University of Wisconsin-Madison
Department of Agricultural Economics
Staff Paper Series

Staff Paper No. 384
June 1995

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by

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## Abstract

We evaluate the on-site land degradation effects of economic changes occurring both within agriculture and elsewhere in the Philippine economy, simulated with the APEX applied general equilibrium model. We derive changes in land degradation rates from changes in land use in rainfed annual crops, using Philippine data on upland erosion under a range of crops, rainfall patterns and slopes. In general equilibrium, land degradation rates are affected by endogenous price changes as well as by direct interventions in agriculture and agricultural processing sectors. We examine the effects of technical progress in corn, and of a capital subsidy to the rice and corn milling sector. Using the nutrient replacement cost method, we calculate the value of changes in land degradation rates and compare them with GDP, government expenditures, and other aggregates used by policy makers.

University of Wisconsin, Department of Agricultural Economics. *Staff Paper Series* No. 384

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## I. Sources of agricultural intensification and land degradation

Agricultural practices leading to soil depletion and land degradation in sloping uplands constitute a significant draw-down of developing countries' stocks of natural resource wealth (Repetto *et al.* 1989; Tropical Science Center and World Resources Institute 1991).[1] While quantification is difficult, the World Bank (1989) estimates the annual value of on-site fertility losses -- land degradation -- attributable to upland agriculture in the Philippines at $US 100 million. This figure is equal to about a quarter of one percent of Philippine GDP per year, a significant figure in an economy where per capita GDP growth averaged -1% per year from 1980-90 (World Bank 1994).

Upland land degradation results from intensification of agricultural land use without compensating investments in conservation of soil structure and fertility. Land degradation rates are dramatically increased by forms of agricultural intensification that involve changes from perennial land uses -- forest, pasture, bush fallow and some tree and shrub crops -- to annual crops, mainly rice, corn, tubers and vegetables. In the Philippines, a watershed-based erosion study by David (1988) concluded that "soil loss increases exponentially as vegetative cover decreases" (p. 49).

Agricultural intensification and changes in land use patterns are clearly related to economy-wide phenomena, including relative prices and market conditions (Coxhead and Jayasuriya 1995). Furthermore, in the Philippines, agriculture as a sector is large in relation to labor markets, private consumption expenditures and international trade. Therefore, changes in agriculture have impacts on other sectors through factor and commodity price changes. These arguments motivate our use of a general equilibrium approach to the study of land degradation in the Philippines. We conduct general equilibrium simulation experiments using the APEX applied general equilibrium model of the Philippine economy.

In this analysis we estimate the value of changes in soil degradation resulting from exogenous economic changes occurring both within upland agriculture and in other sectors of the economy. Nutrient replacement cost estimates are combined with data on annual soil erosion rates for different upland crops in the Philippines. We use this information, together with data on upland crop area, to calculate the aggregate value of changes in land degradation when changes occur in the area planted or the production technology of upland crops. Changes in area planted to each crop are themselves the products of general equilibrium adjustments in relative product and factor prices resulting from the exogenous change.

In the next section we demonstrate several ways in which the rate of upland land degradation is affected by changes in other sectors of a developing economy. We also make some observations on partial and general equilibrium measurement of welfare changes when land degradation occurs. Subsquently we set out our methodology for calculating changes in upland land degradation in response to exogenous shocks. In section III we present and discuss simulation results for two experiments highlighting the soil erosion implications of agricultural policy. Section IV relates our findings to environmental policy concerns by valuing the simulated changes in land degradation, and comparing these values with economic indicators familiar to policy makers.

## II The welfare impact of land degradation in general equilibrium.

Our vehicle for applied general equilibrium simulation experiments is the APEX model of the Philippine economy (Warr, forthcoming), the structure of which is summarized in Appendix B.

In APEX, as in most such models, growth rates of effective factor endowments are exogenous and each factor is regarded as being of uniform quality. These assumptions are contradicted by two points made above about agricultural intensification on tropical soils. First, without compensating investments, more intensive cultivation or an expansion of cultivated area is usually associated with a decline in average soil quality. Second, different land uses may be associated with different rates of quality decline on existing agricultural land. As a first step, any attempt to assess the economic value of changes in agricultural land use should incorporate these on-site land degradation costs. In the following paragraphs we show how we modify the structure of the APEX model of the Philippine economy to allow land quality to reflect agricultural land use, then explore the welfare implications of some changes in agricultural prices and technology.

Let $T^*$ be the effective (i.e. quality-adjusted) amount of upland land available for agricultural production. We define this as the product of $T$, the physical endowment of upland land, and a function of land quality shifters $A(R, M)$, where $R = T_e/T$ is the ratio of land used in an erosive sector to all agricultural land,[2] and $M$ is a vector of land productivity enhancing phenomena, including technical progress and soil fertility-conserving management practices. Given these definitions:

(1) $$T^* = T \cdot A(R,M).$$

Using $A_1$ and $A_2$ to denote the derivatives of $A$ with respect to $R$ and $M$ respectively, we assume $A_1 < 0$; $A_2 > 0$; $A_{11} < 0$; $A_{22} < 0$; and $A_{12} = A_{21} < 0$.

We seek an expression for the welfare (or real income) effect of a change in the effective land endowment. Consider an economy in which aggregate expenditures are denoted by $E(P,U) = \min\{P \cdot C \mid U\}$, and aggregate income from the production of goods and services is given by $G(P,V) = \max\{P \cdot Y \mid V\}$, where $P$, $C$ and $Y$ denote price, consumption and production respectively of a vector of goods, and $U$ is aggregate utility. $V$ is the vector of the economy's effective (i.e. quality-adjusted) factor endowments, of which $T$ is one element. To simplify the exposition suppose there are no taxes or subsidies. In equilibrium, aggregate expenditures are equal to aggegate revenues:

(2) $$E(P,U) = G(P,V).$$

By totally differentiating expression (2) and collecting terms in prices we obtain an expression for the change in aggregate real income, d$Y$:

(3) $$\mathrm{d}Y = -H_p \mathrm{d}P + G_v \mathrm{d}V,$$

where subscripts on $G$ and $E$ denote partial derivatives of the revenue and expenditure functions with respect to subscripted variables, and d$Y$, the change in real aggregate income, is defined as $\mathrm{d}Y = E_u \mathrm{d}U$ (Edwards and van Wijnbergen 1987). The term $H_p = (E_p - G_p)$ is the vector of excess demands for goods; it is positive for net imports and negative for net exports. The derivative $G_v(P,V)$ is the shadow price of the $v$'th factor, equal to its market price in a competitive economy with no externalities.

We next note from (1) that a change in the effective land area is equal to the appropriately weighted sum of changes in the physical land endowment, land use in the erosive activity, and management practices:

(4) $$dT^* = AdT + TA_1dR + TA_2dM.$$

Substituting this expression into (3) and for simplicity holding other factor endowments constant yields an expression for the real income impact of price, endowment and factor productivity changes:

(5) $$dY = -H_p dP + G_t(AdT + TA_1dR + TA_2dM).$$

Equation (5) shows that in the present context four types of change contribute to observed aggregate real income growth: (i) price changes, including the effects of exogenous terms of trade or price policy shocks; (ii) changes in the value of the land endowment due to area growth; (iii) erosion-related changes in agricultural land productivity; and (iv) exogenous increases in land productivity due to technical progress and improved management practices.

Equation (5) captures in the simplest way the distinction between models assuming free disposal and those that value externalities. $R$ is a function of relative commodity price changes which induce shifts in land allocation between more and less erosive crops. If free disposal is assumed, $A_1=0$ by construction. A shift to more erosive land uses is interpreted as unambiguously welfare-increasing as long as it increases conventional measures of national income. In contrast, with $A_1<0$, reallocations of land alter average soil fertility, and thus influence real income in the current period.

In general equilibrium, commodity prices themselves may be determined at least in part by supply and demand shifts in the domestic economy.[3] Price endogeneity is an important consideration when the agricultural sector is large in relation to factor and product markets, trade, household expenditures or government revenues. This is especially true of staple grains in the Philippines, where since 1950 a state trading monopoly has insulated domestic prices from world market fluctuations. While domestic price trends follow those in world markets in the long run, there have been substantial short and medium term deviations from those trends (Intal and Power 1990; Boyce 1993). Similar arguments for a general equilibrium approach apply in factor markets.

For example, the marginal value product of land depends not only on commodity prices but also on prices of other inputs, such as labor. Economic changes that alter relative factor prices outside agriculture may thereby cause reallocation of agricultural land towards crops intensive in the use of relatively less expensive inputs.

In our simulation analysis below we will maintain the restriction that rates of technical progress and land management practices are exogenous, but that changes in land allocation to different crops (and in some cases total land area) are responsive to changes in commodity and factor prices. Even with these restrictions, the environmental, distributional and welfare implications of a given exogenous change cannot easily be predicted *a priori*, because prices, incomes and the allocation of land to soil quality-degrading uses are all simultaneously determined. This suggests that policy makers focusing on sector-specific solutions to the land degradation problem may be overlooking some important indirect sources of change in agricultural resource allocation originating in non-agricultural sectors. Conversely, policies addressing non-environmental goals may have environmental implications. We explore both of these points in more detail in the simulation experiments.

## Modelling land degradation in APEX

Our approach to modelling land degradation focuses on accounting for changes in soil fertility associated with changes in upland land use and technology, rather than attempting to model physical shifts in production functions. By linking erosion changes to estimated costs of soil nutrient replacement, we construct an estimate of on-site erosion costs associated with broad changes in (or expansion of) upland activities.

We begin by defining total upland erosion for each region (Luzon, Visayas, Mindanao) as the sum of erosion losses generated in each of the twelve sectors producing agricultural goods:[4]

(6) $$E_r = \sum_i E_{ir}, \qquad i \in APG,\ r \in REG,$$

where *APG* is the set of agricultural producer goods, and *REG* the set of regions. Converting (6) to proportional changes of variables, we obtain an expression for the total regional change in upland erosion as the share-weighted sum of changes in each sector, the weights being each sector's contribution to total regional erosion in the reference year:

(7) $e_r = \sum_i e_{ir}\alpha_{ir}$ $\quad i \in APG,\ r \in REG.$

where $\alpha_{ir} = E_{ir}/E_r$, and use of lower-case indicates the proportional change in a variable, i.e. $e = dE/E$. Each crop grown in each region is associated with a specific rate of soil degradation. When this rate remains constant (in terms of equation (4), when d$M$=0), the proportional change in the amount of erosion produced in sector $i$ is linearly related to the change in land use ($t^{(1)}_{ir}$) in that sector:

(8) $e_{ir} = t^{(1)}_{ir}$ $\quad i \in APG,\ r \in REG.$

In the APEX data base, land and other factors used in agriculture are non-allocable between sectors (see Clarete and Warr, forthcoming). Therefore, we cannot read sectoral land use changes directly from the model results. Instead, we calculate them by imputing a land demand function equivalent to the demand functions for allocable inputs in non-agricultural industries. In this function, at constant relative factor prices changes in the demand for land are linearly related to changes in sectoral output. Factor price changes modify this demand, to an extent governed by the degree of each factor's substitutability with land. In proportional change form:

(9) $t^{(1)}_{ir} = x^{(0)}_{ir} + \sum_{v \in RA} \delta_{vir} w^{(1)}_{vr} - z^{(0)}_{ir}$ $\quad i \in APG,\ v \in RA,\ r \in REG,$

where $\delta_{vir} = \sigma^{(1)}_{ir}\theta_{vir}$ for each non-land agricultural factor $v$; $\delta_{vtr} = -\sigma^{(1)}_{ir}(1 - \theta_{vtr})$ for land; $\sigma^{(1)}_{ir}$ is the CES elasticity of factor substitution in sector $i$ and region $r$, and $\theta_{vir}$ is the distributive share of factor $v$ used in agricultural sector $i$ and region $r$. [5,6] The variable $z^{(0)}_{ir}$ is the rate of output-augmenting technical progress for sector $i$ in region $r$. Land use changes may take place either through changes in derived demand via changes in sectoral output, or through changes in factor prices and hence substitution of land for other factors used in the sector, or because technical progress reduces land demand for a given level of output. If there is no change in land use in an erosion producing sector then that sector's production of erosion will remain at the base level.

Finally, the national-level change in erosion ($e$) is a weighted sum of regional erosion changes, where weights are regional shares of erosion for the reference year:[7]

(10) $$e = \sum_{r \in REG} \lambda_r e_r,$$

where $\lambda_r = E_r/E$, and $E$ is the base value of the national aggregate erosion rate, measured in tons per year.

To implement the land degradation accounting described by equations (6) - (10) we require estimates of the crop and region erosion weights $\alpha_{ir}$ and $\lambda_r$. All other data are drawn from the APEX database. Table 1 contains our estimates of land use in Philippine uplands. Using these together with data on annual soil loss per hectare associated with these uses (Table 2), we compute total soil loss for each category of upland land use at two slope classifications (Table 3). We allocate these across regions using regional shares of agricultural land use by crop. Final values of $\alpha$ and $\lambda$, calculated from the data in Tables 1-3, are presented in Table 4. Our computation of erosion rates in corn and upland rice takes account of the existence of annual crop-fallow systems in uplands characterized by very high erosion rates during periods of cultivation, followed by declining rates as the length of the fallow increases (for details see Appendix C). For implementation in the model we use estimates only for upland rice and upland corn, ignoring erosion changes associated with land of less than 18% slope, and other forms of agricultural and non-agricultural activity which can not be reliably linked to sectoral output changes in APEX.

## III Simulation Experiments

In this section we report the results of two simulation experiments conducted with the APEX model, extended as described above.[8] In both experiments we assess the environmental consequences (as captured by changes in on-site agricultural land degradation) of exogenous changes affecting production and demand for rice and corn. We first investigate the environmental effects of technical progress in corn, a major crop in upland and rainfed areas. Second we study the environmental implications of a demand shock in the form of a capital subsidy in the grain milling sector. The policy setting of these experiments is a long-standing Philippine government goal of promoting domestic staple grain production while simultaneously subsidizing consumer grain prices. On the supply side, the government has subsidized R&D and extension efforts aimed at increasing productivity in grain production. On the price and marketing side, a government agency has controlled international trade and intervened in domestic markets in efforts to defend legislated price bands, as discussed below.

Closure: the policy setting

Alternative macroeconomic closure rules are possible in APEX, and in these experiments we employ three. These share some characteristics: international prices of imports and exports are exogenously fixed (the small country assumption); the nominal exchange rate is also fixed, providing a *numeraire* for domestic prices. The current account, budget deficit and real savings of households are also fixed, so the effects of exogenous shocks are fully absorbed by current-period changes in real household expenditures. The closures differ in their characterizations of two markets: that for land, and that for grains and grain products.

In the first closure the quantity of agricultural land is fixed and its price is determined by changes in agricultural profitability. Grain prices are endogenous, trade in rice and corn is unrestricted (although the government levies *ad valorem* tariffs on imports), and government grain demand is exogenously fixed. Given its characteristics, we denote this as the *unrestricted* closure.

In the second and third closures we impose a different set of rules on the markets for grains and grain products. Erosion in Philippine agriculture is largely associated with production of rice and corn in rainfed and upland areas, and the government has historically exerted broad influence on grain prices and demand. Our choices are motivated by the need to capture the effects of these interventions. Before describing the second and third closures, we present some some historical information on grain market policies.

Since 1950 international trade, retail prices, and some storage and processing of rice, corn and wheat in the Philippines have been administered by the body now known as the National Food Authority (NFA). The NFA's main objective is to maintain price and supply stability, although promoting distributional equity has always been seen as an underlying goal. The NFA strives to support prices paid to rice and corn farmers whilst supplying urban consumers with cheap staples (Intal and Power 1990; Boyce 1993). Its instruments have included a monopoly on international trade, nominal consumer price controls, and fixed capital, including facilities for the purchase, milling and storage of rice and corn. Imports and changes in the NFA's domestic stocks have been used to defend legislated producer price floors and consumer price ceilings. The NFA's activities are not self-financing; the agency is supported by Philippine government subsidies.[9]

Given these subsidies, the NFA has been reasonably successful in defending consumer price targets. Producer prices, however, have consistently fallen below the NFA floor during periods of rapid agricultural productivity growth, in spite of massive NFA stockpiling (Lantican and Unnevehr 1987).[10] Another side-effect of domestic interventions has been low private profitability in the grain milling and storage. The NFA has used its subsidy to finance a low or negative net margin between producer and consumer prices. This strategy has discouraged private entry and investment in grain milling, and at times has led the government to offer countervailing subsidies to help restore profitability in the sector.

To capture these features within the APEX model we adopt the following modifications to the unrestricted closure described above. We fix rice and corn imports exogenously,[11] and make government purchases of the output of the rice and corn milling sector endogenous. With these changes there is no endogenous trade in rice and corn, so when domestic supply increases more rapidly than demand the excess is bought and stockpiled by the government at a fixed price. As a result nominal consumer prices of cereals are also fixed. Producer prices of palay and corn are influenced, although not exclusively determined, by demand from the rice and corn milling sector, from which the government makes its grain purchases. In the APEX data base the rice and corn milling sector accounts for about 75 per cent of grain purchases from agriculture.

The second and third closures both employ this representation of grain markets. They differ in that the second closure holds total agricultural land area fixed, while in the third closure some land may be brought into or removed from production as agricultural profitability changes.

We name the second closure *NFA-fixed land* and the third *NFA-fallow*. Table 5 summarizes the key features of the three closures.

Technical progress in rainfed crops

In the *1991-95 Philippine Agricultural Development Plan* (Department of Agriculture 1990), domestic corn production was targeted to grow by 5.71 percent per year from 1991-95. Support for this growth was to be provided through a combination of price supports and technical assistance to corn farmers (*ibid.*). The projected growth rate is consistent with the 1950-85 average of 5.8% per year (Intal and Power 1990). Historically, however, more than two-thirds of this growth has come from increases in corn area, and only about one third from yield growth (*ibid.*). Even if half the targeted growth were realized through higher yields (implying a historically high rate of technical progress for Philippine corn), the plan would still require corn area to expand by about 16% over the five year period. Corn production is one of the most erosive agricultural uses of sloping land in the Philippines (David 1988), so the area expansion, if it occurred, would imply a significant increase in total agricultural land degradation.

What economic and environmental effect would be achieved by technical progress in corn production? In our first experiment we simulate a 10% rate of factor-neutral technical progress in this sector. Initially we assume that resulting economic and environmental changes in corn production, demand and price are determined independently of government interventions - we adopt the *unrestricted* closure. We then compare the results with those from the two alternative characterizations of grain and land markets.

Key results of the experiments are summarized in Appendix A, table A-1 and table 6. Column 1 of table A-1 shows the results of technical progress in the unrestricted closure. These show that a 10% increase in the rate of technical progress in corn leads to a less than proportional increase in output (1.9%). Grain imports also decline: rice by 10.5% and corn by 3.7%. These are the expected outcomes given that demand for corn is very income-inelastic (it is regarded as an inferior good by most Filipinos); the productivity gain results not in increased demand but in a substantial price drop (23%). As a result, technical change causes resources to be drawn out of corn production. Imputed regional land demand for corn production falls by 3-6% (Table 6).

Since erosion rates in corn are higher than in other crops, the extent of the price decline thus creates a somewhat surprising environmental result: land degradation rates drop substantially, by an average of 4.3 per cent over all regions. By region, the decline is greatest (5.5%) in Mindanao, where corn occupies about 41% of agricultural land, and smallest in Luzon, where it occupies 18%. In the Visayas corn is initially grown on 32% of agricultural land and erosion declines by an intermediate amount (3%). Technical progress in corn appears to have had a beneficial impact on agricultural land degradation.

Assuming free disposal (as in the standard APEX structure), aggregate real household consumption rises by 1.5 per cent (table A-1). Since land degradation also declines, our results show that technical progress in corn also increases the extended definition of aggregate welfare shown in equation (5). However the distributional effect of this change is regressive, even as average real consumption rises. We return to this subject below.

These results assume that the corn price decline produced by the technical progress shock does not trigger action aimed at supporting producer prices. Price supports could dilute and perhaps reverse our corn production and land degradation results. We examine this contention by repeating the technical change experiment using the policy-distorted NFA closures.

The second columns of table A-1 and table 6 report the effects of technical progress in rainfed crops with the NFA-fixed land closure. As expected, more elastic demand for the output of the rice and corn milling sector, the major purchaser of palay and corn, dampens the price-reducing effect of the technical change. The producer price decline (-19.5%) is only 85% of that observed in the unrestricted closure. Corn output thus rises by more (3.7% as opposed to 1.9%); less land is drawn out of corn production, and erosion declines by smaller amounts in each region. At -3.6%, the national average erosion decline is only 84% of that observed in the first experiment.

The additional resources attracted into rice and corn production contribute to modest declines or reduced growth rates in the output of services, natural resources and manufacturing sectors, and boost agricultural processing industries. However, it is on the consumer side of the economy that the NFA intervention is most strongly felt. With price supports in place, consumer prices of cereal products decline by 1.5% relative to the CPI. The relative distribution of gains and losses among households remains similar, but the aggregate welfare gain from the technical progress, 0.9%, is only two thirds of that indicated in the unrestricted case. One reason is that in order to finance its cereals purchases and maintain budget balance, the government must increase revenues, which it does (in this closure) by means of a lump-sum tax on all households. Another reason is that the price supports increase the relative profitability of production in corn, a sector already characterized by large distortionary interventions, and reduce it in less protected sectors such as export agriculture. The price supports thus increase deadweight losses to the economy as the productivity of corn production increases.

Part of the reallocation of land is an artefact of the assumption that total land area remains fixed. An expansion or contraction of corn land demand due to technical progress must be matched by a corresponding contraction or expansion of land used for other crops to preserve a constant total land area. Empirically, it is much more likely that some of the land used for corn production is of such low quality that farmers reducing their corn acreage will allow the land to revert to fallow rather than plant new crops. The 1980 Census of Agriculture reported about 7% of arable land as fallow in the Philippines.

The third column of results in table A-1 and table 6 shows how our technical progress results are modified when we fix the nominal return to agricultural land and allow the area to adjust endogenously. In table 6 we see that some of the land removed from corn production is fallowed (about 2% averaged over all regions), and that land use and output growth in other agricultural sectors is correspondingly lower. As a result of the removal of some land from production, aggregate erosion declines much more rapidly than in the fixed land case. Other results are broadly comparable between the two NFA closures, except that when land area is endogenous, measured real GDP and welfare increase by less; some resources are taken out of production rather than being reallocated to other uses within the agricultural economy.

The two NFA closures provide in some sense upper and lower bound estimates of the predicted change in erosion. The NFA-fixed land closure overstates farmers' capacity to adjust the agricultural land area. The NFA-fallow closure assumes land can be brought into production at zero cost, and thus probably understates the constraints to expansion at the cultivated margin. When fallow area is increasing, as in the technical change experiment, the NFA-fallow closure is likely to be more representative of actual Philippine conditions than either of the other closures.

Regardless of the structure of the domestic cereals market, the inelasticity of domestic corn demand sets corn producers experiencing technical progress on a 'technological treadmill' in which productivity gains are more than offset by terms of trade losses. As long as land can be reallocated to less erosive uses (including fallow), this inelasticity clearly has positive environmental implications. NFA-type interventions in cereals markets do little to improve the distribution of real household expenditures, and also impose substantial costs on the entire economy. In environmental terms, to the extent that the price supports insulate upland farmers from endogenous terms of trade effects, these interventions reduce somewhat the probability of significant environmental gains from technical progress in the corn sector.

A capital subsidy for the rice and corn milling sector

In our second experiment we examine the economic and environmental effects of a subsidy on variable capital used in the rice and corn milling sector. This policy captures a key aspect of Philippine government support for grain milling, storage and marketing industries. Until the late 1980s private grain mills were eligible for subsidized capital (Intal and Power 1990, Table 2.6) in order to compensate for restrictions on the sale price of milled grains and for competition from the NFA, which engaged in loss-making marketing, processing and storage of grains, subsidized from the central government budget.

The experiment consist of a 15 percentage point subsidy on the rate of interest paid by the rice and corn milling sector. Since prevailing bank lending rates in the early 1990s averaged around 18-20 per cent per year, the subsidy grants loans to the targeted sector at a nominal interest rate of 3-5% (or a real rate of -5 to -7%).

Table A-2 provides a general summary of the results, and table 7 shows land use and erosion changes caused by the subsidy.[12] In the unrestricted closure, the subsidy has minimal impact on intersectoral resource allocation; even the output of the targeted sector itself rises by only one quarter of one percent. Producer prices and the domestic supply of rice and corn and production rise very slightly; imports also increase. Land use in agriculture, and thus land degradation, hardly change. Instead, the subsidy is passed on to consumers: the price of the rice and corn milling sector's output declines by almost two per cent. The most notable features of the grain milling subsidy subsidy in the unrestricted closure are that it produces a modest aggregate welfare gain and has a progressive impact on the distribution of real household expenditures.

In the presence of the NFA interventions this subsidy has a much greater impact. The experiments using NFA closures show the subsidy achieving its goal of increasing the activity level in the rice and corn milling sector. Producer prices of grain rise as a result of increased demand. With the NFA intervention maintaining constant consumer prices of cereals the subsidy still promotes a more equal distribution of real expenditures. However, these distributional gains are secured at some cost in terms both of overall welfare and, less obviously, in terms of increased rates of environmental degradation.

In the NFA closures the results with fixed agricultural land area show that an expanding grain milling sector (the subsidy causes its output to rise by two per cent) increases derived demand for palay and corn. With imports fixed, production of these crops increases, by 1.5-1.7 per cent for rainfed and irrigated rice, and 1.1% for corn. This generates land use increases of 0.6-1.2% in rice and 0.2-0.5% in corn, producing modest increases in the production of soil erosion. However, these are lower bound estimates, given that total agricultural area remains unchanged by the shock. When we permit fallow land area to change endogenously, the magnitude of the agricultural supply response to the subsidy increases (by about one fifth relative to the fixed land case), and land use in corn and rice expands by much more. Erosion increases accordingly, by a national average rate of 1.4%.

The results of this experiment illustrate how an intervention addressing a policy goal in a non-agricultural sector can impact on agricultural land degradation. When prices and trade are flexible the subsidy has little economic impact. In the presence of existing NFA interventions, however, it induces a more substantial response. If we assume free disposal then the modest welfare losses (conventionally measured) attributable to this intervention in the NFA closures might be thought bearable in the light of the policy's redistributive impact, or its promotion of a strategic industry. However, increased land degradation is an unavoidable outcome. Finally, it should be recalled that the initial motivation for the subsidy was a perceived need to compensate for the effects of other policy distortions in the grain milling sector, and that these policies too appear to cause increased land degradation. In addressing a policy distortion with an additional distortionary policy, it appears that the government exacerbates the degradation of its agricutural land resource.

## IV Discussion

Valuing Changes in Soil Erosion

We now locate the results our experiments in a wider economic and welfare context by applying monetary values to the land degradation changes predicted by the model. Complete valuation of these effects, as with most environmental damages, is problematic. In the case of soil erosion, a full valuation is extremely difficult because many off-site damages evolve slowly over time. Downstream damages may also be offset in some situations by downstream benefits -- as when soil deposition increases fertility on lowland farms -- but these are widely regarded as small in relation to the damage costs of erosion. In this study we have maintained a conservative stance by accounting for on-site losses only, and by considering changes in erosion over base levels for two upland activities only: rainfed rice and corn. Combined, these sectors account for roughly 42 percent of land area in Philippine uplands, but over 90 percent of upland agricultural soil loss (Table 4).

We calculate the aggregate value of changes in land degradation (*D*) by the following formula:

(11) $$D = e \cdot E \cdot P$$

where $P$ is the annual estimated value of erosion (per ton), and $E$ and $e$ are initial aggregate erosion and its proportional change as defined in equation (10). Since the erosion estimates provided by the simulations are expressed as percentage changes over a base level, we combine the base estimates of soil loss (the central figures in Table 3) with the model's estimates of percentage changes in erosion to calculate total soil losses. Combining figures for rice and corn lands at all slopes over 18 percent provides an estimate of $E$ of 478 million tons of soil loss per year. For valuations we rely on the most thorough study of erosion costs in the Philippines to date, that of Cruz, Francisco, and Tapawan-Conway (1988). Using experimental plot data from the Magat and Pantabagan watersheds of Luzon, these authors computed losses from erosion for three critical soil nutrients.[13] We adopt their cost estimate of nutrient loss of P 15.46 ($0.60) per ton of eroded soil, a figure which is derived from losses in the Magat watershed. Substituting this value into equation (11) yields the aggregate costs and savings reported in the initial rows of Table 8.

The first of our simulation experiments produces a reduction in land degradation, as land formerly used to grow erosive cereal crops is switched into other uses, including fallow. Depending on the closure, the reduction in land degradation produces gains (or rather, reduced losses) to the economy of $US10-17 million. While amounts are small in relation to total GDP, they represent approximately 0.3 percent of value added in agriculture. They are equal to approximately 4% of government expenditures on agriculture and about one-fifth of the 'environment' component of the Department of Agriculture budget. The reductions in land degradation losses are large relative to the GDP growth gains predicted to occur as a result of the technical progress shock.

The grain milling subsidy produces small increases in erosion. Using the same valuation we calculate the value of additional land degradation losses attributable to the effects of the subsidy at $US1 million when land area is fixed, and $US3.9 million when it is endogenous. These are environmental losses over and above the declines in conventional welfare measures.

We have used the best available estimates of erosion rate and nutrient replacement costs in these calculations. Nevertheless, there is still considerable uncertainty about the true values of these parameters. We have recalculated the value of changes in land degradation under alternative parameter values, varying annual erosion losses by 25% and nutrient replacement costs by 50%. The results of this sensitivity analysis are shown in Table A-3.

In the technical change experiment, the value of reduced land degradation losses under three alternative closures and nine combinations of parameter values (27 estimates in all) ranges from a low of $US3.9 million up to $US32 million. In the case of the grain milling subsidy, the value of increases in land degradation in the NFA closures ranges from $US380,000 to $US7.3 million. In the NFA-fallow closure, which we regard as most representative of Philippine conditions, the lowest estimate is $US1.5 million.

Income Distribution and Land Degradation

As we noted earlier, an important role for the NFA has been to promote a more equal distribution of income in the Philippines by supporting producer prices and containing consumer prices of staple foods. Empirically, however it has had relatively little sucess in sustaining producer prices during periods of rapid agricultural growth. Its impact on the distribution of the gains from economic growth has thus been slight, as can be seen by comparing distributional changes across closures in tables A-1 and A-2. Our first experiment shows that in spite of extensive government stockpiling, the distributional impact of technical change in corn remains highly regressive. Moreover, the modest compression of the distribution of real household expenditures that the NFA intervention does achieve is won at the cost of a reduced gain in overall economic welfare. In addition the grain market interventions diminish some of the beneficial environmental impacts of the productivity growth.

In the capital subsidy experiment also, few differences arise in distributional outcomes as the results of NFA intervention; the welfare cost of the agency's activities is relatively high; and once again the environmental impact of the trade ban and price support scheme is negative.

## V Conclusion

Our analysis in this chapter highlights the importance of general equilibrium linkages for assessments of the environmental impacts of economic change. Environmental outcomes are determined by price-induced changes in factor use and allocation. Policy interventions in support of trade policy or distributional goals may create environmental 'surprises' as agricultural resource allocation and land use adjusts to new commodity price ratios and sectoral terms of trade.

In terms of the overall costs of upland soil erosion in the Philippines, our approach provides very conservative estimates. We ignore all off-site effects, and in constructing our data base have consistently chosen 'low' estimates when parameter values are uncertain. Sensitivity analysis with respect to the structure of key factor and commodity markets, and also with respect to the values of key parameters, indicate the value of changes in land degradation to be large under a wide range of assumptions.

Our results indicate that not all forms of agricultural growth need lead to increased agricultural land degradation. In the Philippines, investment in technical progress in corn -- a relatively erosive crop characterized by inelastic demand -- results in reduced corn area and thus less land degradation, as long as the gains from the productivity growth result in lower producer prices. The gain is also regressive, but only in the sense that the real expenditures of the poor rise less rapidly than those of the rich. In such circumstances the NFA's interventions are likely to have only modest success in supporting producer prices, to have little ameliorative impact on income distribution, and may also diminish the environmental benefits of the productivity gain. Finally, in the absence of substantial technical progress in corn - the more likely case in the Philippines - a subsidy compensating grain millers for profitability losses caused by NFA interventions reduces the welfare of all groups, and in addition promotes more rapid agricultural land degradation.

**References**


Boyce, James K. 1993. *Growth and Impoverishment in the Marcos Era.* Manila: Ateneo de Manila University Press.

Clarete, Ramon L., and Peter G. Warr. 1995. The Theoretical Structure of the APEX Model of the Philippine Economy. In P.G. Warr (ed): *Applied General Equilibrium Analysis of Agricultural Policy: The Philippines* (forthcoming).

Coxhead, Ian, and Sisira Jayasuriya. 1994. Technical Change in Agriculture and the Rate of Land Degradation in Developing Countries: A General Equilibrium Analysis. *Land Economics.* 70(1):20-37.

Coxhead, Ian, and Sisira Jayasuriya. 1995. Trade and Tax Policies and the Environment in Developing Countries. *Amreican Journal of Agricultural Economics*, November (in press).

Cruz, Wilfredo, H. Francisco and Z. Tapawan-Conway. 1988. *The On-site and Downstream Costs of Soil Erosion.* Manila: Philippine Institute for Development Studies, PIDS Working Paper no. 88-11.

David, Wilfredo P. 1988. Soil and Water Conservation Planning: Policy Issues and Recommendations. *Journal of Philippine Development.* 15(1):47-84.

Edwards, Sebastian, and Sweder van Wijnbergen. 1987. Tariffs, the Real Exchange Rate, and the Terms of Trade: On Two Propositions in International Trade. *Oxford Economic Papers*. 39:458-64.

Hazilla, Michael, and Raymond J. Kopp. 1990. Social Cost of Environmental Quality Regulation: A General Equilibrium Analysis. *Journal of Political Economy*. 98(4):853-873.

Intal, Ponciano S. and John H. Power. 1990. *Trade, Exchange Rate, and Agricultural Pricing Policies: the Philippines*. Washington, DC: The World Bank.

Kokoski, Mary F. and V. Kerry Smith. 1987. A General Equilibrium Analysis of Partial Equilibrium Welfare Measures: The Case of Climate Change. *American Economic Review*. 77(3):331-341.

Lantican, F.A. and L. J. Unnevehr. 1987. Rice Pricing and Marketing Policy. Ch. 2 in UPLB Agricultural Policy Working Group: *Policy Issues in the Philippine Rice Economy and Agricultural Trade*. College, Laguna: University of the Philipppines at Los Banos, Center for Policy and Development Studies. pp.31-72.

Lynch, Owen. 1986. " " In S. Fujisaka, et al. (eds.). *Man Agriculture and the Tropical Forest: Change and Development in the Philippine Uplands*. Bangkok: Winrock International Institute for Agricultural Development.

Philippine Department of Agriculture. 1990. *Philippine Agricultural Development Plan 1991-1995*. Manila: Philippine Department of Agriculture.

Repetto, Robert, et al. 1989. *Wasting Assets: Natural Resources in the National Income Accounts*. Washington, DC: World Resources Institute.

Ruthenberg, Hans. 1980. *Farming Systems in the Tropics*. Oxford: Clarendon Press.

Shively, Gerald E. 1995. Do Farmers Really Underinvest in Soil Conservation? Theory and Evidence from an Upland Area of Davao del Sur, Philippines. SEARCA-UQ Uplands Research Project, Working Paper No. 5. Los Banos.

Tropical Science Center and World Resources Institute. 1991. *Accounts Overdue: Natural Resource Deprecation in Costa Rica.* Washington, DC: World Resources Institute.

Warr. Peter G. (ed). Forthcoming. *Applied General Equilibrium Analysis of Agricultural Policy: The Philippines.*

Warr, Peter G., and Ian Coxhead. 1993. The Distributional Impact Of Technical Change In Philippine Agriculture: A General Equilibrium Analysis. *Food Research Institute Studies* XXII (3), pp.253-274.

World Bank. 1989. *Philippines Natural Resource Management Study.* Washington, DC: The World Bank.

World Bank. 1992. *The Philippines: Public Sector Resource Mobilization and Expenditure Management*. Washington, D.C.: The World Bank. Country Economic Report No. 10056-PH.

World Bank. 1994. *1994 World Development Report.* Washington, DC: The World Bank.

**Table 1: Land Use in the Philippine Uplands (hectares)**

| Land Use | Slope Category (%) 18-30 | 30+ | Total |
|---|---|---|---|
| Rice | 315,000 | 52,500 | 367,500 |
| Corn | 375,000 | 61,250 | 436,250 |
| Fallow | 3,970,000 | 1,540,000 | 5,510,000 |
| Other Agriculture | 592,000 | 96,250 | 688,250 |
| Non Agricultural (Forest) | - | - | 7,900,000 |
| All Uses | - | - | 14,902,000 |

Source: Based on data in World Bank (1989), Annexes 1-2.

**Table 2: Soil Loss for Various Land Uses and Slopes (Tons/Hectare/Year)**

| Land Use | Slope Category (%) 18-30 | 30+ |
|---|---|---|
| Rice | 50 | 100 |
| Corn with Fallow | 50 | 150 |
| Other Agriculture | 25 | 50 |
| Forest | 1 | 1 |

Source: Authors' estimates from secondary data. See Appendix C for details.

**Table 3: Estimated Total Soil Loss for Land Uses and Slopes (Tons/Year)**

| | Slope Category (%) | | |
|---|---|---|---|
| Land Use | 18-30 | 30+ | Total |
| Rice | 15,750,000 | 5,250,000 | 21,000,000 |
| Corn with Fallow | 217,250,000 | 240,190,000 | 457,340,000 |
| Other Agriculture | 14,800,000 | 4,812,500 | 19,612,500 |
| Non Agricultural (Forest) | - | - | 7,900,000 |
| All uses | - | - | 505,852,500 |

Source: Computed from data in Tables 1 and 2.

**Table 4: Weights Used in Estimates of Sectoral Erosion Shares**

| | Region | | |
|---|---|---|---|
| Sector Shares in Total Erosion ($\alpha$) | Luzon | Visayas | Mindanao |
| Upland Rice | 0.09 | 0.04 | 0.02 |
| Corn | 0.83 | 0.88 | 0.95 |
| Other Agriculture | 0.06 | 0.06 | 0.02 |
| Non Agricultural (Forest) | 0.02 | 0.02 | 0.01 |
| Regional Shares in National Erosion ($\lambda$) | 0.232 | 0.234 | 0.534 |

Source: Computed Table 3 and National Statistics Office: *Census of Agriculture.*

**Table 5: Key Features Of Three Alternative Closures.**

| Variable | Unrestricted | NFA-fixed land | NFA-fallow |
|---|---|---|---|
| *Land Market:* | | | |
| Agricultural land area | exogenous | exogenous | endogenous |
| Return to land | endogenous | endogenous | exogenous |
| *Grain Markets:* | | | |
| Rice and corn imports | endogenous | exogenous | exogenous |
| Rice and corn trade shifter | exogenous | endogenous | endogenous |
| Gov't purchases of RCM[a] | exogenous | endogenous | endogenous |
| User prices of RCM | endogenous | exogenous | exogenous |

[a] RCM = rice and corn milling sector.

**Table 6: Technical Progress in Corn Production: Effects on Agricultural Prices, Land Use, and Erosion**

| | | Closure | |
|---|---|---|---|
| | Unrestricted | NFA with fixed land | NFA with fallow land |
| *Regional land use changes* | | | |
| Luzon | | | |
| Irrigated palay | 4.09 | 5.57 | 2.92 |
| Non-irrigated palay | 0.34 | 1.51 | -1.01 |
| Corn | -2.98 | -2.50 | -4.78 |
| Coconut | 4.88 | 2.49 | 0.17 |
| Sugarcane | 4.62 | 2.37 | 0.04 |
| Visayas | | | |
| Irrigated palay | 3.61 | 6.04 | 5.94 |
| Non-irrigated palay | 1.27 | 2.63 | 2.63 |
| Corn | -3.47 | -2.94 | -2.59 |
| Coconut | 5.00 | 4.28 | 4.52 |
| Sugarcane | 4.40 | 3.56 | 3.78 |
| Mindanao | | | |
| Irrigated palay | 9.22 | 11.22 | 6.96 |
| Non-irrigated palay | -0.47 | 1.35 | -2.65 |
| Corn | -6.02 | -5.06 | -8.65 |
| Coconut | 6.49 | 3.90 | 0.07 |
| Sugarcane | 10.61 | 8.90 | 4.95 |
| *Regional fallow area changes* | | | |
| Luzon | 0.00 | 0.00 | 1.88 |
| Visayas | 0.00 | 0.00 | -0.19 |
| Mindanao | 0.00 | 0.00 | 3.14 |
| *Erosion Changes* | | | |
| Luzon | -2.75 | -2.34 | -4.46 |
| Visayas | -2.95 | -2.51 | -2.19 |
| Mindanao | -5.55 | -4.60 | -8.13 |
| Total | -4.29 | -3.59 | -5.89 |

**Table 7: Variable Capital Subsidy in Rice and Corn Milling Sector: Effects on Agricultural Prices, Land Use, and Erosion**

| | Closure | | |
|---|---|---|---|
| | Unrestricted | NFA with fixed land | NFA with fallow land |
| *Regional land use changes* | | | |
| Luzon | | | |
| Irrigated palay | 0.03 | 0.73 | 2.21 |
| Non-irrigated palay | 0.02 | 0.57 | 2.01 |
| Corn | 0.01 | 0.24 | 1.61 |
| Coconut | -0.13 | -1.27 | 0.09 |
| Sugarcane | -0.12 | -1.19 | 0.13 |
| Visayas | | | |
| Irrigated palay | 0.07 | 1.22 | 2.04 |
| Non-irrigated palay | 0.07 | 0.72 | 1.44 |
| Corn | 0.05 | 0.31 | 0.95 |
| Coconut | -0.09 | -0.44 | 0.26 |
| Sugarcane | -0.09 | -0.49 | 0.17 |
| Mindanao | | | |
| Irrigated palay | 0.03 | 0.98 | 2.23 |
| Non-irrigated palay | 0.01 | 0.88 | 2.08 |
| Corn | -0.01 | 0.45 | 1.56 |
| Coconut | -0.12 | -1.35 | -0.24 |
| Sugarcane | -0.12 | -0.94 | 0.15 |
| *Regional fallow area changes* | | | |
| Luzon | 0.00 | 0.00 | -1.06 |
| Visayas | 0.00 | 0.00 | -0.53 |
| Mindanao | 0.00 | 0.00 | -0.91 |
| *Erosion Changes* | | | |
| Luzon | 0.01 | 0.21 | 1.47 |
| Visayas | 0.04 | 0.26 | 0.87 |
| Mindanao | -0.01 | 0.45 | 1.53 |
| Total | 0.01 | 0.35 | 1.36 |

**Table 8 - Aggregate On-Site Costs of Erosion Based on APEX Experiments**

| | Experiment | | | | | |
|---|---|---|---|---|---|---|
| | Technical Progress in Corn | | | Variable Capital Subsidy in Rice and Corn Milling | | |
| | Closure | | | | | |
| | Unrest-ricted | NFA - Fixed | NFA-Fallow | Unrest-ricted | NFA - Fixed | NFA - Fallow |
| Percentage Change in Erosion | -4.29 | -3.59 | -5.89 | 0.1 | 0.35 | 1.36 |
| Total Change in Erosion (Million tons) | -20.5 | -17.2 | -28.2 | 0.48 | 1.67 | 6.51 |
| Total Savings (Cost) (million $US) | 12.3 | 10.3 | 16.9 | (0.3) | (1.0) | (3.9) |
| Savings (Cost) as % of 1991 GDP | 0.04 | 0.04 | 0.06 | (0.00) | (0.00) | (0.01) |
| Savings (Cost) as % of 1991 GDP change | 3.18 | 2.66 | 4.36 | (0.07) | (0.26) | (1.01) |
| Savings (Cost) as % of agricultural value added | 0.20 | 0.17 | 0.27 | (0.00) | (0.02) | (0.06) |
| Savings (Cost) as % of govt expenditures on agric. | 1.58 | 1.33 | 2.17 | (0.04) | (0.13) | (0.50) |
| Savings (Cost) as % of the environmental component of govt exp. on agric.[a] | 21.12 | 17.68 | 29.02 | (0.49) | (1.72) | (6.70) |

Base data from *Philippine Statistical Yearbook 1993* except [a] Pesos 1.4 billion at 1980 prices (David, Ponce & Intal 1993).

**Appendix Table A-1: Technical Progress in Corn Production: Summary of Macroeconomic Results**

| | Closure | | |
|---|---|---|---|
| | Unrestricted | NFA with Fixed Land | NFA with Fallow Land |
| A. Macro Results | | | |
| A.1 Overall Economy | | | |
| Gross Domestic Product | | | |
| Nominal (local currency) | 1.40 | 1.44 | 1.25 |
| Real | 1.21 | 1.05 | 0.90 |
| Consumer Price Index | -0.05 | 0.24 | 0.23 |
| GDP Deflator | 0.19 | 0.39 | 0.35 |
| A.2 External Sector | | | |
| Export Revenue (foreign currency) | 0.40 | 0.23 | 0.17 |
| Import Bill (foreign currency) | 0.38 | 0.22 | 0.16 |
| Trade Deficit (in levels, foreign currency) | 0.00 | 0.00 | 0.00 |
| A.3 Government Budget | | | |
| Revenue | | | |
| Nominal (local currency) | -2.47 | 0.49 | 0.76 |
| Real | -2.42 | 0.25 | 0.53 |
| Expenditures | | | |
| Nominal (local currency) | 1.37 | 3.55 | 3.06 |
| Real | 1.32 | 3.31 | 2.83 |
| Budget Deficit (in levels, local currency) | 0.00 | 0.00 | 0.00 |
| A.4 Household Sector | | | |
| Consumption | | | |
| Nominal (local currency) | 1.44 | 1.13 | 0.97 |
| Real | 1.49 | 0.88 | 0.74 |
| Savings (in levels, local currency) | 0.44 | 0.41 | 0.37 |

**Appendix Table A-1 (cont'd): Technical Progress in Corn Production: Summary of Sectoral Results**

| | Closure | | |
|---|---|---|---|
| | Unrestricted | NFA with Fixed Land | NFA with Fallow Land |
| B. Sectoral Results | | | |
| Commodity Supplies | | | |
| B.1. Industry Groups | | | |
| Primary Industries | 2.94 | 3.14 | 2.67 |
| Natural Resources | 0.25 | 0.03 | -0.02 |
| Agricultural Processing | 1.66 | 2.23 | 1.91 |
| Other Manufacturing | 0.17 | -0.06 | -0.07 |
| Services | 0.75 | 0.48 | 0.39 |
| B.2 Regional Composite Agricultural Outputs | | | |
| Luzon | -0.80 | 0.47 | 0.04 |
| Visayas | 2.69 | 3.08 | 3.41 |
| Mindanao | 1.50 | 2.14 | 0.97 |
| B.3 Specific Industries | | | |
| Output | | | |
| Irrigated palay | 2.32 | 5.37 | 4.67 |
| Non-irrigated palay | -2.87 | -0.19 | -0.79 |
| Corn | 1.89 | 3.69 | 3.17 |
| Coconut | 2.76 | 1.65 | 1.12 |
| Sugarcane | 1.99 | 1.43 | 1.11 |
| Banana and other fruits | 6.95 | 5.81 | 4.89 |
| Vegetables | 1.45 | 0.63 | 0.54 |
| Rootcrops | 1.42 | 0.68 | 0.57 |
| Other commercial crops | 4.17 | 3.78 | 3.30 |
| Hogs | 1.44 | 1.32 | 1.07 |
| Chicken and Poultry | 2.03 | 1.50 | 1.25 |
| Other Livestock | 1.88 | 1.48 | 1.23 |
| Prices | | | |
| Irrigated palay | -4.32 | 0.53 | 0.8 |
| Non-irrigated palay | -4.32 | 0.53 | 0.8 |
| Corn | -22.89 | -19.46 | -18.56 |
| Coconut | -3.35 | -2.22 | -1.6 |
| Sugarcane | -4.03 | -3.18 | -2.56 |
| Banana and other fruits | -2.5 | -2.21 | -1.87 |
| Vegetables | -4.41 | -3.44 | -2.51 |
| Rootcrops | -1.24 | -0.82 | -0.53 |
| Other commercial crops | -3.61 | -3.15 | -2.87 |
| Hogs | -4.79 | -3.35 | -2.63 |
| Chicken and Poultry | -5.11 | -4.14 | -3.49 |
| Other Livestock | -5.01 | -3.93 | -3.26 |

**Appendix Table A-1 (concluded): Technical Progress in Corn Production: Summary of Distributional Results**

| | Closure | | |
|---|---|---|---|
| | Unrestricted | NFA with Fixed Land | NFA with Fallow Land |
| C. Income Distribution Results | | | |
| C.1 Functional | | | |
| Nominal factor income changes | | | |
| HH1 (Poor) | -0.28 | 0.45 | 0.54 |
| HH2 | -0.06 | 0.58 | 0.64 |
| HH3 | 0.13 | 0.68 | 0.71 |
| HH4 | 0.33 | 0.78 | 0.78 |
| HH5 (Rich) | 1.55 | 1.44 | 1.24 |
| Real factor income changes (deflated by aggregate CPI) | | | |
| HH1 (Poor) | -0.23 | 0.21 | 0.31 |
| HH2 | -0.01 | 0.34 | 0.41 |
| HH3 | 0.18 | 0.44 | 0.48 |
| HH4 | 0.38 | 0.54 | 0.55 |
| HH5 (Rich) | 1.60 | 1.20 | 1.01 |
| C.2 Household | | | |
| Nominal household expenditure changes | | | |
| HH1 (Poor) | 0.32 | 0.53 | 0.56 |
| HH2 | 0.57 | 0.67 | 0.66 |
| HH3 | 0.78 | 0.78 | 0.74 |
| HH4 | 0.98 | 0.88 | 0.81 |
| HH5 (Rich) | 2.22 | 1.54 | 1.25 |
| Real household expenditure changes (deflated by aggregate CPI) | | | |
| HH1 (Poor) | 0.77 | 0.45 | 0.46 |
| HH2 | 0.93 | 0.57 | 0.55 |
| HH3 | 1.03 | 0.64 | 0.59 |
| HH4 | 1.11 | 0.68 | 0.62 |
| HH5 (Rich) | 2.05 | 1.19 | 0.94 |

**Appendix Table A-2: Variable Capital Subsidy in Rice and Corn Milling Sector: Summary of Macroeconomic Results**

| | Closure | | |
|---|---|---|---|
| | Unrestricted | NFA with Fixed Land | NFA with Fallow Land |
| A. Macro Results | | | |
| A.1 Overall Economy | | | |
| Gross Domestic Product | | | |
| Nominal (local currency) | -0.01 | -0.06 | 0.03 |
| Real | 0.07 | 0.00 | 0.07 |
| Consumer Price Index | -.18 | -0.03 | -0.03 |
| GDP Deflator | -.17 | -0.06 | -0.05 |
| A.2 External Sector | | | |
| Export Revenue (foreign currency) | 0.05 | -0.05 | -0.03 |
| Import Bill (foreign currency) | 0.04 | -0.05 | -0.03 |
| Trade Deficit (in levels, foreign currency) | 0.00 | 0.00 | 0.00 |
| A.3 Government Budget | | | |
| Revenue | | | |
| Nominal (local currency) | -0.59 | 0.77 | 0.65 |
| Real | -0.42 | 0.80 | 0.68 |
| Expenditures | | | |
| Nominal (local currency) | -0.17 | 0.87 | 1.11 |
| Real | 0.01 | | |
| Budget Deficit (in levels, local currency) | 0.00 | 0.00 | 0.00 |
| A.4 Household Sector | | | |
| Consumption | | | |
| Nominal (local currency) | -0.10 | -0.22 | -0.16 |
| Real | 0.08 | -0.19 | 0.13 |
| Savings (in levels, local currency) | -0.03 | -0.03 | -0.02 |

**Appendix Table A-2 (cont'd): Variable Capital Subsidy in Rice and Corn Milling Sector: Summary of Sector Results**

| | Closure | | |
|---|---|---|---|
| | Unrestricted | NFA with Fixed Land | NFA with Fallow Land |
| B. Sectoral Results | | | |
| Commodity Supplies | | | |
| B.1. Industry Groups | | | |
| Primary Industries | 0.11 | 0.21 | 0.43 |
| Natural Resources | 0.00 | -0.10 | -0.07 |
| Agricultural Processing | 0.09 | 0.36 | 0.52 |
| Other Manufacturing | 0.07 | -0.04 | -0.03 |
| Services | 0.05 | -0.08 | -0.03 |
| B.2 Regional Composite Agricultural Outputs | | | |
| Luzon | 0.14 | 0.74 | 0.99 |
| Visayas | 0.15 | 0.34 | 0.45 |
| Mindanao | 0.19 | 0.49 | 0.83 |
| B.3 Specific Industries | | | |
| Output | 0.24 | | |
| Irrigated palay | 0.22 | 1.68 | 2.03 |
| Non-irrigated palay | 0.23 | 1.50 | 1.81 |
| Corn | 0.10 | 1.08 | 1.25 |
| Coconut | 0.08 | -0.44 | -0.18 |
| Sugarcane | 0.15 | -0.20 | -0.02 |
| Banana and other fruits | 0.28 | -0.40 | -0.01 |
| Vegetables | 0.28 | -0.10 | -0.06 |
| Rootcrops | 0.06 | -0.06 | -0.02 |
| Other commercial crops | -0.07 | -0.12 | 0.07 |
| Hogs | 0.00 | -0.12 | 0.00 |
| Chicken and Poultry | -0.05 | -0.25 | -0.12 |
| Other Livestock | | -0.23 | -0.10 |
| Prices | | | |
| Irrigated palay | 0.10 | 2.41 | 2.25 |
| Non-irrigated palay | 0.10 | 2.41 | 2.25 |
| Corn | 0.07 | 1.71 | 1.4 |
| Coconut | -0.05 | 0.49 | 0.19 |
| Sugarcane | -0.05 | 0.36 | 0.02 |
| Banana and other fruits | 0.02 | 0.16 | 0.02 |
| Vegetables | 0.20 | 0.68 | 0.16 |
| Rootcrops | 0.14 | 0.36 | -0.04 |
| Other commercial crops | 0.07 | 0.28 | 0.18 |
| Hogs | -0.09 | 0.61 | 0.18 |
| Chicken and Poultry | -0.22 | 0.26 | -0.1 |
| Other Livestock | -0.19 | 0.34 | -0.04 |

**Appendix Table A-2 (concluded): Variable Capital Subsidy in Rice and Corn Milling Sector: Summary of Distributional Results**

| | Closure | | |
|---|---|---|---|
| | Unrestricted | NFA with Fixed Land | NFA with Fallow Land |
| C. Income Distribution Results | | | |
| C.1 Functional | | | |
| Nominal factor income changes | | | |
| HH1 (Poor) | -0.17 | 0.19 | 0.13 |
| HH2 | -0.18 | 0.14 | 0.09 |
| HH3 | -0.18 | 0.09 | 0.06 |
| HH4 | -0.18 | 0.05 | 0.03 |
| HH5 (Rich) | -0.18 | -0.21 | -0.12 |
| Real factor income changes (deflated by aggregate CPI) | | | |
| HH1 (Poor) | 0.00 | 0.22 | 0.16 |
| HH2 | -0.01 | 0.17 | 0.12 |
| HH3 | -0.01 | 0.12 | 0.09 |
| HH4 | -0.01 | 0.08 | 0.06 |
| HH5 (Rich) | -0.01 | -0.18 | -0.09 |
| C.2 Household | | | |
| Nominal household expenditure changes | | | |
| HH1 (Poor) | -0.09 | 0.03 | -0.01 |
| HH2 | -0.10 | -0.03 | -0.04 |
| HH3 | -0.10 | -0.08 | -0.08 |
| HH4 | -0.10 | -0.13 | -0.11 |
| HH5 (Rich) | -0.10 | -0.39 | -0.27 |
| Real household expenditure changes (deflated by aggregate CPI) | | | |
| HH1 (Poor) | 0.16 | 0.02 | 0.01 |
| HH2 | 0.13 | -0.03 | -0.03 |
| HH3 | 0.11 | -0.07 | -0.06 |
| HH4 | 0.08 | -0.11 | -0.08 |
| HH5 (Rich) | 0.05 | -0.34 | -0.22 |

**Appendix Table A-3: Sensitivity Analysis of Erosion Cost Estimates**

| | | Erosion Estimate | | |
|---|---|---|---|---|
| | | Low (-25%) | Medium | High (+25%) |
| Technical Progress in Corn, Unrestricted Closure | | | | |
| Replacement Cost Estimate | Low (-50%) | -4.61 | -6.15 | -7.69 |
| | Medium | -9.23 | -12.30 | -15.38 |
| | High (+50%) | -13.84 | -18.46 | -23.07 |
| Technical Progress in Corn, NFA Closure with Fixed Land | | | | |
| Replacement Cost Estimate | Low (-50%) | -3.86 | -5.15 | -6.44 |
| | Medium | -7.72 | -10.30 | -12.87 |
| | High (+50%) | -11.58 | -15.44 | -19.31 |
| Technical Progress in Corn, NFA Closure with Fallow Land | | | | |
| Replacement Cost Estimate | Low (-50%) | -6.33 | -8.45 | -10.56 |
| | Medium | -12.67 | -16.89 | -21.12 |
| | High (+50%) | -19.00 | -25.34 | -31.67 |
| Subsidy to Rice and Corn Milling, NFA Closure with Fixed Land | | | | |
| Replacement Cost Estimate | Low (-50%) | 0.38 | 0.50 | 0.63 |
| | Medium | 0.75 | 1.00 | 1.25 |
| | High (+50%) | 1.13 | 1.51 | 1.88 |
| Subsidy to Rice and Corn Milling, NFA Closure with Fallow Land | | | | |
| Replacement Cost Estimate | Low (-50%) | 1.46 | 1.95 | 2.44 |
| | Medium | 2.93 | 3.90 | 4.88 |
| | High (+50%) | 4.39 | 5.85 | 7.31 |

*Notes*: Central estimate of base level erosion is 473,340,000 tons per year.
Central estimate of nutrient replacement cost is $US0.60 per ton.

## Appendix B: The APEX Model of the Philippine Economy

APEX (**A**gricultural **P**olicy **Ex**periments) is an applied general equilibrium model of the Philippine economy developed in a collaborative venture by researchers at the Australian National University and the Philippine Department of Agriculture. APEX is a conventional, real, micro-theoretic general equilibrium model designed to address microeconomic policy issues for the Philippines. It belongs to the class of models (sometimes known as Johansen models) that are linear in proportional changes of variables. APEX shares many features with the well-known ORANI model of the Australian economy, but these features have been adapted to fit the realities of the Philippine economy. Input-output data in APEX are drawn from the Philippine Social Accounting Matrix. Unlike any other AGE model of comparable size, however, in APEX all parameters describing technology and preferences are constructed from original econometric estimates.

The model contains 50 producer goods and services produced in 41 industries. These are aggregated into seven consumer goods. There are five households, each representing a quintile of the income distribution and having unique income and consumption characteristics. Factor demands, aggregation of factors of different types, and consumer demands are all described by flexible functional forms. Imports and their domestically produced substitutes are aggregated using CES forms with econometrically estimated Armington elasticities. Other details of the model structure can be found in Clarete and Warr (1995), and some illustrative experiments and associated discussion in Warr and Coxhead (1993).

In APEX, agricultural production takes place in three regions (Luzon, Visayas and Mindanao) and produces a vector of intermediate and final consumption goods using land, unskilled labor and fertilizer inputs. Land is specific to agricultural uses, while the other inputs are not. Agricultural inputs are non-allocable due to data constraints, so the model cannot directly identify the quantity of each input used in the production of any individual agricultural output.

Within this structure some groups of goods are presumed to be jointly produced. One such group is the category "rainfed crops", which includes rainfed rice, corn, and root crops. We identify this sub-aggregate as the set of agricultural crops in which the potential for measurable soil fertility reduction through erosion can take place. Value-added in the rainfed crops sector is dominated by corn (60% of total value-added); rootcrops account for 28%, and rainfed rice 12%.

The joint production function for rainfed crops is nested within that for agriculture as a whole in each region. The composition of production within the rainfed crops sector is altered by changing relative prices of the three crops or by crop-specific technical progress. Similarly, the share of rainfed crops in total agricultural production depends on prices and rates of technical progress of the sub-aggregate relative to those of other agricultural sectors. Each of the three rainfed crops is classed as an importable in APEX, although in practice the shares of imports in total domestic availability are very small.

## Appendix C: Calculation of Average Annual Soil Loss by Crop

This appendix outlines the method used for calculating rates of soil loss reported in Table 2. Data on soil erosion under different crops and physical conditions in the Philippines are very scarce. We have used all available data in an effort to construct robust, yet empirically sound estimates of soil losses corresponding to the upland and rainfed crops in the APEX model.

We being with an expression for the erosion rate at time t ($E_t$) wherein erosion depends on five time subscripted factors: a ground cover index ($A_t$); a soil erodibility index ($K_t$); slope length ($L_t$); rainfall intensity ($R_t$); and slope steepness ($S_t$):

(C.1) $$E_t = E(A_t, K_t, L_t, R_t, S_t).$$

The expression in equation (C.1) closely parallels the static Universal Soil Loss Equation except that factors describing cropping practice and erosion control effort are replaced by a single ground cover index. We further simplify by assuming homogeneity in soil characteristics ($K$) and slope length ($L$). This permits use of empirical data on soil loss under annual crops from Philippine upland sites. These data are reported in David (1988) and World Bank (1989). With these simplifications, the erosion rate at any point in time is a function of soil cover, conditional on the rainfall index and slope:

(C.2) $$E_t = E(A_t,|R_t, S_t).$$

Table C-1 contains estimates of annual rates of soil loss for three categories of land use (annual crops, grassland, primary forest); two rainfall indices (120 and 250); and two categories of slope (18-30 percent and greater than 30 percent). David (1988) describes conversion of annual rainfall data to rainfall index values. Annual soil losses reported in Table C-1 range from less than one ton per hectare for primary forest on moderate slopes to more than 700 tons per hectare for annual crops on steep slopes with high rainfall. These estimates are similar to data from experimental plots in Mindanao that indicate cumulative soil loss of approximately 1000 tons per hectare over a five year period of continuous corn cropping at 18 percent slope (Shively 1995).

In our calculations, data constraints necessitate additional simplifications. First, we assume that any upland area that is not devoted to rice, forest, or other crops is part of a long-fallow corn rotation. That is, if at any point in time fallow land is brought into cultivation it brought into corn production. A twenty year rotation period characterizes the representative parcel, with corn occupying the land for the first five years, and the land reverting to fallow during the remaining 15 years. This is a very conservative estimate of land utilization: recent evidence from frontier areas of Mindanao and Palawan indicate that corn is typically cultivated for 5 to 10 years, and that fallow periods rarely exceed 5 years.

Consider the case in which the erosion relationship outlined above is unchanging over time and annual rainfall patterns and slope are constant. When ground cover is an increasing function of time since cultivation, cover is lowest and erosion is highest during the initial periods of corn cultivation. After land is converted to fallow it gradually becomes permanently vegetated. At the end of a 20 year rotation, ground cover is at a maximum. Since ground cover can be expressed as a function of time, erosion can be expressed as a function of time also, conditional on rainfall and slope. Over a cycle of T years, total cumulative soil loss is given by:

$$\text{(C.3)} \qquad \int_{t=0}^{T} E(t)dt = \int_{t=0}^{T} A(t|R,S)dt.$$

The maximum erosion rate ($E_{max}$) for a rainfall-slope pairing will correspond to annual crop cultivation. The minimum soil loss for an ($\boldsymbol{R,S}$) pairing ($E_{min}$) corresponds to primary forest. That is, $E(0)=E_{max}$ and $E(T)=E_{min}$.

The change in the rate of soil erosion over the cropping horizon can be described parametrically in several ways. Using a linear relationship, erosion is at a maximum during cultivation and subsequently declines linearly as ground cover increases (i.e., $E = E_{max} - \beta t$, where $\beta = (E - E_{max})/t$ is the average one-period reduction in erosion over the fallow horizon). However, erosion rates more typically decline rapidly once annual cropping is abandoned. For example, data corresponding to grassland (Table C-1) show that soil loss under grass cover is less than 2 percent of that under corn cultivation. For these reasons, estimates of average soil loss based on a linear rate of erosion decline are likely to be too high during the fallow period. A more realistic approach has the erosion rate constant during annual cropping and then declining rapidly in the first years of fallow as grasses and shrubs emerge. In later years, as secondary forest is established, the decline in erosion is less pronounced, asymptotically approaching the soil loss realization under full forest cover. Mathematically, a form such as $t^{-\beta}E_{max}$ with $\beta>1$ seems appropriate.

Assuming a uniform distribution of land allocations across the 20 year cycle, the data in Table C-1 are used with the linear and hyperbolic formulae (with $\beta = 2$) to derive the average erosion rate estimates in Table C-2. Erosion estimates associated with the linear reduction formula are presented in the first row of Table C-2. The linear case provides a rough upper bound on erosion rates. Erosion rates calculated using the hyperbolic formula appear in the second row of the table. These more conservative estimates are reported in Table 2, and are used in our APEX simulation experiments. Examples of the implied erosion rate trajectories are illustrated in Figure C-1. The figure corresponds to the low rainfall, moderate slope case.

Finally, erosion rate differences between rice and corn in Table 2 are based on the typical cropping patterns for these crops. Rice is usually planted once per year, and in many areas corn is planted twice. The more frequent soil disturbance associated with corn translates into higher erosion rates, especially on steeper slopes. Additional and more detailed estimates of rates and magnitudes of soil loss for the Philippines are provided by Cruz, Francisco, and Tapawan-Conway (1988).

**Table C-1: Annual Erosion Estimates (Tons/Hectare)**

| | Rainfall Erosivity Index | | | |
|---|---|---|---|---|
| | 120 | | 250 | |
| | Slope 18-30 percent | Slope Above 30 percent | Slope 18-30 percent | Slope Above 30 percent |
| Annual Crops | 189.1 | 352.3 | 394.8 | 734.0 |
| Grassland | 3.3 | 6.1 | 6.9 | 12.8 |
| Primary Forest | 0.5 | 0.9 | 1.0 | 1.8 |

Source: David (1988) and World Bank (1989) Annex 2, table 1.

**Table C-2: Estimated Average Annual Erosion in 20-year Corn-Fallow Cycle (Tons/Hectare)**

| | Rainfall Erosivity Index | | | |
|---|---|---|---|---|
| | 120 | | 250 | |
| | Slope 18-30 percent | Slope Above 30 percent | Slope 18-30 percent | Slope Above 30 percent |
| Linear | 115 | 200 | 235 | 440 |
| Hyperbolic | 50 | 100 | 110 | 200 |

Source: Computed by the authors.

**Figure C-1 - Erosion rate trajectory for the low rainfall, moderate slope case**

**Endnotes**

1 Soil depletion refers to physical loss of topsoil through erosion, while land degradation (used interchangeably with soil erosion in this chapter) denotes on-site fertility losses due to nutrient loss and damage to soil structure.

2 For simplicity we have assumed here that only one upland crop is erosive; a more general case (and that used in our applied work in Section III) relates the rate of land degradation to the erosivity of each crop grown and the area planted to that crop.

3 Technical progress in irrigated rice has in the past been a major source of relative agricultural commodity price fluctuations. These in turn have undoubtedly influenced upland farmers' resource allocation decisions, as discussed above and in Coxhead and Jayasuriya (1994).

4 Our analysis focuses on agricultural land degradation, and therefore takes no account of land degradation in mining, forestry, or other non-agricultural industries.

5 While the structure of the relationships in (9) allows for greater flexibility, we use a CES specification as a default, since we lack more detailed empirical information about sector-specific factor substitution relationships in agriculture.

6 In each region, the share-weighted sum of sectoral land use changes in (9) must equal the change in aggregate agricultural land area as determined elsewhere in the APEX model. To ensure this we drop one equation from (9) and replace it with an identity equating total regional land demand with the share-weighted sum of regional land use changes.

7 Our aggregation of soil erosion losses assumes that the value of a unit of soil lost has the same importance in all regions, i.e. that initial soil quality is equal in all regions.

8 Our simulations used the revised model version known as APEX II.

9 In the decade 1975-84, the NFA was the second-largest government corporation in terms of these transfers, after the Fertilizer and Pesticide Authority (Intal and Power 1990: Table 2.2). In 1986-90 it ranked first among subsidy recipients, receiving Pesos 2.6 billion ($US 100 million) or 24% of all government subsidy expenditures (Philippine DoF, reported in World Bank 1992:116).

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[10] In spite of this limited success, the nominal protection coefficient of corn in the Philippines has risen substantially over the past two decades (Intal and Power 1990).

[11] Trade volumes can only be fixed by setting some other variable endogenous. We have added a 'shifter' to the import demand equations which, when endogenous, permits us to fix imports without setting endogenous other trade related variables such as import tariffs.

[12] In the present structure of APEX it is assumed that all industries face equal interest rates on variable capital. We introduce a subsidy on this rate by amending equation 8.2 to read:

```
PRICEVCAP     (all,v,vcap) (all,j,nai)
        pfac_nai(v,j) = pvcap + tvc(j);
!8.2    price of variable capital (mobile across non-agricultural industries!
```

The new variable, tvc("varcap", j), is the proportional change in the power of a tax on variable capital used in sector *j*  Our experiment consists of an exogenous 15% reduction of this variable. Because the initial rate of the subsidy is zero, it does not appear among changes in the government budget. Our experiment therefore understates the budgetary cost of this policy, capturing outlays required to purchase excess milled grains supply, but not expenditure on the subsidy itself.

[13] The Magat and Pantabangan are two of the three major rivers rising in the Cordillera Mountains of Northern Luzon. Cruz, Francisco, and Tapawan-Conway (1988) provide kilogram per hectare estimates for nitrogen loss and urea equivalents; phosphorous loss and solophos equivalents; and potassium loss and potash equivalents. Few differences in soil nutrient content were found across soil types. Corresponding replacement costs for these nutrients were P11.09, P1.98, and P2.39 per kilogram, repectively. Note that these estimates, too, are conservative, as they account for losses from sheet erosion only, and neglect changes in economic yield associated with changes in soil structure.