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Food, Agriculture,
and the Environment
Discussion Paper 8

Major Natural Resource Management Concerr in South Asia

Gerard J. Gi

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Food, Agriculture, and the Environment Discussion Paper 8

Major Natural Resource Management Concerns in South Asia

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Foreword

In February 1995, the International Food Policy Research Institute (IFPRI) and the Institute for Integrated Development Studies (IIDS) jointly sponsored a workshop in Kathmandu, Nepal, on "A 2020 Vision for Food, Agriculture, and the Environment: Issues Facing South Asia." The meeting brought together more than 30 social scientists from the region and the two institutes to consider the prognosis for the major countries of South Asia—Bangladesh, India, Nepal, Pakistan, and Sri Lanka—in food supply, agriculture, health, nutrition, and the environment.

In this paper, one of four commissioned for the workshop, Gerard Gill examines the effects of factors such as population growth on degradation of natural resources in South Asia by 2020. In a clear-eyed look at the future, Gill avoids both overoptimism and dire predictions of disaster, concluding that the way out of the dilemma of still-growing populations and rising demand for food is likely to be through increased investment in research and extension and economic liberalization.

Questioning three recurrent themes of conventional wisdom about natural resource degradation, Gill finds that indigenous systems of common property management are sustainable, not degrading; that poor people are often careful managers of natural resources; and that degraded resources can often be restored. While recognizing the likelihood of increasing conflicts over land, water, and forest resources, he offers useful suggestions for sustainably managing these resources while increasing agricultural intensity and food supplies.

Per Pinstrup-Andersen
Director General, IFPRI

The five larger South Asian countries—Bangladesh, India, Nepal, Pakistan, and Sri Lanka—have between them 21 percent of the world's population on only 3 percent of its land area. This makes it one of the most densely populated areas in the world (Table 1). Despite the constraints this imposes, South Asia has made impressive strides toward feeding itself over the past quarter century. In the early 1970s, a time when steeply rising world food prices led to talk of an impending global food crisis, South Asia was facing this crisis in its bleakest form, famine. Yet not only did the widely predicted mass starvation fail to materialize, but the region actually progressed from food-deficit status in the early 1970s to food self-sufficient status in the early 1990s. Almost all of the countries of South Asia have made impressive strides toward increasing per capita food production. The most striking case is that of Bangladesh, the world's most densely populated agrarian country. In 1964 that country had a population of 53 million and was annually importing 3.5 million tons of grain. In 1993, although the population had grown to 115 million, Bangladesh had become self-sufficient in foodgrains (Havener 1994).

South Asia's success in countering the 1970s food crisis was due to the Green Revolution, the widespread diffusion of fertilizer-responsive cereal varieties in areas with access to inputs, credit, and irrigation. This more than compensated for continuing food deficits in less favored parts of the subcontinent. This was achieved at considerable environmental cost, however, as will be shown later. Predictions for the next quarter century are less grim than those of 25 years ago, but they are still extremely worrying. In a recent IFPRI assessment even the most optimistic of three possible scenarios saw South Asia's present self-sufficiency in cereals giving way to growing deficits in the early part of the next century; the shortfall is projected to be almost 50 million metric tons[1] by 2020 (based on Agcaoili and Rosegrant 1994b).

If population density were the only basis for concern about natural resources, the solution would be relatively straightforward. It would begin by

Table 1—United Nations population estimates for South Asia and the rest of the world, 1993

Country/Region	Population	Population Density: Per Kilometer	Population Density: Per Hectare of Arable Land	Growth Rate 1985–92
	(million persons)			(percent/year)
Bangladesh	122.2	938.8	13.9	2.6
India	896.6	301.6	5.4	2.1
Nepal	21.1	154.1	9.1	3.0
Pakistan	128.1	166.1	6.2	3.1
Sri Lanka	17.9	276.9	19.2	1.3
South Asia	1,185.9	290.9	6.0	2.2
Rest of the world	4,386.5	34.6	3.8	1.6[a]

Source: Calculated from FAO 1993, Tables 1 and 3, and United Nations 1994, Tables 1 and 2.
[a]Estimated figure for 1985–90 only.

[1]In this report, all tons are metric tons.

accepting that, given per capita scarcity of land and fresh water and the correspondingly high opportunity cost of these resources, South Asia has little comparative advantage in the production of low-value, high-volume crops like cereals.[2] Inevitably this would point toward a move out of cereal production into alternatives such as high-value crops and nonagricultural activities like manufacturing, alternatives that more closely reflect the opportunity cost of land and water. Exports of these products would then be required to pay for cereal imports.

While the basic comparative advantage argument cannot be denied, several important considerations require that any move toward exploiting this should be gradual and flexible, rather than precipitate and irrevocable. The first problem is the large absolute size of South Asia's population: 1.33 billion in 1995 and still growing (United Nations 1994). This is compounded by high per capita demand for cereals, which are the staple diet of the great majority of the population. Any marked shift out of cereal production toward increasing dependence on imports in such a large, densely populated and heavily cereal-dependent region would exert significant upward pressure on world prices. As in any poor area, purchases of the staple foodstuff take a relatively large share of the average household budget, so that the combined and interactive effects of rising world prices and growing import dependence would have significant welfare implications—and the poorer the family the more negative the implications.

The picture is further complicated by the fact that South Asia's population is still expanding. The growth rate during 1985–92 is put at 2.2 percent, and the latest UN projections, even though they assume that the rate of increase will continue to decline, indicate that the region's population will have grown by 72 percent by 2030. This means that by 2020 the population will be about 60 percent higher than it is today.

The population growth rate is only one factor driving the demand for cereals upward. Another is the well-established fact that the poorer the family the higher the income elasticity of demand ($Y\varepsilon_d$) for food. For poor families in poor countries, this coefficient is positive even for starchy staples. In Nepal, for example, among the poorest groups, the $Y\varepsilon_d$ coefficients for rice, wheat, and maize have been estimated as 0.71, 0.47, and 0.05, respectively (Thapa and Koirala 1992).[3] South Asia is estimated to contain half the world's poor people, half those suffering from protein-energy malnutrition, and more than half the preschool children who are underweight (Pinstrup-Andersen 1994; Pinstrup-Andersen and Pandya-Lorch 1994; Garcia 1994). This indicates a huge potential demand, which will translate into effective demand once incomes start to rise. And the picture is improving: the proportion living below the poverty line is forecast to fall from 49 to 37 percent and the absolute number from 562 to 511 million between 1990 and 2000. Incomes in South Asia rose at an estimated annual rate of 3.1 percent during the 1980s, and this rate of improvement is expected to continue throughout the 1990s (World Bank 1992). If this progress continues on into the next century, cereal consumption will keep growing by significantly more than the projected population increase; and if per capita demand grows by just 0.9 percent per year over the next 25 years, per capita consumption will increase 25 percent by 2020, but aggregate cereal requirements will double.

The final complication arises from the structure of demand for cereals. One category whose demand is likely to grow disproportionately is feedgrains. The income elasticity of demand for animal protein is much higher than that for cereals: FAO estimates of the $Y\varepsilon_d$ coefficients for meat, eggs, and dairy produce for South Asia are in the range of 1.0 to 1.5 (FAO 1993). This in turn gives rise to derived demand for coarse grains for feed. At the moment, however, the quantity of grain output used for animal feed is negligible in Bangladesh, Nepal, and Sri Lanka, and only 2 to 3 percent of production in India

[2]What has been said so far is very much a generalization, and circumstances and the response to them will vary considerably from country to country (even to some extent within countries). Table 1 shows considerable variation among the five countries in population size and density. It may surprise some to learn that Sri Lanka, not Bangladesh, has the highest number of people per cultivated hectare. Although it continues to try to boost cereal production, Sri Lanka has basically accepted that it will never again be self-sufficient in cereals, and it has already begun to shape policies to pay for the necessary imports. This is the future for South Asia as a whole. There is another end to the spectrum, however. Nepal has never had a Green Revolution, even though it has a great deal of suitable land with available groundwater.

[3]The coefficient for maize is for direct consumption only, since it excludes purchases by feedmills. If the latter figure were added, the coefficient would be much higher; this is discussed later in the text.

and Pakistan (WRI 1992). Expansion is likely to be rapid as demand for animal protein grows, but the small base and relative unimportance of feedgrains in strategic terms makes this a lesser concern.

A much more important structural question concerns rice. For most of South Asia's population this is the preferred cereal, and as shown earlier, the $Y\varepsilon_d$ coefficient among the poorer segments of the population tends to be correspondingly high. As incomes rise, the growth of demand for rice can therefore be expected greatly to outstrip that for other cereals. The volume of rice traded internationally, however, is much less than that of wheat and coarse grains, so that the price impact of significantly increased demand for rice imports by South Asia would be disproportionately large.

Fortunately, this particular problem is mitigated by an important feature of the subcontinent's agriculture, the fact that the bulk of the rice crop is produced during the monsoon rains. Not only do monsoonal climates have much heavier than average annual rainfall, but this precipitation is highly concentrated into a relatively short rainy season. An extremely high proportion of South Asia has a monsoonal climate; many areas receive between 75 and 90 percent of annual precipitation at some time during the months of June to September.[4] This production environment represents a very important exception to the generalization that land and water are scarce resources in South Asia. Except in years when the rains are late or light, water is extremely plentiful in the rainy season. The opportunity cost of land is also low at that time of year, as rice is one of only a handful of crops that can be grown in flooded conditions.

The above analysis begins to suggest a way out of the quandary posed by the combination of large population size and high density, and the difficulties of feeding an expanding population while improving nutritional standards without (1) further increasing pressures on a finite natural resource base or (2) causing overrapid growth in reliance on imports or both. The basic thrust would be to channel resources toward achieving large production increases in rainy-season rice, so as to reduce dependence on irrigated dry-season cereals while holding the growth in demand for imports to manageable levels and to commodities whose income elasticity of demand is relatively low. Alternative dry-season crops should also be the focus of a major research and extension effort, both in order to increase the productivity of scarce resources at this time of year, and in order to protect the environment by diversifying crop rotations. All of this is, it must be added, a strategy for the longer term, but one that should be embarked on now, in the realization that it will probably not bear much fruit until the latter part of the period under review.

The next quarter century will be crucial in shaping South Asia's response to the food-population challenge. If present encouraging trends continue, by the year 2020 South Asia's population growth rate should be nearing manageable levels, incomes will be significantly higher than today, cereal purchases will take a much smaller proportion of household budgets, and agriculture will play a relatively less important role in the economy, in terms of both production and employment. By this point it may well be possible for South Asian governments to think much more about production based on comparative advantage and thus to accept that imports will provide a relatively large and growing proportion of nonrice cereal requirements. The implied transition from extensive to more intensive farming means that it will become possible to reduce the amount of land required for farming, and hence withdraw the agricultural frontier from marginal and environmentally fragile areas, which can then be left to revert to forest or other forms of protective cover. This implies more efficient use of the resources that remain in agriculture, which in turn requires inputs and knowledge to supplement these natural resources. The problem for South Asian governments is to devise policies that will effectively manage resources during the run-up to 2020 in such a way as to facilitate the transition while minimizing any adverse effects on the natural resource base that supports agriculture. These desiderata will be the focus of the remainder of this paper.

Agriculture, Food Production, and the Environment

Food production is the largest user of renewable natural resources in South Asia today. These re-

[4]Some of the areas that receive a relatively small proportion of their annual rainfall during this period nevertheless have a marked seasonal pattern, with the peak being at other times of the year. For example, coastal Tamil Nadu and northern Sri Lanka receive 15–25 percent of annual rainfall during June–September, but these areas receive 50 percent during October and November.

sources are land, fresh water, sea water, plant and animal genetic materials (including those found in forests and pastures) and climate. In other words, "the environment."

When South Asian countries first began their push for post-independence development in the late 1940s, environmental issues, if they were on the agenda at all, occupied a lowly position. Today in-country environmental pressure groups have mushroomed throughout South Asia, and have used the media, public interest, and the courts to fight government proposals they consider environmentally harmful. This echoes a global trend, and there are parallel pressures on South Asian governments from both multilateral and bilateral donors. In such a setting, one of the greatest problems facing prospects for increasing food production is the by now common perception of agriculture and fisheries as environmentally unfriendly industries.

It is conceivable that the natural resource base for South Asia's food production may be extended slightly over the next 25 years by bringing more of it into production. But this could not be on any significant scale, nor should it be for environmental reasons. Reflecting its high population density, South Asia already has a high proportion of its land area under cultivation, and a correspondingly low proportion under forest and pastures (Table 2). If in South Asia, with its ancient agricultural civilizations, there is land that is not presently under the plow, it is probably because factors like poor soil, excessive slope, or unreliable rainfall make it unsuited to arable farming. Cultivated area may expand marginally into such areas, but at the cost of despoiling forests, hills, and rangelands; moreover, benefits from sustainable increases in production will be low. While there are continuing doubts about the scope for pushing out the frontier of cultivation, there is no doubt whatever that some of agriculture's present resource base will be alienated over the next 25 years because of continued urbanization and industrialization.

Traditional Agriculture and the Environment

Figure 1 is a schematic representation of a traditional South Asian farming system and its cross-boundary relations to the local environment and the nonagricultural economy. In such a system few purchased inputs are required; most production is for subsistence, and market linkages are correspondingly weak. In contrast, linkages both between on-farm enterprises and between the farm and the local environment are strong, and inputs are either produced on the farm itself or tapped from the surrounding natural resource base. The two most important among the latter are forests and surface water. In some systems, transhumance also plays a major part, allowing farmers to draw upon pasture resources far away from the farm.

In addition to this deliberate tapping of the local resource base outside the farm, there are also natural linkages across the boundary of the farming system through which the outside natural resource base helps maintain the productivity of local farmland. The most important of these linkages is the role of forests in maintaining local climate and in ensuring that stream flows are perennial: for example, that they flow regularly from forested hillsides to the farmland in the valleys. Forests can also play an important role in preventing soil erosion, although, as will be argued later, this relationship is not perhaps as clear-cut as many seem to assume.

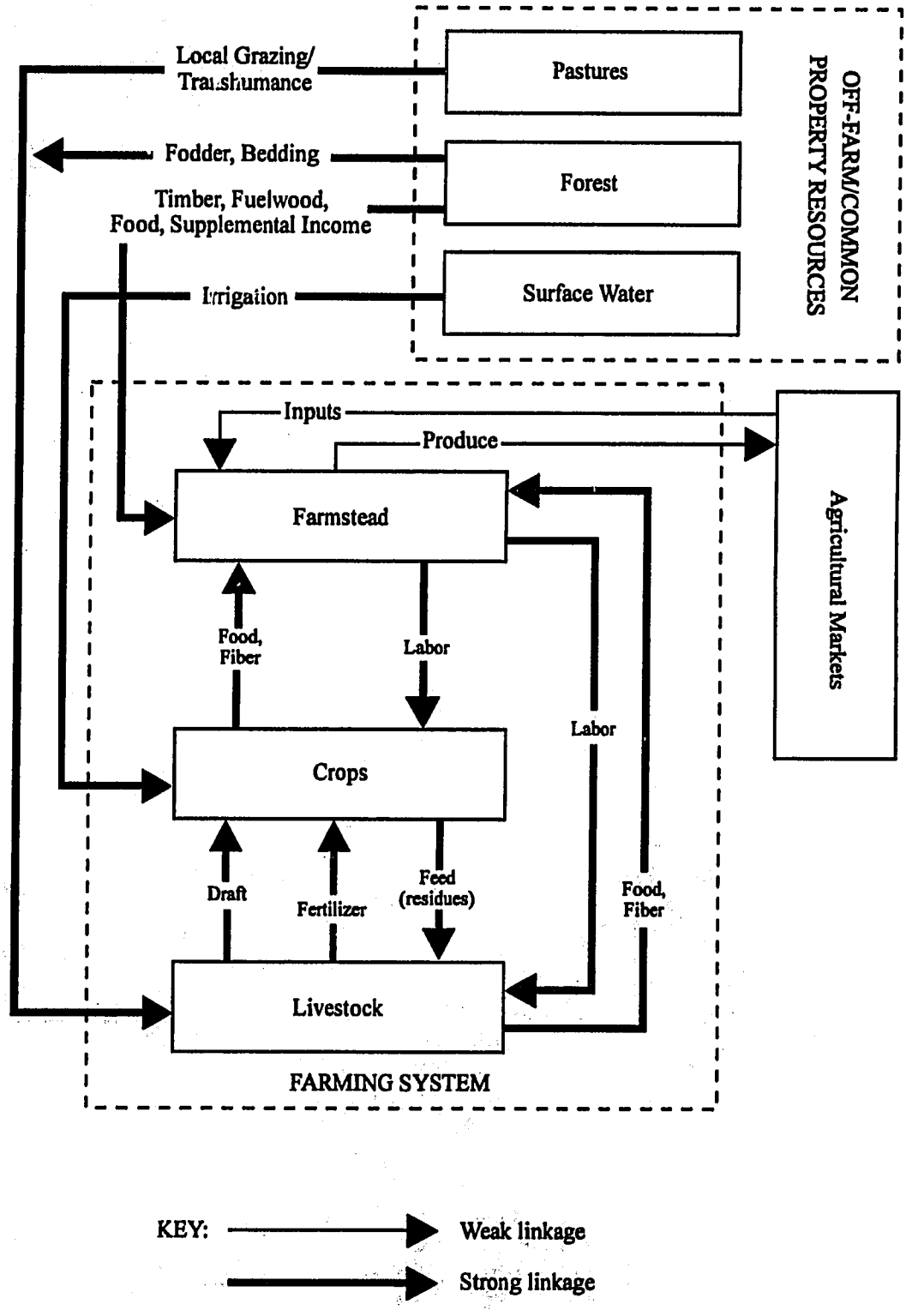
It would be easy to paint an unduly idyllic picture of traditional farming at harmony with nature. But

Table 2—Land use by category, 1992

	Percent of Total Land Area under		
Country/Region[a]	Arable Land and Permanent Crops	Forests and Woodland	Permanent Pasture
Bangladesh (3.2)	69.5	14.5	4.6
India (72.9)	57.1	23.0	3.8
Nepal (3.4)	17.2	39.1	14.6
Pakistan (18.9)	27.4	5.3	6.5
Sri Lanka (1.6)	29.5	32.5	6.8
South Asia	50.0	20.1	4.8
Rest of the world	9.8	30.0	26.9

Source: Calculated from FAO 1993, Table 1.
[a]Figures in parentheses show the percentage of South Asia's land area in each country.

Figure 1—Interactions between a traditional farming system and the local environment



however sensitively off-farm natural resources are managed in traditional agriculture, two major dangers are inherent in their use. They are finite, and the user does not have proprietorial rights. Both can have a negative and interacting effect on incentives to maintain and invest in the resource base. The situation also carries the potential for conflict with other users and potential users, and with it a degree of risk. This important topic will be taken up again later.

Modern Agriculture and the Environment

In South Asia today there is no clear-cut dichotomy between traditional and modern agriculture. Various farming systems are located at different points on the spectrum of transition that runs from the former to the latter. As agricultural transformation continues, the linkages to the market shown in Figure 1 gradually strengthen, while those to the local off-farm environment inevitably weaken. This is not always a matter of choice: in many areas the transformation is driven as much by resource depletion as by the attraction of the market as a source of alternative inputs. Where the local environment is degraded, farmers lose both the natural protection previously enjoyed and an important source of inputs that traditionally maintained the productivity of on-farm crop and livestock enterprises.

Whatever the cause of the transformation, modern high-input agriculture does help reduce dependence on the local environment as a resource base. Consumption of Green Revolution inputs has grown rapidly over recent years in South Asia, as have cereal yields (Table 3). The use of tractors and other machines has reduced or even eliminated dependence on draft animals, thereby releasing resources to produce food for humans. Irrigation in modern agriculture taps increasingly into groundwater, a previously underutilized source of supply and one that can be accessed on-farm, and hence treated like a privately owned resource.[5] Even conflict resolution tends to become less of an immediate issue, given reduced, or at least less obvious, dependence on common property resources.

Modern agriculture does not sever the link to the local environment completely, however, and while it may reduce direct dependence on the local off-farm environment, the indirect linkages are still in place. If that environment is unduly degraded, even modern agriculture may suffer from localized climatic change, increased seasonality of stream flows, and perhaps soil erosion.

For on-farm resources, the adverse effect is more immediate and obvious. Increased intensity of land use occurring simultaneously with reduced return of organic matter to the soil causes deterioration in soil structure and a consequent reduction in the potential for root development and ramification. This in turn adversely affects crop anchorage and uptake of moisture and nutrients. Mechanization compacts the soil and hence exacerbates this problem. Monocropping brings a buildup of pests and diseases and increased vulnerability to attack. Pesticides breed pesticide resistance and a vicious circle of increased application followed by burgeoning resistance. Leakage of chemical inputs into surface water and leaching into groundwater can lead to serious problems of downstream pollution.

On a global scale, the environmental problems caused by modern high-input agriculture are by now fairly well known and need not be elaborated again in any detail here.[6] Within a specifically South Asian context, the effects do need to be scrutinized. In South Asia this issue has been the focus of a major collaborative effort by scientists from Centro Internacional Mejoramiento del Maiz y del Trigo (CIMMYT) and the International Rice Research Institute (IRRI), who have examined long-term effects in farmers' fields of agricultural intensification, particularly when a wheat crop is inserted into traditional rice-fallow and rice-rice-fallow systems. This has been made possible through increased fertilizer use, irrigation, and short-duration wheat and rice varieties developed at the two centers. Rice-wheat and rice-rice-wheat rotations are now grown on approximately 9 million hectares across a broad swathe of the Indo-Gangetic plain covering parts of Pakistan, India, Nepal, and Bangladesh. These rotations are the predominant source of food for perhaps tens of millions of farm families in some of the world's

[5]Groundwater is, of course, as much an open access resource as surface water, but competition between users occurs unseen, deep underground, and, until the water begins to run out, the resource tends to be perceived as privately owned and unlimited in quantity.

[6]See, for example, Conway and Pretty 1991, Pinstrup-Andersen and Pandya-Lorch 1994, and the papers in Breth 1994, particularly those by Harwood, Grove, and Seckler.

Table 3—Input use, irrigation, tractor availability, and foodgrain yields in South Asia since the mid-1970s

Use/Year/Growth	Bangladesh	India	Nepal	Pakistan	Sri Lanka
Fertilizer use (kilograms/hectare of cropland)					
1977/79	40	29	7	42	69
1987/89	86	62	23	85	107
Growth (percent)	115	114	229	102	55
Pesticide use (grams of active ingredients per hectare of cropland)					
1975/77	n.a.	311	n.a.	102	n.a.
1982/84	25	314	n.a.	90	367
Growth (percent)	n.a.	1	n.a.	−12	n.a.
Percent of cropland irrigated					
1977/79	15	22	15	69	27
1987/89	26	25	34	78	29
Growth (percent)	73	14	127	13	7
Tractors (units per 100,000 hectares)					
1977/79	39	198	72	360	991
1987/89	55	468	109	849	1,526
Growth (percent)	39	136	50	136	54
Average yield of foodgrains (kilograms/hectare)					
1978/80	1,940	1,311	1,593	1,530	2,332
1988/89	2,483	1,861	1,832	1,745	2,892
Growth (percent)	28	42	15	14	24

Source: Computed from WRI 1992, Tables 18.1 and 18.2.
Note: n.a. is not available.

poorest areas (Fujisaka, Harrington, and Hobbs 1994). The study found that initially yields in these rotations increased, primarily in response to increased application of fertilizer, but more recently yields have been declining. This may reflect an underlying fall in total factor productivity. There is evidence too of both short- and long-term (sustainability) problems. The latter include deteriorating soil structure, soil nutrient depletion, and possible buildup of insects, grassy weeds, and diseases due to continuous cropping. One might add that, as rice and wheat are both members of the same family, *Gramineae* (grass), it is hardly surprising that the cultivation of two or three grass crops in perpetual rotation would lead to a buildup of grassy weeds and pests of grasses. This reinforces the point made earlier that the level of cereal production in South Asia has reached nonsustainable levels.

Other studies have found long-term problems of waterlogging and salinization resulting from irrigation. One author estimates that because of these difficulties, old irrigated lands in South Asia are going out of use almost as quickly as new irrigated lands are coming into production (Paarlberg 1994). These problems are particularly acute in places like Haryana and both Punjabs, where Green Revolution technologies have been widely adopted. Another major area of concern is pest control. Integrated pest management (IPM) has not been promoted in the subcontinent with anything like the vigor that marked its promotion in parts of Southeast Asia, and heavy reliance continues to be placed on old-fashioned pesticides, particularly organochlorines like DDT and BHC. These have a long half-life, are highly toxic to humans, and are very persistent in the food chain (Paarlberg 1993; Baker and Gyawali 1994).

If the inputs used to date are not a complete answer, the key to sustainable increases in food production on a static natural resource base has to lie in knowledge. For 50 years knowledge has increasingly substituted for natural resources because it is easier to increase the supply of this factor of production (Crosson 1994). Existing inputs embody a great deal of knowledge, but more is required in order to make their use sustainable. Inputs are an example of knowledge made manifest in technology. There are three other areas in which relevant knowledge is embodied: human resources, institutions, and policy. Over the next quarter century, considerable advances will have to be made in all four areas of knowledge if the intensified production required from a static, or even contracting, natural resource base is to become sustainable, while South Asia's growing population is fed at improving nutritional levels.

One area in which knowledge expansion is a vital and neglected first step is that of understanding

processes currently under way that affect the natural resource base. The literature abounds with statements about the extreme scantiness of the data on natural resources throughout the developing world. Such ignorance is itself a problem, of course, but it is compounded by the fact that decisions often have to be made whether there are hard data or not. Unfortunately, this knowledge gap has not deterred certain commentators from making sometimes extreme assessments of the situation—often on the basis of currently fashionable thinking on environmental degradation—and by default these assessments tend to be used in policy formulation. Even when such views are discredited by subsequent scientific investigation, they can continue to hold sway in the popular view and in policy formulation for a very long time. It is difficult to imagine a greater threat to sound natural resource management, and the issue therefore deserves close attention.

Knowledge Gaps and Misleading Data

As part of its centenary celebrations in 1988, the National Geographic Society published a series of maps and charts entitled "Endangered Earth," which have subsequently become popular and influential (NGS 1988). In this publication the following 12 "growing environmental threats" were pinpointed geographically: population pressure, air pollution, ozone concerns, acid rain, water pollution, water diversion, toxic wastes, radiation perils, species extinction, fisheries depletion, deforestation, and desertification. An adaptation of the South Asian segment of the map on environmental threats (Figure 2) shows South Asia as facing four of the perceived dangers: population pressure, species extinction, deforestation, and desertification. Many would consider that South Asia got off lightly in scoring on only 4 counts out of 12, while others would question why some threats are identified on such a limited geographical scale. Why, for example, is species extinction seen as a problem only in the Kathawar Peninsula in Gujarat? Viewed in this light, the Society's cataloging seems conservative, giving added weight to the only perceived threat to South Asia on which any further information is provided, namely deforestation. It says that "demand for fuelwood has denuded African woodland and slopes in Haiti and Nepal—where erosion, landslides, and floods have increased and no cover may remain by 2020."

The date by itself makes this statement of great interest to the present discussion, and, if true, it suggests a dire future for Nepal and possibly also for India and Bangladesh, since both countries lie on the receiving end of any downstream problems. This type of statement is not in fact new. A decade earlier, a World Bank report forecast that in 15 years time—by 1993—there would be no trees left in the hills of Nepal (World Bank 1978). That particular projection can now be seen to be patently absurd, but the dire predictions clearly continue. Only the goalposts have been moved.

This case provides a perfect example of the type of misunderstanding that still exists about South Asia's environment and environmental processes. It also illustrates the need for more basic knowledge as a starting point for informed debate and policy formulation. Given the gravity and extent of the misconceptions about South Asia's natural resource base, and given the mistaken policies that are sometimes based on them, this particular case is worth pursuing further.

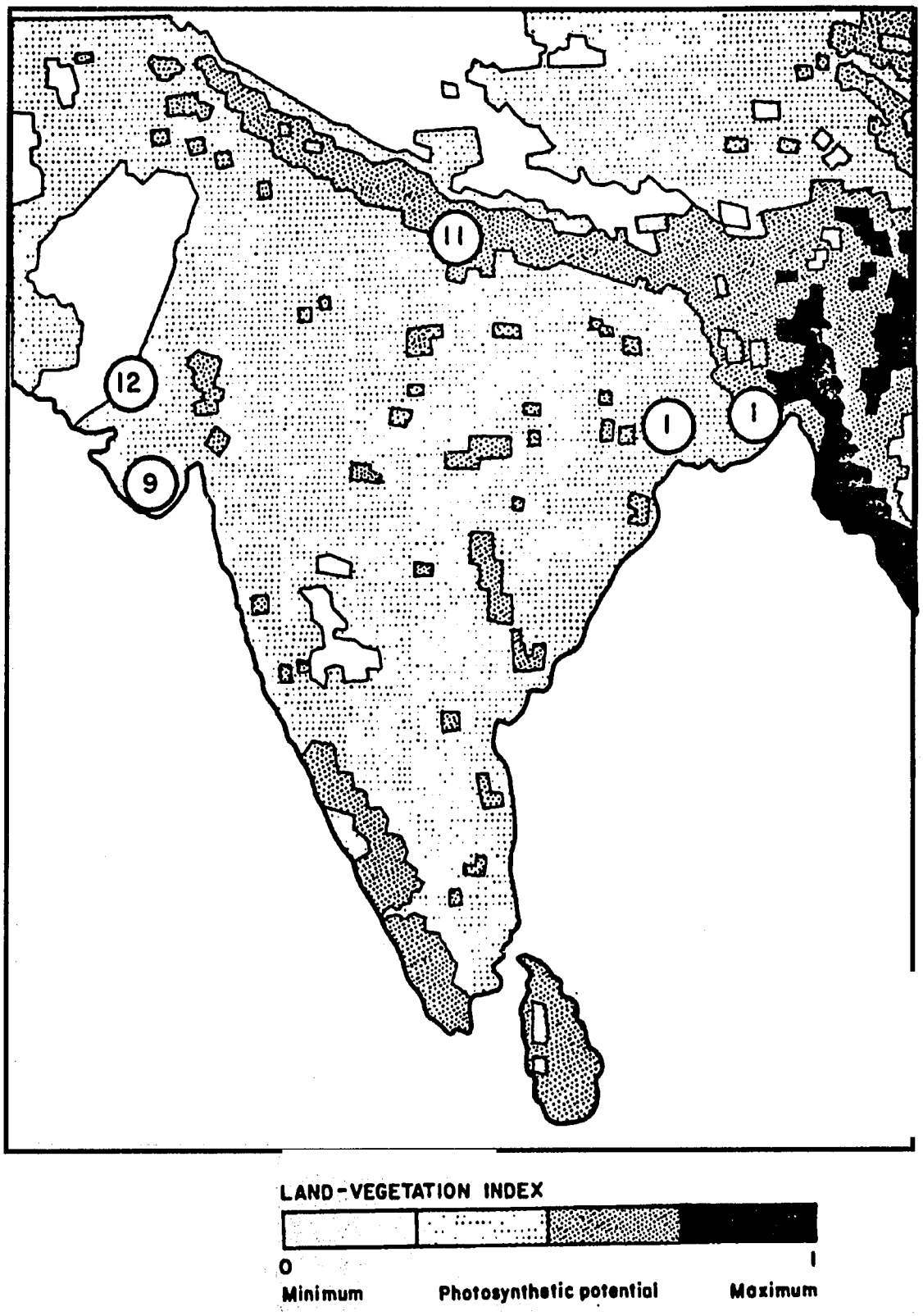
Predictions like those just cited appear to derive from a scenario originally drafted by Eckholm (1975, 1976). His thesis concerned Nepal, but the argument could be applied across the eastern Himalayas and perhaps the entire northern mountain chain:

> There is no better place to begin an examination of deteriorating mountain environments than Nepal.... Population growth ... is forcing farmers onto *ever steeper slopes*, slopes unfit for sustained farming... villagers must roam *farther and farther* from their homes to gather fodder and fuelwood, thus surrounding villages with *a widening circle* of denuded hillsides. Ground-holding trees are *disappearing fast*.... Landslides ... occur *more and more frequently*.... The incidence of flooding by swollen rivers coming down from the mountains is *increasing*.... Topsoil washing down into India and Bangladesh is now Nepal's most precious export.... It is apparent that the *continuation of the present trends* may lead to the development of a semi-desert type of ecology in the hilly regions (Eckholm 1975, 764–765; emphasis added).

According to this statement, not only is there an environmental crisis in Nepal—and by implication in the densely populated plains below—but as the italicized phrases indicate, the problems are ever-deepening. These linkages and similar ones identified by others have been described by Ives and Messerli (1989) as the Theory of Himalayan Environmental Degradation (called here the "HED theory").

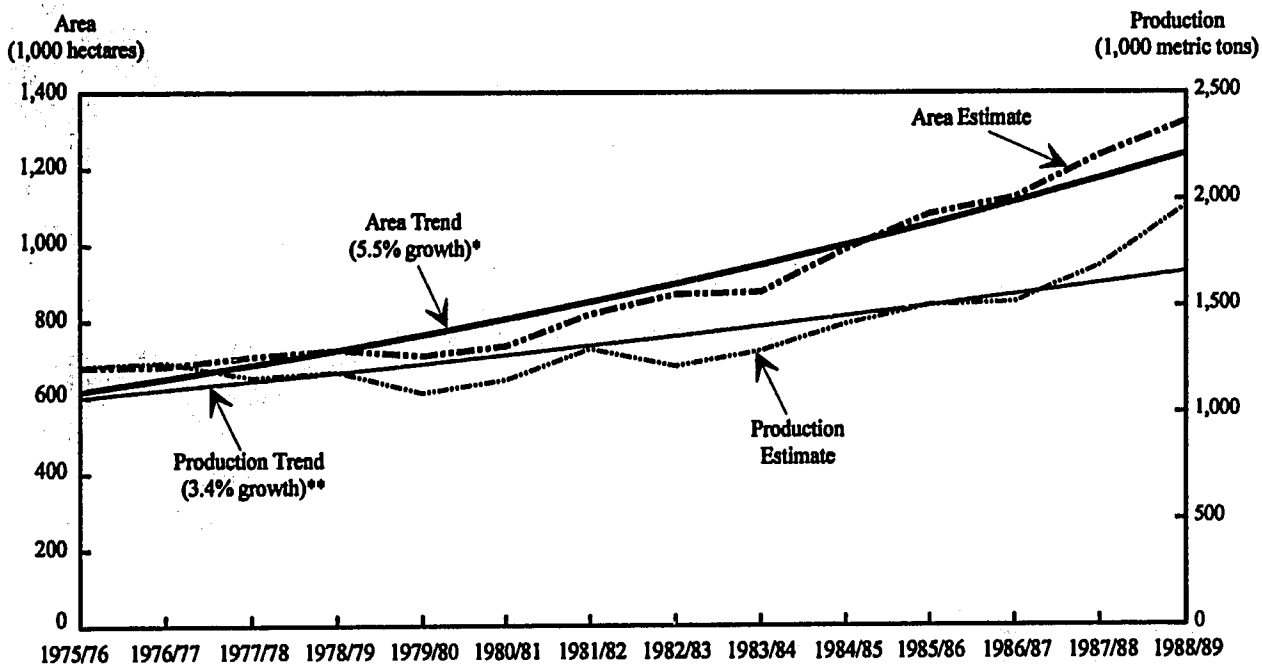
Available statistical evidence seems to support this theory. Figure 3 shows that estimates of both the area under cereals and cereal production have been

Figure 2—Perceived environmental threats in South Asia



Key: 1 = Population pressure; 9 = Species extinction; 11 = Deforestation; 12 = Desertification (based on NGS 1988).
Source: NGS 1988.

Figure 3—Official area and production estimates for foodgrains in hill districts of Nepal



Source: Computed from DFAMS 1990.
*Semilog; r square – 0.939; significance 0.1percent.
**Semilog; r square – 0.716; significance 0.1 percent.

increasing in the Nepalese hills. Both trends are highly statistically significant, but area is growing much more rapidly than production, indicating falling labor productivity, as the HED theory predicts. The combination of the theory and statistics like these gives rise to assessments such as, "Continued population pressure on land resources in the hills and mountains has resulted in expansion of farming onto marginal cultivable land, with ensuing environmental degradation—soil erosion, losses of soil fertility, a deterioration of forests, and forest covers" (NARC-ADB 1991, Main Report, 15).

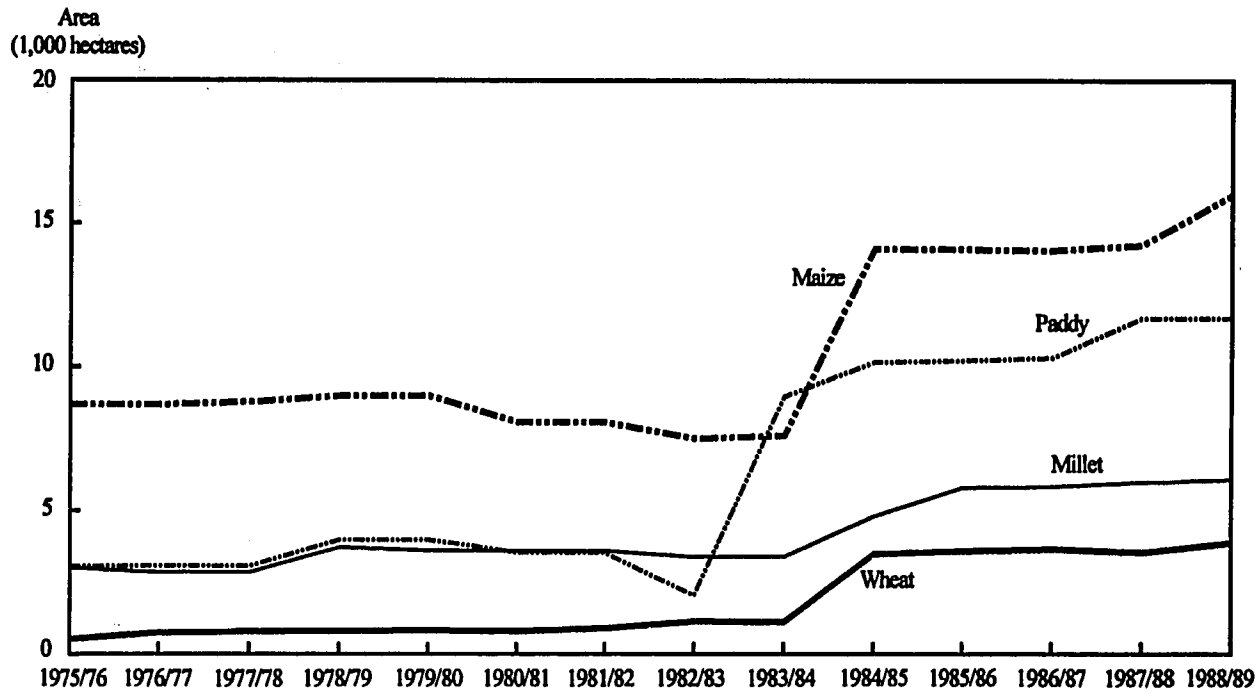
The driving force behind the envisaged process of environmental degradation is population growth. But population growth rate in the hills over the period covered in Figure 3 is officially put at 1.65 percent.[7] This presents an immediate dilemma. How could such a population growth rate be driving area expansion at 5.5 percent, and cereal production at 3.4 percent per year? The "truck" is traveling much faster than the engine that is supposed to be driving it! Moreover, these figures, if correct, mean that per capita cereal production is growing, so that the hills must be becoming increasingly self-sufficient in cereals. Yet more and more hill districts are being officially categorized as food-deficit.

The answer to the dilemma lies in the way the statistics on area are collected. Figure 4 charts the official estimates of area under four major cereals in one hill district, Panchthar.[8] The sudden leap in cultivated area during the period 1982/83–1984/85 needs some explaining! What the figures reflect in fact is not changes in cultivated area, but changes in the way the statistics are collected. A cadastral survey is slowly making its way through the hills, covering one or two districts a year. After this is completed for District X, its figures are substituted for the previous estimate, which was based on the agri-

[7]Calculated from data in CBS 1991 and CBS 1993; semi-logarithmic growth rate; $r^2 = 0.9987$, $p < 0.001$.

[8]Panchthar is not at all unrepresentative. By 1992, with 69 percent of hill districts cadastrally surveyed, the total cultivated area estimated by the survey was 3.7 times greater than that reported for these districts in the 1991/92 National Agricultural Census, a difference of 2.23 million hectares (Gill 1993). It should be added that in 1994 the National Planning Commission ordered that precadastre estimates of cultivated area in the hills be revised upward.

Figure 4—Official estimates of area under foodgrains in Panchthar District



Source: Drawn from DFAMS 1990.

cultural census. The census figures invariably transpire to have been underestimates—sometimes gross underestimates—with results like those shown in Figure 4. Looking at the figures for individual districts shows the absurdity of the situation, but when the figures for all 39 hill districts are analyzed together—which is what outside experts have tended to do—the district-level anomalies are lost in the aggregation process and what emerges is the smoothly rising, statistically significant trend in cultivated area that is shown in Figure 3.

The true picture is much more likely to be one of steadily falling area under cultivation. Soil acidity and aluminum toxicity are growing problems in hill areas, and as these build up, farmers find it increasingly difficult to realize an acceptable return to their labor and inputs. More distant terraces are therefore abandoned and available plant nutrients concentrated ever closer to the farmstead, buffering the soil and permitting a crop to be taken (Carson 1992). The growing shortfall in production is being met increasingly by seasonal migration of the able-bodied men and boys to the plains and to India. This reduces pressure on local resources and finances imports of food and even a little fertilizer (Tamang 1992).

The scientific evidence on deforestation also contradicts the HED theory. The best of this evidence derives from two series of country-wide aerial photographs from 1964 and 1978, the very time when the HED theory was first being enunciated. Analysis of these indicates that the area of forest in the hills did not fall between these two dates (Gilmour 1991). A decline in tree density was found, however, which was almost certainly due to heavy pressure for tree fodder and firewood (Gilmour and Fisher 1991). Most of the land suited to farming was taken out of forest 80 to 100 years ago, so when trees are cut nowadays the land tends to revert to shrub. This certainly represents a degradation of the forest resource, but in areas where the soil is too thin for farming, shrub cover actually does a better job of soil conservation than trees, which can easily blow over in storms, exposing the soil beneath to wind and water erosion.

The argument linking deforestation in the Himalayan foothills and soil washing downstream to cause flooding in India and Bangladesh has also been discredited by scientific investigation. Certainly there are massive landslides and soil erosion in the hills and mountains, but virtually all of this is due to natural factors. The plate tectonic forces that

caused the collision between the Indian and Eurasian plates 40 million years ago raised the Himalayas and armed the antecedent rivers with great erosive power. Compounding this, the enormous watershed thus created is deluged every year by the southwest monsoon, a combination that results in mass wasting on a truly mountainous scale, translating into huge seasonal silt loads on the rivers. In the words of one specialist who has made a long-term study of the area, "the Ganga-Brahmaputra-Meghna (river) system carries a phenomenal load of 2.9 billion metric tons of sediment into the Bay of Bengal every year. It has done this over a vast period of geologic time, eroding the Himalaya to build the Ganga-Brahmaputra plain" (Verghese 1990, 6). Not only does river-borne siltation of the plains and the sea predate the emergence of *Homo sapiens* on the planet, but the alleged hydrological linkage between deforestation and downstream flooding does not stand up to scientific scrutiny either. Bruijnzeel (1989, 116) assembled and analyzed the available information on mountain-plain interactions in the region and concluded, inter alia, that "the presence or absence of forest cover is of negligible importance in affecting flooding in the extreme circumstances of very high rainfall prevalent in the Himalayan foothills." The final piece of the jigsaw was put in place by Hoffer (1993), who investigated the long-term relationship among deforestation, river discharge, and flooding in the Himalayan region. This study demonstrated conclusively that flooding in the Gangetic plain results from rainfall on the plains and bears no relationship whatever to precipitation in the mountains.

The HED theory, then, effectively blames the Himalayan hill farmer for the effects of vast geological and climatic forces over which no one has any control. And the theory still holds sway in the popular imagination today.[9] Much more seriously, it still has credibility with donor agencies and national policymakers. The hydrological and international aspect of the theory, that is, the supposed downstream flooding effects of deforestation, have been particularly influential. As Fisher (1990 69) observed, "the (HED) theory has become so pervasive that it has obtained the status of myth . . . 'a charter for action' justifying a vast amount of foreign aid into reforestation and watershed management projects." This strong emphasis on forestry aid continues today. Over the past 20 years, government spending on forestry has grown 50 percent faster than that on agriculture (Thapa 1994). In 1981/82 foreign aid disbursements to forestry were half of those to agriculture (the much larger sector); by 1991/92 they were equal (Nepal, Ministry of Finance 1994).

If the perception of a problem is wrong, the solution is likely to be equally wrong. If deforestation is seen as the problem, the obvious answer is reforestation, a situation in which forests are viewed as an end result, not as a means of achieving sustainable rural development. Yet this is no more than a quick fix technical solution which does not address underlying social and economic issues (Gilmour and Fisher 1991, 37).

To sum up, an unfortunate combination of bad science, misleading statistics, and, to be frank, environmental scaremongering has led to serious mistakes in "knowledge" as incorporated in technology, human resources (foresters), institutions (government and donor agencies), and policies. The most fundamental issue in natural resource management in South Asia must be to achieve a major breakthrough in the understanding of the state of the environment, of the processes that are changing it, and of the underlying causes.

Much has been written about the potential contribution of remote sensing for achieving this, but although there has been a vast growth in the amount of information generated by remote sensing, processing it has presented difficulties (WRI-IIED 1988). These problems may well be solved by even newer remote sensing technology as it comes onstream, but even this will be able to answer only the "what" and not the "why" questions. For the latter, a judicious combination of remote sensing and participatory learning and analysis seems to hold out the greatest promise (Sowerwine et al. 1994; IIED 1995).

Agricultural Research and Extension

The knowledge embodied in resource-complementing technology is the outcome of agricultural research and its extension to farmers. To push productivity further, previous efforts will have to continue at all points in the spectrum, from strategic research at the international centers through the work at national centers to

[9]An example of this was a November 1993 news broadcast on the influential BBC World Service radio when the announcer asked a Bangladeshi scientist "What can Bangladesh do about flooding? It's all caused by deforestation in Nepal."

the "fine-tuning" adaptive and agronomic research the farmers do in their fields.

Unlike the situation in developed countries, the private sector in South Asia contributes little to agricultural research and extension. All South Asian countries have public-sector agricultural research organizations and extension services. In India this type of work is done at the state level and in Pakistan at the provincial level as well as nationally. All of these institutions rely heavily on the centers of the Consultative Group on International Agricultural Research (CGIAR), most of which have been major suppliers of genetic materials, training, institutional strengthening, and collaborative research to the domestic research and (through it) extension systems.

For the foreseeable future the technology for intensified agricultural development in South Asia will continue to derive from the CGIAR and domestic centers. However, the financial climate for continued collaboration does not look at all promising. Within a context of falling aid budgets, agricultural aid budgets are declining faster and support for agricultural research is dropping fastest of all (von Braun et al. 1993). The CGIAR centers also now face an uncertain financial future. Core funding for them declined, in current dollars, by 21 percent from 1990 to 1993, despite the fact that five new institutions had been added since 1990 (ODI 1994).

Domestic expenditure on agriculture by central governments in South Asian countries is shown in Table 4, alongside comparable figures for selected Southeast Asian countries. The caveat about additional spending by state and provincial governments in India and Pakistan makes the comparison difficult for these two countries, but for the others only Sri Lanka matches the Southeast Asian figures on a per hectare basis. Yet agriculture is so much more important to South Asia than it is further east.

The historical trends are mixed. While Nepal and Pakistan have maintained the share of agriculture at more or less constant levels since the early 1980s, both India and Bangladesh have allowed the sector's share to fall over the same period (von Braun et al. 1993; Thapa 1994). A long-standing problem for the national centers is that they suffer from periodic or chronic shortages of funds, which invariably impinge on operating budgets, so that human and material resources periodically stand idle for want of relatively meager sums of money to cover operating costs. More recently the national centers have also been increasingly caught up in the structural adjustment process, which has sought to cut public-sector spending across the board.

Had the present exercise been conducted 25 years ago, the future of institutions like CIMMYT and IRRI would have seemed secure. The impact of semidwarf, early maturing, fertilizer-responsive varieties of wheat and rice on irrigated land transformed agriculture in the Punjabs of both India and Pakistan and in surrounding areas, holding out the prospect that cereal deficits in South Asia would become—and, more important, remain—a thing of the past. Indeed, as shown earlier, this prospect has materialized even in chronically food-deficit Bang-

Table 4—Central government expenditure on agriculture in selected South and Southeast Asian countries (late 1980s)

Region/Country	Agriculture as Percent of GDP	Spending on Agriculture as Percent of All Expenditure	Agricultural Expenditure (US$/cropped hectare)
South Asia			
Bangladesh	44.3	12	25
India[a]	31.7	8	22
Nepal	58.7	8	19
Pakistan[a]	26.6	1	7
Sri Lanka	26.0	8	87
Southeast Asia			
Indonesia	24.1	7	55
Malaysia	n.a.	8	178
Myanmar	n.a.	21	146
Philippines	23.5	5	38
Thailand	16.9	9	42

Source: Computed from WRI 1992, Tables 15.1, 15.3, and 18.2.
Notes: Agriculture here includes forestry, fishing, and hunting. n.a. is not available.
[a]State governments in India and provincial governments in Pakistan also spend considerable amounts on agriculture, but no figures are available for this expenditure.

ladesh, almost entirely because of the spread of Green Revolution technology.

The record with respect to the adoption of this technology has been mixed. The greatest degree of success has probably been Sri Lanka's, where an estimated 75 percent of the rice area is under high-yielding varieties (Agcaoili and Rosegrant 1994a). At the other extreme, in Nepal, technology has had little impact, even on the Gangetic plain where the environment is eminently suitable (APROSC-JMA 1995). In India the Green Revolution has tended to concentrate in certain well-endowed pockets, and these have made an enormous contribution to the nation's food supply. Between 1951 and 1991 India's population grew by 134 percent, from 361 million to 846 million, but cereal production increased by 229 percent, from 54 to 174 million metric tons. Thus per capita production rose from 150 to 206 kilograms per year, an average annual increase of about 1.1 percent.[10] Most of this production gain came from states in which the Green Revolution had its greatest impact. For both rice and wheat, these states produced about a third of India's output from about a fifth of the area under each crop (Table 5). It was in the 1970s that the first negative reaction set in. Skepticism was voiced originally about the effects on distribution of Green Revolution technologies, but by the 1980s environmental concerns were coming increasingly to the fore. Growing fears were expressed about the types of effects on the natural resource base that were discussed earlier.

Criticisms of the Green Revolution in South Asia, while valid enough in themselves, have tended to concentrate on the purely negative side of the picture. Even if this technology is not sustainable, its lasting contribution has been to provide breathing space to enable these countries to get their population growth rates down without the assistance of Malthus's grim triumvirate. And population growth rates have indeed come down. The Green Revolution also has had an offsetting positive, but largely unacknowledged, impact on the environment. Without the improved varieties released by the CGIAR centers and adapted at national levels, feeding the current populations at prevailing nutritional standards would have required at least 60 percent more land (ODI 1994). And the only place that land could have come from is the expansion of cultivation into forests, pastures, steep hillsides, and other ecologically fragile areas unsuited to arable farming.

The evidence is now fairly clear, however, that the Green Revolution was a one-off event. Once the basic features of the technology had been built into varieties in the early 1960s, there was little more that could be achieved in increasing genetic potential (Pingali 1991; Havener 1994). In South Asia, therefore, yield increases associated with this technology will continue to decline, while related environmental

Table 5—Relative positions of Green Revolution states of India in foodgrain area and production (average of 1991/92 and 1992/93)

Crop/State	Percent of National Area under Crop	Percent of National Production
Rice		
Andhra Pradesh	8.9	12.1
Haryana	1.6	2.5
Punjab	4.9	9.4
Tamil Nadu	5.2	8.9
Green Revolution states combined	20.6	32.9
Wheat		
Haryana	7.9	12.1
Punjab	13.7	22.0
Green Revolution states combined	21.2	34.1

Source: Computed from India, Ministry of Agriculture and Cooperation, 1994, Tables 2.3(b) and 2.4(b).
Notes: Data limitations mean that figures do not include states where the Green Revolution affected only some parts. For example, only the western part of Uttar Pradesh adopted this technology on a significant scale.

[10]Computed from data in India, Ministry of Agriculture and Cooperation 1994, Tables 1.1 and 2.2(a). In order to smooth out year-to-year fluctuations in foodgrain production, four-year averages for the periods 1949/50–1952/53 and 1989/90–1992/93 have been used to represent 1951 and 1991, respectively.

problems will continue to mount. These problems are most serious in pest control, and this should be addressed urgently. There is much to be learned from Southeast Asia's experience with IPM.

The Green Revolution enabled South Asia to avoid the famine that was widely predicted for it 25 years ago. Another such breakthrough is now required in the next quarter century in order to continue to sustain still-growing populations at ever higher standards, while simultaneously moving the agricultural economy in the direction of exploiting comparative advantage. Such a breakthrough is most likely to come from the incorporation of technical knowledge into the genetic resource base. One area in which great progress has been made in recent years is in developing strains that are tolerant of or resistant to various crop diseases and pests (Pinstrup-Andersen 1994). From the vantage point of 1995 the most likely source of a further breakthrough seems to be genetic engineering. It is becoming increasingly possible to produce plants tailor-made to certain production environments, particularly areas that are problematic. Compared to those of the Green Revolution, these technologies can be combined more easily with traditional methods and are inherently more natural resource-conserving.[11] For example, genetic characteristics like pest- and disease-resistance reduce the need for pesticides and other chemicals. Such technologies should also particularly benefit farmers living in the difficult areas the Green Revolution did not reach, so that the equity implications are positive. As noted earlier, the comparative advantage situation suggests that research and extension resources might usefully be concentrated on improving productivity of monsoon rice and non-cereal, high-value, irrigated crops for the dry season.

Technology is the most important embodiment of knowledge as it emerges from the agricultural research system, but there has to be an input of knowledge as well. The criticisms that have been leveled at national agricultural research systems (NARS) in developing countries include undue outside interference; lack of proper coordination within and between institutes; lack of prioritization in order to make optimum use of scarce resources; discipline rather than problem orientation; bureaucratic procedures and delays, which are inimical to the demands of scientific precision, timeliness, and rigor; inappropriate procedures and criteria for staff assessment, placement, and promotion; unscientific management procedures; lack of planning; undue attention being paid by scientists to appearances at international conferences—the list seems endless. South Asian NARS have to varying degrees been the object of similar criticism. Financial resources are certainly essential for the generation of high-quality, appropriate technology, but simply throwing money at such problems will not solve them. Indeed it may make them worse.

One aspect of this input of knowledge that can be expensive, or rather has an expensive component, is human resource development. Training scientists to the high levels required for rigorous research costs a lot of money. A Ph.D. in a developed country now costs a minimum of US$100,000 to train, while, in the Southeast Asian countries to which an increasing proportion of South Asia's trainee scientists are being sent, the cost is still in the region of US$50,000. This is expensive, given the large number required, but it should represent money well spent. If selection procedures are merit-based and followed scrupulously, and if the skills developed are subsequently used in-country, the investment will yield returns for decades and have a high multiplier effect. Unfortunately, this type of human resource development seems to have become even more unfashionable than agriculture itself, but it is difficult to see how research institutes can contribute much without it. (The inexpensive component of human resource development is learning from farmers, which is examined later.)

Democracy, Decentralization, and Economic Liberalization

The participatory approach has come increasingly into favor in development thinking in recent years, and South Asia has played a leading role in popularizing its adoption, particularly through nongovernmental organizations, both acting alone and in collaboration with government.[12] Further impetus has been given to the movement toward more participatory forms of resource management by the restora-

[11] H. F. Massey, in a letter to the editor of IFPRI's *News & Views*, August 1994, p.6.

[12] Examples include the work of the Aga Khan Rural Support Foundation in India and Pakistan, MYRADA and Outreach in India, Proshika and BRAC in Bangladesh and Action Aid throughout the subcontinent. For a recent and authoritative account of the origins, present status, and challenges of this approach, see Chambers 1994a, 1994b, and 1994c.

tion of democracy in recent years in three South Asian countries: Bangladesh, Nepal, and Pakistan. This has meant that all five countries under consideration now have democratically elected governments. In countries where the move is recent, people are beginning to demand enforcement of their rights (or perceived rights) and governments are having to pay more attention than previously.

Another positive recent development that might help this process is economic liberalization. All South Asian economies have a past history of control and management from the center, and this has had a paralyzing effect on efforts to decentralize as well as on private-sector development. It is to be hoped that the general loosening of the strings of control required by the overall liberalization strategy will encourage decentralization of control to locally elected bodies.

The major positive effect of economic liberalization will be the growing commercialization of South Asian economies. Subsistence production is an inefficient user of natural resources because it does not realize the potential of comparative advantage. Market orientation will therefore make for more economically efficient use of natural resources, but a major outstanding issue is whether this exploitation will be both environmentally friendly and sustainable. This will depend on the extent to which ownership and control is vested in the hands of local inhabitants, who have a built-in incentive to maintain the resource. It is impossible therefore to separate out concerns about natural resource management from questions of ownership.

Ownership and Management of Natural Resources

The legal position obviously varies from country to country, but the default position in South Asia is state ownership. Even where there is private ownership, there is provision for compulsory purchase for development purposes. The de facto position is somewhat more complex.

Land is the most privatized of all natural resources in South Asia, although the owner is not always the user. Tenancy is widespread, and land reform is a hot political issue in many places. There is fairly extensive sharecropping and, although in theory this can lead to lower production levels than with owner-cultivation, in fact the impact is probably not very great. Owner cultivation and cash tenancy are becoming increasingly common, especially on commercially farmed land, while the effects of theoretically suboptimal conditions in sharecropping are often countered by the strong bargaining position of the landlord in a land-scarce environment.

Despite current moves toward community forestry throughout the region, forests are still mainly state-owned, and following British colonial tradition, a common attitude among foresters is that forests must be protected, which usually means that people and their livestock should be kept out. There is an unresolved dispute between the forest protection and conservation school of thought, on the one hand, and those who wish to see resources managed in a productive but sustainable way, on the other. This issue will be taken up again later.

Groundwater, surface water, and territorial waters are virtually all state owned, but in practice they are often open to access by individuals or community groups. When ground and surface water are used for irrigation, however, the distribution systems are subject to proprietorial rights of those whose land they cross.

The literature on natural resource depletion and degradation contains three recurrent and related themes. The first is Garrett Hardin's well-known *Tragedy of the Commons* thesis, which has been extremely influential over the past quarter century (Hardin 1968). A second theme is that poverty is a major cause of natural resource problems, the argument being that poor people under enormous pressure to survive are forced to adopt short-term solutions to problems of food and fuel shortage at the cost of longer-term environmental damage. This differs from Hardin's argument in that it applies to privately owned as well as to open access resources and that the driving force is different. The third theme, which tends to be more implicit than stated, is that the processes of environmental degradation are for the most part irreversible.

Recent research on indigenous knowledge in general, and indigenous management of natural resources in particular, is beginning to throw considerable doubt on the above arguments, or at least on the generalizations they have engendered.[13] Hardin's

[13]For numerous field examples from all over the developing world, see issues of *Indigenous Knowledge & Development Monitor* from its inception in 1993

exposition added a great deal to understanding of the conditions under which the commons are degraded and about the lack of proper incentives to prevent this. He failed, however, to distinguish adequately between open access and common property resources and, as recent work has shown, his argument seriously underestimates the importance of the latter. Indigenous community management of natural resources is, in fact, common throughout South Asia. Some of these systems are traditional and some of them are new, but their important distinguishing feature is that the initiative is local and hence indigenous. The most important areas in which these are found are forests and irrigation, but they are also found in, for example, rangelands (Sedhain 1993; Thapa 1993). Such systems are far from informal. Rules are established for access to the resource and the removal of produce; sanctions are applied to rule-breakers; and in the case of forests, guards are often employed to enforce the rules and a committee is usually established for general supervision, collection and disbursement of revenue, and policy formulation. There are established techniques for conflict resolution, and control tends to be democratic. Far from degrading the resource base, these indigenous systems play an often key role in managing it in a sustainable fashion.[14] This phenomenon, in fact, taps into ancient traditions in South Asia, where community management of, for example, religious sites is the norm.

State ownership of natural resources, rather than common property per se, is emerging as one of the most important causes of environmental degradation. Government-owned rangelands and forests are often the most degraded, and the performance of public-sector irrigation schemes has been poor, so that the risk-reducing, yield-enhancing potential of supplemental water resources is often squandered. The mere fact of government ownership has often induced a dependency attitude toward resource issues such as forest conservation, rangeland management and repair, and maintenance of irrigation works. This argument must not, however, be taken to extremes. In cases where the government's effective control is very light, or where community pressure has been forceful, resources have on occasion been taken over de facto by the local population and then managed on a community basis (Tamang 1990; Poffenberg, Bhatia, and McGean 1990).

For a variety of reasons the link between poverty and resource pressure is probably stronger in Africa than in South Asia but the subcontinent has suffered because of extrapolation and generalization from the African experience. Even in South Asia, the link can exist, especially in extreme cases such as famine or an influx of refugees. But as a general proposition the argument that poor people in South Asia are despoilers of natural resources is dangerously misleading. One aspect of this question was addressed earlier in relation to deforestation in Nepal and the misunderstandings surrounding the issue. Further evidence from all over South Asia shows that in fact poor farmers are often the most careful managers of natural resources. One glance at the millions of hectares of terraced land covering so many of South Asia's hills provides stunning evidence of how carefully the soil resource is managed. In other cases outsiders, seeing resource use that looks unsustainable and armed with fashionable views about the environmentally unfriendly nature of agriculture, often jump to conclusions that further investigation would have dispelled.[15]

The implication that natural resource degradation cannot be reversed is also coming under increasingly critical scrutiny. Gilmour and Fisher (1991), after long-term investigation of the issue in the forestry sector, concluded that, when forest resources are plentiful and conveniently located, villagers see little need to conserve them. However, once the resource becomes severely degraded and the opportunity cost of collecting forest products becomes prohibitive, new indigenous approaches and institutions start to evolve, including farm forestry and community management of the degraded resource along the lines indicated earlier. In the area of soil conservation, one long-term study examined the case of a village that had lost a swathe of terraced land to a severe landslide. Over a 10-year period, the farmers managed not only to stabilize the slope, but were

[14]For some of the many examples, see IIMI 1988; Yoder and Thurston 1989; Gilmour and Fisher 1991; Hobley 1992; Chalise et al. 1993; and Tamang, Gill, and Thapa 1993.

[15]The pioneering work in indigenous knowledge of the biophysical environment includes IDS 1979 and Brokensha, Warren, and Werner 1980. Farrington and Martin 1988 provide a useful critical review of work to date on farmer participation in agricultural research. In a specifically South Asian context, the recent literature includes, for example, Carson 1992; the papers in Kerr 1991; Gurung 1994; and Tamang, Gill, and Thapa 1993. The latter is particularly informative on indigenous soil conservation and management in the semi-arid tropics of South Asia.

also able to re-terrace it and bring it back into production (Ives 1991). The world in general and South Asia in particular have learned a great deal about indigenous knowledge in the past few years and information about traditional systems of natural resource management has begun to accumulate. Given the current and growing level of interest in indigenous knowledge, this database should continue to expand (provided, of course, the theme does not go out of fashion too quickly).

The importance of community ownership and management built on a foundation of indigenous knowledge goes beyond equity issues. After a wide-ranging review of the role of indigenous technical knowledge systems in agricultural research, Farrington and Martin concluded that "the relevance and prospects of success of innovations brought in from outside will be enhanced if they build upon indigenous knowledge. Where this is not done, the risk of project failure is high" (1988, 23). The implications for sustainable natural resource management are profound. If, in contrast to public-sector organizations, indigenous institutions embody the knowledge and skills needed to maintain, sustain, and rehabilitate natural resources, the obvious implication is that control of these resources—which at the minimum implies the conferring of inalienable usufructuary rights—should be transferred to local people. In contrast to this, the only solution envisaged in the "tragedy of the commons" scenario was to transfer ownership to private hands. In some cases this would make sense, but it does bring the danger that the rich and powerful will capture all of the benefits of what was previously a national resource and that the rest of the local community will be deprived of customary rights.

None of the above is meant to suggest that rural communities have some special wisdom through which, unaided, they can achieve miracles. There are important constraints on indigenous knowledge. For example, farmers in a locality are limited to what can be done with the local gene pool plus any genetic material from outside that they may happen upon. In addition, certain techniques are closed to them, for example, the crossing of self-pollinating crops where specific plant breeding techniques are required.[16] While participation by farmers (and therefore "ownership" of the experimentation process) is always desirable, often the scientist will have the greater input. The knowledge of the two are, in fact, highly complementary. Because of the highly specialized nature of modern science, the scientist's knowledge is both narrow and deep. The farmer's knowledge complements this because, where the scientist's knowledge is deep, that of the farmer is much less so—in the sense that it is limited to a quite confined geographical area. The farmer's knowledge of this area is profound, however. The farmer's technical knowledge, unlike that of the scientist, is wide and interdisciplinary, embracing agronomy, animal husbandry, agricultural economics, irrigation management, seed technology, and so forth. The scope for complementarity is therefore exceptionally high, but only when the scientist genuinely regards the farmer as a fellow professional.

The question of ownership also arises in the gender sense. Throughout South Asia women are more closely involved than men in the exploitation of certain natural resources. Their responsibility for the domestic water supply is an obvious case in point. Another such area is forest management. Women are the main gatherers of forest produce such as fodder and bedding for farm animals, planting materials, wild foodstuffs, fuelwood, and the raw materials for handicrafts. Over the generations they have acquired an often high degree of proficiency and expertise in managing such resources so as to maintain a finely tuned balance between productivity and sustainability.[17] Where women are the primary users of natural resources, it would be logical to turn management over to them, but it has to be recognized that such a move would break down even more barriers and taboos than transfer of ownership to the community at large.

The scientist and extension worker must also recognize that the farmer is not necessarily a man, for the gender division of labor applies on-farm also. In South Asia women farmers usually play the dominant role in such areas as seed selection and storage and animal husbandry. Scientists in such disciplines have to be particularly sensitive to gender issues and gender typing. Broadly speaking, a similar argument can be put for ethnic minorities, because people who are unusually dependent on natural resources like forests are often from tribal groups, and it is essential that the views and priorities of the majority community are not imposed on them.

[16]This and other examples of the limitations on indigenous knowledge are summarized in Briggs and Clay 1980.

[17]For a case study of the complexity of such management systems, see Rusten 1989.

Conflicts over Natural Resource Use

Resource depletion, degradation, and alienation, together with increased demand for what remains, will generate potential for conflict between competing users or would-be users. Recent disputes in the European Union and countries such as Canada over disappearing fish stocks have brought this issue into sharp international focus. In South Asia, too, there are looming questions over fish stocks. In the Bay of Bengal, for example, there are periodic reports of illegal fishing by modern boats from Southeast Asian countries. Marine fishing in South Asia is not very mechanized at present, so that modern methods of overfishing are not widely available to the domestic industry. Mechanization is growing, however, and disputes can be expected to become an increasing problem.

The worst clashes to date have been over the land resource. Three wars have been fought in South Asia since independence from Britain. There are still outstanding territorial claims between subcontinental neighbors, of which Kashmir is only the most famous.

Water is another source of regional discord. A basic problem for a nation like India, a water-poor country by international standards (WRI-IIED 1988), is that it is "rapidly approaching the physical and economic limits of water development, with little potential for increasing water supply to satisfy additional demands" (Seckler 1994, 72). Pakistan, with 78 percent of its land already under irrigation (Table 3), is no better placed. A basic difficulty is that all the major rivers of the northern part of South Asia, the most populous part, flow through the territories of more than one country, and there are recurring disagreements over water sharing. India and Pakistan are reported to have once almost gone to war over the distribution of Indus Basin water supplies (Seckler 1994) and diversion of Ganges water at the Farakkha barrage is a perennial source of disagreement between India and Bangladesh. The Bangladeshis report that during the winter season, when irrigation is needed, large-scale salt water intrusion into the lower Ganges has rendered large areas nonirrigable.

One problem seems to be that international riparian law is open to varying degrees of interpretation depending upon national interests. At one extreme, it can be argued that no country has the right unilaterally to impede the natural flow of water to another. At the other end of the spectrum is the argument that a country has absolute sovereignty over the waters within its territory. The problem is that downstream countries tend to favor the former argument, while upstream ones seem to prefer the latter. Indeed it is not unknown for a country to adopt the "natural flow" position in talks with its upstream neighbor while simultaneously arguing for absolute sovereignty with the one downstream.

An important consequence of South Asia's largely monsoonal climate is alternating deficit and excess. Rainy-season flooding is a recurrent problem and huge areas, particularly of the Gangetic plain, are hit. As noted earlier, scientific investigation has discredited the myth that this is caused by deforestation in the Himalayas, so at least one potential source of conflict should fade. But other areas of dispute still exist between neighboring countries and states when flood protection measures are taken. This is particularly important when a river forms an international boundary: embanking one side will worsen inundation on the other.

The major international dispute over forestry occurs when atmospheric pollution in one country produces acid rain that then falls on the forests of a country further down the prevailing wind system. This issue has not surfaced so far in South Asia, although the potential for it certainly exists.

A second level at which conflicts arise is between agriculture and competing resource users. Unless one is prepared to make some fairly heroic assumptions about reducing the cost of desalinizing sea water or harvesting an increasing proportion of rainfall, the supply of fresh water is for all practical purposes fixed. Over the next quarter century increasing quantities of fresh water will be diverted from food production to serve the needs of growing urban centers, the manufacturing industry, and power generation, with corresponding needs for water conservation in agriculture. A related issue is industrial pollution of groundwater. Even within the rural areas groundwater has itself become an area of conflict: all over the northern plains handwells for drinking water are failing as the water table is lowered by irrigation. There are also reports that shallow tubewells are failing because they are being undermined by deep tubewells.

In addition to its effect on water, urban and industrial development also entails alienation of land from farming. One "ballpark" estimate is that by 2025 further urbanization might take 5 percent of cropland out of production in developing countries (Crosson and Anderson 1992). But this is not just

any 5 percent. Urbanization typically takes the best land. Urban centers are often located in areas of historically high population density, around which an urban civilization could coalesce. High population density in turn usually reflects fertile agricultural conditions. The Kathmandu Valley is an emphatic case in point. Even when the land is not the most fertile, it is still often among the best for agriculture, because it is by definition close to the market for inputs and output. Hydroelectric schemes present similar difficulties, as it is inevitably the fertile valley land that goes under water.

It was observed earlier that modern high-input agriculture weakens the link between farming and certain natural resources and that this removes or reduces a potential source of conflict. But other sources of conflict clearly remain. One such area mentioned earlier is disputes between the owners of land and those wishing to carry irrigation canals over it. Within irrigation itself, wrangles between those at the beginning and those at the end of a system are a perennial problem. The problem is worse with agency- rather than farmer-managed schemes, and there may also be distinct diseconomies of scale, for the problem seems to grow exponentially with the number of participants and with increasing physical distance between the extreme ends of the distribution network. Conflicts arise even within indigenous management systems, and the literature contains references to intergroup disagreements, rivalries, and conflict. Occasionally these cannot be resolved amicably and the group splits up, but groups usually have mechanisms for conflict resolution, and the more valuable the resource is perceived to be, the more likely it is that members will be prepared to compromise.

Conflict resolution presents peculiar difficulties for natural resource management. No attempt will be made here to address the international and interstate dimensions. At the community level, if pressures on the environment can be reduced by substituting knowledge for natural resources, the pressures that lead to interpersonal and intercommunity conflict should begin to ease, but there will always be conflict. Clarifying legal entitlement and usufructuary rights would make things easier, but few rural people would willingly suffer what Hamlet called "the insolence of office and the law's delay." Less formal approaches are also needed, but even indigenous conflict-resolving mechanisms can sometimes prove inadequate. Remarkably little heed is paid to the provision of training in conflict resolution, and this important area should be the focus of greater attention.

Food Losses

The 2020 Vision debate so far has tended to focus on questions of food production as an aid to increased consumption. Rather less attention has been paid to the prevention of food loss, although this could make a significant contribution to increasing food availability. Where losses have been discussed, the debate has tended to focus on minimizing losses to plant disease, predation, and competition from weeds. Concern with postharvest loss tends to stop at the point of storage, but losses can continue right up to the point at which the nutrients are utilized within the human body. Particular attention should be paid to losses that occur in two areas. The first is the loss of food quality that can occur during processing and cooking. For instance, vegetables are commonly overboiled in South Asian village cooking, a process that dissolves water-soluble vitamins, which are then discarded when the water is drained off. The second area of concern is the wastage of nutrients that occurs within the body. Diarrheal disease is extremely common in South Asia, particularly among children and especially during the rainy season (Gill 1991). The main focus of attention here has been on prevention of illness and death, but diarrhea is also responsible for a huge amount of nutrient loss.

Some of the linkages of these issues to natural resource management will be obvious, while others may be less so. Environmental health and hygiene are clearly of crucial importance here, as is the quality of drinking water. Evidence of a rather less obvious linkage is emerging from anecdotal testimony from several parts of South Asia. Shortage of firewood is apparently forcing people to cook several meals in a single batch in order to economize on fuel. Biological contamination is eliminated by cooking, but if the cooked food is then left around in the heat, unprotected from flies and other sources of contagion, then the probability of recontamination is very high.

The purpose in raising such issues in the present paper is not to introduce a discussion of them in any depth—the author is unqualified to do so. It is rather to argue for the inclusion of nonagriculturalists in the debate. Medicine, nutrition, engineering, education, home economics, and other disciplines have important roles to play in this discussion.

Resource-Specific Issues

This paper has deliberately concentrated on broad systemic issues, rather than questions that are peculiar to specific natural resources. In this section,

however, some important resource-specific issues will be examined.

Forests

Arguments put earlier in this paper concerning misconceptions about the rate of deforestation in hill areas of South Asia and the effects of this on areas downstream should not be taken as implying that South Asia's forests are not being depleted, degraded, or alienated (converted from forestry to other uses). There is little doubt that this is happening (or has already happened) in many areas, with both direct and indirect negative effects on agriculture. The indirect effects mainly revolve around questions of water supply to arable land, including increased seasonality of stream flow, erosion of biodiversity, and the loss of forest-induced rainfall. The direct effects impinge mainly on soil fertility. The loss of leaf fodder and bedding materials means that fewer animals can be kept, which in turn has a negative effect on the organic content of the soil because of the loss of nutrients that were previously supplied in the form of manure and compost from bedding litter. Reduction in firewood availability also means that most of the remaining dung now has to be used as fuel instead of being returned to the land.

The need to prevent further deforestation and encourage rehabilitation of remaining forests is widely accepted throughout South Asia today, but the most appropriate means of doing this is more controversial. The main protagonists were earlier categorized as the "forest protection and conservation" and "sustainable management" schools of thought. Resolution of the underlying issues is absolutely crucial, if community forestry is to be developed further and communities are to be given full rights to develop the resource, rather than hedged in with regulations.

The conventional view in environmental circles is that forest resources must be protected, and that the felling of tropical hardwoods like South Asia's *sal* (*Shorea robusta*) must therefore be opposed. In Nepal, for example, *sal* has been the object of a protectionist policy that for the past 30 years has tried to conserve the forest by restricting legal felling of dead and dying trees. More recently this attitude has been reinforced by pressures from environmentalists for forest conservation through measures like ending the trade in tropical hardwoods.[18]

The countervailing view is that forests must be managed so that they yield an economic return, thus making it economically attractive for people to maintain the forest resource, both quantitatively and qualitatively. This underpins the whole community forestry approach, for poor rural people see little benefit in protection for protection's sake. Sustainable management, its proponents argue, actually improves strictly conservationist policy; far from conserving the forest, this actually degrades it. Dead and dying trees shade out the saplings and stunt their growth, and there may be an additional threat of disease transmission from older to younger stock. Risk is another factor, as dead and dying trees are dry and therefore highly combustible, increasing the risk of fire and the damage that can occur to the forest in the event of a conflagration. Economically, timber from dead and dying trees is less valuable than that from mature ones. A strategy of active forest management which sanctions the removal of mature trees would confer benefits in the shape of increased fuelwood and fodder production, raw materials for industry, employment creation, revenue generation, a reduction in illegal felling, and cost-free forest conservation and regeneration. Contrary to common belief, the cutting of trees does not itself cause soil erosion; this results from associated (and avoidable) activities, such as the use of heavy logging equipment, the building of forest roads, and the grazing of cleared land (Ives 1991).

Tnere are both direct and indirect connections between this type of natural resource issue and food supply. The direct connection is that removal of mature trees would open up the canopy and permit farmers to engage in agroforestry while the saplings are in their first few years. This may not add much to aggregate food production, but agroforestry is usually associated with high-value crops that could contribute to diet quality either directly or indirectly through income generation. Another indirect linkage would be employment generation and therefore poverty alleviation.

[18]This issue was addressed at a seminar on "Economics versus the Environment? *Sal* Forest Management in the Nepal Tarai," presented at the Agricultural Projects Services Centre, Kathmandu, by Olavi Rautiainen, Forest Management and Utilization Development Project, October 1994.

Water Resources

Irrigation cannot continue to expect the lion's share of water in South Asia. Economic development means that increasing quantities of water resources will have to be diverted to the industrial and urban sectors, and the use of water for irrigation will therefore have to become more efficient. At the moment, irrigation in South Asia tends to mean flood irrigation, and this is very wasteful. Application is excessive and evaporation and seepage losses from both canals and fields are high. Often the plants cannot use more than a fraction of the water that is provided.

This raises further important issues concerning the dominance of rice paddies in South Asian agriculture. It was earlier argued that, with the exception of monsoon rice, South Asia has no comparative advantage in the production of low-value, high-volume commodities like cereals. This applies most strongly to dry-season, irrigated rice, an exceptionally water-demanding crop, which requires for example three times as much water as wheat. This wasteful use of water is encouraged throughout South Asia by subsidies on irrigation at all levels, from infrastructure construction and maintenance, to pumpsets and fuel (especially electricity). An immediate priority should be to begin replacing dry-season rice with increased monsoon production of this crop, so that the land presently under the former can be diverted to less thirsty crops. This is not simply an economic issue, as the very term "rice farmer" carries a good deal of prestige throughout South Asia—indeed, throughout the continent as a whole. The countervailing economic forces must therefore be made correspondingly strong.

One way in which subsidy policy might be usefully reformulated is to target it toward encouraging farmers to switch to more water-efficient technologies, such as sprinkler systems or drip irrigation. Subsidies here could be justified as a means of correcting past mistakes, which encouraged investment in inefficient water use. Once subsidies that support water-inefficient technologies are phased out, this particular conflict is likely to be resolved by market forces. On the supply side, as water for irrigation becomes scarcer, its financial or opportunity cost will rise, thus encouraging farmers to use it more efficiently. On the demand side, rising incomes have a disproportionate impact on effective demand for fruits, vegetables, and animal protein, so that the relative prices of these crops will rise faster than those of starchy staples. This will also encourage farmers to make the switch.

Soils

There are two related basic issues here: soil fertility and soil conservation. The switch from organic to inorganic fertilizers accompanied by increasing cropping intensities has, as noted previously, resulted in deteriorating soil structure, which in turn results directly from depletion of the forest resource base and consequent shortages of fuel and fodder. Having said this, it should be added that the use of chemical fertilizer has not reached very high levels, even by the standards of neighboring regions. South Asia's fertilizer use averaged 65 kilograms per hectare at the end of the 1980s, which is much lower than the comparable figure for China of 255 kilograms per hectare. This is one reason why South Asia's average cereal yields, unlike China's, are continuing to rise. However, the rate of increase fell off during the 1980s, and the continuation of this trend is a major reason why the growth rate of food production is expected to dip below that of population early in the next century.

The effect on food production of economic development in the next 25 years may be both positive and negative. On the positive side, rising incomes and improved access may hasten the switch to purchased fuel or biogas. On the negative side, growing commercialization of the economy will increase the trend away from traditional mixed farming toward more specialized production, implying a widening gap between crop and animal husbandry. This is already seen in the rapid spread of commercialized poultry production around South Asian cities. Rural cropland generates the feed for this industry, but the manure is not recycled back into the soil; instead it is permitted to contribute to urban pollution. Underlying this decoupling of crop and livestock production is probably an unstated assumption that urban-to-rural recycling of nutrients is uneconomic. If so, the assumption needs to be questioned, as it has been to good effect in the United States, for example. In Arkansas, the country's largest poultry-producing state, chicken litter is now being shipped, sometimes over hundreds of kilometers, from chicken farms to cropland.

Turning to soil erosion, South Asian farmers do perceive this as a problem and realize there is a relationship with crop yield, but they are unable to quantify it. This is hardly surprising, as soil scientists seem to be equally in the dark. As Dregne notes, there is an "abysmal lack of knowledge" about the exact nature of the relationship (quoted in Crosson 1994). The equations for calculating wind and water erosion were developed in the temperate zone, in the

U.S. Midwest, and their applicability to the tropics and subtropics is unknown (Crosson 1994).

In a recent study in the semi-arid tropics of south India, farmers reported three main harmful effects of erosion: soil loss, water loss, and nutrient loss. Farmers were least concerned about the first, indicating that short-term concerns are more important to them than the longer-term effects (Kerr and Sanghi 1991). Soil and water conservation methods are labor-intensive and expensive for poor farmers, even in a labor-surplus economy. Where the benefits cannot be calculated with any certainty, it is difficult to make a case for conservation on economic grounds. Yet economic factors predominate in farmers' decisionmaking on soil and water conservation. Farmers do invest their time and that of hired labor in such measures. It is reported that this investment was more likely to be made (1) by full-time farmers than by part-timers; (2) by owner-cultivators than by landlords; (3) on fertile plots than on less fertile ones; (4) on irrigated than on rainfed land; (5) on farms where the labor-land ratio is high; (6) on land where the necessary materials are close to hand, and (7) in situations where the necessary investment can be staggered over a number of years but still generate benefits from the start.

If Present Trends Continue . . .

The discussion in this paper has been based on an implicit assumption that present trends will continue. But extrapolation is a dangerous business, and existing trends can be disrupted by unforeseen and unforeseeable developments. To illustrate this point briefly, it is useful mentally to revert back 100 years to 1895 in order to see to what extent it would have been possible to predict what would happen to some of the relevant variables by 1920. The most likely area for unforeseen developments is technology. Table 6 examines the antecedents of remote sensing, a technology now seen as having enormous potential for monitoring developments in the natural resource base. How many people living in 1895 would have predicted these changes? A second area is the environment itself. Although we can now say that the U.S. dust bowl of the 1930s was in the making by the end of the nineteenth century, who would have foreseen its extent and impact? A third area is politics. Some might have predicted in 1895 that the Russian Empire would be socialist within 25 years, but how many would have foretold the disastrous impact this would have on food supply in the short term and on the environment in the long term?

It would be a brave forecaster indeed who would predict changes in variables such as these, but there is at least one area in which present trends might change dramatically in the next 25 years, and that is population growth. This variable is obviously fundamental to all forecasts of food supply and the implications for the environment, but the discussion has largely centered on population size and growth rates, rather than on age and gender structure. It will be argued here, however, that it is far from impossible that major changes could take place in the structural distribution of South Asia's population in the next quarter century, with far-reaching implications for agriculture and the natural resource base on which it depends.

In the easily foreseeable future, the factor most likely to affect the age structure of South Asia's population is the AIDS epidemic. The syndrome is already well established and is spreading both within and between countries in South Asia via the brutal trade in women and girls and a lack of education about unprotected sex. Both men who resort to prostitutes and women ejected from the trade after becoming HIV-positive carry the potential to spread the infection if they return to the rural areas. AIDS particularly affects the most economically active section of the population, and if Africa's experience is any guide, can cause large-scale illness and death among younger adults. When this happens there is an accompanying increase in the dependency ratio.

Table 6—Developments in the antecedents of remote sensing, 1895–1920

Field	1895	By 1920
Flight	No piloted heavier-than-air craft had ever flown.	Such an aircraft had flown the Atlantic.
Electronics	Limited to a few laboratory experiments with little obvious practical application.	Two-way aircraft-to-ground radio communication well established.
Photography	Cameras heavy, slow, clumsy, and earthbound.	Air photo production and interpretation quite well advanced.

The rural parts of developing countries are often thought of as labor-surplus areas, but this is an incomplete picture. There are times of the year, particularly during the planting and harvesting seasons, when there is extreme labor scarcity and everyone must work flat out.[19] Any significant reduction in labor supply at these critical times of year would have catastrophic implications for food production.

The second structural question concerns gender. In most of the sociocultural-religious systems of South Asia (as elsewhere) there is strong gender preference for males. The technology already exists for determining the sex of a fetus, and Indian press reports speak of tens of thousands of cases in which amniocentesis is used for determining sex, followed by abortion where the fetus is found to be female.

This technology is too expensive to allow this particular practice on a scale large enough to have a very discernible effect on the gender structure of the population. Looking at a 25-year time horizon, however, new and much simpler and cheaper technologies may well become available, based, not on abortion, but on gender preselection. There are already well-established differences between the gynosperm and the androsperm (in terms of, for example, sensitivity to pH value), and technologies for gender preselection would most likely be based on these. For example, if at some time in the future it becomes a matter of taking one pill if you want a boy and a different one if you want a girl, there is little doubt which pill would be in greater demand.

If this scenario does materialize, and the new technology is adopted on a significant scale, it would have a double effect in inhibiting population growth. In the short term, the overall birth rate would be reduced because people could have the desired number of sons within the context of a smaller family. The longer-term effect would result from the change in the gender structure of the population. By the time the first such generation grew to adulthood, there would simply be too few women to maintain the population growth rate, which could well drop to negative figures.

If the above scenario seems far-fetched, the experience of China is both illuminating and admonitory. When, a generation ago, the government decreed that each family would be limited to one child, gender preference ensured that the majority were boys (and some of the methods used to achieve this were probably quite horrifying). The effect, if press reports are correct, is that there are now an estimated 30 million young men in China who cannot find wives.

It must be stressed that painting this picture is not in any way meant to suggest that gender preselection (far less AIDS!) be adopted as an instrument of population control. The intention is simply to outline what seems a not implausible scenario and then to examine some of the possible implications for natural resource management and the food production that depends on it.

Both of the structural changes postulated here are likely to reduce population pressure on natural resources. This is obviously the case if changes in gender distribution significantly reduce the population growth rate. In the case of a change in age structure, the effect is likely to be twofold. First, the reduction in the proportion of adults in the high fertility age bands would, like the postulated change in gender structure, tend to lower the population growth rate. Second, the loss in food production could be accompanied by a positive effect on the environment. Ecologically fragile areas are typically areas of low agricultural potential, because of the factors that made them fragile in the first place. Labor productivity in such areas tends therefore to be low, and when labor is in short supply, they are likely to be the first areas to drop out of agriculture and revert to natural cover.

If either or both of the above scenarios come into play on a significant scale in the next 25 years, South Asian policymakers may have even more pressing concerns than the sustainable management of natural resources. Indeed, as suggested above, such management may no longer be a very pressing issue at all. The situation regarding both AIDS and gender preselection needs to be monitored.

Conclusions

South Asia's food requirements in the next 25 years are likely to grow by at least 100 percent, while the natural resource base available to support this increase is more likely to shrink than to expand. The next quarter century will be crucial in ensuring that there is a smooth transition from the present cereal-dominated, land-extensive, water-intensive production system to an agriculture more in keeping with

[19]See Gill 1991, Chapter 3, for a review of the evidence.

South Asia's natural resource endowment. To the extent that this transition is successful, the subcontinent's agriculture will by 2020 use less land and water to produce a higher-value agricultural GDP based on an increased level of knowledge embodied in improved technology, skill levels, institutions, and policies. The level of agricultural trade will also be significantly larger than today, with increased exports of high-value farm produce and more imports of cereals other than rice.

In view of both the extremely large size of the South Asian population and the importance of cereals in the average household budget, any move toward importing a significant proportion of cereal requirements would have to be carefully planned and phased, so as to avoid driving world cereal prices sharply upward. The comparative advantage argument points toward development of policies over the next 25 years that emphasize (1) heavy investment in research and development to produce a significant increase in monsoon rice production; (2) a gradual move away from production of irrigated dry-season cereals, particularly rice; and (3) investment in the development and promotion of alternative dry-season, high-value crops for both the domestic and export markets. All this will require a reversal of the present trend of falling public funding of agricultural research and extension. At the strategic level, a greater range of tailor-made varieties will have to be created. At the adaptive level, there will have to be a much wider range of site-specific, on-farm research and greatly improved feedback from farmers.

The implications of such a transformation for the natural resource base are multiply beneficial. First, in a context of continued economic liberalization and consequent development of an agricultural economy based increasingly on comparative advantage, the reduction in arable area is likely to take the shape of a withdrawal from cultivation of ecologically fragile (and hence agriculturally less productive) areas, which can then revert to natural cover. Second, new technologies such as genetic engineering will make it increasingly possible to breed disease- and pest-resistance into plants, thus reducing the need for environmentally harmful chemical control. Third, breaking the cycle of continuous cropping under cereals will diversify crop rotations and thus help reverse the present trend of deteriorating soil structure. Finally, more efficient water use will reduce problems such as waterlogging and soil salinization that are presently associated with overuse.

Needless to say the above developments will not by themselves guarantee optimal levels of resource management. The linkages between food production and the natural resource base in South Asia are strong, complex, and poorly understood. High priority must be given to finding better methods of measuring and monitoring the natural resource base so as first to avoid counterproductive policies and then to design policies that help maintain and enhance the resource base. High priority must also be attached to the issue of ownership and usufructuary rights. Here, fortunately, the latest evidence indicates that the democratic solution of decentralization to encourage participatory and community ownership and use also offers the most promising approach to sustainable resource management. Conflicts will nevertheless continue to arise from time to time and more attention must be paid to providing training in conflict resolution at all levels.

Throughout South Asia an important start has been made in promoting people's participation in areas of common property resource management, such as community forestry and farmer-managed irrigation systems. The specifics will obviously vary from country to country, but as a general rule adoption of the participatory approach will mean removal of policy anomalies, the enactment and enforcement of laws on users' rights, and above all decentralization of decisionmaking.

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