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World Development Report

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Background paper for World Development Report 1992

Agricultural Pricing and Environmental Degradation

Edward B. Barbier
and
Joanne C. Burgess

Changes in pricing policies are not enough to encourage poor farmers to reduce resource degradation. Other approaches are also needed, such as providing better research and extension advice, improving property rights and management, and establishing more secure tenure or access rights. Just because we do not always understand the economic and social factors determining incentive effects does not mean they do not exist.

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This paper — a product of the Office of the Vice President, Development Economics — is one in a series of background papers prepared for the *World Development Report 1992*. The *Report*, on development and the environment, discusses the possible effects of the expected dramatic growth in the world's population, industrial output, use of energy, and demand for food. Copies of this and other *World Development Report* background papers are available free from the World Bank, 1818 H Street, NW, Washington, DC 20433. Please contact the *World Development Report* office, room T7-101, extension 31393 (August 1992, 17 pages).

The link between agricultural pricing and land degradation is often difficult to analyze empirically. Our understanding of how agricultural supply responds to changing prices in developing countries is incomplete. Even more incomplete is our analysis of subsequent impacts on the resource base sustaining agricultural production. Yet available evidence suggests that some important effects do exist, and much further analysis of them is warranted.

The social, economic, and environmental relationships that determine the often countervailing effects of price changes on land use and management are extremely complex. Not enough is know about:

- Farming systems in developing countries.
- Open-access use and common property resource rights.
- Land tenure regimes and security.
- Access to technology and other farming systems information.
- The distribution of wealth and income.
- Coping strategies for variable climatic, economic, and social conditions.

All these factors influence how rural households respond to price changes in terms of managing land and natural resources, and often they may override the incentive effects of price changes. Changes in pricing policies will then be less effective in "correcting" resource degradation than other approaches to dealing with its underlying causes. Such approaches include providing better research and extension advice, improving property rights and management, and establishing more secure tenure or access rights.

At the same time, it is wrong to assume that poor farmers — even those in resource-poor regions far from major markets — are totally isolated from agricultural markets. Virtually all subsistence households require some regular market income for cash purchases of agricultural inputs and basic necessities; many small farmers provide important cash and export crops. So changes in market prices often significantly affect the livelihoods of rural groups.

Clearly, the economic incentives emerging from these impacts will affect farmers' decisions to invest in land management and improvements. Just because we do not always understand the economic and social factors determining these incentive effects does not mean they do not exist. Nor should the complexity of the links between price changes and resource management — which sometimes appear counterintuitive — deter further analysis of the role of agricultural pricing in land degradation.

AGRICULTURAL PRICING AND ENVIRONMENTAL DEGRADATION

Edward B. Barbier and Joanne C. Burgess
London Environmental Economics Centre

Prepared as a Background Paper for the
World Development Report 1992

The World Development Report 1992, "Development and the Environment," discusses the possible effects of the expected dramatic growth in the world's population, industrial output, use of energy, and demand for food. Under current practices, the result could be appalling environmental conditions in both urban and rural areas. The World Development Report presents an alternative, albeit more difficult, path - one that, if taken, would allow future generations to witness improved environmental conditions accompanied by rapid economic development and the virtual eradication of widespread poverty. Choosing this path will require that both industrial and developing countries seize the current moment of opportunity to reform policies, institutions, and aid programs. A two-fold strategy is required.

• First, take advantage of the positive links between economic efficiency, income growth, and protection of the environment. This calls for accelerating programs for reducing poverty, removing distortions that encourage the economically inefficient and environmentally damaging use of natural resources, clarifying property rights, expanding programs for education (especially for girls), family planning services, sanitation and clean water, and agricultural extension, credit and research.

• Second, break the negative links between economic activity and the environment. Certain targeted measures, described in the Report, can bring dramatic improvements in environmental quality at modest cost in investment and economic efficiency. To implement them will require overcoming the power of vested interests, building strong institutions, improving knowledge, encouraging participatory decisionmaking, and building a partnership of cooperation between industrial and developing countries.

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Dennis Anderson, "Economic Growth and the Environment"

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Other (unpublished) papers in the series are available direct from the World Development Report Office, room T7-101, extension 31393. For a complete list of titles, consult pages 182-3 of the World Development Report. The World Development Report was prepared by a team led by Andrew Steer; the background papers were edited by Will Wade-Gery.

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I. Agricultural Prices and Production

Land degradation is a major problem facing developing countries. Nearly 80% of rangeland and dryland forest areas, 30% of tropical forests and around 50% of all irrigated cropland in developing countries are classified as degraded (Leonard et al., 1989). Much of this degradation is attributed to "unsustainable" agricultural practices, and to economic incentives for overexploitation (Barbier, 1991a). A key issue is the extent to which agricultural pricing policies in developing countries, by influencing farmers' production and land management decisions, are contributing to land degradation.

The direct effect of prices on agricultural production can, to some extent, be traced through to their indirect impact on the environment. Prices act as signals in the market place - indicating to consumers the costs of production, and to producers the consumers' valuation of the good or service. A profit maximizing farmer will produce crops up until the point where his or her private marginal costs of production equal his or her private marginal benefits of production. By affecting the returns from agriculture compared to those from other activities, agricultural input and output prices directly influence the farmer's choice of crop inputs and outputs, production systems, land investments, and the scale and extent of production. These production choices in turn determine the rate and scale of resource use, and the degree to which a farmer invests in land improvements and management.

As a result of these kinds of production decisions, there are essentially four ways in which agricultural pricing can impact on the environment:

- higher aggregate crop prices and lower agricultural input costs increase the profitability of crop production, thus encouraging an aggregate expansion of agricultural production through either agricultural intensification or extensification;
- the impact of agricultural pricing on the relative returns to agricultural production can influence long-run decisions to invest in sustainable land management and conservation;
- changes in the relative prices of crops (and crop inputs) can influence the substitution of more environmentally benign cropping and farm production systems for systems that are more environmentally damaging;
- the variability of crop prices and crop price inputs can affect the farmers' choice of the method and type of crops grown, and decisions to invest in sustainable land management, by affecting the risks associated with alternative agricultural investments and production systems.

In practice, it is extremely difficult to separate out these various effects of agricultural pricing policies; it is harder still to trace out the linkages between pricing and farm-level environmental degradation. For example, although farmers may respond to higher agricultural returns by expanding crop production, the more profitable land use becomes, the more farmers may be willing to invest in improved soil management and environmental conservation. Higher returns to crop production will mean that farmers may be able to afford to maintain terraces and other conservation structures, and to continue with labor-intensive erosion control measures. However, the relatively high upfront costs and long payback periods of the more sustainable methods of cultivation often deter poor, risk averse farmers (who typically experience high discount rates in excess of 50%) from switching to, and investing in, environmentally benign methods of crop cultivation. A lack of investment in soil conservation measures can result in soil erosion, and off-site impacts such as an irregular flow of irrigation water, river/reservoir sedimentation and losses to navigation and hydropower.

The following sections discuss some of the evidence associating agricultural input and output prices with land degradation and off-site environmental impacts, as well as the problem of price variability and risk.

II. Producer Price Responses and Land Degradation

The role of agricultural producer prices in influencing land degradation has been debated in recent years. One argument is that depressing agricultural prices reduces farm profitability and diminishes incentives to improve land productivity through investments in soil conservation. On the other hand, increasing farm prices and land values is thought to drive extensive cultivation of more "fragile" lands (for reviews see Repetto, 1988; and Southgate, 1988). Measuring these effects empirically is extremely difficult.

1. Quantitative Assessment of Producer Price Responses

Supply responses to agriculture producer price changes in developing countries have been recorded for some time. Early studies in the 1950s and 1960s, first in developed economies and then later in developing economies also, indicate that for typical farms small changes in the relative prices of crops may make large changes in cropping practices more profitable (Heady, 1955; Krishna 1963 and 1967; Nerlove, 1956). These studies focus on changes in single-crop acreage as a proxy for supply responsiveness, and provide direct evidence of individual farmers' substituting among crops and adapting farming systems in response to relative price changes. The early analyses also note that developing country farmers may respond to relative price changes by switching land and other resources between different individual crops, yet may be unable to increase (or decrease) aggregate output in response to overall rises in producer prices (Krishna, 1967).

More recent studies in sub-Saharan Africa confirm that the effect of output price changes on aggregate production levels tends to be insubstantial in many countries, but the responsiveness of *individual crop production* to changes in *relative prices* is highly significant. For example, a statistical analysis of nine sub-Saharan countries (Bond, 1983) estimates average short-run and long-run price elasticities for aggregate agricultural supply at 0.18 and 0.21 respectively: a doubling of agricultural prices is expected to increase output by 18% in the short-run and 21% in the long-run. Although these figures do indicate a positive, but low, response to price changes, for a number of countries the elasticities were not highly significant.

Table 1 Short-Run and Long-Run Price Elasticities and Aggregate Agricultural Supply Response

Country	Short-Run Price Elasticity	Long-Run Price Elasticity
Ghana	0.20	0.34
Kenya	0.10	0.16
Ivory Coast	0.13	0.13
Liberia	0.10	0.11
Madagascar	0.10	0.14
Senegal	0.54	0.54
Tanzania	0.15	0.15
Uganda	0.05	0.07
Upper Volta	0.22	0.24
AVERAGE	0.18	0.21

Source: Bond, 1983.

Although individual crop supply elasticities vary between countries and between crops, elasticities of 0.5 or more were common (Bond, 1983; Fones-Sundell, 1987). The evidence again suggests that, as relative producer prices change, the increase in individual crop production is achieved at the expense of a reduction in substitute crops.

Table 2 Individual Crop Supply Elasticities

Crop	Country	Minimum	Maximum
Maize	Kenya	0.33	0.66
Rice	Mali	0.27	
Groundnuts	Nigeria	0.24	0.79
Cocoa	Cameroon	0.68	
Tobacco	Malawi	0.95	

Source: Fones-Sundell, 1987.

However, in a critical review of agricultural supply response models in Sub-Saharan Africa, Ogbu and Gbetibouo (1990) argue that most models are deficient in the choice of relevant explanatory variables: either the structure of agricultural production in these countries is improperly modelled or the issues and constraints facing farmers are unknown or over-simplified. The ability of farmers to respond to price changes often depends on a wide range of factors, including the availability of land, appropriate technologies, the costs and availability of credit, farm labor wage structure and so on. Thus understanding the factors that explain the elasticities derived from empirical models is as important as understanding the elasticities themselves.

Using a micro-economic model of household choice to analyze supply response, Weaver (1989) finds positive and significant own-price responses for rice, cassava and sorghum for smallholders in Malawi. For seed cotton and coffee, negative and significant own price responses are found. Moreover, the model also estimates highly significant relative price effects. An increase in the relative price of groundnut reduces sorghum production, while an increase in the relative price of cassava increases sorghum production. However, Ogbu and Gbetibouo (1990) criticize Weaver's model for failing to distinguish between subsistence and commercial smallholders; they contend that consumption, production and labor market decisions for these two classes of smallholders are different.

Our concern, however, is less with the quantitative effects of small farmer supply responses to price incentives than with the qualitative effects of such responses.

2. Qualitative Assessment of Producer Price Responses

(i) Environmental Effects of Aggregate Production Increases

What, for example, will be the environmental implications of the higher levels of crop production that result from increased crop profitability? **Increasing agricultural production does not necessarily translate into environmental degradation - it is the way in which the extra cultivation is carried out that is important.** The expansion of agricultural production may be achieved through:

- a more efficient and sustainable use of existing factors of production (e.g. improved cropping patterns, land management schemes);
- increased use of land and other inputs in an environmentally sound manner (e.g. extensification of agricultural land onto slopes using sustainable agroforestry techniques and investing in structural conservation works); or,
- expanding unsustainable agricultural production practices and further degrading the natural resource base.

In the first two cases, the impact of increased production on the environment may be negligible, and could potentially be beneficial if degraded land is reclaimed. However, in practice increased agricultural production has typically been achieved at the expense of environmental degradation.

Since 1979 Malawi has gone through a period of rapid macroeconomic adjustment, including extensive agricultural pricing and marketing reform of the smallholder sub-sector (Christiansen and Southworth, 1988; Lele, 1989). The objectives of the new pricing policy were to:

- stimulate increased smallholder export production by paying farmers prices closer to export parity;
- set a maize price that would achieve national maize self-sufficiency;
- leave only tobacco and cotton prices controlled (as the government's Agricultural Development and Marketing Corporation retained its legal monopsony over these two crops, the official prices paid by ADMARC were also the effective prices paid to smallholders); and
- ensure that for all other smallholder crops, including maize, the prices set by ADMARC represented a guaranteed minimum price, ADMARC being obliged to buy all quantities offered at that price.

Although farmers may have been responding to changes in relative prices by shifting their cropping pattern, the impact of pricing policy on their aggregate response is less certain. After growing at an annual average rate of approximately 4.9% in real terms during the 1970s, agricultural growth slowed down to an average of 1.0% in 1980-84, recovering only to an average of 2.5% in 1985-88, and failing to keep pace with population growth. In 1988/89, the total area sown to maize (1.27 million ha) and production (1.52 million tonnes) reached record levels, increasing on the previous year by some 4.9% and 6.6% respectively. Due to drought in early 1990, maize production during 1990/91 was not expected to differ significantly from the previous year's production (Government of Malawi, 1990; World Bank data).

However, what is of particular significance for land management and soil conservation is that the recent increases in agricultural output have been achieved by extensification of agriculture onto marginal lands, rather than by improving the yields on existing cultivated land (Barbier and Burgess, 1990). The reasons for this are predominantly structural:

- rapid population growth and the corresponding fast decline in the land-population ratio has led to increased land pressure and the opening up of more marginal areas for cultivation;
- pricing and marketing reforms have achieved little for the majority of smallholders cultivating less than 1.0 ha, mainly because the severity of the land constraint and low yields preclude production of net marketable surpluses, thus limiting the main income benefits of these reforms to relatively better-off producers;
- the food security of many food-deficit households may actually deteriorate as the price of maize and other food crops increases, thus limiting the ability of these households to take the risk of diversifying out of own-food production;
- consequently, over the past five years there has been little change in the average yield for any of the main varietal maize groups - local, composite or hybrid - despite markedly higher rates of hybrid adoption and fertilizer use, and the low productivity of maize has in turn exacerbated the land constraint.

(ii) Environmental Effects of Product Substitution

A crucial issue for land degradation is the extent to which price-induced substitution encourages farmers to move away from less erosive crops and cropping systems to more erosive crops and systems. If changes in relative prices do influence farmers' choice of crops and land husbandry decisions, which is still far from certain, how well do farmers respond to these price changes in terms of their investment decisions?

Evidence from Indonesia and Malawi suggests that under certain conditions, changes in relative producer prices can affect choice of crops and farming system, thus impacting on degradation (Barbier, 1988, 1989 and 1990b; Barbier and Burgess, 1990; Becker, 1990; Carson, 1987). In Java, for example, the success of conservation projects in encouraging farmers to adopt bench terracing and other erosion management investments, is often determined by whether these investment "packages" allow farmers to shift to higher valued crops, such as dryland rice and groundnuts. The combination of conservation investments with additional returns from higher valued crops enables farmers to move away from more erosive systems involving mono-cropping lower valued crops, such as cassava. In recent years, however, this approach has frequently been undermined by rapid rises in the relative price of cassava that have been encouraged by the government's pricing, targeting and export-promotion policies for cassava. In response, farmers have neglected to maintain bench terraces, and in some instances have destroyed them, in order to maximize the area of land devoted to cassava cultivation (Barbier, 1988).

The relationships governing farmer responses to relative crop prices are very complex, and depend on various factors such as household wealth and income, tenure security, attitudes to risk, access to off-farm employment, labor and capital constraints and intra-household allocation of labor. Nevertheless, the limited evidence does indicate that farmers will respond to higher relative prices for erosive crops by seeking short run economic rents from erosive crop cultivation, thus giving rise to long-term land degradation. This result holds mainly for sedentary farmers cultivating rainfed plots in areas with predominantly "closed" agricultural frontiers (i.e. areas where agricultural extensification is reaching or has already reached its limits). In frontier agriculture, farmers will open up new areas to cultivation when the returns from new land exceed those from existing land under cultivation (Burgess, 1991; Southgate, 1990; Southgate and Pearce, 1988). Higher relative prices for, and returns to, erosive crops and systems will not only accelerate degradation on existing land but, as a consequence, will also induce increased land clearance and more rapid expansion into new areas.

3. A Case-Study in Complexity: Land Use in Thailand

A recent study in Thailand highlights the relationships between agricultural crop prices, the relative returns from different crops and the demand for land (Phantumvanit and Panayotou, 1990). The increase in the demand for agricultural land could potentially be met from a variety of sources, including unused farmland, grasslands, unclassified lands, and forests. Forest clearing is by far the most important source of new agricultural land. Between 1984 and 1985, for example, around 40% of the increase in cultivated land of 4 million rai (0.64 million ha) was met by forest conversion, 23% by returning unused or retired cropland to cultivation and the remainder from unclassified land. From 1962 to 1988, for every 100 rai (16 ha) of forest land cleared, an average of 71% was put under cultivation, 19% replaced retired or unused farmland, 6% was converted to grasslands, aquaculture, etc., and the remainder went for urban and other uses.

The demand for cultivated land, and thus forest conversion, is clearly influenced by agricultural pricing (see Table 3). The most significant factor driving the demand for cropland is the growth of the agricultural population. An increase in the agricultural population of 10% is estimated to lead to a proportionately larger (13%) increase in the demand for farmland. However, agricultural crop pricing also directly affects the demand for land through aggregate and relative price effects, and indirectly through influencing productivity investments.

Table 3 indicates the limited responsiveness of cropland demand to an increase in aggregate real crop prices; a 10% price increase leads to a 0.8% increase in the demand for land. The results suggest that higher aggregate agricultural prices do not act directly as a major incentive for greater agricultural extensification.

Table 3 The Demand for Agricultural Land (Cultivated), 1962-89

Explanatory Variables	Coefficients and T-Statistics
Real price of agricultural crops (lagged one year)	0.081 (2.00)
Agricultural population	1.337 (12.82)
Agricultural productivity (lagged one year)	-0.280 (-2.43)
Relative return to land of land-saving to land-using crops.	-0.155 (-3.95)
Relative return to labor from non-agriculture	-0.308 (-3.37)
Time dummy	-0.352 (-4.12)
AR(2)	0.437 (2.27)

R squared adjusted = 0.987
Durbin-Watson = 2.00
F-statistic = 330.00
Degrees of Freedom = 19.00

Source: D. Phantumvanit and T. Panayotou (1990).

Relative crop prices that influence the choice of cropping system between land-extensive crops such as cassava, maize and rain-fed rice, and land-saving crops such as vegetables and fruits can also influence the demand for land and the level of forest conversion. A 10% increase in the profitability of land-saving crops is estimated to reduce farmland demand by 1.5%. The limited role of trees and vegetables in existing agricultural land-use (only some 13% of the total), and the categorizing of irrigated rice and sugarcane as land-extensive crops may have reduced the impact of relative crop profitability on the demand for land.

Agricultural productivity growth can also offset the pressure on land demand and forest clearance. Productivity growth can have two opposing impacts on the demand for cultivated farmland: first, through higher productivity leading directly to increases in the demand for farmland; and second, through higher productivity of existing farmland reducing pressures to open up new land. In Thailand, the latter effect outweighs the former; a 10% growth in agricultural productivity reduces the demand for agricultural land by 2.8%. The productivity of agricultural land depends upon a range of factors, such as education, rainfall, existing forest area, level of irrigation and capital per unit of cultivated land. Higher agricultural crop prices can indirectly reduce the demand for land and forest conversion by financially enabling more investments in irrigation, education and agricultural capital, thus increasing productivity levels.

The high proportion of the expansion of agricultural land met through forest encroachment results from a lack of better alternatives and from the low cost of obtaining and clearing new land. It should be noted that large-scale clearing of Thai forests has occurred, despite a high percentage of existing farmland remaining idle. Thus the proportion of unused to total farmland has fluctuated between 15 and 30% over the past twenty-five years. It is difficult to know how much of this "unused" land is being fallowed as part of long-term cropping strategy and how much consists of abandoned or prematurely "retired" productive land. Farmers will nonetheless abandon or idle even productive agricultural land if the economic returns for converting new forest land to agriculture provide the incentive to do so.

The incentive to supply productive land from existing stocks of unused cropland depends on the availability of better alternatives for labor and capital in non-agriculture sectors, and on the low cost of keeping the land. The opportunity cost of idle land is influenced by aggregate crop prices, with a 10% drop in real prices leading to a 3.8% increase in unused land (Table 4). Low returns to the agricultural sector relative to the non-agricultural sector, which may be driven by crop price reductions, can also lead to a proportionate increase in unused land.

Table 4 Explaining Unused Agricultural Land 1962-89

Explanatory Variables	Coefficients and T-Statistics
Real price of agricultural crops	-0.383 (-2.57)
Land productivity	-0.627 (-1.97)
Agricultural population	-0.957 (-2.26)
Agricultural holding per farmer	3.872 (7.08)
Differential return between non-agricultural and agricultural land	0.993 (3.36)
Dummy (1979-85)	-0.201 (-5.00)

R squared adjusted = 0.889
Durbin-Watson = 2.32
F-statistic = 43.00
Degrees of Freedom = 19.00

Source: D. Phantumvanit and T. Panayotou (1990).

To summarize, the evidence from Thailand reflects the complexity of the linkages between agricultural producer prices and land use. Higher aggregate real prices slightly increase the demand for cropland, and thus cause forest clearing. However, this direct effect may be counteracted by the indirect impact of higher agricultural prices: these raise the productivity of existing land and increase the cultivation of previously idle land, thus reducing the demand for new land from forest clearing. Changes in relative prices also influence the demand for new cropland by affecting the relative profitability of land-saving, as opposed to land-extensive, cropping systems. The effect of relative price changes on land productivity and the cultivation of previously idle land is more difficult to estimate in such an aggregate analysis.

III. Input Price Responses and Land Degradation

Changes in input prices can also influence land use and degradation by affecting overall profitability of agricultural production, relative returns to different cropping systems, land productivity investments, and price risk. On the whole, the impact of input pricing on land degradation has been less thoroughly analyzed than the corresponding impact of output pricing.

The above analysis of Thailand illustrates some of the potential linkages that need to be explored. Relative returns to land-saving cropping systems, for example, can also be affected by the relative costs of inputs (e.g., fertilizer, seed, credit, irrigation, agrochemicals, etc.), where these differ between land-saving and land-extensive systems. More importantly, investments in land productivity will also be affected by the costs of these inputs. Thus the Thailand case study suggests that lower input prices will generally reduce the demand for new cropland and forest conversion both directly and indirectly by making previously idle land more attractive to cultivate. Changes in relative input prices can also affect agricultural extensification by altering the relative returns to land-saving cropping systems.

If the only impact of input prices was on the choice between land extensification and intensification, then the above case study would suggest a strong rationale for subsidizing agricultural inputs, and perhaps even tying such subsidies to land-saving cropping systems. However, there is widespread evidence indicating that many negative environmental impacts are associated with input subsidies.

Government policies to maintain low input prices through subsidies that encourage adoption and expanded production, have resulted in the mis-use and over-use of agricultural inputs in many developing countries, with serious implications for the environment. For example, short-run increases in land productivity through increased input use may actually lead farmers to neglect problems of soil erosion that have longer term implications for land productivity and returns. High uses of irrigation also cause long-run salinization and water-logging problems. Off-site environmental costs may result from soil erosion, agrochemical and fertilizer run-off.

1. Fertilizer

As in indicated in Table 5, the demand for fertilizer is highly responsive to price. Large fertilizer subsidies in many developing countries in the 1980s encouraged the use of these inputs.

Table 5 Fertilizer Demand Elasticities

Country	Short-Run	Long-Run
Philippines	-0.44	-2.92
Japan	-0.46	-0.73
India	-0.85	-0.62
Brazil	-0.72	-1.94
Korea	-0.44	-0.92

Source: A. Alicbusan (1987).

There are indications that subsidized inorganic fertilizer artificially reduces the costs of soil erosion to farmers and, on more resource-poor lands, substitutes for - perhaps more appropriate -manure, mulches and nitrogen-fixing crops. Overuse of fertilizer can lead to problems of agricultural pollution, with implications for water supply, fishing and human health. On the other hand, the inaccessibility of inorganic fertilizer due to shortages caused by rationing cheap fertilizer imports, can actually lead to their sub-optimal application and encourage farming practices that increase land degradation. Subsidies that increase the distribution of - and access to - fertilizers, particularly for smallholders on marginal lands, may help overcome these problems. Careful analysis of these counter-acting influences is required before the overall impact of fertilizer pricing policy on land and environmental degradation can be assessed.

(i) Indonesia

In Indonesia, past policies to achieve rice self-sufficiency included a generous fertilizer subsidy, which substantially benefitted farmers in lowland irrigated areas of Java, southern Sumatra, southern Sulawesi and Bali. In 1985, for example, total fertilizer subsidies amounted to about US$ 220 million, or an effective subsidy of 38% of the farmgate price. Considerable evidence suggests that such a high subsidy encourages wasteful and inefficient use. Thus, the current rate of fertilizer application is two to three times higher in Indonesia than in comparable Asian countries, with little yield difference.

If application levels were reduced by two thirds, savings of some US$ 150 million per annum could be achieved. Although the fertilizer subsidy is gradually being extended to upland farmers on Java cultivating rainfed crops, with the exception of high-valued vegetables, fruits and commercial crops, these farmers still tend to use relatively less inorganic and more organic fertilizers. There is also evidence that fertilizer subsidies are a disincentive, at least in the short run, against upland farmers facing the full economic costs of declining soil fertility, particularly from soil erosion, and responding with sound conservation techniques. In Ngadas, East Java, farmers are presently using over 1,000 kg of subsidized inorganic fertilizers per ha to produce two 10-tonne potato harvests. These yields are less than half of what could be attained with improved soil management and green manuring techniques. Recently, farmers have increased their use of organic fertilizers, as they have come to realize that increased inorganic fertilizer use no longer offset yield reductions (Barbier, 1989; Pearce, Barbier and Markandya, 1990, ch. 4).

(ii) Nepal

The lessons learnt from the fertilizer subsidy in Java are not necessarily applicable in other countries and regions. For example, in the hills of Nepal most rural households, which comprise about one third of the total population, produce very low levels of agricultural outputs and yields, using traditional methods which involve a balance of cropland, forest and grasslands. Average applications of fertilizer inputs are low, around 35 nutrient kg per ha, compared with the 51 kg applied per ha in Bangladesh and 71 kg per ha in Sri Lanka. With highly dense populations and severe resource degradation in the hills, the government has employed a fertilizer subsidy to relieve pressure on fodder resources by encouraging fertilizer substitution for dung, and to reduce pressures on steep slopes by raising yields on existing croplands. Although fertilizer use in the hills has been growing at over 20% per year in recent years, and there is some evidence of substitution of fertilizers for dung and leaf litter, the high costs of transport and poor distribution have limited small farmers' access to fertilizers. In addition, uniform fertilizer subsidies have encouraged the diversion of supplies to relatively better off farmers in Kathmandu Valley and the Terai lowlands. A more appropriate approach might be to give a transport subsidy for fertilizer distribution in the hills and to extend credit schemes for fertilizer to small farmers in remote areas (Pearce, Barbier and Markandya, 1990, ch. 8).

(iii) Malawi

Similarly, a recent study in Malawi highlights how poor smallholders face various disincentives and constraints in combatting declining soil fertility and erosion (Barbier and Burgess, 1990). Only about 20% of smallholders in Malawi produce a marketable surplus - and these are generally farmers with holdings over 1.0 ha. The majority are food-deficit, low-income households that spend almost half of their cash income on food, and depend heavily on off-farm labor employment. Given that less than 30% of smallholders can purchase or have access to credit for fertilizer, and that the adoption rate for high yielding maize varieties is less than 10%, average yields are low - about 900 kg/ha for maize. The combination of population pressure on scarce land with low yields has led to depressed farm incomes, declining per capita smallholder food production, widespread household food insecurity and land degradation. A high proportion (42%) of the poorest households are headed by females. They typically cultivate very small plots of land (< 0.5 ha) and are often marginalized onto less fertile soils and steeper slopes (> 12%). Moreover, they are typically unable to finance agricultural inputs (such as fertilizer), to rotate annual crops, to use "green" manure crops, or to undertake soil conservation because of capital and labor constraints.

The government policy of encouraging smallholder uptake of fertilizer through subsidies for credit expansion, may in the short term actually ameliorate some of these problems (although in the long run there is a policy commitment to eliminate the subsidy as uptake and distribution improve). On balance, the benefits of increased productivity and poverty reduction from the fertilizer subsidy policy appear to exceed the impact of fertilizer runoff on water pollution, soil conservation disincentives and land degradation. However, improved targeting of fertilizer credit to poor, especially female-headed, households is necessary to improve its effectiveness. Furthermore, the policy of increased fertilizer use has not been adequately integrated with overall conservation and land management planning; in fact, too much emphasis has been placed on the role of fertilizer alone, without sufficient attention being given to complementary improvements in cropping patterns, systems and conservation investments designed to boost long-term land productivity (Barbier and Burgess, 1990).

2. Other Inputs

The complexities and trade-offs encountered in fertilizer pricing policies also occur in designing appropriate pricing policies for other agricultural inputs. We briefly describe some of these difficulties.

(i) Pesticides

Pesticide inputs have been heavily subsidized in many developing countries. Repetto (1985) notes that subsidy rates for pesticides have reached over 80% in Indonesia, Senegal and Egypt. Some developing countries have experienced adverse environmental impacts from contaminated run-off in the form of fish death. The damage to human health of these toxic substances is uncertain, but anticipated to be very serious. In Indonesia, subsidized pesticides have encouraged inappropriate and excessive use, discouraged traditional methods of eradicating pests and made integrated biological and pest control methods relatively less attractive to farmers. However, the high rate of subsidy was halved in 1987 (from the rate reported in Table 6), when evidence suggested that outbreaks of the brown planthopper rice pest were linked to pesticide resistance (Pearce, Markandya and Barbier, 1990, ch. 4: Barbier, 1989).

Table 6 Estimated Average Rates of Pesticide Subsidies

Country	Subsidy Rate as a % of Total Retail Costs
Senegal	89
Egypt	83
Ghana	67
Honduras	29
Colombia	44
Ecuador	41
Indonesia	82
China	19

Source: R. Repetto (1985).

(ii) Irrigation

Irrigation subsidies have been used as a means of encouraging land settlement, crop production and regional development. However, underpricing of irrigation water has resulted in extravagant use, and has led to problems of water logging, over-salinization of land and exacerbation of existing soil erosion problems. In addition, the failure to recover costs undermines long-term operation and maintenance of supply systems (see Table 7). The combination of inefficiencies and mis-use has led to water supply scarcities in many regions, and a tendency to finance more irrigation investments rather than improve existing networks.

Table 7 **Cost Recovery of Irrigation Charges as Percentage of Total Costs (US$/ha)**

Country	Actual Cost Recovery (1)	Total Cost (moderate estimate) (2)	(1) as a % of (2)
Indonesia	25.90	191.00	13.5
Korea	192.00	1057.00	18.2
Nepal	9.10	126.00	7.2
Philippines	16.90	75.00	22.5
Thailand	8.31	151.00	5.5
Bangladesh	3.75	375.00	1.0

Source: Repetto (1988).

Because irrigation water can significantly raise land productivity, its inefficient and wasteful use has a particularly high opportunity cost. In Thailand, for example, increasing irrigation has a positive impact on agricultural land productivity; a 10% increase in irrigation leads to a 3% increase in land productivity (Phantumvanit and Panayotou, 1990). As outlined above, increasing land productivity can offset the demand for agricultural land, and thus the level of forest conversion both directly and indirectly by reducing the amount of agricultural land left idle.

(iii) Credit and Capital

Government credit and capital subsidies may also encourage excessive land clearing. In the Brazilian Amazon, for example, subsidies and other policy distortions are estimated to have accounted, by 1980, for at least 35% of forest area alterations. Specific distortions included: tax incentives for capital investment (e.g.,industrial wood production and livestock ranching); rural credits for agricultural production (mechanized agriculture; cattle ranching and silviculture); subsidized small farmers' settlement; and export subsidies (Browder, 1985). In addition, government-financed investment programs - for road-building, colonial settlement and large-scale agricultural and mining activities - may indirectly be contributing to deforestation by opening up frontier areas that were previously inaccessible to smallholders and migrants.

IV. Price Variability, Risk and Land Degradation

Fluctuations in relative prices can increase the uncertainty and risk borne by small producers in particular. Switching to, and investing in, new cropping systems and methods of cultivation involve high upfront costs and long payback periods for small farmers. Unless they can be assured that relative prices and returns from non-erosive systems will be sustained, these farmers may be less willing to invest in new, less-erosive cropping patterns and systems or in improvements to these systems where they already exist. Similarly, small producers may be less willing to invest some of the short-run profits from *erosive* cropping into expensive physical erosion control measures, such as bunds, contour ridging, bench terracing and so on, unless they can be sure that the high relative prices they receive for their crops today will also prevail in the future. Thus the *price risk* imposed by fluctuating relative prices may deter farmers from investing in land husbandry.

In general, very little empirical work has been conducted on the role of price risk in influencing land management decisions. The available evidence usually focuses on the effects of fluctuating output rather than input prices.

A study of gum arabic production in Sudan indicates that fluctuations in the real price of gum and its price relative to those of other agricultural crops have had important impacts on farmers' cropping patterns, diversification strategies and decisions to replant Acacia senegal trees. This has had important consequences for Sudan's gum arabic belt (IIED/IES, 1990; Barbier, 1990a). Even though it is economically profitable and environmentally beneficial to grow gum, rehabilitation of Sudan's gum belt will only take place once these incentives are properly dealt with by the government.

In analyzing fluctuations in producer prices it is important to distinguish between that part of the variation that is predicted by producers and that which is not (Hazell, Jaramillo and Williamson, 1990). To the extent that producers can predict movements in prices, they will be able to adjust resources and cropping practices accordingly and perhaps avoid any sizeable investment losses. In contrast, unpredictable price changes represent a risk, especially to small producers in developing countries, who must essentially rely on self-insurance mechanisms and their own capital resources in the absence of futures, options or other insurance markets and little or no access to formal credit, especially for conservation investments. Thus a distinction should be made between *price risk*, the part of the total fluctuation in prices that could not have been predicted *ex ante* by small producers, and *price variability*, the simple variation of prices around a trend that is observed in a time series (Hazell, Jaramillo and Williamson, 1990). The main focus of this paper is the effect that price risk - arising from fluctuations in relative erosive to non-erosive crop prices in Malawi - has on smallholders' decisions to control land degradation.

Barbier (1991b) explores the influence of relative producer prices on soil conservation and land management decisions by small farmers in developing countries. This study employs a theoretical model that shows the potential of this problem, especially the susceptibility of farmers' land management decisions to price risk. An empirical analysis of the smallholder sector in Malawi, where price fluctuations have occurred in recent years, shows that fluctuations in relative crop prices and returns, by increasing the degree of price risk, may be exerting a significant impact on the incentives for smallholders to invest in improved cropping systems and land management. The dynamics of price risk may produce the following effects:

- given the very small margins for risk among most smallholders and the wide-spread prevalence of household food insecurity, the uncertainty arising from fluctuating prices and returns is not conducive to improving farming systems, incorporating new crops or investing in substantial improvements in existing cropping patterns, cultivation practices and conservation efforts;
- the poor returns of non-erosive crops - groundnuts and pulses - relative to the more erosive crops, particularly in terms of returns to labor, may be further constraining the income of those poorer households who continue to rely on intercropped systems, with consequences for both their food security and land management; and
- the asymmetrical impacts of pricing for most households - i.e. that food deficit households are more likely to feel the impact of higher food prices as consumers, rather than respond as

producers to increased production - may have reinforced both the disincentive effect of price fluctuations on investment in improved farming systems and land management, and the income constraints faced by poorer households.

V. Conclusion

The linkage between agricultural pricing and land degradation is often difficult to analyze empirically. Our understanding of how agricultural supply responds to changing prices in developing countries is incomplete; the analysis of subsequent impacts on the resource base sustaining agricultural production, even more so. Yet the available evidence suggests some important effects do exist, and much further analysis of these impacts is warranted.

The complexity of social, economic and environmental relationships that determine the frequently countervailing effects of price changes on land use and management, is formidable. Not enough is known about: farming systems in developing countries; open-access use and common property resource rights; land tenure regimes and security; access to technology and other farming systems information; the distribution of wealth and income; and coping strategies under the presence of variable climatic, economic and social conditions. All these factors influence how rural households respond to price changes in terms of land and natural resources management, and in many cases, they may over-ride the incentive effects of price changes. In these instances, changes in pricing policies will be less effective in "correcting" resource degradation than other approaches to dealing directly with the factors behind excessive degradation, such as providing of improved research and extension advice, improving property rights and management or establishing more secure tenure or access rights.

At the same time, it is erroneous to assume that poor farmers, even those in distant and resource-poor regions, are totally isolated from agricultural markets. Virtually all subsistence households require some regular market income for cash purchases of agricultural inputs and basic necessities; many small farmers provide important cash and export crops. As a result, alterations in market prices often have a significant impact on the livelihoods of rural groups. Clearly, the economic incentives emerging from these impacts will affect farmers' decisions to invest in land management and improvements. Although we may not always sufficiently understand the economic and social factors determining these incentive effects, this does not mean that they do not exist. Nor should the complexity of the linkages between price changes and resource management, which may sometimes appear counter-intuitive, deter further analysis of the role of agricultural pricing in land degradation.

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