Poverty and natural resource management in the semi-arid tropics: revisiting challenges and conceptual issues

Bekele Shiferaw
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Bekele Shiferaw

International Crops Research Institute for the Semi-Arid Tropics

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Abstract

As many of the poor in developing countries depend on agriculture for their livelihoods, agricultural development is widely regarded as a viable strategy for reducing poverty and conservation of the natural resource base. This recognition has necessitated a wide range of interventions to increase the productivity of agriculture and enhance food security in poor areas. Despite such efforts and the increased momentum towards globalization, along with increasing scarcity of land and water resources, poverty and resource degradation have increased in some marginalized areas, especially in sub-Saharan Africa. A number of studies in recent times have postulated a self-reinforcing downward spiral between poverty, population pressure, and natural resource degradation. These interlinkages seem to be valid for certain arid and semi-arid areas with fragile and marginal environments where biophysical and socioeconomic constraints limit investment opportunities. With emphasis on semi-arid rainfed areas, this study examines the livelihood-environment linkages in light of the existing theories and empirical evidence; synthesizes major lessons; suggests research and policy implications; and advances a more holistic and interdisciplinary analytical framework for understanding the most limiting structural constraints, farmer decision behavior, and investment strategies.

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Introduction

Degradation of the natural resource base, coupled with high rates of population growth and food insecurity, is a major development problem in the semi-arid rainfed areas of sub-Saharan Africa and Asia. The majority of the poor and food insecure are concentrated in rural areas, where their livelihoods depend on smallholder agriculture, rural labor markets, and livestock production. Alleviating poverty, managing agricultural development, and ensuring food security for fast growing populations in South Asia and sub-Saharan Africa will increasingly depend on intensification of land-use, as much of the land suitable for agriculture has already been used. Sustainable intensification of agricultural production (without degrading the resource base) in the less-favored and marginal environments therefore continues to pose enormous challenges to researchers, development practitioners, and policy makers. Poor soil fertility and scarcity of water (low and variable rainfall), accompanied by underdevelopment of infrastructure, institutions, and markets, make the rainfed areas of the semi-arid tropics inherently risky. This means that the poor inhabiting such areas will have to adjust and adapt their livelihood strategies in ways that ensure their subsistence in a risky environment. Risk-reducing adaptive strategies also influence agricultural technology choice, including investments in natural resource management (NRM) innovations. The high degree of abiotic and biotic constraints in the system also complicate and hinder scientific breakthroughs and slow down progress in designing and developing technologies suitable to these locations.

With increasing scarcity of land, adjustment and adaptation towards increasing population density was initially made possible through area expansion (extensification). As opportunities for expansion disappeared, agriculture encroached into fragile ecosystems largely unsuitable for farming (steep slopes and marginal lands), often without the necessary resource-improving investments and leading to soil degradation, deforestation, and loss of biodiversity. Lack of strong institutional structures governing property rights in land and predominance of open access and unregulated common property rights enabled increasing incursion of farming into marginal areas. In areas where the extensive margin is limited, adjustment to increasing pressure initially necessitated declining fallow periods, increased intensity of cropping, adoption of labor-intensive practices (e.g., weeding and use of farmyard manure), and integrated crop-livestock production (Pingali et al. 1987, McIntire et al. 1992). The evolutionary pathways of agricultural change and the degree to which scarcity of land and water resources and increased intensity of land-use are complemented by investments that sustain or improve the productivity of the resource base are unresolved issues (Turner et al. 1993, Pender et al. 1999b, Templeton and Scherr 1999). These issues require more detailed empirical and policy-oriented research in different eco-regions and spatial levels.

There are two main diverging views among researchers on the pathways of agricultural change in response to increasing scarcity of productive resources. Boserup (1965) advanced the view that increased subsistence demand encourages land-saving and labor-intensive technical change, which increases production per unit of land. In this case, resource scarcity is a major driving force for sustainable intensification of agriculture. This view is supported by the theory of induced technical and institutional innovation (Hayami and Ruttan 1985). The evolutionary process of agricultural change and innovations is expected to offset diminishing returns to labor and counteract degradation of the resource base as intensity of use increases. On the opposite spectrum, the neo-Malthusians reject the positive autonomous role of population growth in the process of agricultural change and strongly argue that population growth, far from being a positive driving force, is a principal agent leading to a spiral of increasing poverty, starvation, and environmental degradation in poor countries (Meadows et al. 1972, 1992, Hardin 1993, Cleaver and Schreiber 1994). Today some empirical evidence lends support to Boserup type adjustments (e.g., Tiffen et al. 1994); others indicate Malthusian population-environment nexus (e.g., Cleaver and Schreiber 1994, Grepperud 1996), while several case studies document mixed results (e.g., Pingali et al. 1987, Turner et al. 1993, Templeton and Scherr 1999). Unfortunately, the fixation of existing theories on population growth per se as a leading driving force in the process of agricultural change has overshadowed other associated factors (e.g., economic policies, technologies, and institutions) that often condition and mediate the link and interaction between poverty, population growth, and environmental quality (Heath and Binswanger 1996, Scherr 2000).

This paper revisits some of the ongoing discourse and highlights the challenges and implications for agricultural development, poverty reduction, and sustainable NRM in marginal semi-arid rainfed areas. It also develops a simplified conceptual framework for understanding the dynamics of poverty-environment interactions and farm household investment behavior. The second section presents the debate on poverty-environment interactions and its relevance to marginal semi-arid rainfed areas. It presents a synthesis of the ongoing dialogue on the mechanisms in which poverty, agriculture, and NRM interact in less-favored environments to key factors that lead to a downward spiral or emergence of more sustainable development pathways. The third section presents the challenges for developing productivity-enhancing conservation technologies with short-term payoffs to small farmers. The focus on soil conservation alone, without proper consideration of water conservation and other livelihood benefits to the poor, and failure to develop cost-effective technologies that offer better alternatives to existing options, lie at the center of past weaknesses of NRM research and development efforts. The fourth section develops an integrating conceptual framework for understanding the decision behavior of smallholders and highlights the crucial roles that access to new technologies and the policy and institutional environments play in determining livelihood options, investment strategies, and development pathways. A synthesis of major findings and implications for policy and future research is presented in the final section.

Poverty-environment Linkages

Understanding the linkages between poverty and the quality of the environmental resource base requires data on the geographic distribution of poverty in each country and region. A detailed poverty-environment mapping is yet to be carried out to generate such policy-relevant knowledge at the global level.[1] Over the decade covering 1990 to 1999, based on the minimum standard per capita consumption of US$ 1 per day, the total number of poor living in poverty in developing countries declined from 1.3 to 1.2 billion, and the poverty rate declined from 29 to

1. Many studies rightly argued for a broader concept of poverty going beyond the traditional indicators of income and asset poverty. These new dimensions like social capital, vulnerability, and powerlessness are very relevant aspects of deprivation, but due to lack of data, this study uses the consumption-based threshold for meeting basic needs. Section four develops a broader concept that will help understand impoverishment as a process and factors that contribute to the emergence of diverse livelihood strategies and development pathways. Similarly, there is no single indicator for the "environment", but we deal with vital resources (like soil, water, and agro-biodiversity) that provide livelihood support functions to the poor and may have a number of quality indicators.

Table 1. The distribution (million) of poor people in the developing countries by region and production environment[1].

Location	Rural areas: High agricultural potential	Rural areas: Low agricultural potential	Urban areas	Total
Asia	198 (36)	265 (49)	83 (15)	546 (100)
Sub-Saharan Africa	69 (44)	71 (46)	16 (10)	156 (100)
Latin America	12 (15)	35 (45)	31 (40)	78 (100)
All developing countries	279 (36)	371 (47)	130 (17)	780 (100)

1. Poor people defined as the poorest 20% of the total population. Figures in parentheses are percentages.

Source: Leonard et al. (1989) as described by Renkow (2000).

23%. During this period, the total number of poor living in poverty in sub-Saharan Africa increased from 242 million in 1990 to 300 million at the turn of the century. Although the percentage of the poor declined slightly over this period, it was not sufficient to reverse the absolute increase in the number of people living in poverty. Owing to stagnation or slow growth of the economy, sub-Saharan Africa is the only region where the absolute number of the poor is expected to rise, reaching 345 million in 2015. This compares to the predicted decline in South Asia from 490 in 1990 to 279 million in 2015. Increased globalization and market integration in many developing countries (e.g., India, China, Mexico, and Brazil), and faster economic growth in many regions outside sub-Saharan Africa, has led to an impressive reduction in the rate of poverty and absolute number of the poor. Although this masks considerable variation across countries, it indicates that poverty is likely to worsen with growing economic marginalization in certain disadvantaged regions where deep-seated structural problems like poor infrastructure, high transaction costs, adverse climate, disease incidence, and shortage of human capital discourage increased capital inflow and reduce trade competitiveness (World Bank 2002a, 2002b).

The best available data also indicates that the absolute number of the poor is higher in rural than urban areas (World Bank 1990) and the majority of the rural poor live in areas of low agricultural potential (Leonard et al. 1989, World Bank 1990).[2] In 1996 more than 75% of the poor in developing countries were located in rural areas and about 47% of them were concentrated in marginal environments of low agricultural potential (Table 1). The regional distribution across the continents displays a similar pattern, with a slightly higher share for Asia (49%).[3] Based on data compiled from different sources, Ryan and Spencer (2001) found that in 1996, three-quarters (995 million) of the poor in the developing countries were concentrated in rural areas. Of the total poor, about 38% (379 million) were found in arid and semi-arid regions, about 50% (500 million) in humid and sub-humid regions, and the rest in temperate areas. The data also indicates that the absolute number of the poor was slightly higher in rainfed areas than in irrigated areas in each agroecological region (see Table 2).

2. "Low agricultural potential" refers to marginal agricultural land, where inadequate or unreliable rainfall, adverse soil conditions, fertility, and topography limit agricultural productivity and increase the risk of chronic land degradation (Renkow 2000).

3. As many of the poor in urban areas also reside in slums and squatter settlements of high environmental vulnerability and pollution, this number increases to about 65% if we include the urban poor.

Table 2. The rural poor (million) in developing countries by agroecological zone, 1996[1].				
Eco-region	Developing countries	Asia	Sub-Saharan Africa	Other developing regions
Arid and semi-arid	**379**	**237**	**79**	**63**
Rainfed	199	89	76	34
Irrigated	180	148	3	29
Humid and sub-humid	**500**	**343**	**120**	**37**
Rainfed	259	104	120	35
Irrigated	241	239	0	2
Temperate/cool	**116**	**49**	**43**	**24**
Rainfed	89	27	43	19
Irrigated	27	22	0	5
Total rural	**995**[2]	**629**	**242**	**124**

1. The poor defined as those subsisting on US$ 1 or less per day.
2. The total poor in developing countries during the period, including the urban poor, is 1.3 billion.

Source: Compiled from Ryan and Spencer (2001) and FAO/TAC database.

Moreover, in agriculture-based rural economies in developing countries, agriculture accounts for most land-use and the livelihoods of the majority of the poor are directly dependent on utilization of natural resources (soil, water, forest, fish, livestock, etc.). The degradation of these resources, therefore, impinges immediately on the livelihoods of the rural communities either through a fall in the productivity of the resources that they rely on or through adverse impacts on their health. Soil degradation, removal of land cover, and overgrazing reduce the productivity of agricultural land, while water pollution through increased accumulation of soil sediments, chemicals, and other contaminants may increase the incidence of water-borne diseases. The degradation of natural resources may also increase the labor time needed for household production, as in fuelwood collection or fetching water from distant locations, and compete with the labor time needed for agricultural production and conservation investments.

If the poor in general are located in areas where land is scarce, agricultural productivity is low and environmental degradation is common (Leonard et al. 1989, World Bank 1990) and depend for their livelihoods directly or indirectly on agriculture, it perhaps indicates a high degree of correlation between the processes of impoverishment and the inability to undertake investments that improve or sustain the environmental resource base.[4] This generally forms the basis for emerging theories on poverty-environment interactions and also calls for a detailed micro-level investigation to understand the mechanisms in which poor people interact with their environment and the associated factors that may lead to improvement or degradation of the resource base.

4. A recent collaborative study, which ranked 122 countries by an environmental sustainability index (ESI), based on scores of 22 core sustainability indicators, shows a highly significant correlation (r=76) between per capita income and ESI and a negative correlation with share of grass domestic product (GDP) from agriculture (r=−0.48). Furthermore, many of the countries with arid and semi-arid environments fall at the bottom of the rank (Levy 2001).

Accordingly, several studies posit a two-way link between poverty and environmental degradation (WCED 1987, World Bank 1992, Cleaver and Schreiber 1994, Reardon and Vosti 1995). Where credit and insurance markets are missing or imperfect, poverty restricts household ability to make resource-enhancing or soil-conserving investments. In their analysis of the poverty-environment links, Reardon and Vosti (1995) distinguish between 'welfare poverty' and 'investment poverty'. Under imperfect markets, a poverty indicator based on a welfare criterion may exclude some households which may afford basic consumption needs but lack the resources needed to undertake critical resource-enhancing investments (e.g., soil conservation, fertilizer use, tree planting, small-scale irrigation). Hence, the ability to invest in resource improvement requires that households be above the 'investment poverty' threshold, which assumes that resource users have access to key assets needed to make such investments above and beyond what is needed to satisfy basic needs. Others also argue that when institutional alternatives for consumption smoothing (livelihood security) are missing, immediate survival needs and food security may be overriding objectives of the poor. This leads to short planning horizons and high subjective rates of time preference (discount). When immediate survival is threatened, households without sufficient assets to fall back upon may lack the ability to forfeit current consumption to undertake resource-conserving or enhancing investments needed to protect future consumption. The positive correlation of high discount rates with poverty or low incomes (Holden et al. 1998) may therefore mitigate resource-improving or conservation investments with long gestation and payback periods (e.g, tree planting, terracing, etc.).

If these arguments hold, some parts of the semi-arid tropics, characterized by unfavorable biophysical conditions (like scarcity of water, infertile soils, high disease and pest incidence) and poor socioeconomic infrastructure, may exemplify the strong interlinkages that may exist between poverty and resource degradation. As conceptualized in Figure 1, adverse biophysical conditions, along with lack of markets and poor development investments, create conditions that favor the emergence of a Malthusian-type two-way link between poverty and resource degradation. Under extreme circumstances, the poverty-environment treadmill may lead to a "development pathway" that forecloses future options for sustainable intensification of agriculture and protection of livelihoods. Smallholder farmers and landless people in poverty-ridden and degrading areas may thus be trapped in a mutually reinforcing cycle of poverty and land degradation. Breaking such a nexus requires sustained investments in human and natural capital, agricultural research for generation of improved technologies for stress tolerance, water conservation, pest and disease management, improved market access, and better opportunities for off-farm employment and out-migration.

The thesis that environmental degradation could worsen poverty in fragile areas suffering from degradation of the resource base adds another dimension to the already complex challenges facing poverty alleviation and sustainable agricultural development. However, one should add that the relationship between poverty and the environment is quite complex and not necessarily a downward spiral (Scherr 2000); also eradication of poverty is not necessarily good for the environment. The livelihood strategies of resource users, and hence the links between livelihoods and the environment, are conditioned by biophysical conditions (e.g., soil quality, length of growing period, pest and disease incidence, etc.) and socioeconomic factors (e.g., access to markets, policies, institutions, etc.). The type of livelihood strategy that resource users practice through production and consumption decisions and existing market, policy, and institutional incentives for undertaking resource-improving investments determine the outcome of the links between livelihoods and the environment (Fig. 1). In certain vulnerable systems, the livelihood-environment link may develop into a downward spiral when demographic pressure is high and households lack access to appropriate technologies, policies, markets, and institutional arrangements. This limits adaptive responses and options available to resource users, and hence impoverishment and resource degradation would ensue. When appropriate technologies, enabling policies and access to markets and institutions create proper incentives to encourage collective and private resource-improving investments, several case studies in developing countries have documented the ability of local communities in successfully dealing with and reversing the problems of resource degradation along the lines of Boserup-type responses (e.g., Turner et al. 1993, Tiffen et al. 1994, Heath and Binswanger 1996, Templeton and Scherr 1999, Scherr 2000). The upward and downward arrows in Figure 1 depict these two possible outcomes of livelihood-environment linkages.

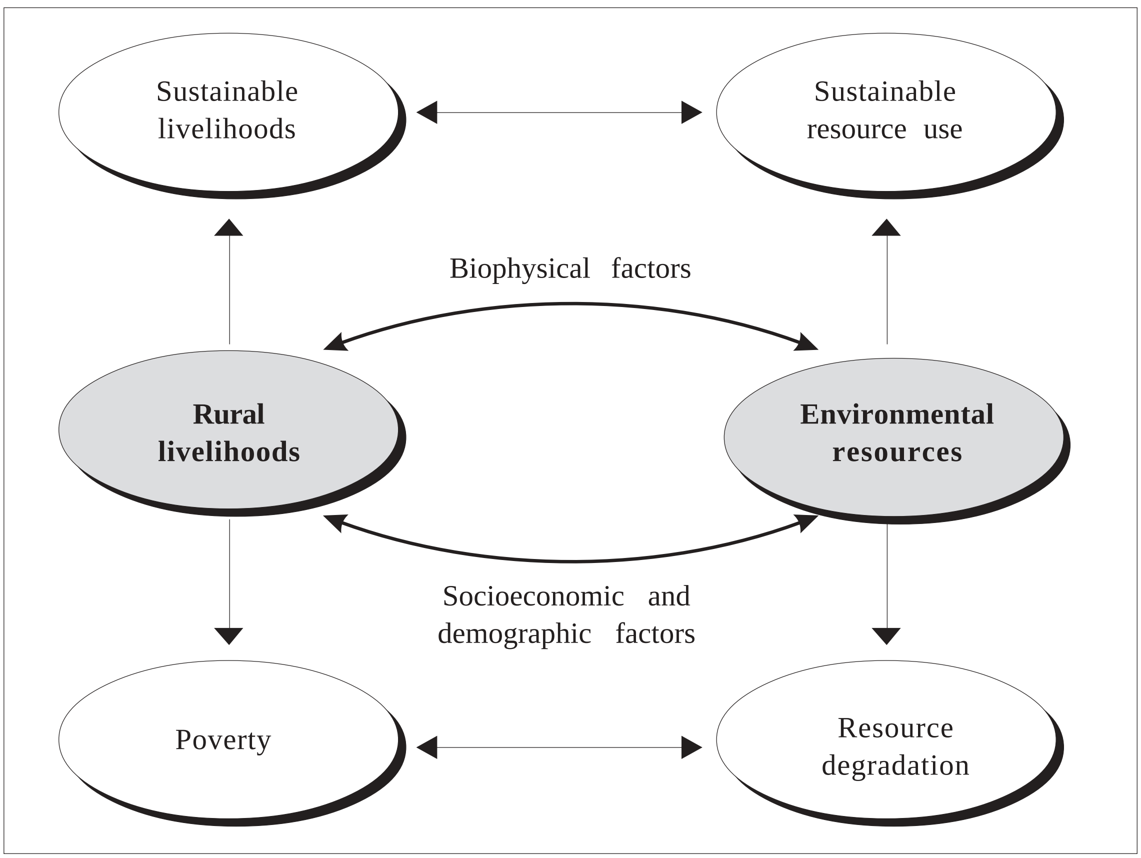

Figure 1. Poverty-environment links in rural areas and the conditioning role of socioeconomic and biophysical factors.

These results indicate that under highly constrained socioeconomic and policy environments, poor people lack the ability in effectively responding to the problems of high population pressure and degradation of soils and other resources upon which their livelihoods depend.

Poor people are not willful destroyers of their life-support system. Rather poor people seem to be unwilling agents and victims of environmental degradation. Degradation of the resource base often ensues when local possibilities and available technological options have been exhausted. Many of the negative environmental effects of livelihood strategies of the poor can be reversed through proper public policies, investments, appropriate technologies and by supporting and strengthening local institutions that encourage private and collective action for sustainable use of natural resources. One should, however, add that degradation of the resources upon which the livelihood of the poor depends would further impoverish the poor and curtail the ability to adapt and adopt more sustainable management practices. This has to be taken into consideration in designing poverty alleviation strategies and programs in degrading areas. As stated above, eradication of poverty may not also be sufficient to improve all aspects of environmental quality. Income growth increases the ability to pay for clean air, water, and amenities while it also boosts the demand for commodities that put pressure on environmental resources. The hypothesis of environmental Kuznets curve, suggesting an inverted U relationship between levels of per capita income and environmental quality, does not therefore hold for certain types of environmental problems (e.g., emission of carbon dioxide and greenhouse gases). This also indicates the essential role that proper policies, institutions, and regulatory mechanisms play in protecting the environment as income grows (World Bank 1992).

Farmer Investment Strategies

As outlined above, the livelihood strategies and resource use patterns of rural households are determined by asset endowments and exogenous conditioning variables, like population pressure, technological options, rural infrastructure, public policies, and access to markets and institutions (Reardon and Vosti 1995). The strength and direction of poverty-environment links and farmers' investment strategies in a given setting, therefore, depend on the severity and spread of poverty, initial quality of resources, productivity impacts of degradation, and access to appropriate technologies, policies, and institutions to avert the problem. The farm-level profitability of production and conservation technologies and available investment options differ across regions and countries based on socioeconomic, policy, and biophysical conditions (Binswanger and Rosenzweig 1986, Pender et al. 1999a, Shiferaw and Holden 2001). This implies that technology development and intervention strategies for sustainable intensification of agriculture should take into account differences in the biophysical and socioeconomic factors in different eco-regions. Farmers' technology choices and investment strategies as determined by markets and policies, property rights, poverty, and biophysical conditions are discussed below.

Markets and policy

The uptake of new conservation technologies will depend on the relative returns and stability of incomes that new options provide compared to existing alternatives. Smallholder farmers are generally risk-averse (Binswanger 1980). Land degradation increases the risk of future crop failures and risk-averse households, under perfect information, can be expected to invest in practices that reduce degradation. The choice of technologies and investment strategies will therefore depend on profitability as well as risk (stability of income) considerations. The ability to manage and spread risk increases with livelihood assets and resource entitlements as determined by public policies, access to local institutions, opportunities for off-farm employment, membership to social groups, and biophysical conditions. Since new technologies are perceived to be risky, food security and safety-first considerations can deter adoption of profitable options. Apart from risk, access to credit and ability to relax capital constraints also affects technology adoption and farmer investment behavior. Credit in many developing countries is made available for productive inputs like fertilizer and improved seeds, which are expected to bring returns in the short term. Conservation and resource-improving investments that often bring benefits in the medium to long term are poorly served in credit markets. The high cost of capital credit, if available at all, may also be higher than the rate of return on conservation investments, thereby discouraging farmers from adopting such alternatives. Since long-term returns tend to be uncertain and information is lacking about future benefits, under an imperfect world lacking perfect foresight, risk-aversion may also discourage such investments that bring long-term benefits.[5]

This shows that yield increase, and indeed profitability of new options, cannot be the sole consideration for farmers in making their technology choice decisions. Stability of incomes despite pest, disease, and drought stresses, and availability and access to inputs needed in the production process are vital considerations for farmers. In addition to profitability, the functioning of local markets determines the level of use of fertilizer, labor, and other inputs needed in the production process. In semi-arid areas, the growing period is very short and farming activities need to be completed within a limited period of time. This increases the pressure on available family labor during the planting season. Imperfections in credit and labor markets also prevent the ability to effectively defuse these constraints.

In view of the HIV-AIDS epidemic and selective flight of male labor out of agriculture to cities and other areas in search of better income-earning opportunities, leading to increasing feminization of agriculture, shortage of agricultural labor is becoming an increasing constraint in many rural areas, including South Asia. This indicates the growing demand for labor-saving options in agriculture and the need for serious consideration of labor demand implications in technology design and development. Soil and water conservation methods, like terracing and leveling, often require enormous labor investments per unit of treated land. Least-cost and labor-saving water and soil management options that require locally available resources are preferred options. In the wake of increasing land scarcity, vegetative methods like grasses, legumes, and agroforestry methods that do not compete much with available farmland and provide additional benefits in terms of increased production of food, fodder, and fuelwood, and reduce wind and water erosion are suitable options requiring more attention in NRM research and development efforts.

In some cases, public policies subsidize certain inputs (e.g., fertilizer subsidies in India) or the public sector accounts for a significant share of the local and national supply (e.g., water sector in many countries). Some of these subsidies may provide distorted signals to resource users and displace individual efforts for undertaking resource-conserving or improving investments. For example, subsidies on fertilizer and irrigation water may discourage farmers from adopting

5. Asked about current and future benefits of soil and water conservation technologies, a wise farmer in our survey once replied: "The past is history, today is a gift, and the future is a mystery." When future benefits are unclear and uncertain, it indicates the preference of the poor for immediate benefits from the new technology to make a dent on poverty. However, when future benefits are more predictable and livelihoods are not threatened, poor people also make useful investments (e.g., planting trees or sending children to school).

innovations that reduce soil erosion and conserve available water supplies. In the absence of alternative plant nutrient management and replenishment practices, removal of fertilizer subsidies and high farm-gate costs for imported fertilizer following devaluation and liberalization of input markets may lead to excessive soil mining and nutrient depletion. Unwarranted conservation and input subsidies also temporarily raise the returns to a given technology and create an impression that farmers are investing in new options, but farmers often switch to old practices when economic incentives dry up and interventions phase out. A case in point is the sustainability of watershed development programs in India, which subsidize more than 90% of the investment costs to encourage adoption of new methods on private and communal land (Kerr et al. 1999). This indicates the need for careful appraisal of equity and social efficiency (including environmental impacts) implications of public policies and programs and the need to look into alternative institutional arrangements and incentive structures that provide proper signals that reflect the full opportunity cost of resources. For example, interlinked policies like cross-compliance mechanisms that link access to public subsidies with environmental quality and conservation efforts undertaken by resource users offer promising approaches (Shiferaw and Holden 2000). Improved local management of water through decentralization, reduction of public monopolies, tradable rights, and scarcity pricing also create incentives for water conservation and increase the economic efficiency of water use.

Property rights and externalities

One other factor, which has received greater attention in the literature in recent times, is right of access and security of rights to resources (e.g., Feder and David 1991, Place and Hazell 1993, Besley 1995). For obvious reasons, farmers lack the economic incentive to invest in resource-improvements unless the existing resource rights ensure that they will reap the fruits of their investment. Security of rights does not however presuppose private ownership or private titles to the resource. What seem to matter most for investment is the degree of security (in terms of ability to exclude others and enforce rights) and the duration of use a given property rights regime provides to the resource user. When the length of use of rights is short or when the probability of retaining rights is low (e.g., due to risk of expropriation), the expected returns from resource-enhancing investments can be very low. This has the effect of shortening the planning horizon of the resource user. Security of land rights may also be correlated with access to credit facilities, as land often serves as essential collateral. In fear of growing inequality and landlessness, a number of countries (especially in Africa) have hesitated to provide transferable long-term land rights to farmers and retained public ownership of land. In light of the existing evidence, public ownership should not diminish security of tenure if land policies and laws allow long-term leases and transferable rights (including inheritance to posterity) that encourage investments and the development of local land and credit markets. Landlessness can also be mitigated through ceilings on land ownership and provision of credit to reduce distress sale of land. One interesting policy option that may also be used to encourage farmer resource-improving investments is linking security of tenure and duration of leases to the extent and intensity of investment undertaken by the land user.

Incomplete property rights and problems of non-exclusion also discourage investments. A classic example of this kind of market failure occurs for open access resources (which are non-excludable). This may also be the case for impure public goods (which are congestible or rival and non-excludable). For example, if one farmer invests in flood control structures upstream, several farmers in the lower-lying areas of the watershed may benefit. Problems of non-exclusion mean that a private farmer lacks the economic incentive to improve the resource or invest time and money to counteract degradation, because others will benefit from such investments without payment. The market failure (lack of private economic incentive) occurs because the cost is private and benefits are shared. The problem of non-exclusion could also occur for common property resources where use and management rights fall under a defined social group, especially when population growth or external factors (e.g., new policies, market opportunities, etc.) make collective action for resource-improvement and regulation of use more difficult. In some cases, investments undertaken in a given plot may not be sufficient to counteract resource degradation because the part of the externality emanates elsewhere and needs to be tackled at the source. In other cases, the externality may flow in several directions (reciprocal externality) connecting a number of farmers. In these cases, a single user may not have complete control on what happens on his/her plot and optimal private investment requires cooperation with other neighboring farmers.

A related problem occurs when part of the benefits of private investments (positive externalities or spillover effects) accrue to the community or society at large. When the social or communal benefits are larger than private benefits, the optimal level of investment undertaken by a private individual will be less than what would be optimal for society at large. This requires public interventions through cost sharing and subsidies that would stimulate private investments to a socially desirable level. In other cases, costs and benefits of investments are unequally distributed or even accrue to different groups of people often geographically separated from each other. This kind of problem occurs in watershed management where water and soil conservation investments on the higher reaches (which often take some productive land out of production) bring disproportionately higher benefits to farmers in the lower reaches of the watershed. This creates problems for collective action unless some innovative institutional arrangements can be designed to compensate the losers. If individual resource users in the watershed invest in conserving or improving the resource, the resulting privately optimal level of investment will fall short of what would be optimal at the watershed scale since such investments also bring spillover benefits to others located downstream.

Poverty and time preferences

As was presented earlier, poverty is one factor blamed for limiting the uptake of more profitable NRM technologies. When markets are imperfect, poverty may be associated with high rates of time preference, which may discourage investments with upfront costs but generate long-term benefits (Holden et al. 1998). To illustrate this, a hypothetical scenario is described in Figure 2. Under adverse biophysical conditions, one may reasonably assume that the productivity of land (returns to land and family labor) will decline over time. In the absence of external interventions this may reflect the status quo for many production systems. Available alternative management systems (compared to the status quo) often require heavy initial investments (e.g., terracing and bunding) and may only improve livelihoods in the medium to long term. While such alternatives provide higher returns than the status quo in the long term, higher initial investments may discourage farmers from choosing such new technologies. High rates of time preference (subjective rate of discount) and insecurity of tenure (short-planning horizons) discourage technologies with high initial investment costs and relatively higher net benefits in the future. In

Figure 2, best-bet options are expected to bring net benefits only after period ‘t’. Before this period, high initial costs mean that farmers are better off choosing existing local options (status quo). The higher the technology gap and the longer the gestation period, the lesser the likelihood for the best-bet option to be preferred by a farmer with a positive rate of time preference (Pagiola 1996, Shiferaw and Holden 2001).

In the absence of better alternatives that provide short-term economic incentives, public intervention would be required to encourage adoption of resource-conserving practices by compensating farmers for an amount equivalent to the technology gap (net short-term losses from choosing new options). Unless subsidized, farmers with a positive discount rate may not be interested in such technologies. The need for cost-sharing and subsidies often depends on the presence of positive externalities (off-site external benefits) and distributional considerations like attainment of food security and poverty alleviation. On the other hand, no subsidies would be needed if other alternatives that bring higher net benefits to the poor in all periods were available. This is indicated by the “second-best” and “first-best” options in Figure 2. “First-best” options, if made available, place the poor on an improving welfare development pathway. This may represent a “gray to green revolution” in disfavored and marginal regions of the semi-arid tropics. “Second-best” options may not be sufficient to improve the welfare of the poor over time, but may provide viable options to existing exploitative resource use and management practices. Under enabling policy and institutional environments, widespread adoption of such technologies by self-interested resource users will take place.[6]

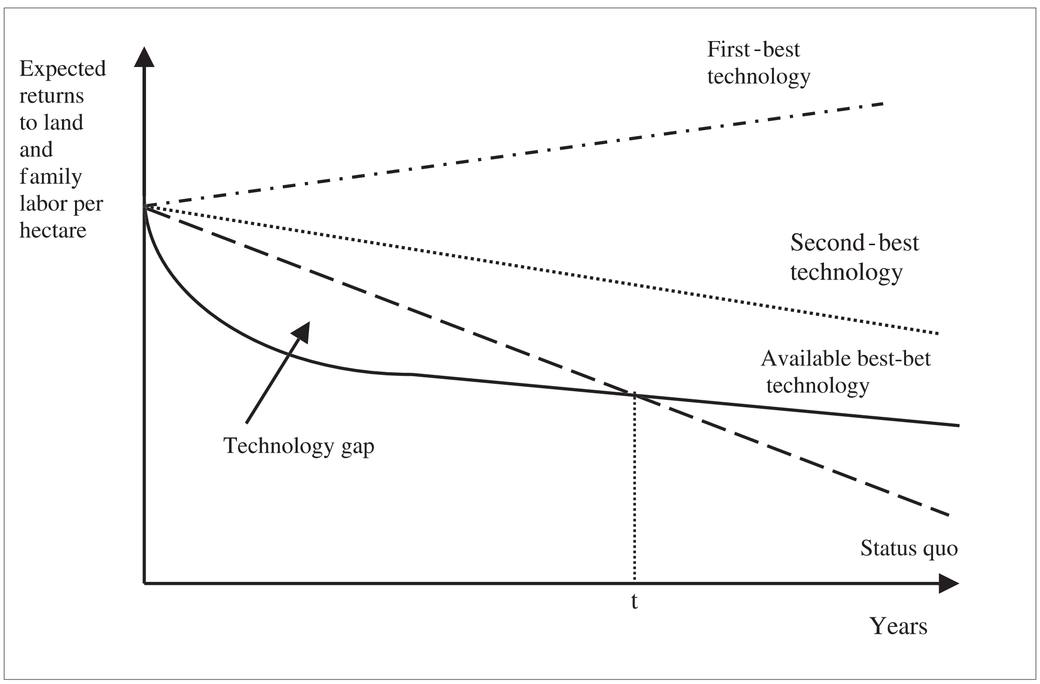

Figure 2. Challenges in the design and development of NRM technologies: stylized flow of on-farm returns to NRM investments.

6. This assumes that returns to labor are higher in agriculture than in non-agricultural activities. In the latter case, conservation investments may not occur as migration or non-agricultural employment may be more profitable alternatives to labor use in agriculture.

Biophysical factors

Factors like the natural fertility of soils, topography, climate, and the length of the growing period also influence the success of research investments and the type of technologies needed to sustain livelihoods and conserve the resource base (Binswanger and Rosenzweig 1986). For example, in semi-arid areas with infertile soils and erratic rainfall patterns, risk considerations imply emphasis on water management to reduce soil erosion and to increase crop yields. This contrasts with the past overwhelming focus of resource conservation efforts in many developing countries on technical solutions for soil erosion and reforestation programs disregarding moisture conservation benefits and water management issues linked with such investments. In semi-arid areas suffering from moisture stress and seasonal drought, the objective of resource conservation efforts should be on providing better options for enhancing in situ retention and productivity of water. Moisture conservation gains are likely to provide insurance against drought risk and reflect easily on crop productivity, thereby providing incentives for farmers to adopt such practices. Technologies for harvesting rainwater and groundwater also provide opportunities for supplementary irrigation, which would increase the productivity of other purchased inputs (e.g., fertilizer) and raise the income of the poor (Oweis et al. 1999).

In higher rainfall areas, soil and water conservation should focus on mitigating soil erosion through cost-effective methods, which reduce overland flow and improve safe drainage of excess water. Even in such locations, the excess water may derive some benefits for supplementary irrigation during the dry season or for domestic and livestock use. The heterogeneity of the biophysical system in both dry and wet areas requires careful consideration of local conditions in development of NRM technologies. The challenge for international agricultural research institutes is to balance applied research needed to adapt to micro-biophysical conditions with strategic research on cross-cutting issues that extend the knowledge base for wider application of the technologies.

In sum, these results imply that soil and water conservation programs should first aim at improving the livelihoods of the people (not just conserving the resource) and effectively demonstrate the potential gains to the poor from resource conservation efforts. Sustainability of such investments can only be ensured when conservation benefits (in terms of higher incomes and/or reduced variability of incomes) are realized by resource users and well integrated into the farming system. A suitable motto of NRM programs in this regard should be ‘conservation for increasing productivity and risk management’. These objectives should not necessarily contradict with each other; water conservation in semi-arid environments, for example, enhances productivity of land and labor and reduces drought risk. Moreover, technology design and development efforts should also take into account the conditioning role of socioeconomic and biophysical factors in different eco-regions that determine private and collective incentives to invest in alternative technology options. Research and development programs which start from careful analysis of the limiting constraints and understanding of livelihood strategies of local people will have a better chance of success. The following section presents a holistic framework, which focuses on the factors that condition the pathways of change and resource use strategies of smallholder farmers and resource users as central decision making agents.

Synthesis and Conceptual Framework

As stated earlier, the livelihoods of the rural poor are directly dependent on utilization of natural capital (land, water, livestock, trees, and agro-biodiversity). The farmer is the ultimate decision maker on how and when to utilize the natural resource to attain the preferred objectives. The challenge is in understanding the behavior of the resource user in terms of his/her production, the consumption and investment decisions, and the most important factors that drive such decisions. In light of the complex issues (discussed above) that influence farmer resource use and investment behavior, a more holistic analytical framework which accounts for the crucial role of socioeconomic and biophysical factors in determining livelihood options is required. The framework developed here is dynamic and captures the intertemporal decision problems across alternative livelihood options (crop production, livestock production, investment, off-farm employment) that resource users face at each period and the consequences of their livelihood strategies on the quality of the resource base (see Figure 3). The pattern of change in the quality of the natural resource base and the associated livelihood strategy would determine the 'development pathway' in subsequent periods.

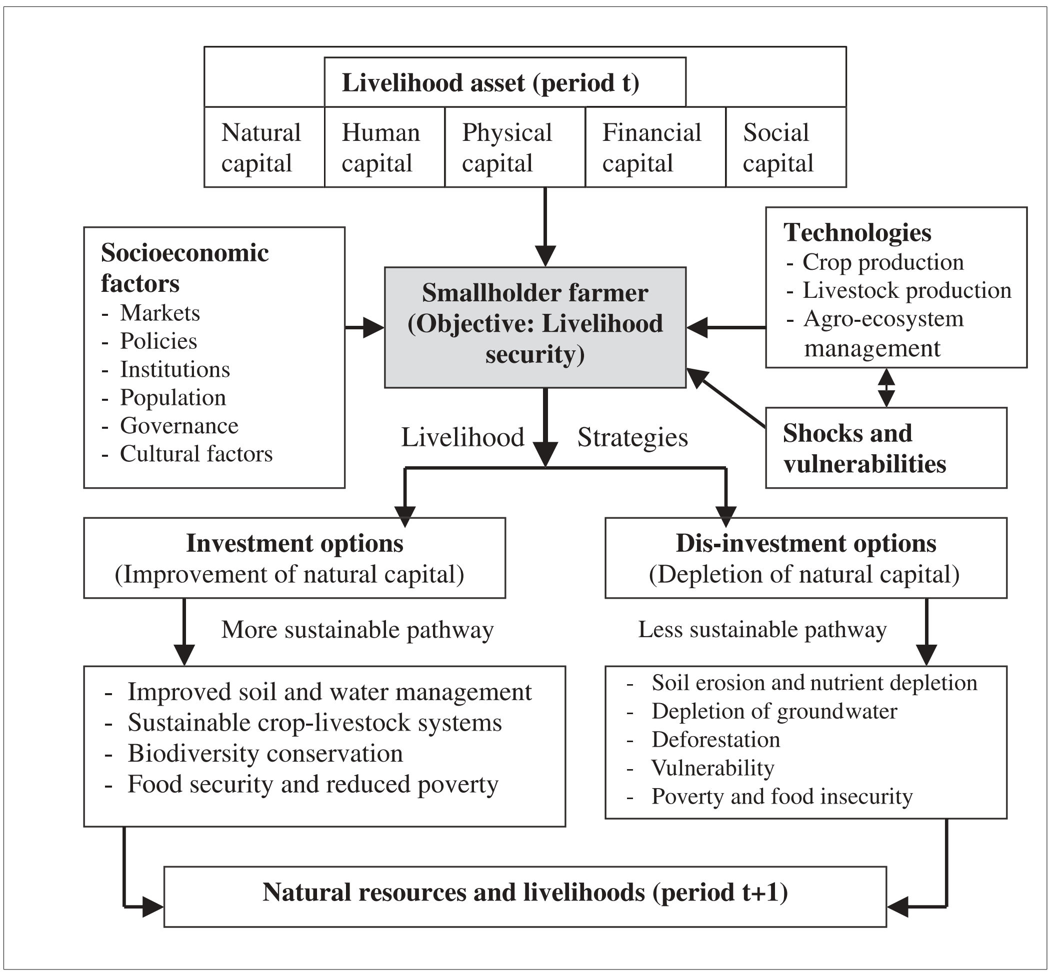

Figure 3. Analytical framework for understanding farmers' resource use decisions and the pathways of change in a dynamic perspective.

This conceptual framework builds from the sustainable livelihoods thinking which places people at the center of analysis (Chambers 1987, Carney and Ashely 1999). It, however, extends the livelihoods thinking by incorporating the theory of farm household behavior and market imperfections (Singh et al. 1986, de Janvry et al. 1991), the economics of rural organization (Hoff et al. 1993), and the theory of institutions and institutional change (North 1990). Unlike the livelihoods approach, which mainly sets out a set of principles or development objectives, the simple framework developed here is more complete, analytical, and suitable for setting out testable hypothesis in development research. Hence, it enriches and extends the livelihood approach by explicitly recognizing the conditioning role of markets, polices, institutions, and technologies in determining the poverty-environment linkages and the pathways of development in rural economies (e.g., see Reardon and Vosti 1995). This kind of cross-fertilization of different approaches and the explicit linking of economic and biophysical data is essential for studying farmer resource use behavior and intertemporal changes in the quality of flow and stock resources. A similar framework has recently been applied in bio-economic modeling of soil and water use decisions and analysis of policy and technology options (Ruben et al. 1998, Shiferaw and Holden 1999). The framework provides an interdisciplinary and dynamic perspective to technology design and development efforts targeting poverty reduction and sustainable management of natural capital.

In each period, farm households as decision makers attempt to maximize their livelihoods over a period of time based on existing household resource assets. The human capital as an asset includes family labor, managerial skills, level of education, access to information, and health. Physical capital includes farm implements and equipment needed in production and investment activities. Financial capital includes economic resources like savings, working capital, and liquidities. Social capital includes ability to access informal community assets such as social networks, groups, and local institutions for the benefit of meeting household objectives. The level of endowment of social capital depends on socio-cultural factors and the type of social organization in communities that determine the distribution of such rights and resource entitlements. Coupled with other socioeconomic factors and assets, social capital determines the motivation for collective action and participation in communal management of natural resources as well as the alternative courses of action and ability to manage risk in times of dearth (failure in crop and livestock production). The emergence of informal institutions in rural communities can be seen as a viable means of adaptation to pervasive local market imperfections (e.g., credit and insurance markets). It will be instructive to understand the level of endowment of livelihood assets as a continuum, ranging from zero to a larger positive quantity. The larger the endowment of such assets, the larger the choice of feasible livelihood options, and the higher the capability of the household to manage risk. When functioning local markets exist, resource users also expand the available production and investment choices through trade.

The livelihood options and investment strategies available to farmers in this model depend on two major conditioning factors: the technological and the socioeconomic environment under which the farmers operate. Access to appropriate technologies and conducive policies and institutional arrangements define the frontiers for relaxing resource constraints and the set of feasible livelihood options, in terms of choice of crops, livestock types, and migration possibilities. While the endowment of family resources determines the initial capabilities for consumption, production, and investment, the socioeconomic and policy environment shapes the resource use patterns and the ability to relax initial constraints through trade and investment. For example, the functioning of markets determines access to credit to relax the capital constraint and the level of use of productive inputs (e.g., fertilizer and high-yielding variety).

The functioning of the output market also determines the ability to produce for markets or for subsistence. In the extreme case, the market may be missing for some products and/or factors of production, and hence the farm household has to be self-sufficient in such non-tradable crop and livestock products and factors. For example, if there is no market for farmyard manure or crop byproducts, on-farm demand for such inputs can only be met by own supply. Similarly, a missing market for staples would limit the household's supply response to price incentives in tradable or commercial products (de Janvry et al. 1991). In some cases, resources like animal dung and crop residues may not be scarce and hence non-producers may also benefit from unrestricted (open) access. As scarcity increases, such resources also attain higher subjective (shadow) prices, but high costs of marketing (e.g., packaging, transport, etc.) hinder market development. Similarly, when transaction costs are low and access to local markets is high, households will have an option of hiring additional labor when needed or the opportunity to earn income from off-farm employment. The returns to family labor in agriculture and other activities would determine the amount of labor allocated between agriculture and migration (off-farm employment). Poor households without sufficient productive resources other than their own labor often engage in non-agricultural livelihood options or depend heavily on exploitation of open access local resources (e.g., fishing, charcoal, and fuelwood).

Therefore, the investment decisions undertaken and the development pathway followed depend on enabling socioeconomic conditions and the available technological options. When socioeconomic conditions are conducive and more profitable resource-conserving technologies are available, farm households may undertake productivity enhancing investments. Improved policies (e.g., secure property rights, credit, and insurance), access to markets and institutional arrangements (e.g., credit delivery and extension systems) in this case create incentives for investing in options that expand short-term and future production and consumption possibilities. Such resource improving and productivity enhancing investments provide opportunities for the betterment of the livelihood of the poor and help combat degradation of the resource base. There may be several such trajectories representing what is referred to here as the green or more sustainable pathway of development. Improved social well-being and investment in sustaining or enhancing the resource base (natural capital) further creates new opportunities for reinvestment and income growth. This shows the potential for de-linking the poverty-environment nexus at the grass-roots level and how the downward spiral can be avoided.

On the other hand, when the socieconomic environment is adverse and/or more profitable technologies do not exist, farm households lack the economic incentives to undertake resource improving and more sustainable investments, unless society provides compensating subsidies to encourage and support such investments. Many governments in the past have attempted to promote conservation efforts through public subsidies, but such efforts have been met with limited success. When available options are exhausted, farm households may engage in practices that mine and deplete the resource base. In such situations, population growth and increasing subsistence demand further undermine the ability to cope with and manage degradation of the resource base. Under such highly constrained conditions, the interplay of lack of technological options and adverse biophysical, policy, and institutional environments may force agriculture in marginal areas to follow a more exploitative and unsustainable pathway of development. There may also be several such trajectories but for simplicity it is referred to here as the gray or less sustainable pathway of development, indicating extractive resource use patterns without supplementary investments to counter resource degradation. In this case, the synergistic effects of poverty and resource degradation lead to worsening conditions of the poor. This is an example of a downward spiral. Even if economic growth may take place initially through extraction of the resource base, failure to replace and recuperate the resource through renewal investments could lead to eventual depletion of the life-support system. The reversal of growing per capita incomes following degradation of resources is a classic example of unsustainable growth. In some cases, income from depletion of some soil and water resource may be reinvested in other income-generating options, but the loss of productivity of the resource base will be irreversible. If many resource users behave in such a way, the critical resources that support livelihoods can be exhausted beyond recovery.

In sum, this analytical framework is able to help us understand the complex factors and processes that determine resource use decisions, livelihood strategies, and the policy relevant factors and incentive structures that may be employed to promote more sustainable resource use in semi-arid regions and similar less favored areas. It could be conveniently applied to understand the different factors at play in areas that suffer from excessive degradation of resources or the complex factors that promote resource-improving investments in areas where farmer and community efforts have reversed or prevented a downward spiral. It also helps us understand why a poverty-environment nexus is not the rule and how the interaction of new technologies, enabling policies, and access to markets and institutions can lead to poverty alleviation and sustainable intensification of agriculture in marginal areas.

Summary and Implications

Policy makers, development practitioners, and policy analysts are increasingly searching for ways in which policy interventions can achieve multiple objectives, more effectively addressing the livelihood needs of people living in poverty and improving the productivity and sustainability of the resource base. Despite widespread poverty, population growth, and resource degradation, sustainable intensification of agriculture (e.g., through increased investment in infrastructure, education, soil fertility management, improved technologies, and irrigation) offers a viable strategy for addressing the problems of poverty, food insecurity, and environmental degradation. A number of recent studies have articulated and documented a two-way empirical link between poverty and resource degradation, leading to a downward spiral. Many others have also found examples to the contrary. The potential for a two-way poverty-environmental link in marginal and fragile areas of high density further complicates poverty reduction and environmental rehabilitation efforts. Therefore, more policy-oriented research is needed to understand factors that lead to a downward spiral or promote the process of agricultural intensification and sustainable use of land and water resources in many densely populated areas of the developing world.

Emerging evidence suggests that poor people in developing countries are both victims and unwilling agents of resource degradation. However, much is not known about the processes and outcomes of environmental change and the processes and outcomes of impoverishment of the people, indicating that the two-way poverty-environment interaction is often indirect and non-linear. Moreover, the links between poverty and environmental change are mediated by a diverse set of factors that affect the range of available options and decisions that poor people make. Biophysical factors and resource entitlements mediate resource user's interactions with particular environments, whilst macroeconomic and sectoral policies, access to local markets, technologies, and existing institutions condition these interactions. Poor people’s resource entitlements depend on a range of factors including tenure arrangements, social relations (including gender), capital endowments, and technology. Environmental degradation and declining resource entitlements, reduce the productivity of poor people’s assets (including the effects of bad health on productivity of labor) contributing to further impoverishment, but environmentally damaging behavior on the part of the poor themselves is usually a result of a lack of alternative choices. Hence, a number of case studies across the developing world attest that a downward spiral is not the rule and sustainable agricultural intensification and resource use can be enhanced through appropriate policies, technologies, and institutional arrangements. Adverse outcomes often occur when biophysical factors like drought, poor soil fertility, and pest and disease incidence interact with poor market access, and disabling policy and institutional arrangements that limit the options available to poor people.

In the context of the marginal areas of the semi-arid tropics, the concept of environmental entitlements indicates the importance of vulnerability of communities to shocks and stresses that influence resource stocks and livelihoods. The variability of rainfall, scarcity of water, and the low fertility of soil resources in semi-arid marginal areas increase vulnerability of livelihoods to shocks and lessen the initial level of environmental resource bundles that poor people can command. As environmental thresholds are reached due to population growth and exploitative resource use patterns, the stability of income and livelihood security deteriorate further. Interventions that extend environmental entitlements of the poor and increase the range of options available to people that depend on declining resource stocks can be expected to reverse downward spirals in fragile resource-poor areas. Such interventions should include favorable policies; improved access to markets, health, education, new technologies, and institutions; and alternative employment opportunities for the poor.

Poor people’s economic incentives to invest in protecting or expanding their environmental entitlements depend on several factors such as availability of alternative technological options that bring higher returns in the short term and stabilize livelihoods, access to markets, relative returns to labor in agriculture and other activities, resource use rights, skills in managing the resource, and enabling policies and institutional arrangements. In some cases, like in watershed management, individual efforts may be insufficient partly because of high transaction costs and market failures (often resulting from policy and institutional failures) that lower private incentives and hinder essential collective action needed to supplement individual efforts and “internalize” local externalities. Incomplete property rights, non-excludability, and non-rivalry in people’s access to resources and ecological services generated by environmental investments are often associated with the persistence of adverse externalities and market failures. Future research in NRM in this direction should focus on understanding the public goods characteristics of environmental investments and identifying forms of interventions that encourage private and collective action by providing the necessary legal, policy, and institutional frameworks.

To enhance adoption and impacts, technology design and development for NRM should primarily aim at improving the livelihood of the people. Participatory and demand-driven approaches that empower local communities and private resource users, and integrate well into existing production systems are very likely to succeed. Failure to recognize these general lessons has delayed progress in reversing degradation of vital life-support systems and attaining sustainable impacts on the livelihood of the poor. Where appropriate and more productive technological options exist, sustainable resource use and management is often hindered by lack of suitable policies and institutional structures that offer inherent incentives for small farmers to undertake profitable investments. The people-centered approach, with its basis in sustainable livelihoods thinking, and the analytical framework developed in this paper, provide a suitable foundation to understand farmer preferences, constraints and investment strategies, and help design better technologies and policies that attain the twin objectives of improving livelihoods and conserving the environmental resource base.

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The semi-arid tropics (SAT) encompasses parts of 48 developing countries including most of India, parts of southeast Asia, a swathe across sub-Saharan Africa, much of southern and eastern Africa, and parts of Latin America. Many of these countries are among the poorest in the world. Approximately one-sixth of the world's population lives in the SAT, which is typified by unpredictable weather, limited and erratic rainfall, and nutrient-poor soils.

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ICRISAT

International Crops Research Institute for the Semi-Arid Tropics
Patancheru 502 324, Andhra Pradesh, India

www.icrisat.org

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