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The Potential, Realised and Essential Ecosystem Service Benefits of Biodiversity Conservation

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Introduction

There are substantial debates regarding the relationships between biodiversity, ecosystem services and human well-being, even though the Convention on Biological Diversity (CBD), Millennium Development Goals (MDGs) and other international agreements explicitly connect biodiversity conservation to poverty alleviation (Sachs *et al*., 2009). As noted in Chapter 1, for example, countries agreed that significantly reducing the rate of biodiversity loss at the global, regional and national levels

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by 2010 was "a contribution to poverty alleviation and to the benefit of all life on Earth" (CBD, n.d.-a), and included this as part of Millennium Development Goal 7 (MDG7, Ensure Environmental Sustainability). In 2010, this agreement was extended to "take effective and urgent action to halt the loss of biodiversity in order to ensure that by 2020 ecosystems are resilient and continue to provide essential services, thereby securing the planet's variety of life, and contributing to human well-being, and poverty eradication" (CBD, n.d.-b). This goal is assessed by country-level indicators on species extinction risk, remaining forest cover and the percentage of lands and seas in protected areas, among others. While conservationists have long held that actions to protect biodiversity and ecosystem services support human well-being (e.g. Curry-Lindahl, 1972), until recently there has been little empirical, broad-scale evidence to support this. Conservation continues to be presented as both a constraint on development and a tool for achieving poverty reduction (Adams *et al.*, 2004; West *et al.*, 2006; Andam *et al.*, 2010; Barrett *et al.*, 2011).

As evidenced in this volume, debates continue over the relationships between biodiversity conservation and poverty reduction. However, there is strong evidence emerging that biodiverse systems show greater productivity and resilience (Flombaum & Sala, 2008; Isbell *et al.*, 2011), with links between conservation and resilience of human communities likely to become even more important given projected climate change impacts (Turner *et al.*, 2009). The links between biodiversity and human well-being can be expressed under the framework of ecosystem services (Millennium Ecosystem Assessment (MA), 2005). Yet the variety and values of these services remain greatly overlooked, by both beneficiaries and decision makers at virtually all scales, from local to global (The Economics of Ecosystems and Biodiversity, 2009).

Discussions of biodiversity conservation actions (what, where and how) and poverty have largely been reviewed at national or local scales, and, indeed, biodiversity and poverty often coincide (Fisher & Christopher, 2007). There is also a general expectation that conservation actions, such as creating protected areas, should benefit human well-being, help secure livelihoods and pose little risk to, if not directly benefit, the poor (World Commission on Environment and Development, 1987). Yet analyses to date have been insufficient to inform decision makers on the potential role of conservation for socio-economic development, especially regarding the linkages that conservation action has to poverty alleviation (Chapter 9, this volume).

Here, we undertake a global analysis by mapping ecosystem service flows from natural habitats to human communities in order to assess the distribution of services among countries and regions, to investigate the flow of these services to the poor in particular and to understand the connection between biodiversity conservation and these important services.

Approach and methods

Previous studies of ecosystem services, human well-being and/or biodiversity have conducted analyses across large, heterogeneous spatial units, such as biodiversity priority regions (Turner *et al.*, 2007; Naidoo *et al.*, 2008), drainage basins (Luck *et al.*, 2009), countries (Ebeling & Yasué, 2008) or the entire globe (Raudsepp-Hearne *et al.*, 2010; Duraiappah, 2011). One of the inherent challenges of this type of analysis is to assess the ecosystem services in a way that allows for accurate comparison among different sites. We resolve methodological problems[1] faced by previous studies by conducting all analyses on a grid of terrestrial equal-area hexagons[2] (Sahr *et al.*, 2003) and aggregate to larger units only for reporting.

We assess the flows of ecosystem services provided to people, especially to the poor, by priority habitats for terrestrial conservation, considering global distributions of biodiversity, physical factors and socio-economic context. Specific studies of a given area using local data may allow for a more in-depth understanding of that place; however, our data set offers the means to compare different places. The data for biodiversity (International Union for Conservation of Nature (IUCN), 2008), human population (LandScan, 2006) and poverty (Center for International Earth Science Information Network, 2005), as well as the base data for improving estimates for valuing climate regulation (Reusch & Gibbs, 2008) and other ecosystem services (Costanza *et al.*, 1997; Turner *et al.*, 2007), have been detailed elsewhere (Turner *et al.*, 2012).

We use four geographically explicit valuation alternatives to estimate ecosystem service value (ESV) delivered to different socio-economic contexts and to understand links between biodiversity conservation and the sources of these services:

1. **Potential services** generated by natural habitats, irrespective of whether people are close enough to receive benefits;
2. **Realised services**, which account for the human population that might capture the services;
3. **Essential services**, the services that flow directly to the poor and provide immediate benefits;
4. **Essential services with transfers**, essential services as in #3, plus amounts the poor could receive from payments for ecosystem services (PES) mechanisms.

In the analysis in this chapter, we use these methods to understand the value of ecosystem services delivered by conservation priority areas,[3] and how these values change when we incorporate human population and poverty into the calculation of

[1] Firstly, spatial variation relevant to ecosystem services is lost when aggregated to large regions. Secondly, unequal areas make it difficult to compare quantities such as those measuring ecosystem service value and biodiversity. Thirdly, boundaries coincide with features such as country and habitat borders that are correlated with multiple variables. Alternatives to these, such as rectangular geographic or equal-area grids, incur oversampling and shape distortion problems away from the equator (Potere & Schneider, 2007). Hexagonal grids avoid each of these problems.

[2] $2{,}592\ km^2 \pm 11.6\ km^2$ SD; N = 58,613.

[3] These areas represent high priorities for conserving terrestrial vertebrate species, and were based on mapped distributions of all threatened vertebrates in taxa comprehensively assessed by the IUCN Red List (IUCN, 2008). Two key criteria used to inform conservation priorities are irreplaceability and vulnerability, the former identifying where conservation options are most limited over space and the latter showing where they are most urgent (Margules & Pressey, 2000). We mapped endemic, threatened biodiversity as 'range-size rarity' or 1/(species range size), summed

ESV. We also explore the importance of ESV to the world's poor and geographic differences by region.

We explore 17 different classes of ecosystem services based on biome- and service-specific value estimates (Costanza *et al.*, 1997) refined by more recent studies using improved land cover and climate regulation data (Sutton & Costanza, 2002; Turner *et al.*, 2007, 2012). This approach does not account for within-biome variation; this and other known assumptions are only partially addressed by the refinements discussed in this chapter. Nevertheless, this approach is the only published, global mapping of values for a range of services and biomes, and has been used as a source for ESV estimates at regional (Viglizzo & Frank, 2006) and global scales (Balmford & Bond, 2005; Turner *et al.*, 2007). We report all monetary values in 2005 US dollars, converted where necessary according to published estimates of annual global consumer price inflation. Our study includes only terrestrial areas, but this does include high-value coastal services and areas. More comprehensive valuation of marine ecosystem services in relationship to biodiversity conservation and human well-being remains a critical research need.

Given our interest in the relationship with poverty, we present our findings comparing the world's regions as defined by the World Bank's *Country and Lending Groups* (World Bank, 2012). We grouped 70 high-income countries, and used the standard regional groupings for all developing countries: East Asia and Pacific (EAP) (24), developing Europe and Central Asia (23), Latin America and the Caribbean (LAC) (30), Middle East and North Africa (MNA) (13), South Asia (8) and Sub-Saharan Africa (47). All countries in these latter categories are considered to be developing, although many are middle-income developing countries.

Potential ecosystem service value: economic values irrespective of use

If all things were equal, the proportion of areas with high biodiversity and the total potential ESV for each region would be similar to its total proportion of land area. However, both biodiversity and ecosystem service value are distributed unequally over the globe. Figure 2.1a shows the variation in land area per region, and Figure 2.1b the biodiversity importance. Figure 2.1c then provides an overview of the proportion, by development status and region, of potential ESV in comparison to these variables.

The developing countries of Europe and Central Asia occupy a large land area (18% of the globe) and have potential ESV roughly proportionate to land area, but harbour only 1% of the total area of high biodiversity value. The high biodiversity and extensive

across all threatened species occurring in a cell (Williams *et al.*, 1996). We defined priority areas for biodiversity conservation as the upper quarter of cells according to this metric.

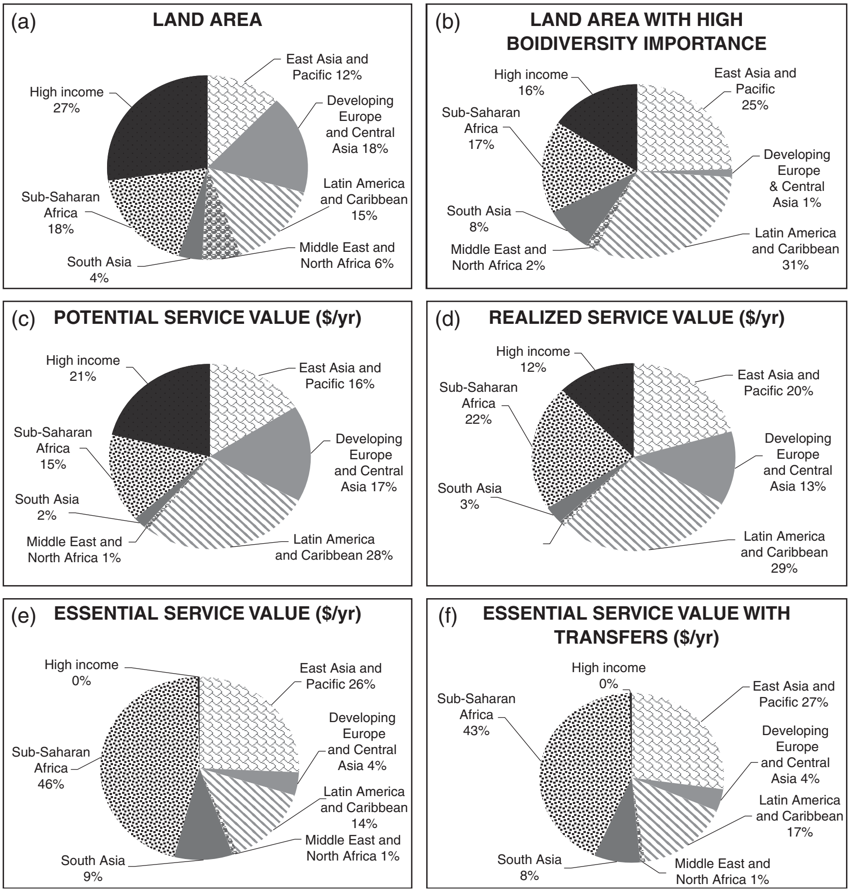


Figure 2.1 **Percentage of global total, by development status and region, of (a) land area; (b) area of high biodiversity importance; (c) potential ecosystem service value (ESV); (d) realised ESV; (e) essential ESV and (f) essential ESV with transfers (payments for ecosystem services).**

Note: Ecosystem service value estimates are for services originating from the habitats in a region, not necessarily those flowing to a region. In (e) and (f), developed countries generate some (<1% of global total) essential ecosystem services that originate within their borders but flow to developing countries in other regions.

Country groupings follow World Bank classifications, but the spatial area of regions and the number of countries (or areas) within vary greatly. There are 70 countries included in the high-income class. Groupings are East Asia and Pacific (n = 24 including China, Mongolia and Indonesia, as well as small island nations (e.g. Samoa and Fiji)), developing Europe and Central Asia (n = 23 with Europe's poor countries (e.g. Bulgaria), and Russia and former USSR), Latin America and the Caribbean (0), Middle East and North Africa (13), South Asia (8) and Sub-Saharan Africa (47).

tropical forests and watersheds in Latin America are reflected by the comparatively larger share of biodiversity and ESV reflected for that region – both around twice as high as expected on the basis of land area. The largely arid MNA region has lower concentrations of biodiversity relative to the area, and even less potential ESV, due in part to the near absence of forest ecosystem services in particular. The potential ESV and biodiversity conservation priority of Africa is roughly proportional to its land area, while EAP countries have ESV slightly higher than land area but twice the expected level of biodiversity importance. Developed nations have ESV roughly proportional to land area but with proportionately less high-biodiversity land area. These findings allow potential ESV to be mapped and hence the relative total potential ESV for different regions to be compared. Critically, however, they say little about the importance of services to people. Our analysis in the 'Realised services' section of this chapter explores this.

Realised services: valuing ecosystem services by considering their use

People, especially decision makers, assign higher value to ecosystem services that are directly captured by human beneficiaries. Some ecosystem service benefits may be captured locally, for example by people depending on firewood or wild food harvest. Yet for other services, those who benefit most live far from the area providing the service – this is especially the case for water supply and carbon storage, where key users may be in distant cities or countries. Our second valuation alternative estimates these *realised services* by classifying the 17 ecosystem services into three service flow models (Figure 2.2) including those services realised only within a given distance ('proximal' services such as pollination), services following river drainage patterns ('downstream' services such as water supply)[4] and services that benefit people everywhere ('global' services such as climate regulation).

While there is similarity in the places with high potential ESV and high realised ESV, the distribution of population density in particular drives major differences in the distributions of potential ESV (Figure 2.1c) and realised ESV (Figure 2.1d) among regions. Realised ESV is lower in regions where relatively few people can capture services, including tundra and boreal forests. The relative importance of realised services declines for developed countries given the low population density across places such as Canada and much of Australia. This is also the case for the developing countries of Europe (e.g. Russia) and Central Asia. Globally, accounting

[4] For those 'downstream' services following hydrological drainage patterns, we used 30-arc-second drainage direction data (Lehner *et al.*, 2008), where available, and Hydro1k drainage direction data (US Geological Survey, 2011) elsewhere to compute the set of cells downstream of each hexagon cell, up to 500 km, as the window for calculating beneficiary populations.

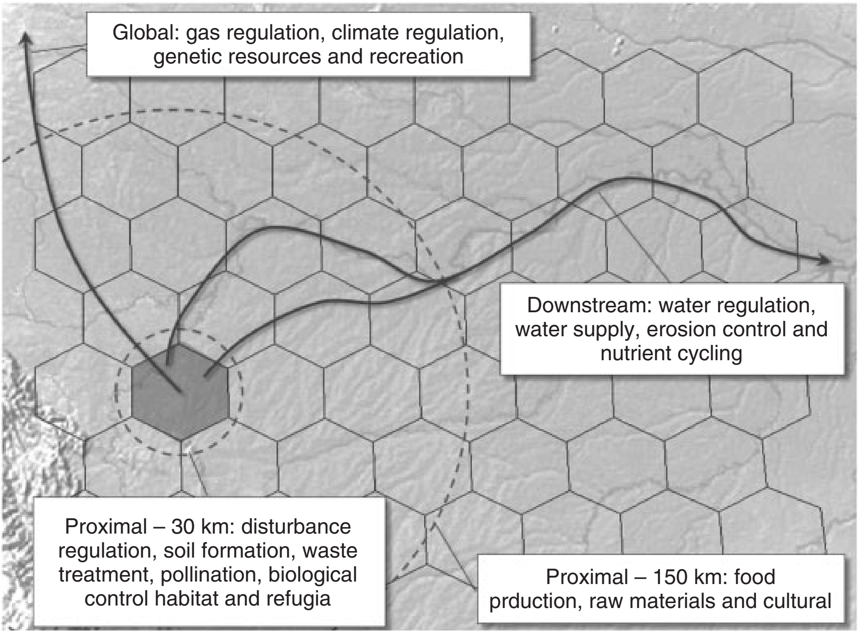


Figure 2.2 **Models for flows of 17 ecosystem services from source ecosystems to human beneficiaries.**

for capture by human beneficiaries results in an aggregate value of US$9.40 trillion in realised services, compared to US$14.03 trillion in potential services. While there are substantial differences in the potential and realised value within countries, in general the patterns for LAC, MNA and South Asia show a correspondence between potential and realised ESV. There is a modest increase for East Asia and the Pacific. The greatest increase from potential ESV to realised ESV – the value of services that people rely upon – is for Africa. Yet, although realised services reflect ecosystems' overall benefits to people, they do not identify how many poor depend on these services. This is explored in more detail in the 'Essential services' section of this chapter.

Essential services: valuing the ecosystem services the poor rely upon

People differ in their ability to access or pay for alternatives if ecosystem services are lost. While affluence frees people from direct dependence on local ecosystem services and can buffer them against some consequences of ecological change, the poor lack these buffers and substitutes (Chapter 4, this volume). Poor communities are thus often critically dependent on ecosystem services to sustain their lives and livelihoods (Luck *et al.*, 2009). Declines in wild resources, biodiversity or ecosystem health that provides food, fuel, clothing, medicines and shelter are linked to declines in rural health and welfare. For example, when water quality declines, the poor have neither the money nor access to buy clean water. *Essential services* are estimates of ESV benefits that flow directly to the poor and provide immediate benefits. Thus, our calculations of essential services resemble those for realised services, but only value benefits flowing directly to poor individuals, such as water supply, disturbance regulation or food production. Additionally, they exclude indirect or longer term benefits (i.e. climate regulation, gas regulation, nutrient cycling, genetic resources and recreation).

Developed countries, with fewer impoverished people, are nearly absent from the estimated maps of essential services (Figure 2.1e). Not surprisingly, Africa shows the highest relative increases in ESV (31% increase over potential ESV), when flows to poor people are taken into account. In these areas, ecosystem services are critical to human well-being. Africa comprises nearly half of the absolute value of essential ESV that the world's poor rely upon, followed by EAP, then LAC. However, the proportional decreases from realised to essential ESV for the LAC region and for developing Europe and Central Asia are offset by the modest increases in both South Asia and EAP.

The economic value of essential services flowing to the poor is high, equalling US$1.814 billion per year for all developing countries. For 36 of the 49 least developed countries, the value of essential ESV exceeds US$1 per person per day. This suggests that, at the national level, ecosystem services may provide a substantial subsidy for the world's poorest countries, representing a significant contribution towards meeting the MDGs.

Estimating all benefits to the poor: essential services and payments for environmental services

PES is based on the premise that market mechanisms should allow users who benefit from ecosystem services to provide equitable support to local residents for their stewardship of these resources (Chapter 14, this volume). There are numerous assessments of how PES systems work in practice, and reason for caution that the theory is easier than implementation (Wunder *et al.*, 2008). One might assume that there is tremendous potential to use PES to correct the failure of markets to value, and to capture the value of, environmental services, and transfer them to resource managers, providing substantial benefits for both nature and people. Yet this overall potential has rarely been addressed over broad spatial scales. For this analysis we assumed that we could identify the beneficiaries of ecosystem services based on their spatial relationship to service flows. We also assumed that non-poor beneficiaries could financially compensate residents who either manage or incur the opportunity cost for sustaining the source habitats (i.e. people within the same hexagonal cell as those habitats). This valuation alternative calculates total value as the value of essential services in a cell (those flowing directly to the poor), plus the value of PES transfers exclusively to the poor.[5] This assumption is important for watersheds, for example where non-poor residents downstream would pay resource managers upstream. In general, PES revenues are distributed without regard to economic status (Chapter 14, this volume). This implies that financial mechanisms targeting the poorest people in particular could deliver even greater PES value to the poor than that estimated here.

A significant finding is that the most important places for effective PES mechanisms are also the same places where the poor depend on essential ecosystem services (Figure 2.1f). If such PES transfers were uniformly realised, they would capture and channel an additional US$858 billion annually to poor resource stewards. This would be in addition to the essential ecosystem services that the poor receive and rely upon. While these numbers sound high, they represent the full value of the ESV if provided and transferred. If effective and equitable PES mechanisms were implemented comprehensively, ESV to the poor would exceed US$1 per person per day for 30% (331 million) of an estimated 1.1 billion people living in poverty. It will remain challenging to implement such transfers, for which a host of socio-economic, policy and institutional challenges must be addressed in many of these countries. But these results – specifically arising from the spatial distribution of population and poverty relative to the sources and flows of ecosystem services – suggest that progress on even a fraction of these possible PES systems could represent major income flows to the poor.

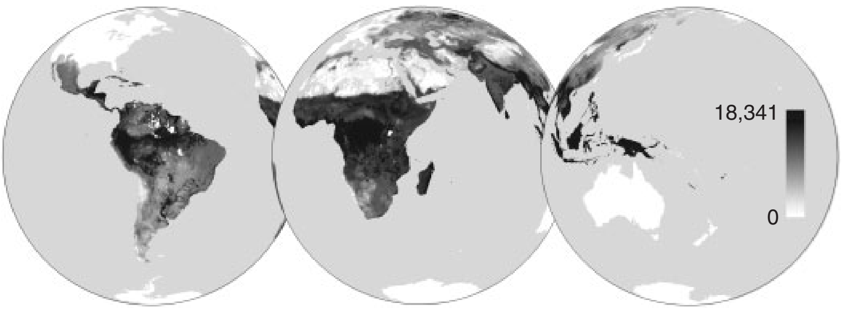
Conclusions: linking ecosystem service flows, people and biodiversity

Biodiversity is the foundation for ecosystem service provision (MA, 2005). We are only beginning to understand how, and how much, intact habitats and biodiversity can be altered without affecting ecosystem functioning and the lasting provision of ecosystem services. Biodiversity loss can change both the magnitude and the stability of ecosystem processes. Ecosystems retaining their original complexity are more resilient, with high numbers of species offering more buffers to change. For example, removing just one of many species of fish from a river can worsen freshwater quality (Taylor *et al.*, 2006), and elimination of biodiversity from landscapes contributed to Lyme

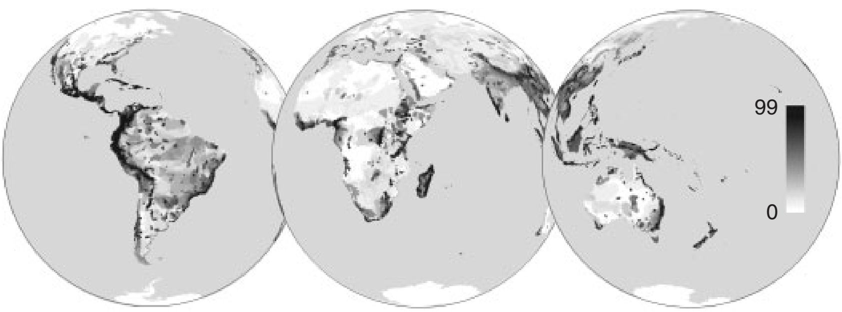
[5] Because our interest is in poor communities in particular, we did not count PES flowing to the non-poor. Specifically, this means the value of PES flowing to the poor in a given cell is (Total PES Value Flowing to Cell) × (Cell Poverty Rate).

disease and hantavirus pulmonary syndrome becoming epidemic, opening pathways for human infection on a large scale (Keesing *et al.*, 2010).

Our analysis allows us to examine the distribution of ecosystem service value (Figure 2.3a) and biodiversity conservation priorities (Figure 2.3b). More importantly, we can identify the places with a high degree of overlap between threatened biodiversity, habitats that provide ecosystem services and poor residents who depend on these resources or services. Overall, there is a strong relationship between biodiversity conservation priorities and ecosystem service provision. For example, conserving the 25% highest priority cells for biodiversity would sustain a disproportionately large 39% of global potential ESV. The relationship between biodiversity conservation priorities and ecosystem service provision increases when realised services are considered: the 25% highest priority cells for biodiversity sustain a disproportionately large 50% of globally realised ESV services – the services actually used by people. And the



(a)



(b)

Figure 2.3 **Mapped global distributions of (a) ecosystem service value ($/ha/yr), specifically essential services with transfers (including payments for ecosystem services), and (b) biodiversity conservation priority (percentile rank) as measured by threatened species endemism.**

relationship becomes stronger still when poverty is considered: the highest 25% of land for biodiversity provides 56% of essential services benefitting the world's poorest, or 57% if PES transfers are additionally considered. Globally, these transfers could add US$858 billion per year in payments to poor communities over all land area; the top quarter of land for biodiversity alone accounts for US$509 billion (59.3%) of this annual increase.

Our findings are particularly critical in the poorest countries given the challenges that they face in achieving the MDGs. These challenges will become especially serious in developing countries as they see their populations swell dramatically by 2050 (Roberts, 2011), with much of this growth taking place in the world's poorest countries (United Nations Population Division, 2011). Our analysis shows that the loss of biodiversity is something that should be alarming to all. It is becoming increasingly evident that as biodiversity loss increases, a significant proportion of the planet's 7 billion are also being deprived of goods and services from biodiversity and ecosystems that they depend upon for their survival. While wealthier countries, or wealthier people within poor countries, have the economic means to replace lost services or pay for higher priced alternatives, poor countries and people cannot. This highlights the importance of conservation actions in supporting both biodiversity and human communities.

While the negative effects of conservation actions on human well-being have been emphasised, recent findings based on more sophisticated research techniques are testing whether people would be better off in the absence of conservation action. Quasi-experimental studies for Costa Rica and Thailand found that districts with protected areas had lower poverty: approximately 10% lower in Costa Rica and 30% in Thailand (Andam *et al.*, 2010). Additionally, there is evidence from across Brazil that an initial economic boom from timber sales can be followed by a bust when the converted habitat loses agricultural productivity. In such boom-and-bust municipalities, the loss of biodiversity and ecosystem services becomes economically apparent, and higher rural poverty rates ensue (Rodrigues *et al.*, 2009). These broad-scale findings suggest that for many countries, the ecosystem services provided by intact habitats outcompete alternative uses, especially in places with steep slopes and poor soils. A clear implication is that the international development community should place biodiversity conservation as a priority concern to avert the unintended deepening of poverty.

Our results suggest that widespread (though not universal) 'win–win' synergies are possible between poverty alleviation and conservation. There are many ways that multiple benefits for the poor, and for biodiversity, could be realised, including creating, expanding or improving management of formal protected area systems; expanding governance structures for land and resource management on community-conserved or indigenous lands (Lewis *et al.*, 2011); decentralising rights over forest commons to forest dwellers (Chhatre & Agrawal, 2009; Ricketts *et al.*, 2010) and introducing incentives for PES (Lipper *et al.*, 2009). The proposed international payment scheme for tackling forest-related carbon emissions – Reducing Emissions from Deforestation and Forest Degradation (REDD) – aims to capture and transfer global benefits to local resource stewards. Such efforts are in their early stages, but are beginning to widely introduce the idea of payment transfers, and may help establish the institutions and mechanisms that will allow other service values to be captured as well. There will undoubtedly be substantial challenges in implementing these programmes, but our ability to target is improving. Meanwhile, decision makers are increasingly looking for ways to accomplish multiple objectives with one investment, heightening discussions about the potential spatial concordance of poverty alleviation, biodiversity conservation and ecosystem service flow protection.

Along with poor governance, the failure of markets to value and capture the importance of natural areas has contributed to both biodiversity loss and persistent poverty when people in remote, rural areas view habitat conversion to marginal agriculture as their only option. Though widespread PES implementation faces challenges such as insufficient policy frameworks and, to date, poor spatial planning (Wunder *et al.*, 2008), our results suggest great potential if effective REDD mechanisms are designed and similar compensation mechanisms for other services are supported widely. Climate change – likely a dominant force impacting our planet in the decades ahead – will increase the value of the many ecosystem services that help ameliorate it and its negative impacts (Turner *et al.*, 2009). If some of the value of these environmental services was captured and efficiently and equitably returned to communities, there would be dual benefits: additional incentives for conservation and new sources of income for rural communities. While funding transfers alone may be insufficient to lift the poor from poverty, they offer better livelihood options and help buffer people facing the increasing challenges of an unpredictable climate. These findings provide important insight for policy makers, as human well-being and poverty alleviation depend critically on the substantial benefits provided by natural ecosystems. Sustaining the places of highest priority for biodiversity conservation will deliver benefits to human well-being and poverty alleviation that are large both in absolute terms and relative to costs and needs.

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