominican Republic. The distinction between the two analyses rests on the inclusion of an externality and the estimation of wages for the project. The externality is considered only in the social analysis, and relates to the effects of downstream sedimentation of a dam used for hydro-electricity. Sedimentation reduces the life of the hydro-electric project, and this externality is internalized by estimating the present value of the additional years of electricity output due to reduced sedimentation stemming from soil conservation. With respect to wages, the social analysis is based on shadow wages, whilst the private analysis uses the institutionalized minimum wages which are higher than the shadow wages. The private analysis reveals that soil conservation is profitable on only 20 per cent of the land area. Alternatively, the social analysis renders soil conservation viable in nearly 70 per cent of the land area. This result of Veloz *et al.* (1985) reinforces the frequent intuitive and empirical observation that private individuals are likely to adopt more erosive practices, whilst society would choose less erosive strategies.

The distinction between private and social values is also featured in some other studies that distinguish between 'on site' or 'up stream' effects on the one hand, and 'off site' or 'down stream' effects on the other (Holmes 1988, Huszar 1989, Ribaudo 1989, and Southgate and Macke 1989). A complicating feature of the analysis of downstream sedimentation damage is what might variously be called the 'counterfactual problem' (Anderson *et al.* 1987) or the 'Nirvana fallacy' (Demsetz 1969), namely what would happen under various intervention scenarios. Geologically young erodible areas will yield sediment whatever the intervention, so analysts must guard against lack of realism in assessing baseline levels of sedimentation. Such assessments must also recognize the likely impossibility of moving people out of fragile watersheds or of preventing others coming in (Southgate and Pearce 1988). There seems likely also to be a persistent tendency to overestimate what may be achieved through downstream benefits of upstream interventions (Dixon and Easter 1986). This tendency is supported by on-going case-study work by the World Bank in Java on the relative costs of upstream and downstream erosion damage using a natural resource accounting approach. All this is not to say that, in other cases, downstream damage may not be great. Then, 'sediment management' becomes a primary policy instrument which may even embrace attempts to put sediments to good purpose - what the Chinese would describe as 'making good from bad.'

5. Implications of the Review

Several implications emerge from the foregoing review. The most important of these is the dominance in the literature of the formulation and application of concepts to problems of land degradation in the developed countries. Further, most of the studies dealing with the analyses of developed countries' problems make use of detailed technical information and frequently with quantitative techniques - notwithstanding their dubious applicability. On the contrary, the literature dealing with the analyses of developing country problems tends to be less formal and more qualitative in nature. The paucity of detailed technical information, such as survey data on rates of soil loss and physical parameters for the definition of the universal soil loss equation (USLE), accounts at least partially for the lack of apparent rigour in much soil conservation research in the developing countries. For example, Veloz *et al.* (1985) were obliged to apply the USLE in the Dominican Republic by resorting to using the site parameters for specific locations in the U.S.

The lack of technical information is partly responsible for the omission in the developing-country literature of yield damage functions of the type presented by Walker (1982), Walker and Young (1986) and Sinden and Yapp (1987). Such damage functions permit the estimation of benefits due to soil conservation, and hence assist the evaluation of soil conservation projects. However, the absence of yield damage functions appears to be constrained not only by the lack of information concerning soil loss, but also by some other factors. For example, Horton (1986) has claimed that production function analysis has not been widely applied in the developing countries. Anderson and Hardaker (1979) have attributed such limitation to the difficulty of modelling complex farming systems, along with the lack of necessary data. Hence an important implication is the need to invest in soil conservation research involving demonstration of the effective use of production functions. This would then improve the application of methods associated with the design and evaluation of agricultural development projects, and could prompt the use of appropriate methods to deal with important questions concerning the intertemporal use of land. Further, the literature also reveals a tendency for the research on decision frameworks to be compartmentalized in terms of the various concepts (production functions, renewability and property rights). Hence, there is also a need for combining these concepts in to a single decision framework, since the application of such a framework is more likely to yield a robust set of policies.

Another shortcoming in the literature dealing with soil conservation in developing countries is the limited orientation to policy formulation. Most of the research in developed countries, especially that concerning the factors influencing the adoption of soil conservation measures, has been directly associated with policy formulation. Research on the factors of adoption has been virtually absent in the developing country context. An important implication of the policy-oriented research in the industrial countries has been the recognition of cross-compliance. This is of relevance to the formulation of projects and policies in the developing countries. For example, cross-compliance has been absent from the great majority of development projects. This absence has been responsible, in part, for the accelerated clearing of forests and the intensification of production on marginal lands. It is thus pertinent to promote research concerning not only the factors influencing the adoption of soil conservation but also a framework for achieving cross-compliance.

A limitation of much research of developed countries as well as of developing countries is the frequently inadequate treatment of the externalities associated with land degradation. For these externalities to be internalized requires the representation of markets for items traditionally not exchanged in conventional markets. Although methods to value unpriced environmental goods and services have been developed (Sinden and Worrell 1979), their application to soil erosion problems has been very limited. A similar observation is also relevant with respect to the treatment of risk and uncertainty. The literature on this topic as such is large, yet the applications to problems concerning land degradation are limited. The review also reveals that empirical analyses dealing with the framework of CPRs is generally limited, and are virtually absent in the literature of less developed countries. However, the useful insights rendered by Quiggin's (1988c) work is worth exploring. That is, the notion that CPR management strategies should be based on the principle of asset value maximisation, instead of income maximisation. In this context, the asset is, of course, top soil.

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