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Poverty, Agricultural Intensification, and the Environment*

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INTRODUCTION

As the world's population increases by almost 100 million people each year during the next two to three decades–the largest annual population increase in history–agricultural intensification, i.e. production of more food on land already being cultivated, is a must. There is little scope for increasing cultivated land in Asia, North Africa, and Central America, while in Sub-Saharan Africa and South America, physical and technological constraints are likely to restrain large-scale conversion of potentially cultivable land [Oram and Hojjati (1994)].

Agricultural intensification is already the main source of increased food production.[1] Intensive use of chemical fertilizers, pesticides, and irrigation technology, in combination with higher-yielding crop varieties, has led to enough food being produced in the world such that if it were evenly distributed, no one would go hungry. Global food production per capita increased from about 260 kilograms (kgs) in 1950 to about 350 kgs in the early 1990s [FAO (1992)]. In developing countries the corresponding increase was from 170 kgs to 250 kgs.

There are growing concerns that the agricultural intensification process has exerted a very high toll on the environment, in the form of degradation of natural resources, and that the goal of meeting current and future food needs may be in conflict with the goal of protecting the productive capacity of the natural resource

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[1]Since 1961–63, yield increases have been the major source of cereal production growth in all regions except Sub-Saharan Africa where area expansion has contributed about half of the increased production [World Bank (1992)].

base. These concerns, while valid, are somewhat misplaced. Agricultural intensification, *per se,* need not degrade the environment. It is inappropriate agricultural intensification that is a significant contributor to environmental degradation such as waterlogging and salinisation of soils, contamination of surface and groundwater, and sinking of groundwater levels. The question is not *whether* but *how* to intensify agricultural production.

Exploitation of natural resources leading to environmental degradation is frequently a result of poverty and *lack* of agricultural intensification. Poverty-led environmental degradation is responsible for much of the degradation of marginal lands, deforestation, overgrazing of fragile rangelands, cultivation of steep slopes, and consequent soil erosion, flooding, and loss of vegetative cover observed in many parts of the developing world. Such degradation will not be prevented by reducing intensification but rather by a strategy hinged on alleviation of poverty, a strategy that in turn is likely to require accelerated intensification. Making it more difficult for poor rural households to gain access to technology needed to intensify agricultural production will have negative rather than positive effects on the environment.

Agricultural activities, whether intensive or extensive, affect the environment. Environmental degradation, in turn, can compromise current agricultural productivity, undermine future production, and perpetuate poverty. Thus, while poverty accelerates environmental degradation, environmental degradation causes poverty. Such a self-perpetuating negative spiral is not an uncommon occurrence. In order to advise policy-makers, the linkages between environment, poverty, and agricultural activities must be fully understood. Since increased food production will have to come from more intensive use of existing farmland, the increasing production capacity must be sustainable. Sustainability of future agricultural development must be ensured, not because it is fashionable to do so, but because if we do not we undermine the welfare and survival of our own species.

This paper discusses the main linkages between poverty, agricultural intensification, and environmental degradation; reviews related empirical evidence; and suggests policies to achieve the triple goal of meeting future food needs, alleviating poverty, and protecting the environment.

Following a quick review of key concepts, the paper presents the context in which the relationships between poverty, agricultural intensification, and environmental degradation are considered. The section on poverty and environmental degradation focuses on what we know about why and how the poor degrade the resource base and the consequences of doing so. The three major components of intensification–irrigation, fertilizers, and pesticides–are discussed in the section on agricultural intensification and environmental degradation. The paper concludes with a comprehensive set of policies to encourage and facilitate sustainable agricultural development while eradicating poverty and conserving natural resources.

The paper addresses the above relationships on a global basis drawing on empirical evidence where it is available, with reference to issues of particular relevance to Pakistan.

KEY CONCEPTS

Agricultural development is considered sustainable if it assures that the productive capacity of the agricultural sector is sufficient to meet current and future needs. This corresponds to the more general definition suggested by the Brundtland Commission: "Sustainable development is development that meets the needs of the poorest without compromising the ability of future generations to meet their own needs" [World Commission on Environment and Development (1987)]. This definition implies that sustainability is compatible with reductions in the stock of natural resources if and only if the productivity of the stock of human-made resources increases sufficiently to compensate for the loss of natural resources and, together with natural resources, to meet future needs. Since future needs cannot be predicted with great certainty, reductions in the stock of nonrenewable natural resources are a very serious matter, even when future generations are fully compensated for the loss in productive capacity through enhanced human-made capital. Furthermore, scarce natural resources may have an intrinsic value over and above their productive value due to their mere existence. This "existence value" increases with increasing scarcity.

Some resource degradation is human-made, but other forms of resource degradation are perfectly "natural" and will take place regardless of human's absence or presence. A sense of perspective needs to be maintained: resource degradation is not always a bad thing, it is not always irreversible, and it is not always undesirable [Scherr and Hazell (1993)]. Not everybody loses from degradation: for example, soil carried away from one location may land somewhere where it can be productively used. As Scherr and Hazell (1993) contend, "degradation must...be defined relative to the optimal use of a resource from a social or communal point of view, and it is bad only if it is excessive relative to that optimum". We also need to be concerned about degradation of habitat for flora and fauna: highly sustainable systems from the human perspective may radically alter habitats and threaten species. In some instances, it may make sense to exploit resources unsustainably for a limited period of time and then, at a later date, invest in their rehabilitation. Thus, while environmental degradation is indisputably a serious problem in many parts of the world, an exclusive and static focus on degradation *per se* is not constructive.

Excessive emphasis on conserving the stock of natural resources may result in economic stagnation. Both current and future generations are best served by a development strategy that enhances the sustainable productive capacity of the combined set of resources–natural and human-made–even when that implies a

reduction in the stock of natural resources. Opportunities for substitution between natural and human-made resources and expanded productivity through research and technology are likely to result in a higher rate of sustainable growth in agricultural output.

ENVIRONMENTAL DEGRADATION DUE TO POVERTY AND LACK OF AGRICULTURAL INTENSIFICATION

Almost 2 billion hectares of land worldwide have been degraded in the past 45 years, equivalent to about 17 percent of vegetated soils (Table 1). About 300 million hectares of this land have suffered strong to extreme degradation such that their original biotic functions are damaged and reclamation may be costly if not impossible. Two-thirds of the world's degraded lands are found in Asia and Africa, but human-induced degradation as a proportion of total agricultural land is most severe in Central America and Mexico, where one-quarter of the vegetated land is degraded.

About 17 million hectares of forests (mainly tropical) are cut down each year (Table 2). Two-thirds of the land clearance is for conversion to agricultural use by farmers. Deforestation is most rapid in Asia (1.2 percent per year), followed by Latin America (0.9 percent per year) and Africa (0.8 percent per year). The rate of deforestation has accelerated by almost 50 percent, from 0.6 percent in 1976–80 to 0.9 percent in the 1980s. Deforestation can cause soil erosion many times higher than "natural" levels, siltation of water bodies, and flooding downstream. Deforestation leads to loss of forest products used directly by the poor for nutrition or as a source of livelihoods.

Overgrazing and deforestation are the cause of almost two-thirds of the soil degradation worldwide since 1945 (Table 3). Overexploitation for fuelwood accounts for another 7 percent of degraded soils, while faulty agricultural practices are responsible for 28 percent of soil degradation. Overgrazing, deforestation, and overexploitation for fuelwood result, to a large extent, from poverty and lack of opportunities for agricultural intensification. It would appear that since 70 percent of soil degradation worldwide is caused by these activities, there is a close relationship between poverty, lack of agricultural intensification, and degradation. The practice of leaving land fallow for too short periods to replace soil nutrients may also be partly attributable to poverty.

There are great regional variations in the causes of degradation. In Africa, overgrazing explains half of the degraded soils while faulty agricultural practices account for a quarter. In Central America faulty agricultural practices are the cause of 45 percent of soil degradation while overgrazing is responsible for 15 percent. Deforestation is the most important cause of degradation in both Asia and South America, followed by overgrazing and faulty agricultural practices. Industrialisation

Table 1

Extent of Human-induced Soil Degradation since 1945

Region	Degraded Area		Degraded Area Share of Vegetated Land	
	Moderate, Severe, and Extreme	Light	Moderate, Severe, and Extreme	Light
	(Million Hectares)		(Percent)	
Europe	158	61	16.7	6.4
Africa	321	174	14.4	7.8
Asia	453	295	12.0	7.8
Oceania	6	97	0.8	12.3
North America	79	17	4.4	0.9
Central America and Mexico	61	2	24.1	0.7
South America	139	105	8.0	6.0
World	**1,215**	**749**	**10.5**	**6.5**

Source: [Oldeman, van Engelen and Pulles (1990)].

Note: These results are from a three-year study sponsored by UNEP that asked more than 250 soil scientists and regional coordinators for their estimates of human-induced soil degradation since World War II.

Table 2

The Extent and Rate of Deforestation in the Developing World, 1981–90

Region	Area Deforested Annually	Annual Rate of Change
	(Million Hectares)	(Percent)
Latin America	8.3	–0.9
Asia	3.6	–1.2
Africa	5.0	–0.8
Total	**16.9**	**–0.9**

Source: Forest Resources Assessment 1990 Project (1991).

Table 3

Causes of Soil Degradation

Region	Defores-tation	Over-Exploitation	Over-grazing	Agricultural Activities	Industrial-isation
			(Percent)		
Europe	38	–	23	29	9
North America	4	–	30	66	–
Africa	14	13	49	24	–
Central America	22	18	15	45	–
Oceania	12	–	80	8	–
Asia	40	6	26	27	–
South America	41	5	28	26	–
World	**30**	**7**	**35**	**28**	**1**

Source: [Oldeman, van Engelen and Pulles (1990)].

is a negligible cause of degradation in the developing world, unlike Europe where it is the cause of 10 percent of the degradation.

We understand that soil erosion, mainly caused by water (rain and rivers) and wind, is a significant problem in Pakistan, and that large areas of cultivated land have been lost because of it [Khan (1991)]. River erosion in the hills is particularly serious given the steepness of slopes and narrow river channels. Floods are unfortunately quite common occurrences in Pakistan, because of Pakistan's extensive accumulation of snow and ice in its mountain ranges. Floods substantially increase the erosive power of rivers. Of course, soils washed away from the hills are not completely lost as much as they are deposited in the plains, periodically enriching the soils there. Land erosion is serious in desert and semi-desert areas, although the magnitude of the problem appears to have diminished because of Pakistan's success with extending irrigation into many of the arid lands. Forest coverage in Pakistan is low–about 5 percent of the country's area, much of it in the mountain areas. Pakistan is one of the leaders in farm forestry in the region and in recent years there have been substantial increases in such forests.

Poverty is a significant and persistent problem in developing countries. Over a billion people live in households that earn a dollar a day or less per person. Half of these poor people are found in South Asia, but their numbers are growing rapidly in Sub-Saharan Africa. Poverty in the developing world is not expected to diminish much in the near future. The World Bank projects the number of poor people to remain around 1.1 billion in the year 2000 (Table 4). Sub-Saharan Africa will be the new locus of poverty, as its share of the developing world's poor increases from 19

Table 4

Poverty in the Developing World, 1990–2000

Region	Number of Poor (Million)		Percentage of Population Below Poverty Line	
	1990	2000	1990	2000
South Asia	562	511	49.0	36.9
East Asia	169	73	11.3	4.2
Sub-Saharan Africa	216	304	47.8	49.7
Middle East and N. Africa	73	89	33.1	30.6
Latin America and the Caribbean	108	126	25.5	24.9
All Developing Countries	**1,133**	**1,107**	**29.7**	**24.1**

Source: [World Bank (1992)].
Note: The Poverty line is $ 370 annual income per capita in 1985 purchasing power parity dollars.

percent today to about 27 percent in the year 2000 [World Bank (1992)]. Poverty and food insecurity are concentrated in rural areas, but urban poverty is growing rapidly.

Empirical information on the dimensions and characteristics of poverty in environmentally threatened or degraded areas is scarce. Leonard (1989) estimates that of the 780 million poorest of the poor[2] he identifies in the developing world, 60 percent or 470 million live in rural or urban areas of high ecological vulnerability, that is, "areas where ecological destruction or severe environmental hazards threaten their well-being". Leonard considers those rural areas judged to be of low agricultural potential–"areas where limited soil fertility, adverse climatic conditions, or other natural factors inhibit success of modern agriculture"–to be areas of high ecological vulnerability.[3] Following this classification, 370 million people live in low-potential agricultural areas: 70 percent in Asia, 20 percent in Sub-Saharan Africa, and the remainder in Latin America (Table 5).[4]

[2]Leonard defines this group as the poorest 20 percent of the population of developing countries.

[3]This is somewhat problematic since areas of low agricultural potential are not always more vulnerable to erosion, desertification, deforestation, and flooding than areas of high agricultural potential, which may also be vulnerable to erosion and flooding as well as to waterlogging, salinisation, and contamination of surface and groundwater by pesticides and fertilizers.

[4]Note that following this classification, about 180 million of the poorest of the poor live in areas of high agricultural potential: to alleviate their poverty and prevent their migration into low-potential areas, their agricultural potential must be generated, but without creating conditions for long-term environmental degradation.

Table 5

Distribution of the Poorest of the Poor within Low- and High-potential Areas

Region	Rural Areas		Urban Areas
	Low-potential	High-potential	
		(Millions)	
Asia	265	198	83
Sub-Saharan Africa	71	69	16
Latin America	35	12	31
All Developing Countries	**370**	**277**	**131**

Source: [Leonard (1989)].

A major consequence of poverty is hunger: in the late 1980s, over 700 million people did not have access to enough food for healthy, productive lives and more than 180 million children under five years of age were underweight [UN ACC/SCN (1992)]. The food situation in many regions of the world is difficult if not desperate. In Pakistan, despite improvements in nutrition, about 40 percent of children are underweight (47 percent in rural areas and 33 percent in urban areas); about one-third of Pakistani mothers are underweight (less than 45 kgs); and 45 percent of pregnant and lactating mothers are anemic [UN ACC/SCN (1993)].

The desire to satisfy food needs has left its mark, sometimes permanently, on the environment. Hunger leads to desperate strategies for survival, and attempts to survive or meet basic needs take precedence in the short term over longer-term sustainability. Rural poverty, combined with increasing population density and inadequate agricultural intensification, is responsible for much of the forced exploitation and consequent degradation of environmentally fragile lands, such as forests and steep hillsides, and the breakdown of indigenous institutions for managing common property resources.

The relationship between poverty and environmental degradation is close, complicated, and with an in-built potential for escalation. It is driven in the first instance by poverty itself, but also by loss of entitlements by the poor or by loss of capacity of the poor to sustainably support themselves. Poor people often lack sufficient incomes or access to credit to purchase appropriate tools and materials, inputs such as fertilizer, and intensive technologies in order to practice environmentally sustainable techniques, protect natural resources against degradation, or rehabilitate degraded resources. In many instances, they do not own the resources or do not reap the benefits of conservation practices and thus have few or no incentives to conserve the soil, harbour the groundwater, or preserve trees.

The existence of externalities, that is, situations where costs and benefits of a particular behaviour or action are not borne by the same person or persons, is a major reason why poverty results in environmental damage. Property rights are particularly prone to externalities. There are four major types of property rights to land, water, and forests: open access, communal property, private property, and state property. Resources with open access are particularly prone to exploitation because exploiters may benefit without paying the costs associated with reduced future productive capacity. Indigenous institutions for managing common property resources are breaking down, partly through misguided efforts by governments and international institutions to privatise common property without a thorough understanding of these common property rights. It is difficult to privatize property rights in circumstances of dependence on key spatially concentrated resources, such as waterholes, or when it could lead to "parcelisation" of resources. So, while private land ownership may be expected to be most effective in achieving food security, poverty, and sustainability goals in many cases, it should not be assumed that it is always superior to common ownership. Another misconception is that state ownership of natural resources assures appropriate use of natural resources. Some of the worst cases of environmental degradation have resulted from inappropriate use of natural resources owned and controlled by the state.

Poverty forces people to use available resources to the limit and often beyond. When survival is at stake, it may be perfectly rational to consume capital, that is, future productive capacity. Poor people do not enter lightly into degradation, given their dependence on the natural resource base. It is only when they have exhausted their arsenal of coping strategies and mechanisms, including running down their own health if necessary, that they are left with no option but to tamper with their resource base. At that point, conservation of natural resources for future generations takes on a lesser importance, particularly when the poor cannot assure that their children will in fact benefit from such conservation.

The poor tend to lose their capacity to sustainably support themselves when their access to resources is diminished or available resources are reduced. Poor people may lose traditional access to resources if they are displaced by population pressure that reduces their access to land, by misappropriation of common resources by other claimants, and by activities such as construction of dams, establishment of plantation forests, and creation of wildlife preserves that take land out of use by the poor. In response, the poor may be forced to migrate to marginal lands,[5] such as higher and higher up hillsides and cultivate steep slopes or into drylands, and to cut down forests for agricultural land and fuelwood. These actions could lead to soil

[5]Marginal lands are lands not suited for continuous tillage or for economic use of inputs such as chemical fertilizers, pesticides, tools, and machinery [Scherr and Hazell (1993)].

degradation, loss of soil nutrients, flooding, sinking of groundwater levels, siltation of rivers and lakes, and other ecological problems, and may initiate a vicious spiral of environmental degradation and poverty.

Population growth is a key catalyst of poverty-led environmental degradation, especially in marginal lands. Rapid population growth diminishes farm sizes and ultimately pushes people off the land to search for land and employment opportunities elsewhere. Landlessness is a growing problem in developing countries: 13 percent of rural households in developing countries are landless and 60 percent are near landless, that is, they have too little land for subsistence [Leonard (1989)]. An estimated one billion people live in households with not enough land to meet their minimum food and fuel needs [FAO (1987)]. As people move into marginal areas in ever-increasing numbers, they displace indigenous inhabitants of these areas who may have developed sustainable resource-use techniques. In Kenya, for instance, increasing population pressure in the highly fertile highlands forced people to move into drier areas to settle near dependable water sources and farm land that is more suited for pastoralism. Pastoralists in turn are displaced and forced to compete for land and water, which leads to overuse and degradation of resources [Kates and Haarmann (1991)].

Expansion of cultivation onto hillsides is estimated to have seriously eroded about 160 million hectares of upland watersheds, including the highlands of Ethiopia, the uplands of the Andean region, the upper Himalayan watersheds, and the central highlands of much of Central America [World Food Council (1988)]. About 500 million people are estimated to be living in these severely degraded hillside areas at risk of soil erosion because of lost vegetative cover. Approximately 200 million people are believed to live in the world's tropical forests depending on agriculture-related activities [International Task Force on Forestry Research (1988)]. Over 850 million people live in dry areas where productivity is declining because of desertification–230 million of these people are occupying desertified lands [UNEP (1984)].

Wars, social strife, and natural disasters such as droughts force populations to become more mobile. Consequently, the risk of environmental damage increases, partly from the movement itself of people on already fragile land and partly from the choice of the final destination of the migrants, usually marginal lands that are not heavily settled (precisely because they are marginal). As populations concentrate in areas not yet degraded, they invariably speed up the degradation process. Large-scale migration both within and between countries may not only cause environmental degradation, it may also result from it. Environmental refugees[6] are said to number as much as 10 million: a large proportion are to be found in Africa

[6]Persons forced to abandon their homes or homelands as a result of human-induced environment conditions that threaten their livelihoods [Jacobson (1993)].

[Jacobson (1993)].

In several countries, for example, Brazil and Indonesia, governments have attempted to relieve population pressures by relocating people into forest areas or into "empty" lands. Land settlement schemes in the Amazon forest area were particularly popular until recently. One programme alone, the Polonoroeste programme of regional development in the Brazilian states of Rondonia and Mato Grosso, led to such large-scale migration that the population of Rondonia increased from 110,000 in 1970 to 1.5 million in 1988 [Browder (1989)]. The environmental impacts of such population increases on land are all too obvious.

Clearance of forests for agricultural purposes is responsible for up to two-thirds of the tropical deforestation taking place today. Unless the cleared land is appropriately farmed, the benefits of forest clearance are few and short-lived. Studies show that a third to a half of the tropical forests cleared for agriculture purposes experience declines in fertility of more than 50 percent within the first three years because soils are shallow and subject to hardening and to leaching of nutrients [UNEP (n.d.)]. As soil fertility declines rapidly with annual cropping, settlers often abandon their lands and move further into forests, continuing the cycle of deforestation and degradation. The consequences of these actions are most evident in the degraded lands now lying bare, stripped of nutrients and unworthy of productive use. Many farmers change over to perennial tree crops or cattle production, but cattle production, as currently practiced, has been found to be ecologically unsound in the Amazon region because of soil compaction by grazing animals [Vosti and Loker (1990)]. Moreover, evidence from the Peruvian Amazon shows that reestablishment of forest cover in abandoned pastures takes longer than in slash-and-burn plots [Vosti and Loker (1990)].

The poorest often suffer most from the consequences of environmental degradation because of their immediate dependence on the natural resource base for their basic necessities (food, energy, water, and housing). Much of the income of the rural poor is derived from natural resources and environment-dependent agricultural activities. Surveys from 13 developing countries show that the rural poor depend for 40–85 percent of their income on agriculture [Von Braun and Pandya-Lorch (1991)]. Women tend to particularly suffer from environmental degradation. In many parts of the world, they are the main producers of food and gatherers of fuelwood and water, activities that are made much more difficult and time consuming by degradation. In Nepal, the time required for collection of forest products increased by 45 percent in areas of high deforestation as women had to travel further afield [Kumar and Hotchkiss (1988)]. Consequently, women's farm labour decreased by 50 percent. Time spent in cooking and the amount of fuelwood consumed also declined. These effects, combined with reduced agricultural incomes, had adverse effects on children's nutrition.

Fuelwood shortages are a significant consequence of environmental degradation. There are indicators that about 100 million people in rural areas and 150 million in urban areas suffered from acute shortages of fuelwood in the early 1980s due to forest destruction, and it is estimated that by the year 2000, 3 billion people will face an acute shortage of fuelwood [FAO (1983)]. Fuelwood shortages imply that more time will be needed to gather fuelwood, reducing time available for other activities such as agricultural production; there will be greater incursions into areas not yet exploited such as very steep hillsides, which would leave these areas vulnerable to soil erosion and mudslides; and there will be substitution of animal dung for fuelwood, which will rob the soil of potential nutrients, further escalating degradation and poverty.

Poverty need not lead to environmental degradation. It is the combination of poverty, population increases, land constraints, and lack of appropriate production technology that results in environmental degradation. Where population pressures on the land base are not strong, poverty may be compatible with appropriate natural resource management. There are plenty of examples where poor people have adapted to and coexist harmoniously with marginal environments. However, such examples are rapidly dwindling as population pressures strain against the boundaries of fragile lands. In fact, poverty is increasingly becoming entrenched in marginal areas and it is acquiring gender-specificity as more poor households are headed by women, often because men migrate to high-potential areas or urban areas in search of employment.

If we are to prevent the children of the poor from perpetuating the poverty-environmental degradation cycle, we must confront poverty. The poor are the stewards of much of the world's natural resources, especially the fragile natural resources. They are going to do their best to survive, even if it means having to degrade their resource base and compromise their future ability to survive. Policies to prevent further degradation and to promote sustainability must recognise this overriding goal and the behavioural responses it generates, or they are doomed to fail. The poor who erode the natural resource base are not so much culprits as they are victims. Their actions that lead to environmental degradation are the result of their poverty, from which they are trying to escape. To prevent degradation, we must help the poor rather than punish them by denying access to resources or by bringing to bear punitive measures or regulations to control their access to resources. These measures may be a panacea in the very short term but do not solve or address the underlying conditions that promote degradation.

AGRICULTURAL INTENSIFICATION AND ENVIRONMENTAL DEGRADATION

The dramatic impact of the Green Revolution on yields and production of

basic grains is well-known and needs no elaboration here. Continued agricultural intensification is essential to achieve the triple goal of: (1) assuring sufficient food for future populations at reasonable prices, (2) protecting natural resources from exploitation, and (3) alleviating poverty, food insecurity, and malnutrition. Agricultural intensification is based on a combination of inputs such as fertilizers and pesticides, plant breeding technology to breed high-yielding and pest- and disease-resistant varieties, irrigation technology, as well as improved agricultural practices such as multiple cropping. The success of past intensification in raising crop yields and production is clear. However, failure to maintain past levels of investments in agricultural research, technology, and irrigation, along with falling real agricultural prices and associated decreases in the use of fertilizers, are contributing to falling yield growth rates for the two major cereal crops, rice and wheat (Table 6).

Table 6

Growth Rate of Asian Wheat and Rice Yields

	Wheat	Rice
	(Percent per Annum)	
1957–59 to 1965–67	n.a.	1.7
1961–63 to 1965–67	6.2	n.a.
1965–67 to 1973–75	4.1	2.3
1973–75 to 1981–83	4.4	2.9
1981–83 to 1988–90	2.7	1.9

Source: [Rosegrant and Svendsen (1993)].
n.a. = not available.
Note: The 6.2 percent per annum growth rate of wheat during 1961–63 to 1965–67 is driven primarily by China, where growth rate during this period was 11.5 percent per annum.

In some cases agricultural intensification has disturbed the ecological balance and led to waterlogging and salinisation of irrigated lands, pollution and contamination of water and soils, sinking groundwater levels, extinction of species, resurgence of pests, growing water shortages, and destruction of wildlife and habitat. The primary reason for this is a mismanaged intensification process and reliance on inappropriate techniques and technology for intensification. For example, while fertilizer use in many developing countries is sufficient to replace the soil nutrients removed and unlikely to cause environmental degradation, excessive use or inappropriate

application of fertilizers in certain localities has resulted in water contamination. Similarly, while expanded irrigation has played an essential role in meeting food demand during the last 30 years, excessive water use has resulted in widespread waterlogging and salination.

Agricultural intensification, if managed properly, need not degrade the environment. In fact, components of agricultural intensification such as fertilizer have an important role to play in conserving the soil by replenishing nutrients and improving soil fertility. Alternative technologies and farming practices already exist that involve appropriate crop rotations, mixed farming systems with crops and livestock, agroforestry, biological pest control, disease- and pest-resistant varieties, balanced application and correct timing and placement of fertilizer, and minimum or zero tillage. So why do farmers sometimes mismanage fertilizers and pesticides and overuse water in ways that may be harmful to their own health and to the environment? The primary reasons include market and policy failures such as inappropriate pricing and subsidies that distort costs to farmers and consumers, externalities, lack of knowledge of the hazards involved with some inputs, and lack of knowledge of alternative techniques. Later in the section we will offer suggestions on how to minimise or prevent adverse effects on the environment of agricultural intensification technologies and inputs, but first we will review the linkage to environmental degradation of three major components of the intensification process: irrigation, pesticides, and fertilizers.

Irrigation

Irrigated area has expanded to over 240 million hectares today [FAO (1993)], with the most rapid growth taking place from the 1950s to the 1970s.[7] Three-quarters of the world's irrigated area is in developing countries, mainly the Far East (Table 7). Four countries–China, India, the United States, and Pakistan–contain half of the world's irrigated land. Irrigated areas, 16 percent of the world's croplands, produce one-third of the world's food and provide a livelihood to an estimated one billion people, mainly in Asia. Irrigation is the main source of food production for a number of countries. Egypt, with virtually all of its cropland being irrigated, is an extreme case of dependency on irrigation, but 80 percent of Pakistan's cropland is irrigated, 48 percent of China's, 36 percent of Indonesia's, and 27 percent of India [FAO (1993)].

Poor management of irrigation has led to considerable degradation of this

[7]Area under irrigation tripled during this period and the growth rate of irrigation acreage exceeded that of population [Yudelman (1989)]. However, in recent years, investment in irrigation projects has slowed, especially in Asia [Rosegrant and Svendsen (1993)], and consequently growth in irrigation area is slowing [Oram and Hojjati (1994)].

Table 7

Extent of Irrigated Area, 1991

Region	Area
	(Million Hectares)
Africa	5.4
Latin America	15.9
Near East	20.4
Far East	135.8
Developing Countries	177.6
Developed Countries	63.9
World	**241.6**

Source: [FAO (1993)].

resource base. About 20–30 million hectares or 10 percent of all irrigated land suffers from severe salinity, which, if not treated, can ultimately destroy the land, while another 60–80 million hectares suffer from some waterlogging and salinity problems [FAO (1993a)]. In India, 7 million hectares of land have been abandoned because of excess salts and another 20 million hectares suffer from reduced productivity due to salts; in Egypt, half of the irrigated area is suffering from saline problems; and in Mexico more than 50,000 hectares have been abandoned due to salinity [Yudelman (1989)]. The salinity problem is growing: possibly as much as 1–1.5 million hectares each year are lost to salinisation, equivalent to about half of the new land brought into irrigation [Postel (1992)].

Waterlogging and salinity are very serious problems in Pakistan, with particularly significant implications for Pakistan's food security prospects given its dependence on irrigated lands. Pakistan has the world's largest contiguous surface distribution system consisting of the Indus River and its tributaries, 3 large storage reservoirs and 19 barrages, and about 60,000 kilometres of canals and 162,000 kilometres of watercourses [Yudelman (1993)]. The introduction of perennial canal irrigation, while transforming Pakistan's capacity to feed itself, has made water constantly available throughout the year, more than can be handled by evapotranspiration, leading to a rise of the watertable. Lack of proper flushing of soils and poor drainage have led to an estimated 3.5 million hectares (about 25 percent of irrigated

lands) being affected by waterlogging and salinity (of which 8 percent is seriously affected), and to another 8 million hectares being vulnerable to waterlogging because the watertable is within 10 feet of the surface [Khan (1991)]. Waterlogging and salinity are particularly acute in Sindh and Punjab, the granaries of Pakistan: In Sindh, about half of the soils are saline, of which 18 percent are strongly saline [Khan (1991)]. According to an estimate by the government of Pakistan, almost one-tenth of the country's best agricultural lands is affected by salinity [Government of Pakistan (1989)].

The effects on crop productivity and profitability of waterlogging and salt build-up are detrimental. In the Sharda Sahayak irrigation project in India, yields of paddy and wheat fell 51 and 56 percent, respectively, on salt-affected land, while net incomes from high-yielding varieties of paddy fell 54 percent on waterlogged soils and 87 percent on salt-affected soils, and net incomes from wheat fell 92 percent [Joshi and Jha (1991)].[8] Waterlogging and salinity have led to 30 percent declines in yields of major crops in Egypt and Pakistan [Barghouti and Le Moigne (1991)], while in Mexico salinisation removes about one million tons a year from the grain harvest [Yudelman (1989)].

Most of the problems arising from irrigation have technical or management solutions. Waterlogging and salinisation can be prevented or minimised by reducing overwatering and seepage from canals, improving drainage to lower the high watertable, and adopting improved and appropriate water management practices, including use of tubewell water. Tubewells have been an important element in the strategy to minimise waterlogging and salinity in Pakistan, as well as to improve the availability of water supplies, and the percentage of area irrigated by tubewells has grown from 2 percent in 1960-61 to 21 percent or more today [Khan (1991)]. Private tubewells are the main spur in this development. Yet, very little efforts have been made to line canals, engage in canal improvements, provide drainage, and improve the efficiency of water use. Even where efforts have been made to provide drainage, structures are not maintained properly. According to one estimate, about 40–55 percent of irrigation water in Pakistan is lost in the canal system and water-courses due to seepage and evaporation before it reaches the farmers' fields; once in the fields, more may be lost depending on the method of irrigation and the extent of land levelling [Afzal (1993)].

The increased prevalence of malaria and schistosomiasis in many irrigated areas has been noted for some time [WHO (1980, 1983)]. Malaria cases in a large irrigation project in Turkey increased dramatically because of poor drainage

[8]Within 10 years of the inception of the canal network in this area, 34 percent of the sample farm area was salt-affected and 18 percent was waterlogged even though these problems had not been experienced before. Farmers responded by decreasing land-use intensity on degraded lands and in extreme cases withdrawing from cultivating degraded lands.

combined with substantial migration of agricultural labour from malaria-endemic areas [Gratz (1987)]. In the Gezira project in Sudan, the proportion of the population at risk of bilharzia jumped from 5–10 percent before the irrigation project was developed to more than 80 percent after the scheme was completed [Olivares (1990)]. Poor water control and drainage in irrigation projects, combined with insufficient public health measures, is responsible for much of the spread of diseases in irrigation projects.

Irrigation projects displace people, voluntarily or involuntarily, in areas where dams are being constructed. Many of these people are often forced to migrate out of these areas and seek a living elsewhere. Often they move into marginal areas, initiating the cycle of degradation and desperation discussed earlier.

Well-managed irrigation systems have the potential to produce more food than nonirrigated areas. Irrigation will remain an important part of the food production equation in the future, and efforts must be made to address the technological and management problems that lead to waterlogging and salinity. Maintenance is a key element of efficient irrigation projects: funds must be allocated and system users and operators must be given incentives, monetary and social, for maintenance. Efficiency of conveyance and timeliness of water deliveries to farmers must be improved as must the use of water by farmers. Other problems can be handled by changes in policies, approaches, and incentives for dealing with water related issues.

Pesticides

Worldwide, over US$ 20 billion of pesticides are consumed each year, mainly in the United States and Western Europe [Conway and Pretty (1991)]. Developing countries consume 20–25 percent of these pesticides: the Asia-Pacific region is the largest consumer, applying US$ 2.5 billion of pesticides each year. Growth rates of pesticide consumption peaked at 12 percent per year in the 1960s and have since slowed down to about 3-4 percent per year. Pesticide consumption is levelling of and even decreasing in the developed countries and some developing countries.

However, in most developing countries, pesticide use has multiplied in recent years with the introduction of high-yielding varieties and spread of irrigation technology and fertilizer application. Pesticide use is concentrated on a few crops: globally, over 30 percent of pesticides are applied to the three main crops of maize, rice, and wheat, while another 20 percent is applied to cotton and soybean. In India, agricultural use of pesticides increased by 3,600 percent between 1960 and 1985, from 2,000 tons to 72,000 tons, while food production increased almost doubled; in Colombia, sales of pesticides increased by 86 percent since 1980 [Pesticides Trust (1989)]. Pesticide consumption increased by more than 10 percent in Indonesia, Sri

Lanka, and the Philippines between 1980 and 1985 [World Bank (1992)]. As mentioned above, these trends of rapid increase are now being replaced by stagnant or falling use of pesticides in some countries.

Where biological or integrated pest management practices have not yet become a major factor, pesticide use is increasing in response to greater needs associated with double-cropping and shifts from mixed to monoculture cultivation. During the last 30 years, agricultural research has been very successful in developing improved crop varieties that are tolerant or resistant to pests. Such resistance, whether alone or as a component of integrated pest management, has reduced the need for chemical pesticides. This is reflected in recommendations and technology packages made available to farmers which, during the early phases of the Green Revolution, often suggested excessive pesticide use as an insurance against pests. Many governments encouraged pesticide use by subsidising, explicitly or implicitly, pesticide prices:[9] in the early 1980s, pesticide subsidies as a proportion of full retail costs were as high as 67 percent in Ghana, 82 percent in Indonesia, 83 percent in Egypt, and 89 percent in Senegal, costing these governments up to several hundred millions dollars a year [Repetto (1985)].

In Indonesia, price subsidies for pesticides were very large until 1986 when a gradual phasing-out was begun. By 1989, all subsidies had been removed. The fiscal savings were over $ 100 million per year. In response to the elimination of the subsidies and accelerated access to integrated pest management approaches, including host-plant resistance to some pests and biological pest control, Indonesian farmers reduced the use of chemical pesticides by 60 percent. Simultaneously with the beginning of the removal of subsidies in 1986, the government banned 57 highly toxic insecticides. The result was virtual disappearance of the brown planthopper, a very serious pest which had flourished because pesticides had controlled its natural enemies [Pesticides Trust (1988); Ruchijat and Sukmaraganda (1992)]. Rice yields increased from 6.1 to 7.4 tons per hectare in 1986 and a further 15 percent yield increase has been recorded since 1986. It appears that a large share of these yield increases are a result of the change from almost total reliance on chemical pesticides to an integrated pest management strategy. The Indonesian experience implies great promise for other countries wishing to move towards integrated pest management.

In Pakistan, about 5 percent of the cropped areas are treated with ground spraying and about 4 percent by aerial spraying. Pakistan subsidised ground spraying until the early 1980s when it was withdrawn in Sindh and Punjab, but continues to subsidise aerial spraying [Khan (1991)]. Treated seeds are also sown as a protective measure against pests and diseases, and so far cover about 5 percent of the

[9]Through mechanisms such as access to foreign exchange on favourable terms, tax exemptions or reduced rates, easy credit, and sales below cost [Repetto (1985)].

cropland [Khan (1991)].

Properly used pesticides have contributed to increased yields and agricultural production and to reduced labour costs. However, it is increasingly evident that improper pesticide use is common across much of the world. Metcalf (1987) suggests that for most insect pests, only small amounts of insecticides are required, and that, in fact, a large share of the insecticides applied is essentially wasted–that is, it does not reach the target organism.

In appropriate or excessive pesticide use has significant environmental and social consequences. Excessive use of broad-spectrum or nonselective pesticides damages ecosystems, sometimes irreversibly, by exterminating target and nontarget species; leads to pest resistance, pest resurgence, and development of secondary pests; contaminates soils and surface and groundwater as well as the food chain; and compromises the health and well-being of people.

Repeated application of broad-spectrum pesticides has led to build-up of resistance in target species. Due to long-term and nonselective use of pesticides, over 1,600 insect species have developed significant resistance to pesticides [FAO (1989)], over 100 weeds have developed resistance to herbicides, and about 150 plant pathogens are exhibiting resistance to fungicides [Hansen (1987); Weber (1992)]. A number of common pests have developed almost complete cross resistance and multiple resistance to the principal classes of insecticides such that they are "virtually uncontrolable by conventional insecticides" [Metcalf (1987)]. Pests, whose populations had initially been controlled by pesticide applications, are rebounding to excessive levels as their natural enemies are destroyed and as their resistance to pesticides makes them increasingly immune to further applications of pesticides. In Indonesia, the debilitating outbreaks of brown planthoppers in the early 1980s are considered an outcome of heavy and repeated insecticide spraying of rice, which destroyed the planthoppers' natural enemies. In fact, it has been suggested that nearly every outbreak of brown planthoppers in the tropics is associated with prior use of insecticides [Kenmore (1980)].

Besides the resurgence of known pests, secondary pests are emerging from nontarget species not originally pests but whose natural enemies are unwittingly destroyed by repeated applications of pesticides to control other target species. For example, in the United States, pesticide treatment for the cotton boll weevil and the pink bollworm destroyed the natural enemies of the Heliothis budworm, leading to development of these budworms such that they caused as much if not more damage than the original pests; efforts to control this secondary pest led to insecticide treatments that cost about half of the crop value [Metcalf (1987)]. In Mexico, emergence of these budworms decimated the cotton industry–acreage under cotton fell from 300,000 hectares to 500 hectares during the 1960s, throwing cotton workers out of work and forcing their migration [Hansen (1987)].

Widespread and indiscriminate application of pesticides contaminates soils and pollutes water as evident from the United States, Western Europe, and Japan where a number of pesticides have been detected in wells, herbicides have been found in drinking water derived from surface water and aquifers, and pesticides have been noticed in rainfall and fog [Conway and Pretty (1991)]. Pesticide contamination of water takes place mainly through run-off and leaching into groundwater. Aquatic life, flora and fauna, is often harmed by pesticide residues. Pesticides can also destroy soil organisms. While some pesticides break down easily in the soil, others take decades to degrade. Pesticides such as DDT have been found to persist in soils for as long as four decades when they are mixed well with the soil. Unfortunately, clear empirical information on the extent of pesticide contamination of the environment is lacking in developing countries.

Pesticide poisoning is a serious problem in developing countries: rates of pesticide poisoning are more than 20 per 100,000 persons compared to 4–6 in the United Kingdom and about 18 in the United States [Conway and Pretty (1991)]. Studies in Malaysia, Indonesia, and Sri Lanka in the early 1980s suggested that 12-15 percent of pesticide users have been poisoned at least once in their careers [Jeyaratnam, Lun and Phoon (1987)]. One indicator of the gravity of pesticide poisoning is that in Sri Lanka the number of deaths from pesticide poisoning–about 1,000–was almost twice the number of deaths from five major diseases, including malaria [Jeyaratnam (1990)].

Improper pesticide use impairs farmers' health, which, in turn, impairs farm household productivity. Exposure to pesticides, especially when prolonged, can lead to cardiopulmonary disorders, neurological and hematological symptoms, and skin diseases [Rola and Pingali (1993)]. Effects of pesticide exposure can be passed on to infants through poisoned breast milk: in cotton-growing regions of Nicaragua, breast milk samples from women contained some of the highest levels of DDT ever measured in human beings [World Bank (1992)]. The effects of pesticides are not restricted to human beings. Wildlife is also affected.

Unsafe techniques for transport, storage, application, and disposal of pesticides is the major cause of unintentional pesticide poisoning. Farmer ignorance of the hazards involved with misuse of pesticides, aerial spraying and wide-coverage methods of applying pesticides, lack of protective clothing and materials such as masks and gloves, impracticality of available protective equipment in the heat and humidity of the tropics, poor labelling of pesticide containers, lack of information on the proper use of pesticides, improper sanitation practices that help spread pesticide poisoning to family members, and even recycling of pesticide containers for use within the house are some of the reasons why pesticide poisoning is so widespread. Horror stories abound of how people have unknowingly consumed poisoned seeds and drunk pesticides under the impression that they were beverages. Efforts

by pesticide producers and distributors to reduce the risks associated with pesticide use through better information and improved packaging and handling have been at best somewhat successful.

Integrated pest management (IPM) is considered the environmentally sound alternative to exclusive reliance on pesticides for pest control. It is a careful integration of a number of available pest control techniques and while it emphasises nonchemical controls such as host-plant resistance and biological and cultural controls, it does utilise chemical controls when it is the best alternative [NRI (1992)]. IPM has many important economic, social, and environmental benefits, and is being successfully implemented for rice in Southeast Asia, among other successes. There is considerable scope for extending IPM strategies to other crops and other regions.

Preliminary results from on-going research in several international agricultural research centres sponsored by the Consultative Group on International Agricultural Research (CGIAR) are indeed promising for enhancing the effectiveness of IPM. Host-plant resistance or tolerance in many of the crops of greatest importance for future food security in the developing countries, improved biological control measures, and use of selected nontoxic biological materials for spraying, e.g. liquefied virus-infected hornworms for protection of cassava, are examples of such promising research results.

As alternative pest control methods are tested and made available to farmers, the reliance on chemical pesticides can be reduced. However, attempts to reduce pesticide use before appropriate alternatives are accessible to farmers at reasonable prices may result in large decreases in food production and should be avoided.

Fertilizers

Worldwide, fertilizer consumption per hectare quadrupled between 1961–63 and 1988–90 from 26 kilograms (kgs) to 98 kgs [Oram and Hojjati (1994)]. Much of the increased consumption was driven by developing countries which as a group increased its fertilizer consumption twelvefold during the same period from 7 kgs to 82 kgs per hectare.[10] The developing countries' share of consumption of the world's fertilizers jumped from 7 percent to 53 percent from the early 1950s to the early 1990s [Rustagi and Desai (1993)] and is undoubtedly one of the major factors behind their increased food production. Fertilizer consumption in the developing world increased by 14.6 percent per year in the 1960s, 9.9 percent in the 1970s, and

[10]However, there is a wide range in fertilizer consumption among the developing regions. For example, in Africa fertilizer application to rice is less than 3 kgs per hectare compared with 138 kgs in Central America, 94 kgs in South America, 73 kgs in South Asia, and 78 kgs in East Asia [Oram and Hojjati (1994)].

5.8 percent in the 1980s.

Some application of fertilizer is necessary to replace nutrients that are removed by crops and to stimulate agricultural production. While organic manures can have an important role, in many developing countries a shortage of animal wastes and crop residues makes chemical fertilizers necessary to support intensive agriculture. Fertilizers can be used to correct environmental damage resulting from soil erosion by enabling a plant cover to be established. Fertilizers also help protect soil organic matter.

Excessive fertilizer use can pollute groundwater through leaching of nutrients, mainly nitrates, which are ordinarily not harmful to humans but in sufficiently high quantities can be reduced to nitrite which is harmful. Nitrate leaching is also a factor of imbalance in fertilizer composition, wrong timing of application, and improper application methods–all of which can be easily corrected. Pollution of surface water mainly takes place through eutrophication, which is the accumulation of nutrients, primarily through soil erosion. Not all fertilizers have negative effects on the environment; potassium, one of the three major nutrients supplied through fertilizers, has no known adverse environmental effects [Rustagi and Desai (1993)]. Balanced application of nutrients provides maximum benefits with minimum environmental consequences.

In some regions of the developing world, notably areas in Asia with highly intensified rice and wheat production, excessive fertilizer use poses serious environmental risks. While these risks should be dealt with effectively, it is important that they not be confused with the situation in most developing-country farms where the problem is insufficient rather than excessive fertilizer use. A recent review of fertilizers and environmental concerns concluded that "In the developing countries, the principal cause of environmental effects is unscientific fertilizer practices and not excessively high rates of application" [Rustagi and Desai (1993)]. Training for farmers on appropriate application and combination of fertilizers would address this problem.

Fertilizer subsidies have been extensively used to promote application of fertilizers by farmers. In some places, they have achieved their objectives and should be withdrawn. The government of Pakistan has subsidised the price of fertilizers and is, we understand, gradually decreasing it, in preparation for eventual withdrawal. In Sub-Saharan Africa, where application of fertilizers by small-scale farmers is minuscule (largely because of the very high prices they have to pay mainly because of transportation costs), subsidies may have a role in the short term while efforts are made to bring down the unsubsidised price of fertilizers to farmers.[11]

[11]African farmers pay about double the price of fertilizers compared to Asian farmers [Pinstrup-Andersen (1993)].

POLICIES TO ENCOURAGE SUSTAINABLE AGRICULTURAL DEVELOPMENT, ALLEVIATE POVERTY, AND PROTECT NATURAL RESOURCES

In pursuing efforts to assure production of sufficient food for future generations, alleviation of poverty and hunger, and protection of natural resources, policymakers are confronted with the fundamental question of whether to focus their attention on high-potential areas or low-potential vulnerable areas. Since the maximisation of food production is not the only goal, it is not intuitively obvious that the focus should be on high-potential areas. A large proportion of the world's poor lives in low-potential areas and the risk of negative environmental effects of their survival strategies in the absence of external support is high. Furthermore, many high-potential areas are now degraded or suffer from environmental stress. There is also some doubt whether high-potential areas have the capacity to meet future food needs in a sustainable manner [Scherr and Hazel (1993)]. Low-potential areas will have to play their part in food provision. To achieve the overriding goal of development–alleviation of poverty in an environmentally sustainable manner –policy will have to focus on where poverty is, which, to a large extent, is in low-potential vulnerable areas.

Some argue that the best policy to pursue in low-potential vulnerable areas is to relieve population pressures by encouraging massive outmigration. As a short-term strategy that, of course, assumes that there is somewhere for these people to migrate to without endangering the natural resource base in those destination areas. Accelerating the rapid increase in urban poverty in many countries is not an acceptable solution to rural problems.

Others argue that everything possible should be done to make low-potential vulnerable areas environmentally sustainable, because continuing to neglect these areas will only make degradation worse and perpetuate poverty. Experience from Kenya shows that the Machakos district, which was heavily degraded a few decades ago, has been rehabilitated despite a fivefold increase in the population, and has even experienced a threefold increase in per capita agricultural output [Mortimore and Tiffen (1993)]. The "secret" of the transformation of the degraded area into a productive area was agricultural intensification encouraged by local land-use innovations, infrastructural development, institutional development, access to a high-income market, and access to off-farm income to make land-related investments. Rehabilitation of resources was triggered when degradation reached an economically important level and the benefits from resource rehabilitation began to exceed the costs. While the Machakos experience is not generalisable to all areas with degraded natural resources, it is nevertheless an encouraging illustration of what can be done under the right circumstances.

There is growing evidence that agricultural intensification in fragile lands is possible and that there is a capacity for rehabilitation of degraded natural resources despite population growth [Scherr and Hazell (1993)]. The key factors promoting intensification include economic growth outside the region which enables households in fragile lands to earn off-farm incomes that can then be reinvested into the land, local farmers' groups to mobilise capital and labour for farm investment and rehabilitation, income diversification, evolution of property rights, and infrastructure investment to extend economic linkages [Scherr and Hazell (1993)]. Strategies different from those employed in high-potential areas may be required, such as more diverse cropping systems instead of intensive monoculture of annual crops, better integration of livestock and green manures into farming systems, and generation of reliable nonfarm sources of income [Scherr and Hazell (1993)].

High-potential areas that have been degraded, e.g. waterlogged and salinated areas, must be rehabilitated and their productivity restored to the extent feasible, physically and economically, if they are to fully contribute to enhanced food production in the future. Their rehabilitation may involve further agricultural intensification, for example, nutrients lost from the soil may need to be replenished through fertilizer application. And, of course, the agricultural production potential of high-potential areas must be developed to the extent sustainable.

In the remainder of this section, we will highlight some of the most important policies required to simultaneously facilitate sustainable agricultural development, eradicate poverty, and protect the natural resource base. Of course, the weights placed on individual policies will depend on circumstances and conditions in specific countries and areas.

Investment in agricultural research and technology is essential. Agricultural research and resulting technologies can serve dual objectives of increasing food production and protecting the environment. There does not have to be a trade-off between meeting future food demands and maintaining the natural resource base. Yield-enhancing technology is the key to sustainable agricultural production. Agricultural research has already successfully developed yield-enhancing technology for many crops, including the most important staples of rice, wheat, and maize. It is important that research continue on these vital crops but that it also be intensified on globally less important crops that are nevertheless important on regional levels, such as roots and tubers which form a large part of the diet of Sub-Saharan Africans. Research can also build tolerance or resistance to adverse production factors such as pests and droughts and develop new varieties and hybrids better suited for various ecological settings, and thereby reduce risks and uncertainties faced by farmers. Higher yields on less fragile lands can reduce pressures on fragile lands. Research can also develop production technologies and techniques for fragile lands, environmentally threatened areas, or degraded areas that would encourage sustain-

able agricultural development for inhabitants of these areas. For example, research has an important role to play in suggesting and developing crop varieties for saline and waterlogged areas. In sum, accelerated investment in agricultural research and technological improvements is not only necessary and urgent, it is the only viable option to assure sufficient food to meet future food needs and demands at reasonable prices without irreversible degradation of the natural resource base.

While essential, research is not sufficient. Farmers frequently lack access to technology resulting from research and to modern inputs and knowledge. Earlier, we noted that many small-scale farmers were forced into degrading practices because they did not know better or because they could not do better, lacking resources as they did. Timely, reasonably priced access by farmers to modern inputs such as improved plant varieties, fertilizers, pest control measures, tools, and water must be facilitated through improved rural infrastructure and institutions and through access to credit and technical assistance. The knowledge base of farmers may need to be extended through education and better and more timely transfer of information. Indigenous practices for resource conservation could benefit from research insights. Improved farm management practices must be communicated to farmers, male and female. Females, whether farmers or not, have not been fully integrated into the sustainable agricultural development process and neglecting them only makes it more difficult to break the poverty-population-degradation links because in many instances it is they who are forced into degradation practices and they who bear the brunt of the consequences of degradation.

Distortions in input and output markets, asset ownership, and other institutional and market distortions adverse to the poor must be minimised or removed. In particular, water management policies, including appropriate allocation mechanisms, are urgently needed to avoid inappropriate water allocation including excessive use or misuse. Existing subsidies for inputs such as fertilizers and pesticides should also be reviewed for their fiscal costs and their effects on production, resource allocation, and the environment.

Access by the poor to productive resources such as land and capital needs to be enhanced. Improved human resources will also contribute to reduced poverty and improved food security as well as higher economic growth. Policies that will expand investment in rural infrastructure, primary health care, and education are needed to enhance income earnings and food security among the rural poor. Besides policies to alleviate poverty, policies such as targeted food and cash transfers of various types, including labour-intensive public programmes, may be needed to protect the poor from economic and weather shocks.

Population growth of the magnitudes expected in the next three to four decades will place severe demands on food production and distribution. Risks of environmental degradation will increase and efforts to improve income and reduce

poverty will be hampered. Renewed emphasis must be placed on efforts to reduce population growth in developing countries. Universal access to family planning information and technology must receive due attention. Although the rate of population growth is falling in developing countries as a whole, the reductions are insufficient to counter absolute increases. Failure to significantly reduce the current high population growth rate in Sub-Saharan Africa within the next two decades will render all development efforts insufficient to avoid poverty and human misery of much greater magnitude than experienced to date and to avoid degradation of land, forest, and water resources.

Intergenerational aspects of policies are difficult to deal with. Efforts to ensure conservation of natural resources for future generations at the expense of the survival of part of the current generation are difficult to justify on moral grounds and difficult to implement. The potential trade-offs between alleviation of current poverty and the needs of future generations must be considered and attempts made to identify policies and strategies that achieve both goals.

Incentives and, where necessary, regulatory policies must be strengthened to endogenise or compensate for externalities related to natural resources. The nature of such policies will vary across countries and over time and may include appropriate water pricing and watershed management, elimination of exploitation of land and forests resulting from free access, and a variety of other policy measures. While usually preferable to regulatory measures, subsidies, taxes, and other incentives should be used selectively and carefully because of possible unintended market distortions, opportunities for rent-seeking, and high fiscal costs. Regulations that contradict the survival strategies of the poor are unlikely to be successful simply because they are difficult or impossible to enforce. However, regulations will be necessary where incentives are unlikely to achieve social objectives.

CONCLUDING COMMENTS

Successful international and national agricultural research focused on increasing yields of wheat and rice together with rapid expansions in the use of modern inputs such as fertilizers, pesticides, and improved crop varieties, as well as improved agricultural practices and more appropriate agricultural policies, removed the immediate threat of mass starvation facing parts of Asia in the early 1960s. The gains in productivity, total grain production, and associated income gains to producers and consumers resulting from the Green Revolution have been and continue to be enormous.

While the challenge of feeding a rapidly expanding world population is greater than ever, the Green Revolution has bought us time to adjust the approach to assure that it is sustainable in the longer run. However, no adjustment will suffice unless existing massive poverty and food insecurity and population growth rates are

significantly reduced.

While inappropriate technological change in agriculture may cause natural resource degradation and should be modified, the most serious environmental threat in low-income developing countries comes from poverty. It comes from the many millions of people who live near the subsistence minimum and who will exploit natural resources if necessary to survive. We must not blame the victims. We must seek to eradicate extreme poverty and associated food insecurity and environmental degradation. Accelerated investments in agricultural research and technology–including international agricultural research by the CGIAR, which provided the foundation for the Green Revolution–rural infrastructure, family planning, education, primary health care, and a variety of other high-priority areas combined with appropriate policies are urgently needed. On-going structural adjustment and policy reforms offer great promise if properly implemented. However, recent cuts in financial support to agricultural development in developing countries are a frightening indication that the international community is neither serious about dealing with current food, poverty, and environmental problems nor is it getting ready to deal effectively with the much larger future problems.

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Comments on "Poverty, Agricultural Intensification, and the Environment"

Poverty, intensification of agriculture and environmental degradation are intimately linked in a complicated way with an in-built tendency toward escalation as long as government interventions, be they realised by national agencies or international ones, do not provide technologies otherwise unaccessable to the poor for stopping degradation of the basic natural resources of agriculture, land and water. A high share of food in consumption and a high share of agriculture in employment at low levels of income and therefore especially in the case of poverty make the poor the stewards of most of these agricultural resources. The poor will only be able to use them in a way which avoids degradation if eradication of poverty allows them to take the future into consideration. They will have access to such a situation only, if they get access to such new technologies as demographic growth has now become so important that the readily available technologies for providing basic goods for survival in the hands of the poor have become resource-degrading.

This statement of the basic threat to environment implies at least two systems of regulation: The decision of the poor on allocation of these scarce resources and the decisions of the agencies on channelling new complementary inputs to the poor which can change either the latter's decisions on the use of resources or the results of these decisions for the environment.

The poor are considered in this paper as rational with respect to their decisions on production and technology, but their rationality is bounded by their poverty and ignorance, i.e. the cost of making available new technologies and even new information on technologies. The logical conclusion is that poverty must be eradicated and, not spelt out in the paper, that such a process requires a larger access of the poor to land and water. Externalities are implied in agricultural production at any level or income. Profit-maximising territorially mobile big landowners do not respect externalities in order to increase profit, because they can avoid to bear the ultimate cost as they are able to migrate with their mobile resource, capital, to other regions. Poor do not respect externalities because they can care for the future only if subsistence in the present is guaranteed. Although poor and rich tend to disregard externalities, they do so for different reasons with the result that in the range of realistic solutions the poor become more respectful of environment when becoming richer, but the rich do not.

Despite this pleading for redistribution implicit in the paper, the paper argues that even an optimal, in this case egalitarian distribution of resources (under this condition no one will be able to increase his preference for the future of the environment without some other disproportionally increasing his preference for present outputs), the poor are unable to use the appropriate modern technologies and this implies intervention from various sources, in the slightest form as subsidies by the "government" sector, i.e. the non-market economy. The paper provides beautiful examples for such successful interventions, but also stresses that these interventions are ambiguous in character. Whereas there is no doubt that fertilizers were land-augmenting and contributed to resource preservation, inconsiderate use of them contributed to resource depletion. Inconsiderate use of water in irrigation schemes triggers off salinity etc. How then can government intervention be made efficient and respectful of resources?

Here lies the crux of the paper by Pinstrup-Anderson and Pandya-Lorch, which probably is not their mistake, but the result of contradictions in the field itself. Obviously, improvements can be achieved by better focussing, especially in agricultural research, or by better management, e.g. in control systems for water delivery in irrigation projects. But take the poor labelling of inputs such as pesticides. Why are agencies not interested in better labelling which would prevent poisoning of the users of the products, i.e. the poor?

Non-market controlled agencies will not develop a systematic orientation to the needs of target groups as long as they are not continuously exposed to the latter's influence and even control. The poor's capacity to exercise such a control or influence is; however, weak due to their lack of material resources which these very agencies have to redress. The basic plot is one of unequal partnership: The agencies are empowered by the international or national bodies which try to represent the public interest in resource conservation in order to fulfil the task of channelling inputs and other resources to the poor who, in exchange, have to offer only services which no other actor in the field can value at an equal rate if compared to these agencies. Due to these monopsone, the non-market sector necessarily acquires the capacity to neglect the needs and requirement of the poor. This can only be redressed by a more vocal statement of the public interest of those who are able to control these agencies, either government or the donor community, which provide the funds. They, however, operate in great distance from the areas where day-to-day conflicts occur, and, in order to achieve the intended results, have in addition to respect some degrees of autonomy of these organisations/agencies. Hence, they have to operate in their controlling function with considerable restraint.

Whereas a redistribution of assets increases the potential for strategies which can mobilise the poor's capacity to preserve resources in the long-run, this potential must be complemented by appropriate strengthening of non-market controlled agen-

cies which deliver supplementary inputs in order to enable the poor to adopt resource-preserving strategies. These agencies are, however, out of control of the poor and, due to the necessary size, out of control of their governing bodies, at least to a large degree.

Hence, the paper by necessity has to come back to the problem of the good patrimonial ruler who altruistically pursues general interest in a systematic way, as contemporary political science has–abusively–identified the non-governmental organisations (NGOs) in the wake of the fierce criticisms addressed to the Third World state and the international governmental organisations as well. This is not a mistake of the paper, but a mistake of reality. The field of underdevelopment is characterised by a distributions of resources where the target groups, the poor, cannot control the resources which can be made available to them by governments and donor agencies in order to bring them above the marginality threshold. On the way to such a situation where the poor would then be powerful, the necessary power of the agencies which are called for assistance may get out of control. Hence an eclectic variety of measures is proposed, from administrative and organisational reform to changes in cultural values etc.

The problem of these eclectic sets of measures is to be found in the fact that no one of them will achieve a long-lasting stabilisation of target-group orientation of the respective agencies. New organisational set-ups are not better than older ones, but provide access to carrier improvement of new strata of staff, which–initially–may be more idealistically-minded than older ones. NGOs are not *per se* better than public administrations, but, in the actual situation at least, have still to fray their way into acceptance of donors.

Hence the conclusion of the paper, which seem to me a rather voluntaristic call for reform and commitment of national and international agencies is, perhaps, an inevitable one. The number and quality of papers read before influential and competent fora is just an element of the process of improvement of the delivery process as long as the goal of entitlement of the poor is not yet achieved. Would it not then be very important to stress also the goal of entitlement and to go directly to the implied redistribution of assets, instead of only implying this. Should not international agencies speak more clearly about this than they do?

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