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ENVIRONMENTAL ASPECTS OF AGRICULTURAL DEVELOPMENT

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IFPRI POLICY BRIEFS make available in capsule form recent research findings drawn from larger studies conducted by IFPRI and others that may not yet be accessible to the general public. Prior to publication the briefs are normally presented at an IFPRI policy seminar where they serve as a basis for an interchange of views between research analysts and decisionmakers on policy issues of immediate concern. Thus, the format is intended to be abbreviated and nontechnical in order to contribute to public understanding of complex issues on which systematic information is often lacking.

The briefs that follow examine some of the issues facing agricultural researchers and policymakers in promoting sustainable agricultural production in environmentally sensitive areas in the developing world. In developing countries ever-increasing populations in rural and urban areas are directly and indirectly taxing the agricultural resource base that is steadily deteriorating as the result of problems such as saline and waterlogged land, deforestation, and desertification. These briefs focus on these complex issues with specific reference to environmentally sensitive areas in Africa, Asia, and South America.

The briefs were presented at a seminar held at the World Bank, Washington, D.C., October 19, 1989. The seminar was jointly sponsored with the Committee on Agricultural Sustainability for Developing Countries.

ENVIRONMENTAL EXTERNALITIES IN SURFACE IRRIGATION SYSTEMS IN INDIA

P.K. JOSHI AND DAYANATHA JHA

Irrigation has traditionally been perceived as the most strategic agricultural investment. Irrigated area in India has increased from about 23 million hectares in 1950/51 to 60 million hectares by 1985. The estimated total investment is about Rs 194 billion.

Yet concerns regarding the efficiency of these investments, particularly in surface irrigation systems, have been rising. Poor design, maintenance, operation, and management are often cited as reasons for poor performance. In addition, productivity and sustainability of the production systems irrigated by canals are often threatened by increasing salinity, alkalinity, and waterlogging.

Reliable estimates of the extent of this problem are not available, but researchers have come up with a figure of 10 million hectares of waterlogged and 25 million hectares of salt-affected land in India. The policy response has been sluggish and passive, however. Lack of empirical evidence showing adverse effects is one reason for this lapse.

The evidence presented here comes from a 1985/86 survey of farmers in the Sharda Sahayak Irrigation Project, which covers several districts in the fertile, Indo-Gangetic plains of eastern Uttar Pradesh. Farmers were selected for the study from an area where canal irrigation is dominant. Though the study is based on a small sample, the results are startling and need to be noted and pursued further. Before the early 1970s (when the project was initiated), such problems were nonexistent; during the survey year, more than 87 percent of the farmers reported these problems. Alkalinity (sodicity) is the major problem in the study area.

LAND USE PATTERN

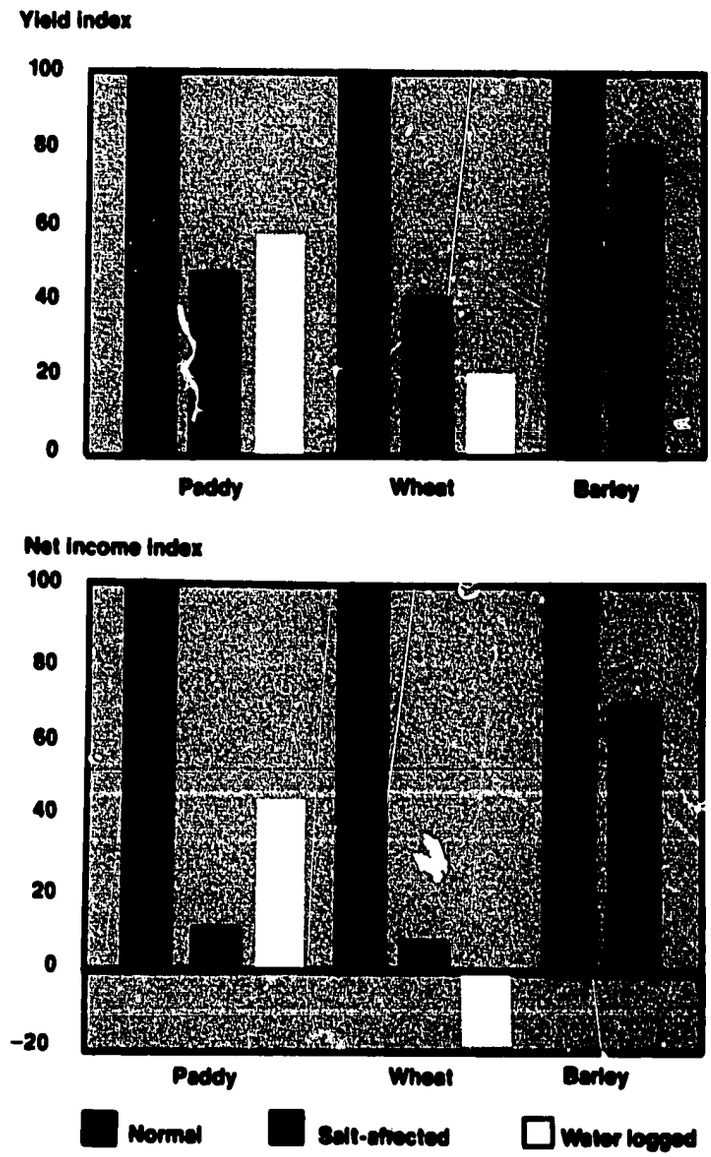
About 94 percent of the holdings in the area are less than 2 hectares in size. Under such circumstances, every piece of land is usually cultivated, but 29 percent of farm area was uncultivated on farms affected by alkalinity, salinity, or waterlogging. Where land is scarce, this is alarming; it points to the catastrophic long-term results of soil degradation. Even on nominally irrigated cultivated land, the land-use intensity is only 110 percent on farms with problem soils, as against 166 percent on farms where these problems are not severe. The land-intensification benefits of irrigation are completely negated by alkalinity and waterlogging problems.

The study also shows that crop production choices are severely restricted under adverse soil conditions. Quite apart from the effects of elimination of high-value garden crops, the disappearance of legumes and oilseeds from the crop mix could have serious nutrition-related consequences.

PRODUCTIVITY EFFECTS

Dramatic declines in yield take place as soil conditions deteriorate. Paddy yields decrease by more than 50 percent on salt-affected soils, and waterlogging reduces wheat yields by about 78 percent (Figure 1). For barley, a more salt-tolerant crop, the yield decline is relatively small.

Figure 1
Indexes of crop yields and incomes from normal and degraded soils, Sharda Sahayak Irrigation Project, Uttar Pradesh, India, 1985/86



These declines are reflected in lower efficiency indicators. For example, production costs for paddy rise by 60 percent on salt-affected soils; those for wheat rise by 88 percent on salt-affected soils and by 211 percent on waterlogged soils. The effects are even more dramatic on farm incomes: net income from paddy declined by more than 86 percent and that from wheat by 92 percent under alkaline conditions.

Finally, the analysis shows that nearly three-fourths of the differences in gross income between normal and degraded soils were caused by the degradation of soil quality. Input use levels are, of course, lower under degraded soil conditions, but this effect does not account for more than one-fourth of the income differential.

POLICY IMPLICATIONS

Problems of soil salinity and waterlogging affect millions of farmers. These adverse production effects are dramatic in the short-to-medium run, and disastrous in the long-run. In a situation where aggregate output keeps growing at a rate of 2-3 percent, such erosion of the production base fails to attract policy attention. The first step is to identify and quantify such vulnerable areas, a step that is now being attempted in India.

Improper drainage is the main cause of deteriorating soils. Promoting horizontal as well as vertical drainage (through pumping) and preventing canal seepage are essential. Irrigation planners in India now insist on incorporating drainage considerations and costs into irrigation project design, which adds substantially to project costs. Because large-scale, surface irrigation projects have become rare anyhow, one could argue that heavy investments in drainage systems may be as important as creating new irrigation potential.

But these options are way beyond the reach of small farmers, both technically and financially. Their strategies are confined to choosing the more tolerant crops and varieties. Some research programs for identifying and developing salt-tolerant varieties are under way, but these are restricted in crop coverage and need to be strengthened. Improvements in on-farm water management and use of soil amendments, where high alkalinity is the problem, are also crucial.

DEVELOPING SUSTAINABLE RAINFED FARMING SYSTEMS IN WEST ASIA AND NORTH AFRICA

PETER ORAM

West Asia and North Africa (the region extending from Morocco in the West to Pakistan in the East), together with Southern Europe, has the longest history of settled agriculture in the world and probably the worst record of mismanagement of its agricultural environment. Plato's graphic description of the effects of deforestation in the mountains of Attica remains to this day one of the most accurate historical records of environmental degradation.

THE PROBLEM

The countries around the southern and eastern Mediterranean have a harsh climate, with some of the highest variations of rainfall and, in most cases, a limited potential for bringing new rainfed land into cultivation or expanding the net irrigated area.

The regional population, which was about 300 million in the mid-1970s, was 415 million in 1987 and will be 600 million by the year 2000. Oil resources and industrialization notwithstanding, 41 percent of the people are in the agricultural sector.

The task, then, is to find a way to improve their incomes, while feeding an additional 185 million people, mainly in urban areas, over the next 10 years. This has to be done from an inelastic and deteriorating agricultural resource base, with widespread salinization and waterlogging in irrigated land, increasing competition for water, and serious erosion and desertification of rainfed land through uncontrolled mechanization and extension of cultivation to marginal areas. Desertification is leading to declining availability of feed for ruminant livestock and extreme pressure on the remaining natural grazing areas. The main sources of past expansion of net rainfed area and new irrigation developments have declined dramatically. To improve the productivity of the resource base and to halt its further deterioration presents a massive challenge both to research and to development policy.

POSSIBLE SOLUTIONS

Technological change is one obvious solution, but the relatively rapid growth of yields in the late 1960s and 1970s, following the introduction of high-yielding varieties (HYVs) of wheat—the key cereal crop in this region—has slowed significantly in the 1980s, whereas yields of most other annual crops—barley, pulses, oilseeds, and vegetables—have risen very little. For most of these crops, HYVs are unavailable or are only just being released, seed production systems are inadequate, and price policies are discriminatory. In the case of wheat, a hard core of nonadopters of modern varieties and fertilizer exists, due partly to the highly risky rainfed environment in the drier ecozones and partly to price and import policies which favor consumers.

Parallel solutions to improving productivity must therefore be found, both to reduce escalating imports and to reverse resource deterioration. The key lies in raising crop intensities and in diversifying production, so as to reduce producer risks while meeting the changing demands of a dynamic domestic and export market, in which urbanization, as well as income growth, is playing a major role.

Present crop intensities are well below unity on rainfed land, and not much above it in irrigated land, although for different reasons. At present, in the region as a whole, there is an estimated 24 million hectares of rainfed land in the traditional cropping system of one year of cereal and one year of fallow. Since 1980, Turkey has demonstrated the potential for increasing rainfed crop intensity by replacing 2 million hectares of this fallow with food or forage legumes in rotation with winter cereals, through a carefully planned campaign that integrates ecological, technological, advisory, and marketing factors. As a result of this effort, Turkey has become the second largest producer and largest exporter of cool-season food legumes in the world, while maintaining the growth of its cereal products. This progress suggests that fallow replacement could be a major source of new growth in ecozones where rainfall is between 250 and 500 millimeters. On sloping land unsuited to arable farming, considerable scope exists for planting fruit and nut trees and olives. In zones where rainfall is even lower—less than 250 millimeters, drought-resistant shrubs and ley farming systems, based on barley and pasture legumes, offer unexploited opportunities for diversification and intensification. In higher rainfall and irrigated areas, a wider range of fruit, vegetable, oilseed, pulse, and forage crops can be grown, and the integration of livestock with settled farming becomes an attractive proposition, given prevailing high prices for livestock products and for animal feed.

Diversification and intensification in rainfed zones is necessary not only to meet changing demand but also to counter the increasing threats to the environment inherent in failure to innovate. These threats include a soil-exhausting trend in low rainfall ecozones toward continuous barley cultivation with no fallow, driven by high prices for ruminant animals; uncontrolled mechanization of steep and marginal lands; and excessive exploitation of rangelands for animal production by substituting traditional extensive nomadic grazing systems with commercial operations involving mechanized movements of sheep.

RESEARCH PRIORITIES

IFPRI has been working closely with the International Center for Agricultural Research in the Dry Areas (ICARDA) and the World Bank to identify opportunities and researchable policy issues. One joint project with ICARDA looks at the prospects for developing rainfed legume and wheat-based systems in the 250-800 millimeter ecozones and another at the barley-ruminant livestock nexus in lower rainfall areas. These studies point to a need for action on a number of important issues.

1. Closer agroecological characterization of the region to identify areas suited to intensification, especially by replacing fallow with farming systems that include legumes (whether for food or feed).

2. Research in a systems context to determine which cropping patterns contribute the most to income growth and sustainability (including soil nitrogen status and moisture conservation) in the major agroecological zones.

3. The role of farm mechanization in an era of increasing labor competition also merits urgent attention. Both individual ownership of tractors, sprayers, combines, and balers, and custom operation of these machines is expanding rapidly, but with little research on how they can be used most effectively without damaging the environment.

4. Market opportunities for fresh and processed products, including potential horticultural and livestock exports, have received little attention, despite considerable research on the production side. If commercial demand continues to be neglected, money spent on production research may be wasted.

5. The social and structural obstacles to intensification, especially through closer crop-livestock integration, have been seriously neglected. These, rather than technical problems, lie at the root of the continued failure of the successful wheat-medick-sheep system developed in the Mediterranean ecozones of Australia to take hold in West Asia/North Africa after 30 years of trials at experiment stations and on farms in at least eight countries.

6. Feed shortage, not disease, is the main factor limiting greater livestock productivity in this region. Not only is uncontrolled mechanization encouraging cultivation of marginal grazing areas that should never be cultivated, but it is leading to the loss of other traditional sources of animal feed from grazing of stubbles and weedy fallows. Thus, in addition to preventing the further encroachment of cultivation on pastures and forest grazings, it is necessary to encourage the cultivation of annual forages in arable farming systems, especially where potential exists for fallow replacement and diversification. Action to improve seed supplies of pasture and forage crops and greater stability of livestock marketing and prices would be helpful in creating incentives to closer crop-livestock integration.

7. While many of these issues are interrelated, the structure and composition of agricultural research systems in the region is poorly adapted to the solution of problems that cut across disciplines. A much better balance in the allocation of international and national research efforts between biological, environmental, animal, and social sciences in this region is, therefore, essential if sustainable increases in productivity are to be achieved and if the environmental deterioration based on short-run opportunism that has characterized land use there for millennia is to be halted.

DEFORESTATION AND POVERTY IN THE NEPAL HILLS—LINKS WITH AGRICULTURAL PRODUCTIVITY

SHUBH KUMAR

Deforestation in Nepal is taking place in both the terai (plains) and the hill regions. In the terai, as in the northern Indian plains, deforestation has been exacerbated by immigration. In Nepal, such settlement has been seen as essential for expanding the productive plains agriculture and for relieving population pressure in hill areas. However, deforestation in hill areas has been just as rapid. Despite outmigration, the press of population continues to outstrip the ability of agriculture to provide for them. Thus more and more land needs to be cleared on the hillsides to sustain the livelihoods based on low-productivity agriculture. Even this low productivity does not appear to be sustainable, however. Human labor is the key to deforestation. As more land is cleared, more labor is needed not only for the clearing itself, but to farm the additional land and to gather increasingly scarce forest products, such as fuelwood and fodder. Thus, deforestation accentuates the competition for household labor between agriculture and other survival needs. This further reduces agricultural productivity and living conditions and also contributes to additional demand for children's labor, which may undercut efforts to improve children's nutrition and education.

What is happening in the Nepalese hills is fairly typical of areas with low agricultural productivity: a high reliance on the surrounding natural resource base, often for livestock; a highly labor-dependent agricultural production process; a relatively high reliance on women's labor in agriculture; high population growth; and outmigration. A recent IFPRI study argues that low-productivity agriculture helps degrade the natural resource base, which consequently draws more labor away from agriculture and further lowers the productivity of the predominantly labor-input-driven agricultural production process.

EFFECTS OF DEFORESTATION

According to the study's hypothesis, deforestation reduces agricultural output from existing cultivated land by increasing time spent in collecting essential forest products such as fuelwood and fodder, which shifts time away from agriculture. As a result, household income from agriculture is reduced. Because livestock production is an important part of household enterprise in these areas, the destruction of forests also influences this sector. A reduction in the availability of leaf and grass fodder from forests increases the pressure for grazing, increasing soil erosion on fragile land not under cultivation. Both the decrease in agricultural income and the increasing demand for household labor for these activities could have a negative effect on child nutrition and schooling, which would ultimately influence the region's prospects for raising the productivity of labor.

RESULTS OF THE STUDY

A year-long household survey was carried out in three hill districts in a region 200 miles northwest of Kathmandu. It was conducted jointly with the Agricultural Projects Services Centre of Nepal and the Food and Agriculture Organization of the United Nations. Results indicate that in the areas of high deforestation the time required for the collection of forest products increased by 45 percent. The effects of this drain on the amount of labor available for agriculture indicate that women's farm labor decreased by 1.4 hours per person per day, or by nearly 50 percent. Women were responsible for about 80 percent of time spent in collection activities. This decrease was not compensated for by an increase in wage labor or men's labor, which may also decrease.

Analysis of production functions for major crops indicate that the marginal product for women's labor is highest for dry season crops—wheat, maize, and mustard. This may be due to competition for their time with collection of fuel, which is more intensively collected during the dry season. In general the study concludes that the reduction in time spent on agriculture would have a significant adverse effect on crop output. An increase in time spent on fuel collection also reduced the time spent on cooking and the amount of fuelwood consumed. These effects together with the reduction in agricultural incomes were found to have a negative effect on child nutrition.

POLICY IMPLICATIONS

The results suggest that it is not enough to rely on outmigration or reforestation efforts alone to improve the economy and ecology of this region. (One out of two households already has a permanent migrant worker and an equal number have seasonal migrants.) Strategies for raising agricultural productivity also need to be considered. At present, agriculture in this area is largely subsistence oriented and the degree of market development is limited. In the short run, it might be most cost-effective to increase the productivity of traditional crops through the use of improved technologies that already exist and can be promoted. This would facilitate a shift away from subsistence production and promote the growth of rural market infrastructure. If the benefits of the increase in labor productivity are distributed equitably, the pressure to farm marginal lands could be stemmed. However, given the labor constraints and heavy work loads of women, labor-saving nonfarm activities involving food processing, fuel, and water supply also need to be incorporated. In the long run, horticultural products, which are agroecologically suited to this area, offer a viable option that is consistent with the objectives of raising incomes and of protecting the environment.

SUSTAINABILITY ISSUES IN SAHELIAN AGRICULTURAL DEVELOPMENT AND RESEARCH

THOMAS REARDON

There is an alarming opposition between increasing environmental degradation in the Sahel[1] and the pressing need to increase food production and reverse stagnation in agriculture. This brief discusses three important issues that face agricultural researchers and policymakers in promoting sustainability in the Sahel: 1) appropriate production systems; 2) incentives for farmers to invest in sustainability; and 3) the effects of policy on these incentives.

Issue 1: What production systems should researchers be proposing to farmers? Where and when should high-input versus low-input systems be promoted? What are the environmental consequences? How do the answers differ between high- and low-potential areas?

There is concern that the introduction of high-input systems may further degrade the environment in the Sahel. Low-input systems are traditionally lauded for being "kinder" to the environment—low tillage, for example, maintains soil integrity. This controversy focuses on the static, direct effects on the environment. Recently, however, proponents of systems to intensify production have stressed that land use is inefficient and performance is poor with low-input systems. The poverty that arises therefrom, combined with increasing food needs (due to rising population), leads farmers to crop marginal lands of lower quality, which is easily degraded.

In the Sahel, higher-input systems perform better than low-input traditional systems mainly in high-potential zones in the Guinean belt. In these zones, intensification of production would reduce pressure to crop marginal lands. Higher incomes would produce growth linkages and provide more cash for investments in soil conservation. In the low-potential areas to the North of the belt, by contrast, fertilizer, new varieties, and deep tillage have not produced more promising results than traditional methods due to a variety of soil and moisture problems. Clearly, intensification is not automatically desirable or sustainable.

Low-input, high-productivity systems are often touted as a panacea, and they are especially attractive in West Africa because of the difficulties experienced in accomplishing a "green revolution" in that region. Modified traditional systems (which include techniques such as green manuring and bunding) promise output increases with a low level of reliance on imported inputs and infrastructure (although extension costs can be substantial). Given foreign exchange constraints and underdeveloped infrastructure, this is quite an advantage. But research on development of "nontraditional" (high-input) systems is still in an early stage. Great hopes reside in their potential, but it is important to note that the extension and support costs (for delivery, storage, and so forth) of these techniques could be prohibitively expensive in countries, such as those in the Sahel, with scarce fiscal resources, small extension services, and poor roads and other facilities.

It is very important to distinguish between types of zones in recommending production systems and designing sustainability measures. Low-potential zones are areas of high degradation combined with high population density (for example, the Mossi Plateau in Burkina Faso). Sociopolitical factors and diseases and pests in higher-potential zones constrain permanent migration out of the low-potential zones. Erosion, porosity, and low organic content typify their soils.

There are also areas where current performance is low, but relatively the potential for increases in productivity and intensification is high. These areas are mainly south of the Sudanian savannah areas, in the Guinean savannah belt (for example, the southwest of Burkina). Population densities are often lower than those in the low-potential zones.

In the two different types of regions, there will be different environmental problems and challenges, as well as different agricultural strategies. This translates to different research approaches. In the low-potential zones, low-input or modified traditional systems appear to be the most sustainable and affordable.

In the higher-potential zones, such as those in the Guinean savannah belt, intensification appears possible and desirable, provided "sustainability" measures (mainly soil conservation investments such as incorporation of organic matter in soil and bunding and terraching to prevent erosion) are given high priority. These will also augment productivity. Until the necessary infrastructure is in place for intensification, modified traditional systems are a useful intermediate step.

Issue 2: Will farmers want to invest in the productivity and sustainability innovations proposed to them by agricultural researchers? How should these innovations be designed to maximize the probability of adoption?

The innovations that are necessary either to sustain high-input systems in the Guinean savannah belt or to sustain modified traditional systems in the Sahelian and Sudanian savannah zones require investments by rural households. The main investments would be in "water-harvesting" structures; these might include bunds of laterite, dirt, or veteba grass, bushrows, terraces, tied ridges, and so on. These require substantial expenditures of cash and labor at the household and village levels.

[1] The "Sahel" is the political-geographic area composed of the CILSS member countries. Within this area, there are agroecological zones distinguished mainly by the rainfall isohyet in which they are located: sahelian (most northerly agricultural zone), sudano-guinean, and guinean savannah.

Expenditures on fertilizer and traction animals and equipment compete for the same pool of cash and labor as do investments in bunding. Researchers and governments want farmers to invest in both kinds of inputs without necessarily taking into account that the household usually does not have enough resources to pay for both, nor a reliable credit market to loan it the money to do so.

Moreover, in a degrading and unstable environment such as the Sahel's, perhaps the household's first priority should be to diversify away from farming. Households may want to maximize present earnings in cropping and invest the surplus in livestock and off-farm enterprises. Instead of reinvesting off-farm earnings in cropping or water-harvesting structures, households may use them to diversify further.

These possibilities are often neglected by crop researchers, governments, and environmentalists, who assume that the rural household in a region at environmental risk is first and foremost a farming household. This implies that innovations that can improve the farm resource base are automatically attractive to households.

It is precisely in areas at the greatest risk that this assumption is least tenable. For example, recent work by Reardon and Delgado (IFPRI) and Matlon (WARDA, formerly of ICRISAT) shows that cropping constitutes from a quarter to a half of income in rural Burkinabé households from the Guinean and the Sahelian zones. Overall income—from cropping and noncropping sectors combined—is a much more important determinant of household food security than is cropping income alone. A substantial portion of these households' food comes from purchases. This runs counter to the conventional image of Sahelian households as autarkic, subsistence farmers. Households diversify income because of extreme fluctuations in returns to cropping (due to output and price fluctuations from erratic rainfall and thin markets). Households are sensitive to the net payoff and when they receive it of investments in the various sectors, including cropping, livestock, and off-farm activities. In this context, investments in water harvesting and soil conservation structures compete with investments in activities that may have higher short-run payoffs, more stable long-term payoffs, and the potential to serve as repositories of savings and hence insurance (such as livestock).

Hence, researchers need to take into account the opportunity costs across sectors and the capital constraints facing rural households when they design sustainability investments. They have to be relatively cheap and emphasize short-run payoffs.

Issue 2: What are the effects of policy on the patterns of farmers' investments in sustainability?

Sustainability proponents often put special emphasis on direct investments in resource conservation by Sahelian governments, due to the problems of externalities, capital constraints, and short planning horizons at the household and village level. The investment of scarce fiscal and foreign exchange resources involves difficult choices.

Governments can influence household investment patterns and incentives through policies that affect 1) net returns and transaction costs (directly via price policy and indirectly via food aid and infrastructure); 2) the stability of the investment climate (even at the rural level) and hence the farmer's planning horizon; and 3) financing of research and hence the stock of appropriate and available innovations from which farmers can choose.

It is important to guard against simply assuming that higher crop prices will lead automatically to either farmers' investment in sustainability or higher rural welfare in degraded zones. Higher prices have occurred without an investment boom taking place. Disincentives to investments in the cropping sector include both the extreme variability of prices and capital market constraints. During the last decade, food prices relative to cash crop prices have trended upward. In individual years crop prices have been extremely high. There have been official farmgate price increases in a number of countries. Despite all this, the riskiness of investment in cropping productivity and sustainability has not changed much because of tremendous interannual swings in prices as the result of fluctuating output. Sahelian governments do not have the fiscal capability to smoothe out these fluctuations through market interventions. Moreover, even when producer prices are high for millet and sorghum from degraded zones, merchants and even governments make available cheap maize and sorghum from zones relatively unaffected by drought, according to research by Reardon, Delgado, and Matlon. Hence, the degraded zones are not closed economies in which incentives can be controlled and enforced.

The ways that policies actually influence markets, intersectoral opportunity costs, and hence the environmental choices of rural Sahelian households are complex. Exchange rates, marketing regulations, and interest rates all play a role.

Overvaluation of the CFA franc reduces the attractiveness of Sahelian cattle exports to the coastal countries, relative to cheap imports of meat from the European Community or Argentina. Given that livestock husbandry is probably one area where the low-potential zones of the Sahel have comparative advantage, these policies may promote distortions in the local economy and act as disincentives to developing appropriate crop-livestock linkages. Bottlenecks and controls resulting from marketing regulations may create thinner markets and greater price fluctuations, which render investment in agriculture less appealing. And high real interest rates due to underdeveloped capital markets may encourage households to shorten their investment planning horizons and will probably discourage sustainability investments.

National and international research organizations need to do both technical and policy research on how governments can most effectively—and cheaply—encourage sustainability investments at household and village levels. Research should help determine where governments should provide indirect supporting investments (for infrastructure) and what they should be. Research emphasis also needs to be placed on tracing the effects of sectoral and macro policies, such as exchange rates, food prices, and price and availability of credit, on investment incentives both in cropping in general and in water-harvesting structures in particular.

SOME ENVIRONMENTAL AND HEALTH ASPECTS OF AGRICULTURAL SETTLEMENT IN THE WESTERN AMAZON BASIN

STEPHEN A. VOSTI AND WILLIAM M. LOKER

Now more than ever, the Amazon Basin is the focus of concern of environmentally conscious groups worldwide. This is particularly true of the western Amazon, where a series of colonization projects, gold discoveries, random settlements, and mammoth infrastructural development schemes have promoted sometimes uncharted (and perhaps uncontrollable) economic growth and devastation in one of the world's most fragile natural resource bases.

At the same time, socially conscious groups are focusing on the Amazon Basin because tropical disease and malnutrition are taking heavy tolls on resident populations, and the lack of primary education and other social services are frustrating colonists' dreams of a better life.

Attempts to meet household food needs increase the pressure on the natural resource base. Here, in the area of nutrition and food production, the concerns of the environmentally and socially conscious converge. On the one hand, the environmentally conscious worry about the vast deforestation of the western Amazon, partially caused by food production by small farmers. On the other, the socially conscious realize that, due to poor soils and limited, seasonally variable links to markets, small-scale production of annual food crops and livestock on recently deforested lands may be the only way to ensure adequate household nutrition. As long as insufficient infrastructure and the incomplete meshing of appropriate technologies and agricultural policies characterize the region, degradation will persist, and good nutrition and health will elude its inhabitants.

LINKS BETWEEN AGRICULTURAL PRODUCTION AND THE ENVIRONMENT

Land-use decisions in this ecologically fragile region reflect farmer management of production factors (land, labor, capital, and technology) in response to information on agroecological conditions, market opportunities, and household demands.

Arriving migrants face severe capital and labor constraints, a lack of technical assistance, and a general ignorance of the potential of the abundant (though poor-quality) land at their disposal. Households often arrive with stores of food and drink to survive for approximately six months, and therefore they must clear as much land as possible during the first preburn season. (Clearing land for food production was a key component in the deforestation of more than 11 percent of the total area of the Brazilian state of Rondonia in 1985, for example.) Once trees are felled and foliage dries, the forest is burned—logically—since the residual ash is the only fertility-increasing additive the Amazon soils are likely to receive. The first phase of ecological degradation is then complete; the forest is gone.

The second phase of degradation begins with land-use decisions. Initial cropping decisions are shaped by food consumption habits and food insecurity, that is, the absence of functioning regional markets that are continuously linked in all seasons. Annual crops of rice, beans, and corn are sown on most of the cleared land during the first two crop cycles, with a substantial portion of the remainder dedicated to manioc (cassava). Because it will grow in even the poorest soils, cassava is a "last resort" crop with an important social function, but, unfortunately, it is low in nutritive value.

Soil fertility declines rapidly in response to annual cropping, prompting major changes in land use, such as extensive planting of perennial tree crops or cattle production; choices depend overwhelmingly on markets for inputs and outputs and the amount of virgin forest land remaining on farmers' plots.

One common response is to convert land depleted by annual crops to pasture for raising cattle, while continuing to slash and burn new land (as available) for annual crops. Cattle raising has been widely criticized as ecologically damaging and even uneconomical. (Recent evidence from the Eastern Amazon suggests, however, that large-scale cattle ranching can be very profitable.) Though subsidy-driven cattle ranching by large landowners has received the most attention, raising cattle is also part of the adaptive strategies of small-to-medium landholders. Although standard economic analyses may show that cattle are not profitable for the Amazonian colonist (due to low rates of weight gain), cattle fulfill multiple objectives: the animals represent an important store of wealth in a highly inflationary economy, are readily marketable, require relatively little labor, and may produce small quantities of milk or cheese for direct consumption or sale.

Cattle raising as presently practiced is, however, ecologically unsound in Amazonia. Pasture, while better adapted than many crops to harsh Amazonian conditions such as infertile soils, soil disease, and weed growth, usually deteriorates over time as the result of soil compaction caused by grazing animals and suppression of successional vegetation caused by farmers' efforts to combat weed growth. Reestablishment of forest cover in abandoned pastures takes longer than in slash-and-burn plots that have only been subjected to annual cropping, as observed in the Peruvian Amazon where bush fallows following pasture took twice as long to rehabilitate as fields abandoned after annual cropping. While cattle raising may provide an important source of security and income in the uncertain world of Amazon farming, it leads to land degradation, thus undermining the sustainability of the farming system.

THE IMPACT OF THE ENVIRONMENT ON SETTLERS' WELFARE

Relatively little attention is paid to the impact of the environment on settlers' welfare. Hundreds of thousands of people were drawn to these areas and are unlikely to return to their places of origin. Concern for their well-being must rank at least as high in priority as concern for the fragile lands they occupy.

Perhaps the most devastating blow dealt by the natural environment to inhabitants of the Amazon is in the area of human health. Malaria is endemic, and migrants unfamiliar with the identification and treatment of the disease suffer disproportionately. Malaria prevalence rates of up to 40 percent (4 out of every 10 randomly selected individuals are found to suffer from the disease at a given point in time) are not uncommon, especially during the initial stages of settlement in some colonization projects. Settlers at one particular colonization project (Machadinho, Rondonia, Brazil), for example, reported an *average* of two incidents of malaria per person a year.

Although the death rate associated with malaria is not alarming, the costs (both in economic and human welfare terms) are unacceptably high. Estimates from Machadinho suggest that out-of-pocket expenses associated with a single case of malaria average approximately 80 percent of total nonmalaria monthly expenses. This is a bleak scenario for migrants who, on average, bring only a six-month stock of supplies with them to the colonization projects and have few income-earning opportunities. Indeed, field research suggests that poor health can initiate a downward spiral of decapitalization as treatment costs outpace income and erode scant assets. This downward spiral may explain why a significant proportion of land is abandoned: poor, malaria-stricken households mortgage their possessions (including land) to pay for health care and depart when their remaining equity approaches the value of bus fare to (and "grub stake" for) the nearest town or next colonization project site.

In addition to malaria, malnutrition and diarrheal diseases also take heavy tolls. Although no reliable data are available on the nutritional status of migrants, it is generally acknowledged that rural inhabitants in these fragile ecosystems suffer severe food shortages, especially during the wet season when normal means of transport and market links are shut down due to the lack of all-weather infrastructure. Young children are particularly susceptible to these precarious health situations, with infant mortality rates running as high as 140 deaths per 1,000 live births—more than twice the national average for Brazil.

POTENTIAL FOR SUSTAINABLE AGRICULTURAL DEVELOPMENT IN THE HUMID TROPICS

In Brazil, most agricultural expansion in the Amazon Basin has been due to politically and economically unsustainable policy incentives provided by the federal government's efforts to settle the frontier. The present tendency is to fiscally wean hinterland areas from government support and allow market forces to dictate the direction and pace of future development, with several possible outcomes. At one extreme, in Brazil, the frontier area could develop its own comparative advantage and become completely linked with other domestic markets. At the other, high transportation costs associated with large distances and decaying physical infrastructure could dictate a situation close to autarky.

The Amazon Basin is a collection of microenvironments, with differing links to markets and subject to the laws and policies of different governments. Resources vary dramatically over relatively small geographic areas. It is an environment poorly understood both by the colonists who seek their fortune there and the governments that encourage its occupation. Colonists bring traditions shaped by distinct agroecological conditions (the Andean highlands or diverse areas in Brazil, for instance), which are often inappropriate to their new circumstances. High failure rates in many colonization schemes reflect this inexperience. All of this suggests that common solutions do not exist—either across regions or over time.

If a viable small-to-medium farm sector in the Amazon is the desired goal, the solution to the problem of agriculturally induced land degradation requires a two-pronged approach: technology is needed to reclaim improperly used and already degraded lands, *and* policies are needed to address the imbalances in resources and the economic uncertainties that drive land use decisions. Research needs to focus on the short-term goal of generating widely available intermediate technologies that reduce land degradation. Any technological solution must maximize returns to labor, minimize capital inputs, and focus on critical food security issues. It must address the farmer's need for diverse sources of income as a buffer against crop failure or price declines. In particular, since cattle raising is likely to remain an important component of agricultural production, research is needed to improve pasture quality and farm management practices, thus enhancing the sustainability of farming and the Amazonian ecosystem.

Most technological solutions offered have focused on perennial tree crops as a potential longer-term strategy due to their ability to provide constant soil cover (avoiding loss of soil nutrients). However, many suffer from severe marketing constraints, such as widely fluctuating prices (coffee and cacao), lack of established markets (achiote and native fruits such as *camu-camu* or *pejibaye*), or perishability (citrus and other fruits). In addition, the capital-short colonist can ill afford the considerable delay (up to three years for some perennial tree crops) between investment and income.

Given the time lags associated with generation and diffusion of agricultural technologies and the urgency of environmental problems in the region, policy may be the most effective short-term instrument for correcting damaging land-use practices. Zoning, tax policies, and selected use of subsidies to encourage less damaging forms of land use may do more to reduce environmental degradation and promote settler welfare than any agricultural technologies on the shelf or in the research pipeline.

In the long run, the critical links between food production, infrastructure, and human welfare in the Amazon Basin cannot be overemphasized. Inappropriate agricultural technologies are responsible for only part of the degradation and poverty in the area. Insufficient infrastructure leads to costly and seasonally nonexistent market links that promote overreliance on traditional small-scale agricultural self-sufficiency and highly detrimental land-use patterns. Large and concentrated investments in physical and social infrastructure are required to expand market options available to settlers and to accelerate the process of economic and geographic consolidation of disjointed foci of economic activity to break the cycle of environmental degradation caused by small-scale, low-input agriculture.