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Poverty, development, and environment

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ABSTRACT. This paper examines the complex relationship that exists between poverty and natural resource degradation in developing countries. The rural poor are often concentrated in fragile, or less favorable, environmental areas. Consequently, their livelihoods can be intimately dependent on natural resource use and ecosystem services. The relationship between poverty and natural resource degradation may depend on a complex range of choices and tradeoffs available to the poor, which in the absence of capital, labor, and land markets, is affected by their access to outside employment and any natural resource endowments. The paper develops a poverty–environment model to characterize some of these linkages, and concludes by discussing policy implications and avenues for further research.

1. Introduction

Most developing economies, and certainly the majority of the populations living within them, depend directly on natural resources. For many of these economies, primary product exports account for the vast majority of their export earnings, and one or two primary commodities make up the bulk of exports (Barbier, 2005, chapter 1). Agricultural value added accounts for an average of 40 per cent of GDP, and nearly 80 per cent of the labor force is engaged in agricultural or resource-based activities (World Bank, 2008b). Further adding to these disparities, by 2025, the rural population of the developing world will have increased to almost 3.2 billion, placing increasing pressure on a declining resource base (Population Division of the United Nations Secretariat, 2008).

Many rural people in developing countries rely directly on natural resources and the environment for agriculture, livestock husbandry, fishing, basic materials, and fuel – to meet their own subsistence requirements and to sell in markets for cash income. The lack of clean water, sanitation, and other infrastructure services suggests that increased public provision of such basic services is highly valued by many households. Rapid land-use change has meant that many natural environments and

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habitats are disappearing quickly, with the result that critical ecological services are being disrupted or lost (Millennium Ecosystem Assessment, 2005). The demise of key ecosystems of the developing world include mangroves (35 per cent either lost or degraded), coral reefs (30 per cent), and tropical forests (30 per cent) (FAO, 2001, 2003; Valiela *et al.*, 2001; Millennium Ecosystem Assessment, 2005; UNEP, 2006).

Given the resource-dependence of rural populations in developing countries, and given that many natural environments and habitats are declining in these countries, it is tempting to conclude that poverty is a major cause of environmental degradation in poorer economies. However, current evidence suggests that such a conclusion may be too simplistic. This paper will shed some light on the more complex relationship between poverty and natural resource degradation in developing countries.

For example, section 2 discusses the tendency of the rural poor to be concentrated in fragile, or less favorable, environmental areas. As section 3 indicates, one consequence is that the livelihoods of the poor are intimately dependent on natural resource use and ecosystem services. But simply because many of the poor people in developing regions are located in fragile environments, and frequently use surrounding natural resources, it is erroneous to assume that they cause much of the environmental degradation that occurs in developing countries. A review of the evidence of various studies of natural resource use by households shows that the relationship between poverty and natural resource degradation may depend on a complex range of choices and tradeoffs available to the poor, which in turn are affected by their access to key markets (e.g., for land, labor, credit as well as goods and services) as well as the quality and state of the surrounding environment. The main features of this more complex relationship are illustrated in a simple poverty–environment trap model. The paper concludes by discussing the policy challenge arising from this key aspect of poverty, development, and environment.

2. The poor and less favored areas

The continuing concentration of the rural poor in the less favored areas of developing regions has roots in the long-run trends of postwar global economic development (Barbier, 2010). This is clearly a phenomenon with a long history. Since 1950, the estimated population in developing economies on 'fragile lands' has doubled (World Bank, 2003, ch. 4). These fragile environments are prone to land degradation, and consist of upland areas, forest systems and drylands that suffer from low agricultural productivity, and which according to the World Bank are 'areas that present significant constraints for intensive agriculture' (World Bank, 2003, p. 59). Today, nearly 1.3 billion people – almost a fifth of the world's population – live in such areas in developing regions (see table 1a). The populations living in fragile environments and on marginal lands in developing countries include 518 million living in arid regions with no access to irrigation systems, 430 million on soils unsuitable for agriculture, 216 million on land with steep slopes and more than 130 million in fragile forest systems.

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Almost half of the people living in these fragile environments (631 million) consist of the rural poor, who throughout the developing world outnumber the poor living on favored lands by 2 to 1 (see table 1b).

Figure 1 further illustrates that rural poverty is correlated with the fraction of the population in developing countries found on fragile lands. As the figure indicates, for a sample of 76 developing economies from Africa, Asia, and Latin America, the incidence of rural poverty rises as developing countries have more of their populations concentrated on fragile lands. Although the average poverty rate across all economies is 45.8 per cent, the rate falls to 36.8 per cent for those countries with less than 20 per cent of their population in fragile environments. For those with more than 50 per cent of their populations in marginal areas, however, the incidence of rural poverty rises to 53 per cent or more.

The tendency for the rural poor to be clustered in the most marginal environments is also supported by studies at the regional and country level, although important differences exist within and between countries. For example, researchers from the World Bank have examined the 'poverty-environment nexus' in three of the poorest countries in Southeast Asia – Cambodia, Laos, and Vietnam (Minot and Baulch, 2002; Dasgupta *et al.*, 2005). In Cambodia, the core poor in rural areas appear to be located in areas that are already heavily deforested; on the other hand, poor populations tend to be more concentrated in the lowlands rather than steeply sloped lands. In Laos, the poorest provinces in the north and northeast also have the highest incidence of poor rural populations. These individuals are located mainly in forested areas and the highlands. In Vietnam, large poor populations confined to steep slopes exist in the provinces comprising the Northern and Central Highlands, but extensive rural poverty is also found along the North Central Coast and the Red River Delta.

Developing economies with high concentrations of their populations on fragile lands not only display high rates of rural poverty but also are some of the poorest countries in the world today. As indicated in figure 2, for a sample of 90 low and middle income economies from Africa, Asia, and Latin America, real GDP per capita declines sharply with the share of the population in fragile environments. For all economies, the average GDP per capita is $1,566, but for those economies with less than 20 per cent of their populations on fragile lands, real GDP per capita more than doubles to $3,326. In contrast, for those economies with 50 per cent or more of the population in fragile lands, GDP per capita is only $822 and for those economies with 70 per cent or more of the population in marginal rural environments, real GDP per capita is $671. According to the World Bank (2008b), the low-income, or poorest, economies of the world are those in which 2006 Gross National Income per capita was $905 or less.

The tendency of rural populations to be clustered on marginal lands and in fragile environments is likely to be a continuing problem for the foreseeable future, given current global rural population and poverty trends. First, despite rapid global urbanization, the rural population of

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Table 1. *Distribution of world's population and rural poor on fragile land*

Region	*Population in 2000 (millions)*	*Population in fragile lands*	
		Number (millions)	*Share of total (%)*
(a) Distribution of world's population			
Latin America and the Caribbean	515.3	68	13.1
Middle East and North Africa	293.0	110	37.6
Sub-Saharan Africa	658.4	258	39.3
South Asia	1,354.5	330	24.4
East Asia and Pacific	1,856.5	469	25.3
Eastern Europe and Central Asia	474.7	58	12.1
OECD Group[a]	850.4	94	11.1
Other	27.3	2	6.9
Total	6,030.1	1,389	23.0
Total Developing Economies[b]	5,179.7	1,295	25.0
Total Latin America, Africa, and Asian Developing Economies[c]	4,677.7	1,235	26.4

(b) Distribution of rural poor in developing regions

Region	*Rural poor on favored lands* (millions)	*Rural poor on fragile lands*	
		Number (millions)	*Share of total* (percent)
Central and South America	24	47	66
West Asia and North Africa	11	35	76
Sub-Saharan Africa	65	175	73
Asia	219	374	63
Total	319	631	66

Notes: In table 1(a), fragile lands are defined as areas that present significant constraints for intensive agriculture and where the people's links to the land are critical for the sustainability of communities, pastures, forests, and other natural resources; they include arid regions with no access to irrigation, areas with soils unsuitable for agriculture, land with steep slopes and fragile forest systems (see World Bank 2003). In table 1(b), fragile lands are equated with marginal lands, which are defined as areas with the greatest potential for land and water degradation; i.e., land with highly weathered soils, steep slopes, inadequate or excess rainfall, and high temperatures (see Comprehensive Assessment of Water Management in Agriculture 2007).

[a]OECD Group: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom and United States.

[b]World Total less OECD Group.

[c]World Total less OECD Group, East Europe and Central Asia and Other.

Sources: Barbier (2008). Table 1(a) is adapted from World Bank (2003, table 4.2). Table 1(b) is adapted from Comprehensive Assessment of Water Management in Agriculture (2007, table 15.1) and Scherr (1999).

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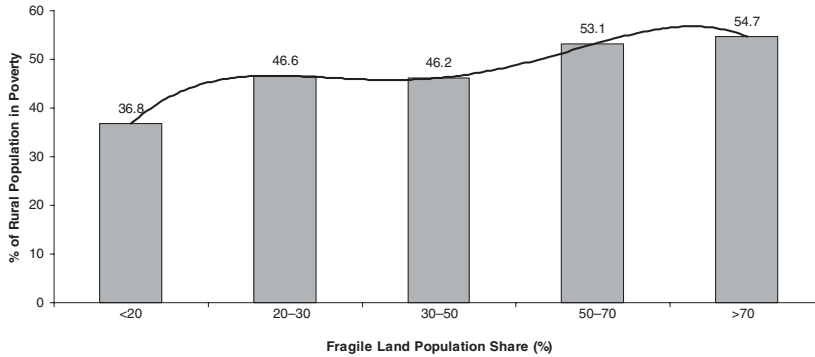


Figure 1. *The rural poor and population on fragile lands in developing economies Notes: Developing economies are all economies from East Asia and the Pacific, Latin America and the Caribbean, Middle East and North Africa, South Asia and sub-Saharan Africa with 2006 per capita income of $11,115 or less, following World Bank (2008). Percentage of rural population in poverty is from World Bank (2008b). Percentage of population on fragile land is from World Bank (2003). Number of observations = 76 countries, of which 12 (<20% of population on fragile land), 26 (20–30%), 28 (30–50%), 7 (50–70%), and 3 (>70%). The average rural poverty rate across all countries is 45.8%, and the median is 42.6%.*

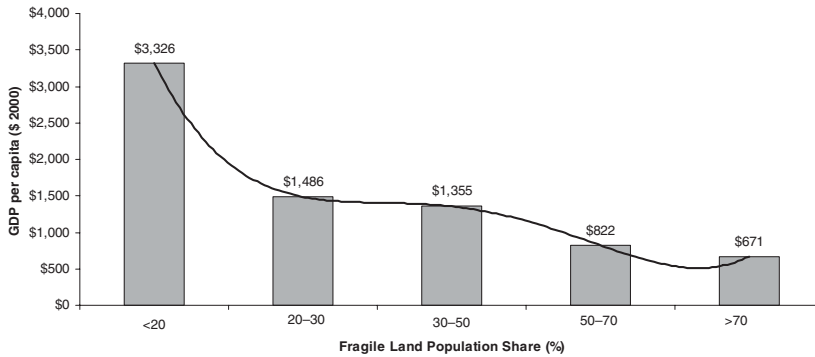


Figure 2. *Fragile land population and GDP per capita in developing economies Notes: Developing economies are all economies from East Asia and the Pacific, Latin America and the Caribbean, Middle East and North Africa, South Asia, and sub-Saharan Africa with 2006 per capita income of $11,115 or less, following World Bank (2008b). GDP per capita ($ 2000), latest year, is from World Bank (2008b). Percentage of population on fragile land is from World Bank (2003). Number of observations = 90 countries, of which 12 (<20% of population on fragile land), 27 (20–30%), 37 (30–50%), 9 (50–70%), and 5 (>70%). The average GDP per capita ($ 2000) across all countries is $1,566 and the median is $661.*

developing regions continues to grow, albeit at a slower rate in recent years. From 1950 to 1975, annual rural population growth in these regions was 1.8 per cent, and from 1975 to 2007 it was just over 1.0 per cent (Population Division of the United Nations Secretariat, 2008). Second, around three-quarters of the developing world's poor still live in rural areas, even

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allowing for the higher cost of living facing the poor in urban areas. In general, about twice as many poor people live in rural than in urban areas in the developing world (Chen and Ravallion, 2007).[1]

3. The environment and the economic livelihoods of the poor

Several economic studies have indicated the importance of various natural environments to the economic livelihood of the poor in developing countries.

For example, estimates from Thailand suggest that the net present value (in 1996 $) over 1996–2004 arising from the net income to local communities from collected forest, shellfish and other products from coastal mangroves ranges from $484 to $584 per hectare (ha). The net present value of mangroves as breeding and nursery habitat in support of off-shore artisanal fisheries ranged from $708 to $987 per ha, and the storm protection service was $8,966 to $10,821 per ha (Barbier, 2007b). Such benefits are considerable when compared to the average incomes of coastal households; a survey conducted in July 2000 of four mangrove-dependent communities in two different coastal provinces of Thailand indicates that the average household income per village ranged from $2,606 to $6,623 per annum, and the overall incidence of poverty (corresponding to an annual income of $180 or lower) in all but three villages exceeded the average incidence rate of 8 per cent found across all rural areas of Thailand (Sarntisart and Sathirathai, 2004). The authors also found that excluding the income from collecting mangrove forest products would have raised the incidence of poverty to 55.3 per cent and 48.1 per cent in two of the villages, and to 20.7 per cent and 13.64 per cent in the other two communities.

The Thailand example is not unusual; poor households across the developing world typically display considerable direct and indirect use values for mangroves (Ruitenbeek, 1994; Bandaranayake, 1998; Barbier and Strand, 1998; Naylor and Drew, 1998; Hammitt *et al.*, 2001; Othman *et al.*, 2004; Badola and Hussain, 2005; Chong, 2005; Walton *et al.*, 2006; Rönnbäck *et al.*, 2007; Walters *et al.*, 2008; Das and Vincent, 2009). However, there is also evidence that coastal people hold important nonuse values associated with mangroves. A contingent valuation study of mangrove-dependent coastal communities in Micronesia demonstrated that the communities 'place some value on the existence and ecosystem functions of mangroves over and above the value of mangroves' marketable products' (Naylor and Drew, 1998, p. 488).

Coral reefs are another critical habitat throughout the developing world that both support near-shore fisheries harvested by poor coastal communities and provide valuable shoreline protection (Moberg and Folke, 1999; Cesar, 2000; Jackson *et al.*, 2001; Moberg and Rönnbäck, 2003; Chong, 2005; Worm *et al.*, 2006). For example, Cesar (2000) estimates

[1] For example, Chen and Ravallion (2007) note that $1-a-day rural poverty rate of 30 per cent in 2002 is more than double the urban rate, and although 70 per cent of the rural population lives on less than US$2 a day, the proportion in urban areas is less than half that figure.

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the losses, in net present value per square kilometer (km^2), in terms of support for near-shore artisanal fisheries and coastal protection from the destruction of coral reefs in Indonesia. The main threats to coral reefs are from poison fishing, blast fishing, coral mining, sedimentation from logging onshore, and overfishing. Together, these threats account for present value losses in coastal fisheries of around $0.41 million per km^2 of coral reef destroyed, and present value losses in coastal protection $0.011–$0.453 million per km^2 of coral reef destroyed. Evidence from Kenya indicates that coral reefs may also be critical to larval dispersal to fishing areas, which could affect the effectiveness of marine reserves and closed fishing grounds in inducing stock recovery and thus eventual re-opening to fishing (Rodwell *et al.*, 2003). Coral reefs also have important cultural and nonuse value to neighboring coastal communities; many cultural and religious traditions have evolved in tropical coastal zones that honor the dependence of local communities on adjacent reefs and reflect the 'bequest value' of preserving this way of life into the future (Moberg and Folke, 1999).

Forested watersheds in developing regions also provide a number of hydrological services that can impact the livelihoods of the poor, such as water filtration/purification; seasonal flow regulation; erosion and sediment control; and habitat preservation (Richards, 1997; Chomitz and Kumari, 1998; Kremen *et al.*, 2000; Guo *et al.*, 2001; Pattanayak and Kramer, 2001; Chopra and Adhikari, 2004; Postel and Thompson, 2005; Silvano *et al.*, 2005; Diwakara and Chandrakanth, 2007). These services will become increasingly important as more and more river basins in developing areas experience rising water use relative to freshwater supplies (Rosegrant *et al.*, 2002). In addition, forests, especially forests of upper watersheds, provide a number of direct uses to adjacent poor communities, including timber, collected nontimber products and community forestry (Kremen *et al.*, 2000; Guo *et al.*, 2001; Pagiola *et al.*, 2005).

Some of the most important benefits of maintaining and improving land uses in upper watersheds accrue to poor communities living downstream. In the central highlands of Bolivia, for example, Richards (1997) finds that a project to improve watershed protection and reduce soil erosion on farmers' fields in the uplands yields a net present value of nearly $34.9 million, with the majority of the benefits due to flood prevention and the increased water availability due to aquifer recharge in the lower watershed. Similarly, improvements to the upper watersheds in Karnataka, India through afforestation and construction of tanks, artificial ponds, check dams, and other reclamation structures leads to significant benefits to downstream farmers through improving groundwater recharge and availability, thus reducing the cost of irrigation and the need for developing new wells or extending existing wells (Diwakara and Chandrakanth, 2007). Pattanayak and Kramer (2001) estimate that increased water flows associated with afforestation of watersheds in Eastern Indonesia yield economic values for downstream farmers equivalent to 1–10 per cent ($3.5–$35) of annual agricultural profits. However, land uses other than forests in some tropical watersheds may also yield beneficial hydrological flows; for example, Aylward and Echeverría (2001) show that

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conversion of forests to pasture for livestock in the upper watersheds of Río Chiquito, Costa Rica actually increases water flow downstream, generating net present values in the range of $250–$1,000 per ha of pasture.

In many poor countries, an economically important natural environment downstream is the seasonally inundated savanna or forested floodplains located in the lower river basins. During seasonal flood events, water often leaves the main river channel and inundates these floodplains. As the floods abate and recede, crops are planted in the naturally irrigated soils, fish are caught more easily in the retreating waters, and the increased alluvial deposits increase the biological productivity of forests, wildlife, and other harvested resources. Around half of Africa's total wetland area consists of floodplains, including huge large-scale ecosystems of several thousand square kilometers such as the Inner Niger Delta in Mali, the Okavango Delta in Botswana, the Sudd of the Upper Nile in Sudan and the Kafue Flats in Zambia (Lemley *et al.*, 2000). Millions of people across the continent depend directly on the floodplains for their economic livelihoods through production activities such as flood-recession agriculture, fishing, grazing, and wood and nonwood harvesting of riparian forest resources; and millions more in surrounding arid land depend on the groundwater recharge service of floodplains for drinking water and irrigation (Barbier, 2003). Similar benefits are found in other extremely poor countries, such as Bangladesh, where 80 per cent of the country consists of floodplains created by the confluence of the Ganges, Brahmaputra, Meghna, and other rivers (Islam and Braden, 2006). Chopra and Adhikari (2004) show how upland economic activity, such as intensified agriculture, in Northern India can affect hydrological flows into the wetlands comprising Keoladeo National Park, thus affecting the income gained by downstream villagers from tourism and extracting biomass, fodder, and other products.

Upstream dam developments are also threatening the economic livelihoods of millions of poor agricultural households dependent on the Hadejia-Jama'are floodplain in Northeast Nigeria. Full implementation of all the upstream dams and large-scale irrigation schemes is estimated to produce overall net losses in terms of agricultural, fuelwood, and fish production to these households of around US$20.2–20.9 million in net present value terms (Barbier, 2003). In addition, the reduction in mean peak flood extent is predicted to cause a one-meter fall in groundwater levels in the shallow aquifers that are recharged by the standing water in the floodplain wetlands, leading to additional annual losses of around $1.2 million in tubewell irrigated dry season agriculture and $4.76 million in domestic water consumption for rural households. Islam and Braden (2006) show that, in Bangladesh, fishing and flood-recession agriculture are important joint products to poor rural households utilizing natural floodplains, although it is largely the landless who benefit from floodplain fish production rather than agricultural landowners. As a consequence, a natural floodplain contains more land devoted to fishing rather than agriculture but actually yields higher overall net economic returns, especially compared to traditional management scenarios of upstream dam

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developments to limit flooding, increase agricultural area and expand crop production downstream.

4. The 'assetless' poor and environmental degradation

A commonly held view is that, because many of the poor people in developing regions are located in fragile environments, they must be responsible for the majority of the world's ecosystem degradation and loss – even though their livelihoods are directly affected by such environmental destruction. This perspective that poor people are mired in a two-way 'poverty-environment trap' has gained credence ever since it was asserted by the World Commission on Environment and Development (1987, p. 27) that: 'poor people are forced to overuse environmental resources to survive from day to day, and their impoverishment of their environment further impoverishes them, making their survival ever more uncertain and difficult.'

However, studies of poor households and communities suggest that their behavior with respect to the environment is more complex. The range of choices and tradeoffs available to the poor is affected by their access to key markets (e.g., for land, labor, credit as well as goods and services) as well as the quality and state of the surrounding environment on which their livelihoods depend (for reviews, see Dasgupta, 1993, 2003; Reardon and Vosti, 1995; Scherr, 2000; Pattanayak *et al.*, 2003; Barrett, 2004; Caviglia-Harris, 2004; Barbier, 2005, chapter 6; Gray and Mosley, 2005; Carter and Barrett, 2006; World Bank, 2008a). As summarized by Dasgupta (1993, p. 475), 'in rural communities of poor countries a great many markets of significance (e.g., credit, capital, and insurance) are missing, and a number of commodities of vital importance for household production (potable water, sources of fuel and fodder, and so forth) are available only at considerable time and labour cost.' In the absence of local labor markets capable of absorbing all the poor and landless households looking for work, or well-functioning rural credit markets to lend needed capital, the landless and near landless in rural communities depend critically on the use of common-property and open access resources for their income and nutritional needs. Thus, it may be the 'assetless' poor who end up most dependent on exploiting the surrounding environment and its ecological services for survival.

A survey of the extremely poor and poor households across 13 countries sheds some light on how they survive (Banerjeee and Duflo, 2007).[2] Although the survey did not include how the poor used their surrounding natural environment, it does reinforce that the poorest rural households have very few productive assets. First, land is one of the few productive

[2] The 13 countries are Côte d'Ivoire, Guatemala, India, Indonesia, Mexico, Nicaragua, Pakistan, Panama, Papua New Guinea, Peru, South Africa, Tanzania, and Timor Leste. The survey identified the extremely poor as those living in households where the consumption per capita is less than $1.08 per person per day, using 1993 purchasing power parity (PPP), whereas the poor were defined as those living in households where the consumption per capita is less than $2.16 per day.

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assets owned by the rural poor, and almost all households engage in some form of agriculture, but the size of landholdings tends to be very small. The median landholding among the poor who own land is one ha or less in India, Indonesia, Guatemala, and Timor Leste; between 1 and 2 ha in Peru, Tanzania, and Pakistan; and between 2 and 3 ha in Nicaragua, Côte d'Ivoire, and Panama. Second, poor rural households tend to rely on selling their only other asset, unskilled labor. Agriculture is generally not the mainstay of most of these households; instead, they generally obtain most of their income from off-farm work as agricultural laborers or in unskilled paid work or occupations outside of agriculture. However, when households do engage in outside employment, they tend to migrate only temporarily and for short distances. Permanent migration for work is rare for most poor rural households. Thus, given the lack of ownership of assets by the rural poor, and their tendency to stay where they are located, it is not surprising that the livelihoods of the 'assetless' poor are often the most dependent on their surrounding natural environments.

The scale of this dependence may be very extensive in some developing regions. For example, in Southern Malawi it was found that surveyed households derive 30 per cent of their income on average from exploiting 'common' forests (Fisher, 2004). Households that are especially lacking in land, education, and goat holdings are more reliant on 'low return' forest activities, such as sales of 'forest-based' crafts (bamboo baskets and mats, grass brooms, and wood-fired pots), roof thatching and brick-burning, sales of prepared foods and drink, sales of firewood and bamboo, and traditional medicines. Similarly, in South Africa the poorest households used more nontimber forest products, such as fuelwood, wild fruits, edible herbs, and grass hand brushes, per capita than wealthier households (Shackleton and Schackleton. 2006). Such findings appear to be consistent with studies of income diversification across Africa, which show that the 'assetless' poor diversify into low-return activities based on exploiting common property environmental resources, but with little hope of escaping the 'poverty trap' (Dercon 1998; Barrett *et al.*, 2001).

This link between asset poverty, lack of income opportunities and resource extraction as insurance may also be very significant in many tropical forest regions, where the livelihoods of the poor often depend on the extraction of biological resources in fragile environments (Pattanayak and Sills, 2001; Wunder, 2001; Takasaki *et al.*, 2004; Vedeld *et al.*, 2004; Adhikari, 2005; McSweeney, 2005; Shone and Caviglia-Harris, 2006; World Bank, 2008a). For example, Vedeld *et al.* (2004) conduct a meta-analysis of 54 case studies globally of rural communities that live in or near tropical forests, and find that on average 22 per cent of household income in these communities depends on forest resources. However, the proportion of forest income was significantly higher for poorer households (32 per cent) compared to the nonpoor (17 per cent). Similarly, López-Feldman and Wilen (2008) find that nontimber forest product use is mainly conducted by households in Chiapas, Mexico with low opportunity costs of time and fewer income generation opportunities. And, in Palawan (the Philippines), hunting pressure on fauna was shown to be inversely related to farm

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size and agricultural productivity, but positively correlated with labor availability (Shively, 1997). The state of the local environment may also affect how the poor utilize its resources, and in turn, their livelihood strategies. In India, Narain *et al.* (2008a) find that, in villages surrounded by good quality forests, the poorest households depend on forest resources for as much as 41 per cent of their income compared to 23 per cent for the richest households. In areas where the forests are in a poor state, both the rich and poor's use of common resources decline, but more so for the poor; both types of households depend on forests for only around 9–14 per cent of their income. In West Bengal, almost 10 per cent of the time of the average household is spent on gathering fuel, either for use at home or for sale (Banerjee and Duflo, 2007).

Lack of assets and access to key markets may also constrain the ability of poor households to adopt technologies to improve their farming systems and livelihoods. In conducting a meta-analysis based on 120 cases of agricultural and forestry technology by smallholders across the developing world, Pattanayak *et al.* (2003) find that credit, savings, prices, market constraints, access to extension and training, tenure and plot characteristics, such as soil quality and landholding size, are important determinants of adoption behavior. Not surprisingly, the result is low adoption rates for sustainable agricultural and forestry technologies among poor smallholders.

The assetless poor are also highly vulnerable to natural disaster shocks, such as droughts, hurricanes, tsunamis, floods, and other extreme events (Badola and Hussein, 2005; McSweeney, 2005; Carter *et al.*, 2007; Barbier, 2008; Das and Vincent, 2009). On the other hand, positive income shocks and targeted programs to the poor can reduce pressure on natural resources (Fisher and Shively, 2005). For example, two studies based on the 1999 cyclone that struck Orissa, India found that mangroves significantly reduced the number of deaths as well as damages to property, livestock, agriculture, fisheries, and other assets (Badola and Hussain, 2005; Das and Vincent, 2009). Statistical analysis indicates that there would have been 1.72 additional deaths per village within 10 km of the coast if the mangrove width along shorelines had been reduced to zero (Das and Vincent, 2009). Losses incurred per household were greatest ($154) in a village that was protected by an embankment but had no mangroves compared to losses per household ($33) in a village protected only by mangrove forests (Badola and Hussain, 2005). However, evidence from Thailand indicate that poor coastal households are less willing to participate in mangrove replanting schemes, even though they are aware of the storm protection benefits of mangroves, because of the high opportunity cost of their labor and lack of community control over the management of the restored mangroves (Barbier, 2008). In many developing regions, poor households rely on natural resources not for protection against storms and other environmental shocks but as insurance and coping strategies for avoiding the income and subsistence losses associated with such disasters (McSweeney, 2005; Carter *et al.*, 2007).

Given that poor rural households engage in some agriculture, and are highly dependent on outside employment for income, their livelihood

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strategies across these activities must be interdependent. In particular, as the 'natural' assets and land available to them degrade or disappear, the rural poor are likely to search for more paid work to increase their earnings from outside jobs. For example, Dasgupta (1993) has hypothesized that such environmental degradation effectively lowers the 'reservation wage' of the poor for accepting paid work, as households are forced to look for additional work to make up the lost income.

Various studies provide evidence in support of Dasgupta's hypothesis from resource-dependent communities across the developing world (Jansen *et al.*, 2006; Pascual and Barbier, 2006, 2007; Barbier, 2007a). For example, Barbier (2007a) finds that mangrove deforestation is likely to increase the probability that both males and females from coastal communities in Thailand participate in outside work, but the number of hours worked in outside employment by males declines with any mangrove loss while the number of hours worked by females rises. Households appear to be highly dependent on males continuing to work on the physically demanding mangrove-dependent activities, such as fishing and collecting products, and as mangrove resources decline, even more male labor will be devoted to exploiting them to maintain the mangrove-based income and subsistence required by the households. In contrast, females are more likely to be sent out for paid employment to earn needed cash income as local mangrove resources decline. In contrast, in the Yucatán, Mexico, in response to increased population density and declining soil fertility, only the better off households are able to devote more labor to off-farm employment; in contrast, the poorer households allocate even more labor to shifting cultivation, thus perpetuating problems of shortened fallows and declining yields (Pascual and Barbier, 2006, 2007). On the other hand, in the rainfed upland areas of Honduras, favorable rainfall during the secondary season lowers the probability that a household's income-earning strategy focuses on off-farm work, probably because it makes their own farm vegetable production more profitable (Jansen *et al.*, 2006).

Evidence from the Philippines confirms that higher wages for off-farm employment can draw away smallholder labor that would otherwise be used for clearing more forests for on-farm agricultural production (Coxhead *et al.*, 2002; Shively and Fisher, 2004). However, poorer households in remote locations are the least likely to participate in off-farm employment, as they face higher transaction and transportation costs (Shively and Fisher, 2004). Bluffstone (1995) finds similar results in Nepal; higher wages reduce smallholder deforestation, but only if there are paid employment opportunities available in remote areas. Nonfarm employment and improved wages in Honduras has also been associated with investments to improve cropland quality in Honduras and improved resource conditions in Uganda (Pender, 2004). In El Salvador, as the employment opportunities and income per capita of agricultural wage owners declined, they relied increasingly on cultivating land for subsistence production. But rising income growth also enables poor and near poor households to acquire more land for cultivation, as a precaution against possible future income losses (González-Vega *et al.*, 2004). In Honduras, there is concern that the 30–50 per cent decline in real wages

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over the past decade has shifted upland households to income strategies emphasizing hillside cropland expansion and resource degradation that has worsened rural poverty (Jansen *et al.*, 2006). Similarly, in the Yucatán, because they have limited access to off-farm employment, the least poor households tend to oversupply labor to shifting cultivation and thus clear too much forest land (Pascual and Barbier, 2007).

Although higher nonfarm income may discourage cropland expansion and deforestation, it does not necessarily follow that households will invest more in conserving and improving existing land. For example, Holden *et al.* (2004) found that, in the Ethiopian highlands, better access to low-wage nonfarm employment improved substantially the income of households, but because it also reduced farming activities and food production, increased nonfarm income also undermined the incentives for soil conservation. Similarly, Pascual and Barbier (2007) find evidence that the poorest households in the Yucatán have a backward-bending supply curve for off-farm labor. As real wage rates rise, these households actually decrease their supply of labor to outside employment and increase clearing forests for shifting cultivation. In contrast, richer households respond to higher real wages by supplying more labor to outside work, thus reducing shifting cultivation and deforestation. In Malawi, the factors reducing forest pressure included favorable returns to nonforest employment, secondary education of the household head, and wealth (Fisher *et al.*, 2005).

In summary, the perception of a 'poverty-environment trap' as a two-way process in which poverty drives rural households to degrade the environment, and a deteriorating environment subsequently worsens poverty, needs to be revised. Although poverty–environment traps are still prevalent, they encompass more complex relationships involving links between asset poverty, lack of income opportunities or access to key markets for land, labor, and credit, and the availability and quality of natural resources, including land, to exploit. The following section develops a simple poverty–environment trap model to capture the key features of these linkages.

5. A poverty–environment trap model

A *poverty trap* is characterized by self-reinforcing patterns of chronic or persistent poverty (Barrett and Swallow, 2006). Such patterns have been characterized in terms of the lack of nutritional status and the capacity for work by the poor (Dasgupta, 1993, 1997, 2003), or an asset-based approach to characterizing long-term structural poverty (Carter and Barrett, 2006; Carter *et al.*, 2007). The following model encompasses elements of both labor and asset constraints. However, its main aim is to illustrate how an environment–poverty trap can easily arise for a poor rural household with access to only marginal lands and natural resources for its own production, and where formal or well-functioning markets for key economic assets and services, such as credit, capital, land, and insurance, are missing. In short, the household has only two productive assets readily accessible to it: the natural resources, including any low-productive land available for agriculture, in the surrounding environment; and the total unskilled labor of the household.

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Consider a representative rural household living in a less favored area for agricultural production, i.e., upland areas, converted forest lands and drylands that suffer from low agricultural productivity, land degradation and lack of irrigation, and other inputs for intensive agriculture. The household also lacks access to formal or well-functioning markets for credit, capital, land and insurance. Thus, members of the household may participate in two broad types of economic activity: (i) production activities that rely on the natural resource endowment available to the household, including any common-property resources or agricultural land for agriculture and, if they choose, (ii) outside paid employment.[3] To sharpen the analysis and to simplify notation, aggregate household labor will be treated as homogeneous.[4] Without any loss of generality, it is also assumed that any household production and consumption of nonmarketed goods can be subsumed under the broad category of 'leisure' (Barnum and Squire, 1979).

In any period, the household is assumed to maximize a utility function with the standard properties

$$U = U(x, l^u, c), \quad U_i > 0, U_{ii} < 0, \quad i = x, l^u, c, \tag{1}$$

where x is a market-purchased consumption good, l^u is leisure, and c is the household's consumption from its own production activities.

Let y be the household's aggregate output from its own production activities (e.g., food, cash crops, fuelwood or charcoal, harvested products), then the following production technology is assumed

$$y = f(l, v, N), \quad f_i > 0, f_{ii} < 0, f_{ij} > 0, \quad \lim_{i \to 0} f_i(0) = 0, \quad i = l, v, N, i \neq j, \tag{2}$$

where l, and v are, respectively, the household labor and purchased inputs employed to produce y. In addition, N is some measure of the quantity and quality of the natural resource endowment available to the household, including the available agricultural land, plus any other accessible natural resources in the surrounding environment that can be exploited or harvested, such as forests, fisheries, wild flora and fauna, and source of water supply.

[3] In the following model, it is possible to separate out agricultural production from resource collection or harvesting activities, but doing so simply complicates the model without changing the qualitative results significantly. See Barbier (2008) and Narain *et al.* (2008b) for examples of rural household models similar to this one that distinguishes the household's activities into agricultural production, resource collection from the commons and off-farm work. López (1998) does not consider the latter, but instead separates agricultural production into labor versus land-intensive activities.

[4] Note that the male and female labor of the household may not be equivalent, and thus the allocation decisions of each type of labor may need to be differentiated in any actual application of the following model. See, for example, Barbier (2007a, 2008) and Fisher (2004) in which differentiating intrahousehold allocation of male and female labor has proved to be important.

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The household may also allocate some of its labor, l^w, to outside paid work, in exchange for cash wages or payments in kind (e.g., food and marketable products). Denoting L as the total labor available to the household implies that

$$L = l + l^w + l^u, \quad l > 0, l^w \geq 0, l^u > 0. \tag{3}$$

Although the household always engages in its own production activities and leisure, the optimal hours of employment in outside paid work may be zero.

Given market prices, p^x, p^y, and p^v for the corresponding commodities and the market wage rate, w, for outside employment, the household faces the following cash income constraint

$$p^x x + p^v v = p^y(y - c) + wl^w + M, \quad v \geq 0, x \geq 0, y > 0, M \geq 0. \tag{4}$$

The left-hand side of (4) represents the cash purchases by the household, and the right-hand side is its income. If $y > c$, then the first term on the right-hand side is the marketed surplus from the household's production activities; if $c < y$ then the household buys more than it sells from its own production. If the household hires labor to assist in its production activities, then this labor is included in v, and the vector of input prices, p^v, includes the market wage, w. The final term on the right hand side, M, represents exogenous nonlabor income (remittances, social transfers, rents).

Maximization of household utility (1) with respect to the constraints (2)–(4) yields the optimal levels of consumption of x, c, and l^u, and of the purchased and labor inputs, v, l, and l^w, respectively. From the first-order conditions, the optimal choices for l, l^u, and l^w are governed by

$$\begin{aligned} &U_{l^u} = \lambda, \quad p^y f_l = \frac{\lambda}{\mu}, \mu w - \lambda \leq 0, l^w \geq 0, [\mu w - \lambda] l^w = 0 \quad \text{or} \\ &\frac{U_{l^u}}{\mu} = p^y f_l = \frac{\lambda}{\mu} \geq w, \end{aligned} \tag{5}$$

where λ is the shadow value of the household's total labor and leisure time and μ is the shadow value, or marginal utility, of additional cash income for the household. Condition (5) states that the household will equate the marginal value of leisure with that of its labor allocated to production activities, and the value of this labor may be equal to or exceed the given market wage for any paid work. If the value of household labor is insufficiently compensated by outside employment (i.e., $\lambda/\mu > w$), then the household will not participate in the labor market ($l^{w*} = 0$).[5]

Let w^R represent the reservation wage rate of the household; i.e., the value of its labor that just ensures that the optimal hours engaged in paid

[5] The household's labor allocation decision is fully recursive (Jacoby, 1993). That is, optimal production and thus input decisions of the household are determined first and independently of consumption and leisure choices, regardless of whether the household decides to participate in paid work.

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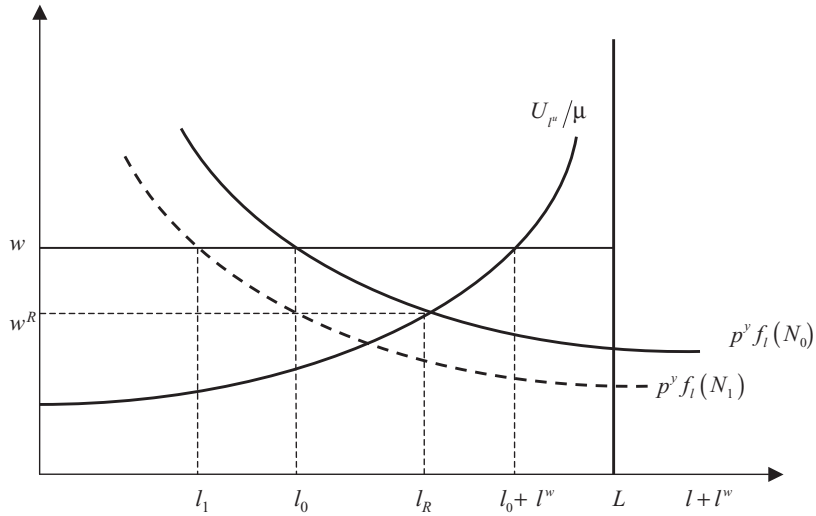


Figure 3. *Labor allocation by the poor rural household.*

work is zero. Thus, the reservation wage is defined explicitly as

$$w^R \equiv \left[\frac{U_{l^u}}{\mu} = p^y f_l\right]_{l_w^*=0}. \tag{6}$$

Two propositions therefore follow from (5) and (6):

Proposition 1. *$l_w^* > 0$ iff $w > w^R$, and $l_w^* = 0$ iff $w \leq w^R$.*

The household will only engage in outside employment if the market wage received exceeds the household's reservation wage. If the wage for paid work is less than or equal to the reservation wage, then the household will not participate in the labor market.

Proposition 2. *If $w > w^R$ then $U_{l^u}/\mu = w$ is the equilibrium defining l^{u*} and $p^y f_l = w$ is the equilibrium defining l^*.*

When it is optimal for the household to devote some labor to outside employment, then its optimal allocation of leisure and labor allocated to production activities is determined by their respective values equated to the wage rate.

The relationships implied by these two propositions are depicted in figure 3. Using (3), the horizontal axis depicts the total labor allocated by the household to both production activities and outside employment. Leisure is therefore defined as $L - l - l^w$. For a given quantity and quality of the natural resource endowment available to the household, N_0, the marginal value to the household of allocating labor to its own production activities, $p^y f_l(N_0)$, is downward sloping because of the decreasing marginal productivity of labor, whereas the marginal cost of this allocation in terms of foregone leisure, U_{l^u}/μ, is upward sloping because of decreasing

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marginal utility of leisure.[6] From condition (6), where these two curves intersect determines the reservation wage w^R of the household. According to Proposition 1, if the market wage for hiring labor is equal to the reservation wage, then the household would not allocate any labor to outside employment,$l^w = 0$. Instead, l_R household labor would be involved in production activities and the remaining $L - l^R$ labor would be devoted to leisure. On the other hand, as shown in figure 3, if the household is offered a wage rate in outside employment higher than its reservation wage, $w > w^R$, then the household would reduce both its labor allocated to production activities and to leisure in order to engage in outside employment. The household will devote l_0 labor to production activities, l^w to paid work, and $L - l_0 - l^w$ to leisure. This equilibrium labor allocation satisfies Proposition 2.

However, for its production activities, the household relies on agriculture and collecting or harvesting products from resource commons. As we have seen, agriculture on marginal lands is prone to land degradation, and many resource commons are subject to overexploitation due to uncontrolled access or under threat from development activities.[7] Thus, it is highly likely that the quantity and quality of the natural resource endowment available to the household may eventually decline, from N_0 to N_1. The result, as shown in figure 3, is that the labor productivity of the household's production activities will fall, as will its reservation wage.[8] The household will now allocate only l_1 labor to its own production activities, and much more labor will be devoted to outside employment. Leisure will be unaffected.

But in less favored areas there will be many poor households facing problems of environmental degradation from farming marginal lands and exploiting natural resources found in the commons or open access locations.[9] If there are large numbers of households seeking outside

[6] Figure 3 is drawn assuming that the marginal utility of leisure tends to infinity when leisure approaches zero, and following figure 2, that the marginal productivity of labor in household production activities tends to zero if the amount of labor allocated to these activities by the household approaches zero.

[7] As noted previously, the assetless poor who live in fragile environments are also highly vulnerable to natural disaster shocks, such as droughts, hurricanes, tsunamis, floods, and other extreme events (Badola and Hussein, 2005; McSweeney, 2005; Carter *et al.*, 2007; Barbier, 2008; Das and Vincent, 2009). If the effect of such shocks is also to lower the quality or quantity of the natural resource endowment available to the household, similar impacts on the household will occur as shown in figure 3 and described here.

[8] This result confirms the hypothesis developed by Dasgupta (1993), from his nutrient-based model of a household dependent on a resource commons, which predicts that environmental degradation effectively lowers the reservation wage of the poor for accepting paid work, forcing them to look for additional work to make up the lost income. See Dasgupta (2003) for a formal model of this process that allows for changes in household size (population).

[9] Poor households may also like wage income for a second reason: because it reduces their risk, or at least transfers it to whoever is paying the wage. That is, households may compare a certain wage and an uncertain return to that labor

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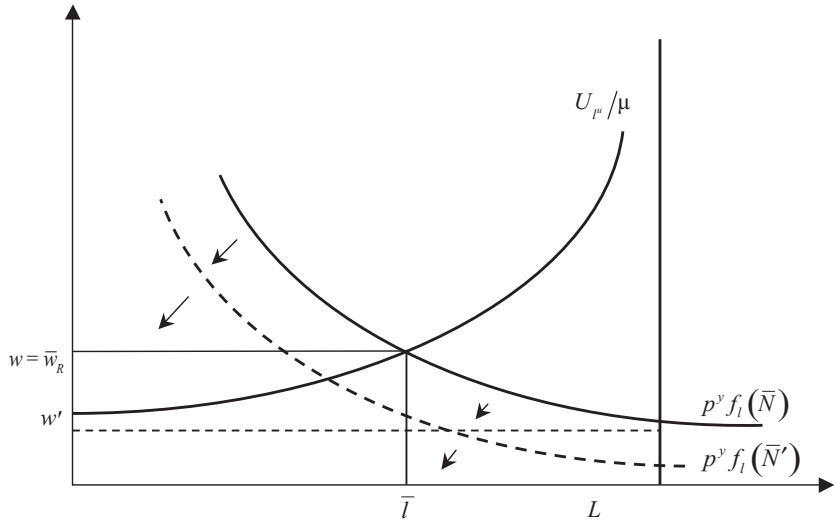


Figure 4. *The poverty–environment trap.*

employment, the supply of labor for paid work is likely to exceed demand. The market wage for hired labor will decline. For some households, the wage rate will fall to the level of the reservation wage or even lower. As indicated by Proposition 1, these households would now stop seeking outside employment opportunities and instead allocate all of their labor to production activities and leisure. The danger for these households is that, at some point, the dynamics of a poverty–environment trap may ensue.

To see this, define $\bar{y} = f(\bar{l}, \bar{v}, \bar{N})$ as the minimum production necessary to meet the basic, subsistence, health and nutritional needs of all household members. From (6), the reservation wage associated with this level of production is defined as $\bar{w}^R \equiv \left[\frac{U_{l^\mu}}{\mu} = p^y f_l(\bar{l}, \bar{v}, \bar{N})\right]_{l^*_w=0}$. From Proposition 1, if $w \leq \bar{w}_R$, then the household will not allocate any labor to outside employment, even though the household is able only to meet minimum subsistence from its own production activities. However, there are even more severe consequences for the household if this condition is satisfied, which can be stated as

Proposition 3. *Iff $w \leq \bar{w}_R$, then the household will fall into a poverty–environment trap as a result of any ensuing environmental degradation.*

The dynamics associated with this trap are illustrated in figure 4. Suppose that, because the market wage rate has fallen to equal its

when applied to their own fields. Under certain conditions, households may be willing to accept a wage that is lower than the 'opportunity cost' of their time (in monetary terms) because it is worth more (in utility terms) to reduce their risk. I am grateful to Jerry Shively for pointing out this second motivation for wage income to me.

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reservation wage, $w = \bar{w}^R$, a household has allocated all its labor to production activities and leisure. But this labor allocation, $\bar{l}$, only allows enough production to meet the basic needs of the household, $\bar{y} = f(\bar{l}, \bar{v}, \bar{N})$. If the household faces problems of land degradation or declining common resources, then as shown in the figure, the labor productivity of the household's production activities will fall as $\bar{N}$ declines to $\bar{N}'$. The household's reservation wage will decline below the market wage, and following Proposition 1, the household will now devote some labor to outside employment. However, the total sum of labor allocated to outside employment and production activities will still total only $\bar{l}$; the remaining $L - \bar{l}$ household labor will remain as leisure. Since the returns to paid work and production activities are just equal to the original reservation wage, $w = \bar{w}^R$, the household will be producing and earning only enough to meet its basic needs. The effect of the environmental degradation is simply to force the household to look for outside work. If the household is able to obtain such employment, it does not allow the household to break out of the poverty trap of just meeting basic subsistence, health and nutritional needs.

The dynamics of the poverty–environment trap can be even worse for the household if the environmental degradation problems are widespread in the region and affect many households. In that case, the large numbers of households seeking outside employment is likely to force down the market wage. As shown in figure 4, if the new wage $w\prime$ falls very low and is less than the household's new reservation wage, the household will not seek outside employment. But to meet its basic needs, the household must continue to devote $\bar{l}$ to production activities. This is clearly a suboptimal labor allocation, as it violates condition (6). There is a further danger to the household, however. By putting too much labor into production activities, the household is likely to overexploit further common resources and degrade its marginal lands for agriculture.[10] As indicated by the directional arrows in figure 4, the result is even further declines in the labor productivity of the household, continuing misallocation of labor, and a deepening poverty–environment trap.

6. Final remarks

Because the tendency for the rural poor to be concentrated in the less favored areas of developing regions has a long history, it is a process that is difficult to reverse (Barbier, 2010). But the complex linkages underlying the poverty–environment trap highlighted here illustrate how important it is to begin this process if the objective of ending global poverty is to be realized. As shown in this paper, the poverty–environment trap is another manifestation of characterizing long-term structural poverty as the lack of nutritional status and the capacity for work by the poor (Dasgupta, 1993, 1997, 2003), or alternatively, their lack of access to key economic assets

[10] This result is confirmed, for example, by Pascual and Barbier (2007), who find that it is the least poor households in the Yucatán, Mexico that tend to oversupply labor to shifting cultivation, thus causing more deforestation.

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(Carter and Barrett, 2006; Carter *et al.*, 2007). Similar policy approaches, therefore, are called for to address these problems.

There are several ways in which expanded global efforts can improve the livelihoods of the poor.

The first is to provide financing directly, through involving the poor in payment for ecosystem services schemes and other measures that enhance the environments on which the poor depend (Grieg-Gran *et al.*, 2005; Pagiola *et al.*, 2005; Alix-Garcia *et al.*, 2008; Barbier, 2008; Bulte *et al.*, 2008; Wunder, 2008; Zilberman *et al.*, 2008). Payments for the conservation of standing forests or wildlife habitat are the most frequent type of compensation programs used currently in developing countries, and they have been mainly aimed at paying landowners for the opportunity costs of preserving natural landscapes that provide one or more diverse services: carbon sequestration, watershed protection, biodiversity benefits, wildlife protection, and landscape beauty (Grieg-Gran *et al.*, 2005; Pagiola *et al.*, 2005; Wunder, 2008). Wherever possible, the payment schemes should be designed to increase the participation of the poor, to reduce any negative impacts on nonparticipants while creating additional job opportunities for rural workers, and to provide technical assistance, access to inputs, credit, and other support to encourage poor smallholders to adopt the desired land use practices. More effort must be devoted to designing projects and programs that include the direct participation of the landless and near landless.

The second is to target investments directly to improving the livelihoods of the rural poor, thus reducing their dependence on exploiting environmental resources. For example, in Ecuador, Madagascar, and Cambodia poverty maps have been developed to target public investments to geographically defined subgroups of the population according to their relative poverty status, which could substantially improve the performance of the programs in term of poverty alleviation (Elbers *et al.*, 2007). A World Bank study that examined 122 targeted programs in 48 developing countries confirms their effectiveness in reducing poverty, if they are designed properly (Coady *et al.*, 2004).

Targeting the poor is even more urgent during major economic crises, which occur frequently in developing economies (Development Research Group, 2008; Ravallion, 2008). Underinvestment in human capital and lack of access to financial credit are persistent problems for the extreme poor, especially in fragile environments. Low income households generate insufficient savings, suffer chronic indebtedness and rely on informal credit markets with high short-term interest rates. Two types of policies and investment programs targeted to the poor are essential in these circumstances. The first is a comprehensive and targeted safety net that adequately insures the poor in time of crisis. The second is the maintenance, and if possible expansion, of long-term educational and health services targeted at the poor. Unfortunately, during financial and economic crises, publicly funded health and education services are often the first expenditures reduced by developing country governments.

Ultimately, however, it is the lack of access of the rural poor in less favored areas to well-functioning and affordable markets for credit,

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insurance and land, and the high transportation and transaction costs that prohibit the poorest households in remote areas to engage in off-farm employment, which are the major long-run obstacles that need to be addressed. As we have seen in this paper, these problems lie at the heart of the poverty–environment trap. Others have reached a similar conclusion. For example, Carter and Barrett (2006, p.195) note that the existence of a poverty trap threshold 'depends on the degree to which the household is excluded from intertemporal exchange through credit, insurance or savings, whether formally or through social networks. A household with perfect access to capital over time and across states of nature would not face a critical threshold.' Similarly, Shively and Fisher (2004, p. 1366) maintain that 'policies to reduce deforestation should focus on increasing returns to off-farm employment, strengthening rural credit markets, and ensuring farmers have secure tenure over existing agricultural land.'

In summary, as rural populations of the developing world continue to increase, the problem of growing numbers of assetless poor and their concentration in less favored areas remains a major development challenge. Although this review has shown that the rural poor are less likely to be responsible for much of the environmental degradation in the developing world than as previously believed, the difficulties posed by poverty–environment traps and labor, asset, and market constraints are considerable. Only by formulating novel policies targeted specifically at reducing these constraints for the rural poor in less favored areas will significant progress in reducing global poverty occur.

References

Adhikari, B. (2005), 'Poverty, property rights, and collective action: understanding the distributive aspects of common property resource management', *Environment and Development Economics* **10**(1): 7–31.

Alix-Garcia, J., A. De Janvry, and E. Sadoulet (2008), 'The role of deforestation risk and calibrated compensation in designing payments for environmental services', *Environment and Development Economics* **13**: 375–394.

Aylward, B. and J. Echeverría (2001), 'Synergies between livestock production and hydrological function in Arenal, Costa Rica', *Environment and Development Economics* **6**: 359–381.

Badola, R. and S.A. Hussain (2005), 'Valuing ecosystems functions: an empirical study on the storm protection function of Bhitarkanika mangrove ecosystem, India', *Environmental Conservation* **32**(1): 85–92.

Bandaranayake, W.M. (1998), 'Traditional and medicinal uses of mangroves', *Mangroves and Salt Marsh* **2**: 133–148.

Banerjee, A.V. and E. Duflo (2007), 'The economic lives of the poor', *Journal of Economic Perspectives* **21**(1): 141–168.

Barbier, E.B. (2003), 'Upstream dams and downstream water allocation – The case of the Hadejia-Jama'are floodplain, Northern Nigeria', *Water Resources Research* **39**(11): 1311–1319.

Barbier, E.B. (2005), *Natural Resources and Economic Development*, Cambridge: Cambridge University Press.

Barbier, E.B. (2007a), 'Natural capital and labor allocation: mangrove-dependent households in Thailand', *The Journal of Environment and Development* **16**: 398–431.

Barbier, E.B. (2007b), 'Valuing ecosystem services as productive inputs', *Economic Policy* **22**(49): 177–229.

https://doi.org/10.1017/S1355770X1000032X Published online by Cambridge University Press

Barbier, E.B. (2008), 'In the wake of the tsunami: lessons learned from the household decision to replant mangroves in Thailand', *Resource and Energy Economics* **30**: 229–249.

Barbier, E.B. (2010), *Scarcity and Frontiers: How Economies Have Evolved Through Natural Resource Exploitation*, Cambridge: Cambridge University Press.

Barbier, E.B. and I. Strand (1998), 'Valuing mangrove-fishery linkages: a case study of Campeche, Mexico', *Environmental and Resource Economics* **12**: 151–166.

Barnum, H.B. and L. Squire (1979), 'A Model of an Agricultural Household: Theory and Evidence', Technical Report, The World Bank Occasional Papers No. 27.

Barrett, C.B. (2004), 'Rural-poverty dynamics: development policy implications', *Agricultural Economics* **32**(1): 43–58.

Barrett, C.B., T. Reardon, and P. Webb (2001), 'Nonfarm income diversification and household livelihood strategies in rural Africa: concepts, dynamics and policy implications', *Food Policy* **26**: 315–331.

Barrett, C.B. and B.M. Swallow (2006), 'Fractal poverty traps', *World Development* **34**(1): 1–15.

Bluffstone, R.A. (1995), 'The effect of labor market performance on deforestation in developing countries under open access: an example from rural Nepal', *Journal of Environmental Economics and Management* **29**: 42–63.

Bulte, E.H., R.B. Boone, R. Stringer, and P.K. Thornton (2008), 'Elephants or onions? Paying for nature in Amboseli, Kenya', *Environment and Development Economics* **13**: 395–414.

Carter, M.R. and C.B. Barrett (2006), 'The economics of poverty traps and persistent poverty: an asset-based approach', *Journal of Development Studies* **42**(2): 178–199.

Carter, M.R., P.D. Little, T. Mogues, and W. Negatu (2007), 'Poverty traps and natural disasters in Ethiopia and Honduras', *World Development* **35**(5): 835–856.

Caviglia-Harris, J.L. (2004) 'Household production and forest clearing: the role of farming in the development of the Amazon', *Environment and Development Economics* **9**: 181–202.

Cesar, H.S.J. (2000), 'Coral reefs: their functions, threats and economic value', in H.S.J. Cesar (ed), *Collected Essays on the Economics of Coral Reefs*, Kalmar, Sweden: CORDIO, pp. 14–39.

Chen, S. and M. Ravallion (2007), 'Absolute poverty measures for the developing world, 1981–2004', *Proceedings of the National Academy of Sciences* **104**(43): 16757–16762.

Chomitz, K.M. and K. Kumari (1998), 'The domestic benefits of tropical forests: a critical review', *The World Bank Research Observer* **13**(1): 13–35.

Chong, J. (2005), *Protective Values of Mangroves and Coral Ecosystem: A Review of Methods and Evidence*, Gland, Switzerland: IUCN.

Chopra, K. and S.K. Adhikari (2004), 'Environment development linkages: modeling a wetland system for ecological and economic value', *Environment and Development Economics* **9**: 19–45.

Coady, D., M. Grosh, and J. Hoddinott (2004), 'Targeting outcomes redux', *World Bank Research Observer* **19**(1): 61–85.

Comprehensive Assessment of Water Management in Agriculture (2007), *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture*, London: Earthscan, and Colombo: International Water Management Institute.

Coxhead, I., G.E. Shively and X. Shuai (2002), 'Development policies, resource constraints, and agricultural expansion on the Philippine land frontier', *Environment and Development Economics* **7**: 341–364.

Das, S. and J.R. Vincent (2009), 'Mangroves protected villages and reduced death toll during Indian super cyclone', *Proceedings of the National Academy of Sciences* **106**: 7357–7360.

https://doi.org/10.1017/S1355770X1000032X Published online by Cambridge University Press

Dasgupta, P. (1993), *An Inquiry into Well-Being and Destitution*, New York: Oxford University Press.
Dasgupta, P. (1997), 'Nutritional status, the capacity for work, and poverty traps', *Journal of Econometrics* **77**: 5–37.
Dasgupta, P. (2003), 'Population, poverty, and the natural environment', in K.-G. Mäler and J.R. Vincent (eds), *Handbook of Environmental Economics*, Volume 1: Environmental Degradation and Institutional Responses, Amsterdam: North Holland, pp. 191–247.
Dasgupta, S., U. Deichmann, C. Meisner, and D. Wheeler (2005), 'Where is the poverty-environment nexus? Evidence from Cambodia, Lao PDR, and Vietnam', *World Development* **33**(4): 617–638.
Dercon, S. (1998), 'Wealth, risk and activity choice: cattle in western Tanzania', *Journal of Development Economics* **55**: 1–42.
Development Research Group (2008), 'Lessons from World Bank Research on Financial Crises', Policy Research Working Paper 4779, World Bank, Washington, DC.
Diwakara, H. and M.G. Chandrakanth (2007), 'Beating negative externality through groundwater recharge in India: a resource economic analysis', *Environment and Development Economics* **12**: 271–296.
Elbers, C., T. Fujii, P. Lanjouw, B. Özler, and W. Yin (2007), 'Poverty alleviation through geographic targeting: how much does disaggregation help?', *Journal of Development Economics* **83**: 198–213.
Fisher, M.M. (2004), 'Household welfare and forest dependence in southern Malawi', *Environment and Development Economics* **9**: 135–154.
Fisher, M.M. and G.E. Shively (2005), 'Can income programs reduce tropical forest pressure? Income shocks and forest use in Malawi', *World Development* **37**(7): 1115–1128.
Fisher, M.M., G.E. Shively, and S. Buccola (2005), 'Activity choice, labor allocation, and forest use in Malawi', *Land Economics* **81**(4): 503–517.
Food and Agricultural Organization (FAO) (2001), 'Forest Resources Assessment 2000: Main Report', FAO Forestry Paper 140, Rome: FAO.
Food and Agricultural Organization of the United Nations (FAO) (2003), *State of the World's Forests 2003*, Rome: FAO.
Gonazález-Vega, C., J. Rodríguez-Meza, D. Southgate, and J.H. Maldonado (2004), 'Poverty, structural transformation, and land use in El Salvador: learning from household panel data', *American Journal of Agricultural Economics* **86**(5): 1367–1374.
Gray, L.C. and W.G. Mosley (2005), 'A geographical perspective on poverty-environment interactions', *The Geographical Journal* **171**(1): 9–23.
Grieg-Gran, M.-A., I. Porras, and S. Wunder (2005), 'How can market mechanisms for forest environmental services help the poor? Preliminary lessons from Latin America', *World Development* **33**(9): 1511–1527.
Guo, Z., X. Xiao, Y. Gan, and Y. Zheng (2001), 'Ecosystem functions, services and their values – a case study in Xingshan County of China', *Ecological Economics* **38**: 141–154.
Hammitt, J.K., J.-T. Liu, and J.-L. Liu (2001), 'Contingent valuation of a Taiwanese wetland', *Environment and Development Economics* **6**: 259–268.
Holden, S., B. Shiferaw, and J. Pender (2004), 'Non-farm income, household welfare, and sustainable land management in a less-favoured area in the Ethiopian highlands', *Food Policy* **29**: 369–392.
Islam, M. and J.B. Braden (2006), 'Bio-economic development of floodplains: farming versus fishing in Bangladesh', *Environment and Development Economics* **11**: 95–126.

https://doi.org/10.1017/S1355770X1000032X Published online by Cambridge University Press

Jackson, J.B.C., M.X. Kirby, W.H. Berger, K.A. Bjørndal, L.W. Botsford, B.J. Bourque, R.H. Bradbury, R. Cooke, J. Erlandson, J.A. Estes, T.P. Hughes, S. Kidwell, C.B. Lange, H.S. Lenihan, J.M. Pandolfi, C.H. Peterson, R.S. Steneck, M.J. Tegner, and R.R. Warner (2001), 'Historical overfishing and the recent collapse of coastal ecosystems', *Science* **293**: 629–638.

Jacoby, H.G. (1993), 'Shadow wages and peasant family labor supply: an econometric application to the Peruvian Sierra', *Review of Economic Studies* **60**: 903–921.

Jansen, H.G.P., A. Rodriguez, A. Damon, J. Pender, J. Chenier, and R. Schipper (2006), 'Determinants of income-earning strategies and adoption of conservation practices in hillside communities in rural Honduras', *Agricultural Systems* **88**: 92–110.

Kremen, C., J.O. Niles, M.G. Dalton, G.C. Daily, P.R. Ehrlich, J.P. Fay, D. Grewal, and R.P. Guillery (2000), 'Economic incentives for rainforest conversion across scales', *Science* **288**: 1828–1832.

Lemley, A.D., R.T. Kingsford, and J.R. Thompson (2000), 'Irrigated agriculture and wildlife conservation: conflict on a global scale', *Environmental Management* **25**(5): 485–512.

López, R. (1998), 'Agricultural intensification, common property resources and the farm household', *Environmental and Resource Economics* **11**(3–4): 443–458.

López-Feldman, A. and J.E. Wilen (2008), 'Poverty and spatial dimensions of non-timber forest extraction', *Environment and Development Economics* **13**: 621–642.

McSweeney, K. (2005), 'Natural insurance, forest access, and compound misfortune: forest resources in smallholder coping strategies before and after Hurricane Mitch in northeastern Honduras', *World Development* **33**(9): 1453–1471.

Millennium Ecosystem Assessment (2005), *Ecosystems and Human Well-being: A Framework for Assessment*, Washington, DC: Island Press.

Minot, N. and B. Baulch (2002), 'The spatial distribution of poverty in Vietnam and the potential for targeting', Policy Research Working Paper 2829, Washington, DC: World Bank.

Moberg, F. and C. Folke (1999), 'Ecological goods and services of coral reef ecosystems', *Ecological Economics* **29**: 215–233.

Moberg, F. and P. Rönnbäck (2003), 'Ecosystem services of the tropical seascape: Interactions, substitutions, and restoration', *Ocean & Coastal Management* **46**: 27–46.

Narain, U., S. Gupta, and K. van 't Veld (2008a), 'Poverty and resource dependence in rural India', *Ecological Economics* **66**(1): 161–176.

Narain, U., S. Gupta, and K. van 't Veld (2008b), 'Poverty and the environment: exploring the relationship between household incomes, private assets, and natural assets', *Land Economics* **84**(1): 148–167.

Naylor, R. and M. Drew (1998), 'Valuing mangrove resources in Kosrae, Micronesia', *Environment and Development Economics* **3**: 471–490.

Othman, J., J. Bennett, and R. Blamey (2004), 'Environmental management and resource management options: a choice modelling experience in Malaysia', *Environment and Development Economics* **9**: 803–824.

Pagiola, S., A. Arcenas, and G. Platais (2005), 'Can payments for environmental services help reduce poverty? An exploration of the issues and the evidence to date from Latin America', *World Development* **33**(2): 237–253.

Pascual, U. and E.B. Barbier (2006), 'Deprived land-use intensification in shifting cultivation: the population pressure hypothesis revisited', *Agricultural Economics* **34**: 155–165.

Pascual, U. and E.B. Barbier (2007), 'On price liberalization, poverty, and shifting cultivation: an example from Mexico', *Land Economics* **83**(2): 192–216.

https://doi.org/10.1017/S1355770X1000032X Published online by Cambridge University Press

Pattanayak, S.K. and R.A. Kramer (2001), 'Worth of watersheds: a producer surplus approach for valuing drought mitigation in Eastern Indonesia', *Environment and Development Economics* **6**: 123–146.
Pattanayak, S.K., D.E. Mercer, E. Sills, and J-C. Yang (2003), 'Taking stock of agroforestry adoption studies', *Agroforestry Systems* **57**: 173–186.
Pattanayak, S.K. and E. Sills (2001), 'Do tropical forests provide natural insurance? The microeconomics of non-timber forest products collection in the Brazilian Amazon', *Land Economics* **77**(4): 595–612.
Pender, J. (2004), 'Development pathways for hillsides and highlands: some lessons from Central America and East Africa', *Food Policy* **29**: 339–367.
Population Division of the United Nations Secretariat (2008), *World Urbanization Prospects: The 2007 Revision: Executive Summary*, New York: United Nations.
Postel, S.L. and B.H. Thompson, Jr. (2005), 'Watershed protection: capturing the benefits of nature's water supply services', *Natural Resources Forum* **29**: 98–108.
Ravallion, M. (2008), 'Bailing out the World's Poorest', Policy Research Working Paper 4763, World Bank, Washington, DC.
Reardon, T. and S.A. Vosti (1995), 'Links between rural poverty and the environment in developing countries – asset categories and investment poverty', *World Development* **23**: 1495–506.
Richards, M. (1997), 'The potential for economic valuation of watershed protection in mountainous areas: a case study from Bolivia', *Mountain Research and Development* **17**(1): 19–30.
Rodwell, L.D., E.B. Barbier, C.M. Roberts, and T.R. McClanahan (2003), 'The importance of habitat quality for marine reserve-fishery linkages', *Canadian Journal of Fisheries and Aquatic Sciences* **60**: 171–181.
Rönnbäck, P., B. Crona, and L. Ingwall (2007), 'The return of ecosystem goods and services in replanted mangrove forests: perspectives from local communities in Kenya', *Environmental Conservation* **34**(4): 313–324.
Rosegrant, M.W., X. Cai, and S.A. Cline (2002), *World Water and Food to 2025: Dealing with Scarcity*, Washington, DC: International Food Policy Research Institute.
Ruitenbeek, H.J. (1994), 'Modeling economy-ecology linkages in mangroves: economic evidence for promoting conservation in Bintuni Bay, Indonesia', *Ecological Economics* **10**(3): 233–247.
Sarntisart, I. and S. Sathirathai (2004), 'Mangrove dependency, income distribution and conservation', in E.B. Barbier and S. Sathirathai (eds), *Shrimp Farming and Mangrove Loss in Thailand*, London: Edward Elgar, pp. 96–114.
Scherr, S.J. (1999), 'Poverty-environment interactions in agriculture: key factors and policy implications', Paper 3 in *United Nations Development Program and European Community, Poverty and Environment Initiative*, New York: UNDP.
Scherr, S.J. (2000), 'A downward spiral? Research evidence on the relationship between poverty and natural resource degradation', *Food Policy* **25**: 479–498.
Shackleton, C.M. and S.E. Schackleton (2006), 'Household wealth status and natural resource use in the Kat River valley, South Africa', *Ecological Economics* **57**: 306–317.
Shively, G.E. (1997), 'Poverty, technology, and wildlife hunting in Palawan', *Environmental Conservation* **24**(1): 57–63.
Shively, G.E. and M. Fisher (2004), 'Smallholder labor and deforestation: a systems approach', *American Journal of Agricultural Economics* **86**(5): 1361–1366.
Shone, B.M. and J. Caviglia-Harris (2006), 'Quantifying and comparing the value of non-timber forest products in the Amazon', *Ecological Economics* **58**: 249–267.
Silvano, R., A.M.S Udvardy, M. Ceroni, and J. Farley (2005), 'An ecological integrity assessment of a Brazilian Atlantic Forest watershed based on surveys of stream health and local farmers' perceptions: implications for management', *Ecological Economics* **53**: 369–385.

https://doi.org/10.1017/S1355770X1000032X Published online by Cambridge University Press

Takasaki, Y., B.L. Barham, and O.T. Coomes (2004), 'Risk coping strategies in tropical forests: floods, illness, and resource extraction', *Environment and Development Economics* **9**: 203–224.

United Nations Environment Programme (UNEP) (2006), 'Marine and coastal ecosystems and human wellbeing: a synthesis report based on the findings of the Millennium Ecosystem Assessment', Nairobi: UNEP.

Valiela, I., J.L. Bowen, and J.K. York (2001), 'Mangrove forests: one of the world's threatened major tropical environments', *BioScience* **51**(10): 807–815.

Vedeld, P., A. Angelsen, E. Sjaastad, and G.K. Berg (2004), 'Counting on the Environment: Forest Incomes and the Rural Poor', Environment Department Paper 98, World Bank, Washington, DC.

Walters, B.B., P. Rönnbäck, J.M. Kovacs, B. Crona, S.A. Hussain, R. Badola, J.H. Primavera, E.B. Barbier, and F. Dahdouh-Guebas (2008), 'Ethnobiology, socio-economics and management of mangrove forests: a review', *Aquatic Botany* **89**: 220–236.

Walton, M.E., M. Giselle, P.B. Samonte-Tan, J.H. Primavera, G. Edwards-Jones, and L. Le Vay (2006), 'Are mangroves worth replanting? The direct economic benefits of a community-based reforestation project', *Environmental Conservation* **33**(4): 335–343.

World Bank (2003), *World Development Report 2003*, Washington, DC: World Bank.

World Bank (2008a), *Poverty and the Environment: Understanding Linkages at the Household Level*, Washington, DC: The World Bank.

World Bank (2008b), *World Development Indicators*, Washington, DC: The World Bank.

World Commission on Environment and Development (1987), *Our Common Future*, New York: Oxford University Press.

Worm, B., E.B. Barbier, N. Beaumont, J.E. Duffy, C. Folke, B.S. Halpern, J.B.C. Jackson, H.K. Lotzke, F. Micheli, S.R. Palumbi, E. Sala, K.A. Selkoe, J.J. Stachowicz, and R. Watson (2006), 'Impacts of biodiversity loss on ocean ecosystem services', *Science* **314**: 787–790.

Wunder, S. (2001), 'Poverty alleviation and tropical forests – what scope for synergies?', *World Development* **29**: 1817–1833.

Wunder, S. (2008), 'Payments for environmental services and the poor: concepts and preliminary evidence', *Environment and Development Economics* **13**: 279–297.

Zilberman, D., L. Lipper, and N. McCarthy (2008), 'When could payments for environmental services benefit the poor?', *Environment and Development Economics* **13**: 255–278.

https://doi.org/10.1017/S1355770X1000032X Published online by Cambridge University Press