Chapter 16: Poverty and the distribution of ecosystem services

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16.1 Introduction

The planet's stocks of natural assets continue to diminish while widespread poverty persists throughout the developing world (Chen & Ravallion 2008). Recognizing the link between humans and nature has never been more salient for policymakers and researchers concerned with conservation and poverty alleviation (Sanderson & Redford 2003, Millennium Ecosystem Assessment 2005). Information detailing the specific links between the poor and the environment is building (e.g. Albla-Betrand 1993, Scherr *et al.* 2003, Delang 2006) and efforts are underway to determine how international agreements concerned with poverty alleviation can, and should, incorporate conservation as a means to their ends. For example, Roe and Elliott (2004) note that United Nations (UN) Millennium Development Goals (MDGs), adopted by the General Assembly of the UN, have direct ties to environmental condition and stability. Of the eight goals, only one is explicitly environmental, but the success of five others will rely on healthy ecosystems (Roe & Elliott 2004).

Incorporation of these advances in local and regional decision-making has proven challenging. Creating policies that account for interactions and trade-offs among environmental, economic and social values is difficult today because many of the connections between humans and the environment are not formally recognized by political and economic systems. Instead, decisions made today based on costs and benefits to society leave out many of the public goods and services provided to the poor by the environment, such as clean water, food from bushmeat and native plants, medicinal plants, and protection from “natural disasters,” such as storms and floods (Millennium Ecosystem Assessment 2005). For example, conventional household economic surveys fail to include directly the contributions of natural assets to rural household welfare (Cavendish 2000), making it difficult to assess how they are likely to respond to public or private programs that change the status of these resources. Similarly, ecosystem services that make up a country’s aggregated natural capital are largely absent in national accounting or show up indirectly after resources have been severely degraded. Progress in economic valuation of ecosystem services is needed to support the development of a standardized methodology for the inclusion of ecosystem values into Standard National Accounts (Mäler *et al.* 2008) and other policy decisions. The fundamental problem with incorporating ecosystem services into the balance sheets used in decision-making is the lack of tools that easily track the status of or changes in these services, and their distributional effects on human well-being.

In this chapter, we examine how the emerging field of modeling and mapping ecosystem services can address this gap. We begin by discussing the need for a detailed understanding of the linkages between poverty and ecosystem services, and provide a brief review of the literature on these links (section 16.2). We then examine the opportunities for and difficulties with an integrated approach to mapping poverty with ecosystem services (section 16.3). Finally, we demonstrate how several of the mapping and valuation models described in earlier chapters

(Chapter 8) and developed elsewhere can be applied in this context using case studies of the Amazon Basin and Guatemala's highlands (section 16.4).

16.2 Ecosystems services and the poor

16.2.1 Dependence of the poor on ecosystem services

Earth's ecosystems provide myriad goods and services that are essential to the well-being of all people, but natural capital contributes disproportionately to the welfare of the poor (see section 16.3.2 for a discussion of "poor"), in some cases significantly, because the poor have much more limited capacity to purchase goods and services from elsewhere (Table 16.1) (World Bank 2008). For instance, Vedeld *et al.* (2004) found that about 22% of rural household income can be attributed to the harvest of goods from forests, contributing almost twice as much to the incomes of the poor as to the non-poor (Table 16.1). This finding cannot be generalized to all rural households, but it is relevant to those living on the fringes of forests, those that are largely dependent on natural resources for subsistence, or those who are engaged in agricultural activities that rely heavily on natural capital and ecosystem processes (Box 16.1).

[Table 16.1 here]

In addition to providing income, natural resources can serve as safety nets for the poor during times of stress (Justice *et al.* 2001, World Bank 2008). The poor have been shown to respond to known agricultural risks and sudden agricultural shocks by increasing their dependence on natural resources (Pattanayak & Sills 2001), and the insurance provided by natural resources can make it feasible for households to recoup after natural disasters (McSweeney 2005). Large changes in access to or availability of these services are likely to have significant effects on the poor (Ferraro 2002, World Bank 2008), making it essential that policy makers recognize the possible costs choices related to resource sectors impose on the poor through changes in services (World Bank 2008).

[Box 16.1 here]

16.2.2 The poor as agents or victims of environmental degradation

Depending on the context, the poor may be agents of degradation, its victims, or both. When the poor are agents of environmental degradation, they can cause declines in ecosystem service provision for themselves and for others. For example, the use of forests for fuel wood and other non-timber forest products by the poor has been the main cause of forest degradation in India (Baland *et al.* 2006) and Tanzania (Luoga *et al.* 2000, Ndangalasi *et al.* 2007). Similarly, degradation in Peru's Pacaya-Samiria National Reserve was largely the result of the subsistence use of resources by households living around the reserve (Takasaki *et al.* 2004). Degradation can affect the functions of local ecosystems, increase ecological fragility, and increase the vulnerability of the poor to natural shocks (Shyamsundar 2001).

Despite its apparent irrationality, one of the reasons that households degrade ecosystem services that they rely on is that the impact of slow and incremental reductions in resource availability on welfare is small due to substitution effects. Households adapt to destruction of one resource over time by obtaining their resources from alternate areas or switching to alternate resources. As long as the opportunity cost of spending time to alter resource-use patterns is low, the welfare impact of degradation is likely to be small. In cases where the poor are agents of degradation, programs and policies designed to incentivize management activities that enhance ecosystem service provision would help advance goals of both poverty alleviation and conservation.

The poor often are victims of changes in ecosystem services caused by the activities of other sectors or people in other locations (Box 16.2). In these cases, the poor may benefit indirectly from regulations or incentive programs targeted at government or wealthier actors to control ecosystem service degradation in poorer areas. For example, through the Clean Water Act, the United States government has unintentionally redistributed wetland services (e.g., fish for food, flood mitigation, etc.) away from urban poor to areas with significantly lower population densities (Ruhl & Salzman 2006, BenDor *et al*. 2008). The equity impacts of this regulation are rarely addressed in the Clean Water Act decision-making process (BenDor *et al.* 2008). An alternative regulatory approach could intentionally direct wetland mitigation activities towards areas with poor populations, thereby improving the poor's access to wetlands' many services.

[Box 16.2 here]

16.3 Mapping poverty and ecosystem services

The relationship between the poor and natural resources is mediated by factors at various scales, such as labor and credit markets, property rights and other institutions, and information about best practices (Bluffstone 1995, Duraiappah 1998, Wunder 2001, Adhikari 2005). In some cases, a lack of markets contributes to degradation of natural systems; in other cases growth in markets can lead to the declines. Weak governance institutions, ill-defined property rights or lax enforcement, high discount rates, and population growth will all likely continue to contribute to degradation of local natural capital.

Given the complexities and variability of connections between the poor and the environment, how can mapping poverty and ecosystem services together help? This type of exercise holds great potential for resource management in diverse settings; however, we are still far from having the tools and information necessary to do such mapping widely. Ideally, poverty and ecosystem service mapping would be done such that (1) the resolution of both poverty and ecosystem service information is sufficient to represent patterns in each accurately, (2) the poverty indicators chosen are directly tied to the component of human well-being of interest and well matched with the ecosystem service(s) of concern, and (3) the institutions that control the provision of services are represented. Here, we discuss what can be done today as first steps towards this ideal and what challenges remain.

16.3.1 Data resolution

Robust poverty analyses require uniform and high-quality data that are often unavailable, especially in developing countries. In most cases, indicators such as poverty rates are only available for relatively large administrative units. These data are often of little use for detailed analysis because administrative boundaries seldom match those of the ecosystems of interest, and because neither ecosystem services nor the poor are likely to be distributed uniformly within these boundaries.

More detailed poverty maps are typically created by using comprehensive data from small-sample household budget surveys to obtain a predictive relationship for poverty rates that is then applied to data from a national census at the highest available level of disaggregation (Poggi *et al.* 1998, Elbers *et al.* 2002). This approach has been used to generate poverty maps for several countries (Hentschel *et al.* 2000, Minot 2000, Müller *et al.* 2006, Bedi *et al.* 2007, Nelson & Chomitz 2007). Although this approach can generate relatively detailed poverty maps, it still produces maps based on administrative divisions (census tracts) and not ecosystem boundaries. Nelson and Chomitz (2007) dealt with this limitation by converting a poverty map of Guatemala to a watershed map. Even with poverty maps aligned to ecosystem boundaries, the assumption of uniform distribution within an ecosystem can seriously distort analysis. Within a watershed, for example, it may matter whether the poor are concentrated in the steeper upper slopes or the flatter riparian zones (Box 16.1).

16.3.2 Poverty indicators

In addition to challenges with mapping poverty at an appropriate resolution for analysis, we also face the challenge of defining poverty in different settings. Poverty historically has been defined in strictly economic terms, with income as the common indicator. Some analysts now argue that consumption is a better measure of poverty, as it is more closely related to well-being and reflects capacity to meet basic needs through income and access to credit. It also avoids the problem of income flows being erratic at certain times of the year, especially in poor agrarian economies where fluctuations can cause reporting errors.

All money-based indicators have the limitation that they cannot reflect individuals' feelings of well-being and access to basic services. In recent years, a broader understanding has developed in which poverty encompasses not only deprivation of materially-based well-being, but also a broader deprivation of opportunities (World Bank 2001, UNEP 2004). The Millennium Ecosystem Assessment (MA) recognized five linked components of poverty: the necessary material for a good life, health, good social relations, security, and freedom of choice (Millennium Ecosystem Assessment 2005). Consider just one of these, security. A household's ability to address risks and threats can change dramatically even as income or consumption remain stable. Factoring in the effect of vulnerability, analysts estimate that monetary-based indicators can understate poverty and inequality by around 25% (World Bank 2001). In response, efforts have been made to develop non-monetary poverty indicators related to health, nutrition, or education, as well as composite indices of wealth (Wodon & Gacitúa-Marió 2001). While promising, these poverty indicators face methodological issues that make data acquisition or comparisons among countries difficult.

Poverty measures used in mapping are typically defined relative to a poverty line which is a cut-off separating the poor from the non-poor. For instance, the headcount index is a measure of poverty incidence that computes share of the population below the poverty line. An important distinction must be made between poverty rate which is the proportion of people in an area that are poor and poverty density which is the number of people in an area that are poor. Many previous efforts to map poverty have found that areas with high poverty rates are often areas with low population density, and thus a small absolute number of poor people. Poverty rates may be most relevant if an analysis aims to locate segments of a population that are worst off, but poverty density may be most relevant if the analysis aims to find regions with the greatest number of poor.

When choosing the appropriate poverty indicator(s) to map, we should also consider the ecosystem service(s) of interest and how the poor relate to those services. Pairings between ecosystem services and poverty indicators can be either direct or indirect. Pairings are "direct" if a change in the ecosystem service directly influences the poverty indicator of choice (Table 16.2). If there is not a causal link between the service and the indicator, the pairing is "indirect" (Table 16.2).

[Table 16.2 here]

In cases where the poor are agents of ecosystem service change, indirect pairings can be useful in mapping and modeling exercises used to design new programs. Consider a carbon offset program where a private sector buyer from a developed country wants to make payments to landholders in the tropics to plant trees in order to offset the buyer's carbon emissions. Mapping exercises could combine information on carbon sequestration potential and any indirect indicator of poverty to identify areas where sequestration projects could meet economic and conservation goals. An indirect indicator is appropriate here because poverty in this location is not directly related to the ecosystem service in question. The only requirement for the desired welfare transfer to the poor is that people who are poor have ownership rights or control over the deforested or degraded lands where carbon sequestration potential is high.

When the poor are victims of environmental degradation, or beneficiaries of services, improvements in well-being occur through improvements in service delivery, not through payments or incentives to the poor. In these cases, directly pairing ecosystem service provision with poverty indicators tied to the service(s) of interest is appropriate. For example, consider a change in the wetland mitigation example given above where the government requires developers to target offsets to benefit the poor. The most appropriate poverty indicators to use are those associated with wetland benefits: hunger where wetlands provide fish for consumption, access to clean drinking water where wetlands provide water filtration, or flood vulnerability where wetlands provide storm surge protection. Using an income-based indicator, such as the percent of the population below the poverty line, to recommend the allocation of improved wetland services would be inappropriate if household income is not sensitive to changes in wetland services.

16.4 Case studies

The following two case studies represent some of the analyses we can do today. They highlight the types of decisions that can be informed by currently available data and methods, while highlighting remaining challenges.

16.4.1 Deforestation in the Amazon Basin

The Amazon Basin is one of the world's most threatened and most diverse ecosystems, in terms of both biological and cultural diversity (~380 ethnic groups; Porro *et al.* 2008). Many of the people who reside here, poor and non-poor alike, rely directly on ecosystem services for their subsistence and livelihoods (e.g., Clement 1993, Barham *et al.* 1999, Pattanayak & Sills 2001). Alarming rates of forest loss in the basin (Malhi *et al.* 2008) cause great concern for biodiversity loss, but we still have little sense of what this loss means for society beyond species extinction and climate change (e.g., Laurance 1998, Ferraz *et al*. 2003). In this case study, we address current and future non-timber forest product (NTFP) harvest levels and implications for the poor.

First, we used a preliminary version of a new suite of ecosystem service models called InVEST (Nelson *et al.* 2008) to predict current levels of non-timber forest product harvest in the Amazon (Porro *et al.* 2008; see final model in Chapter 8). The model estimates the relative abundance of current non-timber forest product (NTFP) harvest as a function of the association between harvested species and habitat types, current NTFP stock (assuming that more pristine forests were harvested less in the past and had a higher stock of products for harvest today), travel time from population centers (≥ 1000 people) along roads and waterways, ease of product harvest and current legal protection from harvest (assuming enforcement) (Porro *et al.* 2008, Peralvo *et al.* 2008). Forest regions with greater stocks of an NTFP, that were easier to reach, and were currently open to all households were assumed t be used the most for the harvest of NTFPs; the region with the highest likely harvest has an index score of 1.0 for that NTFP. We focused on wood, fruits and nuts, and medicinal plants sold in the market and wood, fiber, hunted bushmeat, fruits and nuts, and medicinal plants used for subsistence (Fig. 16.1).

[Figure 16.1 here]

Next, we used both direct and indirect pairings of these NTFP harvest projections with poverty indicators to determine if current NTFP supply is aligned spatially with areas of poverty. We also investigated the impact of projected road expansion and deforestation over the next 20 years on NTFP supply (deforestation scenario from the Instituto de Pesquisa Ambiental da Amazonia, road development scenario from the Initiative for Integration of Regional Infrastructure in the South (Porro *et al.* 2008)). These analyses are the first step in understanding whether the poor are at a greater risk of losing their livelihood and well-being as a result of projected development.

We represented current poverty with percentage of underweight (UW) children (Fig. 16.2 a) and the percentage of the population with unsatisfied basic needs (UBN) (Fig. 16.2 c). The resolution of UW children data varied by country and was generally very coarse (census blocks range in area from 13,202 km^2 to 3,778,690 km^2). Basic needs refer to any human need where lack of satisfaction is considered to be an indicator of deprivation or poor living conditions (Abaleron 1995). Basic needs, and the appropriate measures used to define their satisfaction, vary dramatically across geographies. Therefore, a standardized method for measuring UBN exists and involves defining the basic needs of the population of interest, the appropriate measures for those needs, and the thresholds below which each need is considered unmet and people in such conditions can be considered poor (Abaleron 1995).

[Figure 16.2 here]

In this case, the basic needs considered were: access to housing (type of material used for house flooring, walls and roof and the number of people per room), access to sanitation (type of water supply source in the house and type and accessibility of bathrooms), access to education (presence or absence of at least one school-aged child not enrolled in school) and economic capacity (a calculation based on the age and number of household members, their highest level of education and their condition) (Schuschny & Gallopin 2004). Calculations were made using census data (at the scale of municipalities) from 1993 for Peru, Ecuador, Brazil and Colombia and from 2001 for Bolivia. The size of municipalities varies dramatically across the region and many important patterns in UBN are likely missed by the often large regions included in a single census block. Threshold levels for each need were set according to Feres and Mancero (2001).

We mapped two direct pairings of ecosystem services with a poverty indicator: the percentage of underweight (UW) children with food (fruits and nuts) for subsistence (Fig. 16.2 b) and underweight children with bushmeat for subsistence. All other pairings were indirect, linking UBN to harvest of marketed or subsistence NTFPs. In these cases we assumed that households near areas of greater NTFP harvest would be in a better position to satisfy their basic needs by directly consuming or selling harvested NTFPs than households not located near these bases of consumption and income supplementation.

In 2000, we estimated that forest product harvest for both subsistence and market sale was relatively higher in places where people had high UBN or UW children (Fig. 16.3). Superficially, this finding may suggest that forest products do not improve well-being. However, even though people in these regions are poor, forest products do make up a critical part of local incomes, supporting the health and nutritional well-being of many Amazonian forest-related households (Shanley *et al.* 2002). Deforestation leads to the loss of many of the most prominent and most profitable fruit and medicinal species that are not found in secondary forests (Shanley *et al.* 2002), thus continued forest loss is likely to contribute to declining household health and nutrition.

[Figure 16.3 here]

Finally, we found that over 20 years, the poor and non-poor alike will lose access to nearly all products analyzed (Fig. 16.3 a,c). However, the greatest losses in harvest are likely to occur in areas inhabited by the non-poor, or people with *lower* rates of underweight children and UBN (Fig. 16.3 b,d). That is to say, this preliminary analysis suggests that proposed expansion of roads and development in the Basin will not likely result in greater losses to the poor through decreases in forest products. This is probably because the region is so large and the future time window so relatively short that the overall change in the Basin is relatively small. Most change also happens near already developed areas that tend to be far from indigenous regions where rural poverty is generally higher (Porro *et al.* 2008). However, those currently enjoying low poverty rates are likely to experience the greatest losses and may be pushed across an important threshold as they lose access to forest products, resulting in a growing population of poor as defined by these indicators. Further, small losses to the poor may do greater harm than larger losses to the non-poor. Information on the importance of specific forest products to different groups, and an assessment of additional ecosystem services and revenue streams is needed to explore the impact predicted losses will have.

If we look not at the entire basin but at each country separately, we see a somewhat different story. In Brazil and Peru, regions with high UBN are predicted to see substantially greater declines in forest product harvest than areas that are better off (Fig. 16.4). Losses in medicinal plants harvested for market sale were also higher in underprivileged areas of Colombia (Fig. 16.4 a). We need additional information about resource access, demand and changes in other ecosystem services and other factors associated with well-being to make sound conclusions about how these changes are likely to affect the poor, but these trends suggest that the rural poor in certain Amazonian regions may be most vulnerable to declines in natural capital in these countries over the next 20 years. In addition, these analyses only pertain to the poor living within the Amazon basin, and do not include poor in urban settings in each country. Our analyses highlight the utility of simple mapping in identifying areas where the coupling of institutional information with ecosystem service information should be pursued.

[Figure 16.4 here]

16.4.2 Potential for payments for environmental services in highland Guatemala

Recent years have seen considerable interest in the development of programs of Payments for Environmental Services (PES). The PES approach aims to address the classic problem of environmental externalities by establishing a mechanism through which service users can compensate land users that provide the desired service, or that adopt land uses that are thought to improve provision (Wunder 2001, Pagiola & Platais 2007). Although the approach was conceptualized as a mechanism to improve the efficiency of natural resource management, most land users in upper watersheds are thought to be poor (CGIAR 1997, Heath & Binswanger 1996), and because most ecosystem services are thought to come from such areas (Nelson & Chomitz 2007), many have assumed that most potential PES recipients are poor. Others indicate that the linkages between potential PES recipients and poverty are more complex and show mixed results (Grieg-Gran *et al.* 2005, Pagiola *et al.* 2005, Ravnborg *et al.* 2007, Nelson &

Chomitz 2007, Pagiola *et al.* 2008). Further, while PES can benefit poor landowners, other poor populations may be negatively affected by the changes in land use through higher prices or lost employment (Zilberman, *et al.* 2008).

[Figure 16.5 here]

To examine whether PES approaches benefit the poor in practice, Pagiola *et al*. (2007) analyzed the spatial distribution of poverty in areas that are important to water services in highland Guatemala (Fig. 16.5). With about 56% of its population under the poverty line, Guatemala has one of the highest poverty rates in Central America (World Bank 2004). Guatemalan poverty is predominantly rural and extreme poverty is almost exclusively rural**:** over 81% of the poor live in rural areas. Pagiola *et al.* (2007) asked whether these poor could potentially benefit from PES for water services by comparing water supply areas to the distribution of poverty in highland Guatemala (Nelson & Chomitz 2007) (Fig. 16.6). They mapped the areas that provide water services ('water supply areas') by identifying the specific location of the intakes used by major users to obtain their water and then delineating the portions of the watershed that contribute water to those intakes. For example, Fig. 16.5 shows a sample map, highlighting the water supply areas serving hydroelectric power plants. The relative importance of each water supply area was estimated by constructing an index based on the measures of the magnitude of the service they provide (in this example, installed generating capacity) and the size of the water supply area. This analysis showed that the most valuable areas (on a per area basis) for water service provision are those serving mid-size users (who often have much smaller water supply areas).

[Figure 16.6 here]

The poverty rates in the water supply areas varied substantially (Fig.16.6, Fig.16.7). While some water supply areas had high poverty rates, others had low poverty rates. The water supply areas for hydroelectric power had relatively high poverty rates of 67% on average, but with a very high variance (Fig. 16.7a). Poverty rates were lowest in the water supply areas that provide Guatemala City's domestic water supplies (Fig. 16.6). The poverty density in water supply areas also varied substantially (Fig. 16.6 b). The average poverty density within water supply areas was 103 poor km^{-2}. This is slightly more than the average poverty density in the highland areas of the country of 83 poor km^{-2}, but the difference was not significant (Pagiola *et al.* 2007).

[Figure 16.7 here]

Across the entire highlands region, there was no correlation between the importance of a water supply area and the poverty rate of people living within it (Fig. 16.7). However, there were at least some areas with high water supply importance and a high incidence of poverty. This suggests that payments targeted to these areas would have the potential to meet the joint goals of ecosystem service provision and poverty alleviation. However, these analyses do not include information about the nature of institutions in the region governing control of the water supply or the relationship between the poor and water-regulating land use activities. The poor in important water supply watersheds may have no control over land use practices that alter the provision of water-related services, and as such, payments made to the poor may not result in ecosystem service returns. If the poor control water resources and PES mechanisms were developed in all the water supply areas, 1.76 million people, or 73% of the poor in highland Guatemala could potentially be reached. This figure engenders enough promise that taking the next step to identify water resource institutions in highland Guatemala would be well worth the investment.

16.5 Including institutions: The way forward

As the case studies demonstrate, overlaying maps of poverty indicators and ecosystem services can be an informative first step in understanding the complex relationships between the poor and the environment, but it is not sufficient. Current poverty mapping seldom makes explicit connections between the poor and the resources they rely on. For example, poverty maps rarely distinguish between land owners and the landless, simply because the necessary information is not available. Land users that are renters have less ability to dictate how resources are managed. Similarly, even if land users have title to their land, their tenure may be insecure or not supported by local institutions. Again, this will inhibit their ability to change practices and alter the level of ecosystem services provided by the landscape. Information about institutions such as property rights, ownership, or management responsibility, and their stability must be incorporated into poverty mapping exercises to maximize their utility for understanding who currently provides and benefits from ecosystem services, and who will gain or lose from future management changes.

Box 16.1 Natural capital as a pathway out of poverty

C. Peter Timmer

Historically, the major pathway out of poverty has been the structural transformation of economies, where the share of agriculture in employment and value added to the national economy declines as the share of urban industry and modern services rises. Labor productivity is higher in urban activities, and migration from rural to urban jobs raises wages at both ends. In a broad sense, this transformation has been a transition from dependence on biological processes of production--especially in agriculture--to physical processes of production—primarily in manufacturing processes for metals, chemicals, and automobiles, which are still intensive in their use of natural resources. Ultimately, the main source of economic growth—and poverty reduction--has been in knowledge-intensive processes such as finance, information technology, and communications. In short, reducing poverty has meant reducing reliance on natural capital.

This evolution away from apparent dependence on natural capital as the source of economic growth and livelihoods for the poor obviously missed a key point: we all have to eat. It was easy to miss the point: in rich countries with highly productive agriculture, there are more lawyers than farmers. The structural transformation has as its endpoint "a world without agriculture," or at least a world where the farm sector behaves economically like all other sectors in the economy and apparently has no distinguishing features that matter to economists—productivity of labor or returns on capital.

But the importance of our dependence on agriculture as the most efficient way for human society to capture solar energy in a form that we can consume has returned with a vengeance, in the form of high food prices. There is vigorous debate over the causes of the price resurgence, but most analysts feel that the link between energy prices and food prices that has been established by bio-fuel programs in the Unites States (ethanol from corn) and Europe (bio-diesel from vegetable oils) now means that high fuel prices mean high food prices. “Renewable energy” largely means capturing it from the sun, and photosynthesis remains the most efficient way of doing that over large expanses of land.

Natural capital means far more than agriculture, of course, and most researchers in the field spend most of their energy understanding the value to local economic productivity of biodiversity from natural ecological systems. But this focus is too narrow. Unless we understand the broader context in which natural capital has value, especially in the link between capturing solar energy as an agricultural activity and the subsequent role of agriculture in economic development and poverty reduction, we will not be able to understand the role of natural capital in poverty reduction directly.

The major dilemma, for economists and policy makers, is in placing a monetary value on the output from agriculture. There is simply no other way to know what that output is worth—i.e. how much to invest in expanding that output, what natural resources should be committed to the endeavor, how “unvalued” natural capital should be utilized (and thus valued), and who has ultimate stewardship over all the resources that go into agricultural production.

For many decades rich countries have sought mechanisms to place a higher value on their agricultural sectors than market prices would indicate, and thus, implicitly, value the underlying natural resources committed to agricultural production more highly. At least three rationales for supporting agriculture in rich countries at taxpayer and consumer expense are increasingly accepted by mainstream policy analysts as reflecting appropriate public action in the face of market failures. These are: support for the multiple functions that agriculture performs, beyond the commodity production that is offered for sale ("multi-functionality"); support for "local" food systems that might offer reduced carbon footprints for most food consumers and possibly even fresher and healthier food; and support for bio-fuel production as a mechanism to break dependence on imported fossil fuels and slow emissions of greenhouse gases.

Multi-functionality and the non-market contributions of agriculture.

Bucolic landscapes, green buffers to urban density, preservation and development of rural societies, domestic food security, and flood alleviation through proper land management all have economic value even if there is no market price for their "production." The basic argument for the multi-functionality of agriculture as a basis for policy support to farmers is that these non-commodity outputs, although essential to economic, environmental and social well-being, are unpaid by-products of commodity production. If farmers are paid only the market price for their commodities, the by-products will not be produced in optimal amounts, and may be lost altogether if farmers are forced out of business because of international competitive pressures.

Efforts to value in economic terms the flow of multiple services from natural ecosystems, including agriculture, need far more analytical research and empirical testing. With better valuation will come better designed initiatives to conserve natural resources and better mechanisms to pay the provider of these services, including farmers. From an economic perspective, simply paying farmers to do more of what they do anyway cannot be an efficient use of fiscal or natural resources. Agriculture performs multiple functions, but finding ways for the market to value, and pay for, these functions will be essential to sustainable production.

Local food systems.

Buying food that is produced "locally" is the current agenda for two related causes: the anti-globalization movement and the sustainability movement. The anti-globalization movement has its roots in a clear sense of lost control over something as deeply felt as where the food on our tables comes from. Modern supply chains seem impervious to consumer desires to control what they eat. The sustainability movement has its roots in the broader environmental movement that now links to climate change as the key challenge to quality of life in rich and poor countries alike. Can transporting food thousands of miles, often on jet freighters, possibly be a sustainable way of eating? Will buying and consuming foods produced locally make any difference to either of these agendas?

Economic efficiency has a hard time entering these debates. Both the anti-globalization and sustainability movements specifically reject market prices as the basis for evaluating decisions about what consumers should consume, because these prices have too many subsidies and distortions to reflect real opportunity costs in terms of natural resources used. There is some merit to these arguments. The question is, should the "local food movement" receive more policy support?

Consumers, especially wealthy consumers, like to know where their food comes from and buy from producers who are neighbors. The rapid growth of farmers' markets, of organic food, and of "local food" sections in supermarkets is testimony to this basic desire. The trend bears watching, because it is the ultimate form of agricultural protection. Expanded trade has been the basis of much economic growth, and restricting it could have serious and unforeseen consequences.

Bio-fuels and the potential to reverse the structural transformation.

Bio-fuels are not exactly new. Although coal, the first fossil fuel, was known in China in pre-historic times, and was traded in England as early as the 13^{th} century, it was not used widely for industrial purposes until the 17^{th} century. Until then, bio-fuels were virtually the only source of energy for human economic activities, and for many poor people they remain so today. But the widespread use of fossil fuels since the Industrial Revolution has provided a huge subsidy to these economic activities—because coal and later petroleum were so cheap--a subsidy which seems to be nearing an end. Are bio-fuels the answer to growing scarcity of fossil fuels?

Not surprisingly, the answer depends on the role of agriculture in individual countries, the pattern of commodity production and the distribution of rural assets, especially land. It is certainly possible to see circumstances where small farmers respond to higher grain prices by increasing output and reaping higher incomes. These incomes might be spent in the local, rural non-farm economy, stimulating investments and raising wages for non-farm workers. In such environments, higher grain prices could stimulate an upward spiral of prosperity.

An alternative scenario seems more likely however, partly because the role of small farmers has been under so much pressure in the past several decades. If only large farmers are able to reap the benefits of higher grain prices, and their profits do not stimulate a dynamic rural economy, a downward spiral can start for the poor. High food prices cut their food intake, children are sent to work instead of school and an intergenerational poverty trap develops. If the poor are numerous enough, the entire economy is threatened, and the structural transformation comes to a halt. The share of agriculture in both employment and GDP starts to rise, and this reversal condemns future generations to lower living standards.

A reversal of the structural transformation as the regular path to economic development and reduced poverty would be a historical event, countering the patterns generated by market forces over the past several centuries. Such an event would have stark political consequences, as populations seldom face the prospect of long-term reductions in living standards with equanimity. It is possible, of course, that new technologies will come on-stream and lower energy costs across the board and thus allow the bio-fuel dilemma to disappear quietly. But it could be a rocky couple of decades before that happens.

Box 16.2 Poverty and ecosystem service mapping at work in Kenya

Norbert Henninger and Florence Landsberg

A new atlas of Kenya, designed to improve understanding of the relationships between poverty and the environment, was released in 2007(World Resources Institute 2007). The atlas and its 96 different maps include significant policy and economic development analyses that will be useful to policy-makers worldwide. This collection of maps is a step forward from the landmark findings of the 2005 Millennium Ecosystem Assessment – that 15 of the world's 24 ecosystem services are degraded. It will help enable other countries to develop their own similar maps.

Professor Wangari Maathai, 2004 Nobel Peace Laureate, said of the Atlas, "As a result of this type of work, we will never be able to claim that we did not know. Planting trees has been a way to break the cycle of diminishing resources for the women of the Green Belt Movement. I see the ideas and maps in this Atlas to be much like a small seedling. If nurtured, if further developed and grown, and if used by both government and civil society, this seedling carries the promise of breaking the cycle of unenlightened decision-making that is not accountable to the people most affected by economic or environmental changes; that does not consider the impact on our children and grandchildren."

[Box Figure 16.1 here]

As an example, one map from *Nature's Benefits in Kenya* outlines the upper watersheds of the Tana River and combines that with poverty rates in 222 administrative areas (Box Fig. 16.1). Most of the poorer communities are located in the drier plains downstream of the foothills of the Aberdare Range and Mount Kenya. The quantity and quality of the surface water supply for these poorer communities is highly dependent upon the use of land and water resources by the upstream communities. If upstream users withdraw large quantities of water, little is left for families downstream. If upstream users contaminate the water supply, families downstream bear the consequences. Communities and decision-makers need to be aware of these relationships to make better management and policy decisions. For example, upstream investments in improved watershed management to reduce water pollution and water shortages could yield two benefits: improved ecosystem health and benefits to poor downstream communities. However, any mechanism to pay for these changes in the supply of ecosystem services cannot rely on the downstream communities because of their lack of resources.

Similarly, other maps in the Atlas show how and where people derive benefits from the land and how that relates to the spatial pattern of human well-being. The Atlas is designed to inspire improved analysis of poverty-environment relationships and informed decision-making.

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Table 16.1: Environmental income as percentage of total income in resource-poor and resource-rich areas. In most cases, “poor” refers to poorest 20% and “rich” to the richest 20% of households. Adapted with permission from World Bank (2008).

	Resource-Rich Areas		Resource-Poor/ Low Access Areas		Average	
Study	**Poor**	**Rich**	**Poor**	**Rich**	**Poor**	**Rich**
Jodha (1986)					9-26	1-4
Cavendish (2000)			44	30		
Vedeld et al. (2004)[a]					32	17
Narain et al. (2005)	41	23	18	18		
Chettri-Khattri (forthcoming)[b]	20	14	2	1		

[a] Data reported are from multiple earlier studies.
[b] Nontimber forest product (NTFP) income only.

Table 16.2. Pairing Ecosystem Services with Poverty Indicators. Pairs where the poverty indicator could be directly influenced by a change in the ecosystem service are "direct" (D). Pairs where there is not a causal linkage between the service and the indicator are "indirect" (I). HDI = Human Development Index. UBN = Unsatisfied Basic Needs.

	Poverty Indicator						
Ecosystem Service	**Water Poverty Index**	**Child Hunger**	**Infant Mortality**	**HDI**	**Income**	**UBN**	**Literacy**
Clean water	D	I	D[b]	I	I	D[d]	I
Food	I	D	D	I	I	I	I
Medicinal plants	I	D	D	I	I	I	I
Timber	I	I	I	I	I	I	I
Carbon sequestration	I	I	I	I	I	I	I
Pollination	I	D[a]	I	I	I	I	I
Erosion control	I	I	I	I	I	I	I

[a] If local food crops need insect pollination.
[b] If diarrhea from waterborne disease is large cause of infant mortality.
[c] If one of the unsatisfied basic needs is clean water.

Figure 16.1 Distribution of forest product harvest index in the Amazon Basin in 2000. The relative harvest index for bushmeat for subsistence (a), fiber for subsistence (b), fruits and nuts for subsistence (c) or market (d), medicinal plants for subsistence (e) or market (f), and wood for subsistence (g) or market (h) varied across the Basin. All units are a relative harvest index in which the parcel with the highest likely harvest received a score of 1.0.

Figure 16.2 Poverty indicators and representative forest product harvest distributions in the Amazon Basin. The incidence of underweight children is highest in northern Peru and eastern Ecuador (a) while unsatisfied basic needs are highest in Bolivia (c). High poverty areas defined as those above the 75^{th} percentile for underweight children (outlined in dark black) are shown in a direct pairing, overlaid with the harvest index of fruits and nuts for subsistence (b). High poverty areas defined as those above the 75^{th} percentile for unsatisfied basic needs are shown in an indirect pairing, overlaid with the harvest index of wood for market sale (d). Units for underweight children are percentage of the population under the age of five that is underweight. Units for unsatisfied basic needs are the percentage of the population with unsatisfied basic needs. The legends and units for (b) and (d) are the same as in Figure 16.1 (c) and (h).

Figure 16.3 Distribution of forest product harvest index in 2000 and loss by 2020 between the poor and non-poor in the Amazon Basin. The harvest index for fruits, nuts and bushmeat collected for subsistence use was higher in areas with high rates of underweight children (a, black bars) than in areas with low rates (a, gray bars). The harvest index of products for subsistence or market sale were also relatively more abundant in areas with high rates of unsatisfied basic needs (c, black bars) than in areas with low rates (b, gray bars). Both the poor and the non-poor are projected to lose non-timber forest product provision in the next 20 yrs, but the non-poor will lose more, on average (b, d, gray bars) than the poor (b, d, black bars). High rates are defined as the upper 25th percentile. Meat = bushmeat, Med = medicinal plants.

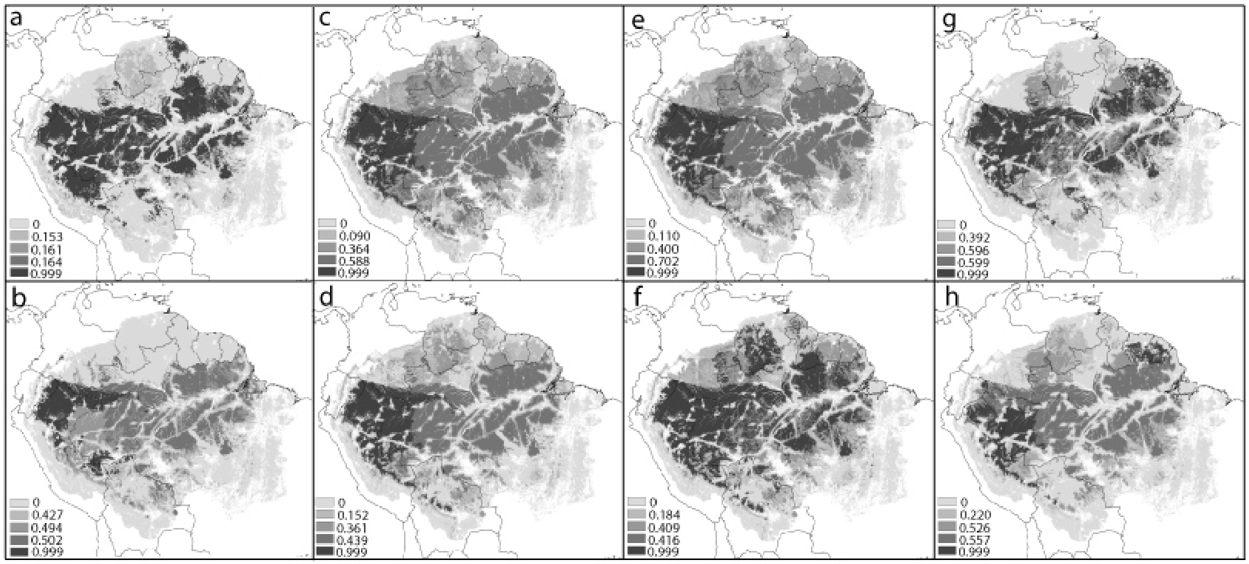
Figure 16.4. Predicted losses of forest product harvest after 20 years of deforestation and road expansion in individual countries in the Amazon Basin. Patterns were different at the country scale. Areas with high rates of unsatisfied basic needs (black bars) showed greater declines in the harvest index for medicinal plants for market sale in Brazil, Peru and Colombia (a). This same pattern of disproportional loss in areas of high unsatisfied basic needs (black bars) held for wood (b) and food for market sale (c) as well as hunted bushmeat (d) and medicinal plants for subsistence use (e) in Brail and Peru. High rates of underweight children or unsatisfied basic needs are those above the 75th percentile value for the country. Units in all graphs are the decline in relative abundance index. Error bars show standard error.

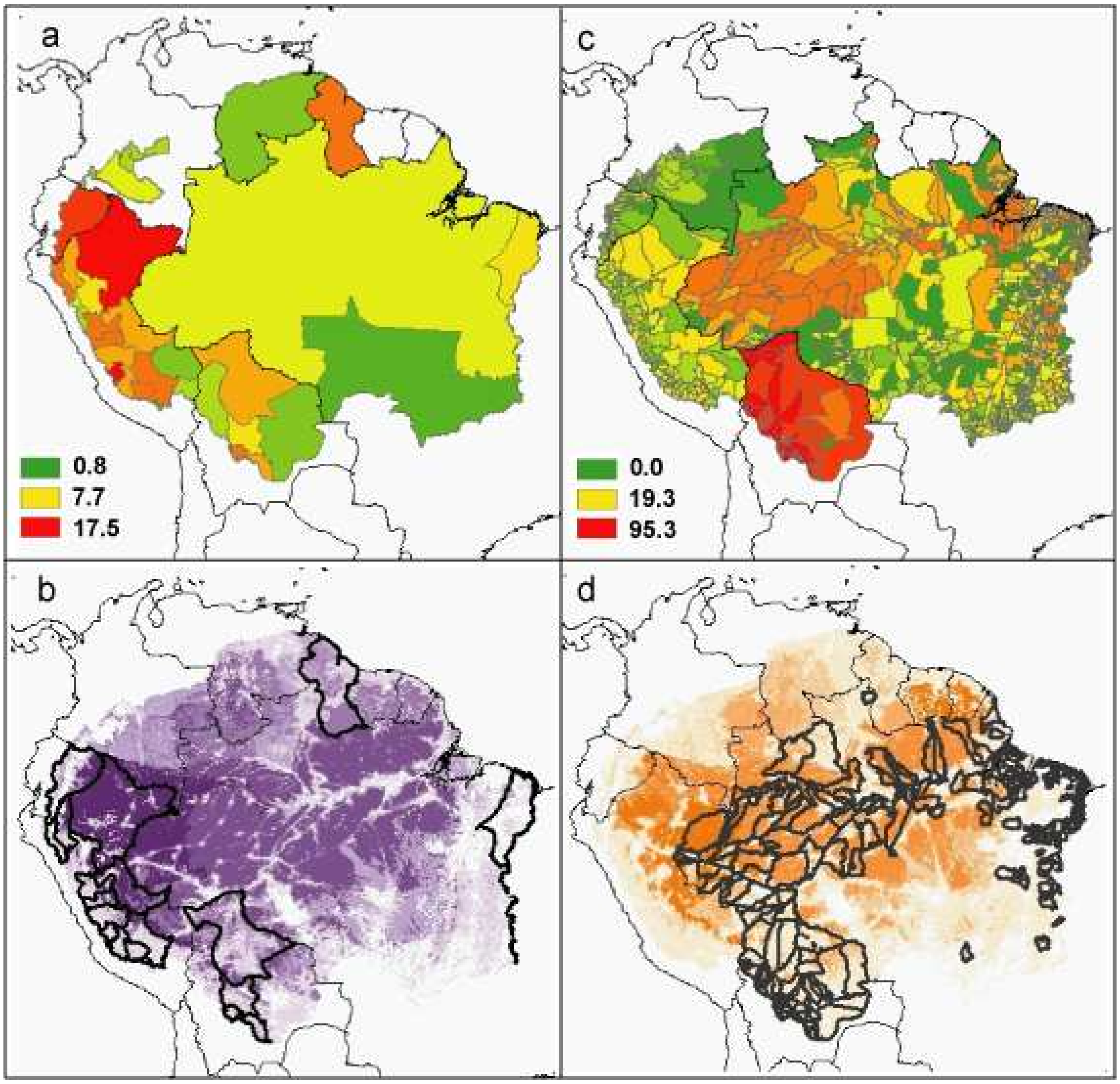
Figure 16.5 Water supply areas for principal surface water users in highland Guatemala. Major uses highlighted are hydroelectric power generation in generating capacity per hectare of upstream area (kW ha^{-1}) (a), large-scale irrigation as irrigated area per hectare of upstream area (ha ha^{-1}) (b), domestic water supply as households served per hectare upstream area (households ha^{-1}) (c) and coffee mills as production quantity per hectare of upstream area (quintal ha^{-1}) (d).

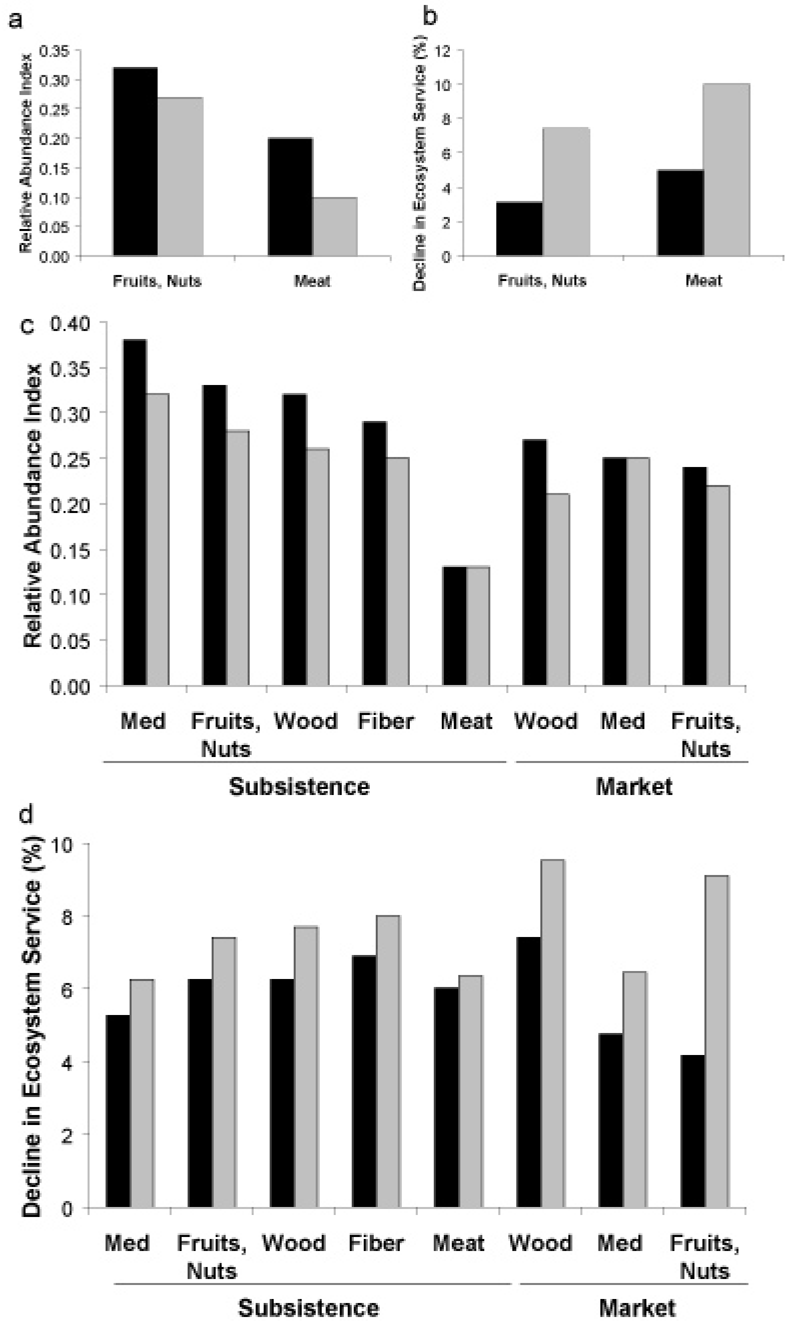
Figure 16.6 Spatial distribution of poverty in Guatemala. Patterns are shown for both the poverty rate (number of poor) (a) and poverty density (number of poor ha^{-1})(b). The water supply areas for major water use points are outlined in black. The poor are defined as those under Guatemala's official poverty line, which is estimated using data from the 1994 census and consumption data from a household survey from 1998-1999. The household-unit imputations are aggregated to small statistical areas to estimate the percentage of households living below the poverty line (Nelson and Chomitz 2007).

Figure 16.7 Relationship between poverty rate and importance of water supply areas. Patterns are shown for water used to generate hydropower (a), for domestic consumption (b), for general irrigation (c) and for coffee production (d). Importance is defined by allocating the amount of supply delivered to a use point equally across the supplying watershed.

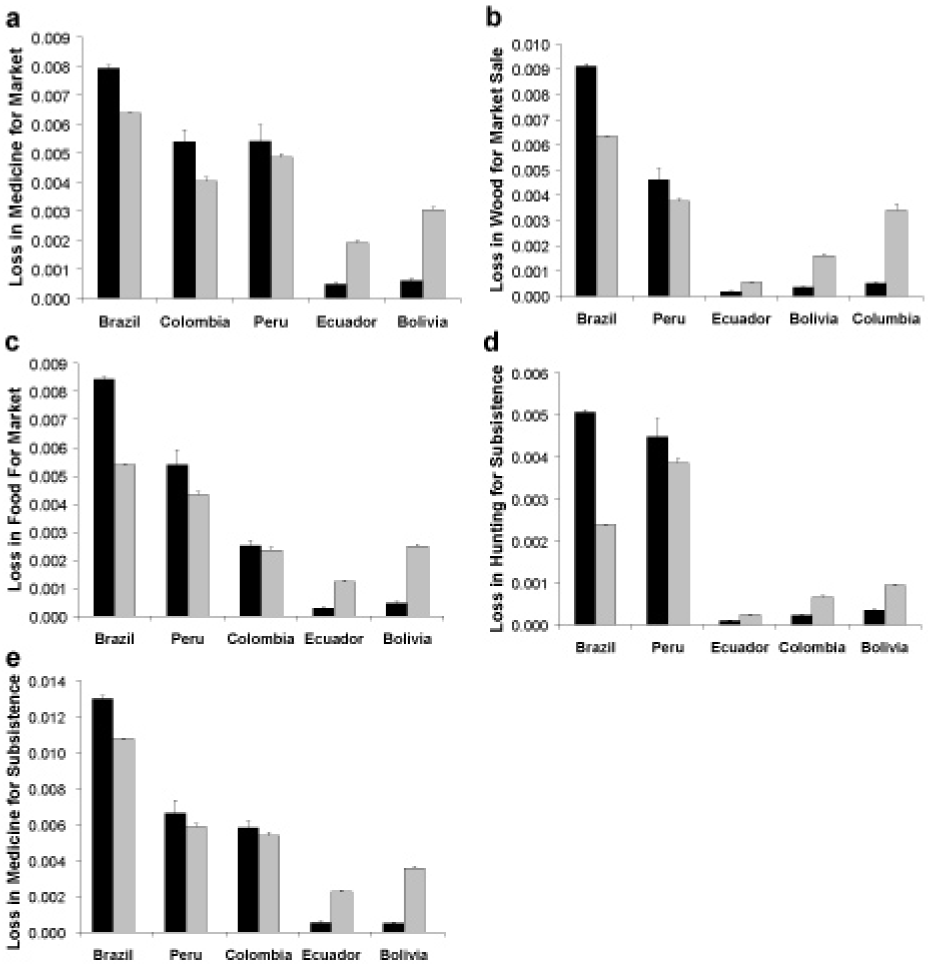
Box Figure 16.1 Map of the Tana River headwaters in Kenya, and the distribution of poor communities.

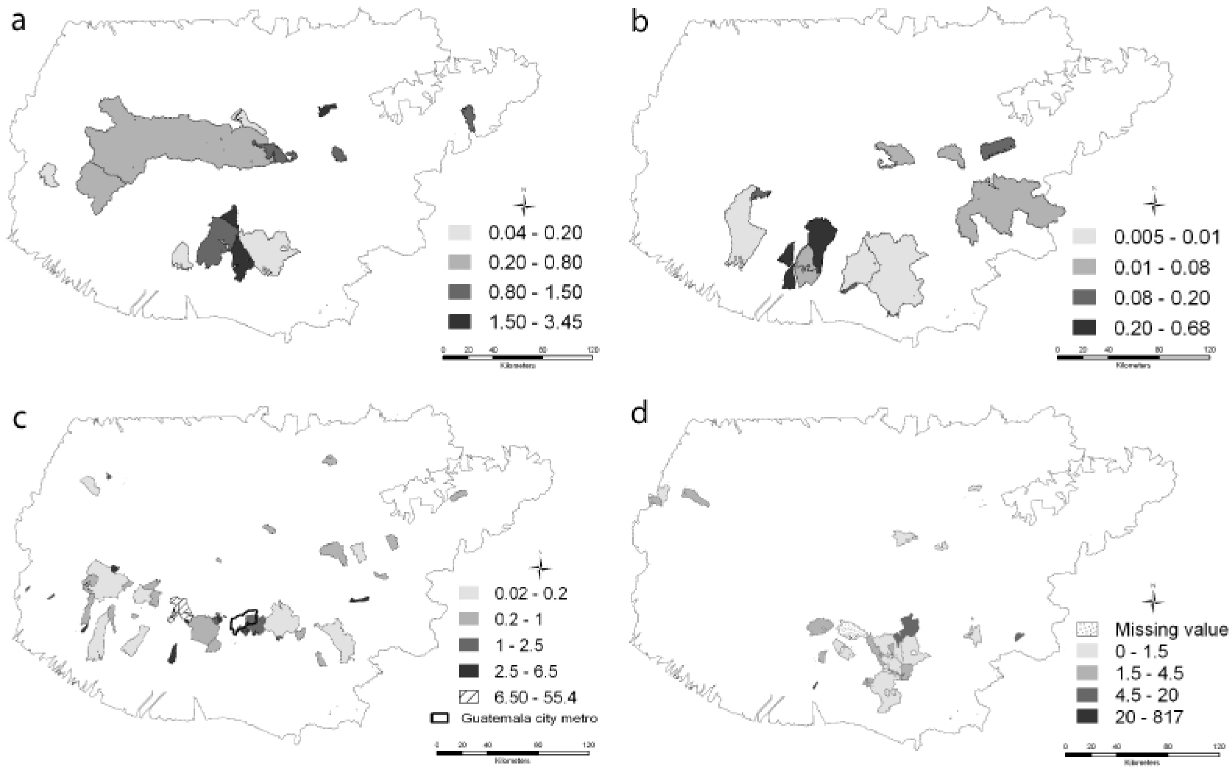

a
0
0.153
0.161
0.164
0.999
c
0
0.090
0.364
0.588
0.999
e
0
0.110
0.400
0.702
0.999
g
0
0.392
0.596
0.599
0.999
b
0
0.427
0.494
0.502
0.999
d
0
0.152
0.361
0.439
0.999
f
0
0.184
0.409
0.416
0.999
h
0
0.220
0.526
0.557
0.999


a
0.8
7.7
17.5
c
0.0
19.3
95.3
b
d

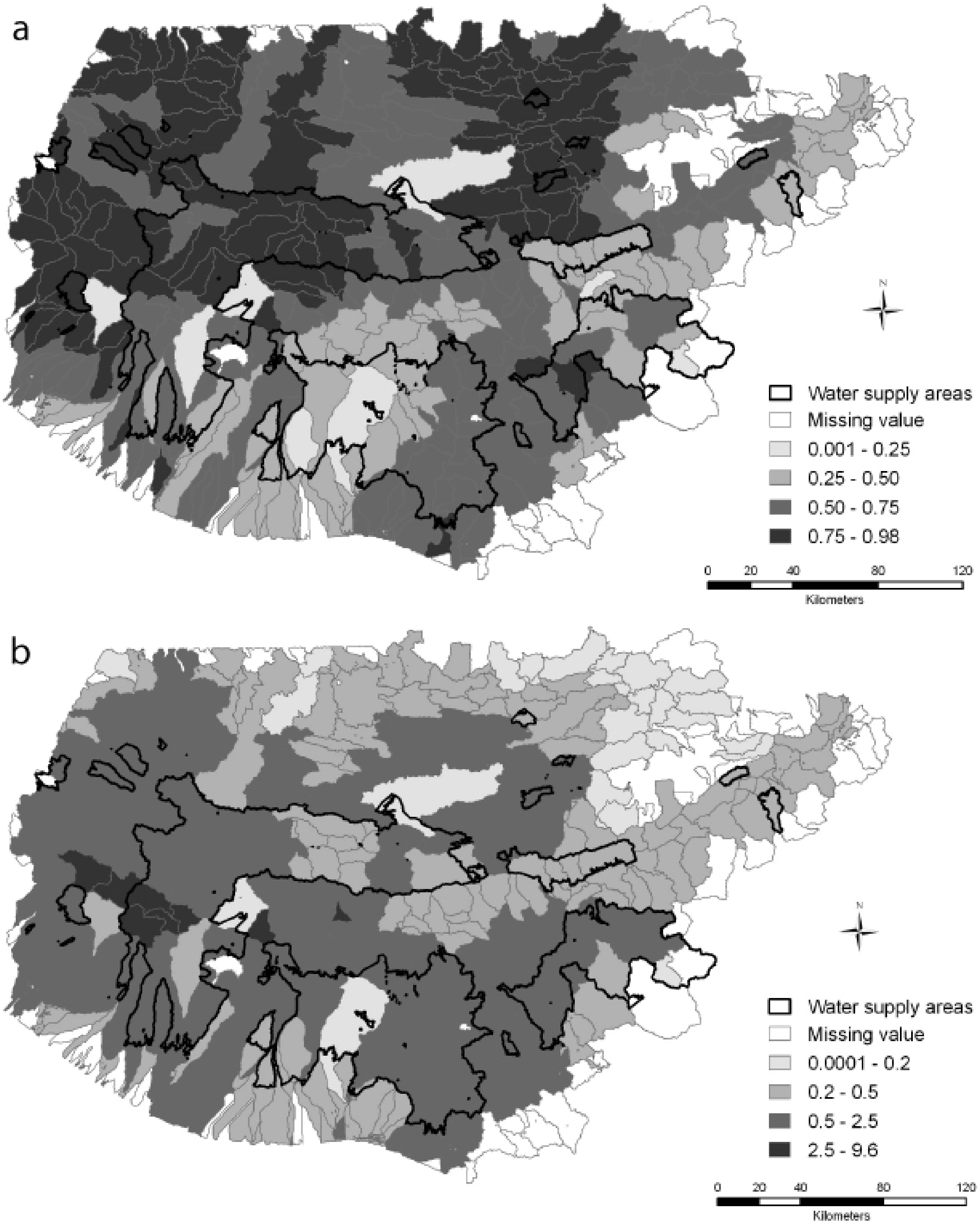


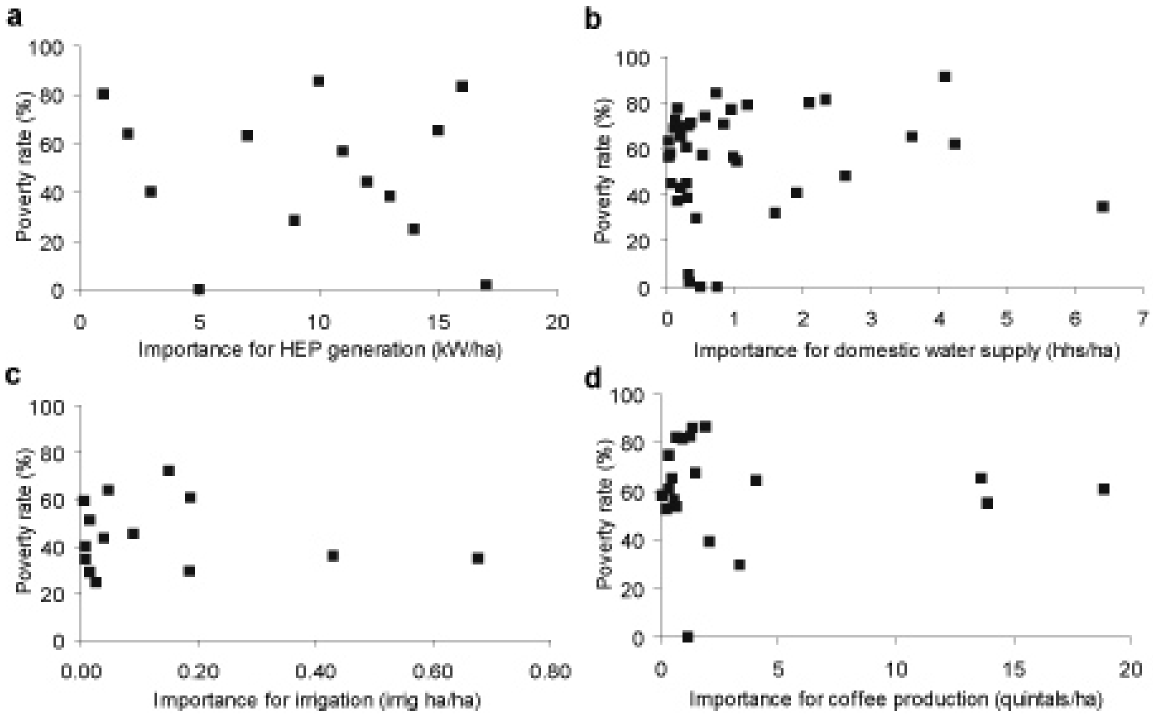
a
Relative Abundance Index
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Fruits, Nuts
Meat
b
Decline in Ecosystem Service (%)
12
10
8
6
4
2
0
Fruits, Nuts
Meat
c
Relative Abundance Index
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Med
Fruits, Nuts
Wood
Fiber
Meat
Wood
Med
Fruits, Nuts
Subsistence
Market
d
Decline in Ecosystem Service (%)
10
8
6
4
2
0
Med
Fruits, Nuts
Wood
Fiber
Meat
Wood
Med
Fruits, Nuts
Subsistence
Market

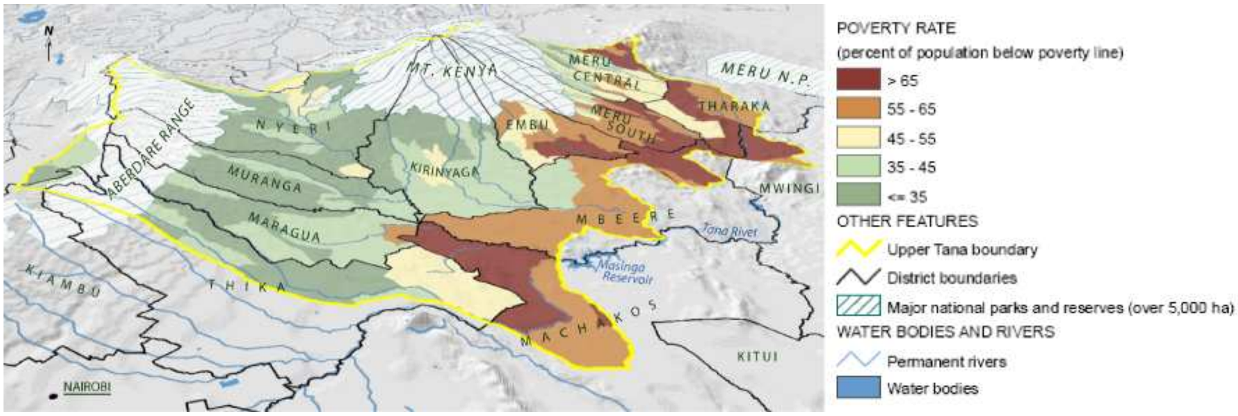

a
Loss in Medicine for Market
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0.000
Brazil
Colombia
Peru
Ecuador
Bolivia
b
Loss in Wood for Market Sale
0.010
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0.000
Brazil
Peru
Ecuador
Bolivia
Columbia
c
Loss in Food For Market
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0.000
Brazil
Peru
Colombia
Ecuador
Bolivia
d
Loss in Hunting for Subsistence
0.006
0.005
0.004
0.003
0.002
0.001
0.000
Brazil
Peru
Ecuador
Colombia
Bolivia
e
Loss in Medicine for Subsistence
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
Brazil
Peru
Colombia
Ecuador
Bolivia



a
0.04 - 0.20
0.20 - 0.80
0.80 - 1.50
1.50 - 3.45
b
0.005 - 0.01
0.01 - 0.08
0.08 - 0.20
0.20 - 0.68
c
0.02 - 0.2
0.2 - 1
1 - 2.5
2.5 - 6.5
6.50 - 55.4
Guatemala city metro
d
Missing value
0 - 1.5
1.5 - 4.5
4.5 - 20
20 - 817


a
Water supply areas
Missing value
0.001 - 0.25
0.25 - 0.50
0.50 - 0.75
0.75 - 0.98
0 20 40 80 120
Kilometers
b
Water supply areas
Missing value
0.0001 - 0.2
0.2 - 0.5
0.5 - 2.5
2.5 - 9.6
0 20 40 80 120
Kilometers


a
Poverty rate (%)
Importance for HEP generation (kW/ha)
b
Poverty rate (%)
Importance for domestic water supply (hhs/ha)
c
Poverty rate (%)
Importance for irrigation (irrig ha/ha)
d
Poverty rate (%)
Importance for coffee production (quintals/ha)


N
MT. KENYA
MERU CENTRAL
MERU N.P.
THARAKA
MERU SOUTH
EMBU
ABERDARE RANGE
NYERI
KIRINYAGA
MURANGA
MARAGUA
MWINGI
MBEERE
Tana River
Masinga Reservoir
KIAMBU
THIKA
MACHAKOS
KITUI
NAIROBI
POVERTY RATE
(percent of population below poverty line)
> 65
55 - 65
45 - 55
35 - 45
<= 35
OTHER FEATURES
Upper Tana boundary
District boundaries
Major national parks and reserves (over 5,000 ha)
WATER BODIES AND RIVERS
Permanent rivers
Water bodies