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A downward spiral? Research evidence on the relationship between poverty and natural resource degradation

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Abstract

Many observers have conceptualised the link between rural poverty and environment as a 'downward spiral' with population growth and economic marginalisation leading to environmental degradation. Recent micro-scale empirical research challenges this model, showing striking heterogeneity in environmental management by the rural poor, their success in adapting to environmental change and the efficacy of policies in influencing outcomes. Local endowments, conditions affecting the adoption of resource-conserving technologies and local institutions supportive of the poor are key factors that condition poverty–environment interactions and outcomes in relation to agriculture. The main strategies to jointly address poverty and environmental improvement are to increase poor people's access to natural resources, enhance the productivity of poor people's natural resource assets and involve local people in resolving public natural resource management concerns. Research is needed to support these strategies, particularly to explore poverty–environment–agriculture interactions, develop technologies for poor farmers and partner with local communities for action research on policies and programmes.

Keywords: Agricultural policy; Downward spiral; Environmental degradation; Land degradation; Rural poverty; Smallholder agriculture

Introduction

Agriculture accounts for most land use in developing countries and thus is probably the single most powerful influence on environmental quality. At the same time,

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agriculture remains the principal livelihood of the rural poor (Malik, 1999). Yet patterns of rural population growth, agricultural expansion and intensification and income growth projected for the next few decades pose serious challenges to achieving both environmental improvements and rural poverty reduction (Pinstrup-Andersen et al., 1997). Indeed, many policymakers assume that a 'downward spiral' of rural poverty and environmental degradation constrains development options and necessarily forces unpalatable policy trade-offs. This paper examines this assumption in light of new evidence and draws policy and research implications.

Poverty–agriculture–environment: a 'downward spiral'?

The nexus of poverty, agricultural production and environment poses controversial policy and research challenges. Our 'mental models' of the relationships between these points of what Vosti and Reardon (1997) call the "critical triangle of development objectives" powerfully shape policy and research design.

Environmental issues related to agriculture and the poor

Environmental concerns associated with agriculture relate mainly to the sustainability of the resource base for agricultural production (e.g. soil quality), protection of biodiversity and habitats, and environmental services of resources influenced by agricultural land use (e.g. carbon sequestration). Degradation of soil and vegetative resources already threatens agricultural productivity, biodiversity, and water quality and availability in many 'hot spots' in the developing world (Scherr and Yadav, 1996). Soils in about 16% of agricultural land area in developing countries, and a higher proportion of crop and dry lands, have degraded moderately or severely since mid-century, mainly through soil erosion, nutrient depletion and salinisation (Scherr, 1999a). At least 28 countries, with a total population exceeding 300 million people, face water stress today, and demand is growing rapidly even as water contamination caused by agriculture and rural domestic uses increases (Pinstrup-Andersen et al., 1997). Declines in agrobiodiversity increase disease and pest problems. Agricultural expansion, intensification and devegetation are the leading causes of species loss and depletion of natural vegetation.

Wealthier farmers, developers and multinational corporations typically control greater total land area and play a prominent role in many types of environmental degradation. However, the poor play a significant role in unsustainable agricultural intensification, expansion of farming into marginal lands and vegetative overexploitation and the consequences for their livelihood can be more serious because they lack assets to cushion the effects.

Agriculture–environment–poverty interactions

Since the late 1980s, it has been widely accepted that the interaction of agricultural development with the environment must be explicitly considered, both to ensure the

long-term sustainability of production systems and to mitigate negative effects on locally and globally important ecological goods and services. This new approach has been dubbed the 'doubly-Green Revolution' (Conway, 1997).

That agricultural growth (especially growth and stabilisation of food staples production) can be a powerful strategy to benefit poor people is also widely agreed (Malik, 1999). In most regions, the rural poor depend more for their livelihoods on agricultural production and employment, and on common lands, than do the rural non-poor. The former's prosperity depends substantially on the forward and backward production linkages—and even more on consumption linkages—from farmers (Reardon and Vosti, 1992). Poverty is recognised as a significant constraint on agricultural growth because of poor people's need to concentrate resources on lower-value food crops to ensure subsistence security and their difficulties in mobilising production and investment resources.

The more controversial side of the critical triangle has been poverty–environment interactions. Much of the early literature on this relationship posited a 'downward spiral' of poverty and environmental degradation. In this model, poor people place increasing pressure on the natural resource base—resulting from population growth, limited access to land or access only to poor quality or fragile lands, or limited resources for investment and sustainable resource management. The resulting environmental degradation leads in turn to declining consumption, human health and food security (Cleaver and Schreiber, 1994; Forsyth et al., 1998). Policy responses suggested by this model emphasise control of population growth, resettlement, controls on resource access and use by the poor, environmental education, subsidies for conservation investment by the poor, and non-farm income growth.

However, recent micro-scale and longitudinal research challenges this model. Studies have found a wide range of environmental outcomes under management by the poor and of welfare outcomes following environmental degradation. Researchers have documented a 'downward spiral' in some rural areas (e.g., Mink, 1993; Grepperud, 1996). But elsewhere they have found, variously, that degradation resulted from natural forces rather than human mismanagement; indigenous technology developed to control degradation; local communities implemented land use controls to stabilise vegetative cover; or farmers diversified activities to reduce degradation while maintaining incomes (Forsyth et al., 1998). A review of over 70 empirical studies in poor hill and mountain regions concluded that the effects of population growth on land and forest quality were indeterminate (Templeton and Scherr, 1999). As the cost of land relative to labour increased, people often changed their methods of managing plants and animals and made land improvements to offset initial declines in productivity resulting from more intensive land use.

Rural livelihoods and adaptive strategies of the poor

A result of this new evidence of variability in poverty–environment interactions has been an emerging focus on 'sustainable rural livelihoods'. Sustainable livelihoods are defined as: "The capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can

cope with and recover from stresses and shocks, maintain or enhance its capabilities and assets, while not undermining the resource base" (Chambers and Conway, 1992; Scoones, 1998). This approach considers both 'welfare poverty' and 'ecological poverty'—the capacity of natural resources accessible to the poor to produce streams of products and environmental services essential for livelihood (Coward et al., 1999).

Studies of livelihood strategies have revealed that although the rural poor may have limited resources, they still have considerable capacity to adapt to environmental degradation, either by mitigating its effects on their livelihoods or by rehabilitating degraded resources. A wide variety of coping mechanisms may be used to deal with environmental stress. Some of these responses imply further impoverishment (e.g. reducing consumption, depleting household, or moving). Others may offset the welfare effects of resource degradation without improving the natural resource base (e.g. increasing off-farm employment, exploiting common property resources). Some strategies *both* improve natural resources *and* reduce household poverty by protecting and preserving the asset base, diversifying and improving on-farm production systems, or taking out credit to invest in future production or resource protection (Davies, 1996; Scherr, 1999b).

Over time, local people develop technical and institutional innovations in natural resource management (NRM) to reduce risks and adapt to or reverse degradation, even as pressures increase. A large case study literature documents innovations in many farming systems and ecozones (e.g. Tiffen et al., 1994; Reij et al., 1996; Forsyth et al., 1998; IBSRAM, 1998). These findings suggest a phenomenon of local innovation in NRM comparable to that of welfare-enhancing agricultural intensification and innovation (Boserup, 1965; Binswanger et al., 1989; North, 1990; Ruttan and Hayami, 1991). As population or market pressures increase, farmers first experience degradation and its welfare effects, but not sufficiently to trigger a response. As effects become more pronounced farmers will seek innovations to stabilise or improve the resource base, or to compensate for their welfare effects by depending less on the degrading resource. Such a positive adaptive response is not assured; resources may eventually be destroyed or a delayed response may permanently reduce resource conditions; consumption may decline (Fig. 1). The central questions in exploring poverty–agriculture–environment interactions therefore become: What factors determine when farmers will respond to environmental pressures in ways that improve livelihood security and natural resource quality? How can policies encourage those positive responses?

Conceptual framework

The conceptual framework (Fig. 2) considers these questions within the broader dynamic of rural change. Pressures from population growth, markets, new technology or other external factors induce change in local markets, prices and institutions within individual communities. The local impacts of these shifts are conditioned by community characteristics, such as their human and natural resource endowments, infrastructure, asset distribution, market linkages and local knowledge base and culture. Resulting community-level changes may induce responses in agriculture and NRM

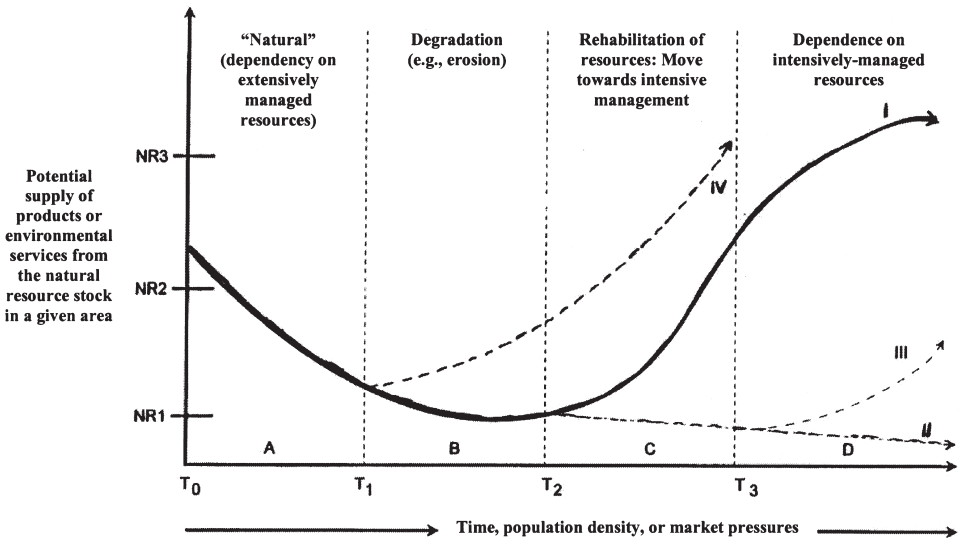

Fig. 1. Innovation in soil resource management under population or market pressure (from Scherr et al., 1996).

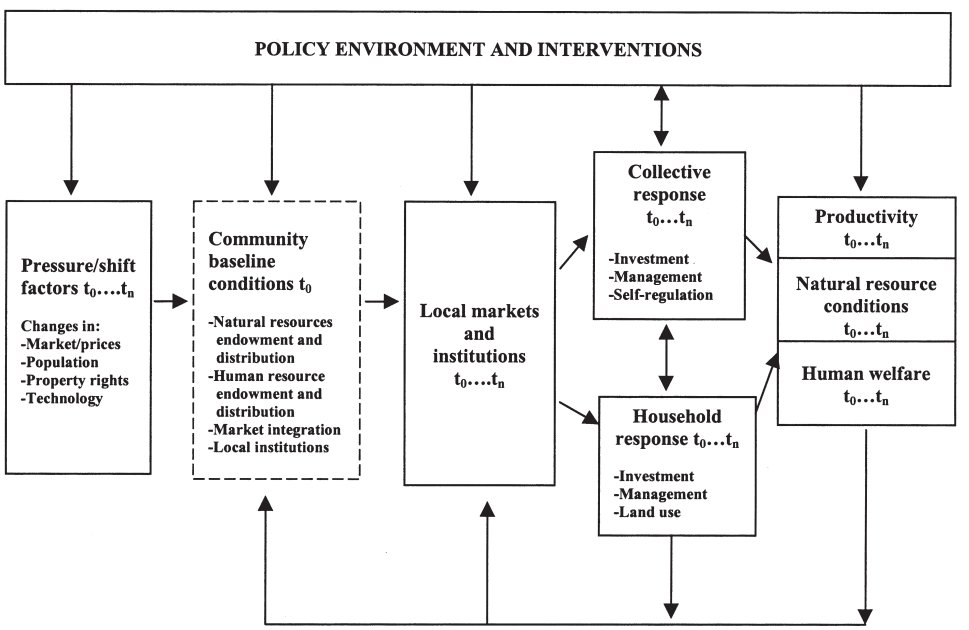

Fig. 2. Conceptual framework (from Scherr et al., 1996).

strategies at both household and collective levels (e.g. changes in land use, land investment, use intensity, input mix, conservation practices and collective action). These responses are similarly conditioned by community characteristics and may thus be path-dependent. Subsequent changes in NRM then affect environmental conditions, agricultural production and human welfare. These in turn have feedback effects on local conditions, institutions and NRM decisions.

Public policies and investments can influence poverty–agriculture–environment dynamics at various points of the framework. For example, public agricultural research investments and food price policies affect shift factors, while technical assistance influences response patterns. The most effective action for reducing poverty and environmental degradation will depend on the dynamics of the local change process and the relative importance of key factors influencing poverty–environment interactions.

Key factors explaining poverty–environment linkages

Within this conceptual framework, empirical evidence suggests that variations in observed poverty and environmental outcomes are influenced most strongly by the points that follow as secondary headings.

Local endowments

Processes and impacts of natural resource change in agricultural environments and their relationship with population growth and conservation management are fundamentally influenced by biophysical conditions. Key factors are soil characteristics (affecting crop choice, cropping frequency and input use), rainfall and ground and surface water resources (affecting crop product choice, risks of soil degradation and land use intensity), and topography (affecting the spatial distribution of production systems). Further landscape differences and resource management challenges arise from variations in settlement history, past history of degradation, crop mix, perennial and livestock components and the mix of commercial and subsistence enterprises (Turner et al., 1993).

In the twentieth century, the developing world experienced five broad pathways of agricultural land use change, varying by type of resource endowment and degree of population pressure (Table 1). Agricultural landscapes in the five pathways shown are distinct and patterns and risks of resource degradation differ (Scherr, 1999a).

We must recognise, however, that underlying resource quality shapes but does not determine the sustainability of agricultural systems. Differences in the design and timing of technical and institutional innovations for resource management cause major differences in resulting resource quality and associated flows of goods and services to poor resource users in similar physical environments. For example, Templeton and Scherr (1999) found that in the tropical hillsides the general relationship between environmental quality and population density (i.e. land:labour ratios) resembled an inverted ‘U’. As populations grew from low densities, agriculture inten-

Table 1
Pathways of agricultural change and environmental impacts[a]

Land type	Arable land (%)	Population (%)	Changes in recent decades[b]	Common problems of land degradation
Irrigated	7.5	35 of rural	60% increase in irrigated area 1961–90; increased multi-cropping; HYVs, high agro-chemical use	Salinization and waterlogging Nutrients imbalance Biological degradation (chemical) Nutrient pollution in groundwater Water-borne diseases Water conflicts
High quality rainfed	23		Transition from short fallow to continuous cropping, HYVs mechanization, high agro-chemical use	Nutrient depletion Physical degradation Acidification De-vegetation, loss of perennials Biological degrad. (chemicals) Pesticide pollution Deforestation of commons
Densely-populated marginal	69	65 of rural	Transition from long to short fallows/continuous cropping; use new landscape niches, low input use	Soil erosion Soil fertility depletion De-vegetation, biodiversity loss Soil compaction Acidification Watershed degradation

(continued on next page)

sified and degradation increased because few incentives existed for resource-conserving investment. Once permanent cultivation became dominant, further intensification was associated (and often only possible) with new household and community improvements in tree, water and soil resources.

Farmers are usually aware when degradation processes threaten resources critical to their own livelihoods. Where they show no concern, it is often because they do not yet consider degradation to be a serious threat (they are still on the left side of the curve in Fig. 1) or the resources under threat are marginal to their overall livelihood strategy.

Farmer awareness is an important constraint to positive adaptation in only a few

Table 1 (*continued*)

Land type	Arable land (%)	Population (%)	Changes in recent decades[b]	Common problems of land degradation
Extensively managed marginal			Immigration and land-clearing for low input agriculture	Soil erosion from land-clearing Soil erosion from cropping Soil nutrient depletion Weed infestation Biological degrad. (topsoil loss) Deforestation, loss of biodiversity Watershed degradation
Urban and peri-urban land	No data	33–80 of urban households	Rapid urbanization; expansion and diversification of urban food markets; urban poverty, unemployment	Soil erosion from poor practices Soil contamination Over-grazing and compaction Air and water pollution Human disease vectors

[a] Source: Scherr (1999a).
[b] HYV=high yielding varieties.

situations. Degradation effects or their causal factors may not be observable to farmers without modern technology (e.g. soil acidification, micronutrient depletion or spread of disease vectors). Recent immigrants farming in unfamiliar agro-environmental conditions or with unfamiliar farming systems may not have adequate local knowledge to recognise resource problems. Finally, if the resource being degraded is a concern to outsiders but not to local people (e.g. natural habitat loss or downstream sedimentation), adaptive response will not be triggered without external intervention.

Use of resource-conserving technology

Researchers have demonstrated that poor farmers adopt resource-conserving practices nearly always because these *also* contribute to increased productivity or output stability and are economically viable in the farmers' context of risk and resource constraints (Arnold and Dewees, 1995; Saín and Barreto, 1996; Enters, 1998; Scherr, 1995). Such dual-purpose technologies are essential to achieve poverty reduction and environmental policy objectives.

Respect for this principle has begun to transform resource conservation programmes oriented to the poor. Vegetative barriers or contour strips using local

materials valued for home consumption or cash sale now substitute for expensive terraces or economically useless vegetative strips. Locally available organic inputs are being promoted to complement or substitute for expensive purchased fertiliser. Conservation interventions stress good soil cover and crop husbandry associated with yield increases as much as landforms. And short-cycle trees rather than timber plantations are promoted on small farms (IFAD, 1992; Current et al., 1995; Pretty, 1997). Scientists and extensionists have taken a new look at indigenous technologies for resource husbandry and discovered many to be suitable for wide dissemination or as the basis for improvements (Reij et al., 1996; IBSRAM, 1998). Scientific institutions are supporting farmer-led adaptive research organisations to provide locally adapted technology in heterogeneous environments and to promote sustainable processes of local innovation.

Reardon and Vosti's (1995) concept of 'conservation investment poverty' highlights poor people's limited capacity to mobilise critical cash, labour, machinery or other resources, even for highly profitable and effective investments. This is partly because of weak institutional development and poor functioning of factor markets in many poor rural areas (de Janvry et al., 1991). A study of 21 projects in Central America and the Caribbean, where land and credit markets were weak and labour markets segmented, found that household factor availability strongly influenced farmers' selection and management of agroforestry technologies (Current et al., 1995).

Poor farmers' and communities' capacity to undertake resource-improving investment and more careful land husbandry will thus often depend upon finding alternative mechanisms to mobilise the necessary resources outside regional factor markets. Given small farm size, the poor may be able to invest incrementally without access to financial credit or hired labour by using divisible technologies and multi-output systems that permit continuous self-financing, or by raising cash through off-farm employment. But collective action may also be a promising avenue, through local credit groups, or mobilisation of labour through sharecropping, or community or kin groups.

Even when farmers are clearly concerned about resource degradation, suitable technologies are available, and farmers are able to mobilise resources to invest in or improve environmental management, they are unlikely to do so unless likely economic returns are attractive. A variety of public policies and investments influence that calculus.

Agricultural input and output prices, taxes, wages and interest rates facing poor farm households and communities influence their income and investment strategies because the poor evaluate returns to sustainable land and water management relative to the returns they might anticipate from other livelihood options. Farmers' strategies will also reflect the extent to which price and non-price incentives internalise the negative and positive externalities of NRM practices and outcomes (Anderson and Thampapillai, 1990).

Because of this sensitivity to relative prices and infrastructure availability, conservation investments by the poor are sensitive to macro-economic conditions and price-related policies. However, these policy impacts are not determinate; regional or local markets and institutions may mediate the local micro-economic incentives actually

facing the farmer (Templeton and Scherr, 1999). For example, generally high agricultural wage levels and non-farm employment opportunities may reduce incentives for conservation investment for farmers in some regions, while providing farmers in another region with a means to mobilise external resources for on-farm conservation investment.

By determining the distribution of physical and social infrastructure between rural and urban sectors, large- and small-scale farmers and agro-ecological regions, public investments will also influence the comparative advantage of poor farmers in agricultural production and their access to social services.

Many natural resources (e.g. land, water and trees) involve diverse property rights that different people may hold, including the right to access, withdraw, manage, exclude others from the resource and to transmit or alienate rights. These rules represent individuals' capacity to call upon the collective to stand behind his or her claim to a benefit stream (Bromley, 1991). The bundle of property rights held by poor people represents key household and community assets that may provide income opportunities, assure access to essential household subsistence needs (water, food, fuel, medicines) and/or insure against livelihood risk. Marginal resource users (e.g. women and the poor) tend to rely more heavily on customary or informal rights. Thus they often lose out because of policies and processes that privatise and reduce complex bundles of rights into a single unitary right (Baland and Platteau, 1996; Otsuka and Quisumbing, 1998).

Property rights affect long-term agricultural productivity and incentives for conservation, and investment in resource improvement. For example, more equitable access to natural resources by women has been found to both improve their welfare outcomes and to raise agricultural productivity, economic returns to agroforestry and use efficiency of water in irrigation projects (Meinzen-Dick et al., 1997). Tenure security, although not necessarily formal titling, is associated with cropland conservation practices and improvements (Templeton and Scherr, 1999). Common property regimes may be more or less effective in resource protection, depending on norms and rules agreed upon and the ability of local people to protect their rights against outsiders (Schlager and Ostrom, 1992).

Institutions supporting the interests of the poor

Local institutions provide the social fabric within which poverty–agriculture–environment interactions are determined. Effective resource management, whether for private, communal or public resources, often requires collective regulation (e.g. use or management restrictions on privately-held resources to influence environmental externalities) or collective investment (e.g. establishment of community drainage systems or trees for public use). Good local organisational and management skills often underpin successful resource management activities (White and Runge, 1994; Veit et al., 1995). Cultural, demographic, market and leadership factors and characteristics of the resource base and local government affect the emergence and success of local organisation for NRM (Rasmusson and Meinzen-Dick, 1994; Pender and

Scherr, 1999). A key indicator of equity in NRM organisations is whether the poor, including women, take part and have an effective voice.

Local institutions also provide community physical and social (e.g. insurance) infrastructure that complements and supports the development of non-farm activities, the commercialisation of agriculture and urban–rural links (Vosti and Reardon, 1997). Support services to the poor for agricultural production and resource management (e.g. technical assistance, credit, marketing information or assistance and resource quality monitoring) influence their capacity to respond positively to NRM challenges.

The political disempowerment of the poor is reflected throughout rural development processes. Given this reality, efforts to combat poverty within the agriculture–environment nexus have tended to treat poor farmers mainly as passive beneficiaries of benevolent policies formulated and delivered by others. Yet the degree to which poor farmers are perceived and legitimated as an active political constituency appears a critical factor in achieving adoption and effective implementation of policies favourable to the rural poor.

'Participatory planning', 'farmer-first', 'from the ground up' and related agricultural development strategies that have arisen in the past two decades reflect the influence of broader movements to promote more democratic decision-making in developing countries with active involvement by the poor (Veit et al., 1995). These strategies are linked to the expansion of civil society, the proliferation of non-governmental development organisations, the devolution of government control over natural resources and the mobilisation of local leadership for change.

These new approaches contrast with both a policy environment that simply excludes the poor and one that depends upon 'technocratic' decision-making on their behalf but fully controlled by others. In the evolving democratic model, poor farmers not only are 'beneficiaries' of policies but also have 'seats at the table' where agricultural and environmental policies and programmes are designed and 'rules of the game' established.

Policies to jointly address poverty and environment objectives

Local endowments, conditions for adoption of conservation technology and local institutions thus appear key to generating increased livelihood security for poor farmers while also improving environmental conditions. By 'diagnosing' the principal constraints related to these factors, within the context of underlying change processes (Fig. 2), public policies and investments can feasibly be designed, at various scales, that jointly reduce poverty and improve natural resources. Three basic strategies seem promising:

1. To increase poor people's access to natural resources essential to their livelihoods.
2. To work with the poor to increase the productivity of their natural resources so they can take advantage of existing or emerging economic opportunities (by co-investing in on-farm natural resources of the poor, promoting agricultural techno-

logies with environmental benefits and promoting low-risk perennial production in poor and marginal areas).
3. To involve the poor in promoting good environmental management under conditions when economic incentives for doing so are not in place (by compensating the poor for conserving or managing resources important to others and by employing the poor to improve public natural resources).

Generally, the first will be driven more by an anti-poverty and social justice agenda, the second by food supply and economic development objectives and the last by natural resource protection concerns, although all three approaches contribute to the 'critical triangle'. All the specific approaches discussed below involve poor people centrally in the design and management, and in many cases leadership, of programme initiatives.

Facilitate access of the poor to natural resources

Access by the landless and rural poor to basic subsistence resources—farmed and gathered food, fodder, water, fuel, building materials, medicines, raw materials for tools and housewares—is essential for livelihood security (Chambers et al., 1989). Well-managed systems for such access should be considered an essential feature of national 'social safety nets' of the poor and for protection of environmental assets in heavily populated agricultural regions.

Innovations are needed to facilitate poor people's access to, and more sustainable use of, resources owned or controlled by or shared with others. Multi-user tenure arrangements may be a way to protect access rights for women and other marginal groups. Land rental reform may require longer-term rental contracts, explicit agreements about the distribution of benefits from resource improvements or the granting of formal tenure rights to individuals or groups currently squatting on hillside and other public lands. They can thus legitimately seek technical assistance, credit and other services and have incentives for conservation-oriented management.

Reform of water rights must ensure secure access by the poor and landless for both productive and consumptive uses, yet make provision for environmental uses of water. Formal arrangements are needed for access to critical resources by the increasing numbers of temporary migrants (e.g. from drought or disasters) and refugees, to limit over-exploitation and conflict. Groups of poor people can be involved in land use planning efforts to ensure that their existing use patterns and future needs can be met without increasing poverty or resource degradation. Finally, poor farmers need insurance systems—cash payments, in-kind provisions or public works employment—to provide subsistence needs after crop failures so natural resources are not over-exploited as emergency reserves.

Co-invest in on-farm natural resources of the poor

Numerous opportunities exist for governments, non-governmental organisations (NGOs) and the private sector to co-invest in the rehabilitation or improvement of

productive on-farm natural resources that are assets of the poor. Targeted access to financial credit, technical assistance and organisational support can help to relieve constraints related to farmer awareness, technology, farmer capacity to invest and local institutional capacity. Co-investment with local communities or farmer organisations may be used to mobilise longer-term investments, through group or micro-credit, labour mobilisation or provision of key inputs that existing markets provide inefficiently.

Well-organised local participation in project design and management is essential. Attention is needed in such projects to ensure participation by the poor, whose landholdings are limited in size and often scattered; transaction costs for local organisation may be high relative to area covered. Technical design must ensure clear short- to medium-term economic benefits for local people. Thus, financial subsidies beyond project management costs are neither necessary nor desirable, although subsidies may be used in the earliest phase of the project to generate interest and wide participation in unfamiliar technologies (Scherr and Current, 1999). Co-investment in improving productive resources of the poor appears most promising in situations where secure tenure and favourable market conditions exist. Initiatives need to be tailored to 'fit' the natural resource base and farming intensity.

Develop and promote agricultural technologies with environmental benefits

Agricultural research can play a crucial role in relieving constraints related to a lack of technologies suitable for poor farmers. Such technologies and resource management systems must raise overall productivity, both increasing household income (to reduce poverty) and protecting or improving the natural resource. Opportunities exist for raising the productive potential of farm components through genetic crop, feed and livestock improvement; lowering per unit output costs of variable inputs (nutrients, labour for field preparation and management); lowering costs of conservation investments; and finding new management systems that integrate agricultural and environmental objectives.

Using the joint criteria of numbers of poor agriculture-dependent people and scale of environmental risks would suggest that much higher priority for technology development and research be given to densely populated marginal lands in the tropics and to integrating environmental concerns more centrally into research on smallholder irrigation systems in Asia (Scherr, 1999a).

Promote low-risk perennial production in poor and marginal areas

A subset of new products and technologies seems especially promising for the rehabilitation and sustainable productive use of fragile resources by low-income farmers—perennial tree and shrub crops providing year-round vegetative cover without need of cultivation. These may produce a variety of income-earning products and/or products that substitute for less sustainable subsistence exploitation of natural vegetation and have flexible harvest demands (Leakey et al., 1996). Establishment and economic operation of plantings on smallholdings requires some technical assistance,

possibly targeted initial subsidies, and development of marketing channels. Subsistence food production must remain part of the system (possibly through agroforestry systems) to ensure household food security. This strategy is most likely to succeed where there are active, high-volume markets for tree products, fairly good market access, and farm size of at least a few hectares.

Compensate the poor for conserving or managing resources

In some situations, poor farmers and agricultural workers have few economic incentives to manage their natural resources more carefully but other groups have an abiding economic or environmental stake in the resource. In the past, the policy instruments most commonly applied in such cases were punitive restrictions or large-scale resettlement; yet these generally had little sustained success and raised serious social justice concerns.

Instead, mechanisms may possibly be negotiated for farmers to be compensated for the costs incurred in changing their management or use of resources, or for the social benefits their continued good husbandry provides. Pilot initiatives are underway in many parts of the world to protect downstream water resource quality or flow, sequester forest carbon for emission offsets, and protect biodiversity reserves.

This approach explicitly internalises the externality benefits of environmental protection. It can achieve both poverty and environmental goals by changing local valuation of resources, local capacity to make necessary investments and economic incentives, while confirming long-term tenure or access rights for the local people involved. Institutional challenges that must be addressed include fair negotiation of terms of trade, mechanisms for payment transfers, establishing of credible but low-cost monitoring and fair payment distribution (Aylward et al., 1998; Smith, 1998).

Employ the poor in projects to improve the public resources

Many landscape-scale environmental improvements are public goods whose benefits accrue only partially to poor local people or which involve public or shared landscape niches. Many of these are labour-intensive and offer an opportunity for public and private-sector organisations to provide paid employment to the poor (von Braun et al., 1992). Longer-term livelihood opportunities for the poor may be integrated into plans for environmental management (e.g. hiring guards for community and national parks and forests, establishing wildlife corridors in agricultural regions or monitoring local water quality). Such projects can enhance local appreciation of environmental resources and resource access by the very poor. Experience suggests success is more likely with supervision by well-established organisations, reliable funding arrangements and involvement of the people hired (who will use the resources over the long term) in landscape design.

Implications for research

This analysis of poverty–environment–agriculture interactions and interventions implies the need to expand investment in three types of research: empirical studies of the dynamics of change, technology development for poor farmers, and action research with local communities on policies and programmes that jointly address poverty and environment.

Exploring poverty–environment–agriculture interactions

The discussion above illustrates that although the heterogeneity of conditions precludes simplistic models of poverty–agriculture–environment interactions, observable and understandable patterns can indeed be identified. These are urgently needed to guide policy and programme design in particular types of physical and economic environments.

Although until recently most assessments have used aggregate, macro-scale data, key questions require micro-level analysis. Emphasis has been more on measuring poverty than on explaining why people are poor and the role played by environmental conditions or degradation (Malik, 1999, p. 14). Few longitudinal studies have linked poverty and resource quality in agricultural systems. Most such studies were reconstructed from oral history, archives, remote sensing or time series survey data originally collected for other purposes; few can relate poverty and agricultural production in a geographically explicit way.

International efforts are needed to collect intertemporal data integrating poverty, environment and agriculture factors at community and landscape scales. These would allow us to confirm and quantify key relationships and identify relevant policies under a range of agro-ecological and socio-economic conditions. For example, a comparative study of 48 communities of central Honduras, 1975–95, identified six 'development pathways' shaped by distinct natural resource endowments, demographic pressure and public investments. Trends in natural resource and welfare conditions differed, as did local response to national policies (Pender et al., 1999).

Developing technologies for poor farmers

An enormous challenge remains to develop technologies and resource management strategies that can transform agricultural landscapes in ways that enhance human and natural habitats and control environmental externalities while also supplying critical livelihood needs of the poor. Such research is needed for most farming systems but the need is particularly acute where agricultural production is intensifying on ecologically vulnerable lands. New production systems will be necessary whose sustainability requires investments to reduce vulnerability to degradation (e.g. building up organic matter, conservation investments). Innovations in soil nutrient management, livestock feeding strategies and other farm resource flows need to function both at plot and landscape levels.

Resource constraints of the poor, their small scale of production and their exposure

to high livelihood risks mean that the technologies they use must have particular characteristics. These include: potential for incremental adoption and adaptation, protection of food security, low risk of crop failure, rapid return on investments, minimal use of purchased inputs (especially for subsistence production, for farmers distant from road networks or where input markets function poorly), amenability to local adaptation, good performance under adverse climatic conditions and use of micro-niches to diversify production. Poor farmers require technologies that maximise returns to their scarcest resource. This is typically cash; meaning that total use of purchased inputs must be limited. Where off-farm employment is a significant component of livelihood and household labour is the scarcest input, labour-enhancing technology is needed (Scherr, 1999b).

For many 'problem' soils, vulnerable water sources and sensitive habitats, neither indigenous nor scientifically developed technologies are yet available that permit continuous production or use over extended periods of time. For example, comparative studies of erosion–agricultural productivity changes over time for different soil types and vegetative covers suggest that currently no low-cost technologies are available to maintain maize yields on certain deeply weathered and unresilient soils in Africa (e.g. Ferralsols)(Scherr, 1999a). Technologies need to be tailored for use on specific soil types and climates thus requiring a heavy investment in on-farm adaptive research.

Innovations in research strategy and institutions can make it economical to undertake such adaptive studies across many different agro-environments and farming systems. These involve more focused attention on diagnosing the nature of underlying resource management problems, early involvement of farmers in technology design and evaluation, use of farmer-focused criteria in economic evaluation and more participatory approaches. A highly effective strategy has been the integration of research and extension functions in pilot field programmes based on diagnosis–design–feedback–redesign with farmers. Another emerging approach is local farmer-led technology development with technical and scientific backstopping (Kumwenda et al., 1996; Franzel and Scherr, forthcoming).

Action research on pilot programmes and policies

As with technology development, many policies and programmes to promote sustainable landscape management while benefiting the poor are recent innovations. Designs are being worked out; their adaptation and applicability to various socio-economic and biophysical conditions are uncertain. Yet there has been serious under-investment in evaluating these innovative approaches, whether led by government agencies, NGOs or farmer organisations. Under data-poor conditions, and for programmes intended to make long-term changes in natural resource conditions, ex-ante analysis cannot reliably predict the outcomes for the poor, agricultural production and environmental quality, while ex-post assessment comes too late for practical input to policy action. Instead, pilot projects must be implemented at operational landscape scales and evaluated regularly to permit strategic redesign, define boundary conditions for their effective use and draw lessons for application elsewhere. Method-

ologies like ‘adaptive management’ (Batie, 1992), ‘action research’ and ‘adaptive collaborative management’ can involve researchers as long-term partners with rural communities in the study of innovations.

Conclusions

The environmental needs of, and pressures on, poor farming communities will certainly intensify in coming decades. Although the relationship between poverty and environment is highly variable, the ‘downward spiral’ is both avoidable and reversible in many circumstances. Poor people have an unrecognised potential for adaptation and innovation. Public policies can positively influence the micro-scale factors that determine how farmers adapt to environmental pressures. However, more pro-active policies are required to achieve environmental and anti-poverty objectives simultaneously, enhancing the access to and productivity of poor people’s natural resource assets and engaging them as partners in public resource management. Research efforts and methodologies to support such policies are now in a formative stage.

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