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SEARCHING FOR EXPLANATIONS FOR THE RESOURCE-POVERTY NEXUS

CHAPTER 1

ECONOMICS OF POVERTY, ENVIRONMENT AND NATURAL-RESOURCE USE

Introduction

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INTRODUCTION

Reduction of poverty is a tremendous and persistent challenge for the global community. Although everyone agrees on the goal of poverty abolishment, policies often remain controversial or ineffective. Indeed, there is continual debate about which policies will be effective in different settings. Given that livelihoods of millions are at stake, there is an urgent need to reconsider the causes of and the remedies for poverty.

Poverty and its reduction are often linked to the natural-resources base (Adams et al. 2004; Sunderlin et al. 2005; Millennium Ecosystem Assessment 2005). Grazing lands may be overused, private plots suffer from a lack of fertilizer and accelerated loss of topsoil, artisanal fisheries are under pressure from local population growth and the incursion of near-shore commercial vessels, landlessness in many countries pushes the poor into indigenous forests – leading to increased rates of land clearing. Shortages in local fuelwood supplies place increased

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importance on the need for better management arrangements for non-traditional forest products. The quality and bounty of the local environment certainly affect living conditions of the poor, and their poverty is often seen as a contributing factor to the degraded condition of the local environment. Teasing apart the direction of causality in this resource–poverty nexus is a serious empirical challenge. What is not in doubt is that livelihoods cannot be improved if the local settings and circumstances remain degraded. It is equally likely that local environmental conditions cannot be improved if most people are living at the very margin of survival. Moreover, it is clear that many poverty reduction efforts will fail if the environmental effects are neglected (Adams et al. 2004).

This book contributes to an improved understanding of the economic dimensions of environmental and natural-resource management and poverty alleviation. In this introductory chapter we offer a brief overview of current knowledge concerning the relation between poverty, environment and natural-resource use. We discuss a number of the causes of the poverty–resource degradation relation that are most often cited in the literature. In addition, we consider some of the comments on these causes and present alternative viewpoints and policy advices. Finally, we offer a brief summary of the papers included in this volume and discuss how those chapters contribute to the discussion on the resource–poverty relation.

THE RELATION BETWEEN POVERTY, ENVIRONMENT AND NATURAL-RESOURCE USE

The nexus of environment and poverty is especially strong in developing countries. The economic well-being of many (especially rural) households directly depends on the quality of the environment and on the availability of natural resources. Especially for low-income countries, a substantial percentage of national income and an even larger share of the active population directly depend on agricultural, forestry and fisheries resources. Moreover, the use of natural resources often carries a high opportunity cost in terms of time required to obtain access to water and firewood – time that could otherwise be devoted to agricultural production. Moreover, poor water quality can lead to frequent illnesses. Where political pressure is strong to protect biodiversity, agricultural production may suffer.

In the literature, a multitude of reasons are advanced for the importance of the resource–poverty nexus. Some common arguments include erosion due to deforestation, contamination of drinking water by agricultural chemicals, depletion of groundwater aquifers, and excessive harvesting of near-shore fish stocks. These circumstances then directly affect income levels of the poor. Second, when national governments and international donors put pressure on the rural poor to alter their use of the natural environment, the income effects can be severe. Third, and often mentioned as one of the most important reasons for resource degradation, communal ownership and management may be identified as contributing to what is often – incorrectly – referred to as ‘tragedy of the commons’ (Bromley 1991). As a result, uncontrolled resource use is said to have important adverse environmental effects. The incomes of the rural poor are often inordinately dependent on land, water, forests and fisheries in settings of increasing population pressure on these resources. When social conventions (institutions) make it difficult to exclude additional claims on fragile natural resources, it is inevitable that resource degradation will set in. In some cases, use rights may be strengthened if the land is properly managed, thereby giving farmers an incentive to invest in erosion prevention or soil fertility management. In other cases, however, fallowing is discouraged as population pressure increases the demand for arable land (see below for a more elaborate discussion on these issues). Coordinated management and robust compliance protocols are required if degradation is to be stopped.

There are, however, many examples of well-managed communal resources (Ostrom et al. 2002; Ostrom et al. 1999; Bromley 1992). But when natural resources are available to all who wish to use them, problems are sure to arise. In this context, it is important to be clear as to which policy failure is the essential reason for resource degradation. It is common to focus on 'missing property rights' but it is equally true that efforts to alter degradation or stimulate development are often frustrated by missing or flawed credit markets, input and product markets that function badly, corruption, well-meaning but ineffective governments, and poor enforcement of existing laws and regulations. The increased pressures from a globalizing economy also figure in here[1]. The point here is that it is often too easy to blame property-rights problems when in fact a number of institutional failures serve to hamper the economic prospects of the poor.

Due to the complex, two-sided character of the resource–poverty nexus, the most promising strategies for poverty alleviation and environmental conservation are those that seek to integrate both dimensions. We will discuss the issue from two sides. One approach concerns to what extent payments for environmental services can be an effective tool for stimulating sustainable resource use and poverty alleviation. The other side of the debate concerns alternative strategies to break the land degradation–poverty cycle. Because of the site-specific nature of agricultural conditions, demographic circumstances, climatic variation, cultural and political specifics, and specific market settings, it is not possible to prescribe one, all-encompassing recipe to stimulate soil quality maintenance (Foley et al. 2005; Pascual and Barbier 2006). The same complexities impede universal guidelines for land use, forestry, and water quality concerns. As we cannot discuss all elements in this volume, we only concentrate on the two themes mentioned above.

ARE PAYMENTS FOR ENVIRONMENTAL SERVICES EFFECTIVE FOR REDUCING POVERTY?

In the last decade, based on the idea that new conservation policies should be developed, the concept of Payments for Environmental Services (PES) emerged as a more direct conservation approach. The core idea is that beneficiaries of environmental services pay others for adopting resource uses that secure ecosystem conservation. Beneficiaries' willingness to pay stems from private preferences (e.g., eco-tourism or reduction of pollution), national or international public preferences (e.g., protection of species) or international policies (e.g., carbon sequestration in forests) (Wunder 2007).

Payments for environmental services are often characterized as a cost-effective means to internalize both the negative externalities of resource extraction and the positive externalities provided by ecosystems (Kosoy et al. 2007). Usually, PES schemes compensate those providing positive externalities or those agreeing not to generate a negative externality. This is in contrast to the ‘polluter pays’ principle, in which those causing negative externalities should pay for the damage caused (Pagiola et al. 2005). The theoretical foundations of PES schemes stem from acceptance of an insight from the Coase theorem (Coase 1960), that when transactions costs – information costs, contracting costs and enforcement costs – are zero, there could be no Pareto-relevant externalities since they would all be costlessly bargained away. When bargaining is costless, either outcome is deemed efficient since the direction of payment will not matter. But of course, transaction costs are never zero, and the market for bargaining cannot possibly be considered costless. With this dose of reality, the Coase Theorem is of great novelty in theory, but of limited use in practice (Dahlman 1979). An additional practical problem is that the ‘polluter pays’ principle is difficult to apply to non-point pollution because often the very poorest individuals are dependent on land that may be suitable for producing environmental services. To be efficient, PES schemes should fulfil two conditions. First, compensation to resource users should at least equal the opportunity costs of the resource use. Secondly, payments should not be higher than the economic value of the environmental externality (Pagiola et al. 2005). This assures that both providers and receivers of payments will be better off and that both will in principle voluntarily participate in the program, at least when compliance is assured. A large strand of literature exists on valuing environmental services, which is necessary in order to determine the correct level of payments (see e.g. Carson et al. 1996; Garrod and Willis 1999; Montgomery et al. 1999). A practical issue concerns the reference level that shall anchor in which direction payments should flow (see Bromley 2000). By reference level we mean what is the ‘correct’ level of some environmental service so that we will know if the individual is adding environmental services over-and-above that level – in which case a payment might be warranted, or if the individual is responsible for a degradation in that reference level – in which case the ‘polluter pays’ principle would be appropriate. Moreover, these reference levels may shift over time and it is too easy to become paralysed by ‘policy lock-in’ (Bromley 2007).

While there is growing interest in PES schemes, experience is still scanty. Some Latin American countries are trying such programs, with Costa Rica being a prominent example. So far, the literature evaluated only a few such programs (see e.g. Sierra and Russman 2006; Pagiola et al. 2005; Zbinden and Lee 2005; Grieg-Gran et al. 2005). Detailed discussions of possible PES schemes are rare (see Landell-Mills and Porras 2002; Mayrand and Paquin 2004), but from the scattered evidence it seems that environmental and poverty effects are rather mixed. The most common PES schemes can be classified into four types (Wunder 2005; 2007):

- Carbon sequestration and storage, which includes long-term storage of carbon in woody biomass and soil organic matter;
- Watershed protection, concerned directly with the provision of sufficient and good-quality water;
- Biodiversity conservation, concerned with all processes that determine and maintain biodiversity at all levels; and
- Preservation of landscape beauty.

Water services are common in PES programs – particularly those oriented to the relation between upstream agricultural and forestry activities and downstream water quality. A number of PES programs seek to increase downstream water availability by increasing upstream forest cover – though scientific evidence on this relation is weak (Kosoy et al. 2007). For water quality management, other payment mechanisms, like water pricing, may be a more appropriate tool to get the incentives right.

Since many of those who might receive PES are poor, it would seem that PES schemes can reduce poverty and improve environmental conditions (Landell-Mills 2002). Those PES programs aimed at watershed protection and biodiversity conservation are usually expected to be beneficial for the poor. This is because poorer households are often relegated to steep upland sites that are ecologically sensitive (Sunderlin et al. 2005). If the poor are prevented from gathering fuelwood, or if their standard swidden agriculture is prohibited, it would seem that some compensation is called for. In addition, if their colonisation of new lands is prohibited in order to protect watersheds or biodiversity, some economic retribution seems particularly justified. Pagiola et al. (2005, p. 248) warn, however, that "PES programs are not a magic bullet, but there can be important synergies when program design is well thought out". But, as with all such schemes, the specifics are essential. If PES programs are oriented towards well-specified environmental services, it might mean that those living in a particular area – even if not necessarily the poorest – will benefit. Moreover, if PES programs limit access to communal land or reduce land-tilling activities, the landless may be affected most and may not be compensated for their losses. That is, landowners may reap significant benefits from PES schemes, at the expense of the landless. In the best of circumstances, say with carbon sequestration, it might be possible to enhance sustainable forestry, contribute to carbon sequestration, and to help alleviate poverty. The evidence seems to suggest, however, that PES programs under the Clean Development Mechanism (CDM) of the Kyoto protocol will be more cost-effective in large-scale industrial plantations due to the high transaction costs and institutional problems in community-based CDM projects in poor communities (Minang et al. 2007; Smith and Scherr 2003). This problem with small-scale projects may also extend to other PES schemes, although clear evidence is still scarce.

Successful implementation of PES programs is hindered by a number of problems, including uncertain or inequitable land tenure, problems with contract monitoring and enforcement, missing information, and the lack of non-agricultural investment and employment opportunities (Ferraro and Kiss 2002). In addition to PES schemes, other creative approaches are needed that will enhance sustainability and also reduce poverty. Ecotourism is a common approach (Neto 2003; Uddhammar 2006). Such developments may encourage environmental conservation and also generate additional jobs and income (Wunder 2000). However, Kiss (2004) argues that in many community-based ecotourism projects, the areas conserved are small, few people are involved, earnings are limited and linkages between biodiversity gains and commercial success are weak. Moreover, the level and distribution of benefits depend on many factors, and for most participants, agricultural and forestry activities remain an important source of income (Wunder 2000). Ferraro and Kiss (2002) and Ferraro and Simpson (2002) argue that, especially when conservation is the main objective, directly paying for ecosystem conservation (i.e. PES programs) is more cost-effective than encouraging commercial activities such as eco-tourism. However, they ignore transaction costs and other policy failures. Moreover, they argue that the community development and spill-over benefits of indirect approaches such as eco-tourism will be rather limited, even though that may be a more important objective for eco-tourism projects than biodiversity conservation.

DO SHIFTS IN LAND USE AGGRAVATE OR AMELIORATE POVERTY?

"Land use presents us with a dilemma. On the one hand, many land-use practices are absolutely essential for humanity, because they provide critical natural resources and ecosystem services such as food, fibre, shelter, and fresh water. On the other hand, some forms of land use are degrading the ecosystems and services upon which we depend" (Foley et al. 2005, p. 570). The relation between land use, land degradation and poverty has been extensively analysed. Two main perspectives have emerged for explaining the causes and consequences of land degradation (Pascual and Barbier 2006). On the one hand, the Malthusian explanation argues that due to increasing population pressure, fallow periods are shortened and this results in a vicious cycle between land degradation and poverty. This trades short-term increases in food production for long-term losses in ecosystem services, many of which are important to agriculture (Foley et al. 2005). On the other hand, the Boserupian argument is that population pressure and declining yields will induce farmers to intensify land use. More fertilizers, pesticides, high-yielding varieties and land management techniques will be used to maintain soil fertility and to replace fallowing periods, which will lift farmers out of their chronic poverty situation. An additional argument put forward in the literature reminds us that the land use–poverty relation is affected strongly by the institutional set-up of rural economies (Panayotou 2000; Pascual and Barbier 2006) and opportunities and constraints created by markets and global factors (Lambin et al. 2001). Institutional factors, such as land tenure, land and labour constraints, and uncertainty in factor, product, and capital markets will affect farmers' land conservation strategies and incentives and affect their willingness to adopt improved production techniques (Panayotou 2000; Lambin et al. 2001; Ruijs et al. 2004; Barbier 1997; Maatman et al. 2002). The risk of low crop yields may seriously hamper the ability of farmers to borrow funds to improve land quality. In many African communities effective interest rates for small-scale farmers may be extremely high. Other factors that affect land management decisions include cultural, demographic and urban labour demand.

Barbier (1997) and Pascual and Barbier (2006) conclude that both the Malthusian and the Boserupian hypotheses are valid, but that the specific relation depends on the institutional set-up. Both conclude that differences in opportunity costs of labour or political and market power will induce the poor to extensify agriculture as a response to increasing population pressure. The better-off farmers will choose intensification and they use their superior position to ensure access to better resources. Improving off-farm labour conditions may help breaking the vicious degradation–poverty cycle. Lambin et al. (2001) conclude that population pressure may result in a 'stressed' system with declining yields and under-investments in terraces, irrigation and land degradation. Another response, however, may be intensification and increasing commercial output as well as diversification strategies by households including migration and off-farm employment. Views on reasons for and effects of migration differ somewhat between the approaches adopted. Roughly, two perspectives are popular: the Todaro-type models focusing on the individual's decision to migrate, and the 'new economics of migration' explanation focusing on the family as decision unit (De Haan 1999; Taylor et al. 2003). An extensive literature review by De Haan (1999) shows that reasons for migration as well as the effects on rural areas and poverty are very much context-dependent, depending on, among other things, aspects such as seasonal movements, educational levels of migrants, length of time spent away, assets and social structures and institutions.

SOME GENERAL OBSERVATIONS ON THE LINK BETWEEN POVERTY AND NATURAL-RESOURCE USE

A few general observations on the linkages between poverty, the environment and natural-resource use can be made. First, institutions matter! Irrespective of the instruments adopted or objectives of intervention programs, if institutions are malfunctioning, objectives will not or only partly be obtained. Well-functioning credit, product and labour markets, effective monitoring of rules and regulations, proper enforcement of policies and secure land tenure are of utmost importance. A complexity is that improvements of institutions in a second-best world may work counter-productive. For instance, allocation of individual land rights to farmers in a situation with imperfect capital markets may induce subsistence farmers to sell their land to large, wealthy land owners. Communal PES schemes for forestry management may fail due to free-rider behaviour by a few participants if proper monitoring of contracts is absent. Correct institutions are necessary to give farmers and landowners the correct opportunities and let incentives work the way they are intended. There still is a large gap in the economic literature on which institutions exactly are important, how they should be organized and whether they will lead the poor out of the poverty trap.

Secondly, large differences can be observed between continents, countries and even within regions. Due to a large array of environmental, climatological, cultural, economic and other reasons, it is difficult to derive general relations between poverty and environmental conditions and to formulate general guidelines on how to break the environmental-degradation–poverty vicious cycle. Moreover, even though much is known on how ecosystems function and how environmental conditions affect economic developments, still a lot of scientific evidence on ecosystem functioning and environmental interlinkages is missing. This makes developing effective policies a complex task, as successful interventions in one location may be counterproductive in other locations. It can be questioned, however, whether it will ever be possible to formulate generic policies that can be applied with disregard for the specific circumstances. For that reason, more knowledge is needed on robust decision making under limited information and under uncertainty.

Thirdly, the above exposition shows that it is often difficult to exploit synergies and reach a win-win situation. Simultaneously reaching multiple objectives may be hard as objectives may be (partly) conflicting, especially in case of missing institutions. Although in theory it may be possible to create synergies, in practice it is often hard to reach multiple objectives with a single policy instrument. It is important that an integrated approach is adopted in which problems are analysed from different angles and by different disciplines and that, as much as possible, indirect effects of envisaged programs are considered.

OVERVIEW OF THE BOOK

Each of the chapters of this book reviews an element of the resource–poverty nexus from a different viewpoint. The book has been divided into three parts.

Part I contains, next to this introductory Chapter 1, two chapters that provide a more theoretical exposition on the relation between resource use and poverty. In Chapter 2, *Barrett* provides an overview of one of the essential issues under discussion here – linking economic decision making with ecosystems analysis (i.e. welfare dynamics with resource dynamics) – to explain poverty traps. Poverty traps are situations where people cannot get out of an equilibrium (or steady state) that has a low level of well-being. This can be explained by (i) the original Ramsey-Cass-Koopmans growth model for an entire population; (ii) by distinguishing groups of individuals with similar characteristics, where some groups may get stuck in a poor equilibrium (club convergence); (iii) thresholds and multiple equilibria for each individual (possibly in combination with (ii)). The third case is the most interesting. As pointed out above, possible causes for multiple equilibria are (i) market imperfections in combination with credit constraints; (ii) imperfect learning and bounded rationality; and (iii) co-ordination and institutional failure. The dynamics of welfare and resources are not only linked through the assets of the household, where poor households are heavily linked to natural resources, but the causes of poverty traps also extend to the natural-resource base. Barrett illustrates these links with detailed examples for various regions and resources. He concludes that intervention is essential to get away from the poverty trap and most likely also to avoid ecosystem collapse. Appropriate interventions are however difficult to design, due to the multiple causal mechanisms of poverty traps.

In Chapter 3, *Hellegers, Schoengold* and *Zilberman* investigate reforms of policies and incentives to improve water resource management. They place special emphasis on distributional issues, i.e. the link between water policies and poverty. They identify four main types of reforms that are required: (i) rules to improve design of and decision-making process about water project development and maintenance; (ii) principles to improve water allocation and pricing, which includes full marginal cost pricing, block-rate pricing and cap and trade systems; (iii) incentives for water conservation; and (iv) incentives to improve water quality. Furthermore, changes will be necessary in conveyance management, groundwater management and tradable water rights in order for these reforms to be efficient. The authors go on to stress the link between water use and energy use, and argue that increased scarcity of energy will impact water not only through higher production costs, but also through increased water demand from alternative fuels. They conclude that while the distributional effects can be problematic in the short run due to higher water prices, there are substantial positive effects in the long run, including better access to water and more sustainable use of water resources.

Part II of the book deals with payments for and values of environmental and forestry resources. The part opens with a contribution by *Meijerink* on Payments for Environmental Services (Chapter 4). Meijerink argues that both goals of PES systems, i.e. providing additional income to the poor and maintaining environmental services, are difficult, if not impossible, to measure and often payments are not made dependant on the quality of the service provided. Thus, good indicators to measure and monitor contributions to these goals are essential. Through extensive literature review and systematic analysis she derives that different institutional arrangements for monitoring are required for successful implementation of different types of PES schemes, taking transaction costs, including monitoring costs, explicitly into account. Several moral-hazard problems may arise that have to be dealt with in the design of the scheme; these depend on (i) the type of environmental service provided (and the underlying production process); (ii) the extent to which the environmental service can be freely observed or measured; (iii) the extent to which activities of the resource managers, who provide the environmental service, can be freely observed; and (iv) the extent to which the outcomes are determined by the production process or by natural processes (such as climate).

Chapter 5, by *Sarr, Boncoeur, Cormier-Salem* and *Travers*, looks at another financial instrument for environmental policy. They investigate whether non-extractive use of a resource, in this case ecotourism, can provide the economic incentives to overcome the ‘tragedy of the commons’ caused by the extractive use of the resource (in this case artisanal fishing). An empirical survey of the Saloum Delta in Senegal shows that demographic pressure and agricultural crises have led to substantial over-fishing. Furthermore, Sarr et al. use a bio-economic model to show how ecotourism and artisanal fishing are interlinked through the use of a common resource and as fishing entails a negative externality on ecotourism, interventions are needed to limit fishing and stimulate ecotourism.

The links between poverty and deforestation are explored by *Pfaff, Kerr, Cavatassi, Davis, Lipper, Sanchez* and *Timmins* in Chapter 6. They review various theories on how income changes affect forest clearing and, as the theoretical results are ambiguous, examine the net impact in a time-series case study on Costa Rica. Using data for four decades, they estimate that, on balance, poverty is not significantly related to deforestation. They show, however, that this result is the combined effect of two significant effects: (i) marginalized lands are cleared less rapidly; and (ii) poorer areas tend to be cleared more rapidly, if these location differences are controlled for, as the location differences imply that the poorer appear to have more marginalized land. The latter effect is less strong for the poorest areas, and in these areas deforestation responds less to changes in land productivity.

Chapter 7 also looks at the link between deforestation and poverty. In their contribution, *Chukwuone* and *Okorji* use contingent valuation to estimate the willingness of households in forest communities to pay for the protection of non-timber forest products through systematic management of the forest. Their case-study area is the rainforest region in Nigeria. Non-timber forest products, especially food, fibre and herbal medicines from flora and fauna species, provide a substantial source of income for many households. The authors use a two-step approach to show that females have a higher willingness to pay (WTP) for community forests than males. This is not surprising since collection of non-timber forest products is mostly carried out by women. Similarly, having more females (males) in the household also increases (decreases) the WTP. Furthermore, farmers and middle-income households have a higher WTP, increased education (years of schooling) has a positive impact and distance to the source a negative impact. The average willingness to pay equalled around $4.50, but the authors also observe a significant and positive starting-point bias, which limits the numerical interpretation of their results.

Part III of the book, on sustainable land use, commences with two investigations of sustainable land use in the upland Philippines. In Chapter 8, *Omura* examines whether traditional, or indigenous, informal institutions encourage or hinder sustainable management of agricultural land. She finds that traditional institutions, especially access to the exchange-labour system, and informal credit can be effective in maintaining the land resource. Construction activities and adoption of sustainable techniques are significantly and positively related to property-rights strength. As technique adoption is also significantly and positively related to restrictions of property rights, the author concludes that moderate restrictions on property rights encourage adoption of sustainable techniques, although her conclusions may hinge on the limited definition of property-rights strength used in the paper. Other informal institutions, such as the presence of a traditional authority, and several household characteristics are found to be of less significance.

In Chapter 9, *Romero* and *De Groot* use similar econometric techniques to examine incentives to invest in land quality. Rather than the destructive slash-and-burn technique that is often applied, farmers can invest in terracing, contour bunds, (sprinkler or channel) irrigation, agro-forestry and/or tree plantation. Regression analysis of their survey reveals that investments in land quality significantly increase with the age of the household head, indicating life-cycle effects. More knowledge of sustainable techniques, availability of non-farming income and village-level characteristics are also significant. Contrary to the Boserupian hypothesis, Romero and De Groot do not find a significant impact of population density.

The last chapter (10) in the book, by *Mensah-Bonsu* and *Burger*, deals with the important issue of migration. They formulate a bargaining model of migration where individuals will migrate only if their remittance is larger than their contribution as resident household member: this ensures that both the migrating individual and the remaining household are better off. Using cross-sectional data from Ghana, they test their model using regression analysis. They find that per-capita farmland size and local employment conditions reduce the probability of migration and, apart from the migrant's sex, age and educational level, more livestock sales of the farm significantly influence remittances. Mensah-Bonsu and Burger cannot validate the core of their theoretical model, however, because they cannot find a significant effect of land quality on migration – or on remittances. It is clear though that migration is a response to overpopulation (which implies, among other things, smaller farmland sizes) and a lack of non-farm economic activities in the region.

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NOTES

[1] These include, e.g., large, internationally operating fishing vessels pushing local fishermen to smaller and near-shore fishing grounds, growing cattle ranches and soybean and sugarcane plantations forcing subsistence farmers to clear more remote forest fields, and ever-increasing urbanization causing an increased demand for water and staple food forcing farmers to invest in more efficient irrigation and cultivation systems.

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CHAPTER 2

POVERTY TRAPS AND RESOURCE DYNAMICS IN SMALLHOLDER AGRARIAN SYSTEMS

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Abstract. Poverty traps and resource degradation in the rural tropics appear to have multiple and complex, but similar, causes. Market imperfections, imperfect learning, bounded rationality, spillovers, coordination failures and economically dysfunctional institutions all play a role, to varying degrees in different places and times. Pinning down these mechanisms empirically remains a challenge, however, but one essential to the design of appropriate interventions for reducing poverty and environmental degradation in areas where livelihoods depend heavily on natural resources.

Keywords. development; feedback effects; multiple equilibria; resilience; stability

INTRODUCTION

The words 'ecology' and 'economics' originate from the same Greek root, *oikos*, meaning 'household' or 'estate', with 'eco-logy' concerned with study of, and 'eco-nomics' with management of the complex aggregate. This common etymological root suggests deep connections between the two disciplines.

Take, for example, the burgeoning literatures in each discipline on thresholds and multiple dynamic equilibria, often referred to as 'stable states'. In this context, multiple equilibria refers to the situation in which different initial conditions lead to qualitatively different equilibrium paths converging on different steady states[1]. Systems characterized by multiple equilibria are locally stable (or 'resilient') in the neighbourhood of attractors (or 'stable equilibria') but prone to sudden shifts in their dynamics at critical thresholds (or 'tipping points' or 'unstable equilibria'). Such systems pique the interest of scholars in both disciplines. At least since the seminal work of Holling (1973), May (1977) and Hanski et al. (1995)[2], environmental scientists have worked tirelessly at identifying and understanding thresholds in ecological systems in order that they might help resource managers avoid catastrophic collapse of key ecosystems. Economists' interest focuses more on the

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reverse process, on understanding why some people, communities and even entire nations remain mired in grinding poverty while others have enjoyed rapid improvements in standards of living, i.e., how to move social systems from low- to high-level equilibria.

The obvious latent connections between these lines of inquiry are too often overlooked, to the detriment of each discipline. Conservationists too often ignore the predictable consequences of human agency; people adapt behaviours in response to changes in environmental management, often generating unintended consequences. Similarly, those of us studying the economics of poverty are only just beginning to grasp the importance of understanding the dynamics of agro-ecosystems on which many livelihoods and technologies depend, and the feedback between the human and natural processes, especially in smallholder agrarian systems.

This paper reflects my current thinking on these issues, approached from the perspective of the economic literature on poverty traps. The next section defines a 'poverty trap' and explores the general mechanisms by which such phenomena might originate. The subsequent section relates the possibility of poverty traps back to the underlying state of renewable natural resources (forests, soils, water and wildlife) in rural areas, explaining how multiple stable states can arise and prove mutually reinforcing with respect to both economic and ecological variables (e.g., pastoralist wealth and range conditions, smallholder incomes and land quality). Drawing on empirical examples from smallholder agrarian systems I know well in sub-Saharan Africa, I then describe how multivariate multiple equilibria emerge naturally from material and informational feedback between natural and socioeconomic systems, feedback that predictably switches between balancing processes that maintain system stability and reinforcing processes that lead to locally exponential growth or decay. The final brief section draws out some of the policy implications that follow from the connection between poverty traps and resource dynamics in the rural tropics. While degradation and persistent poverty are not inevitable, it seems equally true that closely coupled ecological, economic and humanitarian challenges will not be resolved of their own accord over time. Models that integrate the dynamics of human well-being and resource allocation with the underlying dynamics of natural systems have great promise for helping analysts and policymakers think through the relative merits and risks of alternative courses of action.

THE ECONOMICS OF POVERTY TRAPS

The economics literature encompasses a range of definitions of a 'poverty trap'. The basic idea, per Azariadis and Stachurski (2004, p. 33), is that a poverty trap is 'any self-reinforcing mechanism which causes poverty to persist'. This can include single equilibrium systems where the unique equilibrium is at a low-level of well-being. But the more interesting cases of poverty traps emerge in the presence of multiple dynamic equilibria. Let us briefly consider what this means, somewhat more precisely, and how such phenomena might originate.

Assume some scalar measure of well-being that evolves over time, w_t – think of it as income, although the formulation is more general than that – that is generated by the stock of productive assets at the agent's disposal at the beginning of the period, a_t, a set of $m=1,\ldots M$ possible mappings of stocks into flows, $f^m(\cdot)$ – these could be production technologies, dividend or interest rates on financial assets, or terms of trade in market exchange – and an additive, mean-zero exogenous stochastic component (e.g., yield or price shocks) that reflects deviations of realized flows from their expected values, ε_t^m. The simple static view of an individual's livelihood choice, assuming expected utility maximization, is then

$$\underset{m}{Max}\, w_t^e \equiv f^m(a_t) \tag{1}$$

where the agent chooses the means of using the assets at her disposal that yields the maximum expected flow of well-being, w^e, given the costs and benefits of each of the M livelihood mappings available to her. Call the resulting choice f^{m^*}. Realized well-being for the period is subject to stochastic shocks, yielding

$$w_t \equiv f^{m^*}(a_t) + \varepsilon_t^m \tag{2}$$

This simple formulation allows for the existence of multiple production technologies, marketing channels or other means of mapping assets into flows of well-being. If $f^m(\cdot)$ follows the usual monotonicity, (weak) concavity and regularity (i.e., $f^m(0)=0$) conditions for each mapping, then initial asset holdings may effectively limit choice among alternative livelihoods unless complete and competitive financial markets exist, in which case the livelihood mappings are identical for all agents and no one's livelihood choice would be constrained by initial asset endowments, a_0, as one could freely borrow and then repay the loan at a parametric interest rate. However, given the pervasiveness of financial market imperfections in the developing world, livelihood choices typically are constrained by agents' asset endowments.

The possibility of financial contracts raises the issue of the dynamics inherent to the agent's choices. Assume that the asset stock follows a stochastic difference equation,

$$a_{t+1} = g^m(a_t, s_t, \varphi_t^m) \tag{3}$$

that one might reasonably expect to vary according to livelihood choice, where s_t is the chosen savings rate, and φ_t^m captures asset risk that may or may not be correlated with the income risk, ε_t^m, and might follow different distributions according to one's livelihood choice. Of course, the choice problem in equation (1) must now be adapted to value the stream of period-specific well-being measures and one must add the choice of s to the choice of m; but these are straightforward extensions.

The standard form in the economics literature for this growth function is to assume away asset risk and to assume constant depreciation, δ, and a unique law of motion (typically, to assume a unique asset and a unique livelihood/technology option). This simplifies (3) by assuming it follows a simple first-order difference equation:

$$a_{t+1} = s_t w_t + (1-\delta) a_t \tag{4}$$

The assumptions necessary to achieve these simplified dynamics – no allowance for different livelihoods governed by different underlying laws of motion, no prospective nonlinearities in those laws of motion, no asset risk – are rather burdensome if we want to understand patterns of behaviour and natural-resource dynamics in the rural tropics.

When M=1, the model with law of motion (4) reduces to the canonical, convex Ramsey-Cass-Koopmans neoclassical growth model, and global convergence to a unique long-run steady-state asset stock and level of well-being result. If that level of well-being falls below some relevant poverty line, $\underline{w}$, then the intertemporally separable dynamic-programming problem described above defines a simple model of a poverty trap for *all* households. However, overwhelming empirical evidence concludes that (i) much of the world has not converged and is not converging on a low-level equilibrium, so that a simple poverty-trap model seems terribly unrealistic, and (ii) income convergence does not accurately describe economic growth at the macro level of nation states, which reflects instead 'divergence, big time' (Pritchett 1997). The empirical microeconomic evidence remains much less clear on this latter question. An emerging literature tries to explain this pattern.

As Carter and Barrett (2006) explain, one can account for divergent welfare paths through either or both of two alternative explanations. The first is the idea of conditional or club convergence, meaning that groups of individuals who share similar intrinsic characteristics tend to follow an equilibrium path and converge to a living standard and asset stock that are unique to their group or club. While there is convergence within clubs, there can be divergence between clubs. One or more clubs might converge on a unique, low-level equilibrium while one or more others converge on a unique, high-level equilibrium, thereby generating divergence with some persistent poverty. The second alternative posits thresholds and multiple equilibria for each individual, in this case distinct equilibria based on one's initial conditions, not group membership. This approach is quite similar to those found in the ecological literature on multiple stable states and system resilience. From this perspective, there is no unique dynamic equilibrium. Instead, controlling for one's immutable characteristics (that sort individuals into groups), both high- and low-level equilibria exist, with the path dynamics of the system conditional on the ex-ante level of the state variable(s), i.e., the law of motion of a_t, described by equation (3), must be highly non-linear[3], perhaps even discontinuous at some threshold value.

This latter alternative, of threshold-based poverty traps, is inherently more interesting – as well as more promising – for the study of persistent poverty and renewable resource degradation in smallholder agrarian systems. At a low-level equilibrium, agents have no incentive, given the constraints they face, to invest in further asset accumulation, yet the low-level steady state, $\tilde{a}_i^{\ell}$, yields expected well-being below the poverty line, $w^e < \underline{w}$. There nonetheless exists some larger asset stock at which accumulation becomes attractive, leading to a higher-level steady state, $\tilde{a}^h$, and a higher corresponding expected level of well-being, $w^e > \underline{w}$. Asset accumulation thus becomes the engine of growth towards a stable, long-run steady state[4]. If a is a vector that includes natural assets such as forests, soils, water or wildlife, then the coupling of poverty traps and resource degradation becomes obvious and direct.

How might such multiple steady states systems emerge? The following subsections enumerate three distinct classes of explanations, any or all of which may apply in a given setting. Each carries slightly different implications for policy, which should serve as a caution against making facile prescriptions in the absence of detailed, empirical investigation of the etiology of an apparent poverty trap. But before we sketch out these differences, a couple of common characteristics apply to each explanation and thus bear comment. First, there must exist some mechanism(s) that introduce(s) nonconvexities into the envelope of $f^m(\cdot)$ mappings from equation (1) and, in particular, to the law of motion governing the asset stock, as reflected in equation (3). Intuitively, the marginal returns to accumulation must be (locally) *non-increasing* in the neighbourhood of stable equilibria but must also be (locally) *increasing* somewhere between the two, at an unstable dynamic equilibrium, the threshold point at which the asset path dynamics bifurcate. Second, there must be some exclusionary mechanism(s) that prevent(s) individuals from simply choosing to surmount the threshold that divides basins of attraction to different stable equilibria. Otherwise, no one would continuously choose a low-level equilibrium path. The result of these two basic properties of threshold-based poverty traps is that (i) initial conditions matter[5], and (ii) transitory shocks can have persistent effects, i.e., the system can be perturbed from one stable equilibrium to another by a single event.

Market imperfections

Development economics as a subdiscipline has focused heavily on the sources and consequences of market imperfections that generate inefficiency and retard asset accumulation and productivity growth. Such imperfections are the perhaps most obvious candidate explanation for the existence of threshold-based poverty traps.

Several variants of the market-imperfections explanation exist. One holds that input (output) prices or transactions costs are negatively (positively) related to scale over some significant range, with those nonlinear terms of trade generating non-convexities in the envelope of $f^m(\cdot)$ mappings. For example, a small farmer with one or two cows might receive a lower price per litre for milk sold to a trader who incurs costs to reach him than would an identically located farmer with a large herd and much more milk to offer. As a consequence, the returns to investing in a second cow would be less than the returns to adding a cow to a large herd. If the cost of a cow falls between these two returns, there will exist multiple equilibrium herd sizes, each corresponding to a distinct level of expected well-being for the farmer. An economy in which the terms of trade one faces are endogenously determined by one's asset stock and investment decisions clearly suffers a market imperfection that will lead to violation of the fundamental welfare theorems.

A second variant is associated with analytically similar internal economies of scale, for example those that would arise from sunk costs associated with choosing higher-return livelihoods. In the strict internal economies-of-scale case, fixed costs become a nonlinear function of the asset stock. In the sunk-costs case, the costs associated with each possible livelihood choice become time-varying, with higher initial (and irreversible) costs when one first chooses the corresponding livelihood. These create a friction that can lead to locally increasing returns at thresholds where agents rationally switch between alternative livelihoods (i.e., switch their choice of the optimal *m*). As Carter and Barrett (2006, p. 188-189) note, "there are plentiful empirical examples of such patterns, for example, households possessing more assets who adopt higher-return crop varieties or agronomic practices, wealthier households who get skilled salaried employment rather than unskilled casual wage labour, or households who graduate from poultry or small ruminants to indigenous cattle to improved dairy cattle and advanced animal husbandry practices (for example, artificial insemination, supplemental feeding, and so forth) as wealth grows and these methods become affordable".

The same pattern then emerges as under endogenous terms of trade: there can exist multiple equilibrium asset holdings associated with different levels of well-being (and in this case different choices of *m*).

In each of these two cases, a second, implicit market imperfection – a credit constraint (more generally a financial liquidity constraint) – is necessary in order for anyone to remain in the low level equilibrium. If people could freely borrow at an interest rate less than the proportional improvement in the expected terms of trade that result from asset accumulation, anyone initially in the neighbourhood of the low-level equilibrium would rationally borrow the resources necessary to move to the high-level equilibrium and then repay the loan. However, because credit-constrained equilibria exist for a variety of reasons (Besley 1995), the threshold-based poverty trap can ensnare those with relatively unfavourable initial endowments and cause intergenerational transmission of poverty through failure to invest in education (Loury 1981) or induced child labour (Basu and Van 1998). Returning to the simple model of the preceding section, under the assumptions that there exists some mapping that generates non-negative well-being and that no borrowing is permitted, then no livelihood option for which the required costs exceed the asset stock will be chosen, regardless of how great the marginal returns to that activity might be. Suddenly initial conditions become fundamental to determining livelihood choice and the resulting accumulation and well-being dynamics.

Credit constraints are not the only financial market imperfection that might generate multiple equilibria. Uninsured risk may similarly cause some lower-wealth households to allocate their assets so as to reduce risk exposure, trading off expected gains for lower risk, thereby making expected marginal returns to wealth lower for lower-wealth households who are more risk-averse than for those with greater ex-ante endowments that either better enable them to self-insure or make them less risk-averse (Bardhan et al. 2000; Carter and Barrett 2006). The result will be lower equilibrium asset holdings and levels of well-being for the initially poor.

One especially important form of response to uninsured risk relates to fertility decisions. As child mortality risk and the risk of unsupported adult disability fall, so do fertility rates. Beyond the obvious nonmaterial benefits they confer, children offer a source of labour and future financial support in economies where the elderly or infirm otherwise lack ready access to the finance to support themselves or to hire workers. But because human population growth also means increased subdivision of other assets, such as land and livestock, endogenous human population growth can be another process that reinforces a poverty-trap mechanism.

A final, and quite intuitive, poverty-trap mechanism due to market imperfections arises from employers' inability to observe labour effort and productivity accurately and the resulting impact on wage determination. As Dasgupta and Ray (1986; 1987) and Dasgupta (1993) explain, asymmetric information in the labour market can lead naturally to a nutritional efficiency wage and resulting involuntary unemployment coupled with undernutrition. The result is an especially pernicious form of a poverty trap caused by physical impairment and thus reduced productivity.

These explanations of poverty traps based on market imperfections, liquidity constraints and resulting asset thresholds underpin much of the current policy discourse about poverty traps, perhaps best embodied by Sachs (2005). The gist of the Sachsian argument is that poverty traps can be overcome if only the world will provide adequate resources to overcome the market imperfections that presently obstruct capital accumulation and technology adoption in the poorest areas of the tropics. But this is not the only way to understand the origins of poverty traps.

Imperfect learning and bounded rationality

In spite of the plethora of models of imperfect information in development economics and cognate subdisciplines, assumptions of complete information and perfect rationality pervade the economics literature on economic growth. But in a complex environment characterized by highly nonlinear dynamics, it may be somewhat far-fetched to assume that agents have an accurate, even an unbiased sense of the likely effects of discrete behavioural changes. Those who have only ever been poor may have a hard time anticipating the changes associated with decisions associated with transitions well beyond the equilibrium with which they are familiar. Furthermore, agents may have a difficult time observing changes in the environment around them, especially changes occurring at some distance from their current position. In the notation above, individual actors may observe $f^m(\cdot)$ or the law of motion describing the state variable(s), a_t, with persistent error and thus make allocation errors – in livelihood choice and/or savings behaviours – as a result. Differences among agents in beliefs or subjective expectations can thereby generate what Mookherjee and Ray (2001) term 'inertial self-reinforcement'.

There are at least three distinct variants of this problem. First, there may be important informational lags such that some people cannot accurately observe current conditions, which only become apparent after a delay, by which time response may be prohibitively costly although early response would have been remunerative. An example might be the population state of a disease vector (e.g., mosquitoes) that is difficult to observe in the early, larvae stage but, if observed accurately, relatively easy to eradicate through larval management. Yet it is easy to observe but difficult to control once the population matures. Soil quality conditions typically inferred from stochastic yields that are also affected by rainfall and other environmental determinants may likewise evolve with only lagged, imperfect observation by farmers, causing them to miss windows of opportunity for sustaining fertility levels. Similarly, individuals may become aware of new production technologies or marketing channels with different lags, with those slower to learn about new opportunities facing reduced returns to adoption – following the classic 'technology treadmill' argument (Cochrane 1958) – and hence diminished incentives to innovate. Informational lags can thus readily lead to multiple equilibria.

Second, there may be barriers or lags to learning that result from the differentiated nature of the social networks through which information flows imperfectly through a population. People may learn about jobs, emerging market opportunities or improved technologies only if they are well-connected, or the speed with which they learn about such opportunities may affect the payoff from uptake. If there is an associational propensity among similar individuals – the poor network mainly with other poor people, and the rich with the rich – then multiple equilibria can result naturally from either signalling or learning effects (Montgomery 1991; Calvó-Armengol and Jackson 2004). Such models have not been widely adapted to the poverty-traps context yet, but their applicability – to questions of technology adoption, market participation, finding remunerative employment, etc. – is rather intuitive (Durlauf 2002; Barrett 2005). If social networks are exogenously determined (e.g., by immutable factors such as race or gender), then this becomes a form of club convergence.

Finally, as Azariadis and Stachurski (2004, p. 37) discuss, "in a boundedly rational environment with limited information, outcomes will be driven by norms, institutions and conventions. … however, norms, institutions and conventions are path dependent by definition. … [Therefore,] economies that start out in bad equilibria may find it difficult to break free". If people derive nonmaterial value from their relationships, the quality of which depends in part on social proximity and similar behaviours, then there may be strong, if subtle, pressures to conform to traditional local practices, discouraging innovation, which may be regarded as deviancy (Barrett 2005; Moser and Barrett 2006). Here again, the long-term effects of human population dynamics associated with social customs concerning marriage and fertility can have extremely important effects that could perhaps be avoided if human behaviours were less boundedly rational.

The implications of the imperfect-learning, information-limited and bounded-rationality models of poverty traps deviate substantially from those of the market-imperfections explanations. In an informationally limited world, additional resources need not generate the most productivity-enhancing investments. Rather, the highest-return interventions would be to provide more timely, accurate and universally available information so as to surmount barriers to learning and innovation.

Spillovers, coordination failures and economically dysfunctional institutions

This latter point about norms and conventions provides a natural segue to the third category of explanations for poverty traps. Relationships with others matter, and not just because they convey information on which one can act. There may be technological externalities operating through physical spillover effects, as when one farmer's failure to control pests leads to harvest losses on a neighbour's land and thereby depresses the returns to adopting higher-return crops or higher-yielding varieties. Or there may exist pecuniary externalities caused by induced price effects, as in the case of external economies of scale (Murphy et al. 1989). As is well known, such conditions generally preclude attaining even constrained Pareto optima (Greenwald and Stiglitz 1986). These spillover effects not only generate inefficiency, however, they can also lead to multiple stable equilibria. Bowles et al. (2006) describe a range of such cases that lead to poverty traps.

Such spillover effects are special cases of coordination failures, which result whenever externalities affect not only the welfare of others, but also their behaviours. Keeping with the earlier notation, now the livelihood mapping takes additional arguments, taking the general form $f^m(a, \hat{a}, \hat{m},)$ where $\hat{a}$ represents other agents' asset stocks and $\hat{m}$ reflects others' livelihood choices, each of which might now affect the returns to i's decisions. Game theory is replete with examples of coordination failures, in which there exist Pareto inferior equilibria, and often multiple equilibria depending on the rules of play[6].

Coordination failures can all too easily become institutionalized through formal or informal rules that then guide individual and group behaviour. Economically dysfunctional institutions at any of several levels of social aggregation can undermine incentives to accumulate assets or to invest in productivity improvements and, by so doing, perversely reinforce the economic dysfunctionality of the system (Barrett and Swallow 2006; Bowles et al. 2006)[7]. Through corruption, weak property rights, limited contribution to public goods that are complementary inputs to private goods in production processes, etc., the institutions that define societies can both cause low investment and incomes and be caused by those conditions (North 1990; Bowles et al. 2006). A burgeoning literature traces historical paths of institutional development and links these patterns to subsequent economic performance, even centuries later (Engerman and Sokoloff 1997; Acemoglu et al. 2001).

Weak property rights are of special concern. If the security of one's assets is in question, incentives to invest are obviously sharply attenuated. And if assets are scarce because of limited investment, competition for them may become intense, reinforcing the insecurity that causes the scarcity in a reinforcing feedback loop. Some have gone so far as to claim that weak property rights are the fundamental obstacle to development in poor countries, explaining why the poor remain poor and the rich grow richer, i.e., why poverty traps appear (De Soto 1989; 2000; Acemoglu et al. 2002).

The coordination failures and economically dysfunctional institutions explanations for poverty traps point to still a different set of policy conclusions than those that follow from the preceding two classes of explanations. The problem now becomes one of appropriate mechanism design, of crafting rules of interaction – and rules for transitioning to those new rules – that will facilitate coordination, create focal points at Pareto dominant equilibria, and discourage venal behaviours that undermine individual incentives to cooperate and accumulate.

THE POVERTY TRAP – RESOURCE DYNAMICS LINK

The preceding general discussion of the economics of poverty traps foreshadows a range of interlinkages between resource dynamics – and multiple stable states in environmental variables – and multiple socioeconomic equilibria. In spite of some notable efforts in this direction (e.g., Dasgupta 1993; Berkes and Folke 1998; Shepherd and Soule 1998; Van Kooten and Bulte 2000), these links remain relatively underdeveloped in the literature, not only conceptually (e.g., within the realm of formal theorizing), but especially empirically. We know surprisingly little empirical detail about the nature of feedback between closely coupled human and natural systems in the rural tropics. In this section I sketch out the key connections before offering some examples in the next section.

The poor's assets

The most fundamental connection between the dynamics of natural systems and human well-being in the rural tropics arises due to smallholders' heavy dependence on biophysical assets for their livelihoods. When the key state variables of two systems are shared in common, strong interdependence follows automatically. The question becomes the nature of the interrelationship(s) and the ranges over which balancing or reinforcing feedback effects dominate within and between systems.

In the course of long-term economic development, populations typically generate income from biophysical processes associated with crop and livestock agriculture, fisheries, forestry and hunting, saving some of the proceeds to reinvest these in a wide range of manufactured assets (e.g., buildings, financial instruments, machinery and physical infrastructure) and in skills embodied in human capital. The portfolio of human wealth thus evolves steadily, diversifying out of natural assets into manufactured wealth. In this stylized process, nature is a source of riches that facilitates improvement in the human condition, albeit often through unsustainable resource use patterns. Resource dependence plainly need not lead inexorably to a poverty trap; indeed, resource exploitation has often been the pathway out of poverty. Yet, whether one looks at the level of individuals or of nation states, the poor typically depend far more heavily on natural assets than do the rich (World Resources Institute 2005; World Bank 2006). And deepening poverty seems to go hand-in-hand with resource dependence and degradation, sparking much hypothesizing about a 'resource curse'.

The most important biophysical asset controlled by the poor is the health of individual family members. If they own nothing else, the poor at least have some control over their own labour power. But basic physiological functioning – particularly the capacity to work and to learn – depends in a seemingly highly nonlinear way on one's physical condition; so does change in health status, i.e., the law of motion describing human capital reflected in health status appears nonlinear (Dasgupta 1997). As the last section discussed, when laws of motion for assets become highly nonlinear, multiple equilibria can emerge naturally. Consequently, emerging empirical evidence – nicely summarized recently by Krishna (2006) – suggests that health shocks account for an overwhelming share of falls into persistent poverty, as observed in micro-level data from various places in Africa, Asia and Latin America.

Even leaving the complex dynamics of human health aside, the poor also depend relatively more heavily than do the rich on natural assets embodied in renewable natural resources (e.g., forests, soils, water and wildlife). The rural poor earn little-to-no capital gains, dividends or interest on financial assets, rental income on machinery or commercial or residential property, or even salary or wages outside the primary production sectors. They disproportionately earn a living by mixing their labour power with the fruits of nature. The returns to labour then depend on both the quantity and quality of the complementary natural resources available to them. When the human population grows but the stock of resources on which they rely remains fixed – or at least grows less quickly – then marginal labour productivity tends to fall. And within the primary sectors labour productivity – and thus income – depends heavily on the state of complementary inputs provided by nature. Farm workers are more productive on good soils than on infertile land, fishermen land greater catches from abundant fisheries, etc.

The laws of motion that guide natural resources therefore matter a great deal to the dynamics of labour productivity, incomes and investment among the rural poor. If natural resources typically degrade within a particular range of initial conditions and aggrade over (an)other range(s), labour productivity dynamics may then vary predictably based on initial resource conditions. Since renewable resource dynamics are indeed typically highly nonlinear – consider, for example, the generally logistic-shaped population dynamics of most fauna and flora – the possibilities for coupled collapse or abundance in human well-being and biophysical resources become quickly apparent (Perrings 1989; Barrett and Arcese 1998). These dynamics create non-convexities which generate poverty traps.

The most recent estimates by the World Bank (2006) indicate that roughly 70% of the natural capital in low-income countries is found in agricultural and pasture lands. This makes understanding soil fertility dynamics especially important to understanding human-welfare dynamics (Barrett et al. 2002; Pell et al. 2004; Marenya and Barrett 2007). An exponential decay function seems to describe soil organic matter (SOM) and closely related nutrient (e.g., N, P) dynamics in cultivated soils without soil fertility replenishment treatments, although the rate and asymptotic limit of the decay seems to vary markedly with soil properties (e.g., texture, mineralogy) and climate that cannot be managed[8]. There is a further possibility of critical thresholds at which rates of recovery from degradation shift markedly, as is suggested by the apparent contrast between the ease with which SOM recovers in labile pools in response to appropriate management interventions (e.g., short fallows, application of green manures or inorganic fertilizers) during the early stages of degradation and the difficulty of reversing degradation in stable SOM pools (Pell et al. 2004). The implication of such SOM dynamics is that crop yield response to fertilizer (or other nutrient amendment) application will be highly nonlinear with respect to soil state, often muted in heavily degraded soils, thereby discouraging smallholders from replenishing the nutrients they mine from their land with each harvest (Marenya and Barrett 2007).

The nonlinear dynamics of the natural resources on which smallholder livelihoods depend raises the possibility of multiple equilibria in both resource and human well-being states, a prospective explanation as to why collapse might occur alongside a homeostatic system with abundant resources and adequate (or steadily improving) standards of living. Note that this does not imply an automatic vicious cycle nor a ubiquitous 'resource curse' but, rather, a system that may be highly resilient within some ranges, and hypersensitive in others. The sooner a detailed, empirical understanding emerges as to whether such multiple equilibria truly exist and, if they do, the relevant basins of attraction to each, the more effectively can interested parties manage ecosystems so as to facilitate escape from and avoidance of persistent poverty.

Poverty-trap mechanisms' applicability to natural resources

The three general classes of explanation of poverty traps offered in the previous section carry over quite naturally as we think about linked multiple equilibria in both human well-being and natural-resource conditions.

Even when the strong assumptions of perfect markets, complete and perfectly enforceable property rights and perfect information hold – i.e., ruling out all three classes of mechanisms to generate poverty traps – resource conservation effort should increase with income, but at a diminishing rate, generating the usual convergence hypothesis result. However, constraints may impede equalization of the net marginal returns to current consumption and to investment in resource conservation or restoration that will maintain or increase future productivity, interfering with the natural tendency towards convergence in complete, competitive markets. This causes persistent divergence in welfare levels and resource states over time across the initial wealth distribution. For example, credit constraints foster underinvestment in natural-resource conservation (Barrett et al. 2002; Antle et al. 2006), uninsured risk often leads to episodic overexploitation of nature, often when the resource is least able to sustain increased pressure (Barrett and Arcese 1998), and information asymmetries in labour markets – which results in familiar moral hazard and adverse selection problems – can lead not only to nutritional poverty traps (Dasgupta and Ray 1986; 1987), but also to overexploitation of land and thus to soil degradation and lower long-run productivity, even in the face of what seem added incentives to conserve resources (Bulte and Van Soest 1999; Sylwester 2004).

Imperfect information about the state of – and perhaps especially change in – the natural-resource base is an intuitive mechanism by which a poverty trap can emerge that is coupled to resource degradation. For example, given the nonlinear dynamics which seem to characterize soil fertility, significant informational lags in farmer perception of soil conditions, significant errors in those perceptions, or both, could lead to soil management practices that, while optimal given the farmers' perceptions, actually mismanage the resource and lead to resource collapse. Such lags and errors indeed appear realistic in at least some settings (Gray and Morant 2003). Predictable differences among farmers in their subjective beliefs concerning the law of motion governing SOM, for example, could lead to 'inertial self-reinforcement' and multiple resource and welfare equilibria[9]. Similarly, slowly evolving social norms that do not adapt rapidly to emerging information can lead to poverty traps associated with resource degradation, as we discuss in the Madagascar case study in the next section.

The problems of externalities and coordination failures in generating resource degradation and impoverishment have been extensively explored in the literature. Weak institutions have been widely recognized as central to the problems of both resource conservation and poverty reduction in the rural tropics (Barrett et al. 2001). In particular, the prominence of common-property regimes for natural resources in the rural tropics is often thought to lead to coordination failures that foster resource overuse and productivity loss. This leads naturally to the prescription that establishment and enforcement of private property rights will resolve this problem. But a substantial and influential literature has established convincingly that it is less the communal nature of property than open access – i.e., failure to set and enforce rules – that leads to problems (Larson and Bromley 1990; Ostrom 1990; Bromley 1991; Baland and Platteau 1996; Gibson et al. 2005).

The growing focus on rules and equitable and constant enforcement has fostered a sharp growth in the literature on the role of corruption and the rule of law more generally on resource degradation and poverty (Deacon 1994). This quickly leads to questions of power. The correlation of wealth and power can lead to multiple equilibria in which wealthier and more powerful individuals can maintain control over resources, thereby creating incentives to invest in conservation, while poorer, more voiceless persons face considerable risk of asset loss, thereby dampening investment incentives and fostering resource degradation(World Resources Institute 2005). This line of argument has led to increased recent emphasis on good governance as central to the struggle to escape poverty traps and to avert ecosystem collapse. However, the emerging literature on corruption, governance, decentralization and the coupling of resource degradation with poverty traps remains distressingly atheoretical, while the empirical studies typically fail to account for other important control variables pivotal to the relationship between humans and natural resources and are fraught with various statistical problems (Barrett et al. 2006a; 2007).

A range of possible poverty-trap mechanisms therefore exist that integrate readily with the inherently nonlinear dynamics of natural resources to generate what might be termed 'resource degradation poverty traps', i.e., low-level stable dynamic equilibria for both economic and ecological state variables. The problem is that we do not yet have very good diagnostic tools for screening among candidate mechanisms, indeed not even for establishing conclusively the existence of resource degradation poverty traps, as distinct from persistent poverty associated with slow improvement in incomes and resources status. Consider some examples from three quite different agro-ecosystems in sub-Saharan Africa.

SOME AFRICAN EXAMPLES

In this section, I aim to illustrate some of these prospective resource degradation poverty-trap linkages casually by reference to empirical findings from a few sub-Saharan African settings I know well. But these remain relatively loose descriptions that underscore the importance of further research to explore these relationships rigorously and in detail. In each case, a few key features stand out. First, each case underscores that multiple equilibria appear to exist; these ecosystems are not condemned to collapse nor are their human resident managers inextricably trapped in grinding poverty. But without well-targeted interventions based on careful empirical identification of the mechanism(s) that generate the apparent poverty trap, such calamities are possible, even likely. Second, there is suggestive evidence in support of at least two of the three causal mechanisms outlined above, which complicates prioritization and targeting of interventions considerably. Third, empirical analysis of these processes is impeded by (i) the inherently nonlinear dynamics of the system, (ii) the feedback that renders most variables of interest endogenous to the system under study, and (iii) the paucity of data encompassing reliable measures of both biophysical and socioeconomic variables at common locations and intervals. Thus much of the literature remains at best suggestive. This is an area ripe for rigorous – and often multidisciplinary – investigation.

The arid and semi-arid lands of east Africa

The first, core example Hardin (1968) used in describing the 'tragedy of the commons' concerned herders in common pasturelands. Since pastoralists in the arid and semi-arid lands (ASAL) of east Africa, whose entire livelihood depends upon the livestock herds they can sustain on the grasses and water available on the rangelands, are also among the world's poorest populations by many metrics, these areas offer an excellent lens on the problem of resource degradation poverty traps. Recent research has established reasonably convincingly the existence of multiple equilibria in both human-welfare terms – a poverty trap associated with distinct wealth levels – and localized range degradation alongside (seasonally) abundant forage in large parts of the east-African ASAL (McPeak 2003; Lybbert et al. 2004; Santos and Barrett 2006).

The reasons for the apparent poverty trap are several. Market imperfections – not least of which, uninsured asset risk – create two distinct modes of pastoralism, a low-level equilibrium characterized by sedentarized livestock keeping of one or two cows in small, poor settlements subject to serious, but only localized range degradation, and a higher-level equilibrium based on traditional, transhumant grazing of large herds sustained by long-distance treks to areas that retain abundant forage and water (Lybbert et al. 2004; Santos and Barrett 2006). Impoverishment and range degradation seem to go hand-in-hand, exactly as Hardin described[10], and are magnified by human population growth in an area facing receding available grazing lands. But the tragedy of the commons applies only over a specific geographic and economic range. Those conditions by no means apply to the whole of the region, indeed only to a very small proportion of the land area as recent, careful empirical studies find no support for classical commons effects – i.e., one pastoralist's herd size having an adverse effect on the productivity or survival of another pastoralist's livestock (Lybbert et al. 2004; McPeak 2005). This certainly seems a multiple equilibrial system in both ecological and economic terms.

The challenge of resource degradation poverty traps in the east-African ASAL transcends herd sizes and market imperfections, however. Historically, a clan or ethnic group's grazing areas typically have flexible and contested boundaries. As a result, environmental resource management becomes closely bound up with issues of conflict management, as setting and enforcing rules so as to coordinate expectations and actions becomes essential to prevent collapse, not just of the fragile range ecology but also of pastoralist communities into violence and destitution (Haro et al. 2005; Munyao and Barrett 2007). It seems unlikely that one could surmount the poverty-trap problem in the pastoral areas of the east-African ASAL without tackling both the market imperfections and coordination/institutional issues jointly.

Western-Kenyan maize systems

Shepherd and Soule (1998) found, based on a simulation model calibrated using data collected across a range of western-Kenyan farms, that soil nutrient mining by poorer farmers unable or unwilling to invest in soil fertility replenishment can coexist alongside stable soil quality among better-endowed farmers. This important finding is one of the clearest empirical examples in the literature of a resource degradation poverty trap.

Plot- and farm-level survey data collected over the period 1989–2004 in a village, Madzuu, in Vihiga District, western Kenya, and subsequent data collected along a chronosequence of western-Kenyan farms provide corroborating empirical evidence of the patterns Shepherd and Soule (1998) first described (Barrett et al. 2006b; Marenya and Barrett 2007). Those who remain non-poor over time started off with statistically significantly higher endowments of land, improved livestock and educated family members, as well as greater and more remunerative off-farm employment to generate the cash necessary to invest in chemical fertilizer and other critical integrated soil fertility management interventions. As soil N and P stocks decline after a few decades' continuous cultivation in annual food crops and as farms gets subdivided in the face of human population growth, the better-off farmers can afford to purchase and plant tea stems and to forego any earnings from the land converted to perennials during the roughly two years it takes tea bushes to mature and generate marketable leaves. The tea bushes' roots provide outstanding erosion control, however, and the local tea factories' natural monopsony – due to the need to process tea leaves quickly after picking – enables them to provide inorganic fertilizer on credit secured by future delivery of tea leaves. Those who can afford to invest in conversion from maize to tea as soil quality declines thereby escape the seasonal liquidity constraints that impede soil fertility replenishment by poorer neighbours. A homeostatic system of reasonably fertile soil conditions and adequate incomes results for these households.

Meanwhile, those who collapse into poverty all traced their decline to shocks that caused them to lose critical land, livestock or human assets, initiating a spiral from which their family has not recovered. Those who suffer persistent poverty articulate less concern for conserving soil fertility and make fewer efforts to do so, presumably reflecting lower conditional (constrained) returns to investment in degraded soils for the poor. They point to certain higher-return activities as beyond their reach for want of financial capital, education (commonly due to inability to pay school fees), the social connections necessary to secure remunerative full-time employment, or some combination of these. These obstacles dampen the productivity of their limited labour, land and livestock holdings relative to better-off neighbours. The resulting household-level asset dynamics exhibit multiple stable dynamic equilibria (Figure 1), with less than 20% of the population clustered around the higher dynamic equilibrium – at only about $1.50/day per capita – and the rest distributed around, and presumably converging toward, the lower-level equilibrium beneath the poverty line, at less than $0.50/day per person (Figure 2).

Parallel plot-level trials find evidence of nonlinear dynamics in soil fertility and in yield response to soil fertility amendments in this same area, underscoring that low investment in maintaining or reconstituting soil fertility may be rational for some poorer farmers while soil fertility maintenance is attractive for wealthier farmers (Marenya and Barrett 2007). The result seems to be a system characterized by multiple soil fertility equilibria and associated levels of per-capita income, driven in large measure by imperfections in markets for credit and insurance.

Unfortunately, the story seems to get somewhat more complicated still. Farmer perceptions of soil quality appear only weakly related to laboratory measurements of SOM, nutrient stocks, etc. and preliminary, qualitative assessments raise the possibility of significant informational lags, biases or both in farmer assessment of soil fertility dynamics. There remains scant empirical evidence on the relationship between farmer perceptions of soil quality and of soil quality change induced by conservation and fertilization on the one hand, and farmer investment in maintaining soil quality on the other. This is an important gap, as the imperfect-learning and bounded-rationality mechanism may well be at play as well in driving resource degradation poverty traps in this region.

Figure 1. *Estimated asset index dynamics for Madzuu, 1989-2002, based on nonparametric kernel autoregression of Sahn-Stifel asset index. Reproduced from Barrett et al. (2006b)*

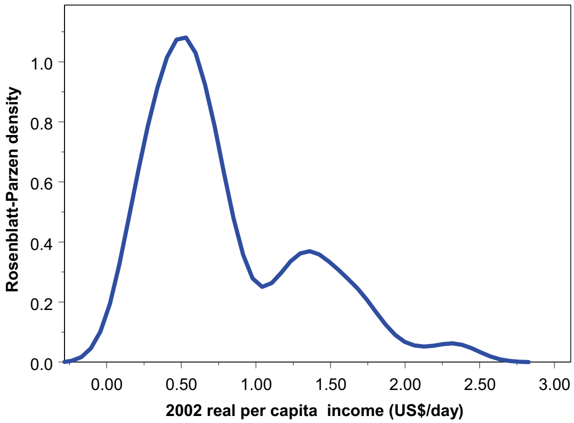

***Figure 2**. Per-capita daily-income distribution, Madzuu, 2002, based on Rosenblatt-Parzen density. Reproduced from Barrett et al. (2006b)*

The coordination-failures mechanism may now play an important role as well. Nutrient-depleted soils in sub-Saharan Africa have become infested with the parasitic weed *Striga hermonthica*, with yield losses now over US$7 billion annually (SPIPM (Systemwide Program on Integrated Pest Management) 2003). Prevention of *Striga* encroachment depends on maintaining high soil fertility and moisture, which is difficult in rainfed lands with infrequent rotation or fallowing. Once established, 'witchweed', as Kenyan farmers understandably call the plant, has proved resistant to conventional methods of weed control via herbicides and hand or mechanical weeding. A single *Striga* plant produces thousands of tiny seeds that are difficult to notice, most of the damage to the crop occurs before the parasite emerges from the ground and can be readily identified, and the seed can remain dormant but viable in the soil for many years. *Striga* is therefore difficult to eradicate because a single surviving plant can recolonize a large area in a single season. And with so many lightweight seeds, it spreads readily from farm to farm via wind, water, animals and humans. Coordinated measures are essential for effective eradication because the returns to an individual farmer's efforts to block the entry of (or to eradicate) *Striga* on his fields are an increasing function of neighbouring farmers' efforts at weed control. It has proved exceedingly difficult, however, to organize communities to combat *Striga* in spite of the parasitic weed's considerable costs. This seems to be especially true in villages with large numbers of recent immigrants, inter-clan frictions and other social phenomena that dampen the strong ties necessary to resolve such coordination problems (Barrett 2005). Thus crop yields and soil quality continue to decline, but in this case, due in large measure to the coordination-failures mechanism behind poverty traps.

Rice systems in Madagascar

Madagascar is perhaps the closest one comes at the macro level to a resource degradation poverty trap. It is at once one of the world's poorest countries and one of the global environmental community's greatest concerns – a 'hot spot' – due to alarming rates of loss of endemic species, forest and topsoil from the island nation. Why does this twin crisis persist in the wake of at least two decades' concerted efforts at both environmental protection and poverty reduction in Madagascar?

More than three-quarters of Madagascar's poor live in rural areas and more than 70% of the population grows rice, which occupies more than half of the nation's cultivated land. The key to understanding rural poverty and resource use thus lies in understanding the dynamics of Malagasy rice systems. Yields are very low, with median yields unchanged over the past quarter century at roughly two tons per hectare. Quite a few different methods of rice intensification have been promoted in Madagascar over the past twenty or so years, but none has yet gained a sufficiently solid foothold to improve productivity appreciably. One consequence is continued deforestation, habitat loss and soil degradation – from both massive erosion that leads to dramatic landslides (*lavaka*) and severe soil nutrient depletion – due to extensification and unsustainable intensification without adequate soil nutrient amendments. Resource degradation poverty traps appear very real in rural Malagasy rice systems.

Part of the problem stems from market imperfections, some of them caused by the formerly Marxist government's misguided attempts at state control over agricultural inputs, land, credit and food distribution. But severe problems persist, as financial liquidity constraints generally inhibit farmers' uptake of fertilizers and other inputs needed to sustain soils and reduce pressures to extensify through deforestation, as well as adoption of promising, low-input, yield-increasing technologies (Moser and Barrett 2006). Uninsured risk likewise encourages deforestation (Barrett 1999), while high transaction costs in a nation with poor transport infrastructure and difficult topography create significant disincentives to the use of purchased inputs and overuse of lands that are relatively ill-suited to intensive cultivation (Minten et al. 2006). The canonical market imperfections-based explanations of poverty traps seem to fit the Malagasy rice systems case well.

Yet other factors matter a great deal as well. Among rural Malagasy, social customs are extraordinarily important and limit adaptation to emerging evidence of the need for new ways of managing forests, land, water and wildlife on the island. For example, although highland Malagasy farmers say they cannot afford inorganic fertilizers or improved seed, they routinely pay extraordinary sums to exhume and reshroud dead ancestors every 3-10 years – an elaborate ceremony known as *famadihana* – and to travel long distances and contribute significant sums for *famadihana* for even distant relatives' ancestors. Further underscoring the social and spiritual importance of death rituals among the Malagasy, several ethnic groups have strong behavioural expectations that households will sacrifice cattle when a household member dies. But because soil fertility and rice productivity are strongly increasing in cattle holdings due to manuring and animal traction services that are imperfectly tradable, livestock sacrifice implies a long-term productivity decline for the household, thereby increasing the probability of subsequent undernutrition and illness leading to death, creating a resource degradation poverty trap (Barrett 2005). There is significant resistance to changing these behavioural expectations in spite of their obvious, and sometimes catastrophic, cost in both human and environmental terms.

And as in Kenya, coordination problems abound and compound the challenges facing rural resource managers and poor farmers. Water management is extremely important in rice systems. One intriguing new method of growing rice – known as the system of rice intensification (SRI) – requires more careful water control as fields are regularly flooded then dried, rather than left under standing water. This becomes problematic along the irrigated rice perimeters in which most lowland rice is grown because all farmers must agree to use similar methods and varieties in order to coordinate the capture and release of water across plots effectively. Meanwhile, those cutting upland forests inadvertently disrupt seasonal hydrological cycles and stimulate increased surface erosion, leading to siltation of irrigation channels and diminished lowland rice yields. Of course, this induces increased extensification along fragile hillsides, reinforcing the problem. Those communities that have managed to coordinate water use and forest access effectively have been able to achieve and maintain higher rice yields and more stable forest margins than those that have struggled to resolve the coordination challenges facing Malagasy rice producers. Just as in western Kenya and the arid and semi-arid lands of east Africa, multiple mechanisms seem to drive apparent resource degradation poverty traps.

IMPLICATIONS

Recent estimates suggest that when natural-resource depletion and population growth are taken into account, most low-income countries face declining per-capita wealth while most high-income countries enjoy increasing per-capita wealth (World Bank 2006), with much of the bifurcation in dynamics directly attributable to degradation of natural resources, thus mirroring and reinforcing the 'divergence, big time' observed in real per-capita income data across countries (Pritchett 1997). This apparent coupling of resource and human population and welfare dynamics raises pressing questions about the possibility of resource degradation poverty traps. So what can and should development and conservation agencies, donors and governments do?

At the most general level, there is a clear compulsion to act. The clear implication of the poverty-traps hypothesis is that intervention is essential if people are to escape and avoid persistent poverty. If it is likewise true that the dynamics of renewable resources are closely coupled to the dynamics of the well-being of the human populations that depend on those resources, then intervention is equally essential to avert ecosystem collapse.

Recognizing the need for some sort of intervention is the easy part, however. While intervention is valuable, indeed essential, the multiple causal mechanisms that can generate poverty traps make it terribly difficult to identify appropriate interventions. For example, if economically dysfunctional institutions are the main problem (à la De Soto), then injections of capital (as advocated by Sachs 2005) intended to surmount asset thresholds are unlikely to work. Conversely, if inadequate resources are the primary problem, not economically dysfunctional local and national institutions (i.e., if Sachs, not De Soto, is right), then the extraordinary attention presently paid by development institutions to governance questions will likely prove just wasted effort with a heavy opportunity cost. The most plausible, but also most complex, scenario is that different mechanisms are at play at once, with different ones dominating at different scales of analysis, with capital shortfalls at the micro levels of individuals, households and firms reinforced by coordination failures at meso levels of communities and markets, which are in turn reinforced by economically dysfunctional institutions at national and regional scales that in turn impede coordination and access to capital, what Barrett and Swallow (2006) term 'fractal poverty traps' due to the self-similarity across scales of the core characteristics, albeit with different causal mechanisms.

We still know distressingly little empirically about these various mechanisms that underpin poverty traps and resource degradation in the rural tropics. The good news is that this makes an especially fertile area for research, both in developing appropriate methods for identifying dominant causal mechanisms and for evaluating interventions, and in establishing generalizable rules of thumb for policy design to overcome poverty traps and renewable-resource degradation.

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NOTES

[1] The key is that equilibrium paths differ as a function of initial conditions. There may not be a steady state; the system could instead be chaotic or follow cycles. In the remainder of this paper, however, I assume a steady state exists for each equilibrium path.

[2] See Muradian (2001), Beisner et al. (2003), Scheffer and Carpenter (2003) and Rietkerk et al. (2004) for good reviews of the relevant literature.

[3] By 'highly non-linear' I mean something that cannot be represented by a low-order polynomial expression, certainly not first or second order, so as to allow for inflection points in the law of motion.

[4] Of course, the stable dynamic equilibrium will evolve as the underlying mappings, $f^{n}(\cdot)$, change due to improvements in technologies and institutions. Hence the dual importance of asset accumulation and technological and institutional change for economic growth: within an institutional-technology regime, assets are determinant, while institutions and technologies likely dominate over longer time spans.

[5] Mookherjee and Ray (2001) refer to this as 'historical self-reinforcement'.

[6] Diamond (1982) is a canonical example.

[7] It is important to note the modifier 'economically' because many of the institutions that have emerged have important cultural or social purposes that, unfortunately, come at the cost of incentives – perhaps especially for the poor – to innovate and accumulate productive assets. Many such institutions – e.g., social sharing arrangements implying high marginal rates of informal taxation, complex property rights with multiple claimants to incompletely alienable property, etc. – are deemed highly desirable by many individuals, thus they plainly play a valued function. Such institutions are thus dysfunctional in the important, but limited, sense that they fail to encourage behaviours that yield medium- to long-term increases in investment and incomes. I thank Felix Naschold for helpfully pushing me on this point.

[8] Johannes Lehmann points out (personal communication) that in western Canada (Alberta), 100 years of cropping without soil nutrient amendments reduced SOM by only 5-10%, while similar experiments in the western United States (Oregon), South Africa and Kenya show declines of 40%, 50% and 60-70%, respectively.

[9] For example, there could be important differences between those who occupy and manage for many years land held under secure tenure, versus those who control a parcel for only a short period due to tenure insecurity who thus do not know a plot's history and thus have far less information to use in land management. This is one of the under-recognized problems of tenurial insecurity.

[10] Hardin, however, posited a unique low-level equilibrium, not the multiple equilibria recent studies in this region consistently find.

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CHAPTER 3

WATER RESOURCE MANAGEMENT AND THE POOR

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Abstract. Water allocations as well as water quality and health concerns are often due to inadequate policies and institutions, which pose major challenges for policy reform. The necessary ingredients of such reform include four elements: rules to improve the decision-making process about water projects, principles to improve water allocation, incentives for water conservation, and incentives to improve water quality. The paper shows that improved policies and incentives can address many of the global water problems and lead to environmental sustainability while addressing distributional issues. Some of the reforms may hurt the poor in the short run through higher water prices, but may provide them better access to water and reduce the toll of unsustainable water use in the long run. The direct and indirect implications of increasing prices of energy for water reforms are also discussed.
Keywords. water management crisis; policy reform; distributional issues; higher prices of energy

INTRODUCTION

There is a perception that water use and allocation have been contentious for a long time. To quote Mark Twain, "Whiskey is for drinking, water is for fighting". There are frequent transboundary disputes about water, and water policies in many countries revolve around the allocation of water between industries, municipalities, the environment, and the agricultural sector, which often consumes 80% of total water. Nevertheless, Wolf's (1998) survey of international water conflicts suggests that in spite of the tensions, water conflicts tend to be peacefully resolved.

In this paper, we argue that much of the concern about water shortages and future availability is the result of inadequate policies and institutions. We establish

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several principles for policy reform, designed to lead to more efficient water allocation and resolve some of the tension about its availability and use. It is critical that general problems of water misallocation are improved, and this needs to be the first priority for policy reform. Therefore, the principles outlined are just as valid for both developed and developing countries, and for both affluent and poor areas. However, such reforms do have distributional implications. In this chapter we will discuss how water policy reforms impact the poor, and suggest mechanisms that can be used to reduce the negative impacts.

In addition, we will argue that a key challenge to water resource management in the future stems from the volatile situation in the energy market and the possibility of increased scarcity and, consequently, higher prices of energy. Thus, we suggest that the major challenges of agricultural and water policies are to reduce the inefficiencies and inequities of water and energy use in a sustainable manner.

In this paper principles of four elements of reform are suggested. Attention will be paid to the relationship between water problems and the global energy situation and we will try to link solutions to both.

THE TRANSITION TO MARKET AND TRADING

Political economic considerations are the major causes of the existing inefficiency and misallocation of water use. For millennia, water has not been a scarce commodity; therefore, markets have not been heavily used as a mechanism to trade water. Instead, governments have established a system of water rights, such as the prior-appropriation system to allocate water. The prior-appropriation system introduced in the western United States and similar systems introduced elsewhere are queuing systems that allocate water according to two principles: ‘use it or lose it’ and ‘first come, first served’. It is a homesteading system that was aimed to attract settlers to frontier areas in the United States, Latin America and even India. This system is very effective when water is abundant. But as water becomes scarce, it leads to inefficiency because it restricts trading and provides no incentives to adopt modern irrigation technologies and conserve water.

A reform to allow trading may require investment in infrastructure, institutional changes, have high transaction costs, and have significant distributional effects. For example, owners of water rights will strongly oppose a reform where the government reclaims the original water rights and starts selling water, but they will support the introduction of transferable rights that allow them to benefit from sales of extra water (the so-called grandfathering rights).

The introduction of incentives to control water quality problems has followed a similar evolutionary process. Initially when farming starts in a region, the waste products of a relatively small population of humans and livestock are disposed into a large body of water with minimal impacts on water quality. The polluters by their action establish *de facto* polluter rights. As the population and the waste it generates grow, water quality becomes a problem. A reform that will reduce pollution and improve water quality has to take into consideration the historical right established by the polluter, and its design is a tricky political economic process. In recent years, trading programs that focus on water *quality* instead of *quantity* have started to develop as a mechanism to improve environmental conditions. Woodward and Kaiser (2002) describe the use of such programs in the United States. The majority of the programs developed have focused on nitrogen, phosphorous or both, as these pollutants are frequent causes of water quality deterioration.

Political and legal systems are quite rigid. Reforming a water-rights system and the introduction of pollution control policies require overcoming substantial economic constraints. Rausser and Zusman (1991) and Shah et al. (1993) argue that a crisis may be required to trigger reforms in water systems. Indeed there are many historical examples that show that depletion of groundwater aquifers led to establishment of surface water projects. Droughts such as the California drought of 1987 to 1991 led to the introduction of water trading. The deterioration of a large number of important bodies of water in the United States preceded the introduction of the Clean Water Act in the United States.

The relative abundance of water in many systems throughout the world, the randomness of water conditions that may lead to quick swings from shortages to surpluses of water, and multiple stakeholders concerned about water systems suggest that reforms of water systems will be gradual and take a long period of time. There are already promising changes occurring in laws and institutions governing water use and allocation. Some of the major ingredients of reform and their implications are discussed below. These are based on both a survey of existing literature as well as observations from case studies of water policy reform. They include four elements*: 1) rules to improve the design of and decision-making process about water project development and maintenance; 2) principles to improve water allocation and pricing; 3) incentives for water conservation; and 4) incentives to improve water quality.*

Improve design of and decision-making process about water projects

Water projects are major investments that modify the landscape and are used to transfer water across locations, to store water, to protect against floods and contaminants, and to generate hydroelectric power. A large body of research on water projects suggests that some have provided immense value, but many others have had low and even negative rates of return. Frequently, water projects may be part of the political work that is distributed to contractors and water users for various forms of political support, for instance employment generation (Zilberman and Schoengold 2005).

One key element of water reform is to improve the process of decision making about water projects. First, it is important that water projects *pass a formal benefit–cost analysis* to assure that they meet some minimum feasibility criteria. Gradually, the World Bank, the U.S. government and other governments are introducing benefit–cost tests to assess new water projects. Indeed, the number of new water projects in the United States has drastically declined since the introduction of the benefit–cost analysis procedures defined by the ‘principles and guidelines’ to assess new projects (Frederick et al. 1997). Reform should go beyond employing the standard benefit–cost analysis. As the work of Arrow and Fisher (1974) suggests, decision making about new projects is done under uncertainty and often leads to irreversible outcomes. *Timing and information about new projects* make a difference. Thus, the decision about water projects should not only determine whether or not to build them out but also when to start them. The first period in which a proposed project has a positive expected net discounted benefit is not necessarily the optimal time to develop it. The timing will be decided in a manner that will maximize expected net discounted benefit.

Furthermore, project managers should pursue adaptive learning and conduct experiments to reduce uncertainty about key system parameters that will allow improved design. Another important element that bears consideration in project design and assessment is *incorporation of nonstructural solutions* in devising new water projects. Traditionally, engineers designed water projects and economists were responsible for making a choice among given alternatives, leading to an emphasis on structural solutions. However, sometimes water management can be solved more effectively by modifying behaviour; therefore, economists and social scientists should be involved in the early stages of project design, so that the project will contain a complete package including both physical structure and also institutional change that will take best advantage of it.

Finally, project assessment should consider both *market and non-market costs*, and develop systems that will be *symmetrical and minimize biases*. For example, if contingent valuation is being used to assess the environmental benefit of a new project, it should also be used to assess the environmental cost. This has not been the case in many situations, and it may lead to overestimation of benefits. Moreover, economic assessments of benefit and cost have to be applied to all projects without any exemption, and even though the final decision may be political, transparent assessment of the costs and benefits is important in the decision-making process.

Improved water allocation and pricing

The main reason for the misallocation of water is that prices water users consider are different from the social marginal costs of the water. However, water prices are elusive. Both actual and optimal pricing of water vary within and between seasons, by location, quality, benefits or value of usage, costs of supply, and institutional setting. For example, during the dry season, the value of water may be \$0.12 per cubic metre, while during the wet season it may be \$0.01 per cubic metre. The cost of water at two adjacent locations may be different if one location is 300m higher in elevation than the other. In one case, Pitafi and Roumasset (2004) show that the optimal price of water for consumers in Hawaii who live in the highest elevation category should pay over three times the price of consumers in the lowest elevation category. Tsur et al. (2004) present a series of fourteen guidelines designed to improve the pricing and economic efficiency of irrigation water use. The main ideas discussed below provide the same general recommendations.

As shown in Zilberman and Schoengold (2005), optimal water allocation requires that the price of water equal the sum of all associated costs. First, there is the cost of extraction at the source. Then, there is the cost of conveyance from the source to the point of use. Next, there is the environmental cost associated with diversion of water from its natural course. Finally, there is a future or opportunity cost which represents the cost that extraction of water at the present imposes on future consumption. When water prices are subsidized (sometimes through subsidizing energy), it leads to overuse of water with significant negative effects on the environment, as well as a reduction in available water for the future.

The subsidization of water is not accidental, while removal is painful. Political-economic analysis of water pricing suggests that cheap water is used as a policy to support farm income. However, this policy is paid by future generations, by the beneficiaries of environmental amenities, and by taxpayers who pay extra extraction and conveyance costs. Transition to optimal pricing may have negative distributional consequences as poor farmers could be required to pay higher prices for water. However, some of these negative distributional effects can be addressed by special pricing schemes, like tiered pricing, and others can be addressed by direct transfer payments. In addition, the transition to optimal pricing may trigger the adoption of conservation technologies, a reduction in acreage of low-value crops and rate of construction of water supply projects, and an increase in the supply of fish and other products of environmental use of water. It will also improve the long-term viability of the system.

The optimal outcome, where water is allocated so that marginal social costs are equal to marginal social benefits, can be attained by several arrangements with different equity implications. The first is *full marginal-cost pricing;* namely, the price per unit of water should be the sum of the marginal extraction, conveyance, environmental and future costs. A government agency may charge a tax equal to the marginal environmental and future costs, and that will be added to the marginal cost of extraction and conveyance. The high costs will have a significant negative effect on the welfare of many users, but the tax revenue generated *can be redistributed to support the poor*. Boland and Whittington (2000) show that in many cases, the poor are better off with a uniform price with rebate as opposed to an increasing block-rate pricing structure.

A second scheme that can address distributional effects is *block-rate or tiered pricing*. With this scheme, water is priced at a low initial rate up to a limited volume (block), and then it is charged at a higher rate for another block. Multiple blocks can be used, and the size and price of the blocks may either be constant or vary by season or other observable socioeconomic variables such as household size. Efficiency may be attained with two rates, where the second rate, which applies beyond an initial level, is equal to the social marginal cost of water. An excellent overview of the arguments in favour and against increasing block-rate pricing, as well as its practical limitations, is presented in Boland and Whittington (2000).

Block-rate pricing is used frequently in pricing urban water in developing countries (Saleth and Dinar 1997). One concern with block-rate pricing is discussed by Whittington (1992)who argues that in case of shared water connections and indirect purchasing in developing countries, block pricing may actually have an effect that is opposite to the intended equity objective. Since it is common for multiple households to share one water service connection, it can penalize poor households instead of helping them. Zilberman and Schoengold (2005) show that when the marginal cost of the water supply is very elastic, and the difference between the marginal and average cost of water is relatively small, the feasibility of using tiered pricing is reduced. Thus, in these situations, the use of tiered pricing requires an extra subsidy beyond what is supported by the water industry.

The initial block that is subsidized for consumers under tiered pricing can cause inefficiency in water use when the initial block is too large. In that case tiered pricing may lead to excessive consumption by individuals with low productivity of water use. In practice, political pressures often lead to initial blocks that cover much more than basic water needs. In a study by the Asian Development Bank (1993) of 17 utilities that use increasing block rates, the average size of the initial block for a household is 14 cubic meters per month. In comparison, a generally accepted standard is that the basic water needs for a family of five can be met with only 5 cubic meters. Only two of the utilities have initial blocks at or below this level.

A third approach to achieve efficiency and address distributional considerations is through *cap and trade systems*. In this case water users are given transferable rights to certain quantities of water and are allowed to trade those rights. The use of this approach is limited, but it is growing (Tsur et al. 2004). This method may entail high transaction costs and may require institutional changes and improved conveyance facilities and effective management and user training. Therefore, this system may be more feasible for facilitating trade between irrigation districts or industrial water users than for individual households.

A water-pricing reform that will reduce the consumptive use of water in the short run may have negative consequences on poor groups in society. For example, if higher prices of water will lead to reduction in supplies of food, the poor are likely to suffer. A reform that will reduce water availability and increase water prices will significantly reduce farm income. The short-run equity loss may lead to a long-run gain if the lower extraction in the short run enhances long-term supplies and leads to innovative activities that increase the productivity of water and the food system. Overcoming some of the political economic constraints and meeting distributional objectives may require transfer payments to affected consumers, farmers or members of other groups. A well-functioning welfare system may make it easier to reform water pricing.

Water is subsidized in developed and developing countries alike. Elimination or reduction of subsidies in developed countries may actually have a positive effect on poor farmers in developing countries, as it will improve their competitive position in global agricultural markets.

The subsidization of water is frequently associated with institutional and infrastructural deficiencies, and thus a reform requires more than establishing the right prices. Below we will address some *required changes that will improve efficiency* and which may have desirable distributional impacts.

Conveyance management

Much of the water is lost on its way from the source to the end user. Water conveyance losses of 50% and above are not uncommon (Wade 1997). As Chakravorty et al. (1995) show, profit maximization by individual producers leads to underinvestment in conveyance because each user is concerned with investing in a conveyance leading directly to his/her site, ignoring the benefit of improved conveyance to the individuals downstream. Thus, conveyance infrastructure has some public-good properties, as improved conveyance facilities benefit a large number of people that jointly utilize it.

One proposed solution to address underinvestment in conveyance is to establish an organization, such as a water user association (WUA), that will build and maintain the conveyance in a way that maximizes regional social welfare. Such an association would both build infrastructure and be responsible for the distribution of water. Globally, the number of WUAs has increased in the last twenty years, due to their support from international agencies such as the World Bank. Evidence has shown that WUAs provide better water delivery services and system maintenance than government agencies (Subramanian et al. 1997). In addition, water pricing should account for geographical differences, with users further away and higher up from the source paying a higher premium, which will lead to conservation downstream.

As shown in Figure 1, a transition to an optimal system will modify the allocation of water over space and expand overall production (Chakravorty et al. 1995). There may be positive distributional impacts from improved conveyance as well. Frequently, the wealthier members of society are located upstream, nearer to the sources of water, while the poorer farmers are located downstream. Introduction of an institutional setup that will improve conveyance systems may enhance the well-being of the poor directly by providing downstream farmers with better access to water and indirectly by increasing food availability.

Groundwater management

The improvement in pumping technologies led to a drastic expansion of groundwater extraction throughout the world. In many regions, for example, in regions of India, China, Mexico and Yemen, extraction rates are much higher than recharge rates, which may lead to temporary or permanent depletion of aquifers. In the past, depletion of aquifers has led to new surface water projects to replace groundwater use, but in many cases, it is either prohibitively expensive or simply infeasible. In most locations, groundwater is a renewable resource and can be sustained with the proper management. However, with groundwater pumping, we see the tragedy of the commons: many individuals share an aquifer, and people undervalue the future cost of excessive pumping in the present. In some cases, the impacts of groundwater pumping on neighbouring wells may be small, especially when groundwater wells are far apart from each other. However, in cases where the

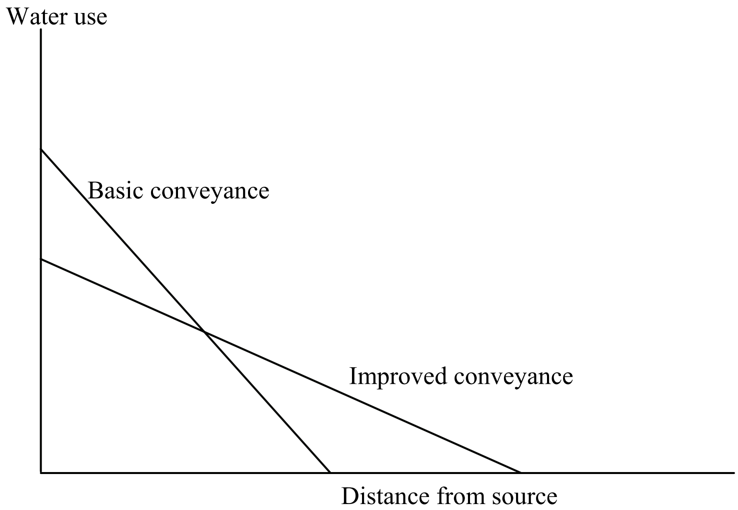

Figure 1. *Impact of socially optimal conveyance on spatial water use/distribution*

location of groundwater wells is unregulated and there are many wells in a small area, one farmer's pumping can have significant impacts on the pumping costs and availability for other farmers. For example, it is common for irrigation wells in the United States to provide water for more than 100 acres. However, a recent study in South India showed that on average, a single well irrigated only 8.6 acres, providing evidence that the common-property problem is much more pronounced in certain areas (Bhat et al. 2006). In some countries, such as India and Mexico, energy for groundwater pumping is subsidized, which may accelerate the tendency to over-pump.

Attaining optimal groundwater pumping may require introducing regional WUAs to monitor aquifer levels and control groundwater pumping. These associations may formalize water rights among users and determine the aggregate cap for regional pumping according to the state of the aquifer. Establishing such an organization requires a friendly legal framework as well as a strong capacity to monitor water use. There are some examples of central management of groundwater resources, such as in Israel. But even there, the decisions about pumping are not purely technical but also political, and may still lead to situations of excessive pumping (Feitelson 2005).

Pumping groundwater near oceans may lead to another problem: seawater intrusion. Again, individual extractors may not recognize the overall collective risk, and control of pumping in vulnerable coastal areas is of especially high priority. On the other hand, some coastal areas may augment their water supply by desalinization. So, while the depletion of groundwater inland may lead to the building of new aqueducts, near the coasts it may lead to desalinization efforts. In these cases, under-pricing of groundwater may accelerate depletion and/or seawater intrusion, and may lead to excessive investment in water projects. The introduction of controlled and reduced pumping may have negative distributional effects in the short run, but in the long run it will ensure sustainability.

Collective action and socially optimal management of aquifers may result in conjunctive use of surface and groundwater. A groundwater aquifer can play an important role as a buffer stock to be used only in periods of shortage. Thus, during wet years the aquifer will be replenished, and during drought periods it will be pumped to provide the needed water. Bird and Shinyekwa (2005) suggest that exposure to negative climatic shocks can actually increase the ranks of the poor as assets of households are depleted. The poor are already the most vulnerable to negative climatic shocks; therefore, building systems that reduce vulnerability to water shortages may be pro-poor.

Another advantage of conjunctive use and storage systems that reduce the volatility of water supply is that they provide incentives for farmers to take a long-term view and invest in high-value activities. Osgood et al. (1997) have shown that reduced uncertainty regarding availability of water and water rights is a significant factor in *ex-ante* decisions to adopt either perennial or specialty crops.

Water rights and trading

As mentioned earlier, rigid water-rights systems that ban trading have been a major source of inefficiency. The introduction of trading, while requiring investment in infrastructure (canals, monitoring, accounting systems, etc.), may expand aggregate production and lead to introduction of new industries. Thus, water reform is justified only if the efficiency gains from trading are greater than the costs of transition. There are not many studies on the benefits and costs of water trading and reallocation and their impacts on processes of rural development and settlement.

Frequently, the water rights belong to well-established individuals, and systems of trading may allow poorer farmers access to water. The transition to trading has to take into account that not all the water applied to a field is consumed in the field. The residual water that ends up as runoff or groundwater is up to 40% of the originally applied water. Others have used this residual water (positive externality); thus, when water trading is allowed, it is important to reduce the third-party effect by allowing people to sell only the rights to their consumptive use of water, rather than the rights to total application. The beneficiaries of residual water are likely to be poor, and assuring that they will be able to get their supply of water even after all primary rights are traded eliminates a possible negative distributional effect of trading.

Because of variability of water availability over time, water can be abundant in some periods while shortages exist in others. Trading may be appropriate in periods of shortage; therefore, regional authorities may prepare for trading by introducing options to buy and sell water that would allow quick adjustments to changes in availability. Water-right holders in Australia have proportional rights and the government determines a cap each year for the aggregate volume available.

The relative volume of trading may be small relative to the overall water use in a region, but the gain from trading may still be substantial. There are significant differences in value per unit of water consumed across agricultural products. For example, rice rarely generates a net return of more than $0.025 per cubic meter of water applied, while horticulture crops may generate 100 times that value. Even if 5% of the water is moved from rice production into horticulture during a drought, the welfare gains can be large.

Incentives for development and adoption of conservation technologies

Zilberman and Schoengold (2005) present evidence that shows that productivity of water systems varies with capital goods, management, and other inputs associated with water users. In particular, water-use efficiency, the fraction of applied water that is actually consumed, is dependent on irrigation technology, geographical characteristics such as land quality, and climate conditions. For example, water-use efficiency on heavy soils and flat lands with traditional gravitational activities may approach 80% to 90%, but gravitational technologies may have water-use efficiency of 30% on sandy soils and steep hills. Irrigation technologies such as sprinkler and drip augment water-use efficiency. For example, average water-use efficiency with gravitational technologies is about 60%, and it may rise to 80% with sprinkler and more than 90% with drip (Khanna and Zilberman 1997). While with drip and sprinklers higher capital costs contribute to improved water-use efficiency, there are low-cost technologies where extra labour contributes to improved water-use efficiency. The efficiency gains from adoption of improved irrigation technologies are especially pronounced at locations with poor land quality, as the irrigation efficiency of gravitational technologies on this land is low.

There is a large body of conceptual and empirical analyses that show that adoption of improved irrigation technologies tends to increase yield and reduce applied water (e.g., Caswell and Zilberman 1986; Schaible et al. 1991; Peterson and Ding 2005). It also reduces the residue of applied water that is not consumed by the crop. If this residue ends up as deep percolating water and has other negative effects, this reduction of residue may be a major source of benefits. The adoption of modern irrigation technologies can be enhanced by introducing appropriate incentives such as higher prices of water or the elimination of water subsidies. Allowing water trading or introducing restrictions or penalties on residue or drainage that collects the residue may also lead to adoption of irrigation technologies that reduce residue. The incentives for adoption may also initially include the subsidization of modern irrigation technologies, in order to enhance learning and trigger a diffusion process. Policies to disseminate knowledge about modern irrigation technologies, including the use of extension, may accelerate its diffusion. In cases where the residual water has positive impacts for the poor, who may be users of the water, distributional effects may need to be considered in a policy reform.

Increasing the price of water and enforcing stricter drainage penalties will not only lead to the increased adoption of modern irrigation technologies in the short run. It will also trigger investment in water-saving innovations and will result in the introduction of improved irrigation technologies and their adoption in the long run. Of course, irrigation technologies are not the only form of technologies that aims to improve water use. Improved efficiency of groundwater-pumping systems is another way to improve the efficiency of water systems. Introduction of weather stations and other monitoring stations that will improve the timing of irrigation may be another source of improved efficiency of water use.

Incentives to improve water quality

The poor are especially vulnerable to water quality problems. Lack of sewage systems and contaminated water that compromise hygiene are sources of water-borne diseases that kill millions. Investment in infrastructure to treat waste is very expensive and may not be affordable in many developing countries. The introduction of basic principles is important for improving water quality. Two sets of incentives are especially important. The first is the introduction of the *polluter-pays principle*, when it comes to source-point pollution. If the dumping of waste to public bodies of water is punishable, there will be private incentives to develop technologies and mechanisms to deal with the waste in an efficient manner. Economists have documented that incentives induce innovation, and build-up of an institutional and legal capacity to make individuals responsible for the waste they generate is a crucial element in improving water quality. In cases of nonpoint-source pollution, where it is difficult to identify the actual polluter (e.g., disposable of animal waste by industries consisting of many small farms), *activities that are correlated with waste generation should be regulated*. For example, requiring improved waste disposal practices from individual producers will reduce contamination risks. The regulation of nonpoint sources may be modified over time as information-gathering and monitoring technologies improve (Millock et al. 2002).

For political reasons as well as legal constraints, pollution control and reduction can be induced by ‘carrots’ instead of ‘sticks’ penalties. Programs that use *payments for environmental services* (PES) frequently provide subsidies for pollution reduction. PES are suggested as a means to induce poor peasants to disengage in activities that contaminate bodies of water or threaten wetlands, and there is a growing emphasis to promote PES as mechanisms that reduce poverty as well as enhance environmental quality (Pagiola et al. 2005). Empirical studies have shown that upstream marginal lands that are generally the focus of PES programs typically have higher rates of land users in poverty than in downstream areas (Pagiola et al. 2005). Other studies have shown that those watersheds that are the most hydrologically sensitive have high concentrations of poverty (Nelson and Chomitz 2004). One example of a PES program designed with a goal of helping those in poverty is the Mexican Payment for Hydrological Environmental Services Program (PSAH). The program targets regions with over-exploited aquifers (Alix-Garcia et al. 2005). Environmental services provided by forests include improving water quality and reducing runoff. The program design focuses almost exclusively on areas with communally owned forests[1]. There is a strong correlation between these areas and poverty rates (Muñoz et al. 2005), and therefore the program results in the desirable redistribution of income to those in poverty.

While this program shows how PES can help the poor, in other cases they may harm the interests of poor people (Zilberman et al. 2006). To evaluate the impacts, it is necessary to divide the poor population into three groups: urban, landless peasants and small landowners. PES activities that take land out of production or reduce supply may harm poor consumers by increasing the price of food, with the largest impact on the urban poor who rely on food purchases. However, municipal water requires a higher quality of water than irrigation demands, and thus the urban poor may see great benefits in water quality improvements due to PES programs. When the demand for food is elastic, PES activities that reduce the risk of flood or improve water quality are beneficial to the poor. Similarly, those activities that reduce production and thus employment may reduce the welfare of some landless poor. On the other hand, PES may enhance alternative employment activities. Thus, the distributional impacts of PES programs have to be analysed in the specific context in which they occur. While PES may not always be the appropriate tools to reduce poverty, they are important in improving water quality and enhancing environmental amenities that benefit all members of society, including the poor.

MIXING OIL WITH WATER

We have shown that the right incentives and management strategies can address many of the global water problems. Some of the solutions may increase water pricing and hurt the poor in the short run, but others will improve water availability in the long run and reduce the toll of water quality problems. However, most of the solutions discussed assume that prices of most inputs remain constant over time. Yet, water systems are energy intensive as water conveyance, purification and pumping demand significant amounts of energy. Modern irrigation technologies require energy for extra pressure. Increased water supply through the use of desalinization is also energy-dependent, but the global energy situation is subject to much pressure and uncertainty. On the one hand, there is concern about climate change and a desire to reduce emissions of greenhouse gases. On the other hand, rapid economic growth in China, India and other developing countries will lead to substantial increases in energy demands. Oil markets are very vulnerable to small changes in supply or demand conditions, resulting in unstable prices. High prices may lead to exploration and increased supply as well as some conservation. But as He and Roland-Holst (2005) suggest, the massive build-up of roads and automobile manufacturing in China and India and the rising incomes in these countries may lead to large increases in the demand for fossil fuels and increased pressure on energy prices.

Today the average Chinese consumes about 11% of what an American consumes, and in India the average consumption is 8% of an American's. These two countries have 10 times the population of the United States. It is reasonable to assume that the consumption of energy per capita in these countries will double in the next 10 years or so, as people start to own cars, computers and household appliances, resulting in the use of twice as much energy as the United States is currently consuming. Current trends suggest that energy use will also increase in the rest of the developing world.

The increased scarcity of energy will have both direct and indirect implications for water. The direct effect will come from higher energy prices, which will result in a higher cost of pumping, conveyance and desalinization. A higher cost of water will put pressure on water utilities, resulting in increased prices for consumers and a growing demand for reform that increases the efficiency of water systems. These impacts will also increase the value of water conservation activities. As we argued before, reform is triggered by crises; and while drought provides one type of crisis, high energy costs are another type of crisis that will trigger change.

The indirect effect will be in the form of demand for alternative fuels. We have already seen the increased production of ethanol and bio-diesels, and these technologies can be improved upon and are likely to become an important part of agriculture. Bio-fuels are attractive because they are feasible with currently available technology, and they are net contributors of minimal amounts of carbon to the atmosphere (they sequester carbon production). They provide new sources of income to farmers. However, the introduction of bio-fuels may lead to major challenges, as Figure 2 shows. Let D_0^F be the initial demand for water devoted to agricultural food production, and let S_0 be the initial supply of agricultural water. The demand for water is a function of the price of food and the price of energy. Increases in the price of energy will reduce the supply of agricultural water, shifting S_0 upward to S_1, and will reduce the demand for water for food from D_0^F to D_1^F. However, increased energy prices will generate demand for allocation of water to bio-fuel production. So, total demand for water will become D_1^T, which includes the sum of the demands for water for food and bio-fuels. The intersection of the integrated demand and the new supply results in price P_1 and quantity Q_1, where the new price $P_1 > P_0$, but the quantity Q_1 may be higher or lower than the initial quantity Q_0. One thing is clear – the amount of water going to food production will be lower, which will reduce food supply. With an inelastic demand for food, prices will increase for food. The net effect is that introduction of bio-fuels may increase water use but reduce food supply, and that may significantly affect the availability of food for the poor.

One solution to this problem is to increase the productivity of both traditional crops and bio-fuels. Introduction of new varieties, including genetically modified varieties can increase per-acre productivity of water and other inputs in food production that may lead, through markets, to increased production of food, reduction of food prices, and consequently a positive effect on the poor. As Cooper et al. (2005) argue, excessive regulation, intellectual property rights constraints and limited technical capacity have constrained the introduction of genetically modified varieties in developing countries, where they have increased crop yields significantly. At the same time, there is a potential to increase the productivity of

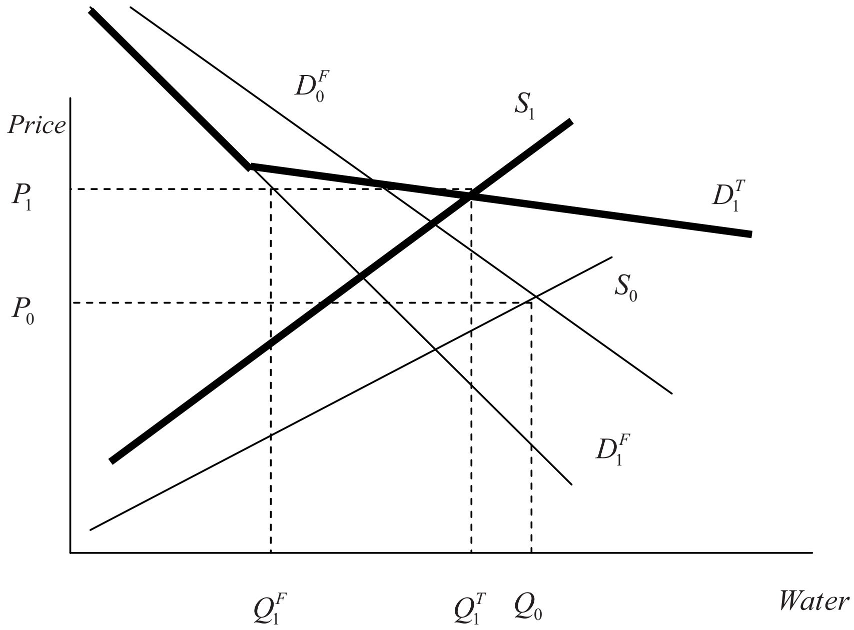

Figure 2. *The impact of higher energy prices and introduction of bio-fuels on water markets*

water used in the production of bio-fuels. Currently, there are two main types of bio-fuels – ethanol, produced from sugarcane in Brazil and other tropical countries and from maize in the United States and China, and bio-diesel, produced from soybeans, palm oil and other crops in Europe. As Ragajopal et al. (2007) document, the net energy gain from bio-fuel production using maize is rather small (less than 20%), while it is much higher with sugarcane. In both cases, the energy is produced from the plant sugars, rather than the cellulose. Ongoing research on conversion of cellulose to bio-fuels may lead to reliance on new crops, including switchgrass and miscanthus, which will increase energy production per acre, expand the possibilities for production of bio-fuels on marginal lands, and increase the sequestration of greenhouse gases.

Bio-fuels are an obvious example of increased energy demand putting pressure on water resources for the production of energy. Production of oil by coal gasification, by mining of tar sands and by increasing utilization of existing wells is also water-intensive. Furthermore, the use of water for oil production with these technologies leads to significant water quality and contamination problems. One avenue to address the pressure on water and other resources due to energy demand is to introduce incentives that reduce this demand, including taxation that reflects externality costs. These policies are likely to emerge and to have significantly negative effects on the poor. Thus, transfer policies may need to be established to offset these negative effects.

CONCLUSIONS

Poverty is widespread in many developing countries. Subsidized water or energy for pumping has been widely used to subsidize poor and not-so-poor farmers, but this subsidization is not sustainable. Groundwater aquifers are being depleted and the environmental and economic costs of existing water-use patterns are increasing. This paper presents the main elements of reform to address efficiency, equity and environmental concerns about water allocation and quality. The reform will emphasize careful application of a social benefit–cost analysis to evaluate infrastructure investments considering both market and non-market benefits and costs and structural and non-structural solutions. It will strive to establish mechanisms, including penalties for polluting activities and payment for environmental services, to improve water quality. Reforms will rely on market forces for water allocation, by allowing trading, and strive to introduce efficient pricing of water and at the same time use mechanisms that will address distributional concerns. Possible mechanisms include the allocation of tradable water rights among users and tiered pricing. Support for efficient water conservation does not directly impact the distribution of water resources, but does increase the availability of water for those needs that are the most critical such as basic health and sanitation (i.e., those needs with the highest value). Some forms of policy reform may hurt the poor in the short run, especially if prices increase and supply of water declines. However, it may lead to sustainability in the long run, and transfer payments should be used to cushion the cost of the transition. In addition, other reforms may provide better access to water for low-income households and reduce the toll of unsustainable water use and poor water quality in the long run.

Policy reforms that aim to modify traditional allocation systems and enhance trading and efficiency often have high transaction costs, and the efficiency gains from improved allocation have to be compared to the cost of transition (Shah et al. 1993). Since water resources are abundant in many locations and the costs of transition can be quite substantial, reform should not be pursued globally but only whenever and wherever it makes sense. Because water systems are subject to random forces, the economic and political feasibility of reform varies over time. Providing the guidelines for transition and economic education to policymakers and the public about possible gains from change is important, as it will provide the intellectual background needed to introduce reforms in moments of crisis or whenever it is most appropriate.

The economics of water has always been affected by other developments. Water scarcity is gradually becoming a problem because of population growth and economic development. Throughout history, water throughout the world was abundant, and institutions to manage it evolved accordingly. However, as demand increases, water becomes scarce, and that is the reason for the gradual transition to market-like solutions. The economics of water is also dependent on the energy situation. Many of the solutions to reallocate water and address water scarcity and water problems are energy-intensive. An increase in energy scarcity affects the capacity to address water problems. Furthermore, this paper shows that water may need to be reallocated to enhance the supply of energy. Thus, we will be challenged to attain sustainable, equitable and efficient solutions to both energy and water problems.

Bio-fuels are expected to be energy production by the poor, rather than energy production for the poor. The poor are increasingly urban as migration from the countryside continues, making the poverty impact of interactions between energy and food difficult to predict. The negative impacts on (poor) consumers of higher food prices may outweigh the positive impacts on (poor) producers of increased income for their food and bio-fuel crops, to the extent that these are not offset by higher input costs.

NOTES

[1] These communities are named *ejidos* and *comunidades*; both are types of communities that have been formed in the decades of land reform in Mexico.

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PAYMENTS FOR AND VALUES OF ENVIRONMENTAL AND FORESTRY RESOURCES

CHAPTER 4

THE ROLE OF MEASUREMENT PROBLEMS AND MONITORING IN PES SCHEMES

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Abstract. Payment for environmental services (PES) is seen as a mechanism that can achieve two goals, providing poor resource managers with an additional source of income and maintaining environmental services. Although some reservations have been made on the effectiveness of PES of reaching the poor, similar reservations can be made about achieving the second goal. Because many environmental services are intangible, developing simple and straightforward indicators to measure and monitor the environmental service provided and linking these to the efforts supplied by the resource managers is difficult and costly. But establishing this link is crucial to those who are paying and ultimately for the success of the PES concept. By reviewing the literature on this topic and analysing in a systematic way what types of measurement problems there are, we will show that the type of monitoring that is required within a PES has consequences for the institutional arrangement needed for a successful PES. We find that the institutional arrangements for monitoring vary according to (i) the type of environmental service and its underlying production process; (ii) the extent to which the environmental service can be freely observed or measured; (iii) the extent to which activities of the resource managers who provide the environmental service can be freely observed; and finally (iv) the deterministic or stochastic nature of production processes.
Keywords. PES; monitoring; measurement; institutional arrangement

INTRODUCTION

There is an increasing interest in Markets for Environmental Services (MES) as an approach to integrate economic growth, ecological integrity and poverty reduction goals (Hope et al. 2005; Landell-Mills 2002). Most come down to payments for environmental services (PES) where the ‘demand side’ is often the government (Kumar 2005). These environmental services have a public-good nature, governments have usually taken up the responsibility of maintaining them. Many PES schemes are funded by development agencies or rural-development programs, reflecting a combined goal of poverty alleviation and conservation of environmental services. However, recent research has shown that the poverty impact of PES is

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often mixed at best and may benefit the wealthier who have more natural assets (e.g., large landowners) (Landell-Mills 2002; Hope et al. 2005; Pagiola et al. 2005; Zbinden and Lee 2005; Grieg-Gran et al. 2005; Zilberman et al. 2006).

The idea of PES has an appealing simplicity, which may also account for its success in recent years. Proposals to apply PES for various goals abound. Successfully implemented PES schemes are far fewer though. Wunder (2005) identifies two key obstacles. The first obstacle is limited demand: too few service users are so confident about the mechanism that they are willing to pay – in some cases, because the link between land use and environmental services (ES) provision is insufficiently understood or ambiguous. The second obstacle is poor knowledge on the institutional requirements entailing incentive and livelihood mechanisms which so far have received comparatively little attention.

Wunder (2005, p. 3) defines a PES as: "a voluntary transaction where a well-defined ES (or a land use likely to secure that service) is being 'bought' by a (minimum one) ES buyer from a (minimum one) ES provider if and only if the ES provider secures ES provision (conditionality)". The last requirement on conditionality is the focus of our paper. It is an extremely important one because it ties in with the first obstacle mentioned by Wunder. As Pagiola and Platais (2005) state: "If services aren't delivered, people won't pay". Demonstrating that ES are in fact provided entails establishing a biophysical link between land uses and ES outcomes and developing suitable methods for measuring and monitoring provision of the service. The lack of information to link changes in practices to increased provision of environmental services remains the 'Achilles heel' for most PES programs (Pagiola et al. 2002).

It seems that poverty considerations may lead to disregarding this conditionality: "… most implementers seem to shy away from the business-like feature of only paying the providers if they actually deliver the agreed-upon service. In general, they are too concerned about disrupting their relationship with poor rural farmers to withhold payment" (Wunder 2006; see alsoScherr et al. 2006; Wunder et al. 2005; Hartmann 2004). Ironically, the concern of the implementers (mostly governments or donor agencies) with the livelihoods of poor rural farmers and ignoring the effectiveness of PES programs may compromise the long-term success of PES, jeopardizing the potential benefits of PES for these farmers.

Another important reason why many PES schemes have poor monitoring schemes is that it is often difficult to measure environmental services and to establish a cause–effect relationship between land use and the services (FAO 2004). Relationships among management practices on specific farmers, effects on environmental services, and benefits derived from these services are often complex and not completely understood (Claassen and Horan 2000; Kleijn 2006). Therefore, good science is important (Pagiola and Platais 2005), with models that can determine cause–effect relationships and predict and quantify environmental services. PES schemes intend to establish an information flow between service providers and users to facilitate the market exchange between both types of agents (FAO 2004). Ferraro (2005) also notes that hidden information (adverse selection) is a problem in all PES contract settings.

The economic literature on moral hazard and monitoring in agri-environmental schemes (Hart 2005; Fraser 2002; 2004; Ozanne et al. 2001) bases monitoring and payment on the *activities* of farmers as specified in the contract. Clear and measurable indicators for the environmental services are often lacking as well as a clear link between the agricultural practices and their effect: "most of Europe's agri-environment schemes have very vague goals, such as to 'prevent damage to the environment' or 'provide wildlife habitats'. Specific targets are not set; progress is rarely monitored; the baselines from which they start are not defined. The good that they do is thus hard to measure, which in some eyes makes the schemes hard to justify" (Whitfield 2006, p. 908). When a study evaluated these agri-environmental schemes and found them to be less effective than assumed (Kleijn et al. 2001), this led to a storm of discussion and possibly to reduced funding for such schemes (Whitfield 2006). In a follow-up project on evaluation of agri-environmental schemes, one of the conclusions was that "insights into cause and effect are important for the design/re-design process, for which monitoring and clarity of objectives are key" ('EASY'-project 2006).

We will analyse the issues of measuring environmental services and monitoring the activities of resource managers. By reviewing the literature on this topic and analysing in a systematic way what types of measurement problems there are, we will show that the type of monitoring that is required within a PES has consequences for the institutional arrangement needed for a successful PES[1]. Monitoring is only one aspect of the institutional design of PES, and so far, it has received comparatively little attention. We shall not focus on other important aspects of institutional design of PES, such as property rights, the necessary legal framework, contract type and length, and hidden information. There is a growing amount of economic literature devoted to this, often making use of principal-agent theory (Rojahn and Engel 2005; Engel and Palmer 2005; Ferraro 2005; Rojahn 2006 and other articles in press which are not yet for citation). More literature is available on agri-environmental schemes (Moxey et al. 1999; Ducos and Dupraz 2006; Ozanne et al. 2001; Fraser 2002; 2004; Hart 2005 to mention some recent literature). Other literature focuses on predicting the supply of environmental services, which can incorporate heterogeneity of opportunity costs and can thus be used to address the hidden information problem (Antle and Valdivia 2006; Antle and Stoorvogel 2006).

THE ROLE OF MONITORING IN PES

In general, a PES scheme includes certain economic agents (resource managers or farmers) who manage resources that provide a positive environmental externality or environmental service. This environmental service benefits another group of people, which can be a specific group of people or society as a whole. These beneficiaries can be labelled as the 'service demand side' or buyers. For simplicity and following principal-agent theory, we will hereafter call the service providers 'agents' and the service demand side the 'principal', except in cases where we want to describe the type of agent or principal. In many cases the government, representing the interests of the beneficiaries, acts as the principal. We therefore assume there is only one principal and refrain from cases where there are multiple principals entering into contract with one or more agents. We also assume that agents face the same opportunity costs and are symmetric in their influence over the production of the environmental service, although we will relax that restriction at the end[2]. The agents and principal agree on a contract which specifies the actions that the agents should undertake and the payments terms. The principal expects the actions of the agent to lead to certain environmental services, for which she is prepared to pay. The payments cover at least the opportunity costs of the actions implemented by the agent, satisfying the participation constraint.

Transaction costs play an important role in PES schemes. Transaction costs are often underestimated and may undermine the viability of a PES scheme (Landell-Mills and Porras 2002). Therefore the setup of any PES scheme must aim to reduce transaction costs. This can be achieved by choosing the most appropriate institutional setup (Eggertsson 2005). Within institutional economics three sources of transaction costs can be distinguished, viz., contact, contract and control (North 1990, p. 28-33):

1. Contact entails the cost of measuring the valuable attributes of what is being exchanged. Individuals engaged in a transaction need to know what they are buying. In case of simple products, such as oranges, the cost of getting information about the product is low. In the case of PES, the cost of getting this information can be high, as was outlined in the introduction.
2. Contract entails the costs of protecting rights. Property rights of individuals over assets consist of the rights, or the powers to consume, obtain income from and separate from these assets. Exchange involves the mutual ceding of rights. The rights people have over assets are not constant; they are a function of their own direct efforts at protection, of other people's capture attempts, and of government protection (Barzel 1989). PES schemes require the allocation of titles *de jure* or *de facto* on environmental externalities benefiting third parties (environmental service). Protecting rights over environmental services can involve high costs because of their transient nature.
3. Control entails the costs of policing and enforcing agreements. Enforcement poses no problems when it is in the interest of the other party to live up to agreements. But without institutional constraints, self-interested behaviour will exclude complex exchange because of the uncertainty that the other party will find it in his or her interest to live up to the agreement. This conflict of interest coupled with asymmetric information gives rise to contract theory. There are two sources of asymmetric information: when the agent can take an action unobserved by the principal there is moral hazard or hidden action, and when the agent has some information about his cost or valuation that is ignored by the principal there is adverse selection or hidden knowledge (Laffont and Martimort 2001).

This paper focuses mainly on the last source of transaction costs. In contract theory, the solution to moral hazard is the internalizing of incentives, via the contract terms while the solution to an adverse selection situation involves offering several alternative contracts, and the agent's choice between these alternatives reveals his private information (Macho-Stadler and Pérez-Castrillo 2001). Many of these models assume that the final outcome can be measured and can be attributed to effort. Monitoring in these models is often costless. Incorporating the right incentives into the contract is therefore key while monitoring usually plays a minor role, although some models do not assume costless monitoring and the use of (external) auditors play a role. When monitoring is not costless, Demougin and Fluet (2001) show that monitoring and incentives can be either substitutes or complements in a moral-hazard situation, depending on the circumstances. Monitoring includes the direct supervision of the agent (i.e., the agent's actions) as well as the use of output-related performance indicators when this is relevant. Demougin and Fluet (ibid.) suggest that the principal will presumably need to combine signals from various sources, taking into account the cost and informativeness of the signals.

Although there is a wide range of economic literature on enforcement (see Polinsky and Shavell 2000 for an overview), monitoring and enforcement have often been ignored by both academics and policy-makers when discussing environmental-policy alternatives (Cohen 1999). In the economic literature on enforcement, the principal's problem is to choose enforcement expenditures (or equivalently, probability of detection through monitoring), the level of fine, the standard for imposing liability and, if relevant, the imprisonment term. Because there is a trade-off between the level of fine and enforcement expenditures, the principal can reduce monitoring costs by imposing high fines (Becker 1968). In PES schemes, the voluntary nature limits the range of punishment mechanisms. Either they do not exist at all (see Wunder et al. 2005) or they are limited either to decreasing payments or to ending the contract completely. In some PES schemes, payments are made to communities in the form of community social support, such as building a road, giving access rights or any other royalties, or building a new school or health centre (Rosa et al. 2003; Van Noordwijk et al. 2004). However, this undermines the conditionality of payments as these cannot be taken away when environmental services are not supplied. We will therefore assume that payments are made contingent and that non-compliance leads to reduction or discontinuance of payments. Finally, information gathered from monitoring serves as the basis for enforcement.

In agri-environmental schemes in Europe and the USA, the possibility of a fine is often included (Ozanne et al. 2001), but because many PES schemes in developing countries aim to enhance rural development and reduce poverty, imposing a fine on poor resource managers in addition to withholding payments might be considered inappropriate. Thus, in most PES schemes there is no additional fine and the 'punishment' consists of reducing payments, which is of a limited range. This can be modelled as limited liability. Given that there is a trade-off between the level of fine and level of enforcement or required monitoring, this implies that monitoring and enforcement expenditures cannot be decreased much.

Three main environmental services can be distinguished (Landell-Mills and Porras 2002)[3]; these categories are also used by Rohjan and Engel (2005):

- Biodiversity conservation
- Carbon offset
- Watershed protection.

Rohjan and Engel (ibid.) categorize these according to production technology. We will do the same but in a slightly different manner. Our criteria are twofold and linked to monitoring of input (activities implemented by the agents) and outcome (the environmental service). The first criterion is thus at the level of the activities where we make a distinction between those services whereby the individual activities can be measured independently and those whereby the activities influence each other, i.e., the activities of one agent affects the activities or outcome of another agent. The second criterion is at the level of the outcome, where a distinction is made between those services that can be attributed to an individual agent and can thus be monitored per agent, and those services that are pooled or joined. This classification is illustrated in Figure 1. Following Rohjan and Engel (2005), we characterize environmental services that can be supplied through an independent, a joint additive or a joint multiplicative production function. One square (bottom left) is left empty because it is technically not possible that a production function is characterized by interdependence but its outcome is not.

		Outcome: environmental service	
		Individual	**Joint**
Input	**Individual**	Production function: *Independent* Example: Carbon offset through tree planting	Production function: *Joint additive* Example: Groundwater management, watershed protection, decrease of run-off
	Group		Production function: *Joint multiplicative* Example: biodiversity conservation through joint forest management or through agri-environmental management practices

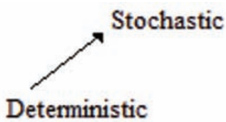

Figure 1. *Classification of environmental services according to measurement of input or outcome*

A third dimension is added in the figure and that is whether the link between input and outcome is deterministic, which means that the outcome is completely determined by the activities implemented by the agent, or whether it is stochastic, and that the outcome is influenced by natural processes such as climate. Most environmental services are more or less influenced by natural processes, and thus the agent has no complete control over the outcome. Generally, in a market, buyers of a good or service pay for the good or service itself, and do not care how much effort was put into the production[4]. When you buy bread from the baker you are not interested in how much effort the baker put into it, you care about the bread you buy.

Similarly, buyers of environmental services presumably therefore care only about the outcome of the production process, and not about the activities the resource managers have put into this. Thus, buyers on the environmental-services markets would pay a certain price for each tonne of carbon offset, cubic metre of water supplied downstream, tonne of sedimentation reduced and number of rare species protected. This would suggest that monitoring would only need to be done at the outcome level. But this is only possible when the production process of environmental services is almost completely deterministic and the cause–effect relation between input and outcome is clear. Since it is not, monitoring is necessary of the activities implemented by the agents.

The stochastic nature of the provision of environmental services thus includes a certain amount of risk. It is possible that certain activities have been implemented (at a certain cost), but that natural processes reduce the outcome. For instance, resource owners are paid to conserve a forest, but this forest is destroyed by natural forest fires. In some cases, climatic conditions render the activities implemented by the agents ineffective. To illustrate this case, farmers are paid to implement soil and water conservation to reduce soil erosion, but in a year with little rainfall there is little erosion anyway and the effectiveness of these structures is negligible. These effects are to some extent measurable – it is easy to verify whether there has been a fire, or the amount of rainfall. But in other cases the exact link between activities implemented by the agents and the environmental service is not clear because the natural processes are not well understood.

The stochastic nature of the production of environmental services means that there is a production risk. Who should bear this risk, the agents or the principal, depends on the contract. Especially when the agents are poor and are vulnerable to financial insecurity the balance should be carefully considered. Rojahn and Engel (2005) discuss the role of risk through environmental processes in optimal incentive contracts (see also Ozanne et al. 2001; Fraser 2002). They observe that the general structure of PES contracts should be a two-part linear payment. The two parts of the payment scheme are a fixed compensation and a variable payment based on the produced amount of the environmental service. They serve to balance risk and reward. In general, risk and risk aversion on the part of the agent increase the risk premium of the agent and in that way their cost of supplying the environmental service. We will not discuss the role of risk further, although we acknowledge that risk and risk aversion are important aspects in designing PES contracts.

INDEPENDENT PRODUCTION FUNCTION

An example of an independent production function is tree planting to provide the service carbon offsetting. The activities of the resource manager planting the trees can be easily observed. The outcome, reduced carbon in the air, cannot be observed easily. Nevertheless the link between the number of trees and the amount of carbon offset is clear and can be measured easily, thus we can safely interpret this as the outcome being easy to measure.

In the simplest case, three criteria are satisfied: (i) the production function is independent; (ii) the link between input and outcome is clear; and (iii) both input and outcome are measurable, and a simple institutional arrangement will probably do. A contract or agreement will specify certain (measurable) targets that need to be met, which can then be verified by the principal with negligible transaction costs. PES schemes are often portrayed in these terms, but this simple case is rare in reality. Even in situations with an independent production function shown in Figure 1, such as tree planting, the principal must make some costs to verify input or outcome. Especially in a PES scheme in which many agents participate, the sum of all monitoring costs can be substantial, let alone the enforcement costs. Monitoring costs can be reduced by using techniques such as remote sensing, which will cover many agents. The number of trees planted and amount of carbon sequestration can be monitored by, e.g., remote-sensing techniques (Vincent and Saatchi 1999), which will reduce monitoring costs per tree planted. Another approach can be to work with groups of agents, where the agents monitor each other and the principal monitors the group and holds the group accountable for the input and outcome. Ghate and Nagendra (2005) for instance examine the impact of the institutional structure on monitoring and on the effectiveness of forest management in India. They find that local enforcement (i.e., by the agents themselves) has been most effective in the case where forest management was initiated by the communities. However, this approach brings about potential problems of free-riding within a group, and specific solutions must be found for this problem. We will discuss group monitoring below under joint additive production function.

When outcome can be observed easily but input cannot, there is a moral-hazard situation. In general, in principal-agent models with moral hazard, if the principal observes the outcome but not the action, she can design a payment rule for the agent, based on the outcome, that provides the latter with appropriate incentives to act (Singh 1985). Monitoring is therefore often excluded from principal-agent models. However, Grossman and Hart (1983) in their seminal paper on moral hazard, acknowledge that the assumption that the principal cannot monitor the agent's actions at all, may in some cases be rather extreme. In such cases, imperfect monitoring of the activities or effort of agents plays a role. Choe and Fraser (1998) and Ozanne et al. (2001) for instance include the option of imperfect monitoring in agri-environmental schemes[5]. They find that risk aversion of farmers plays a role. Risk here is defined differently from above, when risk was linked to the stochastic nature of the provision of environmental services. In this literature, risk is linked to the possibility of being monitored. Choe and Fraser (1998), Ozanne et al. (2001) and Fraser (2002) analyse the potential trade-off between increased environmental benefits and increased cost of monitoring compliance. They find that higher degrees of farmer-risk aversion result in a reduction in the severity of the moral-hazard problem. The ability of compliance monitoring to resolve the moral-hazard problem effectively is therefore largely determined by the degree of risk aversion displayed by the agents and the cost structure of the monitoring process.

In the case of independent production, it is not often the case that the input activities of agents can be observed but outcome cannot. Due to the character of independent production, the outcome arises at the same locality as where the input measures are implemented and is therefore usually observable.

JOINT ADDITIVE PRODUCTION FUNCTION

A joint additive production function resembles the independent production function in that each agent contributes to the environmental function independently. But with joint additive production, the combined efforts of several agents produce a joint outcome. For instance, if several farmers reduce pumping of groundwater, the overall water level will rise. We assume here that the contribution of each agent is symmetric and additive. Thus if the outcome is lower than expected or specified in a contract, the principal knows that one or more agents have not contributed. The principal can only find out who by inspecting each agent. If the group of farmers is large, then the costs of inspecting each agent will rise accordingly.

This seems to be another moral hazard problem for which the solution is a contract that entails the right incentives to overcome this problem. But the common assumption in moral hazard is that outcome is freely observable and sufficiently informative about the agent's effort to warrant using it for contracting, which in the case of joint additive production is not tenable. In the above case, for instance, the outcome (overall water level) is not sufficiently informative about the individual agent's effort. In this case, some form of monitoring becomes necessary (Singh 1985; Baiman and Rajan 1994). The question now is how the principal should monitor the contribution of the agents. In a joint additive production function, it is possible to monitor the individual activities of the agents and the joint outcome, be it at a cost. There are two alternatives. The first is that the principal inspects all agents to determine who is shirking, and the second is that the principal contracts a group of agents and leaves it to the group of agents to monitor each other. We assume here that the activities of the agents can be observed, be it with (varying) cost.

Principal inspects agents

This situation leads to another form of asymmetric information, about the form and type of monitoring. The principal for instance may know when she will inspect the agent, but the agent does not. We will illustrate and analyse this problem by game theory. Inspection games have been applied to various problems, ranging from arms control to environmental regulation (Avenhaus et al. 2002) but could be applied to monitoring in PES too. We will briefly describe a simple inspection game (described in Fudenberg and Tirole 1991) and will then describe some extensions and their implications for the institutional setup.

We assume that there are two players, an agent and a principal. The agent can play two strategies – cooperate (stick to the agreement, denoted by C), or shirk (S). The principal has the choice to monitor and inspect the agent (I), or not to inspect (NI). The pay-offs to the agent and the principal depend on the costs of abiding by the agreement for the agent (c), which can be interpreted as the opportunity costs the agent needs to make to implement the contract, the value of the environmental service (v), the costs the principal needs to make for monitoring (m) and the payment the agent receives when he abides by the agreement (p). If the agent shirks and is detected by the principal he receives no payment. Satisfying the participation constraint means that $p > c$, otherwise the agent would not enter the contract. In many PES schemes, agents are paid only for their opportunity costs[5], which would imply that $p - c = 0$. This means that the agent is indifferent between entering the contract or not. To ensure participation however, we assume that p is slightly higher than c. The pay-off matrix is shown in Figure 2[7].

Agent \ Principal	I	NI
S	0, m	p, - p
C	p - c, v - p - m	p - c, v - p

Figure 2. *Pay-off matrix for monitoring game*

This game can be interpreted as a two-move or sequential game, in which the agent moves first, deciding whether to cooperate or shirk. The decision is made on the agent's expectation about being inspected by the principal. The move made by the agent is not observed by the principal, who decides after the move by the agent to inspect or not. The principal does not know whether the agent has cooperated or shirked. If the agent is found to shirk, the principal needs only to bear the monitoring costs (m) because the agent is not paid (receives 0). If the agent is found to cooperate, the principal needs to pay a reward plus bear the monitoring costs, and receives the environmental service (v-p-m). However, if the principal does not inspect and the agent shirks, the principal confers a payment (-p) which the agent receives (p), but there is no environmental service provided (0). If the principal does not inspect and the agent does cooperate, the target level is achieved and a reward is made (v-p) to the agent, who receives a payment minus costs made (p-c).

The preferred strategies of the principal and agent depend on the monitoring costs m, payments p, costs of input c and value of environmental service v. If we assume that the monitoring costs are very high and larger than the payments made to the agent ($m > p$), then the principal would prefer not to inspect. If the agent is aware of this, he will choose to shirk, and the equilibrium outcome is (S, NI). Clearly this would undermine the PES scheme. If we assume that monitoring costs are not very large (at least smaller than the payments made to the agents) there is no pure strategy equilibrium for this game. If the principal does not monitor, the agent would prefer shirking. Therefore, the principal is better off by monitoring. However, if the agent knows the principal is guaranteed to monitor, and the agent will therefore choose to cooperate, the principal is better off by not inspecting (thus saving monitoring costs). The solution is a mixed strategy, which means that the principal must randomize, so that the probability of monitoring is between 0 and 1. Similarly, the agent must randomize, which means that his probability of cooperating is between 0 and 1. Thus it depends on the probabilities of the fact that the principal will monitor the agent's compliance that determines whether an agent will cooperate or shirk. Mixed strategies are not as intuitive as pure strategies because people do not take random actions. A mixed strategy here can be interpreted as a principal and a number of agents, where the principal selects at random an agent to monitor, with a certain probability. Vice versa, each of the agents chooses to shirk some x percent of the time, and cooperate 100 – x percent of the time. Then x/100 is the probability that an agent will shirk (Rasmusen 2007).

Avenhaus et al. (2002) discuss several variations of the inspection game. In the simplified game above, it is assumed that if there is an inspection, the principal knows whether the agent has shirked or not. However, in practice, this may not be easily verifiable and there may be measurement problems on the input side, while the outcome is difficult to measure, or does not reflect the input (the production function is stochastic). The game is extended with the possibility of the principal inspecting, making an error and calling a *false alarm*, accusing the agent falsely of shirking[8]. The pay-offs of this option depend on the situation. If the agent can show that the principal accused him wrongly, the pay-off to the principal can be a penalty to be paid to the agent. If, for instance, the detection of a shirking agent represents a 'failure of safeguards' and the principal would prefer to avoid such a bad reputation this could be seen as an additional cost. This makes it unattractive for the principal to monitor.

The above game has been modelled as a one-off game, which can, of course, be played several times. However, sequential games may have different implications. Dresher (1962) introduced an inspection game with a number of stages which can be defined as recursive models. Thus the information problem that existed in the above game is partly solved, because the principal and the agent know what each did in the previous round and can base their expectations on this. Avenhaus et al. (2002) discuss this game and combine it with the leadership principle, which states that it can be advantageous to announce one's strategy and then commit to playing it. This ties in with the 'optimal' contract of Fudenberg and Tirole (1991), which maximizes the pay-offs for the principal and agent. They show that when the principal commits to a monitoring level (i.e., the principal chooses and announces a probability y of inspection), the principal and the agent can actually increase their pay-off. The principal needs to set the probability of inspection y at a level whereby the agent will always choose to collaborate (i.e., probability of cooperation is 1).

Another interesting variation of this game is explained by Rasmusen (2007)[9]. An institutional arrangement is possible whereby the principal does not inspect herself but hires an 'auditor'. The principal now has an additional asymmetric information problem with the auditor because she does not know whether the auditor will report truthfully or not. The auditor may receive side-payments from the agent not to report shirking or may save on monitoring costs and report that the agent is cooperating without verifying this. This may be a genuine problem in developing countries, where the institutional framework for resorting to legal action may involve high transaction costs. There are various optimal auditing schemes explored in game theory and principal-agent theory (see Dittmann 1999). One of them includes the idea of cross-checking whereby the principal hires a second auditor and asks him to report simultaneously. If both auditors report the same they are rewarded, but if they report different values they are both punished. This is a solution that will increase truthful reporting, and although monitoring costs will obviously increase by hiring two auditors, this may be the cost that needs to be paid to get information (Dittmann 1999).

Agents monitor each other, principal monitors group

The principal may prefer to establish a contract with a group. This makes it possible for the principal to reduce monitoring costs by transferring these costs to the agents. This is appropriate when monitoring costs are high for the principal but lower for agents. One could think of agents who are neighbours and who can easily observe each other's activities. The principal can then choose to inspect the group, which brings us back to the above situation, where the group can be considered as one agent.

Establishing a contract with a group of agents has a fundamental difference with the principal-agent relationship in the sense that group relationships entail the problem of free-riding since the effect of a reduction on effort (e.g., the principal punishes the whole group) is shared by all agents (Macho-Stadler and Pérez-Castrillo 2001). This problem can be modelled as a non-cooperative game, whereby the players choose between the strategy 'cooperate' and put in the required effort levels, or 'shirk' and free-ride on the other agents. There are two conditions that enable an agent to free-ride: first, the principal cannot detect who is free-riding and second, the principal pays the group of agents according to outcome and this is shared equally between group members.

The extent of the free-rider problem thus depends on the measurability and observability[10] of the agents' efforts. This model assumes that agents will always try to shirk when it increases pay-off. It is interesting that in social-psychology literature, various other motivational reasons for shirking ('social loafing') have been found, such as the lack of identification of individual contributions in a group effort, difficulty to establish a relationship between input and output, and a minimum of evaluation potential (Vermeulen and Benders 2003). This suggests that measurement difficulties and the complexity of input–outcome relations in PES actually contribute to shirking in groups!

If agents monitor each other they can only reduce free-rider behaviour if they also have the means to enforce cooperative behaviour. If they do not have these means, they can detect free-rider behaviour but cannot do anything about it, leaving the principal with a reduced outcome. Such a PES setup would not work: when monitoring and enforcement of activities are very costly, the situation can become a prisoners' dilemma game. In this game, we assume two players, agent 1 and agent 2. If they both cooperate, they obtain the highest payment (p) from the principal, which both share. Their net pay-off is this pay-off minus the costs (c) they make to implement the contract, where $\frac{1}{2}p - c > 0$ (participation constraint). If one player cooperates and the other one shirks, they receive a reduced pay-off, the total payment reduced by a fine for instance, $(p\text{-}f)$ where $p > f$ (the fine is always smaller than the payment), which they share. Since the one who shirked did not make any costs, he will receive a higher net payment. If they both shirk, they get no payment. See Figure 3 for the game.

		Agent 2: C	Agent 2: S
Agent 1	C	½p - c, ½p - c	½(p - f) - c, ½(p - f)
	S	½(p - f), ½(p - f) - c	0 , 0

Figure 3*. Prisoners' dilemma*

Because $\frac{1}{2}(p - f) > \frac{1}{2}p - c$, both players will choose strategy S (shirk) and end up not receiving any payments. This situation only occurs when the principal cannot detect who shirked, and the players cannot enforce cooperation or punish each other for shirking. However, in reality, this situation usually does not occur, and agents can enforce cooperation (Hargreaves Heap and Varoufakis 2004). Agents would not enter into a group contract if they could not enforce cooperation. Enforcement mechanisms do not need to take the form of punishment such as imposing a fine. There are various reasons why people will cooperate. This can be morality (people do what is morally right regardless of what others do), altruism (people are selflessly willing to contribute to a public goal) or inequality aversion (people feel guilty when they disadvantage others). However, Barron and Gjerde (1997) find that what they call 'peer pressure' does not always have a positive outcome when agents engaged in group production can detect and punish shirking (see also Kandel and Lazear 1992; Huck et al. 2002 on peer pressure). They describe for instance that there may be a conflict between the principal and the agents as to the optimal norm or sanction. The potential punishment agent 1 imposes on agent 2 benefits 1 if it induces greater effort by 2. But agent 1, unlike the principal, may not take into account the cost of such punishment in terms of deterioration of the work environment or psychological cost (such as guilt) for agent 2.

Enforcement in terms of imposing a punishment on the other player is made possible when the prisoners' dilemma is played several times. The strategic behaviour of the players can change because in this case, players do get information on what the other players are likely to do and can punish the other player. In fact, the optimal strategy is now 'tit-for-tat' (Axelrod 1984), which implies that a player (1) should play cooperatively in the first round, thus signalling to the other player (2) he is willing to cooperate. If player 2 reciprocates and also plays cooperatively, then both will get the highest pay-off. If they continue to do this, they will receive the highest pay-off for the entire game. However, if player 1 tries to maximize his pay-off at the expense of 2 (and defects), then 2 will punish 1 by defecting in the next round and both players find themselves in the sub-optimal pay-off situation (see also Radner 1981; Barron and Gjerde 1997). There are several variations of this repeated game that also take into account the discount factor of the players.

Several authors have analysed the role that punishment, trust and reciprocity play within game theory (Carpenter et al. 2004; Cox 2004; Engle-Warnick and Slonim 2006; Brosig 2002; Gintis 2000) and in common-pool resource settings (Castillo and Saysel 2005; Cárdenas and Ostrom 2004). Repeated cooperation leads to players acquiring a reputation of being cooperative. This leads to trust, other players expect a player with a reputation of being cooperative to be cooperative also in the future. They then feel confident to reciprocate and also cooperate. The more repeatedly cooperative behaviour is displayed, the higher levels of trust are attained. However, if players defect and obtain a reputation for being cheats, other players lose trust in them and will no longer be willing to cooperate. The more a player cheats, the less cooperation will be achieved.

JOINT MULTIPLICATIVE PRODUCTION FUNCTION

A joint multiplicative production function is characterized by the interdependence of production functions of different agents. Besides the fact that natural processes play a role, the activities of the agents influence each other. Their combined activities, no longer independent, lead to a joint outcome. For instance, the effect of the activities implemented in a certain field under an agri-environmental scheme that aims at improving biodiversity (plants, birds etc.) depends very much on what happens in neighbouring fields. The implementation of agri-environmental schemes on a small number of interspersed fields, as compared to a scattered distribution of isolated fields, can improve the effectiveness of conservation measures by providing stepping stones for species dispersal (Kleijn 2006). Parkhurst et al. (2002) explored the possibility of achieving adjoining fields through an agglomeration bonus.

If it is not just a matter of joining fields but if specific activities of adjoining agents influence each other, it makes sense to contract a group[11] so that agents can coordinate activities. However, this type of group will be slightly different from what we discussed in the previous sections and has been labelled team production. As Robbins (1996, p. 293) described team production: "One of the truly remarkable things about work groups is that they can make 2 + 2 = 5. Of course, they also have the capability of making 2 + 2 = 3". The difference with the type of groups we described above is that these make '2 + 2 = 4'. In team production the individual contributions add up to 5 or 3. Who contributed to the additional unit gained or lost is not clear. Alchian and Demzetz (1972, p. 779) were the first ones to describe team production: "With team production it is difficult, solely by observing total output, to either define or determine each individual's contribution to this output of the cooperating inputs. The output is yielded by a team, by definition, and it is not a sum of separable outputs of each of its members". Alchian and Demsetz thus make a distinct separation between joint additive and joint multiplicative production functions (p. 779):

"Team production of Z involves at least two inputs, X_i, and X_j, with $\partial^2 Z / \partial X_i \partial X_j \neq 0$. The production function is not separable into two functions each involving only inputs X_i, or only inputs X_j. consequently there is no sum of Z of two separable functions to treat as the Z of the team production function. (An example of a separable case is $Z = aX_i^2 + bX_j^2$ which is separable into $Z_i = aX_i^2$ and $Z_j = bX_j^2$ and $Z = Z_i + Z_j$. This is not team production.)".

Thus, joint additive production is not team production. After the seminal paper of Alchian and Demsetz, team production has been analysed by several authors (specifically Holmström 1982; McAfee and McMillan 1991) and has been applied to many different settings.

Alchian and Demsetz emphasize that in team production the marginal products of cooperative team members are not so directly and separably (i.e., cheaply) observable. Because measuring each agent's marginal productivity and making payments in accordance to this is much more costly than under joint additive production, monitoring of activities is no longer feasible. Some authors have studied team production with the possibility that agents *can* monitor each other (Kandel and Lazear 1992; Barron and Gjerde 1997; Moisan-Plante 2003). If this is possible, we are back to the group setting discussed above, where team members can use different sticks and carrots (or peer pressure) to enforce cooperation.

If we take the strict definition of team production however, and assume that it is not possible to observe the cooperation (i.e., marginal productivity) of team members, neither the principal nor the agents can enforce cooperation based on monitoring individual input. This again runs the risk of becoming a prisoners' dilemma in which the Nash equilibrium is shirking by all players. Holmström (1982) has shown that under certainty[12], team incentives alone can remove the free-rider problem. Such incentives require penalties that waste output or bonuses that exceed output. The principal either enforces penalties or offers bonuses. This role is what Holmström calls 'breaking the budget-balancing constraint'. The free-rider problem is not only the consequence of the inability to observe actions, but equally the consequence of imposing budget-balancing. Breaking the budget constraint will permit team penalties that are sufficient to police all agents' behaviour. For a PES scheme, it could be envisaged that agents are paid a flat-rate minimal compensation fee and are given a team bonus to be paid if a certain target is obtained. Imposing a penalty can be interpreted in several ways. In a dynamic context, which most PES schemes find themselves – the agreement between a principal and an agent's cooperation runs several years – the penalty can be a threat to discontinue cooperation. Holmström (ibid.) shows that enforcing team penalties cannot be imposed by the team itself. When less than the target level is produced, it is not in the interest of any of the team members to waste some of the outcome on a penalty. So when it is expected that the penalties will not be enforced, the free-rider problem reappears, because the situation is again similar to the budget-balancing one. Therefore the enforcement problem can only be overcome by bringing in an outside party (principal) who will take on the residual of the non-budget-balancing sharing rules.

Although the role of the principal as a budget breaker is certainly a solution to the free-rider problem in the case where agents' activities cannot be monitored, Rojahn and Engel (2005) point out that this type of collective punishment has several disadvantages. Most importantly, it might be perceived as unfair because it could lead to a situation where complying agents are forced to make up for their free-riding agents to avoid punishment. Bowles (2004) adds to this that when there are significant stochastic influences on the level of performance of the team, which is very possible in PES schemes, Holmström's solution becomes unfeasible. However, it is difficult to find an alternative solution to the case where shirking cannot be detected, and this is why Holmström's contribution is so important.

A more fundamental point of criticism is that Holmström's model assumes that the principal and the agents have conflicting interests. However, one could assume that agents will not enter into a voluntary PES contract under a team production scheme when they do not agree with the goals the principal has set. This will be true for some PES settings, especially when PES contracts only pay the opportunity costs such as in many agri-environmental schemes in Europe. Changing the conflicting-goals assumption changes the uncooperative situation to a cooperative model. More recent literature analysed moral hazard with several agents under a cooperative model (see Che and Yoo 2001 for an overview).

Macho-Stadler and Pérez-Castrillo (1993) analyse such a model and explore a situation in which cooperation between agents is possible and not detrimental to the principal's interests. The effort supplied by each agent is not observable, but outcome can be measured. The degree of cooperation between agents depends on both the incentive scheme they face, and the extent to which there exists a group culture that makes it possible for group members to commit credibly to the implementation of cooperative solutions. The authors make a distinction between groups and teams, similar to Alchian and Demsetz (1972) and in line with the distinction between joint additive production and joint multiplicative production. A team consists of a number of agents who, due to their continuous and close relationship, can reach cooperation on non-verifiable variables such as collaboration and effort. Macho-Stadler and Pérez-Castrillo (ibid.) show that a team is more profitable for the principal than a group of individuals without any commitment capacity.

Cooperation between agents thus depends on whether there exists a group culture or cohesion within a team. This can be achieved by the incentive scheme. According to Harkins et al. (1980; cited in Vermeulen and Benders 2003) rewarding and punishing agents should be based on group outcomes because the individual efforts are not visible. Group rewards are seen as an important determinant for cohesion, as collective rewards increase the 'group feeling'. Itoh (1991, p. 613) analyses the role of cooperation in teams, in the form of help that agents give each other, and finds that: "… teamwork is optimal if own effort and helping effort are complementary so that an agent responds to an increase in help from the other agent by increasing his own effort". An institutional arrangement that stimulates cooperative behaviour can initiate a positive sequence of cooperative behaviour. 'Help' as described by Itoh can take the form of sharing experiences and learning in a PES scheme, which will enhance trust but can also stimulate learning on how best to provide the environmental service together. Case studies in the area of the provision of water-related services by farmers in the Netherlands have demonstrated that interactive learning processes among area-based stakeholders can function as an effective governance mechanism in the water sector (SLIM 2004a; b).

Macho-Stadler and Pérez-Castrillo (1993) find a trade-off between benefits of team size for the principal and agent. If the team reaches a symmetric equilibrium and shares the payments equally, then the expectation of the average wage level of an agent belonging to a team is a strictly decreasing function of the team size. This means that the larger a team is, the more attractive it is to the principal. However, it is possible that the cooperation capacity of the group of agents is a decreasing function of its size. The trade-off between both effects will determine the optimal size of the group (from the perspective of the principal). Olson (1965) has put forward that in collective action (e.g., team production), smaller groups can function more effectively than large groups.

The last case we will briefly discuss here is when joint output is costly to observe and input may also be costly to observe. We have not found many models that incorporate these restrictions. Gautier (1999) developed a model in which the agents and principal invest together to develop a product (in our case a certain environmental service). Agents are responsible for the production of the service, and the principal invests in monitoring. The level of effort by the agents is private information to each agent. The efforts determine, together with a random shock, the output's value. This value remains unknown until the product is brought on the market. Hence there is a time lag between input and outcome. For PES this can be a relevant model, as the outcome of activities implemented by resource managers often only appear after a certain period (in the case of watershed services appearing downstream, or number of birds after the breeding season) and are influenced by natural processes (which can take the form of a random shock). In the model, the principal can observe a signal about the outcome's quality. The accuracy of the signal is affected by the principal's monitoring decision. Without monitoring, the signals are distorted. By investing in monitoring, the principal can observe perfectly informative signals. For PES this may be interpreted as follows. The principal may observe some signal about the environmental service delivered without making too many costs (rule of thumb, for instance). However, in order to measure the environmental service precisely, the principal must invest in a costly measurement exercise: for example an extensive survey of agro-biodiversity in an area, or quantity of water downstream.

The model assumes that the monitoring decision and the signal are private information to the principal. Private nature of monitoring and signals implies that agents will form expectations about the principal's monitoring decision and base their effort on these expectations. Conversely, the principal decides to monitor, evaluating the costs and benefits of this decision according to her beliefs about the agents' unobservable efforts. The principal can decide to accept of outcome on the basis of an imperfect signal, or invest in costly monitoring and on the basis of this decide to continue the PES scheme or discontinue. Gautier assumes that the principal will discontinue the project when she receives a signal that the project might fail, thus risking discontinuing a successful project. We refer to Gautier

(1999) for the model development and will present some of its results. Gautier finds two sources of inefficiencies. First, the ex-ante contract may not be efficient, and second, the ex-post continuation decision may be inefficient. This inefficiency takes its source in the absence of precise signals. Monitoring can remove this be it at a cost. But ex-post efficiency is not the only role of monitoring. It also affects the ex-ante contract decision. The choice of production mode is affected by the accuracy of information about output, obtained through monitoring. Ex-ante inefficiency is not completely restored by monitoring. The absence of proper incentives implies payments of rents to agents, which distort the choice of production.

CONCLUSIONS AND DISCUSSION

Because the idea of PES is so appealing, many PES projects are being implemented around the world. The appeal of PES is enhanced by the fact it can provide poor resource managers an additional source of income, thus combining environmental and poverty-reduction goals. Since the *concept* of PES is widely accepted, it seems less of a concern to actually show the effectiveness of PES projects and measure the environmental services provided or monitor the activities implemented by the resource managers. However, showing the effectiveness of PES is crucial to its long-term success, especially when the private sector is going to buy into the concept and pay for the environmental services they benefit from.

The specific nature of environmental services makes monitoring a multifaceted issue. The institutional setup of a PES scheme depends on (i) the type of environmental service and its underlying production process; (ii) the extent to which the environmental service can be freely observed or measured; (iii) the extent to which activities of the resource managers who provide the environmental service can be freely observed; and finally (iv) the deterministic or stochastic nature of production processes, or put differently, the extent that natural processes determine the environmental service. Transaction costs arise when costs must be made to measure the activities of resource managers and the environmental services. If these are high, implementing a PES scheme may become infeasible. The institutional arrangements must therefore be such that they reduce transaction costs and maximize pay-offs to resource managers and the principal. This may be achieved by providing different types of incentives, which include payment arrangements and punishments, and different monitoring systems.

We have distinguished three different types of environmental-service production processes (following Rojahn and Engel 2005): independent, joint additive and joint multiplicative production. We have shown that there are different monitoring issues for the three production processes. For an independent production process, individual resource managers can provide separate environmental services. Usually the link between input activities and outcome are clear. Although measuring the environmental service may be simple (e.g., observing number of trees planted through remote sensing), there are always costs involved, especially when the number of participants in a PES scheme is large. When outcome can be easily measured (number of trees) but not input (e.g., proper tree management), the classical moral-hazard problem in principal-agent model arises, which can be overcome by the appropriate incentive structure. In many such models it is assumed that input measures cannot be observed at all, and therefore monitoring is not feasible. However, this assumption can be relaxed in many cases of PES. The optimal contract will then include a mix of incentive structure and the possibility of being monitored. This introduces the element of risk, whereby the attitude of the resource manager towards the risk of being monitored by the principal determines the optimal contract.

In the case of a joint additive production process, the activities of several resource managers lead to a joint outcome. For instance, several farmers implement practices that increase groundwater levels. It might seem that this is another classical moral-hazard problem, whereby the outcome can be measured but the individual activities cannot. However, in principal-agent models, it is assumed that there is a clear link between the (unobserved) activity of the agent and its outcome. In the case of a joint additive production process this link cannot be made: the observed outcome does not reveal who contributed to it. Therefore the solution to moral hazard by offering a contract with the appropriate incentive structure alone will no longer be sufficient. In this situation inspection of activities of resource managers becomes necessary, which requires a slightly different institutional setup than under independent production. The principal has various options. She can decide to inspect the agents with a certain probability. It can be calculated which probability will lead to the maximum pay-off for the principal. As under individual production, the attitude towards risk is important, although we have not explored this in this chapter. A more thorough analysis of the role of risk in PES schemes is certainly warranted.

The principal can also hire external inspectors, which introduces additional moral hazard because the principal does not necessarily observe the reliability of the external inspectors. When inspectors can be bribed or are prone to shirking, this may increase the monitoring costs. In developing countries, where the capacity of the legal system to deal with such cases is low or entails high costs, this may be a real problem. A third option consists of leaving the monitoring to the natural-resource managers themselves. Often it is the case that resource managers, who live and work in close proximity, can more easily observe each others' activities. Only if they also have the means to enforce cooperation (e.g., through punishment) they can overcome the free-rider problem. There has been extensive literature developed in this area, and this institutional arrangement may well fit many different PES schemes. It is, however, important to remember that all these institutional arrangements assume that the outcome of group effort can be measured. Thus, whatever institutional arrangement the PES scheme adopts to achieve compliance, there will always be additional transaction costs that have to be made to measure the outcome.

Joint multiplicative production processes occur when there is a synergy between the activities of resource managers that lead to a joint outcome. In the literature this production process has been labelled team production. In fact, many environmental services can be characterized by such a production process to a varying extent. The most applicable is the provision of biodiversity, as measures implemented in one field affect biodiversity in terms of quantity and types in another field. The effect is not additive but multiplicative. This is the most difficult to deal with, because when we assume that the principal cannot observe the contribution of each agent to the joint outcome and neither can the agents, monitoring becomes ineffective, and establishing the appropriate incentive scheme that solicits cooperation is extremely difficult. The only solution that avoids free-riding is a draconian one put forward by Holmström (1982), which punishes all team members severely if one team member shirks. However, the underlying assumption in this model that the principal and the agents have conflicting goals and that therefore agents will always try to shirk needs to be re-examined for some PES schemes.

Natural-resource managers may not necessarily participate in PES schemes merely for the payment. In fact, in Europe, farmers only receive compensation for their opportunity costs when they participate in agri-environmental schemes or water-related services schemes (Van Moorsel et al. 2006). Thus principal and agents may well share the goals of contributing to environmental services such as conservation of biodiversity. In this case, cooperative models need to be applied. The degree of cooperation between agents depends both on the incentive scheme they face, and the degree to which there exists a group culture that makes it possible for group members to commit credibly to the implementation of cooperative solutions. The principal now needs to contribute to an institutional arrangement that enhances group culture. It is important to note that feed-back on the performance of the team, thus feed-back on to what extent the team is successful in providing the environmental service, can enhance group culture. Measuring the environmental service is again necessary, be it for another reason than under non-cooperative situations. In the context of cooperative team production, the principal needs to implement an institutional arrangement that is not geared towards agents monitoring each other to detect shirking, but to agents sharing information to learn and to help each other.

To what extent the interests of the principal and agents are similar in PES schemes will differ from case to case. In PES schemes where the goal is to provide poor resource managers an additional income through PES, the priority of the resource managers may not lie in providing an environmental service, but in receiving additional income. Also in the case where the environmental service is not a public good but a private good benefiting a private company for instance, the interests of the agents may not overlap those of the principal. This is of course completely acceptable, but in the case of an environmental service that has a joint multiplicative production this may pose enforcement problems that are not easily overcome.

We have reviewed here the implications of measurement issues in PES and in doing so have glossed over many important issues. The role of risk was already mentioned, but the issue of uncertainty[13] is equally important, especially in situations where the link between the activities implemented by agents and the outcome, the environmental service, is stochastic. Uncertain outcomes can be perceived as environmental services that cannot be measured, or can be measured only after the investment has been made. What type of institutional arrangement needs to be put in place to manage uncertain outcomes, especially with respect to how the upfront investments and uncertain pay-offs are shared between the principal and agents is a topic for further research.

NOTES

[1] We define institutions as rules here and not organisation. Thus an institutional arrangement specifies a certain set of rules that applies for those involved in a contract.
[2] We therefore do not investigate adverse selection, although this is an important issue in PES (Ferraro 2005). More attention has been given to adverse selection problems in agri-environmental schemes, compared to moral hazard problems (Ozanne et al. 2001).
[3] Landell-Mills and Porras (ibid) also identify landscape beauty, but we will disregard this service for simplicity, as it is often combined with biodiversity protection.
[4] Although increasingly, consumers care about the production process: whether it was environmentally friendly, or socially acceptable for instance.
[5] Ozanne et al. (2001) define imperfect monitoring as the inability of the principal to detect cheating. Two types of imperfect monitoring are possible, (see Polinsky and Shavell 2000): the Type I error as assumed by Ozanne et al. and the type II error, which is the inability to identify accurately whether or not a farmer has complied and may include "false alarms". We will briefly discuss these in a later section on inspection games.
[6] For agri-environmental schemes, the EU allows only payments that cover opportunity costs and transaction costs that farmers need to make to participate (see Van Moorsel et al. 2006).
[7] Following game theory, the pay-offs for the principal are in the columns after the comma, and the pay-offs for the agent are in the rows before the comma.
[8] Choe and Fraser (1998) include this option in their model. However, Ozanne et al. (2001) argue that this is unrealistic in agri-environmental schemes.
[9] Rasmusen uses the term auditing game, which is often used in principal-agent models.
[10] Observability can be interpreted as a dichotomous variable, the agent cooperates or not. Measurability can be interpreted as a continuous variable, which gives an insight into the extent to which the agent cooperates (from 0 to 100% for instance). In the prisoners' dilemma we assume a dichotomous variable.
[11] In the Netherlands, farmers have organized themselves into such groups. The European Union has recently allowed that farmers can participate in groups in agri-environmental schemes (Van Moorsel et al. 2006).
[12] Although group incentives can also work under uncertainty, their effectiveness will be limited if there are many resource managers and if the resource managers are risk-averse. In this case, the need for monitoring arises.
[13] Whereby we make the distinction between risk and uncertainty following Knight (1921): '*risk*' refers to situations where the decision-maker can assign mathematical probabilities to the randomness which he is faced with. In contrast, Knight's '*uncertainty*' refers to situations when this randomness 'cannot' be expressed in terms of specific mathematical probabilities.

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CHAPTER 5

CAN ECOTOURISM BE AN ALTERNATIVE TO TRADITIONAL FISHING?

An analysis with reference to the case of the Saloum Delta (Senegal)

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Abstract. This paper analyses the possible economic consequences of the development of ecotourism on fishing communities of poor countries from two complementary points of view: an empirical survey of a case study, and a bioeconomic model. It is divided into three parts. The first part of the paper is dedicated to the case of the Saloum delta, Senegal, an area where demographic pressure and an agriculture crisis have led to a sharp increase in fishing effort resulting in overfishing, and where attempts have been made to provide alternative income to the local population through ecotourism. The second part of the paper presents a two-sector bioeconomic model, where the link between artisanal fishing and ecotourism relies on their common use of the same natural resource. According to this model, developing ecotourism may help to overcome the dilemma between the need for long-term resource conservation and the immediate necessity to provide jobs and income to the local population. However, due to the negative externality exerted by fishing on ecotourism, the model suggests that this development is likely to be non-optimal if it is left to the initiative of market forces. The last section of the paper discusses the practical significance of these conclusions, with reference to the Saloum delta case. It underlines the major limits of the model, including the assumed non-extractive character of ecotourism, and its lack of spatial dimension.
Keywords. ecotourism; fisheries management; Saloum delta

INTRODUCTION

In many developing countries, a large part of the economy still relies on the exploitation of renewable natural resources, among which fish stocks. For these countries, fishing may represent an important source of foreign currencies, but also of employment, income and animal proteins (Loayza and Sprague 1992; FAO

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2004). However, poverty, demographic pressure and, in many cases, access conflicts and uncontrolled harvesting by foreign fleets frequently result in overfishing, which jeopardizes the potential of sustainable development of the national economy. In this type of situation, social pressure makes it very difficult to enforce conservation policies as short-term considerations are given an absolute priority. Developing non-extractive uses of the ecosystem, such as ecotourism, is frequently recommended as an alternative. The aim is to make ecosystem conservation a source of economic benefits, not only in the long run, but also for the present time.

In this paper, we first illustrate the relations between fishing and ecotourism through the case study of the Saloum delta (Senegal). We then analyse these relations in more general terms, by means of a bioeconomic model describing the interactions between two uses of the same natural resource, one of them being extractive (fishing) and the other non-extractive (ecotourism). Finally, we discuss the conclusions of the model, making use of some empirical evidences derived from our case study.

AN ILLUSTRATION: THE CASE OF THE SALOUM DELTA (SENEGAL)

The Saloum delta is located in the Sine-Saloum country, Senegal (Figure 1). It covers an area of approximately 5,000 square kilometres, representing 2.5% of the total surface of the country. The delta ecosystem is particularly rich in terms of biodiversity, which led to its classification as a national park in 1976 and a Biosphere Reserve by the UNESCO in 1981. It is also a densely populated area, with about 610,000 inhabitants in 1997, representing an average of 122 persons per km^2 and 7% of the total population of Senegal. Moreover, demographic pressure in the delta is growing fast, with a 2.8% annual increase in population (DPS 2001; Dia 2003).

Agriculture, which is the major economic activity in the Sine-Saloum, has undergone a long-lasting crisis caused by a combination of natural, demographic and economic factors (drought, fast population increase, inequal access to land, fall in the export price of peanuts). As a result, farmers were induced to diversify their activity towards artisanal fishing, a move that was eased by the weakness of economic and institutional barriers to entry into this industry (Cormier-Salem 2000; 2006). The number of canoes in activity rose from 1,200 in 1972 to 1,800 in 1978. Estimated yearly landings, which were around 20,000 at the beginning of the decade, reached a maximum of 50,000 tons in 1978 (Figure 2). This peak was soon followed by a sharp decline and, during the 1990s, annual landings fluctuated around 10,000 tons (data source: Marine Fisheries Authority, Dakar). The decrease in the number of canoes was more limited (around 1,600 units were active in the late ’90s), and was probably offset by the increase in individual fishing power due to technical progress. According to various studies, several species are clearly overfished (EPEEC 1998; Diouf et al. 1998; Ducrocq 1999).

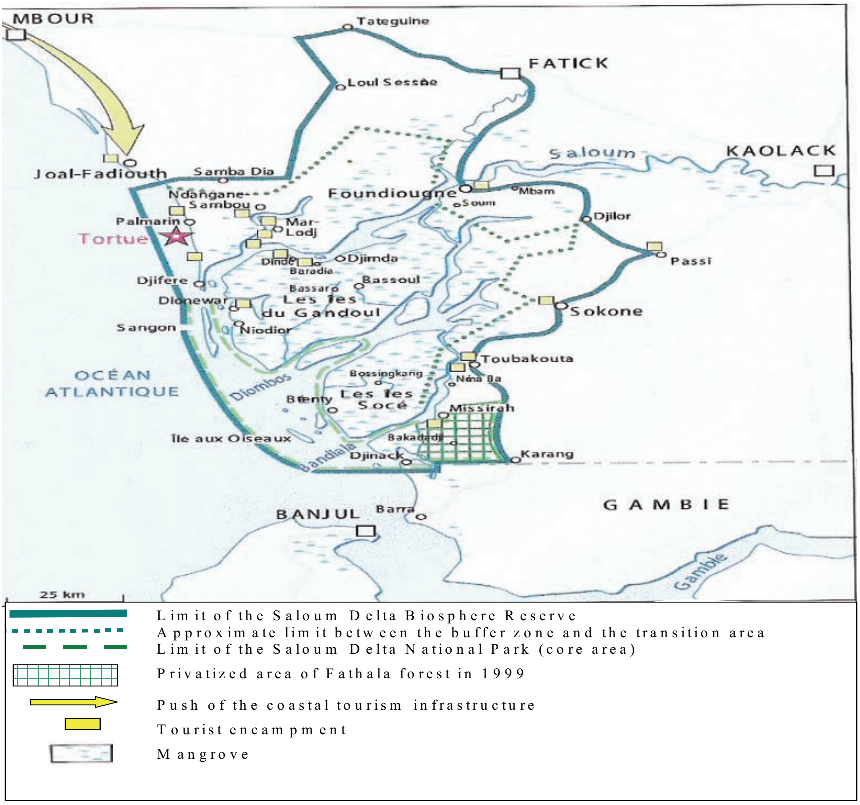

Figure 1. *Map of the Saloum delta (Source: Cormier-Salem 2003)*

In order to protect the estuarine ecosystem, a national park was created in the Saloum delta in 1976. Since that date, tourism has grown fast in the area (Figure 3), which is now the fourth tourist zone of Senegal: between 1975 and 2002, the accommodation capacity rose from 108 to 1,178 beds, and the yearly number of overnight stays rose from 5,181 to 44,327. In 2002, the local tourism industry turnover amounted to approximately 75% of the value of fish landings (data source: Ministry of Tourism, Dakar).

A field survey was carried out in 2003 in order to assess the factors influencing frequentation of the area by tourists and the socioeconomic impact of tourism on the local population (Sarr 2005). This survey covered hotel and holiday resort managers, their customers and local villagers (with emphasis on fishermen). According to the survey results, the fact that the delta is a marine protected area (MPA) is a major attraction factor for tourists: 34% mentioned it as the first motivation for their visit to the area. This feature is confirmed by the nature of their activities during their stay, which are clearly related to the state of the ecosystem: the two main activities

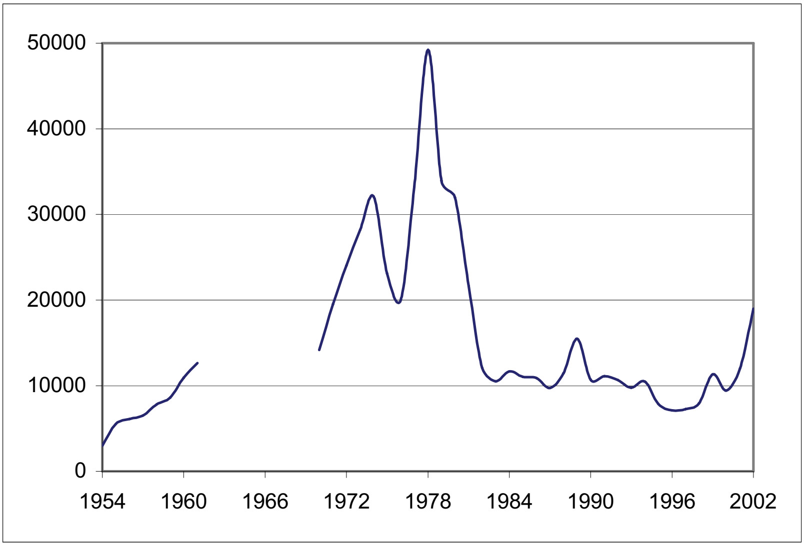

Figure 2*. Evolution of fish landings in the Saloum delta, 1954-2002 (Source: From the data of the Direction des Pêches Maritimes)*

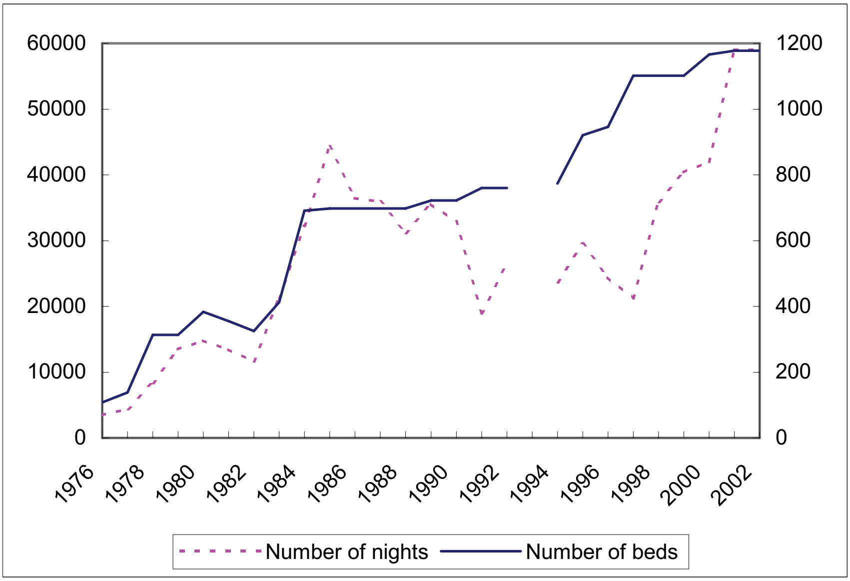

Figure 3*. Tourism in the Saloum delta: evolution of the accommodation capacity and of the number of yearly overnight stays, 1976-2002 (Source: From the data of the Ministère du Tourisme)*

declared by tourists are canoe trips in the delta (which shelters important populations of birds) and sport fishing (which is in principle non-extractive, insofar as the fisher releases his catches). These activities offer small-scale fishermen an opportunity to benefit from the presence of tourists, by providing services of transportation and tourist guides in the delta. According to survey results, 15% of the motorized canoes in the delta are involved in these activities. For the population of the area, the incomes generated by these services are added to the wages paid by hotels and holiday resorts to their local employees (8 permanent jobs per firm on average, according to the survey), and other incomes derived from the presence of tourists such as the sale of handicrafts.

A DIVERSIFICATION MODEL

In this section, we formally investigate the relation between artisanal fishing and ecotourism, with the help of a bioeconomic model. Let industry 1 be the fishing industry, and industry 2 the ecotourism industry. Both industries are assumed to rely on the same natural resource. However, they do not use it in the same way: unlike industry 1, industry 2 is non-extractive. We first present the relationships describing the production activity in each industry, and then we turn to the incomes and jobs they generate. Finally, we analyse the interaction between industry 1 and industry 2, and investigate the incidence of this interaction on social welfare.

Production

In the case of industry 1, the output is fish catch. For the sake of simplicity, we consider the local fish resource homogeneous. We use a model derived from the standard Gordon-Schaefer model to describe the links between fish stock, fishing effort and catch (Gordon 1954; Schaefer 1957; Clark 1976). This model relies on two basic relationships, describing the stock dynamics and the fishing technology.
The dynamics of the fish stock are due to natural dynamics and fishing mortality:

$$\frac{dX}{dt} = g(X) - Y_1 \qquad (1)$$

where:

- X is the fish stock biomass;
- g is a function describing the natural dynamics of the stock;
- Y_1 is the volume of catch by fishermen.

Let K be the carrying capacity of the ecosystem, and X_0 a level of X belonging to the open interval $]0 ; K[$. Function g is assumed to be positive for $X < K$, increasing if $X < X_0$, and decreasing if $X > X_0$ (in the basic Gordon-Schaefer model, g is quadratic, and $X_0 = K/2$).

With regards to fishing technology, the catch per unit of effort (CPUE) is supposed to be proportional to fish abundance:

$$\frac{Y_1}{E_1} = qX \tag{2}$$

where:

E_1 is fishing effort;
q is a positive parameter ('catchability coefficient') reflecting the efficiency of the fishing technology.

Combining (1) and (2), and assuming biological equilibrium ($dX / dt = 0$), we get the following relationships between fishing effort and the corresponding stabilized levels of fish biomass and catch:

$$X = X_s(E_1) \quad \text{with} \quad X_s{}'(E_1) < 0 \tag{3}$$

$$Y_1 = qE_1 X_s(E_1) = h(E_1) \quad \text{with} \quad \begin{cases} h'(E_1) > 0 & \text{for} \quad X_S(E_1) > X_0 \\ h'(E_1) < 0 & \text{for} \quad X_S(E_1) < X_0 \end{cases} \tag{4}$$

In the case of industry 2, the output is the flow of tourists visiting the area. Like fish landings in the case of industry 1, this output is the result of a combination of a natural factor (fish biomass X) and of an anthropogenic factor (attraction effort E_2):

$$Y_2 = f(X, E_2) \tag{5}$$

We assume that f is a standard production function, with substitutable factors and positive but decreasing marginal productivities. As a result, for a given level of X, Y_2 is an increasing and concave function of E_2.

Incomes and jobs

In each industry, the resource rent is defined as the surplus of revenue over effort cost, assuming constant prices and biological equilibrium of the natural resource:

$$\pi_1 = P_1 h(E_1) - C_1 E_1 \tag{6}$$

$$\pi_2 = P_2 f(X_s, E_2) - C_2 E_2 \tag{7}$$

where:

P_i is the unit price of output in industry i ($i = 1, 2$);
C_i is the unit cost of effort in industry i ($i = 1, 2$).
(both P_i and C_i are assumed to be exogenous)

Note that ecotourism rent (π_2) is a function of two variables (X_s and E_2), while fishery rent (π_1) is a function of one variable only (E_1).

Employment in each industry is related to the level of effort. For the sake of simplicity, let us assimilate these two concepts. As a result, the total level of employment generated by the two industries is the sum of E_1 and E_2.

Suppose that open access prevails in the fishery, unemployment is high and no alternative job is available in the area. Fishing effort will then increase up to the point where rent is totally dissipated (open-access equilibrium). Setting π_1 to zero in (6) and solving for E_1 provides the open-access equilibrium value of fishing effort ($\tilde{E}_1$). Corresponding values of stock and catch are then obtained through (3) and (4) (Figures 4 and 5).

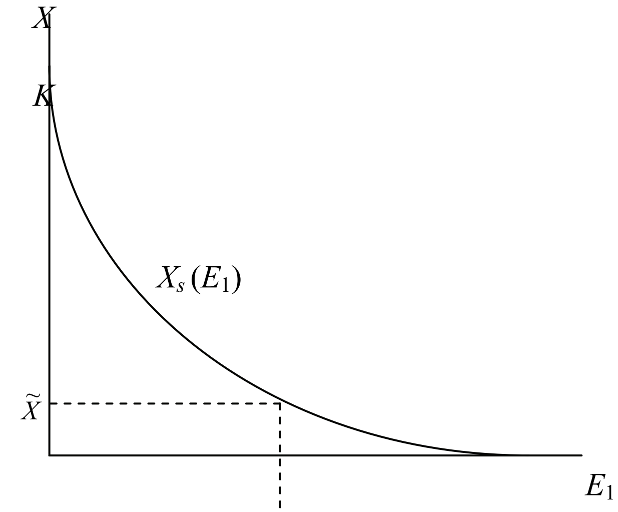

Figure 4. *Relation between fishing effort and equilibrium stock biomass*

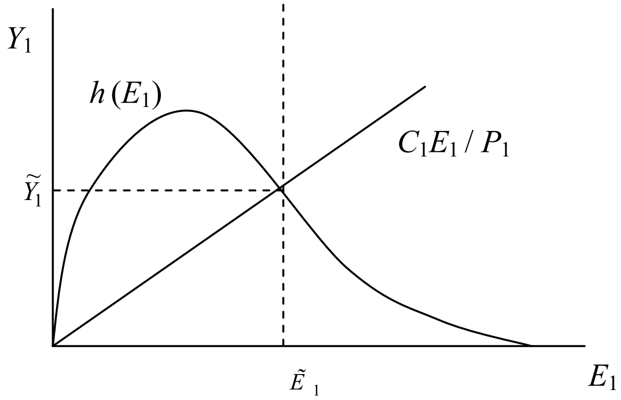

Figure 5. *Relation between fishing effort and equilibrium catch*

If the total available manpower E is larger than $\tilde{E}_1$, the fishing industry cannot provide jobs to everyone. The socioeconomic situation combines rent dissipation and unemployment. Under these circumstances, developing ecotourism would generate several benefits:

1. It would generate additional jobs. If open access prevails in both industries, the maximum capacity of employment in the ecotourism industry ($\tilde{E}_2$) is such that:

$$\frac{f\left(X_s(\tilde{E}_1), \tilde{E}_2\right)}{\tilde{E}_2} = \frac{C_2}{P_2} \tag{8}$$

   This condition corresponds to full rent dissipation (Figure 6). As a result, total employment may rise from $\tilde{E}_1$ up to $\tilde{E}_1 + \tilde{E}_2$, provided enough labour force is available.

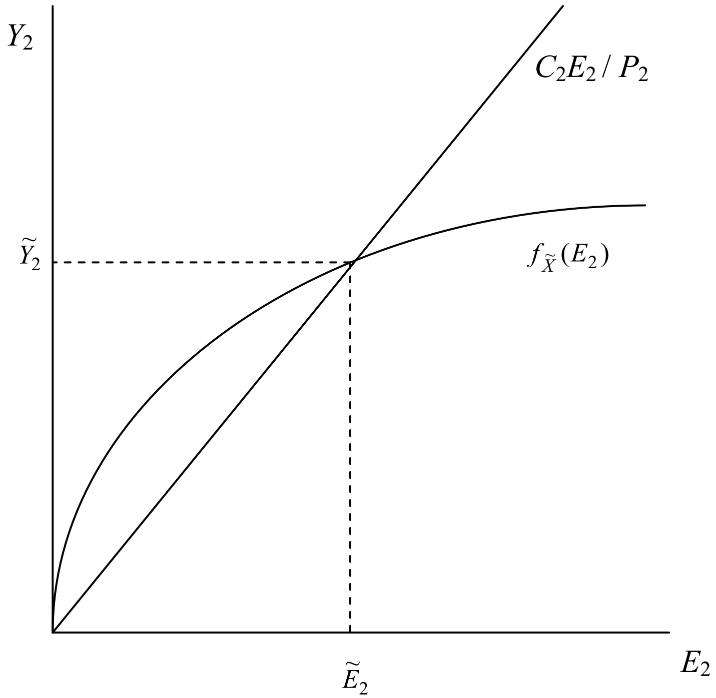

***Figure 6**. Relation between effort and output in the ecotourism industry, assuming open access in the fishing industry ($X = \tilde{X}$)*

2. It might generate economic rents, not only in the ecotourism industry, but also in the fishing industry. This will be the case, even under open access, if E, though

being larger than $\tilde{E}_1$, is smaller than $\tilde{E}_1 + \tilde{E}_2$. Under these circumstances, industry 2 cannot reach open-access equilibrium. Ecotourism generates a positive rent, which is likely to attract some labour force from the fishing industry, thereby alleviating the pressure on the fish resource. As a result, some positive rent also appears in industry 1. The condition of equilibrium between the two industries is then:

$$\frac{d\pi_1}{dE_1} = \frac{\partial \pi_2}{\partial E_2} \tag{9}$$

which corresponds to the maximization of private profitability of effort (if the marginal profitability of effort was higher in one industry than in the other, it would be profitable for producers engaged in the second industry to redistribute part of their effort towards the first one). The corresponding values of E_1 and E_2 are obtained by combining (3), (6) and (7) with (9) and the global effort constraint ($E_1 + E_2 = E$).

However, such a distribution of effort is unlikely to be optimal from a social point of view. This is so because industry 1 exerts a negative externality on industry 2, due to the impact of fishing mortality on the resource that is jointly exploited by the two industries.

Externality

Assuming stock equilibrium and combining (3) and (5), we get:

$$Y_2 = f\big(X_s(E_1), E_2\big) \qquad \text{with} \qquad \frac{\partial Y_2}{\partial E_1} = \frac{\partial f}{\partial X}\frac{dX_s}{dE_1} < 0 \tag{10}$$

This relationship illustrates the negative stock externality exerted by industry 1 on industry 2: when fishers increase their effort, the equilibrium level of fish stock is reduced, which in turn affects negatively the output of ecotourism, for a given level of effort in this activity (Figure 7).

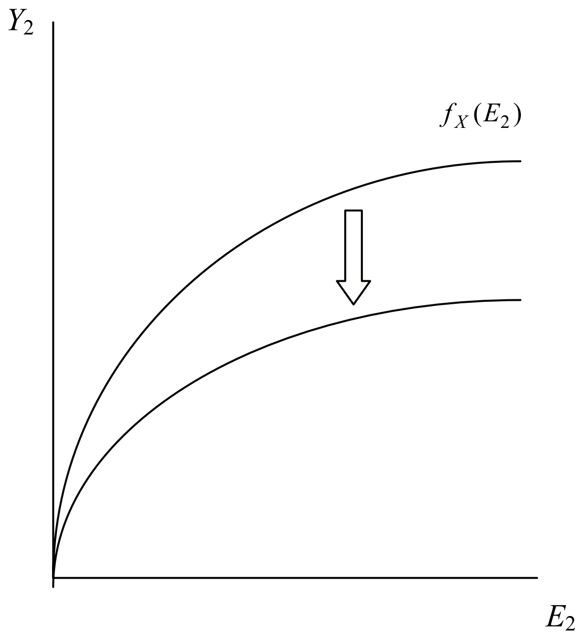

***Figure** 7. Impact of an increase in fishing effort on the effort / output curve in the ecotourism industry ($\Delta E_1 > 0 \Rightarrow \Delta X_s < 0$)*

This externality generates a gap between the private marginal profitability and the social marginal profitability of fishing effort. The latter not only includes the impact of the variation of fishing effort on fishery rent, but also the impact on ecotourism rent, due to the resulting change in the equilibrium level of the natural resource:

$$\frac{d\pi_1}{dE_1} + \frac{\partial \pi_2}{\partial E_1} = \frac{d\pi_1}{dE_1} + \frac{\partial \pi_2}{\partial X}\frac{dX}{dE_1} \tag{11}$$

As derivative dX/dE_1 is negative, we get:

$$\frac{d\pi_1}{dE_1} + \frac{\partial \pi_2}{\partial E_1} < \frac{d\pi_1}{dE_1} \tag{12}$$

which means that the social marginal profitability of fishing effort is smaller than its private marginal profitability.

Now, assuming the two industries may provide employment to the entire available labour force, the socially optimal distribution of effort between these industries is the vector (E_1 , E_2) maximizing ($\pi_1 + \pi_2$), submitted to the constraint ($E_1 + E_2 = E$). As the ecotourism rent depends also on fishing effort (see (7)), the first-order conditions of this constrained maximization program lead to:

$$\frac{d\pi_1}{dE_1} + \frac{\partial \pi_2}{\partial E_1} = \frac{\partial \pi_2}{\partial E_2} \tag{13}$$

i.e., to the equality between the *social* marginal profitability of effort in industry 1, and the marginal profitability of effort in industry 2. Combining (12) and (13), we get:

$$\frac{d\pi_1}{dE_1} > \frac{\partial \pi_2}{\partial E_2} \tag{14}$$

which is not consistent with (9), the equilibrium condition corresponding to private profitability maximization. More specifically, the level of fishing effort that is optimal from a social point of view is smaller than the one that is optimal from a private point of view.

DISCUSSION

The model in the previous section supports the idea that, in a heavily exploited fishery, developing a non-extractive activity such as ecotourism may help to overcome the dilemma between the need for long-term resource conservation and the immediate necessity to provide jobs and income to the local population.

It is worth noting that no restriction on catches or fishing effort was assumed in the model. Such a situation corresponds fairly well to that of many poor countries, where enforcing this type of regulation on artisanal fishing is quite problematic. In the Saloum delta for instance, notwithstanding the status of MPA of the area (national park and biosphere reserve), access of artisanal fishers to fish resources remains close to open access (Sarr 2005). Hannesson pointed out that, even with a strictly enforced no-take zone, an MPA cannot generate economic rent as long as open access to fish stocks prevails in the fishing zone (Hannesson 1998). However, his analysis was restricted to the case where the only use of fish resources was fishing, and assumed that the potential increase in fishing effort was virtually unlimited. In contrast with these assumptions, our model assumes that fishing may be combined with a non-extractive use of fish resources, and that the potential development of cumulated effort in both industries is limited. As a result, even if the available labour force exceeds the level of employment corresponding to open-access equilibrium of the fishery, developing ecotourism may generate a rent and may also help to restore part of the fishery rent by alleviating the fishing pressure on the stock. This result, indeed, holds only as long as the cumulated absorption capacity of the two industries can match the available labour force (which is questionable in many areas, including the Saloum delta). Otherwise, rent will be dissipated in both industries and unemployment will appear. However, in this case, rent dissipation is partly spurious: the opportunity cost of labour is locally zero, which implies that what is registered as effort cost is, in fact, resource rent, i.e., a net contribution to social welfare (at least for that part of effort which corresponds to direct labour).

The model also suggests that the potential benefits of ecotourism for the population might suffer from the impact of fishing on the resource: if the distribution of effort between the two activities is simply regulated by the market, it will not be efficient (Pareto-optimal), because fishing generates a negative stock externality towards ecotourism. Unless internalized, this externality favours an excess development of the first industry compared to the second one, which results in a loss of social welfare. This result calls for a public policy limiting fishing mortality or providing some help to the development of ecotourism. Although several serious reasons speak for the first solution, the social and technical problems related to its implementation may induce governments to adopt the second one. A policy mix combining both approaches could be a pragmatic compromise.

However, our model relies on several simplifying assumptions, which may limit the practical significance of the conclusions that can be derived from it. These assumptions concern each industry considered separately as well as the link between them.

The simplifying assumptions underlying the fisheries component of the model have been thoroughly analysed in the literature (e.g., Hannesson 1993) and will not be recalled here in detail. The most drastic one is probably the treatment of fish resources as a homogeneous stock, disregarding the variety of species targeted by fishermen and the differences between age classes within each species. The powerful impact of environmental variations on recruitment also suggests that assuming a deterministic relationship between the state and time variation of the stock is oversimplifying.

Regarding the ecotourism component of the model, the most questionable simplifying assumption is probably the exogenous character of price. Unlike the output of the fishing industry, the output of the ecotourism industry is not standardized, which implies that monopolistic competition is more relevant than perfect competition for the modelling of this industry. This type of modelling requires taking into account the customers' behaviour and their sensitiveness to price (Deyak and Smith 1978; Anderson 1983; Bhat 2003).

The interrelation between fishing and ecotourism is highly stylized in the model. It is based on the assumption that both industries make use of the same resource, one use being extractive (fishing) while the other is not (ecotourism). This assumption is questionable in several respects. Though both fishing and ecotourism obviously depend on the ecosystem, it does not follow that they make use of the same component of the ecosystem as a production factor: increasing fish biomass does not necessarily attract tourists. It probably does in places, like coral-reef areas (Dixon et al. 1993), with a high potential for recreational activities such as scuba diving and snorkelling (though, in this case, other factors are to be considered, like fish assemblages, presence of emblematic species, or types of fishing and their impact on fish behaviour). In other places, the link between fish abundance and ecotourism is indirect, taking the form of a biological interaction between fish and other species that are attractive for tourists, like seabirds or marine mammals (Boncoeur et al. 2002). This feature probably fits better to the case of the Saloum delta, where important populations of birds attract tourists. However, in this place, the most direct link between fish abundance and tourism is sport fishing. This activity, just like any other kind of fishing, is by itself extractive, and the reference to 'no-kill' practices certainly cannot be taken as a guarantee that it has no impact on fish resources (extended to marine ecosystems, a similar caveat applies to allegedly 'non-extractive' activities like scuba diving or snorkelling). Under such circumstances, it would be necessary to replace the one-way externality of our model by a mutual externality between the two industries, each of them negatively affecting the other by its impact on fish resources (just like individual fishermen do when they harvest the same stock). However, the assumption of a one-way externality may be kept as an approximation if the impact of industry 2 on fish resources is significantly lower than that of industry 1, for the same level of income generated. Empirical evidence seems to back this view: the level of resource rent by kg of fish harvested is usually much higher in the case of sport fishing than in the case of professional fishing.

Even if the relationship between the two industries in the model may be considered a reasonable first-order approximation of real-world stock externalities, this model is likely to give only a partial view of the interactions between artisanal fishing and tourism, because it is not spatially explicit (other types of interaction between local population and tourism – for instance of cultural character – are not considered here, because they are not specific to the fishing industry). Interactions between fishermen and tourists often have a spatial dimension, because their respective activities cannot be exerted in the same place at the same time. This happens for instance in the Saloum delta, when nets set by fishermen across arms of the estuary (so-called "bolongs") stand in the way of boats carrying tourists. Under such circumstances, conflicts may arise between the two activities, the stake being the control over space. Solving this type of conflict is supposed to become easier if participatory mechanisms are embedded in coastal-zone management, and, to this end, governance indicators play an increasing role in the monitoring of MPAs (Pomeroy et al. 2004). However, empirical evidence suggests that, in this field, reality may lag far behind flaunted principles (Sarr 2005).

Aside from considerations concerning the style of governance, possible use conflicts between fishing and tourism and solutions to these conflicts cannot be investigated without taking into account the distributional consequences of the development of the tourism industry, a dimension that is not included in our model. The major case for the development of tourism in a poor country is the benefits it is supposed to generate for the local population, in terms of jobs and income. It is therefore critical to assess how much of the rent generated by tourism is left to the local population.

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CHAPTER 6

EFFECTS OF POVERTY ON DEFORESTATION

Distinguishing behaviour from location

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Abstract. We review many theoretical predictions that link poverty to deforestation and then examine poverty's net impact empirically using multiple observations of all of Costa Rica after 1960. Country-wide disaggregate (district-level) data facilitate analysis of both poverty's location and its impact on forest. If the characteristics of the places the poor live are not controlled for, then poverty's impact is confounded with differences between poorer and less poor areas and we find no significant effect of poverty. Using our data over space and time to control for effects of locations' differing characteristics, we find that the poorer are on land whose relative quality discourages forest clearing, such that with these controls the poorer areas are cleared more. The latter result suggests that poverty reduction aids the forest. For the poorest areas, this result is weaker but another effect is found: deforestation responds less to productivity, i.e., the poorest have less ability to expand or to reduce given land quality.

Keywords. deforestation; poverty; Costa Rica; development; land use

INTRODUCTION

Those concerned with the environment need to understand the role of poverty in land use and its impacts on species habitat, carbon storage and erosion. Those concerned solely with the fate of the poor may not care directly about such outcomes but may well be in favour of eco-payments to the poor. Their optimal targeting would depend upon the impacts of poverty. Finally, since much of the world's forest resides in poor areas, whatever one's motivation it is clear that policies that address rural poverty can affect a large forest area and many people.

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Theoretical predictions on how changing income affects forest clearing are ambiguous. Concerning macroeconomic growth and deforestation, Wunder's (2001) review of the evidence concludes that income levels have an ambiguous link to land degradation. In some countries, higher incomes are associated with higher deforestation while in others the opposite is true. Wunder states that as income growth occurs, forest outcomes will depend upon the strength of capital-endowment growth relative to incentives from the potential returns in other activities. The former change enables deforestation while the latter makes it less attractive. Their relative strengths, Wunder says, will depend on the resource endowment and the type of growth path.

Micro-theories linking incomes and deforestation also yield an ambiguous net impact. Increased wealth may relax capital constraints, raising the capacity to clear forest. However, a rising wage, which decreases poverty, will discourage forest clearing, as it is labour intensive. Such theoretical ambiguity highlights the value of empirical tests of poverty's impact. While this paper does not test each specific hypothesis above separately, as in principle all or many of them could apply we explore empirically the net effect of all of their actual impacts.

We use tropical-forest data for all of Costa Rica in 1963, 1979, 1986, 1997 and 2000, partitioned into over 400 districts. Our other data focus is a poverty index created from census district data for 1963, 1973, 1984 and 2000. These district data offer greater spatial detail than typical 'macro' data over time. Thus the locations of the poor can be distinguished. The location of the poor cannot be distinguished as household level but the census data exist over time, unlike typical 'micro' (e.g., household) data that could also be used to study poverty.

The data are particularly helpful in light of a challenge to estimating poverty's effect. While forest outcomes for poorer areas may differ from those in richer areas due to behaviour, i.e., the poor may use identical land differently, also the poor may have different-quality land. If 'marginalized', they have less profitable land. This can confound cross-sectional inference. However, with data over space and time we can control for the impacts of location differences when testing empirically for whether different decisions in poorer areas affect deforestation.

We analyse deforestation's relationship to poverty with and without spatial controls. Without location effects, we find no significant effect of poverty on the rate of deforestation. When controlling for the effects of the differing characteristics of poorer and less poor districts, we find evidence that the poor are on land whose relative quality (on observable and unobservable dimensions) discourages clearing. Controlling for this, poorer areas are cleared more rapidly than are richer areas.

Examining the very poorest tempers that conclusion, though, as the effect (including the controls for location) of being in the lowest quartile of the poverty index is less significant. However, another piece of evidence of poverty's impacts is found. Clearing in poorest areas responds less to land productivity, i.e., expands less on better and reduces less on worse land.

LAND USE, LOCATION AND POVERTY

Land use

We use a dynamic theoretical model (like Stavins and Jaffe 1990) but emphasize key irreversibilities as well as the dynamics of development[1]. We feel both are important for understanding deforestation within a developing country, including the effects of payments.

Each forested hectare *j* has a risk-neutral manager who selects *T*, the time when land is cleared of forest, in order to maximize the expected present discounted value of returns[2]:

$$\text{Max}_T \int_0^T S_{jt}\, e^{-rt}\, dt + \int_T^{\infty} R_{jt}\, e^{-rt}\, dt - C_T\, e^{-rt} \qquad (1)$$

where:

S_{jt} = expected return to forest uses of the land,
R_{jt} = expected return to non-forest land uses,
C_T = cost of clearing net of obtainable timber value and including lost option value,
r = the interest rate.

Two conditions are necessary for clearing to occur at *T*. First, clearing must be profitable. Second, even if that is so, it may be more profitable to wait and clear at *t+1*, so (2) must hold:

$$R_{jt} - S_{jt} - r_t\, C_t + \frac{dC_T}{dt} > 0 \qquad (2)$$

and if a second-order condition holds this necessary condition is also sufficient for clearing[3].

Consistent with this, we assume that deforestation has irreversibilities, since trees take time to grow and incurring the costs of development changes marginal returns to land uses. We separate deforestation from reforestation and empirically examine deforestation, i.e., examine where forest present at the beginning of a period is cleared by the end of the period[4].

Deforestation occurs when (2) is satisfied for the first time. When that will occur differs across space due to variation in exogenous land quality, access to markets, and both exogenous and endogenous temporal shifts. The model's individual decisions are discrete, while we observe continuous rates of loss in districts. We aggregate the model's predictions.

Specifically, in our data set we do not perfectly observe the plot-level variables in (2), as deforestation and factors that explain it (X_{it}, i = district, t = time) are measured for districts. Thus X_{it} generates one estimated net clearing benefit per district, though returns and changes in costs vary across parcels. Thus we imperfectly measure net benefits, so clearing occurs if:

$$R_{ijt} - S_{ijt} - r_t\, C_t + \frac{dC_T}{dt} \;=\; X_{it}\beta \;-\; \varepsilon_{ijt} \;>\; 0 \tag{3}$$

where again i is an area, j is a specific parcel, ij is a specific parcel j known to be in area i, and ε_{ijt} is a parcel-year-specific term for the unobserved relative returns to forested land uses, so:

$$\text{Prob (satisfying (3) so that cleared if currently in forest)} = \text{Prob}\,(\varepsilon_{ijt} < X_{it}\beta) \tag{4}$$

Predicted district-level clearing rates depend upon X_{it} and on the distribution of the ε_{ijt}. If the cumulative distribution of the ε_{ijt} is logistic, then we have a logit model for each parcel:

$$F(X_{ijt}\beta) \;=\; 1 / (\, 1 + \exp\,(X_{ijt}\beta)\,) \tag{5}$$

For our grouped data, we estimate this model using the minimum logit chi-square method also known as 'grouped logit' (Maddala 1983)[5]. If h_{it} is an area's measured rate of forest loss, then we estimate:

$$\log\,(\, h_{it} \;/\; (1\text{-}\, h_{it}\,)\,) = X_{it}\beta + \mu_{it} \tag{6}$$

The variance of the μ_{it} (referring to areas, not parcels) can be estimated by $(1 / I_{it}\, h_{it}\, (1\text{-}\, h_{it}\,)\,)$. I_{it} is the number of forested parcels in area i at the beginning of interval t and the estimator is consistent and asymptotically normal (Maddala 1983). This is estimated by weighted least squares.

Poverty and location

Poverty may systematically cause land users to have higher or lower values of the X_{it} and to make different decisions because of different X_{it}. This impact may be misinterpreted as poverty that changes behaviour conditional on a given vector of non-poverty X_{it}.

Lacking assets and access to capital, the poor may not be on the most profitable land. Even if they could purchase it they might get lower returns due to lower skill and other inputs. Then poorer people might: have less productive land; migrate to frontiers far from markets; and if very poor, to 'squat' on land with low tenure security. Concerning productivity, Barbier (1996) claims that almost 75% of the poorest 20% in Latin America live on 'low-potential' marginal lands. In a model such as above, this could lower the rate of forest clearing.

Such marginalization could, though, have the opposite effect (Rudel and Roper 1997). In subsistence settings with all output consumed, low yields could raise clearing to meet the minimum consumption requirement. Also, if poor lands degrade faster, e.g., are sloped, again further clearing would be promoted. In the case of migration to frontiers far from markets, farmers could shift to transportable outputs such as cattle, which degrade extensive areas of poor quality land. Finally, farther from markets there may be fewer off-farm job opportunities.

Poverty and land use

Many argue that poverty is a driver of deforestation (i.e., poverty itself is in X_{it}, as it affects behaviour conditional on other X_{it}.). Rudel and Roper (1997) argue that poor households may be more likely to clear a given parcel due to: a) lower skills and lower off-farm economic opportunities; b) a need to insure given commodity and other shocks; and c) less preference on the margin for some environmental services. Others stress less productive capital (such as a tractor), less inputs (e.g., fertilizer) and less tenure security. Figure 1 summarizes many ideas.

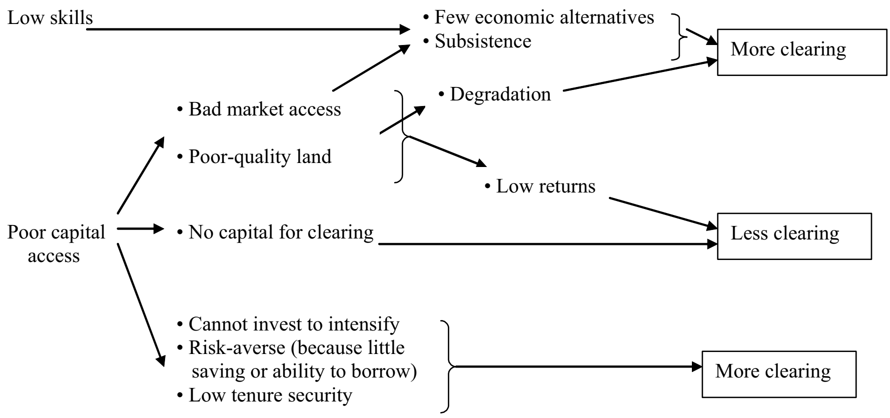

Figure 1. *Poverty and deforestation*

Income and asset levels

Poor households may not be able to invest to prevent soil degradation and lower harvests. Thus they may clear more if their goal is to maintain their level of output. Increased assets and access to capital for poor landowners could then reduce the need to clear forest.

Outside a subsistence setting, relaxing capital constraints could lead to more clearing. Zwane (2002) provides evidence, from a longitudinal household survey in Peru, that the poor use additional income for land clearing. Angelsen and Kaimowitz (2001) review farm-level and regional evidence from Latin America that links increased credit to greater deforestation rates.

Zwane's (2002) relationship between income and clearing is non-linear, however. At lower incomes more income does not increase purchases of fertilizers but at higher incomes it does. Thus farmers may initially clear more land as income rises but, above a certain income level, instead intensify production. Then lowering poverty could lower deforestation too but even then the prediction is not clear as intensification is also consistent with using more land.

Off-farm economic opportunities

In countries with small forests, peasant and shifting cultivator populations with few other economic opportunities may drive deforestation (Geist and Lambin 2001; Zwane 2002). Low skills or weak off-farm labour markets can lead poor households to undertake activities with low returns, such as exploitation of marginal lands. Then the poor may deforest more. Thus, Deininger and Minten (1996), with a focus on alternative income opportunities, find lower poverty to be associated with lower deforestation. Household analyses reviewed by Angelsen and Kaimowitz (2001) also suggest that greater off-farm employment opportunities reduce deforestation. Along these lines, policies that lower poverty could lower deforestation.

Security given income and price risk

Forest clearing for production can also provide income security, given shocks such as recessions, sickness and price changes in a setting of low savings and low ability to borrow. For instance, meeting one's minimal food requirements on one's own lowers effective risk. Rodríguez-Meza et al. (2002) note that this could mean that lowered poverty will yield greater forest clearing. Yet, as in Zwane (2002), this effect too can depend upon initial income. Further, if households can sell wood itself when income or prices shift disadvantageously, they might keep plots of land in forest as a store of natural capital to exploit in tough times. Eventually, though, rising income reduces such precautionary demand for clearing altogether.

DATA

Deforestation

We observe forest cover in Costa Rica at five points (1963, 1979, 1986, 1997, 2000). The country has 436 political districts. Our smallest unit of observation is a form of sub-district, distinguishing different 'lifezones'. The Holdridge Life Zone System (Holdridge 1967) assigns each location in Costa Rica to one of twelve lifezone categories. These reflect precipitation and temperature. On average there are about three lifezones present in a district so we can use up to 1229 observations per year. Yet as poverty is measured for districts, we focus on district (Table 2) while also providing results for sub-district observations (Table 3). In either case, our dependent variable is annual percentage loss of forest during an interval.

The 1963 data are from aerial photos digitized by University of Alberta to distinguish forest and non-forest. The 1979 data from Landsat satellite images come from the National Meteorological Institute of Costa Rica (IMN 1994). The 1986 and 1997 data from Landsat (FONAFIFO 1998) distinguish forest, non-forest and mangroves. The 2000 Landsat images were processed by the University of Alberta EOSL for consistency with 1986 and 1997 data.

For each district and interval, we calculate the area deforested. The 1986, 1997 and 2000 maps have clouds so we use the visible portions of each unit, i.e., images with consistent cloud masks. For intervals before 1986-1997 we cannot distinguish gross from net transitions and assume they are equal. If the measured gross deforestation is negative, we assign a zero.

Our dependent variable is the area deforested divided by the area of forest 'at risk'. We assume national parks and biological reserves are not at risk (they were not cleared[6]). We also drop areas for which we do not have poverty data (see below). Because our time intervals are of varying lengths, we use annualized rates of deforestation. If λ_{it} is the area deforested over a given interval divided by the area at risk and n is the number of years in that interval, then our annualized dependent variable (assumed constant during the interval) is calculated:

$$h_{it} = 1 - (1-\lambda_{it})^{1/n} \tag{7}$$

Explanatory variables

Poverty index

Lacking household data Cavatassi et al. (2002) employ principal-components analysis (PCA) using census data for districts, over four decades, to generate a district poverty index. Seventeen variables are common to the 1973, 1984 and 2000 census data, of which twelve are in 1963 too. The variables used include demographic, labour, education, housing, infrastructure and consumer durables measures (see Cavatassi et al. (2002)) concerning variables' meanings). They find that the variables expected *a priori* to be positively correlated with poverty have positive signs within the index, while the wage and education variables have negative signs.

They first create year-specific indices for 1963, 1973, 1984 and 2000. Those are not comparable as each is based on a scale relevant only to its year. Then they pool all years for a 1973-2000 index using the 17 common variables and a 1963-2000 index using the 12. For these pooled PCA estimations, changes over time arise only from changes in measured variables, not from changes in the weights. We use the pooled indices and, to focus on greater poverty, also their quartiles to allow for non-linearities within the poverty–deforestation relationship.

For the 1963-2000 index, to match the 1963-1979 deforestation interval we use 1963 index values. For 1979-1986 we use 1973 values, for 1986-1997 we use 1984 values and for 1997-2000 we use 2000. We also try 1984 values for 1997-2000 clearing as lagged option. For the 1973-2000 measure the difference is that for 1963-1979 we have only the 1973 values.

Returns proxies
Given the difficulty of perfectly measuring the agricultural returns in monetary units, we use proxies for the returns to clearing. Lacking a monetary measure of the transport costs, for instance, we use the minimum linear distance in kilometres to a major market, DISTCITY, i.e., the shortest of the three distances from an observation to San José, Puntarenas and Limon. For local markets, we include district-level population density POPDEN. The measure is from census data at district level, for 1950 and 1984, divided by the area of the district. As population is potentially endogenous to other factors, we can use lagged population densities.

Ecological variables proxy for agricultural productivity. We create dummies at sub-district level for groups of lifezones: GOODLZ includes humid (medium precipitation) areas, which have moderate temperatures; MEDLZ includes very humid areas (higher precipitation) in moderate to mountain elevations (and hence moderate temperature); and then BADLZ includes the very humid areas with high temperatures (tropical), very dry hot areas and rainy lifezones, all of which are less productive. District values are area-weighted averages of these. We also have data on seven different soil types outside national parks[7]. We create a BADSOIL measure, i.e., the proportion of a district-lifezone with low-productivity entisol soil.

We include a polynomial for total previous clearing in a district-lifezone (%CLEARED) as well as dummies for time periods. These variables proxy for unobservable changes in the net returns to clearing over time which resulted from exogenous improvements in infrastructure and development generally. Costa-Rican history suggests a trend of increasing returns as well as a shift in the trajectory over time (see Kerr et al. 2005). A polynomial for the previous forest clearing, e.g., our quadratic term (%CLEARED^2), is motivated by at least two types of priors. Selection, in which those parcels with the highest returns to clearing are the first to be cleared, would suggest a negative coefficient for the quadratic term. Endogenous local development, in which previous clearing raises future returns, suggests a positive one.

RESULTS

Table 1 provides statistics for the 25% poorest and the other districts. The first three rows do not change with time. The next two were pooled for 1963-2000. Deforestation is by period.

Poorer areas are further from markets and less densely populated. A lower proportion of their area has poor climatic conditions but a higher proportion has poor soil. In a crude first cut they seem, if anything, to have higher deforestation rates although not significantly so.

Table 2 presents results from regressions using districts, starting with poverty alone and focusing on poverty. In all columns, the poverty measure is the pooled 1963-2000 index. In columns I - III, (A) uses the continuous index while (B) uses a poorest-quartile dummy. In IV, to focus on interaction stories that may apply to the most poor, only the (B) version is run. Table 3 has the same format but it provides supporting results using sub-district observations.

Table 1. *Summary statistics for Costa-Rican districts* [a, b]

	Poorer districts	Richer districts
Bad climate [c]	0.47 (0.50)	0.63 (0.48)
Bad soil [d]	0.14 (0.26)	0.09 (0.19)
Distance to market (km)	87 (43)	56 (35)
Population density	0.16 (0.80)	0.79 (4.5)
Per-capita forest cover (ha)	4.5 (6.6)	3.7 (6.2)
Deforestation rate (%)		
1963 – 1979	0.033 (0.044)	0.025 (0.047)
1979 – 1986	0.046 (0.047)	0.018 (0.036)
1986 – 1997	0.0067 (0 .0083)	0.0091 (0.0096)
1997 – 2000	0.0015 (0.0041)	0.00062 (0.0016)

[a] For greatest relevance to the regressions, weights for these averages are the initial forest in each period.
[b] Standard deviations for these measures within these groups of districts are given in brackets.
[c] 'Bad climate' = fraction of district identified as a poor productivity or 'bad' lifezone.
[d] 'Bad soil' = fraction of district identified as a poor performing or 'bad' soil.

Poverty with and without spatial controls

In Table 2's column I, poverty is not significant in (A) or (B) (or in Table 3). While unobserved variation in poverty across sub-districts could complicate Table 3's analyses, given our district-level poverty index, at least for column I, in which there are no other factors, we believe that Table 3 supports Table 2's conclusion that column I's estimated effect is zero.

However, column II suggests that column I masks two significant but opposing effects. Table 2's column II uses district-level fixed effects to control for the fixed characteristics of each location. It also includes our only time-varying explanatory variable, the prior clearing. With the controls for areas' differences, (A) finds that poorer areas have higher deforestation.

Even with column II controls, the (B) result for the poorest quartile is not significant. Yet poverty is significant in Table 3's column II (A) and (B). Thus the poorest-quartile results are less significant but, overall, controlling for characteristics finds the poorer clearing more[8].

Table 2. *Deforestation, poverty and locations – district level* [i]

	I		II		III		IV
	A [ii]	B [ii]	A	B	A	B	B
POVERTY [ii]	0.02 (0.8)	0.04 (0.6)	0.16 (3.3)	0.12 (0.9)	0.004 (0.2)	0.05 (0.8)	0.09 (0.4)
FIXED EFFECTS			F = 6.3 (P=0.00)	F = 6.1 (P=0.00)			
CONSTANT	-2.8 (30)	-2.8 (46)	-3.6 (16)	-3.2 (17)	-3.9 (21)	-3.9 (23)	-3.7 (18)
%CLEARED			1.2 (1.3)	2.0 (2.3)	3.7 (7.2)	3.7 (7.2)	3.9 (7.7)
%CLEARED^2			-3.4 (3.5)	-4.1 (4.4)	-2.2 (3.9)	-2.1 (3.9)	-2.6 (4.6)
BADSOIL					-0.3 (2.4)	-0.4 (2.5)	-0.4 (2.9)
BADLZ					-1.2 (11)	-1.2 (12)	-1.8 (9.6)
POV * BADLZ							0.4 (1.5)
GOODLZ							0.08 (0.4)
POV * GOODLZ							-0.6 (2.0)
DISTCITY					0.01 (7.8)	0.01 (8.0)	0.01 (7.6)
DIST * 79-86					-0.00 (0.9)	-0.00 (1.0)	-0.00 (1.1)
DIST * 86-97					-0.01 (4.2)	-0.01 (4.4)	-0.01 (4.5)
DIST * 97-00					-0.00 (1.1)	-0.00 (1.2)	-0.01 (1.4)
TIME DUMMIES	[these are always significant as controls for time trends[iii]]						
ADJUSTED R^2	0.22	0.22	0.76	0.75	0.51	0.51	0.53
N	961	961	961	961	958	958	958

[i] All regressions are Grouped Logit explaining annualized deforestation probabilities, following expression (6), using district observations. Coefficient is reported, with t statistic below it, except for the fixed-effects component within II where F statistic is reported with P value below.

[ii] 1963-2000 pooled index in all columns. Column IV focuses solely on the poorest quartile as an interaction effect is motivated by the very poor. Within the other three columns (I – III) the A regression uses the continuous-poverty index while the B regression uses a poorest-quartile dummy.

[iii] Coefficients for time dummies not reported as not a focus here and would crowd the table (see Kerr et al. (2005) for discussion of time trends).

Table 3. *Deforestation, poverty and locations – subdistrict level* [i]

	I		II		III		IV
	A [ii]	B [ii]	A	B	A	B	B
POVERTY [ii]	0.01 (0.5)	0.01 (0.2)	0.12 (4.0)	0.21 (2.5)	-0.002 (0.1)	0.02 (0.5)	0.10 (1.4)
FIXED EFFECTS			F = 8.4 (P=0.00)	F = 8.3 (P=0.00)			
CONSTANT	-2.5 (41)	-2.5 (63)	-3.3 (26)	-3.0 (36)	-3.5 (31)	-3.6 (35)	-3.7 (34)
%CLEARED			0.5 (1.3)	0.9 (2.4)	1.8 (6.1)	1.8 (6.1)	1.9 (6.5)
%CLEARED^2			-1.5 (4.0)	-1.8 (5.0)	-0.3 (1.1)	-0.3 (1.0)	-0.5 (1.6)
BADSOIL					-0.1 (1.6)	-0.2 (1.6)	-0.2 (2.5)
BADLZ					-0.6 (11)	-0.6 (11)	-0.5 (6.5)
POV * BADLZ							0.1 (0.9)
GOODLZ							0.4 (5.2)
POV * GOODLZ							-0.3 (3.1)
DISTCITY					0.01 (10)	0.01 (10)	0.01 (11)
DIST * 79-86					-0.003 (2.0)	-0.003 (2.3)	-0.003 (2.7)
DIST * 86-97					-0.01 (5.9)	-0.01 (6.2)	-0.01 (6.5)
DIST * 97-00					-0.01 (2.6)	-0.01 (2.7)	-0.01 (2.9)
TIME DUMMIES	[these are always significant as controls for time trends [iii]]						
ADJUSTED R^2	0.20	0.20	0.79	0.79	0.37	0.37	0.38
N	2604	2604	2604	2604	2421	2421	2421

[i] All regressions are Grouped Logit explaining annualized deforestation probabilities, following expression (6), using subdistrict observations. Coefficient is reported, with t statistic below it, except for the fixed-effects component within II where F statistic is reported with P value below.
[ii] 1963-2000 pooled index in all columns. Column IV focuses solely on the poorest quartile as an interaction effect is motivated by the very poor. Within the other three columns (I – III) the A regression uses the continuous-poverty index while the B regression uses a poorest-quartile dummy.
[iii] Coefficients for time dummies not reported as not a focus here and would crowd the table (see Kerr et al. 2005, for discussion of time trends).

Is there evidence of the poorer being marginalized? We find no impact of poverty on clearing without controls and yet higher clearing in poorer areas with location controls. This suggests that the characteristics of land in the poorer districts are lowering or discouraging forest clearing. If this means that land's productivity or quality is lower, then these results do suggest that the poorer are marginalized.

Observable spatial controls sufficient?

Table 2's column III replaces the district (or sub-district in Table 3) fixed effects with the fixed locational characteristics that we can measure, retaining the prior clearing variable. Now poverty is again insignificant, in both the (A) and (B) regressions in both Tables 2 and 3. Thus our ability to observe the important differences across location seems somewhat limited.

That observables may not fully control for differences across locations finds additional support in column III and in Table 1. While bad soil and bad climate both reduce deforestation in column III, recall from Table 1 that poorer districts have more bad soil but less bad climate. Those districts are farther from markets on average. But while the prior on effects of distance is negative (and see Kerr et al. 2005) pooled regressions including pre-1963 deforestation, plus recent cross-sections), for 1963-1979 the opposite sign is found, i.e., distance raises clearing. Frontier development, perhaps linked to subsidies for cattle in areas far from cities, could well dominate that time interval. In any case, observed differences in Table 1 may not explain all.

Poverty and response to land productivity

Columns IV of Tables 2 and 3 use poorest-quartile dummies to study greatest poverty, specifically whether it limits adjustment. In a subsistence setting, for instance, one might not be able to reduce (and might even increase) clearing when land quality is low. And inability to invest might mean less clearing on good land. Both stories suggest interacting poverty with land productivity. They imply that productivity has less impact on the poorest's deforestation.

Column IV of Table 2 supports that the poor decrease clearing less if land is poor. The poverty–poor–quality interaction is positive. In Table 3, the poverty–poor–quality interaction is insignificant, but high productivity is positive and significant and its interaction with a dummy for poorest quartile is negative and significant. Thus, poorer areas appear to respond less.

DISCUSSION

This paper used a panel data set for tropical forest to control for differences between poorer and less poor areas in examining the effects of poverty itself on deforestation. The district poverty data have greater spatial detail than 'macro' (e.g., country) data, so that the location of the poor can be distinguished, but also have greater temporal coverage than many 'micro' or household-level data. The combination of spatial and temporal variation permits inclusion of spatial controls for locations' differences, which permits a cleaner test of the impact of poverty *per se* on deforestation.

Controlling for locations' differences, we find poorer areas to be cleared more rapidly. This suggests that, all else equal, poverty increases deforestation rates. Without controls for locations' characteristics, the impact of poverty on clearing is underestimated (in this case at zero) as overall the poorer appear to be on land whose relative quality discourages clearing. For the poorest areas, the impact of poverty is weaker, yet we find that there forest clearing responds less to the land's productivity.

An important caveat concerns the lack of parcel-level landownership data. With district-level poverty measures, these results shed light only on poorer *areas,* i.e., not necessarily on the poorer *landowners*. Where people are poorer on average, it still may be the case that much of the land is owned by the less poor or non-poor. This indicates the value of household-level data on both poverty and deforestation.

Finally, despite our results on poverty's impact it is not at all clear either that changing the incomes of the very poorest will affect deforestation greatly or that this would be the best way to affect deforestation. In addition, as noted in the literature, *how* incomes are raised (e.g., capital or off-farm wage) matters. Further, if raising the poorest households' incomes is the goal there may be better justifications, and approaches, than to focus upon and to pay for the forest.

Yet many are hopeful that 'win-win' options to lower both deforestation and poverty can be found. Some existing programs, for instance the PSA program of payments for environmental services in Costa Rica, are often viewed in this light. However as such programs are examined more thoroughly the hurdles to reducing both clearing and poverty, or even to achieving just one of those two goals, become clear even though we believe that there are circumstances where making payments to poor landholders to improve forest management could increase income and forest.

Consider for a moment the actual lowering of deforestation and of poverty by PSA, which did not explicitly target either land-use change or poverty reduction. Sánchez-Azofeifa et al. (in print) and Robalino et al. (2007) find little impact of pre-2000 or post-2000 PSA on clearing rates. This echoes and significantly extends Sierra and Russman (2006) and a World Bank panel evaluating the Ecomarkets Project, though others make claims to the contrary (Walker 2007). It is clear that the first decade of the program did not prioritize 'additionality' (i.e., impact above a baseline that would have occurred without PSA). It was not even a condition of the funding for the PSA.

Thus, payments had relatively little impact on land use and may essentially be transfers. They could reduce poverty if targeted to the poorest, yet such targeting was not central to the PSA effort (in part due to its requirements for participation) and clearly the program was not trying to reduce deforestation by reducing poverty.

This particular, pioneering program may have indirect impacts on forest and/or poverty (not to mention in catalysing others initiatives). Perhaps the 1997 law restricting deforestation would not be accepted without such payments to forested land. But in considering in general the 'win-win' concept that this kind of research raises, the evidence noted above indicates that targeting involving both information and political will would be needed. Even with them, it also seems worth comparing such an approach to programs that directly address either deforestation or poverty.

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NOTES

[1] For more discussion of the model and of structural change over time, see Pfaff (1999) and Kerr et al. (2005).

[2] In assuming full landownership by the manager, we are consciously not laying out a forest frontier model.

[3] Population and economic growth during development path may lead the second-order condition to hold. Yet the condition may be violated if environmental protection becomes more stringent, returns to ecotourism rise, and capital-intensive agriculture requiring less land expands. Should it be violated, our reduced-form empirical specification can also be interpreted in terms of the combination of expression (2) and the profitability condition.

[4] Unlike common regressions for how much forest is present now without regard for the previous deforestation.

[5] See also Greene (1990) for an explicit discussion of the heteroskedasticity.

[6] For discussion of the parks and their forest outcomes see Sánchez-Azofeifa et al. (2003).

[7] This comes from the Ministry of Agriculture of Costa Rica. It resulted from a joint project with the UN FAO.

[8] That the continuous-poverty-index result is stronger suggests that the differences in income above the poorest quartile matter for behaviour. This could be viewed, as was the case for the results from Zwane (2002) noted above, as evidence that marginal changes in income for the poorest simply do permit much behavioural response.

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CHAPTER 7

WILLINGNESS TO PAY FOR SYSTEMATIC MANAGEMENT OF COMMUNITY FORESTS FOR CONSERVATION OF NON-TIMBER FOREST PRODUCTS IN NIGERIA'S RAINFOREST REGION

Implications for poverty alleviation

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Abstract. Despite the importance of non-timber forest products (NTFP) in sustaining livelihood and poverty smoothening in rural communities, they are highly depleted and poorly conserved. Besides, conservation initiatives in Nigeria to date are rarely participatory. Even community forests, the main source of NTFP, are poorly conserved. Therefore, to enhance participatory conservation initiatives, this study determines the willingness of households in forest communities in the rainforest region of Nigeria to pay for systematic management of community forests using the contingent-valuation method. A multistage random-sampling technique was used in selecting 180 respondent households used for the study. The value-elicitation format used was discrete choice with open-ended follow-up questions. A Tobit model with sample selection was used in estimating the bid function. The findings show that some variables such as wealth category, occupation, number of years of schooling and number of females in a household positively and significantly influence willingness to pay. Gender (male-headed households), start price of the valuation, number of males in a household and distance from home to forests negatively and significantly influence willingness to pay. Incorporating these findings in initiatives to organize the local community in systematic management of community forests for NTFP conservation will enhance participation and hence poverty alleviation.
Keywords. non-timber forest products; systematic management of community forest; willingness to pay

INTRODUCTION

Non-timber forest product (NTFP) issues, especially its conservation, has attracted considerable global interest in recent years and is accepted as a veritable means of

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achieving poverty alleviation because of its role in livelihood sustenance, food security and environmental objectives such as biodiversity conservation. Non-timber forest products are goods of biological origin other than timber, derived from forests, other wooded land and trees outside forests (FAO Forestry 1999). In many parts of the world, non-timber forest products provide off-farm employment to a large part of the rural population and accounts for a large share of household income. These resources are essential, especially for the rural poor and women, and may provide them with the only source of personal income (Rodda 1991; Falconer 1996). In Nigeria, NTFP is a dependable source of income and food supply and it remains central in socioeconomic wellbeing and sustenance of the rural population (Osemeobo and Ujor 1999). Non-timber forest products are derived from wild animals, herbs, leaves, latex, gum, resins, ropes, fruits, seeds, fungi, fodder, forage, gravel, clay, limestone and natural salt. Generally, NTFPs are put into two broad categories, namely, flora and fauna species. Some plant species found in Nigeria include; *Gnetum africana, Gongronema latifolium, Ocimum gratisimum, Pterocarpus soyauxii, Treculia africana, Dacryodes edulis, Dennettia tripetala, Chrysophyllum albidium, Piper guineense, Garcinia kola and Irvingia gabonensis* (Osemeobo and Ujor 1999). The key resources of the region, according to Sunderland (2001), include *Irvingia gabonensis, I. wombulu*, *Gnetum africanum*, *Garcinia mannii* (chewing stick) and rattan canes.

Non-timber forest products provide off-farm employment to a large part of the rural population and account for a large share of household income. Estimates of the number of people who are dependent on NTFPs, for at least part of their income, range from 200 million in Asia and the Pacific to 1 billion worldwide (Van Rijsoort and De Pater 2000). In Nigeria, rural communities derive substantial revenue from the collection, processing and marketing of these NTFPs, which improves their economic status through poverty alleviation. Although not well documented, in 1996 in south-eastern Nigeria, 35.7% of the rural population collected NTFPs daily. It accounted for 94% of the total income from minor sources (Nweze and Igbokwe 2000), which has a considerable smoothening effect, especially during hunger periods. In Ghana, total household incomes obtained from non-timber forest products range between 49 and 87 percent, while in Cameroon extractive activities around one forest contribute to over half of the local income (Chege 1994). Income from NTFP is particularly important for poorer groups within the community, especially in places where there is unrestricted access to forest (Arnold 1996). Bisong and Ajake (2001) found that women in southern Nigeria depend heavily on NTFPs. For many women this is the only way to earn an independent income (Van Rijsoort and De Pater 2000). Generally, many Nigerians depend on NTFPs for food, fibre and herbal medicines. In recent times there has been a reasonable and noticeable shift from the earlier preference in favour of orthodox medicine to greater acceptance of traditional (herbal) medicines in Nigeria as in many other countries worldwide (Akunyili 2003). Over 90% of Nigerians in rural areas and 40% in urban areas depend partly or wholly on traditional medicine (Osemeobo and Ujor 1999). NTFPs also provide raw materials for large-scale industrial processing, including processing of internationally traded commodities such as foods and beverages, confectionery, flavourings, perfumes, medicines, paints and polishes. At present, at least 150 NTFPs are significant in terms of international trade. They include honey, Arabic gum, rattan and bamboo, cork, forest nuts and mushrooms, essential oils and plant and animal parts for pharmaceutical products. Thus promotion of NTFPs can complement the objectives of rural development and appropriate forest management (Hammett 1993).

However, despite the importance of non-timber forest products in sustaining livelihood and poverty smoothening in rural communities, especially those living on the forest fringes of Nigeria, they are highly depleted and poorly conserved. NTFP is a diminishing resource because the land base is under pressure of depletion from agriculture and public infrastructure. In fact, a great percentage of Nigeria's luxurious vegetation has been removed and several species have become extinct (United Nations 2002). The World Rainforest Movement (1999) records show that between 70 and 80% of Nigeria's original forest has disappeared and presently the area of its territory occupied by forests is reduced to 12%. In the period between 2000 and 2005, Nigeria lost about 2,048,000 ha of forest (FAO 2005). Although Nigerian government established several forest reserves for conservation of forest resources, these forest reserves have been seriously neglected and received little or no improvement in terms of investment and management. The management of forests has been at low tide since the 1980s due to poor funding and overexploitation of the forests by government and rural communities. The management of forests is practically based on the rule of thumb and is not participatory as the rural communities are rarely involved. Therefore, no adequate records are kept on resource exploitation, yet management attention is focused mainly on timber harvest. Although recent forest management initiatives in several states are beginning to involve rural communities, such as the Cross River State established the Forest Management Committees involving local communities in the management of reserve areas, they are mainly involved in the control of timber exploitation. Free areas, which are mainly community forests and which are a major source of NTFP, are rarely accounted for in conservation initiatives. Notwithstanding that, some non-governmental organizations, for example, DFID and Living Earth Foundation, have helped several communities in Cross River State to implement forest management plans, trained some community members on cultivation techniques of bush mango and *Genetum aficanum*, helped communities establish nurseries and initiated micro-credit programs to help the local population in establishing forest-based enterprises. A lot still needs to be done as many forest areas are still left out. There is a need to involve the rural communities, especially in producing and implementing forest management plans, to ensure that the resources are conserved. It is equally important to know whether the efforts by donors can be sustained by the communities themselves as most of the projects have ended. In addition to this it will also be important to know the value the people attach to their NTFP resource. This study therefore determines the willingness of households in forest communities in the rainforest region of Nigeria to pay for systematic management of community forests using the contingent-valuation method (CVM) to ensure the conservation of plant species for NTFP. Systematic management entails an organized management whereby the community, through their local institutions, will regulate harvest levels and periods, engage in enrichment planting, monitoring to avoid infiltrators, clearing of forest edges to avoid bush fires, etc. It is expected that systematic management will enhance the sustainability of NTFP in their forests and the income and general livelihoods of the community members.

Although there has been some previous research done on willingness to pay for community forestry, for example those by Mekonnen (2000) and Köhlin (2001), their studies focused on establishment and management of community wood lots. Based on our own literature research, no study has ascertained the willingness of the rural population to pay for systematic management of community forests/free areas for conservation of non-timber forest products.

The remainder of this chapter is organized as follows: Nigerian forest resources and management; theoretical basis for involving community people in participatory conservation of a common poll resource; study design and econometric approach and empirical analysis; findings and discussion; and conclusion.

NIGERIAN FOREST RESOURCES AND MANAGEMENT

Nigeria is rich with abundant forest resources; however, its forests are seriously threatened by deforestation and other environmental problems. FAO (2005) statistics indicate that 12.2% of Nigeria's land area, more or less 11,089,000 hectares, is covered with forest. Forest resources in Nigeria include timber, fuel wood, wildlife, inland fisheries and forage, which are physical and have market-determined values. Other outputs of forests are recreation, amenity and environmental protection, which all have non-market-determined value. An estimated 4,614 vascular-plant species have been recorded in Nigeria. According to Hutchinson and Dalziel (1936), these include 38 endemic species of the defunct Western and Midwestern area, 39 endemic species from what used to be the Northern region and 128 from the former Eastern region. On NTFPs resources, Okafor et al. (1994) identified 8 NTFPs from the mangrove swamp, 19 traded products from the moist forests, 17 from the southern Guinea savannah, 12 in the Sudan savannah and 56 for the whole country. Nigeria has a very rich fauna as a result of its diverse vegetation types. With 18 primate species, the Okwangwo Division of Cross River National Park has the highest diversity recorded at any single site in Africa, including the endangered Cross River Gorilla, *Gorilla gorilla* diehli. Eight major forest types are found in Nigeria, including savannah woodland, lowland rain forest, freshwater swamp forest, mangrove forest, montane forest, riparian forest, plantation (agriculture) and plantation (forest).

In order to manage and conserve forest resources, Nigeria established several conservation areas. Aminu-Kano and Marguba (2002) reported that Nigeria's first formal (modern) forest reserve was created in 1889. By 1950, forest reserves covered about 8% of the country's land area and gradually rose to 11% by 1980. Thereafter, an apparent lack of policy making to establish more reserves prevailed across the country, leading to the current era where several protected areas are being de-reserved. Four categories of protected areas are recognized in Nigeria, which are: national parks, game reserves, forest reserves and special ecosystem and habitats such as sacred grooves, lakes and streams. Additionally there are community forests/free areas, which are forested areas that are not under strict management by the State Forestry Departments. They provide additional sources of forest products and services. In fact, they constitute the major part of Nigeria's forest resources and are considered to be very important for private forestry development.

Forest reserves are areas set aside by state governments for the protection of their timber, non-timber forest products, fuel wood and other forest resources in its domains. These forest reserves are owned by the state governments and are managed by the State Forestry Departments, which have professional and technical staff including forest rangers who are responsible for protecting the forest against trespassing and poaching. In some of the forest reserves, harvesting of resources is usually allowed under a permit or when special concessions are granted to local people. Poor management often results in a lack of control of resource utilization and conflicts among resource users (Olaleye and Ameh 1999). Currently Nigeria's forest resources are under threat due to poor funding and lack of proper management plans. In the period between 2000 and 2005 Nigeria's total deforestation rate was about 3.3% per year, meaning it lost an average of 410,000 ha of forest annually (FAO 2005). Even as the situation persists, most community forests/free areas are not under any form of management. Besides several projects for some forest communities, such as the project pioneered by Living Earth Foundation in Akamkpa Cross River State, Nigeria Conservation Foundation in Buru and Krumi Local Government Area of Taraba State, little has been done in putting community forest into any form of management. Some communities have Forest Management Committees but they are involved in controlling timber harvest and warding off poachers. In the Cross River State, the forestry regulations empower communities to exploit their non-timber forest resources. Forest management in Nigeria faces a great challenge, hence there is an urgent need to rebuild and restore the depleting resources in Nigeria. Employing a participatory approach involving local communities in the management of forest resources is a tenable option. Hence it is important to determine whether the local communities would be able to pay to manage their forest to conserve NTFP species. Willingness to pay and manage forests by local communities will have positive implications for forest and environmental conservation and poverty reduction in Nigeria.

THEORETICAL BASIS FOR INVOLVING THE LOCAL COMMUNITY IN FOREST RESOURCE CONSERVATION

Community-based forest management is becoming the main management technique used by governments around the world for enhancing the conservation and management of forest resources. Around one quarter of forests in developing countries is now under the control of local people (White and Martin 2002). This is often as a result of the transaction costs involved in forest management, issues of access and the benefits derived from community participation in management of forests as a common poll resource. In fact, due to the issue of cost involved in forest management, the benefits of common property resource and the fact that rural people depend on the resources derived from forest for livelihood, especially from community forests where the rural people have access, governments around the world are devolving rights on forests entirely to local communities. Thus one of the theoretical bases for researching strategies of involving the community in the management of forests, a parting from the existing management framework where the government is the manager and decision maker, is the transaction-cost theory proposed by Ronald Coase (Coase 1937). The theory describes firms in organizational terms, that is, as governance structures. Coarse defined transaction costs as costs made by using the markets. Transaction costs are costs of seeking information, conducting negotiations, writing up contracts, and monitoring and enforcing compliance among economic agents. Transaction costs are the economic equivalent of friction in physical terms. In the transaction-cost theory, Coase (1960) compares the cost of information, planning, adapting, monitoring, coordination and enforcement of contracts under alternative governance structures. The basic insight of transaction-cost economics is to recognize that in the world of positive transaction costs, some forms of governance are better than others (Macher and Richman 2002). Governance structures that are weak and inefficient are weeded out over time by competitive pressures. Therefore, in order to cope with competition, organizations strive to establish efficient and optimal governance structures. Organizations that choose the wrong governance structure for transactions will incur high costs for a given level of output compared to organizations that choose a more efficient governance structure. Hence, the weaker organizations will eventually be driven out of the market. Within a small closed economy, in which there are few institutions and face-to-face transactions are possible, transaction costs are low due to the fact that economic activities are restricted to interpersonal exchanges. However, in a large complex economy, especially with weak institutions where laws and property rights (weak basic institutions) are not reliable and where public-funded entities act under sub-optimal governance structures (as the network of interdependencies widens), impersonal exchange processes give considerable scope for all kinds of opportunistic and counterproductive behaviour resulting in high transaction costs.

In Nigeria, like most developing countries, there are weak economic, political and legal institutions and a poor property-rights regime. When governance structures are weak and sub-optimal so that opportunistic behaviour, such as cheating, corruption and rent seeking are abound, it will create high transaction costs. In addition to this, marked increase in responsibilities of government with concomitant increase in budgetary provisions under stagnant economies has made the situation precarious. Currently the government can no longer provide the incentives it used to provide. Most ministries and parastatals no longer receive funding for capital projects. The forestry sector is not left out. Due to lean government finances and increased transaction costs, the forest sector, especially the forest reserves in Nigeria, have been seriously neglected, let alone forests outside forest reserves and community forests. In fact, there has been poor funding of the forest sector (United Nations 2002) even as Nigeria plans to increase the area of forest cover from 10 to 25% by 2010. Only about 10% of the budget allocated to the agricultural sector is made available to forestry development (Osemeobo and Ujor 1999). Most state forest sectors have not received funds for capital projects since the era of military governance in Nigeria. Forest workers are not paid their salaries resulting in diminishing returns in their performance incentives. This condition even encourages corruption and unwholesome attitude and hence further increases transaction costs.

In this situation, forest resources, especially NTFPs, cannot be conserved. This may lead to loss of livelihood for those who depend on it. To improve the current situation, there is a need to evolve strategies to reduce transaction costs. Institutions that evolve and aim at reducing transaction costs are the key to the performance of economies (Meier 1995). Transaction costs are generally low in situations where the supply of services is competitive with reduced uncertainty. Involvement of private entities will help make the environment competitive as resources are used efficiently and responsibly by lowering transaction costs. Private involvement in projects can be in the form of private property, partnerships or other collective entities like common-property regimes where access to the use of resources is confined to members of a defined user group, thereby securing the group the same usage rights as private property. In several respects, a well-designed and well-functioning common property resource is like private property (Ostrom and Schlager 1996). In Nigeria, where there is no forest certification and where local people depend heavily on forest resources and own a community forest with access rights, privatization is out of place. Therefore to save the community forests, and sustain the benefits there, it is important to involve the local communities. Community involvement in the management of forest resources is a form of common property resource, which, if effective, will help in lowering transaction costs. In fact, in some ecological and social contexts (when costs of protecting private property are high or when the yields are low and very variable), a common property resource may simply have lower transaction and other costs and thus be more efficient compared to private property (Sterner 2003).

Also, the emerging issue of agrarian forests approach, which drops the distinction between community, state and market as separate and mutually exclusive entities (Sikor 2006), justifies the policy measure of involving the community in modern forest management. The agrarian perspective acknowledges that larger economic and political forces reach forest villages by means of states and markets. Local social relations, states and markets together influence forest relations as they shape the type of actors recognized, distribution of rights and access, objects considered valuable, and sources of authority providing legitimacy. The agrarian perspective emphasizes the linkages between local social relations and larger economic and political forces.

STUDY AREA, DESIGN AND ECONOMETRIC APPROACH AND EMPIRICAL ANALYSIS

Study area

The study was carried out in Cross River State, which is home to the main rainforest area in Nigeria. In fact, all of the country's remaining primary rainforest watersheds, covering about 7,000 km^2, are located in Cross River State (World Rainforest Movement 1999). Thus it is important to conserve the resources in these areas if Nigeria does not want to lose its remaining primary rainforests. Sunderland (2001) observed that many of the species are over-harvested as harvests are uncontrolled and carried out in a highly destructive manner. There have been widespread reports of depletion of some of the species in the area, especially *Gnetum africanum*. Additionally extensive clearing of forests for cocoa planting and farming remains in the area. In addition to this, research undertaken as part of the first Overseas Development Administration (ODA)-assisted project (1992-1995) highlighted the importance of the harvest and trade of NTFPs to the rural communities of the Cross River State (Sunderland 2001).

Sampling and sample size

A multistage sampling technique was used when selecting respondents (households). In the first stage, two local government areas were randomly selected from the list of local government areas, identified as having forest resources in their state. In the second stage, from each of the two local government areas, five rural communities identified as 'having community forests' were randomly selected from the list of communities identified as 'having forest resources', giving a total of 10 communities. The identification of areas with forest resources was done with the help of officers from the Cross River State Forestry Commission. Finally, in the third stage, the list of households in each community was obtained with the help of community leaders. Twenty households were randomly selected out of the total 10 communities, giving a sample size of 200 households for the study. Due to some accessibility problems, actual data were collected from 180 respondent households only.

Study design and econometric approach

CVM was used in this study to determine the willingness per household head to pay for systematic management and improvement of community forests from which they harvest or extract NTFPs. The contingent-valuation method (CVM) measures both use and non-use values. This method uses a survey to determine the willingness to pay (WTP) for a particular environmental good or willingness to accept compensation (WTA) for a loss of a particular environmental or public good. It provides a direct method of measuring the value of natural resources without resorting to the market-valuation method. The CVM application can be split into six stages, namely, setting up the hypothetical market, obtaining bids, estimating the mean WTP and/or WTA, estimating bid curves, aggregating the data and the evaluation of CVM (Hanley and Spash 1993). The WTP figure can be derived through a bidding game, closed-ended-questions referendum, payment card and open-ended questions. CVM is more effective when the respondents are familiar with the environmental good or service and have adequate information on which to base their preferences (Munasinghe 1993). CVM is currently the only way to measure passive uses and has become one of the most widely used methods of non-market valuations (Brian et al. 1995).

The goal of contingent valuation is to measure the compensating or equivalent variation for the good in question. Compensating variation is an appropriate measure when the person must purchase the good, such as an improvement in environmental quality, while equivalent variation is appropriate if the person faces a potential loss of the good (FAO 2000). Both compensating variation and equivalent variation can be derived by asking a person to report a WTP amount either to obtain a good or to avoid a loss. Formally, WTP is defined as the amount that must be taken away from the person's income while keeping his utility constant (FAO 2000). This can be given in the form:

$$U(y - WTP, p, q_1; z) = U(y, p, q_0; z) \quad (1)$$

where U denotes the indirect-utility function, y is income, p is a vector of prices faced by the individual, and q_0 and q_1 are the alternative levels of the good or quality indexes (with $q_1 > q_0$ indicating that q_1 refers to improved environmental quality). CVM is subject to some bias, which includes strategic and compliance bias. Strategic bias occurs when respondents deliberately shape their answers to influence the study's outcome in a way that serves their personal interest, while compliance bias occurs when the respondents shape their answers to please either the interviewer or the sponsors, especially when they do not have a well-considered view of the survey topic (Mitchell and Carson 1989). Strategic bias is reduced if the sample has little or nothing to gain by undervaluing the good, while compliance bias will be reduced through careful development of the survey, training and supervision of fieldwork. Other forms of bias include starting-point bias (the starting bid may influence the respondent to understate or overstate actual WTP if a bidding process is used to determine WTP or WTA); vehicle bias (a respondent may be willing to pay more depending on the hypothetical, such as entrance fees or taxes); information bias (the way information on the hypothetical program is presented, including its sequence, can affect respondent's WTP or WTA); hypothetical bias (results from a hypothetical situation may not reflect the choice a respondent would make in a real situation); and operational bias (the fact that the operating conditions in the hypothetical program may not approximate actual market conditions may bias result). However, not withstanding these biases, proponents' argue that through proper survey design and implementation, CVM is a reliable means to measure the use and non-use values of natural resources. After two months of study, a panel convened by the National Oceanic and Atmospheric Administration of the U.S. Department of Commerce in 1993 and co-chaired by two Nobel laureates in economics, concluded: "CV studies can produce estimates reliable enough to be the starting point of a judicial process of damage assessment, including lost passive values".

The use of WTP in this study is based on the property-right structure. Community forests could be considered a quasi-public good. It satisfies one of the features of a public good by being non-excludable but rivalrous. Non-excludability applies when it is impossible or at a high cost to prevent those who have not paid for the product or service from benefiting from it, while rivalry applies when the use or consumption of a good or service reduces the supply available to the others (Feldman 1980; Kessides 1993; Umali-Deininger 1997). Pure public goods are non-excludable and non-rivalrous. For community forests (a common-property regime), some benefits accrue to the individuals directly, e.g., NTFPs, while some are indirect, e.g., soil conservation and carbon sequestration. Also, it is difficult (only at a high cost) if not impossible to exclude individuals who have not paid for a common resource from using it. Therefore, given the property-rights structure, one would not know the value rural people attach to community forests.

Furthermore, some scepticism has been expressed in the use of CVM in developing countries, especially due to their low income and illiteracy. However, it has been shown by a number of studies that CVM can actually be meaningfully applied to developing countries (Wittington 1996; Georgiou et al. 1997). CVM has also been applied in forestry issues as by Mekonnen (2000) in the valuation of community forests in Ethiopia; Köhlin (2001), who looks into WTP for social forestry in Orissa, India; and Lynam et al. (1991), whose study was on WTP for environmental services from trees on communal land in Zimbabwe. Others are Kramer and Mercer (1997), who used CVM to estimate the U.S. residents WTP to protect tropical rainforests, which was estimated to be $1.9 billion; Garrod and Wills (1994) found CVM a useful tool in informing local-level management decisions, providing information on use and non-use values of forests accruing to members, values of new additional reserves of different habitat types and the income generation potential for a new conservation program.

The value-elicitation format used was discrete choice with open-ended follow-up questions. Although the dichotomous-choice format is a common elicitation method, the use of an open-ended follow-up question to a binary (closed-ended) one has been proposed and used by Mitchell and Carson (1989). In addition, Green et al. (1995) argue that a binary question with open-ended follow-up questions provides far more information on WTP and information on plausibility of responses than alternatives such as the double-referendum method. Generally, introduction of follow-up questions to the dichotomous-choice payment question helps to improve the precision of the WTP estimates (FAO 2000). Also, the idea of unfamiliarity with market scenarios is not always a problem, particularly when open-ended questions are presented as a follow-up to a binary question (Mekonnen 2000). In fact, this type of elicitation format is closer to what the respondents are familiar with as it mimics a bargaining process in which the respondents as buyers of a commodity would first expect the price to be stated by the seller and then after some bargaining would decide on a final amount he or she would pay, as obtained in developing countries. Mekonnen (2000) applied this elicitation format in the valuation of community forestry in Ethiopia, and Köhlin (2001) applied it in contingent valuation in social forestry in Orissa, India.

Before the actual field survey, focus-group discussions were organized for a group consisting of women only and a combined group of men and women from two randomly selected communities out of the communities used for the study. The focus group discussed issues on activities of rural people in NTFP conservation in community forests and gender roles. The findings from the focus-group discussions guided the wording of introductory speech painting the market scenario and payment vehicle in the CVM question. Also, before the actual field survey, a pilot study was done using 30 randomly selected households, using an open-end CVM format. The starting prices of the discrete-choice question in the actual field study were based on answers to the open-ended questions in the pilot survey. The starting prices used were N300, N500, N700 and N1000 (the official exchange rate at the time of interview was $1 to N132.00) per year. The prices were assigned randomly to the respondents. In the CVM questionnaire, the scenario and payment vehicle, which was contribution to a community common fund/purse, were described to the respondents. Also, because of the assumption that several rural people experience cash constraints, they were given an option of payment in kind or contribution of labour for forest maintenance. Individuals who indicated that they were not willing to pay were asked the reason for not willing to pay. In the description of market scenario to the respondents in the CVM, specific management types/activities were not included; this may have affected their WTP bids. However, the focus-group discussions showed that they were familiar with some level of management; the local management in existence in the communities was presented elsewhere in this work. In addition, the study did not aim to identify a particular system of management but to find out if people of the community would pay to enhance NTFP conservation to sustain livelihoods. In addition to the CVM questions, data were collected on the socioeconomic attributes of the respondents and the existing management institutional framework available for forest management in the communities. Data collection was done with the help of trained research assistants.

Empirical analysis and model specification

Before performing the model estimation, the data were checked for valid and invalid responses. Invalid responses include protest zeros, outliers and cases where the maximum willingness to pay is less than the accepted starting price. Protest zeros were those who protested to WTP questions. They were determined based on the statement the respondent made in his/her response to the follow-up questions to the valuation question. Some of the responses of those categorized as protest zeros include: pay what?, the forest is free, the money will not be used properly, the forest belongs to my forefathers, nobody can handle things belonging to the public well, the government will take advantage of us, the forest is not planted by anybody and no good accountability, among others. It is important to note that not all those who gave reasons for not willing to pay are protesters. Outliers include those whose WTP was over 5% of their income (or referred to as (-trimmed means in Freeman 1993) and well above the maximum starting price to be used. From the analysis of responses to the valuation question, out of the 180 questionnaires completed, 25% (45) were considered to have invalid responses. Out of the 45 respondents, 50% protested, 33.3% were cases where the maximum WTP was lower than the accepted starting price, while 16.7% were outliers.

Ordinarily, in estimating the determinants of WTP, the most convenient approach would be to discard the invalid responses and use the valid ones. However, since there is no way to determine if the sample remaining after excluding the invalid responses is a random sample, although the initial sample was a random one, discarding the invalid responses could lead to sample selection bias. This, in turn, could lead to inconsistent parameter estimates of the valuation function to be used to test the theoretical validity. Additionally the estimated benefits measures and hence the aggregated values may also be biased. Therefore, to guard against inconsistent estimates of the parameters due to possible sample selection bias, the means of variables of the valid and invalid response groups were compared using t-statistics to find out whether discarding the invalid responses is justified. Differences in the means will warrant the use of a selectivity model for estimation. The result of mean differences is presented in Table 1.

Table 1. *Mean comparison of some variables for respondents with valid and invalid responses to the valuation question*

Variable	Mean for valid responses	Mean for invalid responses	t-statistics
Starting price	505.93	537.78	-0.86
Age	48.01	46.31	0.73
Number of years of schooling	10.67	8.22	2.74***
Occupation (farming)[a]	0.39	0.78	-4.72***
Proportion of food	4.96	3.96	2.74***
Distance	4.37	5.32	-2.90***

*** indicate significance at 1% level of probability
[a] 1 if occupation is farming; 0 otherwise, civil servant
Source: Computation from field survey data 2005/06

The result of mean comparison shows that the means of the variables of respondents with valid and invalid responses were significantly different at 1% level of probability. The variables include number of years of schooling, occupation (farming), distance to forest from home (km), and proportion of household food that is from NTFP. Thus the significant differences found justify the use of a sample selection model.

Hence a sample selection model (Heckman 1979) was used for the empirical estimation of the bid function. Willingness to pay was censored at zero for households that give valid responses. The estimation was done based on maximum-likelihood estimates, since the estimates obtained using Heckman's two-step estimation procedure, where OLS is used in the second step, would be inefficient and inconsistent (Green et al. 1995) due to the censoring. A tobit model with selectivity (Green et al. 1995) was used to examine more rigorously whether there is a difference between the valid and invalid responses and at the same time estimate the factors that influence the maximum amount willing to pay conditional on being a valid response. The model used takes the form:

$$Y^* = \beta^1 X + \varepsilon$$
$$Y = 0 \text{ if } Y^* \leq 0, Y^* < T \qquad (2)$$
$$Y = 1 if Y^* > 0, Y^* \geq T$$
$$and \text{ Y} = Y^* \text{otherwise}$$

$$Z^* = \alpha^1 V + U$$
$$Z = 1 \; if \; Z^* > 0 \qquad (3)$$
$$and \; Z = 0 \; if \; Z^* \leq 0$$

where Y is a vector of WTP that is censored at 0; T is the offered start price; X is matrix of explanatory variables that are hypothesized to influence WTP; Z is a vector of a dummy variable which is 1 when the observation has a valid response and 0 otherwise; V is a matrix of explanatory variables that may influence the probability of giving a valid or invalid response; α and β are vectors of unknown parameters to be estimated corresponding to the matrix of explanatory variables V and X, respectively; ε and μ are error terms that could be correlated with correlation coefficient ρ; and Y^* and Z^* are unobserved or latent variables corresponding to Y and Z, respectively. Y values are observed when Z equals 1. The existence of selection bias would be confirmed if there is correlation between the error terms of equations (2) and (3) as measured by estimates of ρ and its standard error, hence making the use of tobit model with sample selection appropriate. The outcome equations deal only with individuals that made a valid response, that is, that have positive WTP.

DATA DESCRIPTION, RESULTS AND DISCUSSION

Data description

The result of descriptive statistics of the socioeconomic variables used in the analysis is presented in Table 2. Some of the variables measured household characteristics expected to influence WTP. These include household size, wealth status of the respondents, age and sex of the household head and occupation. The number of males and females in the household was included to ascertain whether gender composition of household influenced WTP. Based on the role of women in forest product collection as found out in the focus-group discussions, it is expected that the number of females in a households will positively influence WTP.

Table 2. *Value means and standard deviation of the variables*

Variable	No of observations	Mean	Standard deviation	Min.	Max.
Start price	180	513.89	215.53	300	1000
Gender [a]	180	0.92	0.28	0	1
Age	180	47.59	13.10	26	77
Age^2	180	2445.94	1351.01	676	5929
Any existing form of forest management	180	0.33	0.47	0	1
Occupation (Farming) [b]	180	0.48	0.50	0	1
Number of years in school	180	10.07	5.33	0	18
Distance to forests	180	4.61	1.93	1	10
Cultivation	180	0.72	0.45	0	1
Wealth category 2[c]	180	0.29	0.46	0	1
No of males in household	180	3.88	2.56	1	16
No of females in household	180	3.34	2.66	1	18
Valid amount willing to pay	135	582.59	433.28	0	2000
Valid amount if start price was accepted	113	696.02	380.73	300	2000
WTP if valid amount was equal to start price	58	465.51	179.23	300	1000
Valid-Invalid	180	0.75	0.43	0	1

Sample Size = 180
[a] 1 if Gender is male ; 0 otherwise (female)
[b] 1 if occupation is farming; 0 otherwise, civil servant
[c] 1 if wealth is medium; 0 otherwise, low
Source: Field survey data 2005/2006

Wealth categories were determined based on ownership of materials that communities use. These were initially obtained through key-informant interviews. Based on the information given by the key informants, who were individuals who had lived in the communities for five years, household heads owning a large cocoa farm (above one hectare), a compound/house of his own, wife and children, a university diploma and a large banana/plantain farm (above one hectare) were categorized as 'high wealth'. Household heads who own either a large cocoa farm or a large banana/plantain farm (above one hectare), a compound/house of his/her own, wife and children were categorized as 'medium wealth', while household heads with a small cocoa farm or a small banana farm (less than one hectare), a compound of his/her own and wife and children were categorized as 'low wealth'.

Starting prices were also included to check whether the responses were influenced by the starting prices. A measure of access to the forests, distance from home to forests where NTFP are normally collected, was also included. Also, when the household food consumption is shared into ten parts, the part that is from NTFP was also included to ascertain whether household demand for NTFP influences WTP. Furthermore, the number of years of schooling of the household head and occupation were also included. It is expected that those who have an occupation that involves entering the forest often, for example, farmers, would be more willing to pay. A household involvement in conservation of private NTFP resources was captured by the cultivation variable. The variable ascertained whether a household was involved in cultivation of NTFP or not. The variable to capture the existence of forest management in a community was also included in the model. The existence of any form of forest management was included as a dummy variable. The mean amount that those who gave valid responses were willing to pay was N582.59 ($4.55) annually.

Institutional approach to existing forest management in the study area

Out of the 180 respondents, 97.8% indicated that they have access to forests in their communities anytime. Only 29.4% indicated that they have an organized form of managing forests. Thus, organized forest management is non-existent in most of the communities. Among those who indicated that they have some organized form of management practices, different approaches are employed across communities. Some of the respondents indicated that forest management committees are established to take care of timber harvesting. Village elders select youths who are organized to secure the forest area while in some communities the selected committee sells mainly timber and renders account to elders. Furthermore, some have a land committee who also take care of forests by collecting rent from timber exploiters. In fact, management is mostly for timber, however, they have regulations for the collection of some NTFP.

Results and discussion

The results of the sample selection model are presented in Table 3. The results show that the ρ was significantly different from zero, thus justifying the use of a sample selection model as discarding the invalid responses will lead to sample selection bias. In estimating the bid function, different variables from the ones listed in Table 2 were used in the selection and outcome equation. The preferred model based on the likelihood ratio test and the z-test is presented in Table 3. The table shows the selection (probability of valid WTP) and outcome (size of WTP) equations.

The result shows that some variables significantly influenced having a valid or invalid response. Considering that the age variable was included in the selection equation in both linear and quadratic forms, the result shows that age had a significant and negative effect on making a valid response up to the age of 45 years ($X=-\beta_1/2\beta_2$; where $\beta_1 = -0.181$ and $\beta_2 = 0.0020$), after which the effect becomes positive. Thus being less than or equal to 45 years decreases the likelihood of making a valid response, but after the age of 45 the likelihood of making a valid response increases. Invariably, individuals after the age of 45 are more likely to make a valid response. The tendency of making a valid response also increases with the household head being from a community where there is an existing form of forest management. This could be because of the fact that they are already more aware of the gains of organized management.

Some variables, on the other hand, influenced the amount of willing to pay subject to being a valid response. It is important to note that the coefficient for the variables that appeared in the outcome equation but did not appear in the selection equation, is the marginal effect of one unit change in that variable on the dependent variable (valid amount WTP). The variables which appeared only in the outcome equation and which positive or negatively influenced valid amount WTP are gender, occupation (farming), number of years in school, wealth category 2, distance to forests where NTFP is collected, number of females in the household and number of males in the household. Gender had a negative and significant effect of valid amount WTP. This suggests that females were more likely to pay for organized/systematic management than males. Previous studies, for example, Bisong and Ajake (2001), have shown that women depend more on NTFP, thus this could be the likely reason for WTP exhibited by females. Responses from the focus-group discussion organized as part of this study show that men do not normally collect NTFP and as a result they may less likely be interested in the conservation of the resource compared to women. A household head being a farmer as against being a civil servant was positive and significant in the outcome equation showing that farmers are more willing to pay than civil servants. In addition, number of years of schooling and number of females in a household positively influenced WTP. The positive and significant effect of number of years of schooling shows that increased education would have a positive effect in involvement of the community in the management and conservation of a common poll resource.

__Table 3__. Parameter estimates of the sample selection model

Variable	Selection equation results (probability of valid WTP)	Outcome equation results (size of WTP)
Start price	-0.000063	1.162***
	0.00047	0.149
Gender [a]		-393.212**
		174.553
Age	-0.181***	0.823
	0.060	2.554
Age^2	0.0020***	
	0.0006	
Occupation (Farming) [b]		427.346***
		79.394
Any existing form of forest management [c]	0.535**	50.171
	0.231	58.890
Production [d]		-86.131
		64.845
Number of years in school		42.477***
		7.930
Wealth category 2		142.321**
		55.794
Distance to forests		-33.514**
		16.812
Number of males in household		-48.745***
		15.010
Number of females in household		55.625***
		12.977
Constant	4.227***	-32.273
	1.413	258.399
Rho (ρ)	-0.817***	
	0.107	
Sigma	320.253***	
	28.879	

Variables in parenthesis are standard errors
Number of observations = 180, censored = 45, uncensored = 135
Log likelihood (full model) = -1040.343
LR test of indep. eqns. (rho=0): chi2(1) = 5.77 prob > chi2 = 0.0163
***, **, indicate significance at 99% and 95% levels, respectively
[a] 1 if gender is male ; 0 otherwise (female)
[b] 1 if occupation is farming; 0 otherwise, civil servant
[c] 1 if any forest management, whether organized or not, exists in the community, 0 otherwise
[d] 1 if household produces NTFP; 0 otherwise
Source: Field survey data 2005

This suggests that household heads who have more schooling and those who have more females in their household are likely to pay more for conservation of a common poll resource. Wealth category 2 was positive and significant in the outcome equation suggesting that households in the medium-wealth category are likely to pay a higher amount compared to those in the low-wealth category. Households in the medium-wealth category have more possessions, therefore they are expected to contribute more to organized forest management for NTFP conservation. The negative and significant effect of the number of males in households suggests that households with more males are less likely to pay for management of community forests for conservation of NTFP. Distance to source of NTFP negatively and significantly influenced WTP. This suggests that households that move a long distance to collect NTFP are less likely to pay for organized community forest management. Thus, poor access to a resource is a disincentive for conservation.

Moreover, the variable that appeared in both the selection and outcome equation and which had a significant influence on a valid amount willing to pay is start price. Usually, the coefficient in the outcome equation, for a variable that appeared in both equations, is affected by its presence in the selection equation as well. Hence, the coefficient of the significant variable in the outcome equation is not the marginal effect of a unit change in that variable on WTP. However, the marginal effect of each of the K^{th} element of the variable on the conditional expectation of WTP is derived after which the mean value is calculated. The equation for deriving marginal effect of the K^{th} element of the variable is $\beta_k - (\alpha_k * \rho * \sigma_n * Dpr)$ where β = coefficient of the variable in outcome equation; α = coefficient of the variable in selection equation; ρ = rho (correlation between error terms in the two equations); σ = sigma, which is error from the outcome equation; and Dpr = inverse mills ratio plus the probability of being selected. Based on the above formula, the mean of the corrected coefficient for start price (corrected coefficient shows the marginal effect of the variable on the conditional expectation of WTP) is 1.169; the standard deviation is 0.002 while the maximum and minimum values are 1.162 and 1.172, respectively. Thus, the average β is close to the estimated β. The result generally shows that start price positively and significantly influenced WTP subject to having made a valid response. The positive and significant starting price for the outcome equation suggests that there could be a significant starting-point bias. It is important to note that there are no reliable methods to deal with starting-point bias. Mitchell and Carson (1989) noted that there is no generally valid method to compensate for the effect of starting-point bias.

CONCLUSION

This study used the contingent-valuation method (CVM) to ascertain the determinants of willingness to pay (WTP) for organized management of community forests for non-timber forest product (NTFC) conservation. A Tobit model with sample selection was used in estimating the bid function so as to guard against the bias that may result from excluding the invalid responses to the CVM questions. The findings show that the mean amount a household was willing to pay annually for systematic management of community forests by community members was N582.59 ($4.55). Some variables, which include wealth category (medium wealth as against low wealth), occupation (farming as against civil servant), number of years of schooling and number of females in a household positively and significantly influenced WTP. Gender, number of males in a household and distance from home to forests negatively and significantly influenced WTP. Hence, to ensure conservation of NTFP resources and to facilitate poverty alleviation, the rural communities in the rainforest region should be organized for the management of community forests as the rural people are willing to pay and contribute to organized management of NTFP resources. The issue of organized/systematic management should be incorporated in the forestry act that is under review. The Ministry of Environment and State Forestry Commissions should institute policy initiatives to encourage communities to organize themselves. Policies to encourage collective action for resource conservation could be in the form of assistance for communities that have organized themselves for systematic management of forests for conservation of NTFP. Such assistance could be in form of increasing the percentage of forest permits remitted to the communities, provision of credit facilities and development of forest management plans especially focusing on NTFP management and conservation for community forests among others. The management plans should indicate that there would not be government intervention and that the communities will pay to facilitate management. However, introduction of payment would be gradual, otherwise those who may be indifferent or who do not have capacity to pay will opt out, for example, those who do not derive much of their household food from NTFP, non-educated people in the community and non-farmers. In organizing them, households with some wealth possessions as indicated by the wealth items of those with medium wealth, women-headed households, those with more females in the household and those whose household head has undergone some years of schooling and who are engaged in farming should be considered potential contributors and supporters of organized management of community forests for NTFP conservation. Particular attention should be paid to women who have shown to be more willing to pay for systematic management. In fact, in several previous studies women have been found to be major users of forests for NTFP collection. International and local non-governmental organizations can help in initiating organized forest management. This can be started with communities that already have some form of management, especially for timber exploitation. Incorporating the findings of this study in such initiatives will enhance participation, conservation of NTFP and hence poverty alleviation.

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SUSTAINABLE LAND USE

CHAPTER 8

TRADITIONAL INSTITUTIONS AND SUSTAINABLE LIVELIHOOD

Evidences from upland agricultural communities in the Philippines

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Abstract. This paper investigates the effects of traditional informal institutions on the sustainable management of upland agricultural fields in indigenous communities of the northern Philippines. The estimated results from the case study suggest significant positive effects of a traditional reciprocal exchange-labour system and customary property rights restrictions on field maintenance activities, although the existence of traditional authority is not found to be significant. The results imply a continuing positive role for embedded customs in these communities, despite some evidences of decaying traditional institutions.
Keywords. traditional/informal institutions; sustainable resource management; The Philippines

INTRODUCTION

Numerous studies in both academic and practical development spheres employ the now familiar buzzwords of 'traditional', 'indigenous' and 'communal' resource management systems. Although not necessarily signifying the same thing, the terms are often commonly applied in developing-country contexts where traditional indigenous knowledge or techniques are used in the management of natural resources, often falling under the common-property regime. The research objective of this paper is to examine empirically whether the so-called 'traditional/indigenous' informal institutions, which are sometimes considered to hinder people's incentives, function to encourage a sustainable livelihood for the local people.

Our particular focus is on the land tenure and management systems. Informal, traditional tenure systems vary depending on the context, yet they are distinguished from formal individualized systems as they are generally sanctioned customarily rather than through formal titling. These informal property rights often lack a certain degree of exclusiveness, in terms of ownership, rights to alienate the land, etc. There

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have been empirical works looking at traditional land tenure systems, inquiring whether formal, as opposed to informal, institutions provide proper incentives for the farmers to manage the land. The findings are mixed. While some find that formal titles are effective (Feder and Onchan 1987; Feder and Feeny 1993; Deininger and Chamorro 2002), some find mixed results (Place and Hazell 1993; Besley 1995) and others do not find formal land tenure to be relevant or effective (Migot-Adholla et al. 1993; Gavian and Fafchamps 1996). These findings have led some of these authors either to recommend for or warn against land privatization/registration schemes.

Our study aims to contribute to the understanding of the linkages between traditional land tenure systems and land management incentives. Whilst most previous studies did not specifically look into the effectiveness of traditional tenure per se but examined possible effects of formal titling and/or privatization schemes, we attempt to investigate the effectiveness of traditional institutions. Also, while the foci of previous works are on the linkages between land tenure and land improvements for productivity enhancement and/or increased credit access, we focus on land improvements in terms of sustainability enhancement. Especially given the fragile upland environment of our case study area, such sustainability-enhancing land improvements are essential for the long-term sustenance of people's livelihood. We analyse the indigenous agricultural communities of Cordillera in the northern Philippines, where traditional institutions are considered to have effectively guided people's livelihoods, yet seem to be in a changing process. This empirical work, utilizing original data, is expected to contribute to the understanding of the probable path of sustainable livelihood for rural populations, which often have a disadvantaged status and depend on a fragile natural-resource base.

CASE-STUDY BACKGROUND

Cordillera, composed of six upland provinces, is located in the centre of Northern Luzon Island of the Philippines, surrounded by lowland provinces. The region mainly consists of indigenous cultural communities whose practices have been less disturbed by immigration, compared with the rest of the Philippines (the majority of population movement has been intra-Cordilleran)[1]. These indigenous communities range from traditional indigenous ones to those that are more recently established, with varying perceptions of customary laws, economic orientations and natural-resource management practices. These predominantly agricultural communities can typically be placed somewhere along the continuum of subsistence-based rice production and commercially oriented vegetable production communities. Fifty-nine percent of the rural households in the region live below the poverty threshold, and most of the communities have only a poorly developed transportation and marketing infrastructure (Source: Philippines National Statistics Office 2000).

Table 1. *Annual-income basic statistics*

	Average annual income (1,000 Philippine Pesos)	Standard deviation	Median
All communities (N=789)	44.27	125.12	16
Rice communities (Nr=396)	13.96	16.79	9.3
Vegetable communities (Nv=393)	78.82	171.23	30

Note a: The reported annual incomes from the survey are net, subtracting costs incurred for agricultural production, based on current prices of year 2000.
Source: field survey data (2000, 2001) by the author.
Note b: Average annual income for Philippines: PP 145,000; average annual income for Cordillera, including the capital city of Baguio: PP 139,613; Poverty threshold for Cordillera (rural): PP 14,616 (all figures of 2000; based on current prices).
Source: Philippines National Statistics Office (2000).

This case study is carried out in eight communities across the provinces of Benguet, Mountain Province and Ifugao. Half of these communities are mainly rice-producing and the other half are mainly vegetable-producing communities. Although no formal statistics are available distinguishing the poverty rate between these two types of communities, rice communities in general are poorer (see Table 1). However, vegetable production is prone to higher degree of fluctuation in its profits due to price changes and crop failures.

Environmental fragility

More than 80% of the land in the region has a slope of above 18 degrees. The fact that the region consists of highly sloped land means that it typically requires certain management techniques and conservation measures in order to practice agriculture in a sustainable manner. Historically, there has been a reduction in the extent and density of forest cover and a conversion of increasingly steeper lands to agriculture, due to increasing population and in-migration, logging concessions and expansion of agricultural activities[2]. Such activities have increased the extent and rates of soil loss and erosion, consequently reducing water availability in local irrigation systems. Of the total regional area of 1,829,400 ha, 28% is classified as 'slight erosion' class, 40% as 'moderate erosion', 23% as 'severe erosion' and the remaining 9% as either 'no apparent erosion' or 'unclassified' (FAO 1990). By far, topsoil erosion is the dominant form of land degradation in the region, accounting for 87% (*ibid.*). Since the region forms the upper watershed for most of Northern Luzon's rivers, the forest and related resource management of the area is also vital for the water supply of the lowlands. The environmental externality effects of their agricultural activities are also critical as chemical pollution can reach the water systems[3].

According to the provincial slope maps, most of the research sites have slopes of between 30 and 70%, where above 50% is considered to be very steep. Highly sloped lands are especially prone to erosion and require proper terracing, construction of retaining stonewalls or other soil erosion prevention measures such as wattling. Also, functioning irrigation and drainage management is necessary in order to avoid overflooding and protect fields from heavy downpours, which can destroy terraces.

Traditional institutions

All eight surveyed communities adopt the formal administrative structure of *barangay*, municipality and province[4]. However, apart from formal organizations such as a *barangay* committee, there are traditional institutions in many communities promoting community welfare. Decisions based upon past precedents and experience are typically made amongst a council of elders. Such institutions appear to be still effective in some communities, especially in rice-growing communities in Mountain Province and Ifugao (field observations 2000, 2001)[5]. They govern different aspects of economic and social lives, including the way in which natural resources are managed and agricultural activities are carried out. For instance, the observance of planting cycles is still seen in some communities. On the other hand, the tradition of various public feasts, which has redistributive characteristics, is still widely seen in more commercialized vegetable-growing communities (Lewis 1989, field observation 2000, 2001).

In some communities, such as Bayyo of Mountain Province, traditional customs still play important roles in regulating various parts of life. Also in Ifugao, some communities are reported to retain their traditional communal forest management systems: forests are managed and inherited according to customary laws in order to maintain a forest environment that protects their lower farmlands from soil erosion and regulates water provision (Department of Environment and Natural Resources 1987, p. 8-9). Yet, general observations from our case study seem to reveal a less active communal management of natural resources compared to the descriptions in some anthropological case studies. Less use of traditional reciprocal labour exchange during peak times is seen, especially in vegetable-growing communities where the arrangements no longer suit all-year-round commercial production. In these communities, wage hired-labour arrangements seem to be more common. Although to a lesser extent, a similar trend is seen in rice-growing communities. Water shortage troubles and complaints about inequitable distributions are reported in the surveyed communities, even though water has traditionally been managed through communal/corporate cooperative organizations. Likewise, although conflicts over land have traditionally been settled by communal authorities, disputes in recent years, especially at an individual level, have been increasingly brought to municipal/state courts[5].

Customary laws on land tenure

The Philippine law defines land with a slope greater than 18 degrees as *de jure* public forestlands. This applies to more than 80% of the region's lands, although they are mostly *de facto* private agricultural lands. While some of the residents possess formal titles, others occupy the land through communal sanctions by customary law, through the virtue of tax declaration, or through the mere fact of physical occupancy. Yet, there has been a strong concept of ancestral property amongst the indigenous people. The 'time immemorial' presumption underlines that land which 'has been held under a claim of private ownership' since time immemorial is presumed 'never to have been public land'. This presumption has proved to be valid at least six times by the Philippine Supreme Court (Lynch 1986, p. 381)[6]. Thus, even at the state level, there exist conflicting statutes on land matters.

In contrast to the concept of private property, indigenous customary laws on land – although their details differ in each community – typically allow lands to be held individually, communally or by corporate groups. For all types of ownership, the land tenure rules encompass the acquisition, access, management, maintenance and transfer of land, including inheritance procedures. Natural resources generally fall into one of three classified property regimes – individual, corporate and communal – where the most valuable (generally the most heavily invested) object falls into the individual property regime[8]. The most valuable lands, i.e., agricultural and residential lands, generally fall into individual property. Agricultural fields in our case study, except for a few cases, are individual property.

Individual property may be governed by customary rules concerning its inheritance and transfers. Land resources are inherited usually upon marriage. Individual rights enable the right holder to use, rent and alienate the property according to the customary laws, which often impose some restrictions on exercising these rights, depending on the kind of property. For instance, one may alienate her/his land only in an emergency, in order to meet mortuary requirements, fine payment, hospital bills, children's education fees and the like. This also often requires the consent of parents, and to be offered first to close relatives (Prill-Brett 1993). The indigenous mortgaging of Ibaloy communities is characterized by an oral contract, with no set duration, no interest, first offered to relatives and no practice of foreclosure, and the arrangement can be passed on to succeeding generations. This is based on the principle that the property remains redeemable by the original owner or her/his descendants in the future. However, the introduction and adoption of another mortgaging arrangement in the 20th century – with a written contract with set duration and conditions – indicate that such traditional arrangements were not always effective (Prill-Brett 1992).

Thus seen, customary rights are often restrictive compared to those property rights with fuller alienability based on western systems. The fact that there are rules/restrictions/communal sanctions on the exercise of various rights can be considered rational consequences of coping strategy with respect to the fragile upland environment. In other words, such an institution may have arisen in order to sustain the productivity of land and minimize the risk of crop production failures. For instance, fields in some Bontoc communities are reported to follow a certain agricultural cycle each year, based on the ecological information. Their planting and harvesting schedules are coordinated in order to enable proper labour rotation. There are also compulsory rest days to prevent the spread of pests[9]. These activities entail restricted use rights and require good coordination. The need for coordination also arises in terms of investments put into a field, since the proximity of fields can produce substantial externality effects. The existence of communal restrictions indicates that the communal authority holds overall management rights so as to promote communal welfare and maintain communal solidarity.

ANALYTICAL FRAMEWORK AND EMPIRICAL MODEL

We analyse whether traditional informal institutions encourage the sustainable livelihood of people. In terms of 'traditional institution', we look at the following factors: the existence of effective traditional authority; the practice of reciprocal exchange-labour systems; the access to informal credit; the strength of property rights; and the existence of restrictions over the exercise of rights[10]. The first factor concerns each individual's perception regarding the effectiveness of traditional authority. The second factor concerns whether the traditional system of exchange labour is still effective or not. The third factor concerns whether a farmer has ordinary access to informal credit arrangements when (s)he is in need. The fourth factor concerns the total number of constituent rights held, regardless of the rights being held in full or restricted. The fifth factor concerns whether there are any restrictions imposed on exercising the rights. As explained earlier, an absence of and/or restrictions on alienable rights are seen especially in those communities where traditional values are still dominant in everyday life. Thus these fourth and fifth factors may reveal the prevalence of traditional institutions. Note that we only consider 'owned fields' and not 'rented' or 'borrowed fields' in order to make consideration of the third factor valid; naturally, more constituent rights are held for owned fields. All the data, except for property rights restrictions, are taken per household. This is to allow for the heterogeneity of perceptions amongst community members, especially in communities in transition. For instance, even perceptions regarding the existence of (effective) traditional authority could differ among members of the same community. Property rights data are taken per field unit.

With regard to sustainable livelihood, we look at people's incentives in exercising sustainability enhancing agricultural practices. In particular, we look at whether farmers actually pursue sustainability-enhancing land management. Activities include the construction and maintenance of terraces, stonewalls, irrigation and hedgerows as well as sustainability-enhancing technique adoption (e.g., application of organic fertilizers and reduced cultivation). These activities are considered to be crucial in conducting environmentally sound agriculture in the upland environment, as they essentially retain soil quality, regulate water inflows/outflows and prevent soil erosion and destruction of terraces. They seem to be done according to traditional practices, imbedded knowledge and norms, although not necessarily stipulated in the customary laws. The customary institutions, if still effective, are expected to have a positive impact, especially on maintenance activities and technique adoption, in the form of ongoing, medium-/short-term land management and improvements. On the other hand, they may not influence construction activities; they require much heavier inputs and thus, such activities are likely to be done infrequently, according to individual needs rather than communal concerns. This may also be reflected in the high zero observation of construction type improvements.

Thus, a farmer's sustainability-enhancing activities (y_{ij}) are set as the dependent variable for field *i* of a farmer household *j*. Independent variables for the base model are: existence of traditional authority (A_j); access to an exchange-labour system (L_j); access to informal credit (IC_j); the strength of property rights over the field (R_{ij}); and the average number of restrictions over property rights per constituent right held (RE_{ij}), i.e., the total number of restrictions divided by the number of constituent rights held. In addition to this basic model, we estimate an extended model incorporating other household characteristics that are considered to be relevant for traditional values as well as sustainability-enhancing activity decisions. These variables are: proportion of agricultural products sold in a market (*propsold*); net annual income (*income*); whether the respondent (either or both in case of a couple) has graduated from a college or a vocational-training school (*college*); and age (average age in case of a couple) (*age*). *Propsold* measures how much a household is commercialized in terms of its agricultural activities. Together with *college*, they may indicate 'less traditional values' held by the farmers. *Income* is considered to encourage sustainability-enhancing activities. *Age* is included as older people are considered to hold 'more traditional values'.

The unit of measurement is field for the dependent variable and independent variables (R_{ij}) and (RE_{ij}). All other variables are measured in household units and are applicable across all fields cultivated by the same household. The relationship is thus depicted as:

$$y_{ij} = f(A_j, L_j, IC_j, R_{ij}, RE_{ij}, others_j) \quad (1)$$

For the dependent variable (y_{ij}), we separately consider (a) 'construction activities' as long-term land management investments; (b) 'maintenance activities' as medium-term land management investments; and (c) 'technique adoption' as short-term land management investments. As mentioned earlier, we expect that construction activities are less likely to be affected by the institutional factors of our concern. The dependent variable (y_{ij}), a farmer's sustainability-enhancing activities, is an ordinal index constructed to reflect a farmer's actual land management deeds that are considered to be sustainability enhancing. For long-term heavy investment, however, we essentially estimate it via binary mode given its high observation of zero deeds; '1' if one or more investment deed is taken and '0' if none is taken.

Table 2. *Sustainability-enhancing activity indices*

Activity / Investment category	Mean (standard deviation)			Value range	Investment deeds
	N	Nv	Nr		
Construction: long-term, intensive	0.30 (0.46)	0.48 (0.50)	0.19 (0.39)	0-1	Horizontal terrace; non-horizontal terrace; stonewall; irrigation canal/hose/pipe; stone-piling
Maintenance: medium-term, less intensive	2.77 (0.73)	2.44 (1.01)	2.97 (0.35)	0-5	Terrace maintenance; stonewall maintenance; irrigation maintenance; tree hedgerow; tree crop planting; grass hedgerow
Sustainability-enhancing technique adoption	2.30 (1.49)	2.86 (1.34)	1.95 (1.47)	0-7	Organic fertilizer; contour cultivation; nitrogen-fixing crop planting; cover cropping; crop rotation; multiple cropping; reduced cultivation; lime application

Notes: For owned fields only (N=523). Nv (vegetable-growing communities): 202; Nr (rice-growing communities): 321.
Source: Survey data (2000, 2001) by the author.

The existence of traditional authority (A_j) is a dichotomous variable taking a value of (0,1). Access to an exchange-labour system (L_j) employs three categorical dummy variables: (1) reciprocal exchange labour only; (2) exchange labour and casual daily labour; and (3) no access to an exchange-labour system, as the base category. The first one is considered to be the most traditional form. Access to informal credit also has three categories: (1) informal credit without interest; (2) informal credit with interest; and (3) no access to informal credit, as the base category. The strength of property rights (R_{ij}) is a summation of the number of constituent rights (use; rent/tenant; mortgage; sell; give; exchange; bequeath; modify) held by a farmer, regardless of them being full or restricted rights. With eight constituent rights, a strength-of-rights index accordingly takes a value ($0 \leq R_{ij} \leq 8$). Some have only use right, even being the owners of the fields, while others have several or all of these rights. We do not weigh each constituent right with its degree of importance, since weights must be arbitrary in their nature, having no clear criteria. The simple summation measure is considered to reflect the overall strength of rights, since those less frequent rights, e.g., rights to sell, give, etc., are, by definition, included only in stronger rights. The total number of restrictions over property rights (RE_{ij}) is an average number of all restrictions posed on these constituent rights. For household-level variables measured by a couple unit or single unit if unmarried, we take the higher value for education among the couple and the average value for the age. Table 3 provides summary statistics of independent variables.

Table 3. *Summary statistics of independent variables*

Variable	Type	Mean (standard deviation)	Note
Traditional authority **(A_j)**	Binary	0.64 (0.48)	
Access to exchange-labour system (exchange labour only) *(L_j)*	Binary	0.32 (0.47)	
Access to exchange-labour system (exchange and wage labour) *(L_j)*	Binary	0.33 (0.47)	
Informal credit market access (no interest)	Binary	0.16 (0.36)	
Informal credit market access (interest)	Binary	0.20 (0.40)	
Property rights strength *(R_{ij})*	Numerical	4.40 (2.59)	Total number of constituent rights held
Number of restrictions per right *(RE_{ij})*	Numerical	0.35 (0.52)	Restrictions on property rights (per constituent right)
Proportion of crops sold	Numerical	0.36 (0.42)	
Net annual income	Numerical	45.36 (133.32)	
Age	Numerical	45.20 (12.81)	Years (average value for a couple)
College graduate	Binary	0.11 (0.31)	

Note: N=523 (owned fields only).
Source: Survey data (2000, 2001) by the author.

ESTIMATION MODELS

For the empirical model (1), we simply represent household-level variables as a vector of household characteristics ($\mathbf{h}_j$) and field-level variables as a vector of field characteristics ($\mathbf{z}_{ij}$):

$$\begin{aligned} y_{ij} &= f(A_j, L_j, IC_j, R_{ij}, RE_{ij}, others_j) \\ &= f(\mathbf{h}_j, \mathbf{z}_{ij}) = \boldsymbol{\beta}_0 + \boldsymbol{\beta}_1 \mathbf{h}_j + \boldsymbol{\beta}_2 \mathbf{z}_{ij} + \varepsilon_{ij} \end{aligned} \quad (2)$$

where y_{ij}: investment activity index for a field *j* of a household *i*;

$\mathbf{h}_i = (A_j, L_j, IC_j,$ other household-level variables): a vector of household characteristics;

$\mathbf{z}_{ij} = (R_{ij}, RE_{ij})$: a vector of field characteristics.

We apply an ordered logit model (Ologit) for main estimations (maintenance activities and technique adoption), as it is found to suit the data best, especially since the dependent variable is of ordinal nature (number of investment deeds taken). Household cluster effects are applied to adjust for standard errors, given the fact that certain households have several fields. Since the Ologit estimated parameter values also reflect the identifying assumptions regarding the variance of errors, we also compute the 'factor change in odds ratios' in order to interpret the probability of an event that is independent of the assumptions (see Long (1997) for details).

For construction activities that are recoded into a binary index, we apply the household random-effects logit model (RElogit): in particular, a random-intercept model, which is one of the simplest forms of the random-effects model. The random effects are found to be significant and its specification passes the Hausman test. The estimation equation takes into account the variables and the error terms measured at different levels, those corresponding to a field (*i*) and a household (*j*). Here, equation (2) is respecified as:

$$y_{ij} = f(\mathbf{h}_j, \mathbf{z}_{ij}) = \boldsymbol{\beta}_0 + \boldsymbol{\beta}_1 \mathbf{z}_{ij} + \varepsilon_{ij} \tag{3}$$

Having $\boldsymbol{\beta}_0 = (\omega_{00} + \omega_{01}\mathbf{h}_j + u_{0j})$

$$y_{ij} = (\omega_{00} + \omega_{01}\mathbf{h}_j + u_{0j}) + \boldsymbol{\beta}_1 \mathbf{z}_{ij} + \varepsilon_{ij} = (\omega_{00} + \omega_{10}\mathbf{z}_{ij} + \omega_{01}\mathbf{h}_j) + \varepsilon_{ij} + u_{0j} \tag{4}$$

where a row vector $\boldsymbol{\beta}_1 = \boldsymbol{\omega}_{10}$ represents fixed coefficients. In the last part of equation (4), the coefficients are all systematized to $\boldsymbol{\omega}$ from $\boldsymbol{\beta}$, where $\boldsymbol{\omega}_{00}$ is the average intercept, $\boldsymbol{\omega}_{10}$ and $\boldsymbol{\omega}_{01}$ are coefficient (row) vectors at level one (field level) and at level two (household level), corresponding to each element of the $\mathbf{z}$ and the $\mathbf{h}$ (column) vectors, respectively. The last part of equation (4) within the parenthesis is the fixed part of the model, while $\varepsilon_{ij} + u_{0j}$ is the random part. Any random factor that is not captured by the fixed system of the equation should be reflected in the error terms.

ESTIMATION RESULTS

Estimations are carried out for the base and extended models for each activity category, construction, maintenance and technique adoption activities. The base model contains limited variables that are considered to be particularly relevant to the analysis. The extended model contains other household characteristics that are considered to affect the investment incentives. As mentioned above, if traditional institutions are still effective in coordinating people's activities, we expect that they should encourage sustainable resource management, especially in the form of maintenance activities and technique adoption. Traditional institutions are reflected in the existence of traditional authority, the practice of reciprocal labour exchange, the access to informal credit, the overall strength of property rights and the existence of restrictions on the exercise of certain rights over one's land.

Table 4.1. *Estimation results*

	Construction		Maintenance		Technique adoption	
	Logit with random effects		Ordered Logit with cluster effects			
	Base model	Extended model	Base model	Extended model	Base model	Extended model
	Scalar measures					
Wald χ^2(K)	48.65 (7)	60.13 (22)	56.60 (7)	74.58 (11)	74.29 (7)	88.35 (11)
Deviance (DoF)			879.92 (511)	857.95 (505)	1671.17 (509)	1654.04 (503)
McKelvey and Zavoina's R^2			0.23	0.26	0.24	0.26
AIC			1.728	1.71	3.249	3.244
BIC			-2318.73	-2301.21	-1514.96	-1492.61
	Estimates (absolute z-value); significant at 0.01***; 0.05**; 0.1*					
Traditional authority	0.17 (0.47)	0.06 (0.17)	-0.08 (-0.29)	-0.08 (-0.29)	0.42* (1.66)	0.41 (1.56)
Exchange labour only	-0.09 (-0.18)	0.03 (0.06)	1.55*** (3.92)	1.40*** (3.26)	-0.05 (-0.16)	-0.03 (-0.07)
Exchange and wage labour	-0.34 (-0.75)	-0.18 (-0.39)	1.23*** (3.18)	1.05*** (2.82)	0.44 (1.52)	0.38 (1.32)
Informal credit (no interest)	-0.65 (-1.38)	-0.79* (-1.65)	-0.09 (-0.28)	0.13 (0.40)	-0.04 (-0.15)	0.03 (0.10)
Informal credit (interest)	-0.18 (-0.46)	-0.32 (-0.78)	-0.76*** (-2.58)	-0.55* (-1.74)	0.00 (0.01)	0.08 (0.25)
Property rights strength	0.31*** (3.77)	0.27*** (3.09)	-0.08 (-1.13)	-0.04 (-0.48)	0.351*** (5.31)	0.33*** (4.14)
Restrictions per right	0.12 (0.28)	0.20 (0.48)	0.456* (1.79)	0.39 (1.46)	1.11*** (3.75)	1.19*** (3.93)
Proportion sold		0.74 (1.40)		-0.76 (-1.56)		0.03 (0.07)
Annual income		-0.00 (-0.53)		0.00*** (5.25)		0.00** (1.96)
Age		0.00 (0.11)		0.01 (1.27)		-0.00 (-0.19)
College		-0.49 (-0.91)		-0.46 (-1.26)		0.29 (0.94)
Constant	-2.49 (-3.75)	-2.55 (-2.84)				

Notes: Base model (N=523; Households=269); Extended model (N=507; Households=259)
Source: Survey data (2000, 2001) by the author.

Overall, the scalar measures suggest a reasonably good fit for the models. With regard to the estimated significance and the degree of coefficients, general similarities between the base- and extended-model estimations are seen. Some of the traditional institutional factors are found to have significant positive impacts especially on maintenance and technique adoption activities, but not on construction activities. Apart from these factors, *annual income* is found to be significant with positive effects in some of the estimations.

For 'construction activities', in both the base- and extended-model estimations, *property rights strength* is found to be statistically significant at the 1% level, having positive effects. This indicates that a strong level of restrictions that leads to the absence of rights does not encourage construction activities. None of the traditional institutional factors is found to be significant, apart from access to *informal credit without interest* exerting negative effects, although it is found to be significant only at the 10% level. This is a reasonable finding since these activities typically require heavy inputs and long-term perspectives in realizing benefits. Thus the decisions over such long-term investment activities are expected to be affected by individual/field-level factors, rather than customary rules and institutions.

Table 4.2. *Selected estimation results in standardized coefficients and factor change in odds*

	Maintenance		Technique adoption	
	Base model	Extended model	Base model	Extended model
	Estimates (absolute z-value) ; significant at 0.01***; 0.05**; 0.1*			
	(a) (b)	(a) (b)	(a) (b)	(a) (b)
Traditional authority	0.92 0.96	0.92 0.96	1.52* 1.22*	1.50 1.22
Exchange labour only	4.73*** 2.07***	4.06*** 1.93***	0.95 0.98	0.98 0.99
Exchange and wage labour	3.44*** 1.79***	2.87*** 1.65***	1.55 1.23	1.46 1.20
Informal credit (no interest)	0.92 0.97	1.13 1.05	0.96 0.99	1.03 1.01
Informal credit (interest)	0.47*** 0.74***	0.58* 0.81*	1.00 1.00	1.09 1.03
Property rights strength	0.93 0.82	0.96 0.91	1.42*** 2.48***	1.39*** 2.35***
Restrictions per right	1.58 1.27	1.48 1.22	3.02*** 1.78***	3.30*** 1.86***

Notes: N=791; Household=412
(a) Factor change in odds [exp(β)]for a unit change; (b) Factor change in odds [exp(β)]for a standard deviation change

With regard to 'maintenance activities,' some of the traditional institutional factors are found to be significant, consistent with our *a priori* expectations. Amongst the customary institutional factors that are considered, access to exchange-labour systems, both *exchange labour only* and *exchange and wage labour* are found to be particularly significant at the 1% level with positive effects. This suggests that those with an access to reciprocal exchange-labour arrangements are more likely to make maintenance activities. The results particularly indicate a strong impact of *exchange labour only*; having a unit higher access to the exchange-labour system increases the odds of observing extra maintenance activities by a factor of 4.1-4.7. On the other hand, *informal credit with interest* is found to be significant with negative effects at the 1% level in the base-model estimation, although the significance is dropped to the 10% level in the extended-model estimations. While *restrictions on property rights* is found to be significant at the 10% level with positive effects in the base model, the same significance is not found in the extended model; this suggests that the finding is not robust. In the extended model, *net annual income* is found to exert positive effects at the 1% level of significance.

Regarding 'sustainability-enhancing technique adoption', *restrictions on property rights* is found to be statistically significant at the 1% level with positive effects in both the base and extended models. The magnitudes of effects are the highest among those estimated coefficients. On the other hand, *property rights strength* is also found to be significant with positive effects in both estimations. As in the case of 'construction activities', having stronger rights seems to induce these activities, i.e., too much restriction is not desirable. *Traditional authority* is found to be significant with positive effects, although only at the 10% level, in the base-model estimation. Like in the case of 'maintenance activities', *net annual income* is found to have positive effects with the significance level of 5%. Other household characteristics, such as *age*, are not found to be significant. These findings suggest that traditional institutions, especially in terms of moderate restrictions put on property rights, encourage sustainability-enhancing technique adoptions/activities that are integrated in daily cultivation practices and are often productivity enhancing.

CONCLUSIONS

We have investigated whether traditional/indigenous informal institutions function to encourage sustainable management of resource bases, as a part of coping strategies. Such traditional institutions, although sometimes considered to hinder people's incentives, may enhance the sustainable livelihood of people living in a fragile environment. Unlike previous studies, which focused on the effects of formal institutions, we have directly focused on the effects of traditional institutions. In particular, we have examined how traditional authorities, reciprocal exchange labour systems, informal credit access and restrictions over exercise of property rights affect the sustainability-enhancing activities of the farmers. Despite the seemingly changing significance of traditional institutions, as suggested by less use of labour exchange, increasing resource conflicts regarding water and land that are not being resolved by the traditional authorities, and increased reliance on formal judicial systems, we have found significant effects of traditional institutional factors, especially on maintenance activities. Although the existence of traditional authority per se was not found to be particularly significant, the exchange-labour system was found to have significant positive effects on the exercise of maintenance deeds. In addition, restrictions on property rights were found to have positive and significant effects on the adoption of sustainability-enhancing techniques, although too much restriction may exert opposite effects. The analysis suggests that embedded customs are likely to encourage the sustainable livelihood of these upland communities. This seems to support the previous findings that formal institutions are not necessarily a solution to better management of natural resources.

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NOTES

[1] The term indigenous cultural communities (ICCs), as it is used in the Philippines, refers to communities and social groups that have a cultural and social identity distinct from the dominant Filipino society. They are regarded as homogenous societies – though this is not necessarily true. They generally have strong communal bonds and distinct cultural traits, being historically differentiated from the majority of Filipinos (Asian Development Bank 1995, 59-60).

[2] Although no data are available for the region alone, the Philippine forest cover decreased at a rate of over 2% annually, during the period 1950-1990. The region nevertheless still contains a higher proportion of forest cover than other regions, estimated to be 672,320 ha (data source: DENR 2003), although it is only 45% of the 'classified' forestland of 1,487,073 ha.

[3] Not only loss of forest cover but also mine development, where production was estimated at 10.8 million tons in 1987, can cause serious damage to land and water resources if it is not managed properly (Department of Environment and Natural Resources 1987, p. 28).

[4] A community generally refers to a *barangay*, the smallest administrative unit in the Philippines, but it sometimes refers to several neighbouring *barangays* and/or smaller units, *sitios*.

[5] Especially Bayyo of Bontoc, Mountain Province still upholds the customary law effectively. Such a case was also observed in Batad of Banaue, Ifugao, and to a more limited extent in Fidelisan of Sagada, Mt. Province, although both sets of data had to be discarded due to data collection problems. On the other hand, Maligcong of Bontoc, Mt. Province, whose data also had to be discarded, seemed to experience the demise of the traditional system, perhaps due to their community being increasing 'touristicized' (field observation 2000, 2001).

[6] It is known as the Cariño Doctrine; this 'time immemorial' presumption results from the decision made in the U.S. Supreme Court in 1909 over the land disputes between the indigenous Cariño family and the colonial government.

[7] It is known as the Cariño Doctrine; this 'time immemorial' presumption results from the decision made in the U.S. Supreme Court in 1909 over the land disputes between the indigenous Cariño family and the colonial government.

[8] Here our review refers mostly to the major customary laws of Ibaloy and Bontoc communities, where extensive reports are available (for further detail, see Prill-Brett 1992). They can be considered to be more or less representative cases of indigenous customary laws. For a summary of property rights types and governing rules in the Cordilleran communities, see, for instance, Prill-Bret (1989; 1993) and Rood (1989).

[9] For fuller details, see Prill-Bret (1987).

[10] Note that the included variables are not the whole representation of 'traditional institutions'. For instance, the practice of a 'redistributive feast' given by wealthy families, which is considered to represent a traditional value, as stressed by Lewis (1989), is not considered here.

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CHAPTER 9

FARMERS INVESTING IN SUSTAINABLE LAND USE AT A TROPICAL FOREST FRINGE, THE PHILIPPINES

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Abstract. A transition from slash-and-burn farming to sustainable land use is essential for the prevention of poverty and the conservation of the rainforest in the Philippine uplands. The key of this transition is that farmers invest in the quality of their land, e.g., through terracing, contour bunding, irrigation facilities, agroforestry or tree plantation. In their turn, these investments depend on a variety of factors, such as the households' socioeconomic and agro-ecological conditions.

This chapter presents an econometric analysis of the determinants of households' investments in land quality in the Philippines. A logit model of investments is formulated using the information generated from an in-depth household survey of 104 households randomly selected in four upland villages located in Luzon, Philippines at varying distance to the major markets of metropolis Manila.

The findings show that older household heads have a higher probability of investing in land quality improvement. This is due to 'lifecycle effects' on the part of the farmers since they accumulate capital and knowledge as they grow older. Household heads with more knowledge of soil and water conservation techniques, and households with additional, non-farming income are also more likely to invest in land improvements. Significant influence is also observed of village-level characteristics. Contrary to (neo-) Boserupian theory, population density did not appear to have an influence.

Traditional upland policies tend to see farmers as destructive agents that must be forced towards sustainable agriculture – usually without much success. As suggested by the research results, many opportunities exist for policies that rather aim to reinforce and spread the positive actions that farmers are already carrying out spontaneously.
Keywords. agricultural transition; agricultural intensification; Malthus; Boserup; Von Thünen; soil and water conservation; sustainable land use; rainforest; slash-and-burn agriculture; uplands; the Philippines

INTRODUCTION

Tropical forest degradation is commonly blamed on the slash-and-burn practices of upland farmers who are often portrayed as resource-poor households, unable to undertake soil-conserving investments and driven only by short-term survival

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perspectives. Likewise, with low educational levels, these households are branded to be largely ignorant of soil and water conservation techniques, which exacerbates the risk of soil degradation. This long-standing view of Philippine upland farmers, popularly known as *kaingineros*, has led to flawed designs of projects addressing the degradation problems, e.g., confronting farmers with pre-formatted farming-system designs that they are unwilling to adopt, often for good reasons. For instance, farmers in upland development programs in the Philippines have a low adoption rate for contour hedgerows despite the technical and financial support being offered during project implementation – see the description of Balete, below, as an example.

An alternative way of looking that recently emerged recognizes that partially or fully, some farmers do already transform their cultivation practices to more intensive and sustainable land-use systems. For example, they may convert part of their agricultural lands to irrigated rice terracing, organic and contour farming, agroforestry or tree farming. Policies then should aim to reinforce and spread these practices. Such scenarios make use of the phenomenon often called *agricultural transition*, which is the process of agricultural change from one form of land-use system to another that is more environmentally sustainable. While some farmers may go through this process early and consistently, other farmers may not be motivated yet or too poor to carry out the necessary investments. A better understanding of agricultural transition in the uplands will give policy makers and development managers an information tool to bring more farmers and more land into the transition process, e.g., by way of economic carrots and sticks, or by strengthening the farmers' individual or collective capacities to implement the actions, or by reinforcing the cultural notions that farmers have of what it is to be a good farmer.

CONCEPTUAL FRAMEWORK

The question of what compels households to shift from extensive land-use systems (such as slash-and-burn) to intensive and more sustainable land-use systems is linked to a number of basic perspectives on land-use change. Some consider population as the force that drives the transition process while others point at the market as the force necessary to motivate and capacitate farmers to make investments in sustainable land use.

The population paradigm consists of a pessimistic neo-Malthusian variant and more optimistic (neo-)Boserupian variants. From the Malthusian perspective, natural-resource degradation is inevitable because of increasing population. A finite earth can only support a limited number of people. This proposition puts the blame for the environmental disaster that is currently happening on growing population, such that population must be controlled for a sustainable management of natural resources. This theory disregards technological advances which, if within reach of people, shift threshold levels and allow for an increase in food production. For the Philippine uplands, this perspective focuses the policy maker on the curtailing of in-migration and the removal of existing migrants back to the lowlands, combined with the notion that better technologies will have to be forced upon those who remain.

The optimistic view on the effect of population on land-use change is inspired by the seminal work of Esther Boserup (1965). She points out that facing land shortages, farmers will be inclined to invest in intensification even though on the long run, this will tend to result in lower returns to labour. This process may in extreme cases ('involution', see Geertz (1963) and also Netting (1993)) lead to very high (and often sustainable) returns to land combined with very low returns to labour, with farmers escaping from extreme poverty only through seasonal migration, remittances or other non-farm income.

Other population-centred authors whom we will call neo-Boserupians here, assert that in fortunate circumstances of soils and markets, the intensification may in fact lead to higher returns to labour. The description of Tiffen et al. (1994) of the 'miracle of Machakos' (Kenya) is a case in point, showing that an increase in population density, coupled as it was with reduced transaction cost, influx of new ideas and more available labour, motivated as well as enabled people to innovate and find a higher level of productivity in agriculture that is now terraced and irrigated. Conelly (1992) reports on a similar case in the Philippines, where irrigated rice and hillside fruit trees now provide higher incomes to more people than the original short-fallow swiddens. The neo-Boserupian vision posits population growth as the prime cause neither of Malthusian disaster nor of slow Boserupian income decline in spite of sustainable intensification, but of sustainability and prosperity.

As put forward by De Groot (1999), cognitive and economic factors will co-determine which pathway will be taken by farmers or regions. When extensive farming methods lose their economic attractiveness under conditions of rising population density, some farmers may be aware early enough and have enough capacity to invest in the land and follow a neo-Boserupian road towards a new and sustainable system. Other farmers, however, may postpone the transition and enter a period of 'soil mining', e.g., because investments in soil and water conservation are less attractive than other options on the short term (Pender et al. 2004). These farmers may become motivated only at a time when they have no more capacity left. They are then caught in a Malthusian poverty trap. Research of Murton (1999) has shown that even in the neo-Boserupian miracle region of Machakos, many farmers individually have gone the Malthusian way, ending up, for instance, as labourers making terraces on the very land that more successful, neo-Boserupian neighbours have bought from them. (Note that, with Platteau (2000), private land titles as prevalent in Machakos pave the way for this process of efficiency at the cost of equity.)

Writing on Uganda, Pender et al. (2004) show that many agricultural development pathways are market- rather than population-driven. Out of the group of more market-oriented and exogenous perspectives on agricultural transition we may take the neo-Thünian theory as explicated by De Groot (2006). In this perspective, large urban centres function as 'point markets' with areas around them of (going from the city outward) intensive agriculture, extensive agriculture and extraction of natural products. These zones are circular in a theoretically 'smooth' landscape and may be highly fragmented in practice. Growing 'point markets', however, always result in expansion of these zones and farmers residing in a zone where only extensive agriculture was economically feasible before, may one day find that the economic 'intensification frontier' has passed their area, along with the associated feeder roads, farm-gate prices, extension, credit facilities, tenure security and so on. Thus the farmer will be inclined to switch to the now more attractive intensive options. Note that in this mechanism, local population density does not play any role.

As stressed by Pender (1998), Lipton (1989) and Netting (1993), the population- and market-based perspectives should not be applied as if mutually exclusive. The three population-based views differ only gradually, and the results of external market expansion intermingle freely with the effects of endogenous population growth. Each region will display its own mixture of mechanisms, and explanations, rather than work from one point of view, should focus on how this intermingling goes about and which of the mechanisms dominates – see for instance Zaal and Oostendorp (2002) discussing the case of Machakos in the light of both the population- and the market-driven points of view. Answers to these questions may also shift over time; a neo-Boserupian 'up' may be followed by a steady Boserupian decline, for instance, when the innovation potential cannot outstrip population growth any more.

Against this background, this chapter focuses on the key element of agricultural transition: investment in the quality of the land (IQL), specified as terracing, contour bunding, constructing irrigation facilities and agroforestry and tree planting. We take explanatory factors from both the market and population perspectives into account. The study sites are chosen from a basically Thünian perspective with varying distance from Manila, but local population densities are noted as well.

METHODOLOGY AND DESCRIPTION OF STUDY SITES

The data used in this chapter are mainly generated from a survey of 104 farmers living in four villages described below. The villages were selected on the basis of having a significant presence of investments in the land and being positioned along a long gradient of distance to the markets of the Manila metropolitan area. This distance varied between 1 and 13 hours drive. Care was taken, moreover, to avoid correlation of distance to Manila and local population density, so as to be able to distinguish between the market and population effects in the later analysis. Although each village is not saliently different from others in its region, regional representativeness has not been a criterion, and consequently we will not make any claims on the regional level.

Figure 1 shows the location of the research sites. There were 26 household respondents randomly selected for each village. Systematic random sampling was done using a list of households kept by the *barangay* (village) secretaries. Additional lists of households were also drawn, which served as possible replacements of the initial lists of sample households if, for any reason, they would be unable or would refuse to be interviewed.

Kapatalan (population density 235 people per km^2) is the most accessible among the *barangays* (villages), connected as it is to Manila by a two-hour drive. Almost 90 percent of the *barangay* area has slopes of 18 percent and above, located in the

Sierra Madre Mountains with elevations ranging from 300 to 450 m asl. From the time of settlement in the late 1950s, coconut and citrus have been the major agroforestry tree species grown in the village. Under the coconut trees are papaya and root crops, namely *gabi, taro* and ginger. An Integrated Social Forestry Project was carried out in the village from 1988 onwards.

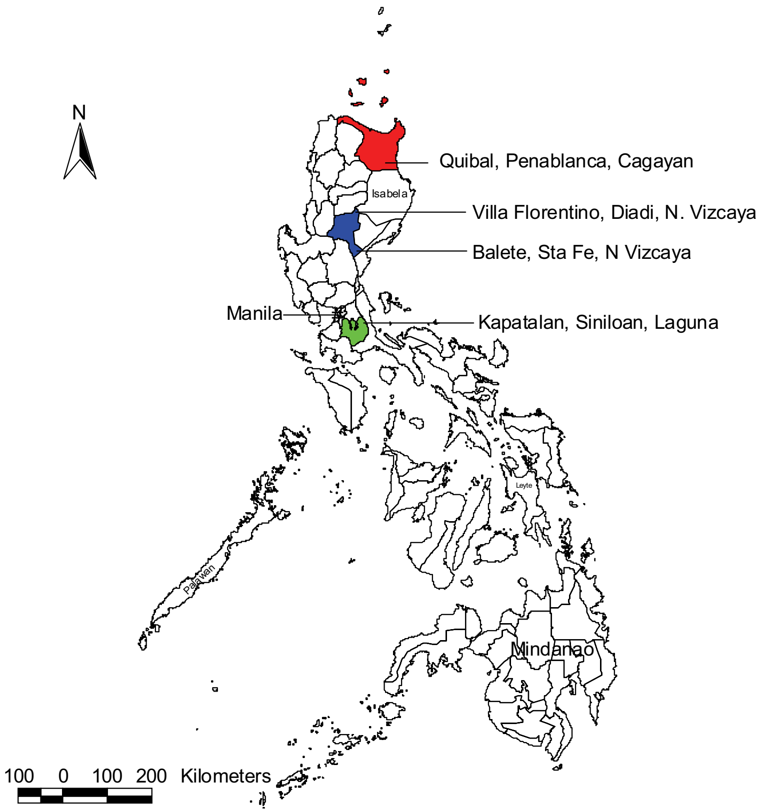

Figure 1. *Location of the study sites*

Balete (population density 13 people per km^2) is a recently settled village where most of the households produce various kinds of vegetables, such as tomato, *baguio* beans, celery, carrots and string beans. For growing these vegetable crops, contour bunds are constructed by the farmers (to be remade every year), deviating from the hedgerow technology promoted by the Integrated Social Forestry Project that entered the village and declared it a model site in 1988. Most of the households are located about one to three kilometres away from the national highway that reaches Manila in some 4 hours. The highway can only be reached over a footbridge during the rainy season and the roads crisscrossing the village become difficult to pass during that time.

At Villa Florentino (population density 235 people per km^2 and at 9 hours from Manila), the first wave of Ifugao migrants settled in 1973 followed by Igorot migrants the following year. It was claimed by key informants that Ifugaos occupied the valley areas where they easily tapped water in creeks and later constructed rice terraces. The Igorots occupied the higher-elevation parts of the village planting maize, upland rice and vegetable crops. During heavy rainfall, Villa Florentino is not accessible by any motor vehicle. Unlike in the other villages, there is only a minimal presence of the government in Villa Florentino; no project was ever carried out. Only the local government unit (LGU) of Diadi has constant interaction with the village officials.

Quibal (population density 93 people per km^2) is located about 15 km from the urban market centre of Tuguegarao City, Cagayan, and some 13 hours from Manila. Large portions of Quibal lie within a declared Protected Area Landscape of the DENR (Department of the Environment and Natural Resources). The Itawes are the major ethnic group of households in the village who came from neighbouring villages and other municipalities of Cagayan province. Maize is the major crop grown in the village. Yellow maize varieties are sold in the market while the native varieties are planted for local consumption. Stimulated by a Community Forestry project that started in 1992, boundary planting of forest (Gmelina) and fruit (mango) trees species is the most common type of agroforestry adopted by the households. Fuelwood gathering provides a significant source of income.

THE MAJOR INVESTMENTS IN THE QUALITY OF THE LAND (IQL)

Table 1 presents the main characteristics of the major investments in land quality: terracing, contour bunds, irrigation facilities and tree planting. They are briefly described here in preparation for the regression analysis.

Terraces are established through the transformation of sloping lands into productive areas where lowland rice and vegetables can grow. Considering the availability of abundant water supply, the decision to terrace rests solely on the household as a unit since it requires high capital and labour use, both family and non-family, to construct a productive unit. This may be the main reason why, in the villages studied, only 28 plots out of 235 were terraced. The average area terraced is also low at about 0.40 ha for all households that made terraces. Labour required per hectare for terracing is the highest among the major investments, standing at about 875 man-days on the average and ranging from about 64 man-days per hectare in Quibal to as high as 1300 man-days in Villa Florentino. These variations reflect the material used in terracing as well as the slopes of the land. This trend is similar in terms of cost (1998 prices, hired plus family labour) showing an average of Php 77,905 per hectare for all villages. Although costly, rice terraces allow two times harvesting of lowland rice ensuring food consumption of the households as well as cash if surplus production is realized.

There were 46 plots out of 235 in the villages studied that were developed with contour bunds. The average productive area was about 0.49 ha while the total labour required per hectare of productive area was about 86 man-days, to be repeated every season because the bunds were only temporary constructions. The total cost per hectare (1998 prices, hired plus family labour) was about Php 8,190 per year. Vegetables, considered to be high-valued crops, were grown in these areas, usually at two croppings per year. The revenue generated from vegetable production was usually high enough to support more than the basic needs of the household.

Table 1. *The major investments in land quality adopted by households in Philippine villages (barangays)*

INVESTMENTS IN LAND QUALITY	MEAN VALUES
1. Terracing	
Length, metres	404
Height, metres	0.90
Area, hectares	0.40
Labour required per hectare, man-days	668
Total cost per hectare, Php	77,905
No. of plots with terraces	28
2. Contour bunds	
Area, ha	0.49
Total labour required per hectare, man-days	78
Total cost per hectare, Php	8,190
No. of plots with contour bunds	46
3. Irrigation	
3.1. Channel irrigation	
Channel length, meter	368
Average labour required, man-day	32
Total cost of channel per metre, Php	28
No. of channels	26
3.2. Sprinkler irrigation	
Sprinkler length, metre	751
Average labour required, man-day	4
Total cost of sprinkler per meter, Php	11
No. of sprinklers	47
4. Major tree plantation (≥0.25 ha)	
Area, ha	1.26
Average labour required per hectare, man-days	27
Total cost per hectare, Php	2,300
No. of plots with trees	88

The sprinkler irrigation system was only practiced in Balete and Villa Florentino with an average length of 751 m of piping and an average total cost per metre of Php 11.

Irrigation facilities are constructed in support of agricultural production in both rice terraces and contour bunds. Two types of irrigation facilities are used: the channel system and the sprinkler system. The channel system is mostly used for lowland rice cultivation while the sprinkler system is used in vegetable gardening. Households also used the sprinkler system for domestic or household purposes by detaching the sprinklers from the pipes. The average total length of channel constructed was about 368 m although values varied much from as low as 60 m in Quibal to as high as 461 m in Villa Florentino. The average total cost per metre of channel irrigation investment is about Php 28.

Major tree planting activities were undertaken on 88 out of the 235 plots for all the villages with an average total area of 1.26 ha per household. In this study, 'major tree planting' means that the area planted with trees is greater than or equal to 0.25 hectare per plot. Households usually termed these as their agroforestry and tree farms, which required an average total labour of 24 man-days per hectare. This value is much lower than the other major investments.

The average number of household members that were capable to work in the farm was about 3.52. This number was derived from the number of household members with ages ranging from 15 years up to 64 years. If working household members were going to school, then they were set to contribute only about 30 percent of the total labour of 312 days per year. From this calculus, the total number of working days per year in a household was 766 man-days. One hectare of terracing, requiring 668 man-days, then is equivalent to about 87 percent of the average household total working days. If labour for rice cultivation is added, the total labour required is more than the average household's total. Because of this, a household has an option of hiring outside labour or spreading out over several periods the establishment of the terraces. Making a one-hectare plot with contour bunds in two cropping seasons per year requires on average about 20 percent of the available household labour. The construction of an irrigation channel requires only 4 percent while sprinkler irrigation needs less than one. For tree plantation, the total labour requirement per hectare is only about 4 percent of the available total household labour. Labour requirement for terracing and contour bunding increases if labour for irrigation facilities is added. Obviously then, the availability of cash is important for many investments, either to hire outside labour or to buy the equipment such as piping. Only tree planting tends to be available to all, if seedlings are provided at low cost. For that reason, off-farm income has been included in the dataset.

A CONCEPTUAL MODEL OF INVESTMENT BEHAVIOUR

The problem of investment in improving the quality of the land is analysed from the perspective of the individual household which is confronted with multiple and relatively complex choices involving both production and consumption. In production, decisions have to be made on the allocation of resources, such as land, labour and capital, the techniques used in farming, and other accessible options readily accessible to them. The outcome of the household's decisions may be realized within one growing season or may extend into the future. Households also have to consider marketing strategies which influence choices on what crops to grow, the scale of the farm enterprise and where to sell the crop produced. Consumption decisions involve food consumption of the households, shelter or housing, domestic purchases, and savings for the education of their children, among others.

For farmers in developing countries, production and consumption decisions cannot be analysed separately. This is due to the existence of market imperfections in relation to labour, credit, leisure, land resources and some basic food products. In this case, the proper framework considers the household as one that maximizes a utility function over time with respect to consumption and production, including investments in land quality and other things (education of children and new farm technology). The utility function includes as arguments all the goods that are 'consumed' by the household, such as food commodities and leisure. (In principle, the utility function may also include 'social goods' such as the well-being of others and social status.) Households also make rational decisions that are influenced not only by their needs and aspirations but also by the resources available to them as well as the constraints put on by the environment. In developing countries like the Philippines, resources include not only physical resources and cash availability (due to imperfect capital markets) but also private social capital, such as socio-political linkages to facilitate the participation of the households in government programs or in the release of personal and legal documents, personal and economic security ties with government officials and rich families, and market and information ties as regards to product prices, technology and opportunities. The physical, socio-political and economic environments provide limits on the choice options available to households.

An analysis of the households' decisions to invest in the quality of the land (IQL) therefore needs to consider the general decision-making context of the households, and may be incorrectly analysed if standard micro-economic theory based on only profit maximization is used.

In the present study, the constraints on the household are labour and cash availability, agricultural production technology, slope and soil quality of the land. The process of optimization gives the household's investment as a function of the profitability of investment (influenced by slope and soil types, technology and other factors), labour availability (due to imperfect labour market), credit or cash availability (due to imperfect capital market), knowledge (including expectations), as well as time horizon (tenure and risks) and time discount. With these variables, we analysed the household's choice between IQL and non-IQL as a function of household, farm and village characteristics using a binary model, implying a focus on the adoption of soil and water conservation rather than their intensity. This falls in line with most other studies on IQL. A model with intensity as dependent variable has been estimated too but with poor results, probably due to a low number of observations.

The model utilizes a logistic distribution that subsequently allows for the calculation of marginal effects of the explanatory variables. The logit model for IQL is specified as (Greene 2000):

$$\Pr[\,inv\,] = \frac{e^{\beta x}}{(1 + e^{\beta x})} \tag{1}$$

where $\Pr[inv]$ is the probability of a household to invest in IQL, x is a vector of explanatory variables and β is a vector of coefficients. The marginal effect of an explanatory variable x on the probability of that the household invests in IQL is a nonlinear function of x and β and is given by:

$$\frac{\partial \Pr[inv]}{\partial x} = \Lambda(\beta x)[1 - \Lambda(\beta x)]\beta \quad (2)$$

where β is the coefficient corresponding to x and

$$\Lambda(\beta' x) = \frac{e^{\beta' x}}{1 + e^{\beta' x}} \quad (3)$$

Obviously, the marginal effect will vary with x and therefore with households. An alternative is to measure the effect of the explanatory variable x by the odds ratio, which is given by:

$$odds(x) = e^{\beta} \quad (4)$$

The odds ratio can be interpreted as the odds of investing in land quality after a one-unit change in the explanatory variable as a ratio of the base odds while controlling for other factors. The odds refer to the probability of IQL over the probability of not investing in land quality. For example, if the odds ratio $e^{\beta} = 2$ on the dummy variable "with irrigation", this indicates that households using irrigation technology are twice as likely to invest in land quality as compared to households "without irrigation", the reference group. An odds ratio equal to 1 indicates that there is an equal probability that the two groups of households will invest in the quality of the land.

EXPLANATORY VARIABLES OF INVESTMENTS IN LAND QUALITY AND HYPOTHESES

The mean values of explanatory variables in this study are shown in Table 2. These are data at the household level and they are presented here to provide clear understanding of the factors that have been found in the literature to affect investment decisions of households.

The dependent variables are major investments in land quality. They are aggregated into two categories; one category combines terracing, contour bunds and irrigation facilities while the other category includes tree planting. These categories are selected considering the capital requirements (see above) and the time span of yields. Terraces, contour bunds and irrigation facilities generate immediate benefits, while trees have a much longer gestation period, running up to 5 to 7 years for fruit trees and 7 to 10 years for forest trees.

The explanatory variables are grouped into two categories: (1) household characteristics and (2) farm characteristics. The variables in each category are defined below including our hypotheses explaining their effects on the investments in the quality of the land (IQLs), the dependent variable. The regression analysis is undertaken at the household level, which takes into account the household variations of the explanatory variables. The analysis is at the household level because the investments, and especially large investments, on separate plots within household are correlated through budget and time constraints. The plot characteristics, therefore, are transformed into their arithmetic mean values within households.

The top horizontal part of Table 2 gives the distribution of the two categorized dependent variables. It shows that those households that invested in terracing, contour bunds or irrigation also invested in agroforestry or tree planting with a proportion of households of about 42 percent. The proportion of households that invested in agroforestry or tree planting and also invested in the other category is about 36 percent. This implies that many households in the four villages studied undertake both forms of IQL.

Table 2. *Means of explanatory variables of major investments in land quality for the four selected Philippine barangays (N=104)*

Explanatory variables	*Terracing, contour bunds and/or irrigation*		*Agroforestry and/or tree plantation*	
	No	Yes	No	Yes
IQL Interaction				
Investments in T, CB and IF[a]	0	1	0	0.42
Investments in TP[a]	0	0.36	0	1
Household Characteristics				
Age (Hh head)	47.10	46.85	43.47*	51.48*
Educ (Hh head), %				
Up to primary level	0.41	0.52	0.51	0.38
Intermediate level	0.36	0.25	0.27	0.38
Secondary/college level	0.23	0.23	0.22	0.24
Household (Hh) size, No.	5.50	6.18	5.86	5.62
No. of working Hh members	3.35	3.82	3.50	3.55
Proportion of Hh with off-/non-farm, self-employment income	0.66*	0.83*	0.82*	0.60*
Equiv. weekly per cap. expend., Php	191.22	154.49	169.75	187.55
Material assets	0.40	0.33	0.26	0.51
Knowledge on SWC, No.	3.19*	4.55*	3.23*	4.33*
Man-land ratio	2.83	2.80	3.12	2.42
Dependency ratio	81.31	98.47	92.15	78.08
Farm/Plot Characteristics				
Prop. of plots with secure tenure	0.61*	0.75*	0.63	0.71
Farm size, ha	4.10	4.47	3.41	5.32
Plot size, ha	1.99	2.19	0.90*	3.58*
No. of years of plot cultivation	13.77*	6.93*	13.56*	5.40*
Slope categories: Flat slopes (0-3%)	0.22*	0.04*	0.19	0.10
.Rolling/moderate (4-18%)	0.55*	0.30*	0.46	0.55
.Steep/mountainous (>18%)	0.23*	0.66*	0.35	0.35
Soil types: Clay loam	0.58	0.60	0.64	0.51
.Sandy loam	0.42	0.40	0.36	0.49
Dist. of plots from residence, m	1314*	606*	380*	1909*
Dist. of plots fr. village centre, m	2106*	1104*	1324	2240
Number of observations, N	64	40	59	45

Note: * Indicates that differences between means are significant at least at 5% level using t-test.
[a] T = terracing, CB = contour bunds, IF = irrigation facilities, AF = agroforestry, TP = tree plantation

HOUSEHOLD CHARACTERISTICS

Age and education

The variables age and education in this study consider the age and education of the household heads, who, in the Philippine paternalistic culture, make major decisions with regard to farming.

Many researchers agree that the age of the household head may have an ambiguous influence on investments in IQL. Younger generations, as compared to the older ones, may be more inclined to adopt new techniques as they learned these in school and they might have a longer time horizon. However, older people may have saved money to invest (lifecycle effect) and gained more knowledge through their actual experiences in farming; thus they become more knowledgeable in dealing with soil fertility maintenance and IQL. Furthermore, older farmers may be motivated to leave something of lasting value for their children, hence invest in long-term assets such as terraces and trees.

There are four levels of education existing in the research area that are to be taken in succession: primary level, which corresponds to the initial four years in school; intermediate level, another two years; secondary level, additional four years after intermediate level; and the college level, four or more years after secondary.

For education, Pender and Kerr (1996) observed that in their study of villages in India's semi-arid tropics, investments in soil and water conservation increased by about 25 % of the average investment level for every additional year of education.

In Table 2, household heads who invested in tree planting were significantly older (about 51 years old) compared to those who did not. The highest proportion of household heads of about 52 percent who invested in terracing, contour bunds and irrigation had low education (up to primary level). The proportion of household heads of about 38 percent who invested in agroforestry and/or tree planting had finished intermediate level of education. This inclination follows that of the households that did not invest in any of the different categories of IQL.

Household size

A measure of the household size is the number of children plus the husband and wife. We used the equivalence scale of 1.0 for household head, 0.7 for other adults and 0.5 for household members with ages less than 18 years. The Table shows that the household sizes of those who terraced, made contour bunds and irrigation facilities were larger than those who did not. Of those who invested in tree planting, the household size was lower than of those who did not. The differences are statistically insignificant, however.

Number of working household members

This variable reflects the amount of labour that households have at their own disposal, which is measured as the number of household members whose ages range from 15 to 64 years including husband and wife. This households' own labour capacity is expected to have a positive effects on IQL, especially the labour-intensive types such as terracing. *Ceteris paribus,* we hypothesize that larger households are more capable of undertaking this type of IQL (Clay et al. 1998). In Table 2, the numbers of working household members are indeed slightly higher for this category of IQL, but the difference is not significant.

Income from off-farm agricultural and non-farm employment and self-employment

This variable, measured as a dummy (equal to 1 if at least one member of the household is significantly engaged in off-farm, non-farm and self-employment, and 0 if otherwise), may have an ambiguous role in IQL. On the one hand, greater alternative income opportunities provide more cash available to households for IQL (Reardon and Vosti 1995). On the other hand, a negative correlation may also show up, reflecting competition of labour between farm cultivation and off-farm activities or a better income in off-farm opportunities, which may provide a signal to shift household interests away from farming activities. In some ways, labour and financial capital utilized for off-farm activities may also reduce pressure on the land since this provides money to buy food. By this manner, it may encourage households to undertake less erosive cultivation practices, such as planting trees and allowing lands to fallow. In a previous Philippine research by Delos Angeles (1986), she observed a negative relationship between conservation adoption among upland farmers and their level of non-farm income. She concluded that farmers without off-farm income had more incentives to maintain land resources.

As shown in Table 2, a higher proportion of those households that had off-farm agricultural and non-farm income and self-employment invested in terraces, contour bunds and irrigation. A different scenario is visible in tree planting because the proportion of households with off-farm, non-farm and self-employment is lower than the proportion of those that did not.

Equivalent per-capita cash expenditure (weekly) and material assets

This variable is determined by initially summing up the cash expenses incurred per household in clothing, school fees and food (rice, maize, salt, coffee, sugar etc.). Expenses in clothing and school fees are usually made annually but were calculated on a weekly basis, consistent with the reported weekly food expenses. The values of equivalent per-capita expenditure are then estimated using the FAO standard weight equivalents of equal to 1 for household head, 0.7 for household members with ages equal to or greater than 18 years, and equal to 0.5 for other members of the household with ages less than 18 years. Material assets are those acquired by the households, such as a car, motorcycle, tricycle and refrigerator, but it was treated as a dummy variable: 1 for those who have at least one of these items and 0 otherwise. There is no clear hypothesis about the effect of per-capita cash expenditure and material wealth on IQL. Households with high per-capita cash expenditure may have higher cash availability which is favourable to farm investments because they can hire labour and buy inputs for land improvements. But the availability of cash may shift the interests of households towards non-farm activities (such as establishing small business or *sari-sari* store, tricycling and peddling) thus lowering IQL. Hence, households with more wealth have greater capacity to do IQL but possibly less motivation. This relationship may also hold true for material assets. In the regression analysis, the material-assets variable is the only variable that is considered. A problem of causality exists in the per-capita expenditure and material-asset variables. While more wealth enhances the capacity of households to invest, maybe IQL also leads to higher income and material assets.

Table 2 shows that the average weekly equivalent per-capita expenditure of households that invested in terracing, contour bunds and irrigation facilities were lower than of those households that did not. This was the opposite in agroforestry or tree planting; the households that did invest had a higher equivalent per-capita expenditure than those that did not. The differences are, however, insignificant. Table 2 also shows that the proportion of wealthy households investing in terraces, contour bunds and irrigation is lower than the proportion of those that did not. The opposite situation is observed in agroforestry and tree planting with a higher proportion of wealthy households investing in this category. The differences between those that did invest and those that did not are insignificant in all categories of investments.

Knowledge of conservation techniques

This was measured as the number of conservation techniques reported to be known by the household heads, such as contour ploughing, cover crops, hedgerows, agroforestry, reforestation, green and animal manuring, sprinkler and channel irrigation and contour bunds. Our hypothesis is that more knowledge on soil and water conservation techniques may have a positive influence on farmers' investment decisions. In their study of Ethiopian villages, Shiferaw and Holden (1996) found a positive correlation between adoption of level bunds and the number of conservation techniques known.

Table 2 shows that the number of SWC technologies known to the household heads was significantly higher in households with terracing, contour bunds and irrigation investments. The differences between those households that did invest in agroforestry and tree planting and those that did not were insignificant although the number of SWC technologies known to the households that invested was higher.

Man–land ratio

This variable is derived by dividing the household size by the total farm size owned for each household. It is considered to be a measure of the number of people per cultivable area and therefore land scarcity. According to (neo-)Boserupian theory, the man–land ratio will be positively correlated with IQL. As shown in Table 2, however, households investing in land quality (all categories) had a lower man–land ratio, indicating an opposite relationship. The difference was statistically insignificant.

Dependency ratio

The dependency ratio is the number of economically inactive members of the household, i.e., the number of children with ages 0 to 14 years and elderly with ages 65 and above, relative to the total number of working household members. This variable was expected to have a negative relationship with investments since a significant number of children and elderly within a household can siphon off labour and money that may be intended for IQL.

As shown in Table 2, the values of the dependency ratio for all IQL categories and chemical inputs had insignificant differences. The trend of the values, however, shows that the dependency ratio was higher in households that invested in terracing, contour bunds and/or irrigation but lower values in those that invested in agroforestry and/or tree planting compared to those that did not.

FARM CHARACTERISTICS

Security of tenure

This variable is the proportion of plots owned by the farmers with secure tenure such as private title documents or the tenure instrument called "Certificate of Stewardship Contract' (CSC). It is often expected that farmers make longer-term land improvements on landholdings that are owned (Clay and Reardon 1997; Shively 1996). The hypothesis then is that IQL correlates positively with the proportion of plots with secure tenure. In other instances, however, farmers' investments on their plots serve as proofs of good behaviour, helping to obtain *de facto* if not *de jure* land rights on these plots. In these cases, the direction of causality between IQL and tenure is reversed. Moreover as stressed by Platteau (2000, p. 139), informal tenure arrangements may in fact be felt by farmers as just as secure as formal titles or certificates. In such cases, correlations are expected to be insignificant (except, as Platteau notes, if credit is conditional for investments, if farmers are wiling to take loans, and if formal tenure gives access to credit).

Table 2 shows a higher proportion of plots with secure tenure in both categories of the major investments. However, a significant difference was observed only for investments in terracing, contour bunds and irrigation.

Plot and total farm sizes

These variables reflect the amount of households' landholdings that could serve as collaterals in market transactions as well as an input to agricultural production. We hypothesized that farmers with larger plot and farm sizes are more capable of undertaking investments because they can spare land areas for terraces and irrigation channels, for fallow, and for trees while putting larger portions of their lands under cultivation. A household study of Semgalawe (1998) in rural Tanzania revealed a positive effect of farm size on the probability of adoption of improved soil conservation techniques. This relationship is further confirmed by studies in the Philippines by Shively (1996) on the probability of hedgerows adoption and in other countries by Feder and O'Mara (1981), Just and Zilberman (1983), Pender and Kerr (1996) and Shiferaw and Holden (1996).

As Table 2 shows, the values of the plot size and farm size exhibited similar trends in relation to the dependent variables. Both had higher values in all categories of investments. This means that households with large areas had a stronger tendency to invest in land quality. Insignificant differences for the variable farm size, however, was observed in any of the major investments while a significant difference was observed on the plot size variable for the investments in agroforestry and tree planting.

Number of years of plot under cultivation

This variable is the number of years the plots had been continuously cultivated by the farmers until the time of investments in land quality. Our hypothesis regarding this variable was ambiguous. Long cultivation results in declining yields so that an investment in the quality of the land would sustain its productivity, thereby increasing the benefits from the investment, which might encourage farmers to invest. On the other hand, a declining yield due to low soil fertility resulting from long-term cultivation will cause a declining capability of the households to invest thereby leading them into the Malthusian 'poverty cycle'. In conditions of low fertility, plots require increasing labour from the households, which may not be compensating because production output from the plot is not proportionately increasing or even to attain, at least, the current level of production. In Rwanda, Clay et al. (1998) observed that farmers have more investments in land conservation and soil fertility in plots cultivated only a short period.

In terms of the number of years of continuous cultivation, higher values are observed for those households that did not invest in any category of land quality. The differences are also significant.

Plot slopes, soil types and distances

Plot slopes were defined in three categories, namely flat slopes (0-3 %), rolling/moderately sloping (4-17 %) and steep slopes (≥18 %) while the soil types were defined in two categories, namely clay loam and sandy loam. These variables were transformed into household-level data by getting the average of the plots within a household. We hypothesized that steeper slopes increase the incentive to invest in land protection particularly in areas where rainfall is relatively high. In the Philippines, cultivation on lands with slopes higher than 18% is prohibited and instead farmers are encouraged to reserve these areas for trees.

In Table 2, a higher proportion of plots with steep slopes appear to have been selected for terracing, contour bunds and irrigation while investments in agroforestry and tree planting had a higher proportion of plots in the rolling to moderately sloping plots. However, significant differences were observed only for the investments in terracing, contour bunds and irrigation. In terms of soil types, the proportion of plots with clay loam soil types was higher in both categories of IQL.

Households perceived that these soil types have lower fertility caused by continuous cultivation. Table 2 shows, however, that soil types do not differ significantly in any category of IQL.

As plot distances from home increase, farmers have less incentive to make land improvements due to higher transaction costs. An opposite relationship, however, is expected for agroforestry or tree farming because of their low maintenance requirements.

Distances of plots from residence and from barangay centre have similar trends in terms of their relationships to investments. Investments in terracing, contour bunds and/or irrigation facilities have shorter distances to home than investments in agroforestry and/or tree plantation. Significant differences in distances to plots from residence in any categories of IQL are observed. For plot distances from the village centre, significant difference is only observed in terracing, contour bunds and tree planting.

The pairwise correlation for the explanatory variables, however, showed that the dependency ratio was strongly correlated with age (correlation coefficient –0.59), size of plots was strongly correlated with total size of plots (correlation 0.73), distance to home was strongly correlated with distance to village centre (correlation 0.57), number of working household members was strongly correlated with household equivalent size (correlation 0.72) and the village dummy for Kapatalan was strongly correlated with the wealth dummy and distance to home (correlation 0.62). Multicollinearity of the variables suggests that the value of the coefficient of one variable in the regression analysis will affect the value of the coefficient of the other variable for which it is found to be collinear.

Thus, dependency ratio, size of plots, distance to village centre and number of working household members were dropped in the regression analysis. The village dummy of Kapatalan and wealth dummy variables were retained, however, because of their relevance to determining village and wealth effects, respectively. The man–land ratio and total landholdings were also retained because of their pervasiveness in literatures concerning soil and water conservation adoption and the fact that the multicollinearity coefficient was only just below 0.5. All other variables had correlations below 0.5 in absolute value with others.

DEFINITION OF THE REGRESSION VARIABLE

Table 3 presents the summary statistics of the variables selected for the regression model. For reasons explained earlier, regression analyses were done separately for the combined investments (IQL) in terraces, contour bunds and irrigation facilities and the combined investments (IQL) in agroforestry and tree planting.

The variable *age* refers to the age of the household heads, who are either males or (sometimes) widowed females, at the time of the survey. The average age of household heads for this study was about 47 years with the youngest of 24 years while the oldest was 81 years old. *Education* indicates the level of education completed by the household heads. The omitted education category is the category variable, *up to primary*. The *household size* variable is transformed into the equivalent household size. The average equivalent household size was about 4. *Man–land ratio* is the ratio of the (real) household size over the total landholdings of the households. This ratio had a mean value of about 3 and a maximum of about 12 people per hectare. The dummy variable *off-farm and non-farm employment and self-employment* equals one if at least one household member brings in some income from a non-farming source. About 76 percent of the households enjoyed this extra income. *Knowledge of SWC techniques* is a measure of the number of soil and water conservation techniques known by the household heads. The average was about 4 while the maximum is 10. Some household heads have no knowledge of SWC technologies at all. The variable *security of tenure* equals 1 if a household has at least one plot with secure tenure, and is zero otherwise. About 65 percent of the households in this study had at least one plot with secure tenure. *Material asset* is a dummy variable equal to 1 if the household owns at least one of such items as cars, motorcycles and household facilities, and zero otherwise. Due to measurement problems and endogeneity, this variable is not considered in the initial analysis but it is used later to test its effect on the other variables. On average, about 41 percent of the households owned at least one item.

Table 3. *Descriptive statistics of model variables*

Variable	No. of observants	Mean	Standard deviation	Mini-mum	Maxi-mum
Investment in land quality					
Investment in T, CB and/or IF[a]	95	0.36	0.48	0	1
Investment in AF and/or TP[a]	95	0.42	0.50	0	1
Household characteristics					
Age	95	47.01	12.05	24	81
Education: Up to primary level	95	0.45	0.50	0	1
.Intermediate level	95	0.33	0.48	0	1
.Secondary level	95	0.22	0.42	0	1
Equivalent household size	95	3.90	1.49	1	8
Man-land ratio	95	2.91	3.97	0.31	12
Prop. of Hh[a] with off-/non-farm, self-employment income	95	0.76	0.43	0	1
Knowledge of SWC tech.	95	3.68	2.41	0	10
Security of tenure	95	0.65	0.49	0	1
With material asset	95	0.41	0.49	0	1
Farm characteristics	95				
Total landholdings, ha	95	4.28	3.54	0.06	16.5
No. of years of cont. cult.	95	6.12	11.66	0	43
Distance to home, m	95	1064	2188	1	10000
Slope types: Flat (0-3%)	95	0.19	0.39	0	1
.Rolling/sloping (4-17%)	95	0.49	0.50	0	1
.Steep/mountain. (≥18%)	95	0.32	0.47	0	1
Soil types: Clay loam	95	0.57	0.50	0	1
.Sandy loam	95	0.43	0.50	0	1
Village dummies: Balete	95	0.20	0.39	0	1
.Kapatalan	95	0.27	0.45	0	1
.Quibal	95	0.27	0.45	0	1
.Villa Florentino	95	0.26	0.44	0	1

[a] T = terracing, CB = contour bunds, IF = irrigation facilities, AF = agroforestry, TP = tree plantation; Hh = households

For farm characteristics, *total landholding* is, in hectares, the total area of lands occupied by each household. On average, households owned 4.28 hectares. *Years of continuous cultivation* variable is the number of years the plots were continuously cultivated by the households before investments were made (if any). The average number was about 6 years, with some households making the investments immediately after settling. The *distance to home* (m) is the distance of plots to the household farmstead. The slope and soil types are presented as dummy variables. The slope variables *Flat slopes, Rolling slopes* and *Steep slopes* are defined above. The steep-slopes variable is the omitted variable for the slope dummies. For soil types, *Clay loam* and *sandy loam* indicate the share of plots within households that have clay loam or sandy loam soil types. Sandy loam is the omitted variable. Table 3 shows that the proportion of plots with rolling to moderate slopes was about 49 percent, with steep slopes about 32 percent. The average proportion of plots with clay loam soil types was about 57 percent and about 43 percent had sandy loam. *Village dummies* are also included in the regression analysis to control for other village differences, such as: cultural differences, distance to major urban markets, and climate. Villa Florentino is the omitted village dummy in the model.

REGRESSION RESULTS AND DISCUSSION

Table 4 presents the results of two logit regressions for the four Philippine villages. The first regression considers the combined investment in the quality of the land (IQL) through terracing (T), contour bunds (CB) and irrigation facilities (IF). The second regression considers the combined IQL of agroforestry (AF) and tree plantation (TP).

Generally, there were more parameters on the household variables than on the farm characteristics that were significantly different from zero at a 90- or 95-percent level of confidence. Likewise, the village dummies with Villa Florentino, as the omitted variable or the basis for comparison between the villages covered in the study, show significant differences from each other with regard to IQL.

Household characteristics

The regression results show that the age of the households was positively correlated in both categories of IQL with significant relationships. This indicates that the older the household heads, the higher the probability that they invested in the various IQL. The odds ratios (i.e., the ratio of the probability of investing to the probability of non-investing) of 1.06 on the age variable for the combined IQL in terraces, contour bunds and irrigation facilities implies that the odds of investing in IQL is 1.06 times with each additional year of age of the household head. Since the regression analyses considered age of the household heads at the time of the survey, this indicated positive ‘life-cycle effects’ on IQL. This relationship did not change if the age variables were redefined as age of the household head at the time of investment.

Household heads who finished the intermediate levels invested significantly more likely in agroforestry and/or tree planting than those with lower or no education or those with secondary and/or college education. The weak and negative effects of higher levels of education on IQL may be due to the loss of interest in sustainable farming by those household heads that attained high education. With high education, these household heads may have engaged in wage labour or in other livelihood enterprises apart from farming. Household heads with low or no education, on the other hand, invested more likely in terracing, contour bunds and/or irrigation facilities and less likely in agroforestry and/or tree plantation. This may reflect the preference of these households to make investments in land quality that generates short-term benefits.

The household size variable had a positive relationship in the regression for both IQL categories. This relationship was, however, insignificant, indicating that labour availability in the households has no effect on investment. This may be due to the existence of a good labour market in the study villages, so that working household members can easily find jobs apart from their own farm.

Households with off-farm, non-farm and self-employment incomes were much more likely to invest in IQL. This relationship was particularly strong for combined IQL in terracing, contour bunds and/or irrigation facilities. The significant regression results show that the odds ratio of IQL for households with incomes other than farming their own land was about 7 times higher than for those households without other income for terracing, contour bunds and/or irrigation. Reardon and Vosti (1995) and Clay et al. (1998) had similar results in their studies of African farmers concluding that off-farm income or non-cropping income provides the necessary capital for investments in land improvements. This result also shows the imperfection of credit markets in the villages because credit for IQL would lift the cash constraint on IQL.

The numbers of SWC techniques known to household heads were positively correlated with IQL in all categories. This means that households who had more knowledge of SWC techniques were more inclined to do IQL, which confirms the hypothesis. This result may indicate the positive role of extension programs on IQL that increase the level of information of households concerning sustainable farming systems that addresses their household needs while maintaining land quality. But the possibility of reversed causality may occur in the households; i.e., households that started investing may also learn while doing or want to learn more SWC technologies afterwards.

Households invested more likely in IQL when they had secure tenure as shown by the positive regression results. The regression coefficient though, is insignificant. As said, the possible explanation for the insignificant results may be the fact that investments facilitate the households for the acquisition of land rights. Conelly (1992) similarly observed that investments help farmers acquire rights to the lands they occupied as *de facto* land rights. Farmers in a Palawan village in the Philippines were given full ownership of the lands they occupied because of their ‘good behaviour’, which implied the practice of agroforestry or establishment of tree farms on their lands.

For the man–land ratio variable, households were likely to invest slightly more in terracing, contour bunds and irrigation and slightly less in tree planting. These relations are insignificant, however. This represents a contradiction with population-based perspectives on investments in land quality.

The material assets variable is a proxy for wealth. The regression results for IQL since settlement show that wealthy households were less likely to invest in terracing, contour bunds and irrigation facilities and more likely to invest in tree planting. This relationship is, however, weak. Although various researches in some areas (Clay et al. 1998; Shively 1996) found that wealthy households are capable of having their lands under fallow, and also that they are not compelled to undertake investments to meet their daily needs for food and cash. The insignificant effect plus the endogeneity problem of the material-assets variable with IQL makes the result difficult to interpret.

Farm characteristics

The farm-characteristic variable that is statistically significant at the 99-percent level was the number of years of continuous plot cultivation in the regression for investments in agroforestry and/or tree plantation. The number of years of continuous plot cultivation had a negative relationship with IQL, which indicates that households are less likely to undertake investments after longer periods of cultivation. It was only insignificant (but negative) for investment at settlement in terracing, contour bunds and irrigation. Baland and Platteau (1996) theoretically described a scenario of farmers' rationality in which it is optimal for a farmer to extract soil nutrients till a certain level because they are concerned in meeting their subsistence requirement in each period.

This holds intuitive appeal: that households postpone or withhold investments on plots with remaining productive potential. The results of the regression suggest, however, that the longer the plot is cultivated, the less households are likely to invest. Because we did not have a given exogenous measure of fertility at the time of investment, we used the period of cultivation till investment as a proxy; this proxy might be too primitive. This proxy, however might be endogenous as it is defined in terms of the investment made leading to a negative correlation between investment and the variable period of cultivation till investment.

The contradictory and insignificant regression coefficients for the variable total landholdings[1] indicate the ambiguous effects of this variable on investments. De la Brière (1999) and Clay et al. (1998), in their studies of farmers in Dominican Republic and Rwanda, respectively, found out that farmers with large landholdings invested less in soil conservation. They attributed this to labour constraints to undertake conservation investments. Large farmers could allow plots to lie fallow such that they were less pressured to undertake conservation investments, while households with smaller landholdings were more likely to undertake IQL because they might have recognized that IQL was vital to their livelihoods. In contrast, Feder

Table 4. *The β-coefficients, odds ratios and probability values for the various investments in land quality*[a]

	Investments in T, CB, and/or IF			Investments in AF and/or TP		
	β	*Odds ratio*	*Prob. value*	*β*	*Odds ratio*	*Prob. value*
Household (Hh) characteristics:						
Age	**0.06***	**1.06**	*0.07*	**0.09***	**1.10**	*0.04*
Education: (with up to primary level as basis for comparison)						
Intermediate level	-0.52	0.60	*0.53*	**2.92***	**18.59**	*0.02*
Secondary/College level	-0.88	0.41	*0.31*	0.59	1.80	*0.63*
Household size	0.15	1.16	*0.51*	0.03	1.03	*0.95*
Off/non-farm and self-employment	**1.95***	**6.99**	*0.02*	-1.51	0.22	*0.12*
Knowledge of SWC techniques	**0.36***	**1.43**	*0.07*	0.20	1.23	*0.37*
Security of tenure	0.39	1.48	*0.61*	0.08	1.08	*0.93*
Man–land ratio	0.05	1.05	*0.72*	-0.32	0.73	*0.17*
With material asset	-1.34	0.26	*0.30*	2.55	12.83	*0.15*
Farm characteristics:						
Total landholdings	0.10	1.11	*0.43*	-0.12	0.89	*0.46*
Ave. dist. to home	0.0001	1.00	*0.64*	0.005	1.00	*0.38*
Years of cont. cultivation	-0.01	1.00	*0.30*	**-0.18****	**0.83**	*0.01*
Slope:(with steep slopes as basis for comparison)						
Flat (0-3%)	-1.93	0.14	*0.18*	0.61	1.84	*0.73*
Rolling (4-8%)	-1.52	0.22	*0.11*	1.15	3.15	*0.27*
Soil types: (with sandy loam as basis for comparison)						
Clay loam	0.25	1.28	*0.73*	-0.06	0.94	*0.94*
Village characteristics						
Village effect: (with Villa Florentino as basis for comparison)						
Balete	**2.15***	8.57	*0.07*	0.68	1.98	*0.54*
Kapatalan	-1.31	0.27	*0.44*	**3.80***	**44.87**	*0.09*
Quibal[b]	-2.06	0.13	*0.24*	**-3.19***	**0.04**	*0.07*
Pseudo R^2	*46.94*			*60.48*		
Number of observations	*95*			*95*		

Note: [a]T, CB, IF means that households invest in either terraces (T), contour bunds (CB) or irrigation facilities (IF); AF, TG means that households invest in either agroforestry (AF) or tree growing (TG).
[b]Missing value of the regression coefficient of this variable indicate non-variation of variable values at the household level.
* Indicates that the estimated coefficient is significantly different from zero at the 90-percent level; ** indicates significantly different from zero at the 95-percent level.

and O'Mara (1981), Fujisaka and Wollenberg (1991) and Delos Angeles (1986) found out that farmers with large landholdings were more likely to adopt soil conservation.

The insignificant positive relationship between investments and distance of plots to the farmstead as shown in the regressions indicates that other local spatial factors may have influenced the investment decisions of households, such as planting of trees on land boundaries.

Although not statistically significant, investments in land quality seem somewhat more likely in plots with steep slopes for terracing, contour bunds and/or irrigation facilities which may be due to greater relative returns to conservation investments (Adégbidi et al. 2004; Pender and Kerr 1996). Although not significant as well, investments in terracing, contour bunds and/or irrigation facilities appear slightly more likely in clay loam soil types but investments in agroforestry and/or tree plantation are less likely invest for this type of soil. This may reflect the farmers' preference of clay loam for terraces and contour bunds which they expressed during informal conversations. The relationship with slope steepness may reflect that households have knowledge of the severity of soil erosion and its effects on their livelihoods. This then would be consistent with findings of Clay et al. (1998) from Rwanda, concluding that farmers tend to make more conservation investments in lands of medium steepness.

The village level

With respect to the village dummies, the regression analysis shows clear trends for major IQLs, indicating that each village has its specific characteristics separate from the variables included in the dataset. The results show that farmers in Balete were more likely to invest than those in Vila Florentino in all the major IQL, which is particularly significant in terracing, contour bunds and/or irrigation facilities. This especially concerns contour bunds.

The results further indicate that the probability that these investments are undertaken in Balete ranges from about 2 to 9 times higher than Villa Florentino. Farmers in Kapatalan were more likely than those in Villa Florentino to invest in agroforestry and/or tree planting, which is significant, but less likely on terracing, contour bunds and/or irrigation facilities. Compared to Villa Florentino, farmers in Quibal are less likely to undertake IQL, which shows a strong negative correlation particularly in agroforestry and tree planting. As said, this holds quite apart from all other variables such as off-farm and non-farm income, knowledge of SWC, slopes etc.; the communities have their own unique character. Households in Kapatalan, for instance, are quite in favour of agroforestry or forest-related investments irrespective of other factors. Cultural aspects such as ethnicity (e.g., the Ifugao traditions of rice terracing), risk-avoidance and learning effects (e.g., doing what the neighbours do) as well as economies of scale (e.g., helping each other or a market position towards traders) may be in the background here.

INVESTMENT DECISION FACTORS: REFLECTIONS ON THE HYPOTHESIS AND CONCLUSION

The econometric analysis provides empirical evidence that households' specific variables, farm characteristics and village conditions influence households' decisions on investments in land quality. The evidence presents a set of findings that characterize the trends of investments in the quality of the land (IQL) in the study villages. These findings may conform or contrast the hypotheses which were developed from previous studies.

Older people invest more

Age of household heads significantly influenced investments in the quality of the land, with older household heads more likely to practice sustainable land-use systems than younger ones. One underlying factor may be the farmer's capacity, older household heads having accumulated more capital and more knowledge and skills during their lifetime. Concurrently, motivational factors appear to play a role, with older household heads expressing in informal conversations that they want to leave a valuable farm to the next generation.

More people, not more investment

An increase in household size and the man–land ratio did not appear to lead to more investments in the land. This is opposed to the population-based (Boserupian and neo-Boserupian) perspectives on land-use change. Also the overall population density in the village areas does not show such a relationship. This discrepancy could possibly be explained by the labour market. Chayanov (1966), for example, concluded that farm labour input depends on household composition only in cases of missing or imperfect labour markets. In such situations, an increase in the household size would stimulate investments in the quality of the land. In our study areas, however, households could easily find farm labour that could be tapped for these investments. Reversely, large households could participate in wage labour on other farms or in urban areas.

Additional income of households induces investment

Income generated from off-farm, non-farm and self-employment is utilized by the households to finance investments in the quality of the land. This is in conformity with the hypothesis that off-farm income provides the necessary capital for investments in sustainable land-use systems. Clay et al. (1998), from a study of Rwandan farmers, supports our findings, concluding that non-farm income is "an important source of own liquidity". In an economy of underdeveloped or imperfect credit markets, non-farm income is used to buy material and labour inputs needed for sustainable farming. A purely rational choice explanation is that, compared to other investment options, farming appeared to be perceived as generating the most benefits. Additionally, the image of being a well-embedded farmer rather than some footloose opportunist may have held appeal for many.

In contrast to our result, Delos Angeles (1986) and Shively (1996), who conducted separate studies of upland Filipino farmers, concluded that farmers with off-farm income had less motivation to maintain on-farm resources. Some of them started businesses that competed for capital investments and labour. No conclusion can be reached on which pattern will prevail over the Philippines as a whole but we surmise that markets and local culture play a role.

Knowledge and investments go hand in hand

Knowledge of soil conservation techniques correlates strongly with investments in the quality of the land such that households that have more knowledge gained from whatever sources have more tendencies to invest in sustainable farming. Since it is unlikely that the only causal direction is that farmers learn about the techniques by simply doing them, it appears that the diffusion of knowledge of sustainable farming practices, such as agroforestry and tree-farm establishments, building of terraces and contour bunding, that are promoted in extension programs, have contributed to farmers' adoption of investments in the quality of the land. Clay et al. (1998) observed that, in Rwanda, farmers who had more exposure to soil conservation technologies were more capable of establishing hedgerows than other farmers.

Does tenure really matter?

Households' control of land through the various forms of security of tenure existing in the Philippines did not appear to influence investments in the quality of the land significantly. In other words, neither the mechanism that tenure security invites these investments (due to the certainty to reap the future benefits) nor the reverse mechanism that tenure *in*security invites investments (because government will be less likely to evict farmers from improved land) appeared to prevail. The informal impression from the field is that tenure for all farmers is felt as secure enough to not really make a difference in decisions to invest in land quality. Although this finding falls in line with many cases discussed in Platteau (2000), the relation between tenure security and investments depends much on the institutional context of formal and informal securities and access (Platteau 2000; Lipton 1989), which may very much across locations.

The importance of physical farm characteristics

Farm and plot variables appeared to be additional but weak considerations for investments in the quality of the land. With respect to tree-based investments, households appeared to be less likely to make investments if their plots had a longer cultivation period. In other words, trees tended to appear on newly settled farms relatively fast but with a slower rate of adoption afterwards. Other relationships between investments and farm characteristics showed a certain logic but were statistically insignificant.

The village-level effects on investments in land quality: ethnicity and government

Each village could be characterized by a concentration on one major type of investments in the quality of the land. Households in Balete were mostly investing in contour bunds and irrigation facilities with little investments in tree planting and terracing. Tree planting could be observed mostly in Kapatalan but they tended to plant more fruit trees rather than the traditional coconut-based agroforestry. Although households in Quibal invested least as compared with the other barangays, they tended to plant both forest and fruit trees. Households in Villa Florentino were investing in all major investment types but more on terracing and irrigation facilities. Since trees were perceived to be an integral part of terraces, they tended to plant more trees especially in upstream watersheds to maintain continuous water supply.

Thus, investments in the quality of the land might have been influenced not only by household and farm variables but also by ethnicity, public-policy variables and other things captured in the village dummies. In terms of ethnic traditions, for instance, Ifugaos are known for their ingenuity in making rice terraces notwithstanding their knowledge of growing vegetables gained through their interactions with other people. Igorots, who migrated from the vegetable-growing province of Benguet in the Cordillera mountains, brought these knowledge and skills to their new settlements in Balete and Villa Florentino. Coconut-based agroforestry, as practiced by the Tagalogs of Kapatalan, is widely practiced throughout the Southern Tagalog region.

Even though the four villages had been selected for their relatively high level of adoption of land investment methods, it is striking that active environmental government projects were present in three of them, as described above. The other (Vila Florentino) had rejected to host an environmental project out of distrust of government intentions but both the villagers and the local government unit (LGU) were quite active to show the outside world that they were capable to invest in sustainability even without external control and support.

At the same time, it may be noted that in Balete, Vila Florentino and Kapatalan, farmers were already practising their particular forms of investment in the quality of the land before government projects arrived, and these forms of investments in the quality of the land did not change during or after project implementation, even if, as in Balete, government prescriptions were opposed to the local method of investment in land quality. It could be, therefore, that government efforts did work to sustain and enhance farmer capacities and motivations to invest even though farmers rejected that particular method.

As a policy-oriented conclusion, we may say that first of all, the image of slash-and-burn farmers as intrinsically opposed to or incapable of transition to sustainable land use is ripe to be buried forever. Even without government control and support, markets and local traditions can stimulate farmers to invest in their land.

Government interventions in the upland remain important, however. First of all for the sake of an issue not covered in the present paper, namely biodiversity conservation and protection of the forest against illegal small-scale logging. Secondly, with a view to sustainable land use, government presence (preferably in close collaboration between the line ministry DENR and the local government units) appears to be important in order to reinforce the capacity and motivation of farmers. Based on the present analysis, essential elements in such support projects appear to be the provision of knowledge and possibly of credit for households lacking off-farm income sources. This should go alongside with putting a soft but persistent pressure on farmers that focuses on the general need of transition but leaves the choices of how to arrive there to local markets and traditions.

NOTES

[1] The variable total landholding has a correlation coefficient with the man-land ratio variable of – 0.47, indicating a problem of collinearity.

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CHAPTER 10

A BARGAINING MODEL OF MIGRATION

Getting the permission of the farm household

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Abstract. This chapter models migration decisions as joint individual and family decisions and develops a model in which family members can migrate on the condition that they remit more than they would have contributed as resident household member. The upper bound on remittances is set by their own net benefits after migration. The paper uses cross-sectional data collected in 2000 from northeast Ghana to investigate the effect of farm household population, family landholding and the perceived soil quality on migration and remittance decisions of members of the farm household in Northeast Ghana. Nested logit and Tobit models estimation techniques are employed. The empirical results confirm the negative effect that per-capita farmland size has on the probability of migration. More livestock sales coincide with fewer remittances. The core factors of the theoretical model could not be confirmed, however. Land quality appears to have no effect on migration or remittances. Local employment conditions help mitigate migration, however.
Keywords. migration; remittances; soil quality; man/land ratio; bargaining.

INTRODUCTION

Many migration studies in the past have focused on individual decisions and optimized individual behavioural models. In recent years, the focus on migration decision as family decision that could stimulate or prohibit migration of some members of the household has gained much attention. For example, studies such as Burger (1994), McElroy (1985) and Stark (1991) have indicated that migration decisions are often jointly made by the potential migrant and some non-migrants (the family). According to Stark (1991), migration by one person can be due to, fully consistent with, or undertaken in pursuit of rational optimizing behaviour by another person or a group of persons such as the family. Hence, these migration studies

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involving the farm economies have included farm household characteristics like size of landholding, household size, farm assets etc., in addition to individual characteristics such as education and age as explanatory variables.

A presumption of this paper is that during the period of rapid population growth the rate of migration from the farm communities is likely to be higher due to increasing pressure of population on land resources. The paper therefore investigates the importance of the farm household population, family total landholding and how the perceived soil quality of household's farmland affects the migration and remittance decisions of members of the farm household in northeast Ghana in recent periods. A member of a farm household may migrate to another community, either to an urban town or another rural area where land is in abundance, in search of a job or to undertake other economic activities. From the new location the migrant may send remittances in order to support the farm household to meet production-consumption needs. This paper presents a theoretical model that draws on the migration-modelling approach followed by Burger (1994) and extends his theoretical analysis to include a variable to measure the soil quality, which is important for sustainable farm production as an additional factor-variable that affects the farm household's migration decision-making process. Using cross-sectional data collected in 2000 for about 170 farm households in northeast Ghana, the empirical analysis is used to investigate the effects of the farm household and individual person characteristics on migration decisions and amount remitted. The nested logit model and the Tobit model estimation techniques are used to estimate the migration and remittance models, respectively.

The rest of the paper is organized as follows: In the next section, a brief review of migration models is presented. Then, our theoretical model for the migration and remittance decisions is presented. The amount remitted is considered to be at least equal to the amount that is required to get the permission to leave from the family members and at most just enough to keep migration attractive for the migrant. Next, the data source employed for the empirical analysis is outlined, before the section for the estimation functions and results for migration and remittance is presented. The discussion of this paper ends with a concluding section.

BRIEF REVIEW OF MIGRATION MODELS: NEW ECONOMICS OF LABOUR MIGRATION

It is understood that both the causes and the consequences of migration are context-dependent (De Haan 1999). The migration of labour geographically, out of rural areas and occupationally, out of farm jobs, is one of the most pervasive features of agricultural transformations and economic growth. The approaches to rural migration studies have revolved around some key models: the classical two-sector model, the neoclassical and expected-income (Todaro) two-sector models, human-capital models and the new economics of labour migration (NELM). Detailed reviews of these models, their contributions and limitations as well as some migration studies based on these models, are available in Taylor and Martin (2001) and De Haan (1999), and this section draws much from these two papers. The section briefly describes only the NELM models, which our analysis follows.

The fundamental view of the new economics of labour migration (NELM) is presented in Stark (1991)[1]. Under NELM, migration decisions are not taken by an individual person alone but are agreed upon by larger units of related persons, typically the other household or family members. The NELM contends that people act collectively to maximize income, minimize risks and loosen constraints created by market failures: missing or incomplete capital, insurance and labour markets. Through the remittances from migrants, migration is seen as an intermediate investment that facilitates the transition from familial to commercial production by providing the rural households with capital and a means to reduce their risks.

Because skill-related attributes of individual family members influence the cost and benefits of migration for households as well as for the individual, the human-capital theory has been incorporated into NELM models. The household perspective also implies critical interactions between individual and household variables, including assets and the human capital of household members. These variables influence the marginal cost of migration for households (including the marginal effect of migration on farm production) as well as the impacts of remittances and the income insurance provided by migrants on the expected utility of the household as a whole.

Taylor and Martin (2001) list four key implications to account for why the NELM models differ sharply from the migration models: (i) contrary to both classical and neoclassical theories, the loss of labour to migration may increase production in rural economies by enabling households to overcome credit and risk constraints on production; (ii) a positive income (or expected income) differential between urban and rural areas is not a necessary condition for migration. Migration in the presence of a negative urban-rural income differential is consistent with the NELM, provided that the variance of urban incomes and/or income covariance between the two sectors is sufficiently low; (iii) the individuals who migrate are not necessarily those that a traditional human-capital model would predict: the impact of an individual's out-migration on the productivity of other family members also matters; and (iv) equal expected income gains from migration across individuals or households do not imply equal propensities to migrate, as predicted by a Todaro model, when risk and/or relative income considerations also influence migration decisions. From a migration policy point of view, the NELM shifts the focus of migration policy from intervention in rural or urban labour markets to intervention in other (most notably rural capital and risk) markets, in which an underlying motivation for migration is found.

The classical and neoclassical models treat migration as the result of an individual decision-making process, while the NELM models consider the family or household as the unit of analysis. Methodologically, the NELM approach, with its focus on risk and market imperfections, requires the use of non-recursive farm household models to analyse both the determinants and impacts of rural out-migration. The classical and neoclassical models of migration behaviour do not explain the remitting of a share of migrant earnings back to the rural place of origin.

The explanation of remittances is a cornerstone of the NELM, representing one of the most important mechanisms through which determinants and consequences of migration are linked.

The consensus in the literature about the relationship between migration and rural development remains thin. The evidence suggests that migration does not usually lead to radical transformation of rural agriculture but that it often occupies a central part in the maintenance of rural people's livelihoods (De Haan 1999). Croll and Ping (1997) note from a series of field studies centred on villages of migrant origin in China that high rates of out-migration are caused by land scarcity, rising cost of agriculture and a strong desire of villagers to leave agriculture, and these in some cases lead to shortage of labour. Bigsten (1996) argues that high wages (pull factor) are more important than land scarcity (push factor) in explaining migration decisions.

It has been noted that in the absence of complete markets in an economy, the decision to send out migrants may have significant effects on other household economic activities (Taylor et al. 2003). While migrants are away, households have less labour to allocate to local production activities. If a migrant household's marginal product on the farm is positive, crop production will fall when the household sends out a migrant(s). Taylor et al. (2003) note that the adverse effect of loss of labour may be high since migrants tend to be younger and better educated than the average rural labourer. Rozelle et al. (1999) report a significant and negative effect of loss of labour on yields, but the same authors (Taylor et al. 2003) using the household farm survey data collected by Rozelle in another paper find out that although loss of labour to migration has a negative effect on household cropping income, the overall effect of migration on crop yields is positive. The loss in yield due to the reduction in available labour may be compensated for (partially) by remittances from the migrant(s) (Taylor et al. 2003; Rozelle et al. 1999), which are used to purchase additional inputs or rent substitutes for labour in cropping.

This paper adepts the NELM approach by including negotiations to explain migration and remittance decisions of farm households, given, among others, the marginal (value) product of labour. It shows that the remaining members of the household would appreciate the departure of a worker-cum-consumer, even when no money would be remitted, if consumption per person (i.e., remaining members) is greater than marginal value product per worker (barring any adjustment made). In the light of the findings from other studies, even though loss of labour may reduce yields, if the average consumption is greater than the marginal production value of the migrant lost, then the migration is appreciated. This suggests that factors that lead to higher (lower) marginal value productivity of labour would reduce (increase) the probability of migration and set up a higher (lower) limit for remittances as compensation.

THE THEORETICAL MODEL

Labour migration decisions among adult members of a household are mostly made for economic and, in recent periods, for environmental reasons. Many migration studies in the past have focused on individual decisions and optimized individual behavioural models. In recent years, the focus on migration decision as a family decision, under the new economics of labour migration (NELM), that could stimulate or prohibit migration of some members of the household has gained much attention.

The empirical estimates obtained by McElroy (1985) involve the maximum-likelihood estimation of a trinomial probit: an individual may stay at home without a job; stay at home with a job; or leave with a job. The approach adopted by Burger (1994) accounts for remittances and does not assume that the individual may stay at home without making any contribution to family income. Burger considered three options: stay and contribute (at least do farm work); leave without remitting; leave and remit. Burger considered a bargaining (agreement) situation in which the family and the prospective migrant consider how much the migrant should remit in return for the family's consent to his departure. This paper extends Burger's theoretical analysis to include the effect of the quality of the soil, which is important for sustainable farm production, as an additional factor-variable that affects the farm household migration decision-making process. The inclusion in the migration model of a variable to account for the soil quality and not just the size of land held by a household makes the model quite different from other known models for migration studies. The model is then applied to the cross-sectional data collected from farm households in northeast Ghana. The three options considered for an individual in the present study regions include: an individual stays and contributes to farm production and income, though there is increased pressure on farmland and its quality; an individual leaves without remitting but the pressure on farmland and its quality is reduced; an individual leaves and remits, and the pressure on farmland and its quality is reduced. The theoretical migration model which is built between the farm household and the potential migrant in this paper, using farm and individual characteristics, is therefore aimed at explaining the reasons why some farm household members leave while others stay behind. It shows, for example, that the remaining members of the household would appreciate the departure of a worker-cum-consumer, even when no money would be remitted, if consumption per person (i.e., for the remaining members) is greater than marginal value product per worker (before any adjustments made).

The model assumes that a household in the rural economy faces imperfect labour and land markets, but there are perfect markets for farm products and other inputs like fertilizer. A time constraint exists that equates household leisure and labour (farm and non-farm) time to total available time. The available landholding is allocated between cultivation Θ and fallow $(1 - \Theta)$, where $0 \leq \Theta \leq 1$. The existence of market imperfections suggest that the utility and profit maximization decisions of the farm household are not determined by separate decision-making processes (non-recursive), but they are jointly determined and the optimal household production and consumption levels are determined within an integrated framework (Lopez 1986).

The ability of the farm household to maintain farm production at a sustainable level (Y_s) and therefore the soil quality (Q) is influenced by the indirect effect of the current soil quality index (Q_t) on the household's utility over time through its effect on farm output (Y). Assuming that the household decides on farm labour and purchased (external) input for farm production in order to maximize the discounted utility per member (U) dependent on its consumption per capita (C) and leisure per worker ($T - h$) in each time period t and $t+1$, the household intertemporal (discounted) utility (U) maximization function is presented as:

$$U = \max_{C_t, h_t, X_t \Theta_t} u(C_t, T - h_t) + \rho E u(C_{t+1}, T - h_{t+1}) \tag{1}$$

subject to the total aggregate consumption for the time period t and $t + 1$:

$$p_c M C_t + p_x X_t = p_f Y_t + I_{e_t} \tag{2}$$

$$p_c M C_{t+1} + p_x X_{t+1} = p_f Y_{t+1} + I_{e_{t+1}} \tag{3}$$

farm production (actual output level) for each time period:

$$Y_t = f(Q_t, N_t h_t, X_t, \Theta_t A; Z_t) \tag{4}$$

$$Y_{t+1} = f(Q_{t+1}, N_{t+1} h_{t+1}, X_{t+1}, \Theta_{t+1} A; Z_{t+1}) \tag{5}$$

and an index of soil quality:

$$Q_{t+1} = Q_t (Y_{st} / Y_t)^{\delta} \tag{6}$$

where Y_{st} is the sustainable farm production level defined as:

$$Y_{st} = g(Q_t, N_t h_t, X_t, \Theta_t A; Z_t) \tag{7}$$

The subscripts t and $t+1$ are time periods, ρ is the rate of time preference and E is the mathematical expectation operator. The symbol C is consumption of goods (food and other items) per household member (person) in each time period. p_f, p_c and p_x are output, consumption-good and purchased-input prices, respectively, while T and h are total hours and average farm labour hours provided by a family worker per day, respectively. (The non-farm labour and income have been ignored here for simplicity.) Y is (actual) farm output and X is purchased farm input (including hired labour), A is the total landholding, Θ is the proportion of land cultivated, M is the size of the farm household, N is number of family workers ($N \leq M$) and Z includes exogenous factors. Also, I_e is exogenous income such as remittances. Q represents the soil quality index[2], while Y_{st} represents the sustainable production level.

The household's total aggregate consumption in each period is made up of the value of goods (food and other items) consumed and value of inputs purchased for farm production. These are assumed as the total farm expenditure, which is financed from the total farm income made up of the values of farm output ($p_f Y$) and exogenous income (I_e). Each of the factors, included in the production functions (equations 4, 5 and 7), is important for production and has presumably a positive effect on farm output. Higher soil quality and the use of more purchased input should, in each case, give higher farm output. Also, an increase in either the number of family workers (N), average farm labour hours provided per day by a family worker, the proportion of land cultivated (Θ) or total land available to the household (A) is expected to raise farm output. But is it assumed that in the short run, actual production function is more responsive to labour increases than the sustainable production function. That is, the marginal product of labour in equation (4), f_2, is greater than the marginal product of labour in equation (7), g_2. Equation 6 gives the relationship between the next-period soil quality (Q_{t+1}), the current-period soil quality (Q_t), sustainable production level (Y_{st}) and actual production level (Y_t), such that a greater actual production above sustainable level would suggest lower soil quality for the next period. The index of the soil quality is assumed to remain the same over time if the actual farm production is at the sustainable level.

The Lagrange form for the household utility maximization is given as:

$$\begin{aligned} L = {} & u(C_t, T - h_t) + \rho E u(C_{t+1}, T - h_{t+1}) \\ & + \lambda_0 \{ p_f f(Q_t, N_t h_t, X_t, \Theta_t A; Z_t) + I_{e_t} - p_c M C_t - p_x X_t \} \\ & + \lambda_1 \{ p_f f(Q_t (g/f)^{\delta}, N_{t+1} h_{t+1}, X_{t+1}, \Theta_{t+1} A; Z_{t+1}) + I_{e_{t+1}} - p_c M C_{t+1} - p_x X_{t+1} \} \end{aligned} \tag{8}$$

The Lagrange multipliers, λ_0 and λ_1 represent the shadow values of farm income in terms of additional utility in periods t and $t+1$, respectively; f and g are the actual and sustainable production functions, respectively. Assuming an interior solution we consider only the first-order condition for farm labour hour in period t, which gives:

$$\frac{\partial L}{\partial h_t} = -u_2 + \lambda_0 N_t p_f f_2 + \lambda_1 N_t p_f f_1 Q_{t+1} \delta \left[\frac{g_2}{g} - \frac{f_2}{f} \right] = 0 \tag{9}$$

The condition states that the marginal utility of leisure u_2 should equal the (utility of the) marginal contribution to income. This latter contribution is in the form of production itself (the factor $N_t\ f_2$) and by its effect on sustainability, which comes through the change in soil quality f_1, which itself is due to the indirect effect of labour. f_2 and g_2 are marginal products of labour hour for the actual and sustainable production functions, respectively. If the relative marginal production f_2 is greater than its equivalent of sustainable production technology g_2, the sustainability effect will be negative. For later use we rearrange equation (9) as:

$$\lambda_1 N_t p_f f_1 Q_{t+1} \delta \left[\frac{g_2}{g} - \frac{f_2}{f} \right] = u_2 - \lambda_0 N_t p_f f_2 \tag{10}$$

If h_t is optimal, then it follows from equation (8) that a change in utility per member (U), dL, following the departure of a worker from the farm (i.e., $dM_t = dN_t = -1$) and who remits $dI_e = I_e^*$ is given as:

$$dL = \lambda_0 \{h_t p_f f_2 dN_t + dI_{e_t} - p_c C_t dM_t\} + \lambda_1 h_t p_f f_1 Q_{t+1} \delta \left[\frac{g_2}{g} - \frac{f_2}{f} \right] \tag{11}$$

The change in utility per member becomes positive if

$$I_e^* > p_f f_2 h_t + \frac{\lambda_1}{\lambda_0} \left\{ p_f f_1 Q_{t+1} h_t \delta \left[\frac{g_2}{g} - \frac{f_2}{f} \right] \right\} - G_t \tag{12}$$

where $G_t = p_c C_t$. That is, G_t is the aggregate value of consumption per person in period t. This is the optimal consumption level if a person stays on the farm. The change in utility per member for the remaining household members would be positive (the remaining members benefit) if the amount remitted by a migrated member is greater than the terms on the right-hand side of the inequality. There we see the marginal value product of labour ($p_f f_2$) times working time per person h_t minus consumption per person (G_t), adjusted for the effect of present production on the next-period income constraint. The higher the person's net contribution to the household income (production value minus consumption), the higher should be the compensating remittance. If the marginal labour effort led to more degradation, the compensation may be less. A person who hardly contributes but shares in the consumption, may have a negative lower bound for his remittances.

Substituting equation (10) into equation (12) gives a simplified form of equation (12) as:

$$I_e^* > \frac{u_2}{\lambda_0 N_t} h_t - G_t \tag{13}$$

It follows from equations (12) and (13) that, for $I_e^* = 0$, migration is permitted if

$$G_t > \frac{u_2}{\lambda_0 N_t} h_t \tag{14}$$

Equation (12) sets the lower bound of the amount to be remitted by a (potential) migrant. It indicates, from equation (14), that the remaining members of the household appreciate the departure of a worker-cum-consumer even when no money would be remitted ($I_e^* = 0$), if consumption per person in period t (G_t) is greater than marginal shadow income of a single adult worker. In these shadow costs the effects on future income are accounted for by virtue of equation (9). The more household members there are (greater N), the easier it is for this condition to be met.

The upper bounds for remittances from the farm family and potential migrant perspectives (derived from the potential migrant's intertemporal utility maximization problem: see Appendix 1 for derivation) are, respectively:

$$I_e^* < wh_t^u - (h_t^u - h_t^f)\left\{p_f f_2 + \frac{\lambda_1}{\lambda_0} p_f f_1 Q_{t+1} \delta \left[\frac{g_2}{g} - \frac{f_2}{f}\right]\right\} - G_t \tag{15}$$

and

$$I_e^* < wh_t^f - G_t \tag{16}$$

Equation (16) applies when we value the difference in working time before and after migration (h^u-h^f) using urban wages, rather than using the marginal farm product as in (15). The lower and upper bounds for remittances from the perspective of the farm family (equations 12 and 15 or 16) would be reduced to the derivations in Burger (1994), if the soil quality effect (i.e., the term including f_1) would not apply. The consideration of the soil quality would make a farm family and a potential migrant reach an agreement on migration that internalizes the effect of future income in the present decision. An agreement between the farm family and the potential migrant can only be reached if the upper bounds (equations 15 and 16) are above the lower bound for remittance (equation 12) that is imposed by the rural family[3]. Thus, the ranges of I_e^* that are acceptable to both the remaining farm household members and the migrant can be stated (using equations 12 and 15 and then equations 12 and 16), respectively, as:

$$p_f f_2 h_t + \frac{\lambda_1}{\lambda_0}\left\{p_f f_1 Q_{t+1} h_t \delta \left[\frac{g_2}{g} - \frac{f_2}{f}\right]\right\} - G_t$$

$$< I_e^* < wh_t^u - (h_t^u - h_t^f)\left\{p_f f_2 + \frac{\lambda_1}{\lambda_0} p_f f_1 Q_{t+1} \delta \left[\frac{g_2}{g} - \frac{f_2}{f}\right]\right\} - G_t$$

and

$$p_f f_2 h_t + \frac{\lambda_1}{\lambda_0}\left\{p_f f_1 Q_{t+1} h_t \delta \left[\frac{g_2}{g} - \frac{f_2}{f}\right]\right\} - G_t < I_e^* < wh_t^f - G_t \tag{17}$$

Equation (17) provides two influential factors: the bandwidth for testing the basis for migration and the level of the lower bound for testing the basis for remitting to the remaining household members at home. The wider the bandwidth, the greater is the probability that an individual member of the farm (if there is a suitable candidate) will migrate (Burger 1994). The bandwidth, from (17), is independent of the farm's current aggregated value of consumption per person (G_t), a characteristic of the willingness of the farm household to share whatever is on hand among members present, though changes in factors like migration that raise the level of the aggregated value of consumption per person would be appreciated. The upper bound of the bandwidth rises with higher wage levels that the person could command (say, by higher education) and by an increase in labour hours that are possible after migration. The lower bound falls when more persons are working on the farm, when less land or land of lesser quality is available or other factors diminish his marginal product. All the above reasons lead to a wider bandwidth and a greater chance of reaching a mutual agreement about leaving.

We have assumed that in the short run, actual production is greater (more responsive to labour increase) than the sustainable production level. Hence, the sustainable relative marginal product of labour per output (g_2/g) should be less than the actual relative marginal product of labour per output (f_2/f), and this would widen the bandwidth and therefore the probability of migrating, assuming that the number of labour hours provided for urban work is greater than that provided for farm work ($h_t^u > h_t^f$). Also, a greater actual production above sustainable level would suggest lower soil quality for the next period (from equation 6), meaning a wider bandwidth and therefore increase the probability to migrate.

If the level of the lower bound is expected to be high, then the amount of money that must be remitted once a person has migrated would be high. Thus, it would be expected that, among the migrants, those from farm households with larger values for the lower bound should be sending more monetary support. A higher rate of soil quality loss or poor soil quality status, for example, would mean a lower level for the lower bound and therefore the lower would be the agreed (bargained) 'price' to get a permission to migrate and, consequently, the lower would be the remittance to the farm household after migration. Thus, it would be expected that migrants from farm households experiencing poorer soil conditions are more likely to migrate, but they would typically be remitting less.

Remittances may be used, among others, to purchase fertilizer and other productive inputs for investment in farm production and for consumption purposes. Like in Burger (1994), the impact of land size [landholding (A) and allocation parameter (Θ) between the amount cultivated and fallow[4]] on the lower bound is less clear. If the farm household could find more land for farm expansion, landholding should increase the marginal product of labour, raising the lower bound and therefore the amount to be remitted. However, an increase in Θ from a fixed landholding would decrease the soil quality (weighted) for the next period (from equation 6), increase the marginal product of labour in the current period, but would leave the sustainable marginal product of labour per output (g_2/g) to be less than the actual marginal product of labour per output (f_2/f). The net effect on the lower bound and therefore the amount remitted is not very clear. The understanding could be that migrants remit less money to households that can expand the cultivated area. Household size (*M*) is expected to affect remittances positively while unearned income like transfer from other migrants to the household is likely to affect total remittances negatively, but not the probability of migrating. As the two factors, the bandwidth and the lower bound, are related, it can be deduced that between two potential migrants with the same wage, the one who was more likely to migrate (i.e., to have larger bandwidth) is also likely to remit less as the corresponding lower bound would be lower. Hence, a positive relationship would be expected between the inverse Mills ratio (which is inversely related to the probability that a person migrates) and the amount remitted to the farm household.

If the above considerations for the migration decisions apply, what can we expect to observe in reality? The households and prospective migrants that face a wide bandwidth and may agree on low levels of remittances, will indeed show migration to have taken place. In these households, the marginal labour product (MVP) has increased because of reduced labour input into farming. In households where the MVP is very high, such migration may not have occurred (unless compensated for by large remittances). Therefore, we expect to see less variability in marginal labour product than before, and the MVPs may not be such good predictors of migration. If all households had the same endowments in terms of land but different household sizes, we would expect some equilibration to occur, even to the extent that all households after migration have the same size again. At this point, the resident household with a remitting migrant is better off than a same-size household without such unearned income, and may even show higher levels of MVP due to the use of the remittances. We anticipate therefore that the explanatory power of the ex-post measured MVP is not high, even though it may determine the decision to migrate.

DATA

The farm household data examined in this section were collected in April 2000 from 30 villages; 10 villages each selected from three designated regions in northeast Ghana: Nangodi and Bawku-Garu regions in the Upper East Region and Langbensi region in the Northern Region of Ghana. A detailed description of field survey methods is available in Mensah-Bonsu (2003). After data cleaning, 166 compound households[5] out of the total 175 interviewed were included in the household-level analysis. The three rural areas have different population densities. The Nangodi area is a fastly growing and very densely populated district of Bolgatanga. The Bawku-Garu area is a slowly growing but densely populated district of Bawku-East, while the Langbensi area is part of the slowly growing and less densely populated district of East Mamprusi.

ESTIMATING MODELS AND RESULTS

Estimating models

Two models (the migration decision and remittance models) were estimated from equation (17). From the theoretical discussion of equation (17) the factors that may affect the bandwidth and therefore the probability of migration include the next period's aggregate value of consumption per person, the soil quality and the marginal value product of labour hour. It is expected that the factors that affect the marginal value product of labour like the farm size cultivated, and production knowledge (education) would also affect the probability of migration. No earning equation was estimated for the migrants, since data on migrants' earnings were not collected. This is because the pre-testing of the questionnaire indicated that it would have been very difficult to obtain any meaningful record on migrant earning levels from the resident-respondents. A functional model of a household's member migration decision (*m*) can then be expressed as:

$$m = m(\Theta A, M_{TH}, Q, f_h, Z_i) \tag{18}$$

where A (and Θ) is landholding (land allocation parameter) and M_{TH} represents the compound household size, Q is the soil quality, f_h the marginal product of farm labour during the farming season (calculated from the a translog production function estimated in Mensah-Bonsu (2003)), while Z_i includes individual and other household characteristics as well as dummy variables. The amount remitted is affected, similarly, by the factors affecting migration, though it is assumed that the relevant household size variable is the resident household size. The function (R) for the amount remitted by a migrant can be expressed as:

$$R = r(\Theta A, M_{RH}, Q, f_h, Z_i) \tag{19}$$

where M_{RH} is the resident household size and the other variables are defined as above.

The individual characteristics included the age and educational level attained by the individual household (adult) members. The farm household characteristics used included the changes in soil quality index between 1989 and 1999 (calculated from the estimates of soil quality indexes for farmland in 1989 and 1999 presented in Appendix 2) and the difference between a person's marginal value product during the whole farming season and his/her average consumption of farm crop produced, food and non-food purchased (excluding farm cost). In order to capture the effect of changes in the level of farm household's soil quality better, the estimation included only migration decisions taken in 1989 or thereafter. It was assumed that it is the change in the soil quality index (between 1989 and a current period [1999]) rather than the level which would influence migration levels in the current period (1999). This is because if the levels of soil quality were to improve between any two periods, then more people would stay at home and the migration level (probability) would be low in the current period. Members who had left the farm less than a year from the survey time were regarded as seasonal/temporary migrants and were included in the resident household. Also, only members aged 15 and up to 60 (adults) were included in the estimation. Persons who left the farm household for reasons of taking up a job or drought/famine were the only migrants included in the estimation. No restriction was placed on sex since a reasonable number of females (49.3 percent) have left the farm household for job and drought reasons, more than to be with spouses. The personal characteristics of the compound household heads were not included in the estimation as found in most studies, because in the present case all the heads of the compound households were residential and only three females (who were either widowed or single) were head. Instead, the mean values of the members' age and other household characteristics were used. The compound household size included all members (adults and children) either residential or non-residential. The mean values of variables are presented in the Tables together with the estimated results.

Estimation of the migration model

Two forms of migration regression estimations have been performed: including the soil quality variable in one and excluding it in the other. The compound household migration decision was specified as a dichotomous model and evaluated at the level of whether a member is a migrant or non-migrant. But it is important to note that the option of non-migration does not necessarily imply on-farm work. The dichotomous-choice nested logit model is therefore selected and the maximum-likelihood estimation method applied. Thus, the logit estimation of the migration decision proceeds in two steps. First, a logit for an option of off-farm work by a resident adult member is estimated and the inclusive value obtained (the estimation results is presented in Appendix 3) for each of the two forms of the migration model estimation. Then the logit for the choice between resident and migrant is estimated by including the inclusive value as an explanatory variable to account for the choices made within the non-migrants. The specification, properties of the logit model and its associate statistical distribution are well-known (Amemiya 1981; Maddala 1983). The logit maximum-likelihood estimator is consistent, even when the independent variables are not normal. In this paper, some of the variables are farm household-level variables, making such observations independent across the households but not necessarily within the households. Therefore, the assumption of independence is relaxed within the farm household and the regression estimation allowed for clustering of observations on the households. This procedure gives standard-error estimates adjusted (robust) for clustering on the household. The Wald test for significance suggests that the variables used as regressors jointly explained variation in the migration probability. The fit of the estimated models given by the pseudo R-squared is low; this is not very surprising as the maximum likelihood estimator characteristically is not chosen to maximize a fitting criterion but to maximize the joint density of the observed dependent variables (Greene 1993).

The estimated coefficients for the migration equations are omitted here but marginal effects of the regressors reported as marginal probabilities are presented in Table 1 for northeast Ghana as a whole. The Wald test conducted rejected the hypothesis that the inclusive value was not significantly different from 1, meaning nesting the logit model was important, as the parameter estimates would have been inconsistent without the inclusive value variable. Its inclusion, as has been done in the present case, therefore meant the results obtained are more efficient.

The important factors of migration are age, farm shadow wage and per-capita land held. The results obtained suggested that at younger ages an increase in age would significantly increase the probability of an individual migrating from northeast Ghana, particularly from the densely populated (Nangodi and Bawku-Garu) areas. But, old age significantly discourages migration from the study regions. The maximum effect of a person's age on the probability that he or she would undertake a migration option from northeast Ghana occurred at about 35 years for both models. Zhao (1999) using a rural household survey and including individual, household and community characteristics as explanatory variables found a similar shape for the effect of a person's age.

The estimated results of Table 1 indicated, in general, that the effect of an educational level attained on probability of migrating from the study areas was insignificant; contrary to the model assumption that a person's own educational attainment would favour the migration option. Burger (1994) found that a person's years of schooling increases his migration chance but that of the household head may or may not reduce the person's migration chance. Our results show that migration opportunities for lesser schooled household members are not much worse than for the better educated. This is related to the fairly large degree of rural-rural migration observed in Ghana (Owusu 2007).

The estimated net effect of the farm shadow wage (marginal value product of an adult farm worker) on migration probability contradicts the negative a prior expectation.

For Northeast Ghana as a whole, the net effects were significant and positive, with elasticities of 0.23 and 0.21 for the model with and without the soil quality index, respectively. The act of migration would raise the marginal value products of the remaining member and the more people migrate, *ceteris paribus*, the higher would be the marginal value products. This may explain the positive sign found in the estimated model. Other studies, such as Greenwood (1971) and Banerjee and Kanbur (1981) in India and House and Rempel (1980) in Kenya, have obtained positive effects of rural (origin) income on migration. It has generally been argued that increasing farm income increases the migration chances of a potential migrant since it increases the ability to finance the initial migration cost.

The estimation results indicate that per-capita land held had a negative and significant influence on the probability of migrating for northeast Ghana as a whole. Detailed results for the regions (not shown) give even stronger results for the densely populated (Nangodi and Bawku-Garu) areas. These findings support the theory of the effect of expansion of land cultivated on migration probability. It shows that increasing household size relative to farmland size (i.e., decreasing per-capita land held) in the future would increase the likelihood of a person migrating from such farm households and vice versa. That is, increasing population pressure on farmland enhances the migration decision of a person. Zhao (1999) also estimated a significant and negative effect for per-capita land, explaining that sinceland is a significant determinant of rural agricultural income, reduced land size tends to reduce rural income, which leads to increased motivation to migrate. Taylor et al. (2003), however, found a positive and significant relationship between per-capita land and the percentage of migrants in a farm household. In our model, a 10-percent increase in per-capita land holding decreases the migration probability by about 1.8 percent. The regional results show stronger effects in the densely populated areas.

Table 1. *Nested logit estimates of migration decision: northeast Ghana (basis is non-migration)*

Explanatory variables	Marginal probabilities: Model including ΔQ		Marginal probabilities: Model excluding ΔQ .		Mean values of regressor	Response to 10% change in regressor: Model inc ΔQ.	Response to 10% change in regressor: Model exc ΔQ.
Individual characteristics							
Age	0.028	***	0.028	***	30.37	9.61	9.61
Age^2	-0.0004	***	-0.0004	***	1079.31		
Sex	-0.020		-0.020		0.55		
School level$^+$:							
Primary	0.004		0.004		0.09		
Middle/Junior sec.	0.002		0.006		0.10		
Senior secondary^{++}	0.051		0.052		0.11		
Household characteristics							
Mean age	0.040	***	0.037	***	33.62	18.33	9.71
Mean age^2	-0.0005	***	-0.0005	***	1160.26		
Farm shadow wage (f_h)	2.99e-06		2.78e-06	**	9071.09	2.33	2.14
Farm shadow wage^2	9.66e-13		-9.37e-13		1.53e+08		
Per-capita land (A/M_{TH})	-0.031	***	-0.030	***	0.68	-1. 80	-1.74
Quality index change (ΔQ)	0.002		--		-0.65		
Inclusive value	-0.094	***	-0.096	***	0.086 & 0.096	-0.69	-0.79
Village characteristics							
Location:							
Langbensi	-0.078	***	-0.078	***			
Nangodi	-0.032	***	-0.034	***			
No of Observations	1136		1136				
Pseudo R-Sq.	0.3467		0.3391				
Log likelihood	-267.971		-271.069				
Predicted prob. of migration	0.0366		0.0373				

*** = Significant at 1%, ** = Significant at 5%, * = Significant at 10%

Note: Standard errors have been adjusted for clustering on households; $^+$The comparison school level is no education. $^{++}$Tertiary-level education dropped due to insufficient number of observations

Source: Estimated from Field Survey Data, April 2000

For northeast Ghana as a whole, the change in the soil quality between 1989 and 1999 appears not to influence the migration decision directly. Only in the Bawku-Garu area a significant negative influence was found. In this area, migration is also higher than in the other regions as shown in Table 1.

A significant effect is found for the inclusive value. The higher this value, the lower is migration. A higher value results from better opportunities for the resident household members, either on farm or off-farm. Improvements in local employment conditions affect migration through this variable.

Estimation of the remittance model

To estimate the effects of the migrant's personal characteristics and farm household characteristics on the amount remitted, we employed a Tobit model. The remittances, which were in cash and/or in kind[6], were recorded for the two periods (farming season and dry season: April 1999 – March 2000) in a two-way directional flow: migrant to compound house and the reverse. Only the remittance flow from the migrants to the farm household has been estimated and presented in this paper. As explanatory variables we used the difference between a person's marginal value product and average consumption, as dictated by the theoretical model, livestock sales, off-farm income, and other variables to reflect the situation of the resident household and that of the migrants as regressors. No earning equation has been estimated for the migrants as no information was collected on migrants' earnings, because the pre-testing of the questionnaire indicated that it would have been very difficult to obtain any meaningful record on earning levels of migrants from the respondents. A correction term for possible sample selection bias was calculated from the estimated migration equation and included as an explanatory variable. Since the migration equation estimation was restricted to persons who left the farm household for reasons of taking up jobs or drought/famine only, the error correction term (inverse Mills ratios) has been based on the probability that a person has migrated for these two reasons. Though the present study has no information on the earning levels of migrants it has been assumed that persons who have migrated for reasons of taking up a job or drought/famine are engaged in a form of employment and therefore have positive earnings. The inverse Mills ratios were calculated as the probability density divided by the cumulative distribution functions of the normal distribution from the migration model estimated for northeast Ghana.

The estimation results are presented in Table 2. Parameters are given with robust standard errors adjusted for clustering of two or more migrants in a household. The Wald test statistics indicated that the explanatory variables in the remittance equation were jointly significant at a one-percent level.

Table 2. *Tobit estimates of determinants of remittances in northeast Ghana (robust standard error estimates adjusted for clustering on households)*[7]

Regressor	Migrant's total remittance in a year: Marginal effect: Model including ΔQ	Model excluding ΔQ	Mean values of regressor	Response to 10% change of a regressor: Model incΔQ	Model excΔQ
Indiv. characteristics					
Age	10914.39	11583.79	28.92		
Age squared	-154.59	-163.76	902.86		
Sex	27613.19**	27211.46**	0.82	4.17	4.11
School level+:					
Primary	40058.62*	39588.70*	0.14	1.03	1.02
Middle/Junior sec.	36779.39*	35981.59*	0.14	0.95	0.93
Secondary	29411.45	30456.52*	0.16		0.90
Duration	5648.51	5244.23	5.16		
Duration squared	-1211.71	-1171.58	34.92		
HH characteristics					
Land-use ratio ($\Theta A/A$)	34515.58	43148.60	0.97		
Resident size (M_{RH})	563.76	600.50	14.98		
Livestock sales	-0.009*	-0.009*	428616.50	-0.71	-0.71
Off-farm income	-0.004	-0.004	1508489.00		
Diff in pers. MVP & AC	-0.010	-0.014	-112,351.30		
Quality index chg. (ΔQ)	1756.50	--	-0.58		
Inverse Mills ratio	53202.13	65750.47	0.5668 & 0.5716		
Village characteristics					
Location dummy:					
Langbensi	-59909.56	-61169.51***			
Nangodi	3431.65	21770.31			
Observation number	133	133			
Left censored	78	78			
Uncensored	55	55			
Wald chi-sq. (16)	55.95***	51.25***			
Log likelihood	-776.710	-776.382			
Pred. remit (+ values)	¢114,135	¢113,883			

*** = Significant at 1%, ** = Significant at 5%, * = Significant at 10%
Note: Marginal effects of determinants are conditional on being uncensored (Positive values)
+The comparison school level is no education. Tertiary-level education dropped due to insufficient number of observations
Source: Estimated from Field Survey Data, April 2000

While the estimated models do not contradict the theory, the estimated effects of the core variables are not significant. The factors that have significant influence on the amount of money remitted by a migrant to his/her farm household were the migrant's own personal characteristics like sex and educational level attained but not, for example, a person's net contribution to the household income. The existing conditions in the farm household (such as land-use ratio, resident size, off-farm income, quality status of their land resources) had no significant impact on the remittances, with the exception of the value of livestock sold. Male migrants remit significantly more than their female counterparts. The level of education of migrants had a significantly positive effect on the amount remitted, which suggested the importance of investment in human capital in the form of education for the farm households in the study regions. Various studies such as Rempel and Lobdell (1978) and Johnson and Whitelaw (1974) had similarly estimated a positive and significant effect of education on remittances. According to Rempel and Lobdell (1978), for some migrants, in the initial stages of urban residence, remittances represent a repayment of social debt arising from past assistance received from extended family.

The difference between the marginal value product per person during the farming season and the average consumption had a negative but insignificant effect on the amount remitted. Theory predicts that the larger the difference between the marginal value product per person and the average consumption, the larger would be the value for the lower bound for remittances and thereby for the average amount remitted. This could indicate that either the lower bound is irrelevant as migrants remit (much) more than this, or that the diversity of migrants (old and young, male and female) is beyond what the model can capture.

While the positive sign of the coefficient of the change in the soil quality index is as expected, the statistical insignificance leaves the theoretical model unconfirmed. The same holds for the effect of the inverse Mills ratio and for the effect of the proportion of land cultivated. A positive and significant effect of the size of the migrant's extended family or the number of consumers in the home area on the amount remitted has been found by Burger (1994) and Mohammad et al. (1973). The effect of farm household income from livestock sold on remittances is negative in both models. A 10-percent increase in income from livestock sold by the farm household reduces remittances by 0.71 percent. The negative effect of livestock income on remittance meant that it is possible for income from livestock sales and remittances to be substitute sources of income for the farm household. Accordingly, the farm households that sold more of their livestock asset to generate cash income received less remittance from migrated family members.

CONCLUSION

This chapter investigated the effect of farm household population, family landholding and the perceived soil quality status on migration decisions of members of the farm household in northeast Ghana. A theoretical model was derived that indicated the lower and upper bounds for remittances to make migration a win-win decision for family and migrant. Cross-section data collected in 2000 in northeast Ghana were used in the empirical analysis. The nested logit model and the Tobit model estimation techniques have been employed to estimate the migration and remittance models, respectively.

The logit model provides some evidence for significant influence on the migration probability of the age of a person, the farm shadow wage (marginal value product) and the per-capita land held by the household. The estimation results supportive of the theoretical model indicate that per-capita land held had a negative influence on the probability of migrating. The estimated effect is an elasticity of around 0.18. The implication is that increasing population pressure on farmland favours migration. The estimated net effect of the farm shadow wage (marginal value product of an adult farm worker) contradicts the negative prior expectation. For northeast Ghana in general, the net effects of farm shadow wage are significant and positive. This may indicate that the level of migration has already reached a mature stage where resident household sizes are in accordance with their natural endowment. Effects of land quality changes were only found for one of the sub-regions, the densely populated Bawku-Garu area. Higher quality reduces migration here.

The Tobit estimation results for the remittance equation indicate that the factors that have significant influence on the amount remitted are the migrant's sex and educational level attained. Apart from the value of livestock sold, no variables of the farm household had a significant effect on remittances.

This chapter concludes that increasing the farm household population relative to available land size (i.e., decreasing per-capita land held) would increase the rate of migration from the affected farming areas (in northeast Ghana). It suggests that migration is clearly a response to overpopulation. But local employment conditions are also important. More non-farm economic activities in the regions would help to reduce dependency on the land resources as well as curb migration. Otherwise no clear environmental effects on migration were found.

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NOTES

[1] Stark (1991) includes mostly reprints of some published journal articles on migration studies undertaken by Oded Stark, and with other research scientists.

[2] The soil quality index is defined as a weighted average of soil quality over both cultivated and fallow land. That is, land is assumed to be homogeneous, which implies that fallow land also improves the quality of the land that has just been used.

[3] The lower bound for remittance imposed by the family is the same for both family and migrant, but the upper bound for remittance is different from the perspectives of the family and migrant.

[4] Burger (1994) did not differentiate between landholding and amounted cultivated.

[5] A compound household includes two or more nuclear households.

[6] The monetary value of remittance in kind was either estimated with respondent or later after the survey in Cedis. The Cedi is the unit of currency used in Ghana. The average of the interbank quarterly exchange rate for the Cedi during the period April 1999 – March 2000 was about US$ 1 = 3,200 Cedis (calculated from ISSER 2002)

[7] Stata FAQ Statistics a procedure for obtaining robust standard errors for Tobit estimates using Interval Regression since Interval Regression is a generalization of Censored Regression (which is itself a generalization of Tobit). By the procedure right-censored and interval observations are both zero. Source: www.stata.com/support/faqs/stat/Tobit.html

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APPENDICES

Appendix 1. Derivation of upper bound for remittance

For the potential migrant the Lagrangian function for his intertemporal utility maximization problem is given as:

$$\begin{aligned} L &= v(C_t, T - h_t^f) + \rho E v(C_{t+1}, T - h_{t+1}^f) \\ &+ \lambda_0 \{ p_f f(Q_t, (N-1)_t h_t^* + h_t^f, X_t; Z_t) + I_{e_t} - p_c MC_t - p_x X_t \} \\ &+ \lambda_1 \{ p_f f(Q_t (g/f)^\delta, (N-1)_{t+1} h_{t+1}^* + h_{t+1}^f, X_{t+1}; Z_{t+1}) \\ &+ I_{e_{t+1}} - p_c MC_{t+1} - p_x X_{t+1} \} \end{aligned} \tag{A1}$$

The first-order condition for h_t^f, assuming an interior solution, is

$$\frac{\partial L}{\partial h_t^f} = -v_3 + \lambda_0 p_f f_2 + \lambda_1 p_f f_1 Q_{t+1} \delta \left[\frac{g_2}{g} - \frac{f_2}{f} \right] = 0 \tag{A2}$$

Rearranging equation (A2) yields,

$$\frac{v_3}{\lambda_0} = p_f f_2 + \frac{\lambda_1}{\lambda_0} p_f f_1 Q_{t+1} \delta \left[\frac{g_2}{g} - \frac{f_2}{f} \right] \tag{A3}$$

Consider that this person now works in an urban wage job, earning *w* Cedis per hour and remitting I_e^* Cedis per year and maximizing the same utility function intertemporally would imply that

$$\begin{aligned} v &= v(C_t^u, T - h_t^u) + pEv(C_{t+1}^u, T - h_{t+1}^u) \\ &+ \lambda_0 (w h_t^u - I_e^* - p_c C_t^u) + \lambda_1 (w h_{t+1}^u - I_e^* - p_c C_{t+1}^u) \end{aligned}$$

and the first-order condition becomes

$$\frac{\partial v}{\partial h_t^u} = -v_3 + \lambda_0 w = 0 \quad \text{and} \quad \frac{v_3}{\lambda_0} = w \tag{A4}$$

The urban utility would exceed the farm utility if

$v^u > v^f$ or $v^u - v^f > 0$.

To find out how this condition changes when the arguments of the utility function, consumption and leisure, change, v^u is approximated to the first condition as

$$v^u = v^f + \lambda_0 dG_t^u + v_3 d(leis)$$

where $d(leis)$ is the differential in leisure (i.e., T - h^f when at home or T - h^u when in town). The condition now becomes

$$\lambda_0 dG_t^u + v_3 d(leis) > 0 \tag{A5}$$

If dG_t^u and $d(leis)$ represent the differences in consumption value and leisure, respectively, for this person between the two situations, then

$$dG_t^u = (wh_t^u - I_e^*) - G_t \text{ and}$$

$$d(leis) = h_t^f - h_t^u$$

$$\text{where } G_t^u = p_c C_t^u$$

Substituting in equation (A5) results in:

$$\lambda_0 (wh_t^u - I_e^* - G_t) + v_3 (h_t^f - h_t^u) > 0$$

and the upper limit for remittances is

$$I_e^* < wh_t^u - G_t + \frac{v_3}{\lambda_0}(h_t^f - h_t^u) \tag{A6}$$

which from the farm perspective, substituting for v_3/λ_0 from equation (A3) means that

$$I_e^* < wh_t^u - (h_t^u - h_t^f)\left\{p_f f_2 + \frac{\lambda_1}{\lambda_0} p_f f_1 Q_{t+1} \delta\left[\frac{g_2}{g} - \frac{f_2}{f}\right]\right\} - G_t \tag{A7}$$

and from an urban perspective, using $v_3/\lambda_0 = w$ from equation (A4) means that

$$I_e^* < wh_t^f - G_t \tag{A8}$$

Appendix 2. Estimate of soil quality index for farmland

Q has been defined as the weighted average of soil quality over both cultivated and fallow land, and following a similar approach by Feder et al. (1988) an index of soil quality was estimated from some physical attributes of the soils. The estimation was done at plot level using a log-linear function as:

$$F = a_0 + a_1 \ln TC + \sum a_i Z_i$$

where F is the farmer's assessment of the quality status of the soil, TC is the number of trees and Z_i other attributes of the soil, and a_i (i = 0, 1, … n) are parameters. The other attributes used were location of plot (compound = 1, 0 otherwise), slope (flat = 1), extent of erosion (low = 1) and extent of the striga attack on plot (low = 1). The coefficients of the explanatory variables are used as weights to calculate the quality index (Ip) of a plot. That is, $Ip = a_1 \ln TC + \sum a_i Z_i$. The weighted soil quality Index (Q) of household's land is given by the sum of the weights of the plots' quality indexes using the land size as weight. The coefficients were estimated using a probit function and the results obtained for household's plot attributes in 1999 are presented in Table A1 below. A similar coefficient estimates for the household's plot attributes in 1989 are presented in Table A2.

Table A1*. Probit estimates of the soil quality of farmers' plots, 1999*

Plot attribute	Coefficient	Coefficient correlation matrix				
		Trees	Locat.	Slope	Eros	Striga
Trees number (log)	0.169***	1.000				
Location: (Comp =1)	0.113	0.449	1.000			
Slope (Flat =1)	0.164	0.172	-0.019	1.000		
Erosion: (low =1)	0.690***	-0.029	0.011	-0.190	1.000	
Striga attack (low=1)	0.955***	0.094	-0.093	-0.105	-0.058	1.000
constant	-0.867***					
Observation	684					
LR	147.19					
Pseudo R-squared	0.1735					

Significant level: * = 10% level; ** = 5% level; *** = 1% level
Source: Estimated from Field Survey Data, April 2000

Table A2. *Probit estimates of the soil quality of farmers' plots, 1989*

Plot attribute	Coefficient	Coefficient correlation matrix Trees	Locat.	Slope	Eros	Striga
Trees number (log)	0.087	1.000				
Location: (Comp =1)	0.515***	0.447	1.000			
Slope (Flat =1)	0.024	0.225	0.008	1.000		
Erosion: (low =1)	0.866***	-0.099	-0.057	-0.186	1.000	
Striga attack (low=1)	1.211***	-0.097	0.024	0.147	-0.232	1.000
constant	-0.404					
Observation	684					
LR	109.66					
Pseudo R-squared	0.3109					

Significant level: * = 10% level; ** = 5% level; *** = 1% level
Source: Estimated from Field Survey Data, April 2000

Appendix 3. Logit estimates of off-farm work participation

Table A3. *Logit estimates of off-farm work participation: northeast Ghana*

Regressor	Marginal probability Model including soil quality index variable	Model excluding soil quality index variable
Age	0.042***	0.041***
Age^2	-0.0005***	-0.0005***
Sex	-0.234***	-0.236***
School level:		
Primary	0.001	-0.004
Middle/Junior sec.	0.006	0.0123
Senior secondary	0.141*	0.142*
Tertiary	0.226	0.273**
Mean age	0.075**	0.068**
Mean age square	-0.0009**	-0.0008*
Farm shadow wage	5.23e-06	3.98e-06
Per-capita land	-0.056*	-0.049*
Quality index change	0.014*	--
Observation	1010	
Pseudo R-sqared	0.1105	
Log likelihood	-621.608	

*** = Significant at 1%, ** = Significant at 5%, * = Significant at 10%
Note: Standard errors have been adjusted for clustering on households
[+]The comparison school level is no education.
Source: Estimated from Field Survey Data, April 2000

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