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REVIEW OF ENVIRONMENTAL DAMAGE ESTIMATES IN AGRICULTURE AND INTERNALIZATION MEASURES

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Abbreviations

BOD	biological oxygen demand
DC	developing country
EPA	Environmental Protection Agency (United States of America)
FAO	Food and Agriculture Organization of the United Nations
GATT	General Agreement on Tariffs and Trade
LDCs	least developed countries
NPS	non-point source
NPV	net present value
OECD	Organisation for Economic Cooperation and Development
O & M	operation and maintenance
PS	point source
ROR	rate of return
SNA	System of national accounts
USDA	United States Department of Agriculture
%	per cent

Review of Environmental Damage Estimates in Agriculture and Internalization Measures

Introduction

In this report we provide an overview of environmental damages and internalization policies (primarily) in LDCs. We review an empirical and an institutional literature. The empirical literature measures environmental damages related to agriculture; our review summarizes the type of information that is available. Economists are accustomed to working with abstract models, which involve concepts such as "damage functions". These concepts are useful for discussing general issues, but it is difficult to give them the precise empirical content needed for policy analysis. Economists need to know much more than "stylized facts" if they are to move beyond generalities. The information assembled at the end of Chapter I will, we hope, make it easier for economists to find the data. The last part of the chapter discusses internalization policies that have been proposed and those which are currently being used. In the Devoloping Countries (DC), environmental policy is inadequate, often contradictory, and sometimes counterproductive. Environmental policy is at an earlier stage in the least developed countries (LDCs).

An Overview of Environmental Damages Associated With Agricultural Activities

Externalities in agriculture cause inefficient use of valuable resources. A goal of economic policy is to allocate efficiently scarce resources. "Internalization mechanisms" are economic policies designed to correct the inefficiencies associated with externalities. The purpose of this report is: 1) to review studies attempting to quantify externalities associated with agricultural activities; 2) to review potential internalization mechanisms that might be used to correct these externalities; and 3) to summarize past, current, and proposed policies designed to address these problems. While examining agricultural externalities is our major focus, we will also review estimates of the private costs of inefficient agricultural production techniques to underscore the potential value of farmer education programs and international technology transfer efforts.

An overview of significant environmental damages associated with worldwide agricultural production and processing activities is presented in Table 1. These damages are difficult to quantify, especially at levels of aggregation, because agricultural activities have site-specific characteristics such as soil type and slope, rainfall, temperature, and wind velocity, that influence damage. Quantification is also hindered by the difficulty of observing and monitoring spatially diffuse agricultural processes. Analysis is complicated because definitions of the various types of damages often overlap and depend upon one’s perspective. Although the items in Table 1 are classified according to the damaging agent or the party damaged, an economist might classify them as extensive or intensive damages, a farmer as on-site or off-site damages, and an environmental regulator as point source or nonpoint source (NPS) damages. We discuss environmental damages from each of these perspectives in the course of our report. For the present, however, we examine the significance of, and the distinction between, point source and NPS damages.

Vigon (1985) defines NPS pollution by three characteristics: (1) it originates over large areas; (2) it is intermittent; and (3) it is not easily measured by structural techniques (pipes or weirs). Vigon writes: "Nonpoint source pollution remains as the primary reason for the designation of many of the nation's [U.S.] streams as 'water quality limited.' . . . even with

Table 1. Environmental Damages Associated with Agricultural Activities

General Damage	Associated Problem
Soil erosion damages	Decreased soil productivity Increased soil salinity Increased stream salinity Decreased water holding capacity leading to increased flow irregularities (problem for agricultural and wildlife) Increased agrochemical runoff due to adherence to soil particles
Sediment damages	Accelerated reservoir siltation Blocked navigation channels and increased dredging costs Interference with water conveyance systems Increased costs of removal of sediment from roads and ditches Increased probability of floods Increased maintenance costs for roads, bridges Stream habitat degradation, harm aquatic plants and animals, genetic diversity losses Loss of mangrove forest wood stock, and associated fisheries habitat Degraded recreational resources

General Damage	Associated Problem
Over-irrigation damages	Accelerated depletion of groundwater stocks Increased land-subsidence associated with groundwater depletion Increased water-logging of soil Accelerated salinization of soil Increased salinization of groundwater Increased naturally occurring toxic leachates in agricultural drainage water Increased naturally occurring toxic leachates in groundwater
Agrochemical damages	Increased risks to agricultural worker health and safety Increased risks of contamination of groundwater Increased treatment costs for municipal intake water Increased treatment costs for industrial intake water Increased eutrophication of lakes, rivers and coastal areas, and increased costs of cleaning Increased weed choking in lakes associated with fertilizer runoff, and increased costs of cleaning Increased pest resistance Increased risks to wildlife, fish and plant health Costs of restocking lakes and rivers after fish kills Decreased recreational and commercial fish catches Genetic diversity losses
Soil compaction damages (from tractor use)	Decreased soil productivity
Deforestation damages	Increased soil erosion and sediment damages (see above lists) Increased crop damage from high winds Genetic diversity losses
Wetlands drainage damages	Biological productivity losses (decreased fisheries, waterfowl, or mangrove production) Decreased water purification services Genetic diversity losses

General Damage	Associated Problem
Air pollution damages	Dust from tractor use Odor from manure, decomposing crop wastes, etc. Smoke from diesel fuel from tractor use, crop dryers, coffee roasters, etc. Crop damage from air pollution, esp. ozone and sulfur oxides Increased risks to agricultural worker and health and safety
Costs of studies of these problems	

the application of technology-based effluent limitations on point sources, ambient water quality standards will not be met." The nonpoint nature of most agricultural externalities limits the applicability of conventional policies used to combat point-source externalities. Dosi’s (1992) study emphasizes the increasing importance of NPS issues in agricultural environmental policy. “Many contemporary problems . . . are caused by the combined activities of small polluters along with natural processes, intermittent and unpredictable events, and often involve pollutants with complex environmental outcomes.” Dosi cites a number of examples, including acid rain from ammonia emissions due to animal manure spreading and groundwater contamination from nitrates and pesticides.

Griffin and Bromley (1982) note that the economic problem of agricultural NPS pollution can be separated into three distinct categories. First, the sediment, nutrients, and chemicals removed by runoff represent a loss of soil resources. These costs are borne privately by farmers. Provided he has adequate information regarding these costs and methods to prevent them, a reasonable farmer would undertake preventive or remedial actions to maximize the time-discounted profile. Second, if the discount rate of the individual farmer is greater than the social discount rate, or if the farmer has a planning horizon which is shorter than society’s, the farmer will mine the soil resource more rapidly than is socially optimal. Third, physical resources lost by the individual farm must appear elsewhere in the environment. In sufficient quantities, these resources may become NPS pollutants, harming farm workers, nonfarm residents or their property, and aquatic or wildlife resources.

Data Sources

We have investigated two basic sources of data: Country or

Case Studies and Macro-scale Aggregate Databases. Country or Case Studies are becoming available for an increasing number of countries, regions, and crops. These studies provide data for estimating changes in behavior due to internalization mechanisms. Examples include UNCTAD country studies and World Resources Institute case studies. We also want to have a measure of the aggregate impacts of changes in micro-behavior associated with internalization mechanisms to help determine the effects of internalization mechanisms on international commodity flows. For this purpose, it is not sufficient to gather information on "per unit" environmental damages (i.e., per bushel or per person). Because supply-response effects may by important, we also need aggregate information on, for example, the total number of hectares of crop X, or the total number of people affected by a given type of environmental damage. Macro-scale Aggregate Databases provide these data, which may be useful in translating changes in micro-level behavior into macro-level effects. Examples of Macro-scale Aggregate Databases include FAO Yearbooks, World Bank databases, and World Resources Institute databases.

Case studies can be used to derive estimates of environmental damages per unit of some relevant metric, such as crop area, crop production, head of livestock, input use, or agricultural population. We could then use these damage estimates to calibrate internalization mechanisms to promote efficient micro-level behavior. For example, one might set an internalizing tax rate on an agricultural input equal to the environmental damages per unit of its use. The aggregate implications of changes in micro-behavior could then be derived using data in the Macro-scale Aggregate Databases. For example, a 20% reduction per hectare in the use of a taxed environmental input might lead to a 5% reduction in crop yield per hectare. When multiplied by the total hectares of land planted to that crop, this might result in a significant change in world supply, affecting international trade in that crop and its substitutes and complements.

Chapter I

Environmental damage estimates from case studies

We review a selection of case studies of environmental damages associated with agricultural production and processing activities in developed, industrial countries, new market economies, and developing economies. We focus here on summarizing quantitative estimates of environmental damages. Additional descriptive information is in the Annotated Bibliography that accompanies this report. We discuss policies which attempt to address environmental damage problems in Section 4.

Few case studies give monetary estimates of environmental damages associated with agricultural activities in developing countries. However, it may be possible to derive estimates of such damages indirectly using existing information. For example, in many case studies data are presented in the form of "crop yield improvements possible with the implementation of conservation project X." The case study then presents the (generally positive) rate of return (ROR) or net present value (NPV) of the conservation project. In such cases, the increase in crop yield benefits, less the conservation project costs, is a measure of the environmental damages associated with the old, inefficient cropping practices.

The body of information collected on environmental damages associated with agricultural activities in the U.S. and the EEC is another source of information with the potential for extrapolation to developing countries. For example, symposium papers (Waddell, 1986) on the off-site costs of soil erosion in the U.S. provide dollar estimates. Although this work is for the U.S., the results may be useful for making order of magnitude cost comparisons across types of off-site damages in developing countries.

Our review of country studies provides an empirical database on environmental damages by type of environmental damage, geographic location, type of crop, type of farming method, date or season the damage occurred, and date the country study was done. The date is important when issues of research methodology arise or when factors taken by the study as exogenous change over time. We organize these data in Table 2, which shows country studies containing the following information: author, date of study, countries studied, crops considered, types of environmental damages identified, and policies discussed. This table can be scanned to locate environmental damage information for particular countries, crops, or types of environmental damages. We also present summaries of the quantitative environmental damage estimates found in the country studies, and organize this information by type of environmental damage. We begin with environmental damages due to the *extensification* of agriculture and proceed to damages associated with the *intensification* of agricultural activities.

Extensification Damages

Extensification damages are those associated with the expansion of agricultural land areas rather than with production methods on existing land. Extensification damages include deforestation, desertification, and wetlands destruction. We present only a brief summary of these damages.

Table 2. Damage Estimates

Author	Year	Crop	Country	Environmental Problems	Policy Dimensions
Abelson	1979	Sheep Cattle Crops	Australia	Soil erosion Dryland salting Siltation of road Irregularities of flows of river	"Soil Conservation Project"
Akande	1989	Cocoa	Nigeria	Excessive use of agrochemicals and pesticides	Green taxes
Anderson	1987	Firewood	Nigeria	Deforestation Desertification Soil erosion	"ARID ZONE Afforestation Program"
Bishop and Allen	1989	Groundnut Millet Sorghum	Mali	Soil erosion	
Bojo	1990		Lesotho	Soil erosion	"Farm Improvement and Soil Conservation Project"
Clarke et al.	1985		U.S.	Soil erosion Sedimentation Lost of recreational opportunities	
Cruz et al.	1988		Philippines	Soil erosion	
Duda	1985	agriculture	U.S.	Sediment in water Eutrophication	
Faeth	1993	agriculture	India Chile Philippines	Soil erosion	
Faeth et al.	1991	agriculture	U.S.	Soil erosion	Integrated Farm Management Program Pesticide record-keeping
Finney and Western	1986	forest agriculture	Philippines	Soil erosion Sedimentation of river	
Golitsyn	1992	agriculture Cattle	USSR	Soil erosion Arid pastures Water pollution	
Khalid and Braden	1993	Palm oil	Malaysia	High BOD	
Kim and Dixon	1986	agriculture	Korea	Soil erosion	
Mahar	1989	tree crops	Brazil	deforestation	Credit subsidy

Author	Year	Crop	Country	Environmental Problems	Policy Dimensions
May	1993	Coffee Cocoa	Brazil	Soil exhaustion Pesticide residues Air pollution	Emission charge Green Labeling New technology adoption Integrated pest management
Pagiola	1994	Maize Beans	Kenya	Soil erosion	Correct price distortion
Segura and Reynolds	1993	Coffee	El Salvador Costa Rica	Groundwater pollution Sedimentation Agro-chemical wastes	Emission Fees
Sfeir-Younis and Dragun	1993	agriculture	LDC	Soil erosion	
Solorzano et al.	1991	Corn Potato	Costa Rica	Soil erosion	
Southgate	1988	agriculture	LDC	Soil erosion	
Southgate and Macke	1989	agriculture	Ecuador	Soil erosion	
Southgate et al.	1984	agriculture	Dominican Republic	Sedimentation	
Witte et al.	1993	Rice	Thailand Philippines	Health problem Groundwater pollution Soil erosion	

Deforestation

Deforestation can damage biodiversity and eliminate supplies of non-timber forest products. In Brazil, for example, cocoa may be grown under the traditional "Cabruca" cropping system, which replaces the native forest understory with cocoa while retaining the native forest canopy. The alternative, a "clearcut" cropping system, replaces the native forest with a banana tree canopy and a cocoa and leguminous shade tree understory. Recent studies (May 1993) suggest that the Cabruca system is less detrimental to Brazil’s threatened Atlantic Forest region than any other form of agriculture because it retains a range of threatened species. However, since the mid-1980's, market and environmental conditions have not favored cocoa farmers, and deforestation and illicit timber trade have become commonplace. Research has shown an inverse relationship between cocoa prices and forest area cleared for sale of timber. Such deforestation results in loss of wildlife and vegetation species diversity and productivity; unbalanced microclimatic conditions can cause uncontrolled fires, crop and livestock loss downstream, and shifts in the global carbon budget. Agropastoral expansion can cause ecosystem damage from pesticide residues, erosion, and sedimentation of watercourses.

Desertification

Overgrazing and poor implementation of grass cover restoration have resulted in increasing desertification in countries such as the former Soviet Union and India. Golitsyn (1992) reports that "In the Kalmykia and adjacent Dagestan republics the area of moving sands on pasture land has increased since 1954 from 15,000 ha to 1 Mha, and it is continuing to grow by 40-50,000 ha annually. Similar processes are observed in many places in Kazakhstan and the Middle Asian states. The Academies of Science of Turkmenistan and Uzbekistan have a wealth of experience in fighting desertification and transforming desert lands into productive pastures. The time needed for a return on the investment of making pastures in arid zones is four to five years. . ."

Khoshoo and Deekshatulu (1992) provide estimates of the land area subject to shifting cultivation in the North Eastern Region of India.

Wetlands Destruction

Wetlands drained for cultivation and pasture continue to compromise biodiversity worldwide. However, the useful role of wetlands is now being recognized, and in many regions they are now protected.

Intensification Damages

Damages associated with agricultural production and processing activities can be classified as either on- or off-site. On-site damages affect the agricultural production or processing activity causing the damage, while off-site damages affect other agricultural production or processing activities.

On-site Damages of Soil Erosion

Soil erosion reduces productivity in at least three ways: it reduces the soil's capacity to hold water; it restricts seedling emergence and root penetration; and it results in the loss of nitrogen, phosphorus, and potassium. Faeth (1991) studies two farming regions of the U.S.: Nebraska and Pennsylvania. He estimates Net Farm Income (which includes government transfer but ignores environment) and Net Economic Value to Society (which includes environment but ignores government transfers) under a variety of government policy scenarios, including a 25% tax on farm chemical inputs. Faeth also outlines a method for calculating lost farm income due to the on-site damages of soil erosion. Dawkins et al. (1994) develop a full-cost, life-cycle case study of spring wheat production in the Northern Plains of the U.S. They estimate the cost associated with decreased soil productivity as $58.67 per bushel, and the private cost of production of spring wheat at $8.94 per bushel.

Conacher (1990) discusses the environmental damages associated with agricultural production in the Australian Wheat Belt. In 1983, the director of the Western Australian Department of Agriculture estimated that wind erosion was responsible for $38 million in production losses annually. Golitsyn (1992) estimates that, in the former Soviet Union, soil erosion reduces the value of production by 36 to 47%. Khoshoo and Deekshatulu (1992) edit a volume on land and soil problems in India which compares soil loss and yield across crop types and cropping methods; provides estimates of soil erosion by Land Resource Regions; and describes the distribution of salt-affected soils. It also compares mean soil loss to wind erosion under different cropping methods; presents gross estimates of erosion-susceptible land areas; and provides information by state on land areas degraded by ravine erosion.

Faber (1993) notes that in El Salvador, overexploitation in cotton production is causing extensive fertility loss, soil erosion, ravine and gully formation. More than 77% of the country suffers serious soil erosion. An estimated 16 to 20 tons per hectare of topsoil were being washed and blown from the cotton fields each year. Trees necessary to protect the fields from wind erosion are removed to facilitate cheaper forms of pesticide application by aircraft. Rather than practicing crop rotation, weeds and protective ground cover are also eliminated because they might host potential cotton pests. Solorzano et al. (1991) calculate the value of loss in soil productivity due to soil erosion in Costa Rica using a linear programming model. They provide estimates of depreciation due to soil erosion as a percentage of agricultural value added; 68% in 1987, 7% in 1988, and 5% in 1989. Pimentel (1993) discusses soil erosion in Argentina, where approximately 24% of agricultural land is affected. He reports the cost of replacing soil nutrients lost through erosion to be $5000 million per year.

May (1993) examines the soil erosion due to coffee and cocoa production and processing sectors in Brazil. He refers to a study by Bertoni, et al. in 1972 which compared perpendicular to contour planting systems on steep slopes. Soil losses were reduced from 4.4 to 3.1 t/ha, and rainfall runoff by 25%. Planting grass within coffee groves reduced soil losses to 0.2 t/ha, and rainfall runoff by 90%. Soil erosion control increases organic matter, which helps to control nematode problems.

Magrath and Arens (1989) discuss the on-site costs of soil erosion on Java. Productivity loss due to erosion has several effects on farming systems: profits can fall as the result of lower output; farmers can be influenced to make radical changes in the mix of crops and the level of input use; and, in extreme cases, erosion may lead to the complete withdrawal of land from cultivation. To calculate the impact of erosion-induced productivity loss on changes in net farm income, they assumed that as output falls farmers adjust variable inputs in proportion to yield declines with no change in fixed costs; they conclude that the annual capitalization cost of erosion is approximately 4% of the value of six major rainfed crops.

Costanza et al. (1990) analyze farming practices that increase sustainable production in the barley-cropping area of Jordan. They examine soil and moisture management alternatives, including conserving technologies for semi-arid conditions where wind and water erosion would otherwise make sustainable agriculture unlikely. Erosion is accelerated by extensive use of conventional tillage techniques. Preliminary results indicate that conserving and incorporating crop residues increase grain yield, conserve soil, but reduce feed supply available for livestock production.

Bishop and Allen (1989) study the on-site costs of soil erosion in Mali and estimate the annual net farm income lost due to continuous cultivation at $31 to $123 million. They report declining yields, ranging from 12 to 83%, for groundnut, millet, and sorghum under continuous cultivation from 1931-1955.

Pagiola (1994) discusses the returns to soil conservation policies in Kenya. For example, on a 15% slope with conventional tilling and a crop of maize and beans, soil erosion causes a 20% decline in productivity in 10 years and a 40% decline in 20 years. However, given the high cost of terracing and the low crop prices, an investment in soil conservation is not repaid until the 48th year.

Dazhong (1993) and McLaughlin (1993) review soil erosion in China's Gansu Province. On the Loess Plateau organic matter, nitrogen, and phosphorous are 10% or less of original levels. Soil erosion in the region is correlated with population growth and has reduced crop yields by 30 to 69%. McLaughlin provides figures on the increased productivity of areas where soil conservation programs are used.

Conacher (1990) surveys the environmental damages associated with agricultural production in the Australian Wheat Belt. For thousands of years salt has accumulated in both the groundwater and the deeply weathered soils of Western Australia. The transformation from natural vegetation to agriculture in this region has disturbed the soil layers and the hydrologic cycle so that salt moves toward the surface. In 1983, the director of the Western Australian Department of Agriculture estimated that salinization was responsible for $26 million of production losses annually. Soil acidity also appears to have increased, and the older agricultural areas are most affected.

Kim and Dixon (1986) used a cost-effectiveness analysis to examine two alternative methods of avoiding soil erosion and soil-nutrient losses in Korea. The prevailing method involves replacing soil and soil nutrients in the uplands and clearing silted paddies in the lowlands; the alternative method requires mulching the upland areas. The benefits associated with implementing either method were not estimated, but they were considered to exceed the costs.

Southgate et al. (1984) examine the problems associated with soil erosion in the Valdesia Watershed in the Dominican Republic. Soil erosion there results in private damages to farmers due to reduced soil productivity and social damages to the region due to accelerated loss of storage capacity in the Valdesia reservoir. The authors estimate both private and social net present values of proposed soil conservation policies. Although farmers on gentle slopes have large private incentives to implement the policy, farmers on steep slopes do not. Their analysis reveals that the region as a whole has a very large incentive to persuade farmers on steep slopes to implement the policy. The discrepancy between private and social implementation incentives on steeply-sloped land suggests a need to develop appropriate internalization mechanisms.

The Kim and Dixon (1986) and Southgate et al. (1984) studies provide good examples of the links between the on- and off-site costs of soil erosion. We now turn to a more thorough examination of off-site damages caused soil erosion.

Off-site Damages of Soil Erosion

Sedimentation Effects

Southgate (1988) reports that soil erosion and sedimentation can affect the frequency and severity of flooding. Runoff from non-eroded watersheds tends to be less variable because topsoil holds water better than other strata. The frequency with which water breaches stream banks is a positive function of the amount of eroded material accumulated in steambeds. In watersheds containing reservoirs, sedimentation causes loss of storage capacity, and eroded materials may pass into generators and irrigation systems, damaging machinery and clogging irrigation canals.

Clark (1986) presents estimates of the off-site costs of soil erosion for the U.S. He surveys recreation, water storage facilities, navigation, fisheries, property and preservation values, flood damage, and water conveyance facilities. In the same volume, Ribaudo (1986) divides the U.S. into regions, estimates total off-site soil erosion costs, and provides cost breakdowns for: recreation; water storage facilities; navigation; commercial freshwater and marine fisheries; flood damage; drainage and irrigation systems; municipal water treatment, municipal and industrial users, and steam electric power plants; and salinity. Faeth (1991) updates Ribaudo's figures. Using these data, Dawkins et al. (1994) estimate the environmental cost of water pollution to streams and rivers (excluding lakes and groundwater) from spring wheat production to be $3.61 per bushel. They estimate environmental damage to wetlands at $44.00 per bushel; this compares to $8.94 per bushel, the estimated private cost of spring wheat production.

Malik and Faeth (1993) analyze the costs associated with canal sedimentation from agricultural soil erosion in the Punjab region of India at about Rs 43 per ton of eroded soil. Segura and Reynolds (1993) note that coffee production in Costa Rica has resulted in the removal of shade trees, which has caused an increase in the sediment load of nearby rivers. Faber (1993) estimates that in El Salvador, 16 to 20 tons of topsoil per hectare are washed and blown from the cotton fields each year. Sedimentation from cotton fields also contributes to the destruction of El Salvador’s marine habitats. In Argentina Buck (1993) found that, for each ton of cereal exported, an equivalent amount of silt must be dredged from the port of Buenos Aires. In 1983, $61,250,000 was spent to dredge silt from the port; this amounts to $1.50 for each ton of cereal exported. Dazhong (1993) reports that the Loess Plateau region in China's Gansu Province lost approximately 30% of reservoir storage capacity and 48% of irrigation capacity from 1949 to 1975 due to sedimentation from the Plateau.

Magrath and Arens (1989) discuss the costs associated with irrigation system siltation in Java. Silt causes higher operation and maintenance (O&M) expenditures and lowers operating efficiencies, decreasing returns to irrigation investments. They analyze the total operation and maintenance costs of Javanese irrigation systems to demonstrate the cost of siltation. World Bank engineers estimate that the portion of O&M expenditure due to silt removal is 15 to 20% of cost. Indonesian irrigation authorities calculate that silt removal costs are $0.67 per cubic meter. The authors report the level of dredging in the major harbors of Java from 1979 to 1986. Based on available data for nine major reservoirs on Java, the authors summarize capacity reduction due to sedimentation.

Southgate and Macke (1989) estimate the off-site benefits of soil conservation for a project to reduce erosion in a hydroelectric watershed in Ecuador. They calculate the benefits of maintaining the service level of a hydro project while conserving given levels of reservoir and generating capacities. They also consider the savings from reduced expenditures on remediation such as removing soil and rock from the dam. They estimate the cost of soil erosion on the sedimentation of the reservoir as well as on the lifetime of the hydro facility. The results of their model show the benefits of different watershed management techniques but do not estimate losses associated with no management.

Off-site Damages of Agricultural By-Products

Most coffee in Brazil is dry processed, resulting in the by-product of hulls and hull lining (May, 1993). Hull lining is often dumped directly into rivers. The wet process is more complex and requires more capital, energy, and worker training. It causes pulp disposal problems as well as water pollution. The biological oxygen demand (BOD) from sugars generated in wet processing one ton of raw coffee is equivalent to that generated by the domestic waste of 2,000 persons (Gathuo et al., 1991). The pulp residues from this process have a high moisture content, and their leachate can pollute neighboring streams. The secondary processing associated with the manufacture of soluble coffee produces both a residual liquor and a sediment by-product. Most liquor wastes are dumped directly into watercourses or sewage treatment plants. Sediment residues are compressed to reduce water content and then used as animal silage, fertilizer, fuel, or landfill.

Segura and Reynolds (1993) note that waterways in Costa Rica are polluted with water from coffee processing as well as sediments, agro-chemical wastes, municipal, and industrial wastes. Most surface water cannot be used for human consumption, irrigation, or even recreational activities. Wet processing coffee is a water-intensive procedure, requiring 3 to 4 cu.m. to process 240 kg. of coffee. In Costa Rica, this water is not treated before it is discharged to rivers. This organic discharge amounts to 275 tons/day, and is concentrated in the coffee-harvesting period of November through February. This period coincides with the dry season in Costa Rica, which exacerbates the problem because rivers are at low flows. Coffee processing contributes an estimated 66% of the total BOD in the country's rivers.

Khalid and Braden (1993) discuss water pollution associated with palm oil manufacturing in Malasia. Residue from the oil-processing process creates high BOD when dumped into waterways.

On-site Damages of Over-Irrigation

Mercer and Morgan (1991) review the externalities associated with over-irrigation in the San Joaquin Valley of California, including accelerated depletion of groundwater stocks, waterlogging of soil and land subsidence.

Conacher (1990) estimates that water erosion and waterlogging annually were responsible $19 million in production losses in the Australian wheat. Increased surface water-repellence also contributes to accelerated soil erosion.

Malik and Faeth (1993) examine the environmental damages associated with several alternative crop production regimes in the Punjab region of India. This region produces rice in the wet season and wheat in the dry season. Groundwater is currently used at about 15% above recommended levels, and water tables are falling about 0.8 meters per year. "Under the rice-wheat rotation at 15% over-irrigation, a typical farm’s operating costs would triple over 25 years owing largely to the need for progressively larger pumps."

Off-site Damages of Over-Irrigation

Johnson (1986) calculates the direct costs to agriculture and municipal agencies, and the indirect regional costs to the Colorado River Basin, associated with various levels of salinity in the Colorado River. He also estimates micro-level household costs associated with high salinity in the Colorado River.

Klasing (1991) discusses the potential effects of heavy metal and nitrate-contaminated agricultural drainage water on human health in California's Central Valley. Mercer and Morgan (1991) review the naturally-occurring toxic leachates in agricultural drainage water in the San Joaquin Valley of California.

Golitsyn (1992) notes that, in the former Soviet Union, because agriculture uses almost all the water from the AmuDarya and Syr-Darya rivers, the Aral Sea is catastrophically shrinking. This phenomenon has been labeled the Aral ecological crisis. "The fast decrease in the Aral sea level, about 1 m per year, denudes its bottom, and winds blow salt and dust to distances of more than 500 km away, which increases the salinization of the soil."

On-site Damages of Pesticide Use

One of the most emotional, and potentially one of the most costly, environmental damages associated with agricultural activities is the effect of pesticide use on human health. It is difficult to quantify the effects of pesticides on either farmworker or consumer health because there are several links in the chain of events from agricultural spraying to health damage.

Although the U.S. EPA and the FAO have investigated the dosage-response link and set various dosage limits and health effects thresholds for many pesticides, estimating the number of persons exposed to pesticides and quantifying the link between exposure and dosage is difficult. The FAO (1993b) has recently developed methodology, based on global diets, to screen out some pesticides from a list of contenders that might cause health effects through food consumption.

Rola and Pingali (1993) investigate the effects of pesticides on the health of rice farmers in the Philippines. They list the hypothesized health effects caused by chronic exposure to pesticides and compare the prevalence of actual health effects in an exposed and control group of farmers. The authors also supply micro-level information from the town of Neuva Ecija, estimating mean health cost for the rice farmers there, detailing the percentage of farmers who use unsafe pesticide spraying practices, reenter fields too soon after spraying, and store and dispose of pesticides unsafely. A large number of pesticides which have been banned in other countries are still used in Thailand and the Philippines (Witte et al., 1993).

Faber (1993) reports that, in El Salvador and Guatemala, intensified use of phosphate-based pesticides is responsible for 400 worker deaths annually. Surveys conducted in 1988 and 1989 by the Nicaraguan Ministry of Health show that 12% of small farmers in the country’s principal agricultural region reported being poisoned at work. A major cause of the long-term contamination of the land surface, water table, and food chain is the use of aircraft spraying, which produces smaller and more concentrated droplets. From 50 to 75% of these droplets never reach the crop, but drift up to five miles or more.

Several cotton pests in Central America developed resistance as insecticide use became widespread. By the mid-1960s this had led to even more extensive use of pesticides, a situation known as the "pesticide treadmill." Another effect of the pesticide treadmill was a new outbreak of malaria that affected millions of Central Americans. Malaria is transmitted by the bite of anopheline mosquitoes, which developed resistance to the standard chemicals used by cotton growers. Poor soil conservation practices, combined with heavy pesticide use, further destroyed the beneficial microorganisms, insects, and earthworms necessary for soil vitality. To combat the pesticide treadmill and the crisis of cotton agroexport, growers adopted a number of alternative strategies. Many diversified into other export crops (i.e., mechanized rice and sugar production); however, these products were sometimes contaminated by pesticide residuals from cotton production.

Weinberg (1991) describes environmental problems associated with the pesticide treadmill generated by cotton cultivation in Central America. The humidity and heat of the Pacific zone provide fertile breeding conditions for insects, and there is no winter frost to keep insects in check. By the 1970s Central America was the world’s highest per capita user of pesticides; 75% of the pesticides it imported from the U.S. were either banned, restricted, or unregistered there. Nicaraguans and Guatemalans are estimated to have a higher concentration of DDT in body fat than any other population. During the 1960s and 1970s Honduras and Nicaragua were the world leaders in per capita illness and death from pesticide poisoning. Every year, more than 1,000 Guatemalans receive medical treatment for exposure to pesticides—many more may suffer without access to medical care.

Chemical pesticides are used widely in the coffee and cocoa production and processing sectors in Brazil (May, 1993). In the 1970s increased use of BHC and Lindanc, the recommended organochlorides, caused many pesticide intoxication problems. In the 1960s the government advised cocoa growers to eliminate some shade trees and apply fertilizers. Among other chemicals, the government subsidized use of Agent Orange. While pesticide misuse continues to be a serious problem in the cocoa zone of Bahia, overall use has decreased sharply since 1985. There has not been a correspondingly sharp fall in yields.

<u>On-site Damages of Soil Compaction</u>

In the northern plains of the U.S., Dawkins et al. (1994) report that the cost due to soil compaction in Spring wheat production is $.52 per bushel, or approximately 5% of the private cost of production. Golitsyn (1992) estimates similar crop losses in the former Soviet Union at 5 to 25%. Conacher (1990) estimates that deteriorating soil structure is responsible for $11 million in production losses annually in the Australian wheat belt.

<u>Off-site Damages of Fertilizer Use</u>

Lake Ladoga, the largest lake in Europe, is being polluted by 7 paper mills, a large aluminum plant, and intensive agriculture. This has endangered St. Petersburg's water supply (Golitsyn, 1992). Phosphorus has increased by 300% over the last 30 years, and nitrogen has increased by about 30%. Fertilizer run-off is a major problem. Khoshoo and Deekshatulu (1992) present similar data for India.

Nitrogenous fertilizer use was expanded in Costa Rica after 1975, following the increased density of coffee plants and the loss of leguminous shade trees. Fertilizer use is a primary cause of the increase in nitrate in the groundwater used for drinking in the Costa Rican Central Valley (Segura and Reynolds, 1993). Recent studies on groundwater contamination from fertilizer nitrates in the Virilla watershed found levels exceeding WHO recommended limits. Nitrates in drinking water have been linked to metahemoglobinaemia and gastric cancer. Fertilizer use is responsive to crop price; the fall in coffee prices since 1989 has resulted in decreased use of fertilizers.

Rice production in Thailand and the Philippines uses synthetic fertilizers (Witte et al., 1993). Because these inputs are not available to many farmers, there has been widespread underfertilization, i.e. "soil mining". Pingali et al. (1990) found a declining yield trend in both on-station and farmer-irrigated rice, which they attributed to environmental degradation. "Probably not more than 10 to 15 percent of soluble phosphorus added to the soil is absorbed by the crop due to fixation."

On-site Damages of Air-Polluting Activities

Brazil's dry-processed coffee production generates dust that contains allergenic compounds, chiefly chlorogenic acid (May, 1993). Various studies have found 4 to 92% of exposed workers develop asthma, rinitis. or dermatitis. Secondary coffee processing (roasting) produces a dense smoke containing a large quantity of fine particles. Roasting also produces organic gasses including alcohols, organic acids, and sulfur and nitrogen oxides.

Off-site Damages of Air-Polluting Activities

Waddell (1986) estimates the total cost of wind erosion damage to New Mexico's Major Land Resource Areas by examining costs to households, businesses, irrigation and conservancy districts, county road and state highway maintenance. Dawkins et al. (1994) estimate environmental damages from air pollution associated with the diesel fuel used for Spring wheat production in the northern plains of the U.S.to be $.001 per bushel. Rice paddies, especially those under irrigation, contribute an estimated 5 to 30% of atmospheric methane, which contributes to global warming (Witte et al., 1993).

Macro-scale aggregate databases

Aggregate data can provide an international perspective on the populations and land areas affected by the environmental problems described in the case studies. These data provide information on the potential magnitudes, likely geographic distribution, and relative importance of environmental problems. Often these environmental damage estimates are reported in detail (i.e., "dollars per irrigated acre" or "percent of coastal fish population affected"); these data may provide the links between the micro-level effects of internalization and the aggregate impacts of internalization on country-level production and trade flows. Some relevant data sources are listed below.

FAO. 1991. Fishery Statistics Yearbook.
FAO. 1992. Fertilizer Yearbook.
FAO. 1993a. Forest Products Yearbook.
FAO. 1993c. Production Yearbook.
OECD. 1991. Environmental Indicators - A Preliminary Set.
UNEP. 1993. United Nations Environment Programme Annual Report 1992.
World Resources Institute. 1994. World Resources 1994-95.
World Bank. 1993. Commodity Trade and Price Trends: 1989-1991.

Chapter II

A Review of incentive-based policy instruments

A recent report by the OECD (1993b) examines the potential role of economic instruments for environmental management in LDCs, where controversy continues over what kind of government intervention is necessary or justified. In DCs, governments historically regulated resource users and polluters through rigid "command and control" methods, setting limits on *levels* of resource exploitation or pollution generation. However, there are valid reasons why command and control regulations do not work in the majority of LDCs and why market based incentives have a better chance. For example, following the DC model, environmental regulations in LDCs stipulate terms of imprisonment and/or fines for noncompliance. However, many developing societies, most notably in Asia, are not given to litigation. Because courts are rarely used, regulations become "paper tigers". It is difficult for LDCs to monitor hundreds or thousands of scattered, small-scale operations which each generate little pollution but together account for the bulk of pollution emissions. There also is a mismatch between the high costs of regulation, monitoring, and enforcement, and the manpower and administrative constraints in LDCs. In addition, fines are too low to deter violations; since the probability of apprehension is very low, fines should be high enough to exceed the benefits from the violation. A final flaw of command and control regulations in LDCs is the rent-seeking behavior they elicit. Violators are willing to pay a fraction of the stipulated fine to the enforcement officials as a bribe. Increased fines or stricter enforcement predictably lead to more bribes rather than less environmental degradation.

An alternative is indirect regulation using economic incentives to "internalize" environmental externalities. Economic incentives have many advantages over regulations. First, they can achieve the desired effect at the least possible cost. Second, they are easier to enforce. Third, they present fewer opportunities for rent-seeking behavior; therefore, they are likely to be more effective and more equitable. Finally, unlike regulations, economic incentives generate revenues which may be used to finance the incentive program in the face of tight budgets and budgetary deficits.

The policy instrument or mix of instruments that should be chosen depends on the nature of the pollution problem. In the case of large numbers of small polluters, where monitoring imposes practical difficulties, a tax on polluting inputs may be a second-best policy. However, the efficiency of such a tax would depend on whether the quantity of input purchased is closely correlated with the volume of pollution emissions generated. More importantly, the effectiveness of this instrument depends on the elasticity of the input demand response to the higher input prices.

We review below the policy instruments that could be used to influence the economic incentives to engage in environmentally-damaging agricultural activities. Our discussion draws heavily on Dosi (1992). Depending on the specific legal environment, some of these policy instruments may be unavailable to administrators. Policymakers should investigate possible municipal, state, national, or international legal constraints on internalization mechanisms. If the administration of internalization programs is financed through income or commodity taxation, any deadweight losses associated with such taxation should also be considered in the development of incentive-based policies.

Remove Existing Market Distortions that Exacerbate Environmental Damage

Although agricultural activities can be expected to produce externalities even in a complete policy vacuum, many externalities are exacerbated by government programs which distort relative prices. For example, the U.S. price support programs were designed to maintain farm incomes but provide incentives for over-production and over-specialization in crops that require large levels of agrochemical inputs. Incentives for over-production lead to the expansion of environmentally-damaging agricultural activities at both the extensive margin (e.g., deforestation and filling wetlands) and intensive margin (e.g., overuse of agrochemicals and irrigation water). In the EEC, the Common Agricultural Policy creates similar distortions. In many LDCs agrochemical subsidies provide incentives for the overuse of environmentally-damaging chemicals at the expense of traditional manuring and crop rotation practices as well as modern conservation-oriented cultural methods.

From the previous review of case studies, it is clear that existing market distortions are responsible for a large proportion of the environmental damage caused by agricultural activities around the world. These distortions increase over-production, over-specialization, and over-intensification. Although removing market distortions would seem to be a technically straightforward way to reduce environmental damage, this is also one of the most difficult policies to implement from a political point of view. Interest groups can be expected to fight for the economic rents that accrue to them under existing policies.

Emissions Taxes or Marketable Emissions Permit Systems

Emissions taxes are direct taxes on the activity or substance that causes problems; e.g., taxes on eroded soil leaving farmland, on pesticides harming farmworkers, or on fertilizers polluting groundwater. If emissions taxes per-unit of externality-causing activity or substance are set at rates equal to the marginal per-unit level of damages caused by an externality, then profit-maximizing agents would reduce the externality-causing activity or substance emissions to socially efficient levels. In principle, emissions taxes are superior to taxes on outputs or inputs because emissions taxes do not cause additional distortions in output or input markets. In practice, however, emissions taxes are difficult to implement because the externality-causing activity or substance and the damages caused by the externality must be measured in order to calculate the appropriate tax rate. Such measurements are very difficult in the case of nonpoint source pollution emissions because sources are spatially diffuse, damages are often distant from sources, and are the result of emissions from several sources. An alternative approach is to use mathematical models to estimate emissions based on soil type and slope, input use, cultural practices, etc. Damages are estimated based on distance to potential victims, weather, season, protective measures taken, etc. Emissions taxes are then based on estimated emissions and damages.

Marketable emissions permits are tradable rights to engage in environmentally damaging activities. Regulators determine the allowable amount of the activity, and an appropriate number of permits are allocated to agents, who may then buy or sell the permits. The allowable externality level is thereby achieved in an efficient manner. Permit systems can achieve outcomes as efficient as an emissions tax system. However, marketable emissions permit systems also have practical drawbacks. It is difficult to decide on an equitable initial allocation of permits, and to monitor compliance. In addition, markets for emissions permits may not be competitive if one or a few market participants control a large share of the permits.

Taxes on Agricultural Outputs or Inputs

Due to the difficulties involved in measuring and monitoring emissions and establishing emission tax or marketable emissions permit systems, policymakers may try to deter externalities indirectly through taxes on agricultural outputs or inputs. Such indirect control measures have several drawbacks because they fail to "target" the externality itself. For example, output taxes create incentives to reduce agricultural output, but the production of agricultural output, per se, is not the cause of externalities. Alternative methods may exist to produce the same level of output with lower levels of externalities. Output taxes provide no incentives to find alternative production methods. Another problem associated with output taxes is that the externalities generated per unit of output may be very different across agents. In that case, the efficient tax rate varies across agents. For administrative convenience, however, the tax rate is almost always the same across agents. A uniform output tax rate is inefficient because it does not allocate the strongest incentives to reduce pollution to the worst polluters.

Although input taxes, such as a tax per unit of fertilizer or pesticide use, may address externalities more directly than output taxes, their use also entails targeting problems. As is the case for output taxes, the externalities generated per unit of input may differ across agents. However, a uniform tax rate is easier to administer. In addition, some studies suggest that the price elasticity of fertilizer use, for example, is relatively low, so that a fertilizer tax would not affect fertilizer use—or the magnitude of associated externalities to a great extent. A final problem with input taxes is that some inputs, such as manure fertilizer, may not be purchased; this would present additional difficulties for tax administration.

Deposit-refund Systems

Deposit-refund systems require that a deposit be paid on potentially polluting products, to be refunded upon return of the products or proof of nonpolluting use. Most agricultural externality problems do not seem amenable to deposit-refund systems because most purchased inputs are incorporated into the product (i.e., fertilizers), destroyed by the environment (i.e., pesticides), or so diffused in the environment as to make their collection prohibitively expensive. However, such a system might be useful to ensure proper disposal of unused pesticides and pesticide containers.

Cross-compliance Restrictions

Cross-compliance restrictions require that a producer engage in, or refrain from, specified activities in order to be eligible for other government programs, such as income support programs. However, it may be difficult to reconcile the objectives of a pollution control program with the objectives of a linked program. For example, an erosion control program may prohibit production on highly erodible soils as a requirement for price support payments, while the goal of the price support payment program is to maintain income levels on low income farms. If most highly erodible soils are found on low income farms, then erosion control through cross-compliance could be at odds with the goal of income maintenance.

Chapter III

Existing and proposed internalization policies

In this section we review existing and proposed policies to internalize agricultural externalities in industrialized and developing countries. After a brief overview of recent internalization initiatives at the international level, we close with a summary of policy proposals and recommendations from several sources.

National Policies — Industrialized Countries

Dosi (1992) examines policies aimed at controlling NPS pollution in the U.S., EEC, and Italy. Section 208 of the 1972 U.S. Federal Water Pollution Control Act (renamed the Clean Water Act in 1977) required each state to formulate a plan to identify areas with "substantial water quality problems" and to propose suitable solutions. "Prior to the area-wide water quality management process defined in Section 208. . . , most nonpoint source programs could be considered [only] research" (Vigon, 1985). However, in general, states faced no requirement or incentive to implement their Section 208 plans. The 1987 rewrite of the Clean Water Act required (under Section 319) states to submit to the EPA an assessment report and a management plan for controlling NPS pollution. States were further required to obtain legal authority and identify funding to implement the plan. The only sanction for states which refused to do so denied them federal funds to finance the management plan they had not implemented! The EPA was forced to conclude that, although decentralization of NPS regulation is desirable, voluntary programs without sanctions would not achieve environmental quality goals.

The U.S. has other federal laws which affect NPS pollution. The Safe Drinking Water Act requires that states submit public water wellhead protection program plans to the EPA. The Coastal Zone Management Act of 1972 was amended in 1990 to require states to submit Coastal Nonpoint Pollution Control Program plans to the EPA and the National Oceanic and Atmospheric Administration. But again, the only penalty for failing to implement these programs is denial of federal cost-share funds. The Federal Insecticide, Fungicide, and Rodenticide Act prohibits "any legal use of any pesticide which concentrates in processed food and is shown to present cancer risk." There has been no move to apply this rule to pesticides which concentrate in water. The Soil and Water Conservation Act of 1977 requires that the USDA periodically update a National Program for Conservation of Soil and Water. The 1989 update calls for voluntary programs to address both on- and off-site damages associated with soil erosion and NPS contamination of surface and groundwaters.

The 1985 U.S. Food Security Act established several programs affecting NPS pollution. The Conservation Compliance Program requires that farmers develop and fully implement farm conservation plans by 1995 or lose access to federal farm program benefits. The Sodbuster Program prohibits conversion of highly erodible land to agricultural production just as the Swampbuster Program prohibits the conversion of wetlands; violation of the provisions of either program results in the loss of many federal farm program benefits. The Conservation Reserve Program pays farmers to remove highly erodible land from agricultural production for 10 years and to plant it with groundcover. There is debate over the definition of highly erodible land: is it land with high erosion rates or land where erosion causes high levels of environmental damage? A Nonpoint Source Index that would account for proximity to surface water bodies as well as gross erosion potential has been proposed. The U.S. Wetlands Reserve Program authorizes retirement of up to one million acres of farmland for 30 years or more. The Water Quality Incentives Program authorizes incentive payments and cost share assistance for farm management plans that protect water quality and improve wildlife habitat. The Integrated Farm Management program allows 20% of base acreage to be planted to resource-conserving crops while farmers collect deficiency payments as if they were planting cash crops.

In 1988 the EC Commission passed a proposal (COM(88)708) regarding "measures relative to the protection of fresh, coastal, and marine waters from pollution due to nitrates deriving from nonpoint sources." Dosi (1992) considers this the first official

EC document to specifically target "a precisely identified subset of NPS pollution problems." EC countries were required to identify vulnerable areas, regulate the use of animal waste and the distribution of chemical fertilizers in these areas, and register the quantities of animal and chemical nitrogen used. Voluntary compliance was allowed only in nonvulnerable areas. The Commission subsequently weakened this proposal with Directive 676/1991, which allowed several provisions to be "at the farmers' discretion" and eliminated nitrogen use registration requirements.

The EC has also implemented a series of set-aside programs since 1988. These focus on reducing crop surpluses and, unlike U.S. set-aside programs, do not have provisions for targeting NPS problems. However, EC Regulation No. 2078 outlines a program of subsidies for farmers who commit to specified conservation practices, including fertilizer or pesticide reduction, grazing density reduction, and leaving land fallow, for a minimum of 5 years.

Italy passed Act No. 319 (the "Merli Law") to protect surface and groundwaters from pollution in 1976. This Act instituted a system of discharge permits, established standards for effluents, and began a system of charges for activities causing discharges. The focus on "discharges" rather than ambient quality standards, and the intent to rely on structural devices as a primary means to achieve control, limited the effectiveness of this legislation for NPS pollution control. In 1979 Law No. 659 established a committee which found that the Merli Law should not be applied to farms that do not produce "terminal discharges." However, in part to conform to EC directives, several recent laws and decrees have established conservation areas (Decree 236/1988) around springs, catchment points, and aquifer recharge areas where some agricultural activities (i.e., application of pesticides or fertilizers) are prohibited. The newer laws emphasize ambient quality standards (Decrees 235/1992 and 16/1990) in regard to nitrogen fertilizer and herbicide contamination of water supplies destined for human consumption.

In 1987 the Western Australian government created the Integrated Catchment Management (ICM) Policy Group to develop a strategy to coordinate efforts to reduce and manage environmental impacts from land use (Wallis and Robinson, 1991). The ICM process there: 1) determines the boundaries of catchment areas; 2) sets environmental limits by determining the assimilative capacity of each catchment; 3) takes into account community desires in determining the best uses for land and resources in the catchment; and 4) helps communities to develop strategies ensure that the assimilative capacity is not exceeded.

Both Japan and Republic of Korea continue to rely primarily on command and control regulations (OECD, 1993a). In countries where a small number of very large firms account for a sizable share of industrial output and related industrial pollution, an approach targeting the worst offenders can be quite effective and monitoring costs are relatively low. Although industrialized East Asian countries may have relatively low levels of policyinduced price distortion compared to many LDCs, they may employ some pricing policies which undermine environmental objectives (e.g., the Republic of Korea has fertilizer subsidies). On the other hand, it has also introduced a deposit-refund system for a number of products, such as cans and bottles, pesticide containers, batteries, and tires, which contribute to waste disposal problems.

The former Soviet Union faces institutional and administrative problems in introducing water and wind erosion control measures because private property rights are difficult to delineate (Golitsyn, 1992). Where erosion measures have been fully implemented, production has doubled or even tripled. The disintegration of the country has also delayed the mass production of machinery designed to reduce soil compaction. Formulation and implementation of effective agricultural externality policy in this region is predicated upon the creation of markets and credible government agencies.

The United Nations (1992) reports that environmental costs related to pollution are normally not recognized. It calls for a proper value to be placed on the services provided by the environment, since degradation often results because the environment is treated as a zero-priced resource. Improved accounting should reflect proper valuation of the natural resources, both as factors of production and as sources of waste absorption. Ahmad et al. (1989) note that there are several controversial issues concerning national income accounting as currently practiced; with respect to environmental and natural resource issues, the two outstanding issues are the treatment of environmental protection costs and the treatment of natural resource depletion.

Peskin and Lutz (1990) survey resource and environmental accounting in industrialized countries; they suggest that natural resource accounts ought to be separable additions to existing national accounts. The U.S. Department of Commerce (1994a, 1994b) provides an overview of the environmental satellite accounts for the U.S. (and a long-term plan to implement the framework); it also presents the results of such an analysis for the U.S. mineral resource sector.

National Policies — Developing Countries

Asia

Taiwan Province of Chinaand Thailand appear more inclined to experiment with the use of economic instruments than do Japan and Republic of Korea (OECD, 1993a). Perhaps one reason for this is that the former two countrieshave many more small and medium-sized geographically dispersed enterprises. A straight command and control approach would not be practicable under these circumstances, although both countries do have a basic regulatory framework which defines environmental quality standards. Moreover they are actively studying the introduction of pollution taxes. In Tapei in 1991 the government passed an Air Pollution Control Act which allows for a system of emission charges; a similar system of levies is being considered for water pollution. Bangkok is considering a pollution tax. Subsidies on pollution control investments or on less-polluting inputs also are in place. For instance, the Thai Ministry of Finance discounts the standard tariff on imported capital equipment for end of pipe waste treatment technology.

In establishing a basic regulatory framework, the Indonesian government is concentrating on building up monitoring and enforcement capabilities (OECD, 1993a). Indonesia may assign a less important role to incentive instruments as its environmental management system has been patterned after Canada’s, which remains one of command and control. For example, the pollution control agreements are part of a tightly focused program to clean up the most heavily polluted rivers. Firms with the largest pollution loads were asked to draw up pollution abatement plans. Although not legally binding, the abatement agreements have been effective in deterring polluters. Aware that reform of existing pesticide subsidies could yield both environmental and economic benefits, the Indonesian government recently reduced from 82 to 40% the retail subsidy of pesticides. This reduction, combined with a ban on the use of 57 pesticides and the introduction of an integrated pest management system, has helped avert disaster. The Indonesian Ministry of Population and Environment has recently announced an import tax reprieve for waste water treatment equipment.

Chapman (1990) finds that the Indonesian government’s agricultural pricing and subsidy policies contribute to environmental degradation by encouraging inappropriate land use. Rigid import controls and a heavily protected domestic pricing structure may provide indirect disincentives to soil conservation. As the average returns to highly commercialized and input-intensive crops such as vegetables increase, share tenancy and absentee ownership become more common. This can reduce the incentive for long-term investments in improved land management if tenancy arrangements are insecure and if the objective of absentee owners is short-term profit maximization or land speculation. The increased profitability of vegetable crops also encourages farmers to cultivate on steeply sloped volcanic soils, where water run-off and soil erosion are greater.

Repetto, et al. (1989) apply resource accounting to natural resources in Indonesia. Their study concentrates on the depletion of those natural resources that generate marketed output (oil, timber, top soil). They estimate harvesting, deforestation, and degradation net of regrowth for forestry, and suggest that it be treated like depreciation of man-made assets. That is, they propose reducing the NDP by the estimated depletion.

Magrath and Arens (1989) estimate the cost of soil erosion in Java at $350 to $415 million annually, which is slightly less than 0.5% of GDP. Khalid and Braden (1993) discuss Malaysia's restrictions on pollution from palm oil manufacturing residues. They review the effectiveness and cost of the regulations and calculate the negative producer welfare effects from different BOD levels. Peskin and DeLosangeles (1994) provide an overview of a current project to develop environmental and natural resource accounts in the Philippines. This paper also provides some general discussion on System of National Accounts (SNA) and presents a summary of accounting approaches.

Central and South America

El Salvador and Costa Rica have a number of old laws controlling pesticide regulation, soil conservation practices, protection of soil and water resources, and the introduction of new coffee plant varieties that might influence the environment (Segura and Reynolds, 1993). Fines are very low, and these laws are only weakly enforced. Water is much more expensive in El Salvador than in Costa Rica, and processors must pay to dump processed water into rivers. As a result, coffee processing uses less water in El Salvador, much of the processed water is treated before it is discharged, and groundwater pollution is less prevalent than in Costa Rica. El Salvador is considering the implementation of the International Code of Conduct for the Distribution and Use of Pesticides. Costa Rica has a new policy aimed at eliminating 80% of organic discharge from coffee processing plants over five years through subsidized loans from the Inter-American Development Bank and the Banco de Costa Rica. Research is currently underway in the areas of mixed-species cropping, soil conservation, integrated pest management, organic farming techniques, and the use of coffee processing residues as fertilizer. International agencies now require environmental impact assessments, including economic assessments of environmental damages, for these countries to qualify for loans. However, it is widely believed that influential groups may be finding ways to circumvent these requirements. Solorzano et al. (1991) discuss the national income accounts of Costa Rica. They include estimates of depreciation values for soil, timber, and fisheries.

Swezey and Murray (1986) review pesticide policy in Nicaragua. Nicaragua’s heavy reliance on chemical technology is rooted in the production of cotton, a mainstay of the nation’s economy. With help from the U.S. Department of Agriculture and the Food and Agriculture Organization of the United Nations (FAO), a group of Nicaraguan technicians laid the groundwork in the late 1960s and early 1970s for a comprehensive Integrated Pest Management program. It was designed to make maximum use of naturally-occurring insect controls, using biological, environmental, cultural, and legal methods in a complementary fashion. The Nicaraguan government established some of the most innovative regulations to control pesticide abuse ever introduced in Latin America (Faber, 1993).

Although current environmental policies in Brazil include pesticide registration, pesticide labeling, and the environmental licensing of polluting industries, actual fines for polluting are very small. In the mid-1960s, the Brazilian government launched an agricultural credit program that restricted credit to areas "agroecologically apt for coffee" and required contour planting practices, in addition to subsidizing inputs (May, 1993). Plantings from this period demonstrated reduced soil erosion.

With trade liberalization, a relative decline in product prices, and the recession of the early 1990's, Brazilian coffee producers have adjusted pesticide use to levels even below those recommended for control of principal pests and diseases. There are no environmental policies for the coffee primary processing sector, it does not generate much pollution. In the coffee secondary processing sector, fairly rigid technology-based regulations have led to the widespread adoption of protective equipment, and even to the export of such equipment to the EC. In cocoa, environmental policies protecting the remnants of the Atlantic Forest ecosystem are failing due to lack of government coordination and enforcement capacity. In both the coffee and the cocoa sectors, subsidized credit or minimum price guarantees may reinforce soil exhaustion and excessive pesticide application.

Mahar (1989) discusses government policies and deforestation in Brazil's Amazon Region. Early settlers in the Rondonia region engaged in environmentally-unsound farming practices and deforestation. Recognition of the growing problems in Rondonia led to a government program to reduce forest clearance on land without long-term productive potential and to promote adoption of sustainable farming systems based on tree crops. The program has not worked because: 1) subsidized credit for the inputs necessary for risky tree cultivation has not been available in sufficient quantities; 2) the government has not been able to enforce the "50% rule," prohibiting settlers from clearing more than half their land; 3) the rural land tax structure, where tax rates decrease as utilization increases; 4) the government accepts deforestation as evidence of land improvement; and 5) land speculation is rampant, and pasture is the least expensive way to holding land while it appreciates.

May (1993) notes that Brazil is considering a number of environmental policies including: 1) increased emissions charges or taxes; 2) strengthening regulatory and enforcement institutions; 3) green labeling, or environmental certification of chocolate products; 4) a precautionary "Polluter Pays Principle", which would require potential polluters to purchase ex ante insurance against future environmental damages; 5) financing new technology adoption; and 6) promoting integrated pest management.

<u>Africa</u>

Chapman (1990) finds that inadequate investment in research and extension, governmental interventions that keep food prices artificially low, and formal and informal tenurial regimes often discourage the adoption of conservation measures, encourage excessive land clearing, or both. In the Sahelo-Sudania and Sudanian climatic zones, the regional governments maintain low food prices for the benefit of urban consumers and ignore the marketing bottlenecks responsible for price instability and the farm-gate price collapse at harvest time. Because agricultural research and extension are not strong, incentives to adopt high-yield sustainable crop production systems are weak, and farmers opt for extensive production on fragile lands. Some property arrangements discourage environmental conservation. Under the communal tenure regimes that prevail in the Sahel, a family wishing to plant crops is entitled to temporary use of a parcel. However, planting trees or even perennial crops is often regarded as an attempt to assert permanent individual rights in communal land. Under these circumstances, there is an institutional constraint on afforestation.

Governments in equatorial Africa also accelerate resource degradation by attempting to supplant local tenure regimes. Ignoring the distinction between common property and open access, they have failed to offer legal mechanisms for protecting communal land rights. Instead, attempts are often made to convert common properties into government lands or private properties, even though the public sector's capacity to manage its resources and the legal infrastructure needed to enforce private tenure are both poorly developed. Weakening traditional property arrangements without providing a viable institutional alternative reduces the incentive for forest dwellers to conserve natural resources.

As a final note on this section, Lutz, et al. (1990) discuss environmental accounting issues from the perspective of developing countries.

International Initiatives

Dawkins et al. (1994) review recent internalization initiatives at the international level. They examine two contemporary initiatives to address the lack of full-cost pricing for agricultural products under the GATT. The first proposes 'anti-dumping laws', defined as the export of goods at prices below the cost of production in Article 6 of the pre-Uruguay Round of GATT. The second, newer approach involves a formula called the 'Aggregate Measure of Support' or AMS. All taxpayer-paid costs of production for agricultural products have been identified and listed with a specified financial value. "Everything from easily quantified water and fertilizer subsidies to more complex items such as the value of government-paid maintenance of inland waterways are included. . . . in June 1994, the GATT hosted its first symposium with non-governmental organizations to consider the internalization of costs as an environmental measure in trade policy." In addition, the OECD has created two working groups to study the issue, one to consider the impacts of economic instruments and environmental subsidies in trade policy, the other to look at the mechanics of life-cycle analysis.

A Review of Internalization Policy Recommendations

Ribaudo (1986) looks at off-site vs. on-site benefits of soil erosion prevention programs in the U.S. He finds that focusing on on-site criteria rather than off-site could lead to inefficient allocation of soil conservation funding. Dosi (1992) provides a list of recommendations for policy development: 1) promote public awareness of NPS problems; 2) develop mechanisms (e.g., bio-physical models, to identify polluters other than traditional expensive/infeasible monitoring at the emission source; 3) develop pollution prevention programs and provide appropriate incentives for participation (voluntary programs are not sufficient).

Peskin (1986) suggests that, rather than concentrating on cropland controls as the only practical policy target, it might be worthwhile to investigate indirect control strategies for difficult-to-control nonpoint sources. In certain regions upstream interception of pollutants, using small reservoirs and holding ponds, may be a cost-effective approach for any NPS, including cropland. While this approach has been implemented, its cost-effectiveness has not yet been thoroughly explored. Braden and Lovejoy (1990) discuss a three-part policy package to address issues involving agriculture and water quality: 1) a set of input taxes designed to reduce pesticide and fertilizer use and to raise revenue; 2) mandatory regulation of soil erosion targeted toward water quality, which could be coupled with cost-sharing provisions financed by input taxes; and 3) regulation of pesticide and fertilizer use and explicit farmer liability for remaining groundwater contamination, with the possibility of purchasing pollution liability insurance. Although such a package is imperfect, it provides an example of how a variety of policy instruments, based on both incentives and regulation, could be combined in an attempt to balance policy concerns.

Shortle and Dunn (1986) examine the relative expected efficiency (net benefits) of four general strategies suggested for achieving agricultural nonpoint pollution abatement. Referring to the flow of pollutants from a farm as runoff, the four strategies considered are: 1) economic incentives applied to estimated runoff (e.g., a tax on estimated soil loss); 2) estimated runoff standard (e.g., estimated soil loss standard); 3) economic incentives applied to farm management practices (e.g., taxes on nutrient applications); and 4) farm management practice standards (e.g., required use of non-till). Setting aside policy transaction costs, the principal result of this analysis is that an appropriately specified management practice incentive should generally outperform estimated runoff standards, estimated runoff incentives, and management practice standards for reducing agricultural nonpoint pollution.

Letson et al. (1993) discuss methodological issues in PS/NPS trading and the feasibility of P/NPS trading in coastal watersheds in the U.S. A set of simple screening rules reveals that 10% of coastal watersheds have significant contributions of loadings from both point and nonpoint sources. These results suggest that PS/NPS trading is more likely to work in a small number of coastal watersheds rather than as a means for bringing NPS in coastal watersheds under national control.

Shortle (1987) examines the possible use of information on the relative marginal costs of point and NPS pollution abatement to assess the efficiency implications of shifting more of the burden for water pollution control to nonpoint sources. Although some of the specific results of this analysis are contingent upon the underlying assumptions, two are pertinent. First, the conclusion that the marginal costs of point source and expected nonpoint source abatement will differ in a balanced allocation when the pollutants are perfect substitutes is due to the uncertain effect of resource allocation on nonpoint pollution loads. Second, whether the pollutants are perfect substitutes or not, the exact relationship between the marginal costs of point source and expected nonpoint source abatement in a balanced allocation cannot be determined without a well-defined damage cost function.

Southgate (1988) proposes that the solution to many LDC land degradation problems involves action by small farmers who often farm their fragile land in a way that does not conserve soil. In part, farmers' reluctance to adopt conservation measures is a consequence of distorted price signals. In addition, the suboptimal use and management of natural resources is explained largely by the tenure regime they face. They rarely possess "unattenuated" private property rights in the resource they use and often live where traditional systems of common property tenure are breaking down or where open access resources are available. A change in market forces or government policies that results in an increase or decrease in labor's opportunity cost affects small farmers' decisions regarding the use and management of land. In addition, other price signals such as interest rate, commodity prices, exchange rates, and prices for non-labor inputs to agriculture, affect small farmers' decisions and may be used as incentives for proper land management.

Kox (1991) has proposed a new International Coffee Agreement that would establish a tax on coffee "of no less than 1% of the cost of coffee in international markets. These economic resources would go directly to producing countries where one institution or committee would be in charge of distributing them according to environmental national priorities."

Discussion and Conclusions

In reviewing *extensification damages* we find that, although qualitative descriptions of environmental damages are available for several regions, quantitative estimates are limited to a small number of specific case study areas. Quantification of *intensification damages* is somewhat further advanced, especially the on-site damages of soil erosion to crop productivity and the off-site damages of sedimentation to reservoirs. However, other on-site damages (pest resistance and beneficial insect destruction) and off-site damages (pesticide effects on fish and wildlife) await quantification.

In the U.S. educational, voluntary, and cost-sharing programs have been somewhat successful in curbing soil erosion, but such programs have not successfully addressed other types of NPS pollution. This probably reflects the fact that farmers have private incentives to reduce soil erosion (i.e., maintaining soil productivity), but have no similar private incentives to combat other types of NPS pollution.

In many regions of the world, the key impediments to the solution of agricultural externality problems are economic and institutional rather than technological. Environmental damages could be reduced greatly through the application of appropriate economic policies and institutional reforms; no major new technological advances would be required. Unfortunately, most national and international policies attempting to address the problem of environmental damages caused by agricultural activities could be described as "projects." They are very limited in scope, do not consider the interaction of the project problem with other economic markets and policies, are incorrectly targeted to reduce crop output or acres harvested rather than to reduce environmental damages, and are designed to terminate after meeting narrow goals within fixed project budgets and time horizons. In contrast, appropriate internalization policies should have a broad-based, general-equilibrium design. Features of such a program are described below.

Internalization policies must be broad in scope to recognize the trade-offs which exist in reducing off-site environmental damages. For example, Faeth (1991) reports that Crutchfield (1987) estimated that "the establishment of a permanent vegetative cover reduces nitrogen in surface runoff by 90 percent, but increases nitrogen in [groundwater] leachate by 26 percent" in one region of the U.S. Internalization policies also should have a general equilibrium nature, taking into account interactions with other economic markets and policies. For example, the agricultural market distortions in many countries alter the relative prices of agricultural outputs and inputs (price supports in the U.S. and EC, pesticide subsidies in the Philippines and India). These distortions can exacerbate environmental damages through altering crop production methods and input choices. Under distorted market conditions, internalization mechanisms must be more severe to achieve environmental policy goals because they must correct both the market distortion and the environmental damage externality.

Whenever possible, attempts to internalize environmental damages should target the actual damages themselves rather than some proxy variable. This is especially relevant in situations where the quality and magnitude of environmental damages associated with a given level of crop production depend on production methods. For example, Faeth (1991) discusses two case studies in the U.S. where conventional farming systems are compared to alternative methods. In one of the case study areas, the alternative production methods increased yield while reducing environmental damages. Internalization policies which target environmental damages instead of crop production allow these win-win outcomes. Targeting environmental damages also provides incentives to develop the new, alternative cropping methods which can maintain yields while reducing damages.

The design of internalization mechanisms should take into account the dynamic nature of some environmental problems. For example, groundwater depletion is a common dynamic problem in irrigated regions. The common property nature of the groundwater pool often results in inefficient, accelerated depletion. Soil erosion is another example of a dynamic problem. The benefits of reducing erosion rates are higher at lower levels of erosion (Anderson, 1987). At higher levels of erosion, the value of maintaining or enhancing the fertility of the significantly degraded soil is much less, so it is better to protect soils earlier rather than later.

In theory, it is necessary to know the marginal environmental damages associated with an activity in order to set efficient internalization charges. This review points out that there are limited data on the *average* environmental damages associated with agricultural activities (much less the marginal damages), especially for developing countries. Even if marginal damage data were available, they would vary by geographical region, year, season, and even time of day. Relationships between marginal environmental damages and agricultural activities are often nonlinear, resulting in sudden surprises and dashed expectations. Researchers should give some thought to establishing a global system to collect, update, and disseminate estimates of environmental damages efficiently and quickly, in order to respond rapidly and *adaptively* to changing environmental conditions.

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Annotated Bibliography for Papers in Table 2

Abelson (1979)

- The benefits of soil conservation project are increased livestock output, flood mitigation, improved water quality, improved amenities.
- The timing of the implementation of the project is important.
- Bojo et al.(1990) pointed out that if the project is financed through general tax revenues, the associated deadweight losses would be added to the costs of the project.

Akande (1993)

- Review the effects of producing and processing cocoa on the environment.
- Cocoa is a labor intensive industry in Nigeria, and capital input occurs mainly in the form of pesticides.
- Pesticides are highly subsidized by the government.

Anderson (1987)

- Discuss the destruction of trees in woodland and farms.
- The consequences are decline in farm tree stocking, decline in soil fertility, degradation of forest reserves.
- The program focuses on the designation of shelterbelt, which improved the environment.
- The benefit of program depends on the timing of implementation.

Bishop and Allen (1989)

- Focus on the on-site costs of soil erosion, especially the loss of fertility of the soil and the resulting loss in agricultural product.
- The present value of net farm income loss due to one year of soil loss is 3.95% of agricultural GDP and 1.54% of total GDP in Mali.

Bojo (1990)

- Discuss the environmental degradation and proposed program in Lesotho.
- The project encourages the use of inorganic fertilizer and hybrid seed varieties as well as the rehabilitation and construction of waterway and drainage system.

Clarke et al. (1985)

- Present estimates of costs of soil erosion in the U.S., including sedimentation and flooding damages, lost recreational opportunities, instream damages to fisheries, and degraded water conveyance facilities.
- Total damage costs attributed to cropland is estimated to be 2.2 billion per year in 1980 dollars.

Cruz et al. (1988)

- Provide suggestions for how to assess the economic impacts of soil erosion focusing on watershed.

Dada (1985)
- Discuss on-site and off-site costs resulting from nonpoint source pollution in U.S.

Faeth (1993)
- Present estimates of soil depreciation cost.
- Good case studies with comparative farm budgets across several alternative methods of production.
- It provides an expected utility model incorporating health costs of pesticides exposure for rice farmers in the Philippines.

Faeth et al. (1991)
- Develop estimates of Net Farm Income and Net Economic Value to Society under a variety of government policy scenarios in two farming regions of the U.S., Nebraska and Pennsylvania.
- The principal finding is that where erosion-prone soils are causing substantial environmental demage both on and off the farm, resource-conserving production systems are economically superior.
- Point out that U.S. agricultural policies carry with them serious unintended environmental costs.

Finney and Western (1986)
- Explain the integrated environmental program for the island of Palawan commissioned by government and EEC.
- The proposed program consisted of : protection of upland forests, increased regulation of commercial logging, stabilization of agricultural systems, establishment of parks and reserves, and infrastructure investments.
- Present the expected benefits of the program: agricultural benefit, infrastructure benefits, tourism benefit, mangrove forest protection benefit, and coral reef protection benefit.

Golitsyn (1992)
- Discuss the states of environmental damages in some regions of former USSR.

Khalid and Braden (1993)
- Discuss the effectiveness and costs of government regulations.
- Provide estimates of the negative producer welfare effects from various levels of BOD standards.

Kim and Dixon (1986)
- Discuss the damage in the environment due to the inadequate soil management technique in Korea.
- Suggest two alternative methods of avoiding soil erosion : the prevailing method which involves replacing soil and soil nutrients in the uplands and clearing silted paddies in the lowlands, and the prevention method which involves mulching the upland areas.

Mahar (1989)
- Discuss the causes of deforestation and suggest environmental program in Brazil's Amazon region.
- The suggested program is to reduce forest clearance on land without long-term productive potential and to promote a more widespread adoption of sustainable farming systems based on tree crops.

May (1993)
- Discuss the environmental effects of coffee and cocoa production and processing.
- By pointing out ineffectiveness of current policies, it provides potential environmental policies.

Pagiola (1994)
- Discuss the returns to soil conservation policies.
- It concludes that given the low cost of production, the investment in soil conservation is not repaid until the 48th year.

Segura and Reynolds (1993)
- Discuss the environmental impacts of discharge of untreated water to rivers in coffee processing industry.
- Discuss the current and proposed environmental policies.

Sfeir-Younis and Dragun (1993)
- Provide estimates of soil erosion rates and causes and effects of this erosion in LDC.
- Major causes are shifting cultivation, illegal encroachment on forests by subsistence farmers, over-exploitation of common property, settlement of land for commercial agriculture, and inappropriate forest harvesting techniques.
- Major effects are flooding, siltation of waterways, and destruction of marine ecosystems.

Solorzano (1991)
- Calculate the value of loss in soil productivity due to soil erosion.

Southgate (1988)
- Explores some of the causes for soil erosion on small subsistence farms in LDC.
- Tenure regimes, some agricultural development strategies as well as distorted price signals induce development of fragile hinterlands and can discourage the use of conservation measures.

Southgate and Macke (1989)
- Present a model for estimating the off-site benefits of soil conservation project on a hydroelectric watershed, and applies it to a project to reduce erosion in a hydroelectric watershed.

Southgate et al. (1984)

- Provide figures on the net present value of soil conservation project on private lands.

Witte et al. (1993)

- Discuss the damages from the fertilizer and pesticides use in rice production.