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Agriculture, rural poverty and natural resource management in less favored environments: Revisiting challenges and conceptual issues

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Abstract

There is a continuing debate on the relationship between poverty and the environment. Although many agree on the impacts on poverty of degraded environments, there is less agreement on how this occurs and whether poverty could indeed worsen environmental degradation. Meanwhile, despite continued efforts to enhance agricultural productivity 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 less-favored areas, especially arid and semi-arid regions, where biophysical and socioeconomic constraints limit investment opportunities. With emphasis on the semi-arid rainfed areas of the tropics, this study clarifies the debate on the livelihood-environment linkages in light of the existing theories and empirical evidence; synthesizes major lessons and policy implications; and advances a more holistic conceptual framework for understanding farmer decision behavior, investment strategies and the conditions that may lead to a more sustainable pathway or a downward spiral.

Key words: Poverty, rural livelihoods, natural resources, development pathways, less-favored areas, semi-arid tropics.

Introduction

Degradation of the natural resource base, coupled with high rates of population growth and food insecurity, is a major development problem in the semiarid 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 environments therefore continues to pose enormous challenges to researchers, development practitioners and policy makers.[1]* 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 semiarid 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 slowdown 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. 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, groundwater depletion, deforestation and loss of biodiversity. Along with population growth, lack of effective institutional structures governing property rights in natural resources (land, groundwater, forests) contributed to the 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 [23]. 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 that require more detailed empirical and policy-oriented research in different eco-regions and spatial levels [33, 35].

There are two main diverging views among researchers on the pathways of agricultural change in response to increasing scarcity of productive resources. Boserup[3] 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 [10]. 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 [6, 9]. Today some empirical evidence lends support to Boserup type adjustments [34]; others indicate Malthusian population-environment nexus [6, 8], while several case studies document mixed results [23, 33, 35]. 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 [11, 29]. Although these are important underlying factors that often deter or aggravate the process of ecosystem degradation and agricultural change, very little is known about their implications for technology design and policy formulation in less-favored areas.

This paper revisits some of the ongoing discourse and highlights the challenges and implications for agricultural development, poverty reduction, and sustainable natural resource management in less-favored arid and semiarid rainfed areas in the tropics. It also develops a simplified conceptual framework for understanding the dynamics of poverty-environment interactions and farm household investment behavior. The analysis indicates how favorable policies and public agricultural investments could contribute to poverty reduction and more sustainable intensification of agriculture in less-favored and marginalized areas. The paper is organized as follows. Section two presents a synthesis of the ongoing dialogue on the mechanisms in which poverty, agriculture and natural resource management interact in less-favored environments and identifies 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 and cost-effective conservation technologies with short-term payoffs and livelihood benefits to small farmers. Based on the review in Section two and three, Section four develops an integrating conceptual framework for understanding smallholders' decision behavior 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 in less-favored areas. 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.[2]* Over the decade coving 1990 to 1999, based on the international poverty line (the purchasing power parity adjusted 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 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 by 2015. This compares to the predicted decline in South Asia from 490 in 1990 to 279 million by 2015. Increased globalization and market integration in many developing countries (e.g., India, China, Mexico, Brazil, etc.), and faster economic growth in many regions outside of 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 [38].

The best available data also indicates that the absolute number of the poor is higher in rural than urban areas [36] and the majority of the rural poor live in areas of low agricultural potential [16, 36]. Table 1 shows that about 75% of the poor in developing countries are located in rural areas and about 47% of them are concentrated in less-favored environments, where biophysical and socio-economic conditions limit agricultural productivity. 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 [28] find that, in 1996, three-quarters (995 million) of the poor in the developing countries are concentrated in rural areas. Of the total poor, about 38% (379 million) are found in arid and semiarid regions, about 50% (500 million) in humid and sub-humid regions and the rest in temperate areas (Table 2). The data also indicates that in most eco-regions, the poverty incidence in rainfed areas is higher than in irrigated areas. Although the breadth of poverty is high in irrigated areas in Asia, the relative incidence and severity of poverty is expected to be high in the rainfed and less-favored regions. This is supported by other more recent findings that show a higher poverty incidence in marginal areas at risk from poor soils, low rainfall, and adverse climate change [14].

Agriculture in many developing regions 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 quickly 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

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

Location	Rural areas		Urban areas	Total
	Favored environments	Less-favored environments		
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)**

[a] Poor people defined as the poorest 20% of the total population. Figures in parentheses are percentages.Source: Leonard et al. [16] as described by Renkow [26].

Table 2. The rural poor (millions) in developing countries by agro-ecological zone, 1996 [a].

Eco-region	Developing countries	Asia	Sub-Saharan Africa	Others developing regions
Arid and semiarid	**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**[b]	**629**	**242**	**124**

[a] The poor defined as those subsisting on US$ 1 or less per day.
[b] The total poor in developing countries during the period, including the urban poor, is 1.3 billion.
Source: Compiled from Ryan and Spencer [28] and FAO/TAC database.

pollution through increased accumulation of soil sediments, chemicals and other contaminants may increase the incidence of water-borne diseases. Resource degradation may also increase the labor time needed for household production (and hence the drudgery on women and children) as in fuelwood collection or fetching water from distant locations, and compete with the labor time needed for production and conservation investments. Therefore, if the poor in general are located in areas where land is scarce, agricultural productivity is low and environmental degradation is common [16, 36] and depend for their livelihoods on agriculture, it exemplifies a strong 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 several studies posit a two-way link between poverty and environmental degradation [6, 25].

Understanding the complex mechanisms in which poor people interact with their environment and the associated factors that may lead to sustainable improvement of livelihoods or degradation of the resource base requires a micro level assessment of farm household behavior and investment strategies. Why do we find degradation and poverty co-existing together while communities escape the potential nexus in certain situations? What role do socio-economic and biophysical conditions play in less-favored areas? In order to facilitate this understanding let us consider a stylized situation presented in Figure 1 that depicts household income and poverty profiles as a function of the quality of the resource base and agricultural investments. The resource stock (an index of the inherent quality of the resource) is given in the horizontal axis. To simplify the exposition, the vertical axis represents household income from an average farm size in a given location. The income profile (Y_a) depicts how household income increases with improvement of the quality of the resource stock under the existing production technology. The income profile shifts upward to Y_n if a new more productive (or cost-saving) technology is adopted. The income profile may also shift downwards to Y_d if resource productivity declines due to stress (e.g., droughts). X^m defines the minimum resource stock below which no profitable production would be possible under average growing conditions. Shocks and disasters affect this threshold level. For example, in a drought year the threshold level increases from X^m_a to X^m_d because infertile and shallow soils below this level, for example, lack the moisture holding capacity for a profitable production. Conceptually, technological change may also lower the threshold level (not shown). Let us assume that X^* denotes the average quality of the resource stock on the farm in a semi-arid drought-prone region. Under normal growing conditions, this would provide an income level Y^*_a, which could decline to

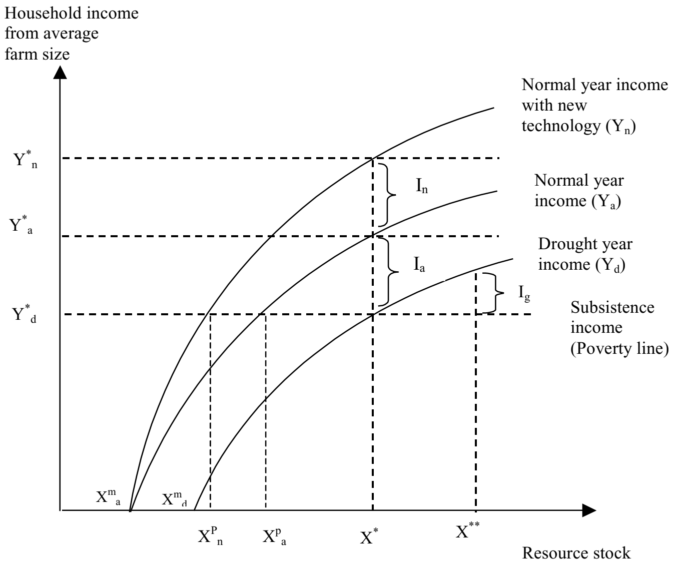

Figure 1a. The effect of resource stocks on household incomes under varying technological conditions.

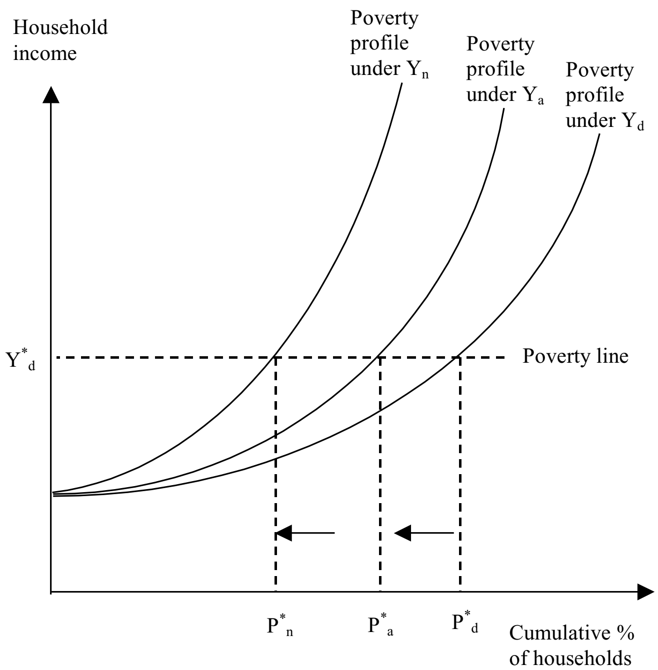

Figure 1b. The effect of resource stocks on household poverty under varying technological conditions.

Y^*_d in drought year or improve to Y^*_n if a new technology is adopted. Alternatively, even in a drought year, with investment in supplementary irrigation, the household could attain an income level of Y^*_a with the existing technology or Y^*_n with the improved technology. Hence, I_a represents the returns to investment in irrigation with current production technologies, which increases to I_a+I_n if the improved technology is adopted.

If the poverty line income is given by Y^*_d, which for simplicity coincides with the drought year income, it indicates the degree of vulnerability of livelihoods in drought-prone regions. Without investment in irrigation or adoption of new technologies, all households with resource stocks below X^* will fall under the poverty line. The resource stock required to escape poverty however decreases from X^* under drought years to X^p_a and X^p_n with investment in irrigation and adoption of new technologies, respectively. With a better resource stock (e.g., X^{**}), the income level attained ($Y_g=Y_d^*+I_g$) even in drought years would be well above the poverty line (Y_d) and hence household vulnerability would be less. Panel *b* depicts a hypothetical poverty profile under the corresponding stock levels and technology scenarios. Under Y_d, the percentage of households possessing resource stock below X^* and falling below the poverty line is given as P^*_d With investment in supplementary irrigation and new technologies, the percentage of these households falling below the poverty line will consistently decline to P^*_a and P^*_n. The poor (with resource entitlements below X^*) escape poverty because investment in irrigation and adoption of more profitable technologies would raise their incomes. However, poverty eradication may not be possible because some households lack productive resources (those with resource stocks below X^p_a and X^p_n) or the very benefits from investment in irrigation and in the new technology may be limited. This stylized analysis shows the crucial role that access to productive resources, appropriate technologies, and investment in small-scale irrigation play in reducing vulnerability to climatic shocks and in increasing the productivity of available resources in less-favored areas.

Nevertheless, escaping poverty (in terms of meeting basic needs) *per se* will not be sufficient to prevent resource degradation. As Reardon and Vosti [25] argue, 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., 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 (welfare poverty). If these arguments hold, some parts of the arid and semiarid tropics, characterized by unfavourable biophysical conditions (like scarcity of water, infertile soils, high disease and pest incidence) and poor socio-economic infrastructure, may exemplify the strong interlinkages that may exist between poverty and resource degradation. Along with the unfavourable biophysical conditions, the peripheral location (remoteness) and low population density in these marginal areas often elevate the per unit investment costs in social services (e.g., roads, education, health).

As conceptualized in Figure 2, the interplay of adverse biophysical conditions, poor market access and inadequate 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 nexus may lead to a livelihood strategy that forecloses future options for sustainable agricultural intensification 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 to generate appropriate technologies, improved market access, and creating opportunities for non-farm employment and out-migration.

However, the relationship between poverty and the

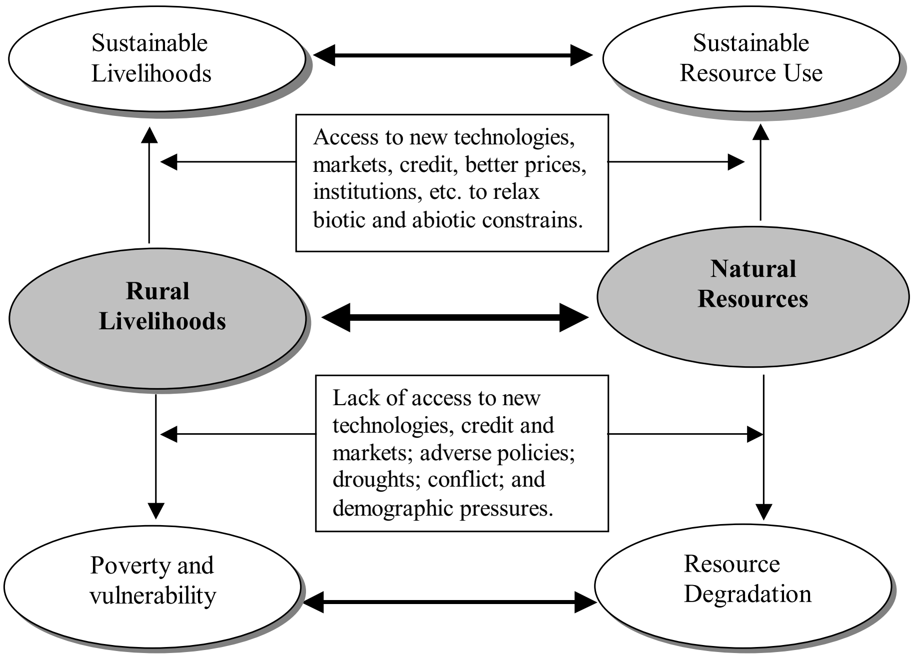

Figure 2. Poverty-environment links in rural areas and the conditioning role of socioeconomic and biophysical factors.

environment is quite complex and not necessarily a downward spiral [29] nor is eradication of poverty 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, growing period, drought, pests and diseases, etc.) and socioeconomic factors (e.g. access to markets, technology, policies, etc.). The type of livelihood strategies that resource users pursue, and the existing market, policy and institutional structures jointly determine the nature of the poverty-environment relationship and outcomes (Figure 2). In certain vulnerable systems, under the influence of demographic pressure and/or lack of access to new technologies and markets, the poverty-environment link may develop into a downward spiral. Degradation of the resources base would further impoverish the poor and curtail the ability to adapt and adopt more sustainable management practices. 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 [11, 29, 33-35]. The upward and downward arrows in Figure 2 depict these two possible outcomes of livelihood-environment linkages.

These lessons indicate that in less-favored areas constrained by socioeconomic and biophysical conditions, 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. This also indicates that the high incidence of poverty in less-favored areas is much less a cause than a consequence of environmental degradation. 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 after 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 local institutions that encourage private and collective action. However, eradication of poverty may not also be sufficient to improve environmental quality and agricultural sustainability. For example, inappropriate intensification, as is the case in many irrigated areas of South Asia, may lead to depletion of groundwater, salinity and water-logging problems that severely diminish the potential of once highly productive lands. This indicates how conducive policies, technologies, and regulatory systems could play a vital role in stimulating more sustainable pathways in the process of poverty eradication and later as rural incomes grow and people move out of poverty.

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 [25]. 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, on the initial quality of resources, on the productivity impacts of degradation, and on 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 access to markets and biophysical conditions [21, 32]. This implies that technology development and intervention strategies for sustainable intensification of agriculture should take into account differences in the biophysical and socio-economic factors in different eco-regions. Below we discuss how risk, markets and policies, property rights, poverty and biophysical conditions determine farmers' technology choices and investment strategies.

Risk: In a risk prone environment, the uptake of new 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[1]. 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. This indicates that choice of technologies and investment strategies will 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. To the extent that 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. To the extent that delayed benefits tend to be uncertain, risk-aversion may also discourage investments that bring benefits in the long term. This shows that increase in yields (and indeed profitability of new options *per se*) cannot be the sole consideration for farmers in making their technology choice decisions. Stability of incomes in the face of pest, disease and drought stresses, and availability and access to inputs needed in the production process are vital considerations for farmers.

Markets and policy: In addition to expected profitability, the functioning of local input and output markets determines the level of use of fertilizer, labor, and other inputs needed in the production process. In dryland 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. Along with chronic poverty, land scarcity, low productivity, and wage differentials are leading to selective flight of male labor out of agriculture to cities and other areas in search of better income-earning opportunities. Although such diversification of livelihood strategies is important, the extent to which off-farm income is re-invested in improving agricultural productivity is not clearly understood. Coupled with the devastating effects of HIV-AIDS and the feminization of agriculture, shortage of agricultural labor is also becoming an increasing constraint in many rural areas of South Asia and sub-Saharan Africa. This indicates to 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 innovations that reduce soil erosion and conserve available water supplies. However, in the absence of alternative soil fertility management practices, removal of fertilizer subsidies and high farm-gate prices for imported fertilizer (often following devaluation) 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 lands. There is evidence showing that the rate of maintenance of investments created through watershed programs decreases with the level of subsidy provided [15]. Unjustified subsidies not only lead to inefficient use of public resources but also encourage farmers to adopt technologies that they do not really want and undermine the sense of ownership required for sustainable maintenance of these investments. 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 develop alternative institutional arrangements (e.g., credit facilities) and incentive structures that encourage cost-sharing and private investments. For example, interlinked policies like cross-compliance mechanisms that link private access to public subsidies with attainment of certain levels of environmental quality and conservation efforts offer promising approaches [31]. 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 [2, 24]. 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 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 for 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 (e.g., India) 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 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 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 bring disproportionately higher benefits to farmers in the lower reaches of the watershed. A related problem is lack of clear rights to groundwater, which *de facto* belongs to the rights owner to the land lying above it. When recharging facilities are under communal ownership, private rights to the recharged groundwater discourage collective action. Unless innovative policy and institutional arrangements are designed to compensate the losers and regulate private harvesting of groundwater, such problems not only undermine incentives for collective action, but also lead to depletion of the contested resource.

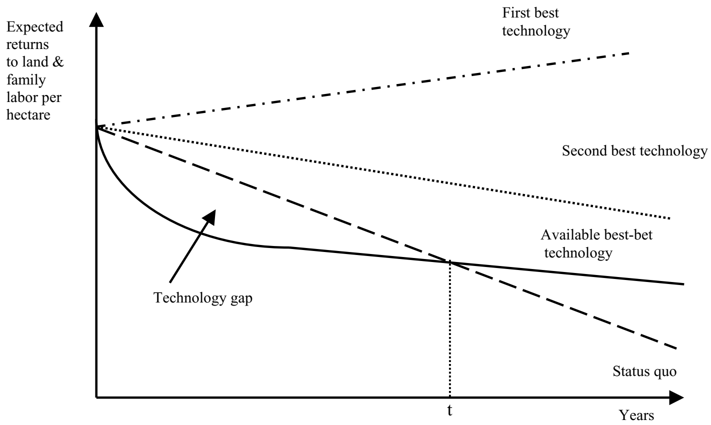

Figure 3. Challenges in the design and development of NRM technologies: stylized flow of on-farm returns to NRM investments.

Poverty and time preferences: As was presented earlier, poverty is one factor blamed for limiting the uptake of more profitable natural resource management technologies. When markets are imperfect, poverty may be associated with high rates of time preference, which may discourage investments with upfront costs but generating long-term benefits [12]. In order to illustrate this, let us consider a hypothetical scenario described in Figure 3. In marginal environments, one may reasonably assume that without resource-improving investments land productivity (returns to land and family labor) will decline overtime. In the absence of external interventions, this may reflect the status quo for many degrading production systems. However, available alternative management systems often require heavy initial investments (e.g., water harvesting and terracing) 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 poor farmers from choosing such new technologies. High 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 3, 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[20, 32].

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 3. First best options, if made available, place the poor on a development pathway that would lead to sustainable intensification and eradication of poverty. Second best options may not be sufficient to reverse the process of degradation, 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[5]*.

***Biophysical diversity**:* 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. For example, in drought-prone semiarid areas with infertile soils and erratic rainfall patterns, risk considerations imply emphasis on water management to reduce vulnerabilities to drought and to increase crop yields. This contrasts with the past overwhelming focus of conservation efforts in many developing countries in providing technical fixes through soil conservation and reforestation programs overlooking water conservation benefits that often provide immediate benefits to the poor. In semiarid 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 [19].

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 post-rainy 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 crosscutting 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 and for most 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. Unless smallholder farmers quickly realize the conservation benefits (in terms of higher incomes and/or reduced variability of incomes), the sustainability of such investments cannot be ensured. Natural resource management research and development efforts in the semi-arid areas should jointly aim at reducing vulnerabilities to production risk and increasing productivity. 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 a careful analysis of the limiting factors and livelihood strategies of local people, will have a better chance of success. Below we develop a holistic analytical framework that integrates the various factors that condition the pathways of change and resource use strategies of smallholder farmers.

Synthesis and Conceptual Framework

The farm household, pursuing certain feasible livelihood strategies, is the ultimate decision maker on how and when to utilize natural resources to attain preferred objectives. The challenge is in understanding the behavior of the resource user in terms of his/her production, consumption and investment decisions and the most important factors that drive such decisions. In the context of multiple outcomes and pathways that are possible, how could policy makers, analysts and development practitioners motivate and tailor farmer resource use, production and investment strategies towards win-win pathways that reduce poverty and enhance future production possibilities? In the light of the complex issues (discussed above) that influence farmer resource use and investment behavior, this requires a more holistic analytical framework which accounts for the crucial role of socioeconomic and biophysical factors. The conceptual framework developed here captures the intertemporal decision problems across alternative livelihood options (crops, livestock, and non-farm diversification) and on-farm investment choices that resource users face at each period and the consequences of these livelihood strategies on the quality of the resource base (Figure 4). The pattern of change in the quality of the natural resource base and the associated livelihood strategy would determine the poverty-environment link and the evolution of the 'development pathway' in subsequent periods.

This conceptual framework builds from the sustainable livelihoods principle which places people at the center of analysis [4, 5]. It however extends the livelihoods framework by incorporating important elements from the theory of farm household behavior and market imperfections[7], the economics of rural organization [13] and the theory of institutions and institutional change[18]. Unlike the livelihoods framework, which mainly sets out a set of principles or development objectives, the framework developed here is more complete, analytical and suitable for setting out testable hypotheses in development research. It further enriches and extends the livelihoods

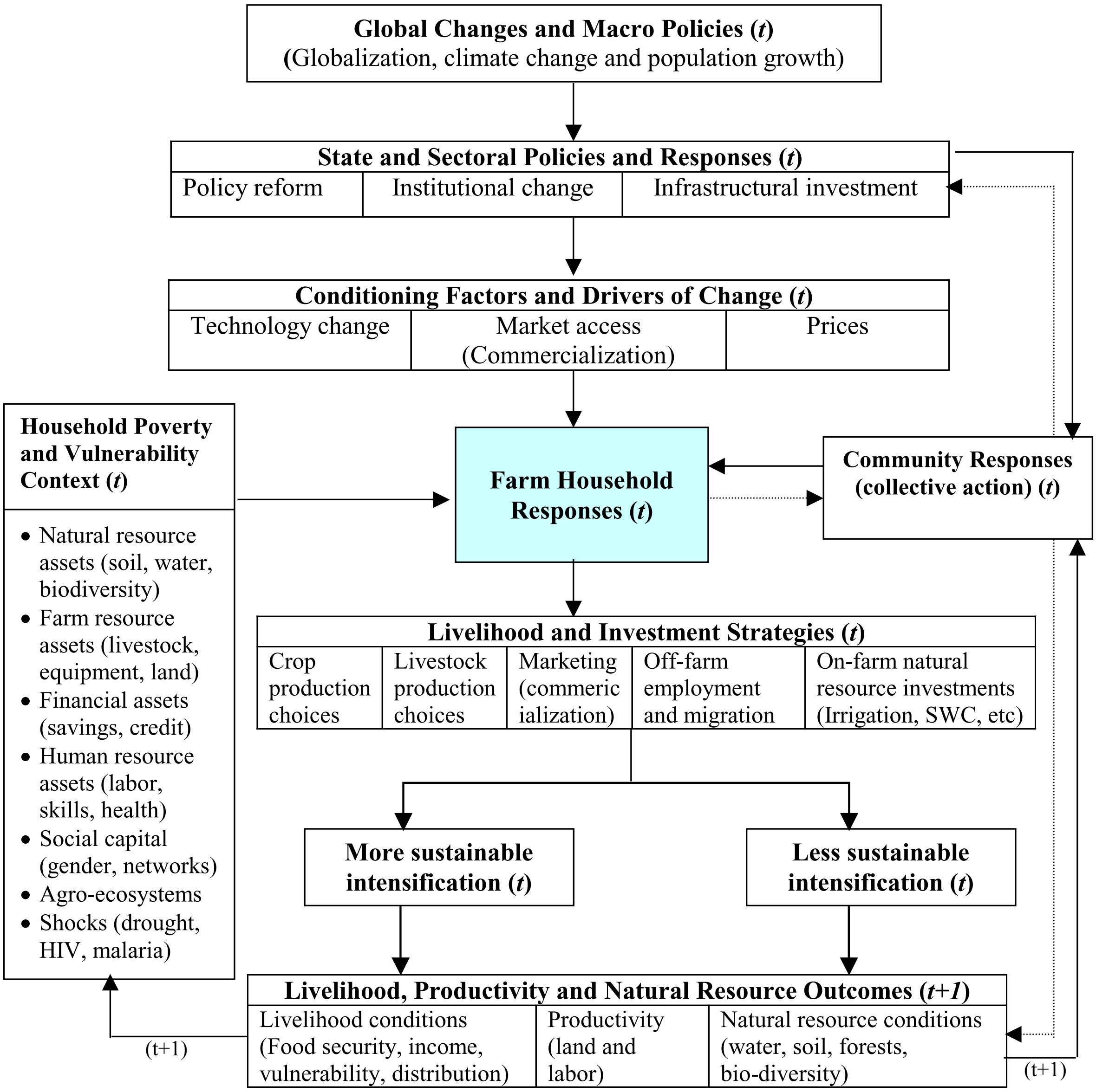

Figure 4. Analytical framework for understanding farmers' resources use decisions and the pathways of change in a dynamic perspective.

framework 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[25]). This kind of interfacing of different analytical approaches and the explicit linking of economic and biophysical information is essential for understanding 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 [27, 30]. Unlike many previous studies, the conceptual framework clearly recognizes and places household decision making in the context of the evolving global, national and local policies and institutional changes that shape production and investment opportunities available to the poor. It provides an interdisciplinary and dynamic perspective to technology design and development efforts targeting poverty reduction and sustainable natural resource management in agriculture.

In making their production and investment decisions in each period, farm households attempt to maximize their livelihood security (expected utility) over a period of time based on existing resource assets and expected shocks that jointly determine the vulnerability context. These decisions are conditioned and mediated by the prevailing socio-economic and policy environment, including sub-national and sub-sectoral policy changes and responses to shifts in global and macro policies, transmitted to the local level through policy reforms, institutional changes and infrastructural investments that in turn determine input-output prices and access to new technologies and markets at the local level. The extent to which global changes (e.g., effects of globalization) and macro policies are transmitted to the local level depends on trade policies, the extent of market integration and governance structures in a given context. Other global and national changes like the effects of climate change and population growth transmitted through non-market channels could however have direct effects at the local level. In some situations, farm households and communities (as shown by the broken lines) may be able to have some influence on the shaping of sub-national and sectoral policies that affect their livelihood and investment strategies. When feasible, collective action by the community may further enhance and supplement individual production and investment decisions.

The diversity of household assets and the prevailing biophysical and socioeconomic environment therefore jointly determine the livelihood options and investment strategies available to farmers. Access to markets (including output, credit, input markets), appropriate technologies, and the input and output prices 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 local markets determines access to credit that will help relax the capital constraint and the level of use of productive inputs (e.g., fertilizer and high yielding varieties). The perception of risk and expected returns from investments in new technologies and productivity enhancing inputs will in turn determine the choice of the livelihood strategy and the level of adoption of available technologies.

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 [7]. Likewise, when transaction costs are low and access to local markets is high, households will have an option of hiring in additional labor when needed or the opportunity to earn income from off-farm employment. The returns to family labor in agriculture and other non-farm activities would determine the amount of family labor allocated between agriculture and other diversification options (e.g., migration and small business). Poor rural households without sufficient productive resources other than their own labor often work as agricultural laborers or engage in non-farm livelihood strategies (including migration). In extreme cases, these vulnerable groups may depend heavily on exploitation of open access local resources (e.g., fishing, charcoal and fuelwood production), which may lead to resource depletion and degradation of local commons.

Moreover, when more profitable resource conserving or improving technologies are available and capital and institutional constraints are not limiting, farm households may undertake productivity enhancing resource investments. Enabling policies (e.g., secure rights to land and water), access to markets and institutional arrangements (e.g., credit services and extension systems) create incentives to invest in options that expand future production and consumption possibilities. Such resource improving and productivity enhancing investments provide opportunities for intensification of agriculture and diversification of livelihood strategies that will help combat degradation of the resource base. Depending on the livelihood strategies followed, there may be several such trajectories representing the more sustainable intensification pathway. This will in turn determine the livelihood conditions of the poor and natural resource outcomes in the next period (*t+1*). The improved level of well-being and natural resource conditions at the end of the first period (t) will in turn enhance the stock of livelihood assets available for production, consumption and investment decisions in the subsequent periods. This shows how the interplay of biophysical and conducive socioeconomic conditions creates the potential for de-linking the poverty-environment nexus and how the downward spiral can be avoided.

On the other hand, when the socio-economic 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. The interface of lack of viable technological options and adverse biophysical, policy and institutional environments, may force smallholder farmers in marginal areas to practice a more exploitative and unsustainable livelihood strategies. There may also be several such trajectories leading to the less sustainable intensification pathway, 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 resource extraction may lead to initial economic growth, failure to invest in maintaining productivity could lead to eventual depletion of the life-support system. In some cases, the increased income from depletion of some natural resources may be reinvested in other income-generating options that enhance future possibilities. Therefore, resource degradation or depletion should not necessarily lead to a downward spiral.

In sum, this holistic conceptual framework is able to help us understand the complex factors and processes that determine resource use patterns and livelihood strategies of rural households, and the policy relevant factors and incentive structures that may be employed to promote more sustainable resource use in less-favored areas with high poverty incidence. It could be conveniently applied to explain diverging development experiences and outcomes documented in several case studies on the interaction of poverty and resource use patterns. It also helps us understand why a poverty-environment nexus is not the rule and how the interplay of new technologies, enabling policies, and access to markets and institutions can lead to win-win options for poverty reduction and sustainable intensification of agriculture in less-favored and marginalized 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. In the face of 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 polices, 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 behaviour 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 semiarid 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 semiarid 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 favourable policies; improved access to markets, health, education, new technologies, and institutions; and alternative livelihood diversification opportunities for the poor.

Poor people's economic incentives to invest in protecting or expanding their environmental entitlements depend on a host of factors that include 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. Technology design and development for natural resource management should, however, primarily aim at improving the livelihood of the people. Participatory and demand-driven approaches that empower local communities and private resource users, and well integrated 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. This is especially the case in the less-favored areas of the arid and semi-arid tropics where unfavorable policies, lack of markets and institutional structures prevent small farmers from undertaking profitable resource improving investments. The

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[1]* Following Pender and Hazell [21], we define less-favored environments as areas with relatively low agricultural potential often overlooked or neglected by socio-economic investments in the past as well as areas of good agricultural potential but have limited access to infrastructure and markets.

[2]* Many studies rightly argued for a broader concept of poverty going beyond the scalar indicators of income and asset poverty. 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 cannot be a single indicator for the "environment"; natural resources (like soil, water and agro-biodiversity) that provide livelihood support functions may have a number of multi-dimensional indicators.

[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.

[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=0.76) between per capita income and ESI and a negative correlation with share of GDP from agriculture (r=-0.48). Furthermore, many of the countries with arid and semiarid environments fall at the bottom of the rank[17].

[5]* 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.

analytical framework developed in this paper provides a suitable foundation to understand farmer decisions and investment strategies in a broader perspective, and help design better technologies and policies that attain the twin objectives of improving livelihoods and conserving the resource base in many vulnerable and marginal environments.

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