On biodiversity conservation and poverty traps

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This paper introduces a special feature on biodiversity conservation and poverty traps. We define and explain the core concepts and then identify four distinct classes of mechanisms that define important interlinkages between biodiversity and poverty. The multiplicity of candidate mechanisms underscores a major challenge in designing policy appropriate across settings. This framework is then used to introduce the ensuing set of papers, which empirically explore these various mechanisms linking poverty traps and biodiversity conservation.

development | ecosystem | natural resources | sustainability | wildlife

Stemming biodiversity loss and reducing poverty are global challenges of the first order, enshrined in both the Convention on Biological Diversity and the Millennium Development Goals, agreed by virtually all countries over the past decade. The world is nonetheless struggling to meet the ambitions expressed in those global accords. The World Wide Fund for Nature International finds that the earth's wildlife populations have declined by a third over the past 35 y alone but by even more, 60%, in poorer tropical regions (1). The rate and magnitude of these losses will define the earth's sixth mass extinction period unless we quickly reverse this decline (2). Meanwhile, leaving aside the remarkable case of China, the number of people living in extreme poverty increased by more than 30% from 1981 to 2004 and now surpasses 1 billion (3).

The persistence of extreme poverty and continued rapid loss of biodiversity appear intimately related. Extreme poverty and biodiversity hot spots are geographically coincident, concentrated in rural areas where livelihoods depend disproportionately on natural capital embodied in forests, rangelands, soils, water, and wildlife. Colocation naturally gives rise to closely coupled human-managed ecosystems that are in a precarious balance at best. Lack of resources, institutions, and governance structures often leaves local people ill-equipped to institute mechanisms to ensure long-term resource maintenance. Compounding this problem, the conditions of the human and nonhuman species within ecosystems coevolve in response to subtle shifts in any of several subsystems.

Despite the importance of this coevolutionary relationship, connections between poverty traps and biodiversity conservation remain remarkably underexplored, not only in formal theorizing* but especially empirically. We have surprisingly little observational or experimental detail describing interactions in closely coupled human and natural systems in the rural tropics. In the absence of rigorous evidence on the synergies or tradeoffs between biodiversity conservation and escape from poverty traps, opinion and untested hypotheses predominate and crucial linkages are too often overlooked. Conservationists typically ignore the predictable consequences of human agency; people adapt behaviors in response to changes in environmental management, often generating unintended consequences that undermine conservation objectives (6). Similarly, those implementing economic development interventions often cannot foresee environmental sequelae, whether direct or triggered by changes in human behavior in response to an intervention. Poverty researchers are only beginning to grasp the importance of understanding the dynamics of the ecosystems on which many livelihoods and technologies depend and the feedback between human and natural processes, perhaps especially in smallholder agrarian systems (7). Few efforts to achieve "win-win" solutions (e.g., bioprospecting, ecotourism, integrated conservation and development projects, payments for ecosystem services) have fully delivered on their promises. In addition, few studies carefully assess both the socioeconomic and environmental impacts of such efforts. There is scant empirical evidence that could support or refute the hypotheses underlying these approaches, or could provide a basis for modeling of the interrelationship between biodiversity conservation and poverty traps in areas of endemic poverty.

This special feature explores these connections, particularly marshaling empirical evidence from a range of poor areas and at different scales of analysis to begin to assemble a solid evidence base that can be used as a foundation for conservation and poverty reduction efforts moving forward. We seek more than mere statistical associations; we want to push toward a firmer grasp of causal mechanisms to guide interventions aimed at conserving nature, at helping people escape poverty, or both. Several serious challenges are broadly noteworthy for studies associating biophysical and social aspects of conservation and poverty: the absence of landscape-scale matched controls, the absence of sufficient baseline or historical data in both disciplines, and the general absence of credible counterfactual analysis. The research papers assembled in this special feature do not conclusively surmount all these challenges, but they improve our empirical understanding of the complex connections between biodiversity conservation and poverty traps, and describe new approaches to tackling these interrelated global problems.

Definitions and Concepts

The underexploration of these connections is somewhat surprising, because theorists working in both ecology and the social sciences use similar frameworks that draw on basic concepts from the mathematics of dynamical systems. Let us begin with more precise definition of these terms and concepts and then illustrate them with examples.†

Coupled human and natural systems can be represented in terms of their time-specific states in multiple dimensions, including human poverty or biodiversity. A system's "phase space," representing all possible states of the system, can be partitioned into regions, such that if the initial state of the system falls within that region, the system remains there. The system is stable, or resilient, within that region, meaning that perturbations that change

*Important exceptions offering integrative modeling approaches include those described by Dasgupta (4) and by Carpenter and Brock (5).

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†These concepts are developed with greater detail and precision by Dasgupta (8).

a state within the region merely change the short-term path to the same long-term state. However, when there exist multiple such regions, often termed "basins of attraction," there necessarily exist boundaries among them, commonly referred to as "separatrices," "thresholds," or "tipping points." If there exist multiple basins of attraction, multiple stable states (sometimes called "equilibria") emerge. In such cases, seemingly small initial differences between two households or species can position them very close to each other yet on opposite sides of a separatrix or threshold. Thus, seemingly innocuous initial differences can become magnified over time as each element follows the path inherent to its own basin of attraction.

When an element (e.g., household, species) of the system is somehow moved beyond the boundaries of the region in which it began, whether by a natural or manmade shock, it settles into a new region with a different steady state and basin of attraction, altering its specific path dynamics. In this way, the random experience of exogenous shocks can lead to markedly different futures.

It is essential to keep in mind, however, that a system's dynamics are not defined merely by its initial distribution across states. The existence and location of separatrices shift with the basic parameters of the system. Thus, when key parameters change, so can the partitioning of the system's phase space, and thus its underlying dynamics. In particular, the phase space diagram can shift discontinuously, for example, from one with a unique stable state to one with multiple basins of attraction. Such flips, or "bifurcations," are a different sort of mechanism that changes underlying dynamics, distinct from those that move a system across an unchanged separatrix.

This brief stylized representation of the salient concepts and terms from the more formal literature on dynamical systems captures key concerns and concepts in both the biodiversity conservation and poverty traps literatures. First, both are fundamentally dynamic concepts. Theorizing about and measurement of these concepts therefore needs to focus explicitly on both the level of appropriate metrics of (or proxies for) poverty or biodiversity as well as temporal changes in those metrics.

A poverty trap is about staying poor, not just being poor at a moment in time. It is any self-reinforcing mechanism that causes poverty, however measured, to persist (9). Research on poverty traps therefore focuses on understanding why some people, communities, and even entire nations remain mired in grinding poverty, whereas others have enjoyed rapid improvements in standards of living. Through such understanding, it is hoped that interventions can be designed that move individuals, households, and nations from low living standard to high living standard basins of attraction. Because "poverty" is an elusive concept, the literature mixes measures of well-being based on flows of income or expenditures with measures of assets and/or human education, health, or nutritional status (9–11).

Unlike the situation with poverty traps, in which the goal is to change equilibrium standards of living away from the undesirable stable state, the typical goal of in situ biodiversity conservation is to maintain the current equilibrium if it is indeed in a stable natural condition or to restore it if it is not. "Biodiversity" encompasses the variety that occurs in living things, ranging from the diversity of genes within a species, to the various species, to the complex interrelationships between species and their habitats in various ecosystems (12). Complex ecosystems possessing sufficient scale and original biodiversity typically exhibit resilience to natural shocks; they remain within a favorable basin of attraction. However, when scale or genetic diversity falls "too far," ecosystems or constituent species can tip downward into an alternate less desirable state, including the limiting (and absorbing) state of extinction. Environmental scientists have worked tirelessly at identifying and understanding thresholds in ecological systems in order that they might help resource managers avoid catastrophic collapse of biodiversity (13–15).

Second, because multiple basins of attraction commonly exist, initial conditions matter. There can be pronounced long-term differences that result from seemingly small initial distinctions. A single change, be it an intentional intervention or a random event or shock, can therefore trigger shifts into dramatically different and sometimes profoundly less desirable equilibria. Because the critical distinguishing initial conditions cannot easily be appreciated, the impacts of specific interventions or actions on biodiversity conservation and poverty traps can be unexpected, unintended, and possibly quite contentious. The principle of horizontal equity is violated by the divergent futures of the initially similar.

Third, positive feedback attributable to complementarities, fixed costs, direct spillover effects, or other phenomena often cause subsystem failures to become mutually reinforcing (16). For example, the loss of an apex predator species can affect prey populations and foliage/habitat in a trophic cascade (17). Likewise, herd loss because of drought can drive pastoralists to sedentarize around towns offering relief services, leading to localized range degradation attributable to the excessive spatial concentration of the remaining livestock, which causes further herd loss (18).

Fourth, transitory shocks, such as drought, fire, flood, war, or disease, can have persistent effects. Such shocks can directly affect the current state of the system, as when a sudden die-off or change in sex ratio shifts a species' population dynamics or the loss of productive assets drives a household into long-term destitution. Even a seemingly short-lived shock that does not change the basic parameters of the underlying system can alter outcomes.

Fifth, separatrices can shift and bifurcations can result from human agency (e.g., introduction of a park, permanent change in legal institutions) or natural processes (e.g., climate change). For example, a change in rainfall regime can induce farmers to change land use patterns in a manner that shifts the separatrice between distinct livelihood strategies, with each having different dynamic properties and spillover effects on the supporting agroecology.

Finally, and looking toward the empirical cases explored in the papers of this special feature, conservation and development interventions involve at least one of two basic activities meant to change the long-term state of the system. Some efforts try to change the initial state (e.g., through asset transfers to households or species reintroduction) to try to move the system into a more desirable basin of attraction. Others change the parameters of the system (e.g., by installing infrastructure, gazetting a park, and changing resource use rules within the newly protected area; by changing governance or management rules, such as protecting an area from specific uses; by introducing new technologies or markets) in the hope that this will change the system behavior. Most interventions that aim to ignite an escape from poverty traps or to protect an ecosystem seemingly on a path to collapse fail because they make inadequate or inappropriate adjustments in one or both areas. This is not surprising, because the separatrices that divide basins of attraction and the parameters that guide their location are often not directly observable and have rarely been the subject of direct scientific study. Inadequate empirical understanding of coupled systems predictably is manifested in projects and policies that have short-lived effects but do not fundamentally change where the human or natural subsystems are headed. At this stage, what is needed first is enhanced understanding of the deep interlinkages among ecological and socioeconomic processes in order that we might better grasp the key parameters and behaviors of the closely coupled human-managed ecosystems that give rise to biodiversity conservation and poverty concerns of first-order global importance.

Interlinkages Between Biodiversity Conservation and Poverty Traps

Multiple stable states emerge naturally from material and informational feedback between natural and socioeconomic systems, feedback that switches between balancing processes that maintain system stability and reinforcing processes that lead to locally exponential growth or decay. Several candidate mechanisms link the dynamic processes that underpin biodiversity conservation and poverty traps, with their relative prominence varying across space and time. We identify four distinct classes of mechanisms that define distinctive interlinkages between biodiversity and poverty.

Dependence on Inherently Limited Natural Resources. Perhaps the most fundamental class of mechanisms arises as a result of poor rural peoples' heavy dependence on restricted biophysical assets for their livelihoods. When the key state variables of two systems are shared in common, strong interdependence follows automatically. As households choose to clear forests, convert rangelands, drain wetlands, or overharvest biota to meet consumption objectives, reinforcing material feedback effects naturally emerge because degradation in the natural state leads to deterioration in the human condition. Because the rural poor disproportionately earn a living by mixing their labor power with the fruits of nature, the returns to labor depend on the quantity and quality of the complementary natural resources available to them. When the human population grows but the stock of complementary resources does not grow as quickly, marginal labor productivity and, with it, standards of living fall.

This is the well-known "poverty-environment trap" asserted by the World Commission on Environment and Development. Furthermore, if livelihood and technology choices vary with control over natural capital, lock-in effects can arise from historical accidents that affect the distribution of assets. That is true at household scale, where open access land can often be privately appropriated through conversion using a household's stock of labor and mechanical tools. It is perhaps most true at the macroscale, as in the case of vast, mechanized, and chemically intensive monocultures practiced in *hacienda* agriculture that resulted from vast colonial land grants in Latin America. The initial natural resource state also matters to poverty dynamics. If biodiversity declines within a particular range of initial conditions and grows over (an) other range(s), labor productivity and human welfare dynamics may then vary predictably based on initial resource conditions. Because renewable resource dynamics are indeed typically highly nonlinear (consider, for example, the generally logistic-shaped population dynamics of most fauna and flora), the possibilities for coupled collapse or abundance in human well-being and biophysical resources become quickly apparent (6, 19). Spatial spillovers also emerge naturally, because behaviors in one place affect system performance in adjacent areas.

Shared Vulnerabilities. Of course, the different types of pressures faced by poor households, and their choices of response, depend fundamentally on many factors beyond their control. It is therefore an egregious oversimplification to chalk up tropical biodiversity loss to the inexorable consumptive tendencies of poor households. Larger scale processes heavily influence the paths that households choose as well as biodiversity dynamics independent of coresident household behavior. A second class of mechanisms is based on the interrelated responses to cyclically occurring natural conditions, or to stochastic or induced events. These can be site-specific natural drivers, such as hydroclimatic conditions, that give rise to environmental and reproductive externalities that fundamentally shape both human behavior and local population dynamics (20). For example, spatiotemporal variability in water availability in drylands naturally causes both human and wildlife migrations, along with resulting competition for scarce resources and the emergence of both human and nonhuman predators to prey on migrating populations. In settings where nature throws up formidable challenges and regular shocks (e.g., regular drought, floods, earthquakes), poverty, population growth, and environmental degradation can quickly become mutually reinforcing responses to natural perturbations. This shared vulnerability is a major reason why climate change so concerns activists and scholars in both the poverty and biodiversity communities. Shared vulnerability also raises contested issues about the "natural insurance" role of natural resources as a buffer to help people respond to shocks.

Failure of Social Institutions. The third class of mechanisms describes inadequate human sociopolitical and economic institutions that shape the human behaviors in an ecosystem. To economists, missing and imperfect markets are perhaps the most pervasive and obvious example of this mechanism (4, 7). If we resolve financial market failures, for example, landless and near-landless households can often abandon low-return livelihoods that depend on exploiting common pool resources for more remunerative strategies less taxing on their host ecology. Political failures, as reflected in war, corruption, bureaucratic incompetence, unregulated open access resources, and inability to enforce policies formulated to preserve resources, for example, can likewise leave both the poor and nonhuman species vulnerable to overexploitation. In addition, where the institutions that govern natural resource use, through formal property rights or informal social norms and cultural practices, do not check the excesses of self-interested individual behaviors, both poverty traps and ecosystem collapse become more likely (10, 21, 22). Market, political, and institutional failures commonly go hand in hand, reflecting coordination failures that lead to geographic poverty traps and tropical resource overexploitation (23, 24).

Unintended Consequences and Lack of Informed Adaptive Management. The fourth class of mechanisms relies on imperfect informational feedback rather than material flows. In complex environments characterized by highly nonlinear dynamics, it seems unlikely that decision makers have an accurate, or even an unbiased, sense of the likely effects of behavioral changes or exogenous shocks. People might have a hard time anticipating changes associated with decisions with which they are unfamiliar and/or might have a difficult time observing changes in the environment around them. This is especially true concerning changes occurring at some distance (in space or time) from their current position, such as with international interventions. Differences in beliefs can generate "inertial self-reinforcement" (25). This can arise when downstream changes in a system only become apparent after a delay, by which time response might be prohibitively costly, although early response would have been remunerative. These effects can be felt at a distance, such as when development of new agricultural land or areas for mineral resource extraction leads to changes in watershed or maritime ecosystems that have a negative impact on communities that never derived benefit from that development. More direct examples would include how forest clearing can result in increased contact with wild species, leading to transmission of zoonotic disease. Conversely, introduction of people and domestic animals into previously undisturbed areas can introduce diseases into wildlife that can devastate wild populations and/or create wild reservoirs for the disease to be transmitted back to the domestic animals of rural farmers (12).

These latter three classes of mechanisms give rise to geographic poverty traps (26) and to fractal poverty traps (24) in which microscale mechanisms aggregate up to generate macroscale patterns, which, in turn, acquire their own dynamics that reinforce the meso- and microscale behaviors. The same logic carries over to ecosystem fragility that is spatially concentrated and linked across trophic scales.

The multiplicity of candidate mechanisms underscores a major challenge. Any or all of these might apply in a given setting, and each carries slightly different policy implications. Careful site-specific diagnostics that take into consideration the multiplicity of potential mechanisms are therefore essential to tailor interventions to those factors that seem most salient in that specific place and time. Caution must be exercised when interpreting prescriptions made in the absence of detailed empirical investigation of the etiology of an apparent poverty trap or threat to biodiversity. Further, one should take care to explore not just the "treatment effects" of interventions but, as best as can be established with the available data, the opportunity costs of any interventions in terms of the foregone gains of using the same resources for a different type of intervention. Conversely, one must also attempt to analyze the counterfactual outcome to an intervention: Are the impacts of allowing the status quo to continue either socially or environmentally acceptable? Lastly, it is worth repeating that interventions must be evaluated in terms of both social and biodiversity metrics. Even if a change in program or policy has a single objective, be it social or environmental, we must recognize that the impacts may be felt by both the human population and the ecosystems in which they live.

In light of site-specific complexities, we are skeptical about the prospects for single strategies to reconcile biodiversity conservation and poverty reduction objectives across the globe. Common interventions, such as payments for environmental services (including those mooted for reducing carbon emissions from deforestation and forest degradation), protected areas, and resource commercialization, for example, might prove to be valuable components of holistic approaches to these coupled problems. However, the practical impacts of such components might differ markedly depending on the mechanisms that guide coupled human and natural system dynamics in a locale.

Introduction to the Papers in This Special Feature

The rapid growth of human populations living in areas of endemic poverty and the rapid loss of natural habitats and the species within them have drawn international attention to interventions designed to effect positive socioeconomic and environmental change. Unfortunately, when data have been collected for the purposes of monitoring the impacts of these interventions, they have often been restricted to metrics appropriate for individual academic disciplines. This practice reinforces the failure to explore connections between poverty traps and biodiversity conservation. In part, because of the discrepancy between the long time frame necessary to evaluate socioeconomic and ecosystem impacts and the short time frame of grants that fund academic research, research spanning social and biophysical disciplines has tended to emphasize theoretical outcomes as opposed to empirical observation and experimental testing of hypotheses. This substitution of theory for actual data has led to claims of predicted win-win outcomes that are often later found to be exaggerated and nongeneralizable. To avoid these pitfalls, each study collected in this special feature is based on data from both biophysical and social science disciplines.

The articles contained within this feature can be coarsely divided into two groups. The first empirically examines the relationships between poverty traps and biodiversity conservation. Ferraro et al. (27) address a fundamental controversy: Do protected areas make or reinforce poverty traps, or do they instead offer a mechanism to improve the condition of rural households? Using geospatial data and econometric analyses, the authors estimate how the impacts of protected areas on poverty and deforestation vary according to biophysical and demographic characteristics across diverse sites in Costa Rica and Thailand. They find no evidence that gazetting a protected area traps historically poorer areas in poverty. However, they find that the spatial characteristics associated with the most poverty alleviation are not necessarily the characteristics associated with the most avoided deforestation, such that win-win outcomes are not to be expected either. The authors illustrate how these findings have readily identifiable applications to land use planning, which can help government officials determine where land protection is most likely to have social in addition to environmental benefits.

Naughton-Treves et al. (28) address a similar set of issues, exploring the impact of Kibale National Park in Uganda on both local poverty and biodiversity. They use satellite imagery in conjunction with longitudinal primate censuses, forest transects, household surveys, and econometric analyses to establish that the park has indeed protected forest and primates. They then compare the outcomes of households that live at varying distances outside the protected Kibale National Park vs. those that live outside of communal forest patches that were exploited far more intensively. Through this comparison, the authors draw an important distinction between two mechanisms by which households can lose access to forest resources. Biological resources can be protected from human exploitation, or those resources can be consumed to the point where ecosystem services no longer provide coping mechanisms in the form of timber and nontimber forest products for the area poor. The authors found no evidence that the Kibale National Park itself constituted a poverty trap. Indeed, the park appears to have provided some protection against desperation asset sales and farm loss among the poorest households living adjacent to the park.

In addition to the relationship between protected areas and poverty, this section of the special feature also explores the factors that influence how people use unprotected forest and wildlife resources. Coomes et al. (29) study how forest and riverine lands have been used in an Amazonian village in Peru over a period of 30 y. Using detailed plot-level and household longitudinal data, they find strong evidence for path dependence. The initial holdings and assets of a family have lasting impacts on their patterns of land holding and land use, such as the time period that land is allowed to lie fallow and become secondary growth forest, leading some households to be caught in what the authors refer to as "land use poverty traps." Path-dependent land use patterns not only have obvious impacts for poverty, forest cover, and biodiversity conservation, but they have a strong impact on how households rely on other natural resources. For example, these authors found that the poor rely more heavily on income gained from fishing, day labor, small livestock, and unsustainable harvesting of nontimber forest products. They also find evidence for demographic change in terms of outmigration as one way in which land pressures have lessened in this village and enabled households to avoid being trapped in poverty.

Brashares et al. (30) tackle a question that plagues many interventions that seek to achieve wildlife conservation outcomes by improving rural livelihoods: Will improved household incomes increase or decrease bushmeat consumption? Using multiple reinforcing survey approaches across four African nations, the authors find compelling evidence that in addition to household wealth, geographic distance to urban areas (and markets), relative pricing vs. meat from domestic animals, and the opportunity cost of time spent hunting vs. other activities all have important effects on patterns of bushmeat consumption and sale. These findings have clear application to the design of interventions that seek to achieve wildlife conservation by ameliorating human poverty and hunger. Just as other papers in this special feature find that protection of ecologically valuable forests does not automatically lead to improved living conditions for the rural poor, so do Brashares et al. (30) reciprocally find that economic growth does not automatically translate into reduced hunting pressure on wildlife.

The second group of papers in this special feature describes and analyzes new economic, social, and political approaches to achieve biodiversity conservation and social improvement. Dickman et al. (31) review various strategies that have been used across diverse settings to conserve large carnivores. Highly valued for both cultural and ecosystem benefits, these species are also among the most difficult to conserve because of the real costs they can inflict on the people who share their local environment. The authors reframe the now-familiar "payment for ecosystem services" approach to one of "payments to encourage coexistence" (PEC) to reflect more accurately the objectives of these interventions. They review the literature documenting the strengths and weaknesses of a variety of financial mechanisms that have been used to promote carnivore conservation, concluding with a framework for an idealized PEC system that combines key attributes of existing approaches.

McNally et al. (32) describe the economic impacts of mangrove forest protection in coastal Tanzania. Saadani National Park restricts households from harvesting mangrove wood. The authors use remotely sensed imagery analysis to examine the effects of this protection on mangrove cover and use econometric analyses of household survey data to investigate the impacts on household behavior and well-being. They document increases in fishing and shrimping income for households across all wealth classes. Their data suggest that enhanced ecosystem services provided by the mangroves generate significant indirect benefits for rural livelihoods. This study demonstrates the need for broad investigation of impacts when performing monitoring and evaluation of a landscape-scale intervention. By comparing the data in their study area vs. country-wide trends, the authors also demonstrate the need to ensure that indirect benefits are themselves sustainable and do not merely reflect displacement in the identification of alternative resources that will be harvested in an unsus tainable fashion.

In an area in which both people and threatened hornbill populations share a vulnerability to severe weather events, Chantarat et al. (33) describe a unique index insurance mechanism they designed to provide both socioeconomic and wildlife conservation benefits. One problem that has historically plagued both conservation and international aid agencies is that they must often behave reactively to stochastic shocks. In the event of a humanitarian or conservation crisis induced by a severe weather event, there is unnecessary delay as donors and operational agencies mobilize financial and other resources. In too many cases, this lag in response is long enough for systems to descend into new and less favorable equilibria. Chantarat et al. (33) draw on years of meteorological, social, and hornbill life history data to design an index insurance mechanism that should provide a quick and reliable response in the event of cyclones. Should routine meteorological data reach a key trigger point (in this case, high wind speeds that cause loss of older trees with appropriate nesting cavities as well as loss of local farm income), the insurance will disburse payments to conservation managers who use these funds to employ villagers to construct, install, and monitor artificial nest boxes that replace storm-damaged nesting trees, a limiting ecosystem feature that might tip the endangered hornbill populations below a threshold of sustainability. The opportunity for employment at a time when crops and jobs are lost should also help smooth household consumption, preventing families living on the margin from tipping into poverty traps.

Lewis et al. (34) describe a unique market-based approach that seeks to achieve biodiversity conservation goals by focusing on human livelihoods and food security. Historically, integrated conservation and development projects have often tried to base social development on utilization of wildlife resources, with typically poor results. Instead, a different model is being implemented in rural Zambia that functions as a cooperative agribusiness that operates across the value chain from the farm through national and international markets. Participation in the organization, known as Community Markets for Conservation (COMACO), is dependent on adoption of conservation farming methods and cessation of unsustainable activities, such as poaching. By providing infrastructure for farm product transportation, generation of value-added products, bulking, and packing, along with critical access to high-value markets, this intervention seeks to incentivize sustainable natural resource management. Wildlife, business economic, and social science data are presented to explore COMACO's impacts. Their results suggest that markets can be structured to enable economic and social development that is dissociated from reliance on forest and wildlife resources yet still achieves environmental objectives.

The special feature closes with a "cautionary tale" by Lybbert et al. (35) that social/economic development based on a natural resource does not guarantee conservation of that resource. In part to promote, and in part to take advantage of an international boom in demand for argan oil, there are many claims for a win-win scenario in which rural women's cooperatives improve livelihoods through the sale of argan oil, incentivizing the preservation of the wild argan trees that produce the fruit seed from which the oil is extracted. By analyzing remote images of vegetation cover, longitudinal household survey data, and commune-level data on school enrollment, the authors find that although the argan oil price boom has improved educational outcomes, especially for girls, and predictably made households more vigilant guardians of the soon-to-be-harvested fruit on the tree, it has not induced investments in longer term forest health. This "killing of the golden goose" scenario underscores the complex relationships between human economic and social development and the conservation of valuable natural resources. We must guard against the naive belief that just because a resource is economically valuable, it will be conserved.

The papers collected in this special feature empirically explore the causal relationships between poverty traps and biodiversity conservation as well as novel attempts to effect change. Each article highlights one or more aspects of the theoretical connections linking poverty and the need for sustainable management of natural resources described above. Dependence on limited resources underlies almost every situation described in these papers but is especially prominent in the works of Coomes et al. (29), Ferraro et al. (27), and McNally et al. (32). Shared vulnerability to shocks is clearly demonstrated by the works of Naughton-Treves et al. (28) and Chantarat et al. (33). Failure of social institutions is highlighted by the articles of Brashares et al. (30), Dickman et al. (31), and Lewis et al. (34), whereas unintended consequences and the lack of informed adaptive management are perhaps most clearly shown in the analyses by Lybbert et al. (35).

Throughout the February 2010 workshop on biodiversity conservation and poverty traps that led to this special feature, participants repeatedly remarked how much of the existing literature revolves around synergies or tradeoffs between poverty and environmental objectives and the quest to identify win-

win options. Our sense of these papers (and of the broader literature) is that, in reality, most options are at best "win-settle," in the sense that they advance one or the other objective, although merely settling for a do-no-harm result with respect to the other objective(s). Economists think of this as progress, an efficiency gain known as "Pareto improvement" (making at least one person better off without making any worse off). Projects should not necessarily try to do it all. Achieving demonstrable success in biodiversity conservation without imposing suffering on the poor or sustainable improvement in living standards without compromising ecosystem function is a laudable achievement. We must take care not to set the bar too high and thereby undermine our ability to accomplish either conservation or development goals. Conversely, we must not shy away from recognizing that it will be impossible to attain biodiversity objectives without attending to the legitimate aspirations of coresident human populations for reasonable standards of living for their families, just as it will be impossible to achieve lasting socioeconomic development without ensuring that impacts on the local ecosystem do not undermine progress or reduce crucial ecosystem services.

Biodiversity loss and persistent poverty are not inevitable. However, closely coupled ecological and socioeconomic challenges will not be resolved of their own accord over time. We need models underpinned by rigorous empirical evidence of the interlinked dynamics of human well-being and biodiversity to help analysts and policy makers think through the relative merits and risks of alternative courses of action. We hope that the papers of this special feature will help shape how we think about this complex relationship, how we devise interventions to improve human and natural conditions, and how we evaluate the socioeconomic and biophysical results of these interventions.

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