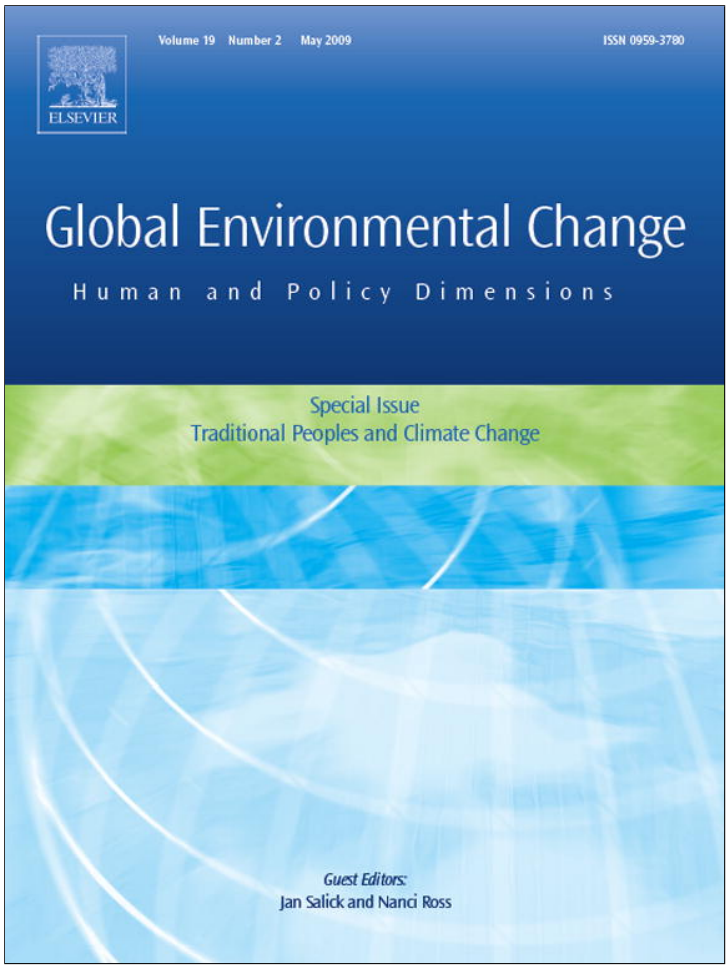

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Avoiding deforestation in Panamanian protected areas: An analysis of protection effectiveness and implications for reducing emissions from deforestation and forest degradation

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ABSTRACT

Reducing greenhouse gas emissions from deforestation and forest degradation (REDD) is likely to be central to a post-Kyoto climate change mitigation agreement. As such, identifying conditions and factors that will shape the success or failure of a reduced deforestation scheme will provide important insights for policy planning. Given that protected areas (PAs) are a cornerstone in forest conservation, we draw on interviews and secondary data to analyze the effects of available PA resources, governance ability, the level of community involvement, and provincial deforestation rates on land-cover change in nine PAs in Panama. Our results illustrate that coupling surveillance measures with greater funding and strong governance are paramount to reducing deforestation. Alone, however, these factors are insufficient for forest protection. We argue that conservation approaches that complement effective surveillance with community participation and equitable benefit sharing will address the wider issues of leakage and permanence.

1. Introduction: avoiding deforestation and protected areas

In the last decade, climate change mitigation has received much international recognition, most notably with the implementation of the Kyoto Protocol under the United Nations Framework Convention on Climate Change (UNFCCC). Deforestation, occurring primarily in tropical forests, is a prevalent and, until recently, overlooked source of greenhouse gas (GHG) emissions, accounting for up to one-third of global emissions (Houghton, 2005). In 2005 at the 11th Conference of Parties to the UNFCCC (COP 11), Papua New Guinea and Costa Rica pushed for the establishment of a mechanism to address deforestation. Such a mechanism, either market-based or fund-based, would constitute a relatively inexpensive means to reduce non-energy sector GHG emissions and to encourage broader participation in climate change mitigation by generally poorer forest-endowed non-Annex I UNFCCC states (Luttrel et al., 2007; Stern, 2007; Forner et al., 2006; Santilli et al., 2005).

Reduced emissions from deforestation and forest degradation (REDD) was a hot topic at COP 13 in Bali in December 2007 and in COP 14 in Poznan in December 2008 and is likely to be central to a post-2012 climate agreement (Skutsch and Trines, 2008). Notwithstanding the enthusiasm surrounding the prospect of such a scheme, no substantial movement has been made on the details of the REDD mechanism(s) to be adopted (Skutsch and Trines, 2008); thus, uncertainty relating to the architecture of the mechanism remains. Decisions need to be made regarding the

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nature of carbon buyers (industrialized countries, companies, organizations, individuals) and sellers (national or sub-national government, private projects), the mode of financing (market or non-market), the compensation scheme (government regulated or direct flow to deforestation stakeholders), as well as the type of land use targeted (pristine forests or degraded lands) (Skutsch and Trines, 2008). The specifics of a REDD mechanism, expected to be readdressed before or at COP 15 in December 2009, will need to be critically assessed if REDD is to be effectively implemented.

A number of environmental policy instruments such as sustainable forest management and forestry certification, payment for ecosystem services, fiscal and trade policies, and the designation of protected areas (PAs) have been used to counter deforestation threats in the context of biodiversity conservation (Wunder, 2005). PAs have been particularly central to forest conservation efforts (UNEP and WCMC, 2008; Sánchez-Azofeifa et al., 2003); yet with additionality being a fundamental stipulation of climate change mitigation projects, it remains uncertain as to whether previously established PAs will be eligible for REDD (Skutsch and Trines, 2008). Additionality refers to carbon emission reductions that would be in excess of those that are all ready in place. For several tropical nations, much of the remaining intact forests are bound up in PAs or other derivatives thereof; thus PAs, if accepted for REDD, could play a key role in state-led initiatives by committing forests as carbon reservoirs (Forner et al., 2006).

Before engaging in an international REDD agreement, tropical forest nations will need to evaluate their ability to curb deforestation, pinpoint factors that will guarantee permanence – the sustained and effective protection of forest carbon – and develop strategies to circumvent leakage – the displacement of deforestation to relatively unprotected areas. A nation's ability to avoid deforestation within its PAs could be used as a good primary gauge of the country's capacity to protect forest biomass under a REDD scheme.

We use Panama as a case study to investigate the effectiveness of PAs at conserving forest integrity. If these PAs are performing well, implementation of a REDD agenda could promote their use and increase the prominence of PAs within a suit of tools to reduce GHG emissions. If they are failing to avoid deforestation, an analysis of the factors and the underlying dynamics driving these failures will identify strategies most likely to contribute to effective forest carbon conservation. Consistent with the objectives of REDD, we define PA "effectiveness" as the maintenance and/or the increment of mature forest cover within PA boundaries. We draw on interview data relating to available PA resources as well as indicators of PA governance and community–PA rapport to evaluate the effectiveness of nine Panamanian PAs (Fig. 1). The three categories used in this study represent the main theoretical pillars of protection capacity: resources (staff, funds, and infrastructure), governance (political support, legislation, and management design) and community rapport (awareness and support) (Hockings et al., 2006).[2]

2. Case study context: protected areas and management approaches in Panama

Effective PA protection is seldom easy for industrializing states, especially when faced with extreme poverty, growing populations dependent on agriculture, limited financial resources, corruption and oftentimes political instability and conflict (Naughton-Treves et al., 2005). In Panama, conservation efforts occur within a context of unequal arable land distribution (Contraloría, 2003), rapid rural population growth and poverty, laws that afford land titles via forest clearing and the existence of vast tracts of unprotected forests (ANAM, 2003a). Such contexts not only restrict the state's capacity to effectively protect but also contribute to deforestation (Peskett et al., 2006; Lambin et al., 2003; Geist and Lambin, 2001). Such circumstances can explain the fragility of many established and newly formed PAs that are unable to limit deforestation within their boundaries.

Historically, Panama's PA management strategies worked to counter the anthropogenic pressures exerted on ecosystems by applying top-down, 'command and control' measures—an often coercive, state-lead approach to protection that maintains ecological integrity at the expense of local resource use. While this model has been effective under certain conditions (the United States National Park System for example), the exclusionary ideology upon which 'command and control' is based has been rebuked for failing to address many of the underlying causal factors of environmental degradation in tropical industrializing areas (Lambin et al., 2003; Geist and Lambin, 2001). Consequentially, top-down resource management has been linked to marginalizing poor populations and exacerbating natural resource depletion (UNEP and WCMC, 2008; Griffiths, 2007; Luttrel et al., 2007; Peskett et al., 2006; Wunder, 2005).

Faced with these realities, Panama has begun to move away from the 'command and control' model and adopt alternative community-based conservation approaches. This school of conservation philosophy is founded upon devolution of PA management and some level of relinquishment of state authority to actors at the local scale (communities and/or non-governmental organizations (NGOs)) (Vedeld, 1996). These programs can be structured in a variety of formats to offer participating communities indirect benefits from conservation, such as land ownership rights, market access, infrastructure, social and technological capital, etc. With these benefits in mind, some community-based models work to explicitly merge their mandates with 'green' development strategies to serve some of the overlapping interests of both development and conservation programs.

While community-based PA protection approaches reduce the social costs of conservation (Igoe, 2004; Brockington, 2002), conflicting conclusions are still being drawn as to which management strategy (top-down versus bottom-up) can best achieve conservation goals (Hayes and Ostrom, 2005; Locke and Dearden, 2005; Putz et al., 2001; Rice et al., 1997). For example, Bruner et al. (2001) finds PA effectiveness in tropical regions to be significantly related to enforcement measures, but not community participation. In direct response to these findings, however, Hayes (2006) offers evidence to argue that community-managed PAs are equally if not more effective than centralized, traditionally managed PAs. Because community-based approaches may better address the pressures underlying deforestation than a 'command and control' model, they offer the prospect of offsetting the threat of leakage when establishing measures to produce GHG emissions' credits under REDD.

Panama is currently working to apply a new conceptual conservation paradigm: payment for ecosystem services. The rationale behind this approach lies in the creation of economic incentives for conservation and, as in the case of ecotourism, the generation of alternative livelihood options to forest-dependent communities (Wunder, 2005; Gossling, 1999; Ruschmann, 1992).

[2] Hockings and colleagues (2006) define these factors as the basis for the capacity to effectively manage PAs. Under REDD, forest conservation would be a principal PA management objective, thus we use their criteria as a benchmark to study the capacity to protect.

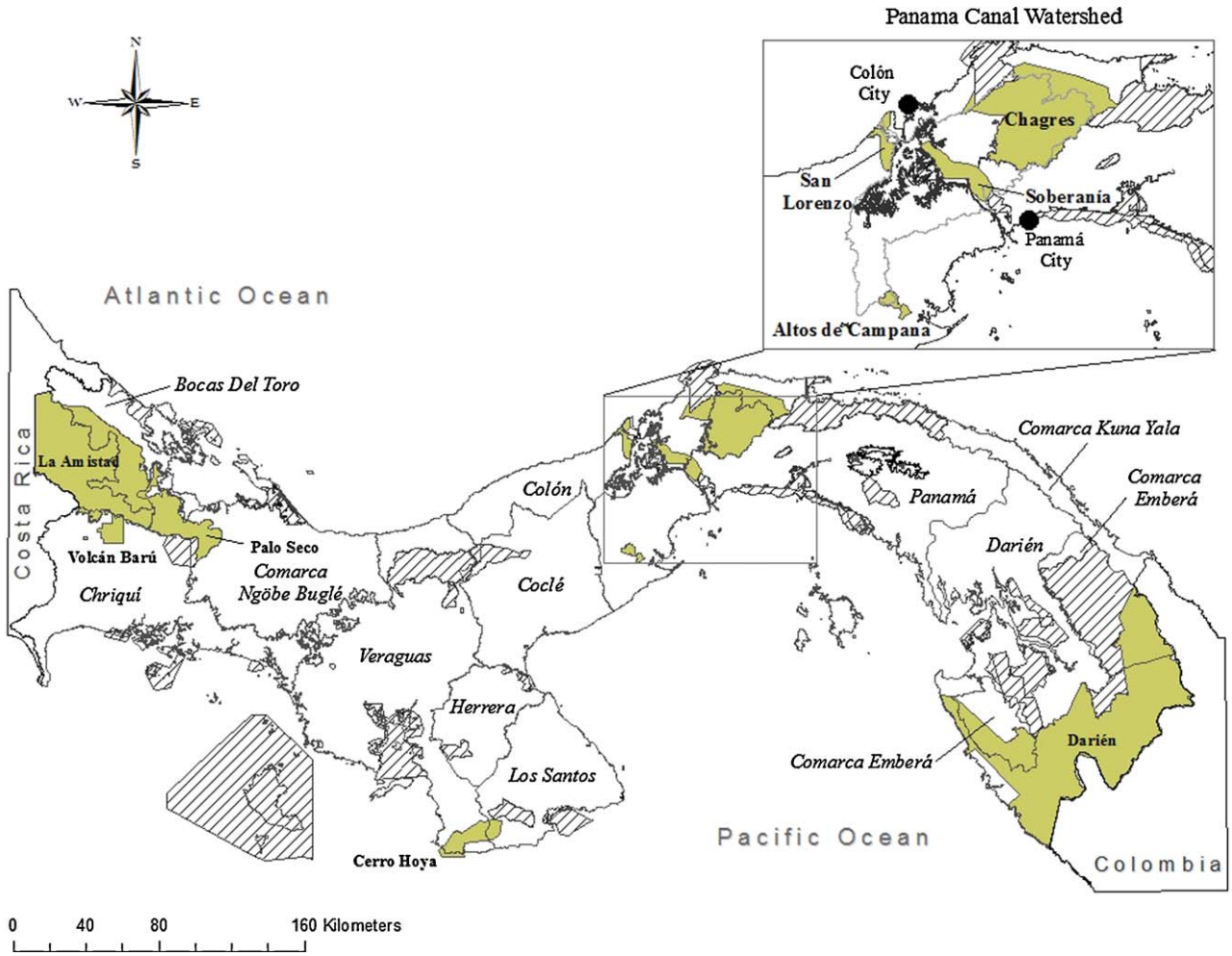

Fig. 1. The Republic of Panama. All legally recognized protected areas in Panama are demarcated. The solid fill pattern indicates the nine PAs considered in this study; their corresponding names are in bold. All other PAs are denoted by the forward slash pattern. Provincial boundaries are indicated and names are in italics. Circles represent the two main urban centers of the metropolitan region. It should be noted that La Amistad is an international park, shared with Costa Rica, and that Darién is contiguous with the Katios National Park of Colombia. Most of Panama's unprotected forests are found in the province of Darién and along the Atlantic coast.

3. Methods

3.1. Interviews

PAs in Panama depend on a variety of entities to support conservation efforts. The National Environmental Authority (ANAM) is the main funding and administrative institution for PAs, however direct and indirect additional support is sometimes provided by aid agencies and national and international NGOs. The national police force exclusively maintains the authority to issue fines and jail time for infractions and illegal activities in PAs.

Semi-structured interviews with some of these PA stakeholders were carried out in four PAs – San Lorenzo, Soberanía, Chagres, and Altos de Campana (Fig. 1 and Table 1) – using open ended, single

Table 1
Interviews carried out in nine protected areas. The position and number of ANAM staff interviewed is indicated. In some protected areas, supplementary interviews were carried with organizations involved in the park: El Centro de Estudios y Acción Social Panameño (CEASPA), a national NGO with sustainable development objectives; The Nature Conservancy (TNC); The Interoceanic Region Authority (ARI), which patrols a former US-military base in San Lorenzo where unexploded ordnance still exist; The Smithsonian Tropical Research Institute (STRI), an institution that collaborates with PAs on biodiversity and conservation research in Panama; Fondo Chagres, a cooperatively managed fund for the conservation of Chagres; Fundación NATURA, an international NGO that financially and logistically supports ANAM conservation programs; and the national police (NP).

Protected area	ANAM interviews	Supplementary interviews
Altos de Campana	3 guards	Peace Corp regional director, STRI researcher
San Lorenzo	3 guards	CEASPA director, 2 ARI guard staff
Volcán Barú	1 administrator	
Soberanía	3 guards	STRI researcher, Fundación NATURA representative
Cerro Hoya	1 administrator	
Chagres	2 guards, 1 administrator	Fondo Chagres director, TNC representative, 2 members of the NP
Palo Seco	1 administrator	
La Amistad	1 administrator	
Darién	1 administrator	
Total	17	11

answer, and multiple choice formatted questions. These PAs were chosen for their accessibility. Interviews were exploratory in nature, designed to gain a thorough understanding of the PA management structure, governance, roles and responsibilities of stakeholders, community–PA relations, deforestation threats, and resources necessary for effective protection.

ANAM representatives from five additional PAs – Volcán Barú, La Amistad, Darién, Cerro Hoya, and Palo Seco (Fig. 1 and Table 1) – were interviewed using a structured format. Questions focused on available and deficient resources, necessities for effective protection, deforestation threats and local community relations with the PA. When available, secondary data from PA management plans and physical maps were used to complement interviews.

In total, twenty-eight interviews were carried out in nine PAs (Table 1), representing about 43% of terrestrial PAs in Panama. In an effort to triangulate the qualitative data-collection procedures, interview data was cross-referenced with secondary data when possible. We do nonetheless acknowledge that the interview data is ultimately subjective; however it was the most cost-effective and, often times, the only available source of information. Moreover, PA stakeholders that work directly in PAs are likely to have a clear understanding of resource deficiencies, requirements to improve protection and prevailing issues in their PAs, an assumption corroborated, for example, by the strong agreement between reported and published numbers of guards (MNRE, 2005).

3.2. Defining protected area resources

From the interview data we defined the following five general resource categories and quantified their values and distribution across the nine PAs: (1) personnel; (2) transportation; (3) infrastructure; (4) NGOs; and (5) funding. Where informants gave varying responses for the number of resources (e.g., personnel), we used the median value. Although other resources also support PA protection (e.g., information, computers, radios, telephones, training and education, etc.), we restricted our analysis to resources that were easily quantified and that make up the core of the basic protection framework. The following section briefly details each resource category.

ANAM personnel (guard and administrative) were documented for each PA. Although the national police and the Interoceanic Region Authority (see Table 1) do participate in PA vigilance, their staff numbers and rotation schedules were not available and were therefore not included.

Transportation available for patrolling and other official duties was documented detailing the number of functional trucks, motorcycles and boats (including dugout canoes or other river transportation).

The infrastructure estimate for each PA included the number of roads, trails and bases. Bases were defined as any post where guards are able to rest during patrols. Tourist offices were not included because they do not directly support protection efforts.

Only NGOs with a physical presence in the PA were counted and not those that contribute indirectly through logistical, technical and financial support.

Funding was divided between internal (state) and external sources. While financial resources issued by ANAM provide the bulk of PA staff salaries and finances for infrastructure and equipment, PAs may also receive external funding donations from national and foreign organizations. The total external and state funding for each PA was adapted from MNRE (2005) for the 2005 fiscal year.

3.3. Defining PA governance and community rapport

Resources are just one node in a complex web of factors that influence PA effectiveness. We therefore include two indicators variables taken from a global study of PA management effectiveness in Panama (ANAM, 2001) to integrate the social and political dimensions of effectiveness into the analysis. In their study, ANAM (2001) used a system of indicators developed by PROARCA/CAPAS (2000) to rank PAs according to the following criteria: (1) social capacity: stakeholders recognition, participation and benefit sharing, conflict resolution ability, land-title status in and around the PA, environmental education, ecotourism management; and (2) governance capacity: PA legal status and legislative implementation, administrative and technical staff decentralization, inter-institutional relations.

3.4. Land-cover change and threats estimates

Satellite-derived estimates of land-cover change for the period 1992–2000 (ANAM, 2003a) were used to estimate forest cover and agricultural change in Panamanian PAs. Forest cover change estimates have a ground resolution of 30 m (Landsat TM satellite imagery used by ANAM (2003a)), with the exception of that for Palo Seco. For Palo Seco, land-cover change was estimated at a 100 m resolution by comparing the 1992 and 2000 maps of ANAM (2003a) with the PA boundaries defined by The ANAM Environmental Indicators Project (ANAM, 2006c). We defined land-cover categories as follows: (1) mature forest cover is primary and mature secondary forest with canopy closure greater than 80%; (2) transitioning land-cover includes pioneer forest growth, grasses, shrubs and forests with more than 60% of their canopy altered by human activities; (3) agriculture is land used for subsistence agriculture and other agricultural activities including pastures for livestock grazing.

PA effectiveness is in part a function of the external pressures exerted on a PA. Regardless of the capacity to protect separate forest stands, PAs in areas where threats are significant or mounting have a higher deforestation risk than their relatively unthreatened counterparts. We therefore use average annual provincial deforestation rates from 1992 to 2000 (ANAM, 2003a) as an indicator of pressures beyond PAs and to make inferences about the externalities of PA protection. In cases where PAs cross provincial boundaries, the median provincial deforestation rate was used. The role of agriculture within PAs can either be threatening as agricultural lands expand into forests or beneficial by allowing local communities to make a livelihoods without overexploiting the adjacent forest. In Panama, agriculture within PAs is mainly at the subsistence level. Regardless of the potential outcome, PAs with agricultural lands are at a higher risk than forest with no agriculture nearby. We therefore consider agriculture within a PA as an indicator of pressure on a PA's effectiveness.

3.5. Qualitative comparative analyses

We undertook qualitative comparative analyses (QCA) to determine the conditions contributing to effective PA protection. QCA is a small-sample analysis that uses cross-case comparisons to reduce causal complexity into a minimal set of conditions necessary for an outcome (Rihoux, 2006). QCA uses Boolean logic to maximize the number of permutations of conditions (to $2^{[\#\ \text{of conditions}]}$) across a limited sample and infer *conjoint* causation between conditions and the outcome, that is, causation of a specific *set* of conditions acting collectively and interactively on the outcome. Causation is inferred not merely by the consistent presence of a condition relative to an outcome but also by its absence, across all possible permutations of conditions (Rihoux, 2006). Therefore, QCA validates the role of a condition through negative-case analysis, highlights interaction between conditions and recognizes 'absence' as a causative factor. The incorporation of counterfactual cases – combinations of conditions for which

Table 2
Outcomes, conditions and thresholds for the qualitative comparative analysis.

	Threshold for status of 'sufficient for outcome'	Rational for threshold
Outcome		
Effective PA protection	No loss of mature forest cover in PA, 1992–2000	–
No PA threat	No or negative aerial change in agricultural activity, 1992–2000	–
Conditions		
Guards	≥3 guards per 100 km^2 of PA, 2006	Bruner et al. (2001) observe 3 guards per 100 km^2 as the median ratio for effective protection.
Social	Social capacity indexed as 'acceptable' or better (≥601 out of 1000), 2000	Acceptable social capacity suggests fewer and less severe threats to PA integrity (ANAM, 2001).
Governance	Governance capacity indexed as 'acceptable' or better (≥601 out of 1000), 2000	Acceptable governance capacity suggests efficient enforcement and regulation of protection (ANAM, 2001).
NGO	≥1 NGO present per 100 km^2 of PA, 2006	NGOs may enhance social capacity and state-community cooperation, and seem common in Panama's better-protected PAs.
Funds	Combined state and external funding ≥$656 per km^2 of PA, 2004–2005	Combined funding for Chagres PA, Panama's well-protected and second most well-financed PA, was $656 per km^2 for 2004–2005.
Transport	≥1 vehicles and boats vehicle or boat per 100 km^2 of PA, 2006	Guards require at least one working vehicle to effectively monitor PAs.
Deforest	No provincial deforestation, 1992–2000	No deforestation suggests a generalized reduced threat to PAs.

unobserved outcomes are estimated based on theory and substantive knowledge – enhances this process by promoting diversity in the sample, which partly counteracts the limitations of small-sample size (Ragin and Sonnett, 2005). Readers interested in detailed discussions of QCA may consult Ragin and Rihoux (2008), Ragin and Sonnett (2005), Rihoux (2006) and Hellstomöm (1998).

We define two outcomes for two separate QCAs. The first, 'effective PA protection', is defined by no mature forest loss in the PA over the period of 1992–2000. The second, 'unthreatened PA', is defined by no (or negative) agricultural land-cover change within the PA over 1992–2000. While no agricultural expansion would suggest effective protection and thus appear redundant, we conduct a QCA for each outcome to test this assumption and compare their respective conditions. Table 2 lists the conditions considered relevant to these outcomes, and the threshold values beyond which they are deemed 'sufficient' for the outcome. We set thresholds in accordance with theory and substantive knowledge, and summarize our rationales in Table 2. We specified a combination of conditions as causative of an outcome when ≥75% of its cases actually resulted in the outcome. Intermediate and parsimonious solutions were derived to reveal the 'necessary' (essential) and 'sufficient' (facilitative) conditions for each outcome, respectively.

4. Results

4.1. Land-cover change in protected areas

Owing to the predominance of PAs in the current forest-protection toolbox, assessing a nation's ability to avoid deforestation in its PAs can provide important insights for REDD implementation. Our land-cover change analysis shows that PAs in Panama have had mixed success in terms of their ability to control deforestation. Some PAs have been relatively effective while others, such as Palo Seco and La Amistad, have not (Fig. 2a). Amongst PAs that have lost mature forest cover, aerial increases in transitional forest cover appear more frequent than aerial increases in agricultural (Fig. 2a). These transition forests are either lands left in fallow or are the product of an edge effect whereby anthropogenic and ecological stresses degrade the margins of proximate mature forest stands (Laurance et al., 1997).

Analyzing the varying protection capacity across PAs will help identify conditions contributing to effectiveness. A comparison of the social and political landscapes in which various PAs function can further illuminate some of the reasons behind these disparate records of protection and can therefore contribute to an improved assessment of REDD potential. In presenting the remainder of the results, we consider how some of these conditions operate.

4.2. Personnel

Guards, with a direct and everyday involvement in patrolling and monitoring PAs and reporting illegal activities, constitute the lower, yet critical, echelon of state-led PA protection in Panama. Bruner et al. (2001) estimate that approximately three guards per 100 km^2 are necessary to deter the encroachment of threats on PAs. Administrative staff complements the on-ground activities of PA guards, serving as the central line of communication between PAs, state offices, and the national police to convey concerns about resource needs, management, and illegal activities.

Many informants stressed the need for more personnel; a warranted demand given that guard staff is inadequate (<3 guards/100 km^2) in more than half of the PAs (Fig. 2b). In larger PAs, such as Darién, insufficient staff has led to primarily patrolling 'priority areas', leaving some zones to be monitored once or twice yearly. Staff shortages have left other PAs, such as Palo Seco, to be administered by one person or, in the case of La Amistad and Volcán Barú, by a single staff member for two PAs.

On the contrary, PAs in and around the Panama Canal Watershed, most notably Chagres, are well staffed (Fig. 2b). Chagres is the largest of five PAs (Fig. 1) established in response to the mounting deforestation in the Panama Canal Watershed during the 1970s. These areas now constitute the foundation of conservation strategies in the region. Under the former United States (US) occupation of the Canal Zone, Chagres and Soberanía were stringently protected and certain areas, such as San Lorenzo, were used for US military activities until the Canal Zone was abdicated in 2000. Panama still has a vested interest in protection of the watershed given the country's economic link to the Canal. Accordingly, these PAs are afforded protection priority.

4.3. Transportation

Vehicles, boats and motorcycles are used by guard staff to patrol the PA, communicate with local communities and for other official duties. In general, the largest and most remote PAs rely heavily on transportation to exercise their functions, but have very little available (Fig. 2c). Although scarce transportation equipment was noted as a deterrent to effective monitoring, respondents also mentioned that having transportation consistent with PA geo-

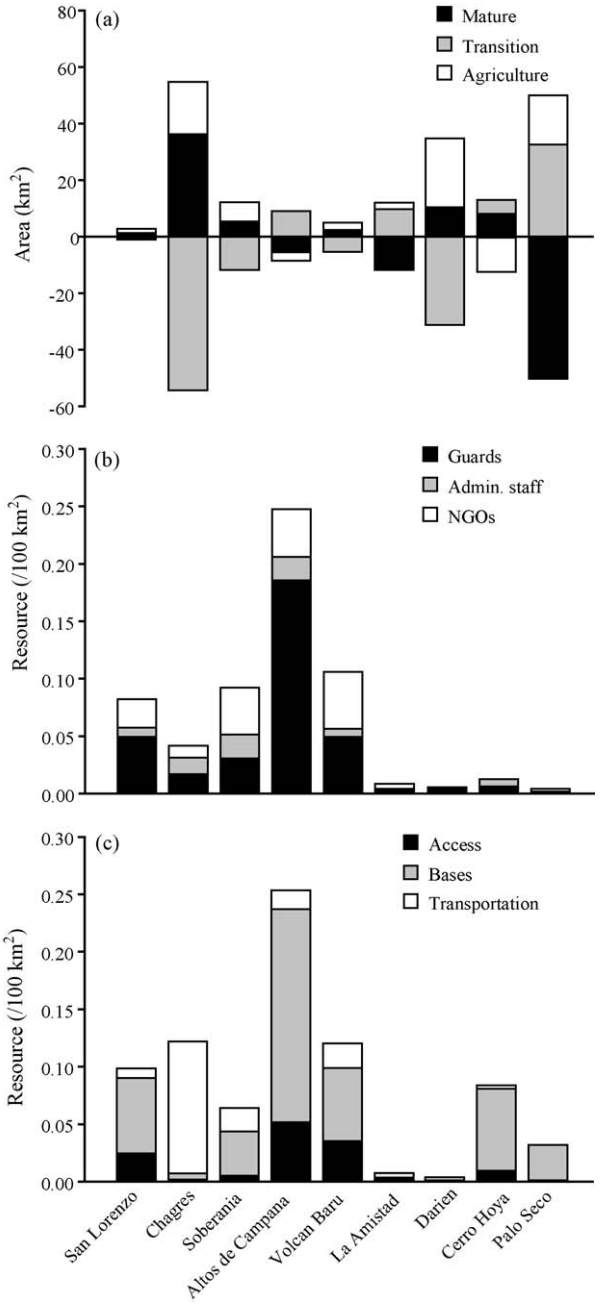

Fig. 2. Resources and land use change across protected areas. (a) Land-cover change in protected areas from 1992 to 2000; (b) ANAM personnel and NGOs working in protected areas; (c) transportation, bases used by ANAM guard staff, and protected area access.

graphy is a necessity. With no functional boats, guards in San Lorenzo have been unable to monitor the coastline which, according to the local NGO (Table 1), has resulted in uncontrolled resource extraction in the PA. Similar circumstances have left guards in Palo Seco and La Amistad unable to patrol the river networks or communicate with in-PA communities. Issues of maintenance and repair of existing equipment also cause transportation difficulties. Five PAs reported having at least one or more damaged means of transportation, some of which had been out of service for several years.

Transportation is relevant mainly in areas where it is practical. In large PAs, with difficult-to-access areas, informants emphasized that helicopter flyovers and aerial or satellite images could improve PA protection effectiveness. These measures could complement on-ground patrolling activities and assist monitoring of areas where access by vehicles, boats or on foot is impractical.

4.4. Infrastructure

In most PAs, informants identified guard bases as inadequate, some requiring varying degrees of reparations in order to be operative. In large PAs, increasing the number of bases would allow guards to take the overnight trips that are necessary to reach and monitor remote areas; without more bases, patrolling these areas is often logistically unfeasible.

While bases certainly support surveillance activities, trails and roads play a contrasting role. Road networks providing patrol routes for guards concurrently facilitate access into PAs for illegal activities. The example of Palo Seco is a case in point. In this PA, 50 easy-access roads and trails, compounded by a weak protection capacity and the presence of several forest-dependent communities marked by rapid population growth and poverty (Fig. 2 and Table 3), have caused, according to one respondent, deforestation in Palo Seco to perceivably increase. This inference is certainly supported by the forest cover loss in this PA (Fig. 2a). It was also mentioned that infrastructure construction and elongation – direct deforestation drivers (Laurance et al., 2004; Geist and Lambin, 2001) – have triggered forest loss in and around Palo Seco and Darién. Informants in Chagres, Soberanía, and San Lorenzo, in contrast, described the construction of new trails and the maintenance of existing ones as a necessity for promoting ecotourism to metropolitan dwellers, which could in turn generate additional income for the PA.

4.5. NGO participation

NGOs have, by and large, been the momentum behind the adoption of community-based conservation approaches that create benefits for communities and other stakeholders and strengthen the technical, administrative and institutional capacity of the PA managing body. Examples include pioneering payment for ecosystem services programs (principally ecotourism) in numerous PAs, sponsoring sustainable resource-management initiatives in Darién and Cerro Hoya, and endorsing cooperative management planning in 36 PAs across Panama (ANAM, 2006a). Such approaches are generally geared towards community empowerment and capacity building, promoting a democratic and decentralized decision-making process, and may also aim to bridge conservation and sustainable development goals. Financial and logistical support from The Nature Conservancy (TNC) in collaboration with national NGOs, ANAM and other public institutions has made many of these programs possible.

The central role NGOs can play in conservation is well illustrated in the case of Cerro Hoya, a PA created in the late 1980s after extensive deforestation and immigration to the Peninsula in the mid-20th century (see Fig. 1). With the appropriation of land for protection, conflicts between locals and conservation authorities grew in the densely populated region. Through the work of several local NGOs in collaboration with communities and foreign funding agencies – most notably the German Agency for Technical Cooperation (GTZ) – land tenure was secured in the region, community environmental education and capacity building programs were initiated, sustainable resource use was encouraged, and severely degraded areas were reforested. Presently, deforestation in the region is minimal or has been halted (Table 3).

4.6. Protected area funding

Although PAs count on the state for financial support, many conservation efforts are made possible by donations from external

Table 3
Protected area description. In-park communities and population numbers do not include buffer-zone communities. The social capacity and governance capacity of PAs are ranked on a scale from 0 to 1000 according to the following scale: unacceptable (0–200); poor (201–600); average (401–600); acceptable (601–800); satisfactory (801–1000). Annual average forest loss is shown according to the province in which parks are located. For protected areas that cross provincial or Comarca (indigenous territory) limits, data from both areas is shown. It should be noted that urban centers in Colón and Panamá provinces will influence demographic indicators.

Protected area	Size (km^2)	Age (years)	Communities and population	Social capacity	Governance capacity	Province	Population growth rate (%)	Forest loss (% area)
Altos de Campana	49	42	4 (100)	311	624	Panamá	8.20	1.53
San Lorenzo	120	28[a]	0	618	623	Colón	7.23	1.02
Volcán Barú	140	32	6 (907)	407	558	Chiriquí	5.17	−1.93
Soberanía	195	28	0	569	634	Panamá	8.20	1.53
Cerro Hoya	326	24	20 (2000)	632	552	Los Santos/Veraguas	2.41/2.81	−3.95/0.78
Chagres	1295	24	33 (2700)	362	624	Colón	7.22	1.02
Palo Seco	1250	25	73 (5114)	324	499	Bocas del Toro/Comarca Ngöbe Buglé	10.29/11.6	0.36/2.72
La Amistad	2070	20	5 (500)	494	624	Chiriquí/Bocas del Toro	5.17/10.29	−1.93/0.36
Darién	5790	28	11 (3000)	401	446	Darién/Comarca Embera-Wounaan	4.35/1.65	1.74/0.13

Sources: Protected area size and age is from ANAM (2006a,b); communities and population are from ANAM (2006a,b,d, 2005, 2004a,b); provincial statistics are from Contraloría (2003).

[a] Although this PA was declared a national park in 1980, the area was used as a US military base from 1911 to 2000.

organizations or funds generated through international agreements (Fig. 3). While some studies have found that PA budget does not significantly affect PA effectiveness (Bruner et al., 2001), we found that the role of funding in Panama more closely follows findings that herald this resource as a top priority (Balmford et al., 2003; James, 2001). As demonstrated by the examples that follow, reliable funding plays a central role in the establishment, long-term maintenance, and legitimate protection of PAs in Panama.

The effective forest protection in Cerro Hoya exhibited in the 1990s (Fig. 2) is testimony to the encouraging outcomes of the community-based conservation strategies initiated in the surrounding region, evidently owing largely to the GTZ-funded management of this PA (GTZ, 2002). Yet, when the GTZ-program came to term in 2004, the funds supporting these necessary endeavors were withdrawn. With no readily available alternative funding sources at hand, Cerro Hoya was unable to maintain staff salaries (MNRE, 2005). This paternalistic dependence on a finite and single external source of aid for forest protection subjected Cerro Hoya's conservation mandates to risk of failure. After several months of being left unprotected, the PA's management structure was partially restored when the state conservation authorities allocated internal funds to rectify the situation.

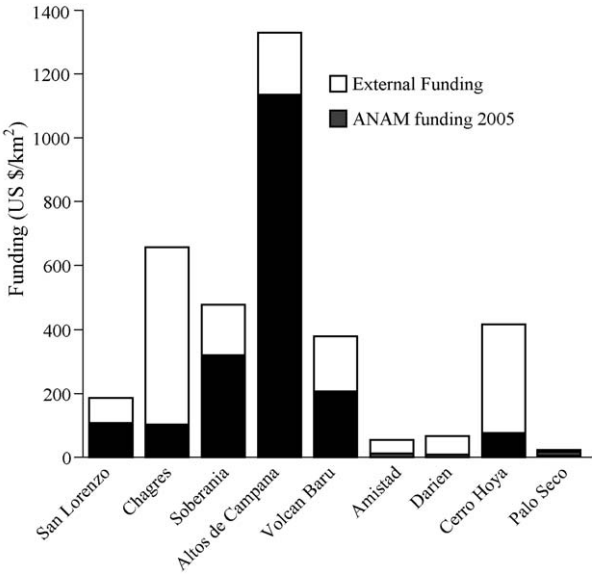

Fig. 3. Annual protected area funding for the 2005 fiscal year. Adapted from MNRE (2005).

Such vulnerability to funding failures is minimized in the successful PAs in and around the Panama Canal (see Fig. 1), where a variety of funding agencies – including the United States Agency for International Development (USAID), TNC, the Japanese International Cooperation Agency (JICA) and The Panama Canal Authority – source a steady and abundant flow of financial contributions (Fig. 3). The sustained allocation of funds towards long-term, integrated social–environmental conservation and sustainable development projects in these PAs and the adjacent regions has likely been a contributing factor to the prolonged integrity of forests in these areas (Fig. 2).

In addition to the funding provided by agencies and organizations, Darién and Chagres have also engaged in a 'Debt-for-Nature' swap program with the US. Funds generated from this program have been used to finance improvements to infrastructure and equipment, implement sustainable development programs, and support cooperative management planning. In 2005, with additional support from USAID and TNC, an auxiliary vigilance team of 32 guard and administrative staff was recruited in Chagres to complement the already established state presence. With rapid movement of the agricultural frontier and resultant biodiversity loss, international interest in the Darién region has also increased. Consequently, the Global Environmental Facility (GEF), a fund engendered by the Convention on Biological Diversity (CBD), contributed US$3 million for conservation of Darién. This PA, along with Volcán Barú and San Lorenzo, also profits from a fund of US$39 million that supports sustainable development and conservation of the Mesoamerican Biological Corridor of the Panamanian Atlantic.

In addition to international agencies and finance mechanisms that directly fund PAs, state conservation funding in Panama is also largely subsidized by foreign contributions. About 70% of the conservation budget was financed by external sources in the 1999–2004 time period, including national and international NGOs, aid agencies, the GEF fund, and most predominantly the Environmental Trust Fund of Panama (FIDECO), a joint venture of USAID, TNC, and the Ecuadorian NGO Fundación NATURA (MNRE, 2005).

4.7. The cost of reducing deforestation: the case of the Charges protected area

What does it cost to be achieve effective protection? Indeed, a dollar value is difficult to estimate as protection costs are ultimately a factor of land opportunity cost, a constituent of economic and development status around the PA, and PA remoteness and size (Balmford et al., 2003). Nevertheless, evaluating the funds required to protect a successful PA can

Table 4
Current Annual average protected area budget. All budgets represent funding secured for protected area management and is averaged for the 2005–2009 period for all parks with the exception of Soberanía and Cerro Hoya (for 2005–2008) and Palo Seco (for 2007–2011).

Protected area	Budget (US$/km^2 year)
Altos de Campana	6314
San Lorenzo	2640
Volcán Barú	1057
Soberanía	2994
Cerro Hoya	341
Chagres	432
Palo Seco[a]	80
La Amistad	77
Darién	73

Source: Budgets are adapted from ANAM (2006a) except Palo Seco which is from ANAM (2006d).

[a] The budget for this PA has not yet been approved. Current funding available to the PA is about 8 orders of magnitude less.

provide an estimate of the cost of effectively reducing deforestation—valuable information for tropical countries assessing the costs, benefits, and trade-offs of committing to a REDD agreement. To do so, we evaluated the Chagres budget. This PA was chosen because it has been a successfully protected area (Fig. 2a) and because the necessary data was readily available.

Owing to its extensive financial support and local and international NGO participation, Chagres has been able to increase surveillance, work on institutional capacity building and decentralization, encourage community–PA collaborations and develop viable economic alternatives to deforestation. While the start-up and maintenance costs of these initiatives will augment the financial requirements of the PA and demand considerable institutional, logistical, and technical support to succeed, PA managers, ANAM, and advising external organizations (TNC and USAID) judge these additional costs as necessary for the longevity of Chagres' success. Our results certainly support this conjecture, as do other studies (Balint, 2006; Kruger, 2005; Naughton-Treves et al., 2005; Pretty, 2003; Gossling, 1999; Gould, 1999; Ruschmann, 1992).

The average yearly funding in Chagres based on financing for 2005–2009 amounts to $432 per km^2 (Table 4) (ANAM, 2005). In order to accomplish the objectives identified in the management plan, the PA requires an additional $1,739,618, representing about 64% of the existing funds for 2004–2009 (ANAM, 2005). Based on this deficit estimate, ideal yearly funding for effective PA protection would be $889,922, corresponding to $709 per km^2. Funding is needed to repair infrastructure, purchase new equipment, expand administrative and technical staff size and increase the number of guards to 2.4 per 100 km^2. A detailed analysis of the proposed expenses is difficult to undertake because the management plan does not specify what resources the PA currently has or additional resources required. If the number of guards were increased to 3 per 100 km^2, the median ratio in effectively protected PAs (Bruner et al., 2001), Chagres would require between $728 to $744 per km^2 per year, depending on salary value (ANAM guards are paid about $250 per month while guards hired for the Chagres auxiliary team are paid about $450 per month). This corresponds to a yearly deficit of $296 to $312 per km^2 per year. All values are in United States Dollars for the year 2006.

Given that Chagres is already well-established and well-equipped, we consider this estimate conservative and predict that the cost of attaining effective protection will be considerably higher in areas where resources are limited and institutional capacity is weak. In light of the current budgets for Panamanian PAs (Table 4), we predict continued forest loss in the most ineffective and highly threatened PAs if no additional support is acquired.

4.8. Comparative analyses: towards a synthesis

Our QCAs suggest that PA protection may cost less than our assessment of Chagres PA indicates, but they also underscore the centrality of PA investment to protection. Table 5 presents the intermediate and parsimonious expressions of the combinations of conditions accounting for the outcomes Effective PA Protection and No PA Threat. Expressions follow a Boolean logic of subsets whereby of a single line of an expression accounts for a subset of PAs, all lines account for all PAs, and terms in the parsimonious expressions are necessary for the outcome while those in intermediate solutions are merely sufficient for the outcome.

The most striking result is the apparent irrelevance of funding for PA protection. As the expressions for effective PA protection show, when levels of guards, NGOs, transportation and social capacity are sufficient, total funding may be 'insufficient' – that is, less than the $656 per km^2 threshold defined by the Chagres PA (Table 2) – without compromising the effectiveness of protection. This, however, does not imply that funding is unimportant. On the contrary, the expressions reveal that investments in guards and transportation are essential for protection, and as most Panamanian PAs are deficient in these resources and others they may represent (e.g., administration), achieving effective protection will still entail significant expenditures. The central role of guards also suggests that the REDD mechanism would need to dedicate funds to surveillance and favour a 'command and control' approach (Anger, 2008; Forner et al., 2006). Yet the expressions also note that

Table 5
Causal combinations of conditions for effective PA protection and no PA threats. Capital letters denote the fulfillment of a condition, and lower-case letters the contrary, as per Table 2, e.g., "GUARDS" denotes a sufficient number of guards for the outcome, while "guards" denotes an insufficient number.

Outcome	Solution
Effective PA protection	Parsimonious: GUARDS *and* funds *or* govern
	Intermediate: GUARDS *and* NGO *and* SOCIAL *and* funds *or* GUARDS *and* NGO *and* TRANSPORT *and* funds *or* govern
No PA threat	Parsimonious: GUARDS *and* FUNDS
	Intermediate: GUARDS *and* NGO *and* TRANSPORT *and* GOVERN *and* FUNDS

Notes: The condition 'deforest' does not appear in these solutions due to its indifference to the outcomes in the presence of the remaining conditions. Refer to Table 2 for definitions of the outcomes and conditions.

the surveillance role of guards, however necessary, is facilitated by favorable social conditions of engaged NGOs and enhanced social capacity, perhaps by reducing threats or by increasing state cooperation with locals. Given the debate over the relative merits of top-down versus bottom-up conservation approaches, it is interesting that these findings unite these seemingly divergent strategies (Bulte and Engel, 2006; Baland and Platteau, 1996).

The conjoint conditions for No PA Threat generally agree with those for Effective PA Protection – guards are essential and NGOs facilitative – with the notable exception being that sufficient funds are also essential for the No PA Threat outcome. Though some of this apparent inconsistency owes to the fact that the only PA for which a no threat was specified was also the most highly funded (Altos de Campana), reducing a threat to none may also entail a greater expenditure than that of merely holding a threat at bay (i.e., effective protection).

The protection of certain PAs may be attributable in part to the accessibility of vast remaining tracts of unprotected forests (Fig. 1) to those who would convert them to agriculture and pasture. Thus, the effective PA protection afforded by surveillance and enforcement may simply push local populations to convert forests elsewhere. REDD projects must address the possible externalities of effective protection if GHG-reductions are to be legitimate. While this study cannot directly quantify leakage, it does note an affinity between social sustainability (NGO and social capacity) and effective PA protection that is indifferent to provincial deforestation rates (Table 5), suggesting that social investments around protected forests may play an important role in reducing leakage (see also Griffiths (2007), Peskett and Harkin (2007), and Peskett et al. (2006)). Linking this conclusion with our findings implies that a symbiotic PA management structure of communities and state institutions will prove the best means of providing win-win outcomes for all REDD stakeholders.

4.9. Conservation policy approaches in Panama

PA protection strategies in Panama are shifting from a focus on conventional, top-down protection measures to bottom-up approaches that aim to offer alternative livelihood options to PA-dependent populations, endorse cooperative management planning, and sanction sustainable resource use. While this shift is on the agenda for most PAs in Panama, the reality is that many PAs are still working to effectively put these ideas into practice (Table 2). More recently, Panama aspires to apply payment for ecosystem service projects as an adjunct conservation strategy to PAs. Examples include the incipient carbon storage and watershed conservation pilot projects planned for Chagres and La Amistad, respectively, and the ecotourism projects currently being planned or implemented in all nine PAs.

Effective PA protection also relies on legal and institutional tools that assist rather than hinder enforcement (Bruner et al., 2001). Recent advances in environmental legislation in Panama, such as criminalizing illegal resource extraction, may support protection by creating negative incentives towards committing environmental crimes, yet the effectiveness of such tools remains uncertain due to slow infraction response-time and a heavy reliance on the police force to administer them. In general, PA staff must complete a report and submit it to the central ANAM office before the police are notified. As one informant mentioned, the rate of report processing by the bureaucratic system is so slow that offenders often have time to clear and sometimes harvest the land illegally before the authority to penalize the action is granted.

Cross-PA collaboration represents a potentially powerful support network that could enhance protection effectiveness and efficiency (Fall, 1999); in Panama, however, we found the inability or unwillingness of national and international PAs to synchronize management activities to be a latent weakness for conservation initiatives. In La Amistad, for example, the competency of the Costa Rican conservation authority has been questioned and the ineffectiveness of adjacent PAs (Fig. 1) has been blamed for illegal activities 'spilling' over PA boundaries (Thorson et al., 2007; ANAM, 2004a). In Darién, minimal intergovernmental dialogue and limited resources to finance protection efforts have left this PA struggling to regulate squatters, illegal logging, cattle grazing and encroaching agriculture from both the Columbian and Panamanian boarders (ANAM, 2003b).

5. Discussion: some necessary ingredients for REDD

In Panama, forest stands have been effectively protected by applying a balance of strong surveillance and enforcement measures and stakeholder participation to find protection strategies that generate alternative livelihood options and economic benefits from conservation for local communities. Meeting these goals has relied on cooperative management planning, ecotourism and sustainable resource use and management projects fronted by NGOs in cooperation with state authorities. In agreement with previous findings by Brown and Corbera (2003), our research indicates that vertical management restructuring and devolution of administrative powers to both communities and civil servants around PAs are important for achieving effective protection. However our results also support the idea that efficient and effective forest protection also entails concerted horizontal coordination between national and international public institutions, organizations, groups, and other key actors (Engle and Palmer, 2008; Culas, 2007; Barrett et al., 2001).

With a variety of policy options available for forest conservation, selecting the appropriate tool(s) will be one of the many challenges for industrializing countries when considering REDD. Although the inclusion of established PAs or the creation of new ones is still up for debate (Skutsch and Trines, 2008), our case study illustrates that PAs could be a key asset in the REDD toolbox. We contend that PAs could serve as a strong backbone for a national reduced deforestation regime; however effectively implementing REDD will also rely on complementary policy instruments that are able to integrate carbon mitigation objectives with other governmental and local communities' priorities, including poverty alleviation and economic growth objectives (Ebeling and Yasue, 2008; Luttrel et al., 2007; Skutsch et al., 2007; Brown and Corbera, 2003).

To conclude this study, we discuss some of the environmental policies that could be used to complement PAs in a REDD regime and argue that effectively realizing REDD in tropical industrializing nations demands an assortment of adaptable conservation approaches that are able to work to at both the local and national levels to deal with the broader issues of leakage, permanence and equity.

5.1. Protected areas and complementary policy instruments

With advancements in the resource-management sciences and recognition of the shortcomings of 'command and control' strategies (Hollings and Meffe, 1995), alternative resource-management approaches, such as community-based conservation, have surfaced. Yet, after more than a decade in practice, the various permutations of community-based conservation initiatives have a disappointing track-record, both in terms of environmental and economic outcomes (Ferraro and Kiss, 2002; Oates, 1999; Wells et al., 1999; Wells and Brandon, 1993). Only a handful of successful programs operating within contexts where conservation goals align with cultural values (e.g., traditional or indigenous groups), with social structures (i.e., groups with a pre-existing constitution

for common-pool resource use) or with sound institutional policies have been documented (Berkes, 2003; Becker and Ostrom, 1995; Alcorn, 1993). In communities where the necessary social cohesion is weak or institutions are unstable, the indirect incentive structure of community-based conservation will be a contributing factor in program failure (Berkes, 2003). Indeed, the equitable and adequate distribution of communally shared, benefits is often difficult to harmonize across diverse cultural and socioeconomic groups (Grieg-Gran et al., 2005). Under these circumstances, the indirect incentives generated from these programs are not liable to inhibit malcontent participants from continuing depletive activities in the managed ecosystem or exploiting close proximity, open-access resources (Wunder et al., 2008; Ferraro and Simpson, 2002; Ferraro and Kiss, 2002; Kellert et al., 2001). The latter of the two outcomes also applies to the 'command and control' case, where offering no palatable conservation incentives (often involving the strict enforcement of fines) can lead to the displacement of extractive activities to unregulated zones or unfairly restricting small-scale resource users and poor, forest-dependent people (Wunder et al., 2008; Griffiths, 2007; Kellert et al., 2001).

In the case of REDD, the negative outcomes unintentionally engendered by both community-based and 'command and control' tactics bring issues of equity, leakage and permanence into question and could thus undermine the long-term sustainability of a reduced deforestation scheme. These realities have led conservation activists and scholars to push for solutions that branch away from the community as the sole base-unit and venture into working more closely with different social and political institutions at multiple levels (Wells and McShane, 2004; Agrawal and Gibson, 1999; Leach et al., 1999).

A newer conservation option, Payments for Ecosystem Services (PES), aims to bolster conservation by providing direct economic benefits to participating actors via fungible rewards (exceeding land opportunity cost) and non-compliance sanctions (i.e., payment annulment or suspension) (Wunder et al., 2008). PES schemes restricting forest use have been proposed for REDD, yet legitimate implementation may be compromised when targeting 'deforestation hotspots' or areas where land tenure is insecure as it could further deforestation or encourage land speculation by attracting people looking to qualify for payments (Wunder, 2005). PES may also raise issues of social justice when excluding the landless poor or paying those doing the damage while disqualifying groups that have always protected forests. Such structures can drive inequality and exacerbate poverty—factors which may further deforestation (Bhattarai and Hammig, 2001; Koop and Tole, 1998). While sound policies can help circumvent such occurrences, PES programs will ultimately only be effective when executed where deforestation threats are emerging and conservation opportunity costs are minimal (Wunder, 2005). Outside of this ideal scenario, other conservation instruments may be preferable, such as taxes, subsidies, payouts, or certifications, among others (Dudley, 2007; Wunder, 2005). Consequently, PES cannot completely substitute any other conservation mechanism, but may be used as a complement (Wunder, 2007).

The applicability of any one forest conservation tool and the limitations associated with each are context-specific and dynamic in both space and time (Christensen et al., 1996); as such, there will be no REDD policy prescriptions (Bhattarai and Hammig, 2001). Rather, we believe that a variety of adaptable forest-protection strategies using PAs as a foundation is necessary to help foster long-term favorable outcomes for all participating entities. The voluntary market-based REDD projects Noel Kempff (Bolivia) and Ilha do Bananal (Brazil) are shaped around PAs and use a hybrid management framework that more closely resembles community-based conservation than a PES scheme *per se* (Grieg-Gran et al., 2005; May et al., 2004). Launched by NGOs, these projects address some of the abovementioned pitfalls by combining both monetary and in-kind payments for opportunity costs while concurrently working towards strengthening local and social institutions (Grieg-Gran et al., 2005). The impacts of these pilot projects, however, are still unclear (May et al., 2004; Asquith et al., 2002).

Extrapolating from prior experience in ecosystem management and our case study, finding the appropriate mélange of PA management and resource conservation techniques requires consideration of the historical and political–ecological milieu in which the PA exists or will exist (Hammond and Zagt, 2006; Bates and Rudel, 2000; Swetnam et al., 1999; Yaffee, 1999). For Cerro Hoya, where land tenure is secure and deforestation is near absent, limited state-presence and relinquishment of stewardship to local communities have been key factors in this PA's effectiveness. In Chagres, community participation working in tandem with strong surveillance measures have lead to a highly effective PA, despite deforestation pressures in the surrounding region. In the Darién PA, on the other hand, the successful conservation previously provided by passive protection strategies can no longer function in a rapidly shifting neighboring environment.

Thus, success would seem to hinge on crafting pliable PA management models that are molded around and can change with the PA context (DeFries et al., 2005; Wells and McShane, 2004); yet, the question of how to do so remains. Although it is still irresolute as to whether REDD will work as a large-scale, state-led initiative or as multiple micro-projects administered by private or non-profit organizations, experience with PES shows that latter of the two tend to customize approaches to local conditions and monitor and enforce more effectively than government regulated projects (Wunder et al., 2008). With the consolidation of forest lands under REDD, the benefits of locally focused micro-projects could be particularly central to addressing the issues of leakage, permanence, and equity (Peskett and Harkin, 2007).

Yet, the high costs of such PES projects and community-based initiatives have lead some to the conclusion that conservation is best assumed by public authorities, where the geographical scope can be larger (Chapman, 2003) and projects can build upon already established institutions and policy tools. As long as institutional weakness and instability is not a significant hindrance, this will make REDD implementation and monitoring a simpler task and could encourage the necessary coordination between national and international conservation endeavors. Although carbon mitigation projects are rendered more complex by the presence of human activities (Forner et al., 2006; Richards, 2004; Richards and Andersson, 2001), successfully reducing deforestation and curtailing leakage distills to effective design and execution of conservation mechanisms that generate secure incentives, tangible benefits, and guaranteed transfer to those paying the price for forest preservation (Engle and Palmer, 2008; Prowse and Peskett, 2008; Peskett and Harkin, 2007). This means acknowledging humans as an integral component of the ecosystem and, accordingly, including communities as a high priority in resource management and conservation planning and activities (Neely, 1994).

Thus, reducing tropical deforestation will ultimately bank on reconciling international forest-protection initiatives with locally tailored solutions (Scrieciu, 2007). Drawing on insights from our analysis of protection, a successful system of PAs under REDD will need to give critical attention to details at the community and landscape level but would be best administered and monitored by the state. A significant challenge will be the effective design and implementation of such policies in countries with weak institutional and bureaucratic designs, corruption and conflict, extensive governance incapacity, and flawed democratic structures (Ebeling and Yasue, 2008; Peskett et al., 2006; Smith et al., 2003; Didia, 1997). Bundling compatible objectives (i.e., carbon mitigation, biodiversity conservation, ecosystem service use, sustainable

development, etc.) and making use of pre-existing programs and institutions will likely be a principal means to easing the burden of forest protection and acquiring the substantial assistance (logistical, technical and financial) necessary to curb deforestation in tropical countries (Balmford and Whitten, 2003; Braatz, 2002; Neely, 1994). Considering evidence from this case study and the important niche that NGOs fill in conservation efforts in Panama and in Latin America in general (Price, 1994), these organizations could be a critical ally for successful REDD projects.

5.2. Funding

Beneath these necessary ingredients lays funding, the nexus of effective protection that is required to address deficient resources, plan and execute adaptive management planning, and build physical and social capital in communities and public institutions. In tropical industrializing areas, however, PAs are commonly destitute, the available conservation funds are paltry (Balmford et al., 2003; Molnar et al., 2003) and, as PAs in Panama are experiencing, where funding is available its duration remains highly uncertain and thereby endangers successful initiatives in the future.

Currently, conservation funding at the global level spans an enormous range, from upwards of \$50,000 per km^2 in some industrialized nations to below \$10 per km^2 in some tropical regions (Balmford et al., 2003; James et al., 1999). Funding for Panama's PAs echoes these global disparities. Comparatively, the operating budgets for the next several years (Table 4) in the most ineffective PAs are similar to the average of tropical industrializing areas (~\$93 per km^2), while successful PAs in and around the Panama Canal Watershed exceed the industrialized world average (~\$1000 per km^2) (Balmford et al., 2003; James, 2001; James et al., 1999).

These disparities, we found, are exacerbated by the disproportionate financial resources successful PAs have been able to obtain from international NGOs, bilateral and multilateral agencies, and international treaties and agreements. In Panama, the dependence on external funding goes deeper; the national conservation budget is also heavily financed by foreign entities and mechanisms. Alarmingly, across the globe, as in Panama, external donations for conservation initiatives in tropical industrializing countries are on downward trend (Molnar et al., 2003). In the absence of a fall-back plan, these curtailing funds represent a considerable vulnerability for forest-endowed non-Annex I parties to the UNFCCC seeking to meet conservation goals.

An international agreement ensuring a stable flow of sufficient funds in exchange for REDD could provide an alternative finance mechanism to conserve forest biomass. Although it is possible that carbon funds could help ineffective and threatened PAs combat deforestation, none of the currently proposed finance mechanisms will fully meet the costs associated with REDD (Potvin et al., 2008). Failing REDD or other adequate financial support mechanisms, forests will continue to be degraded within and outside the ineffective PAs in Panama and other areas facing similar pressures. A fundamental question that underpins forest carbon stock protection, therefore, still pertains to acquiring ample and secure funding.

6. Conclusion

Building on the lessons learned from this case study, effectively reducing deforestation will rely on a mechanism that endorses a blend of different environmental policy instruments and conservation program structures that are able to adapt to local conditions while functioning under the umbrella of a publicly administered REDD scheme. We believe that properly funded PAs may serve as an ideal tool within this endeavor. Community-ecosystem dynamics must also be understood so that REDD conservation tools can be appropriately adjusted and equitable and commensurate benefits reach those paying the price for conservation. Achieving these goals means fostering synergistic relations between individuals, communities, governments and intermediaries so that the weaknesses of various conservation mechanisms and institutions can be complemented by the strengths of others. Experience from community-based conservation, payment for ecosystem services and our case study points to internal and international institutional (re)organization and coordination as an essential building block. NGOs will likely be one of the main vehicles of these changes and serve as a vital liaison between civil society and the state. In the end, conserving tropical forests means easing the obstacles posed by resource scarcity that PAs and other conservation initiatives face.

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References

Agrawal, A., Gibson, C.C., 1999. Enchantment and disenchantment: the role of community in natural resource conservation. World Development 27, 629–649.
Alcorn, J.B., 1993. Indigenous peoples and conservation. Conservation Biology 7, 424–426.
ANAM, 2006a. El Sistema Nacional de Áreas Protegidas. Autoridad Nacional del Ambiente, Panamá, República de Panamá.
ANAM, 2006b. Estado de la Gestión Compartida de Áreas Protegidas en Panamá. Autoridad Nacional del Ambiente, Panamá, República de Panamá.
ANAM, 2006c. Indicadores ambientales de la República de Panamá. Autoridad Nacional del Ambiente, Panamá, República de Panamá. Available at: http://www.anam.gob.pa/indicadores/index.htm.
ANAM, 2006d. Plan de Manejo del Bosque Protector de Palo Seco. Proyecto Corredor Biológico Mesoamericano del Atlántico Panameño, Panamá, República de Panamá.
ANAM, 2005. Plan de Manejo del Parque Nacional Chagres: Documento Técnico. Autoridad Nacional del Ambiente, Panamá, República de Panamá.
ANAM, 2004a. Plan de Manejo del Parque Nacional La Amistad. Proyecto Corredor Biológico Mesoamericano del Atlántico Panameño, Panamá, República de Panamá.
ANAM, 2004b. Plan de Manejo del Parque Nacional Volcán Barú. Proyecto Corredor Biológico Mesoamericano del Atlántico Panameño, Panamá, República de Panamá.
ANAM, 2003a. Informe Final de Resultados de la Cobertura Boscosa y Uso del Suelo de la Republica de Panamá: 1992–2000. Autoridad Nacional del Ambiente, Panamá, República de Panamá.
ANAM, 2003b. Parque Nacional Darién Plan de Manejo. Autoridad Nacional del Ambiente, Panamá, República de Panamá.
ANAM, 2001. Informe del Programa de Monitoreo de Efectividad de Manejo de Áreas Protegidas. Autoridad Nacional del Ambiente, Panamá, República de Panamá.
Anger, N.J.S., 2008. Reducing deforestation and trading emissions: economic implications for the post-Kyoto carbon market. Centre for European Economic Research, Mannheim, Germany. Available at: http://ssrn.com/abstract=1114044.
Asquith, N.M., Vargas-Rios, M.T., Smith, J., 2002. Can forest-protection carbon projects improve rural livelihoods? Analysis of the Noel Kempff Mercado Climate Action Project, Bolivia. Mitigation and Adaptation Strategies for Global Change 7, 323–337.
Baland, J.M., Platteau, J.P., 1996. Halting Degradation of Natural Resources: Is There a Role for Rural Communities? Oxford University Press, Oxford, UK.
Balint, P.J., 2006. Improving community-based conservation near protected areas: the importance of development variables. Environmental Management 38, 137–148.
Balmford, A., Gaston, K.J., Blyth, S., James, A., Kapos, V., 2003. Global variation in terrestrial conservation costs, conservation benefits, and unmet conservation needs. Proceedings of the National Academy of Sciences of the United States of America 100, 1046–1050.
Balmford, A., Whitten, T., 2003. Who should pay for tropical conservation, and how could the costs be met? Oryx 37, 250–338.

Barrett, C.B., Brandon, K., Clark, G., Gjertsen, H., 2001. Conserving tropical biodiversity amid weak institutions. BioScience 51, 497–502.

Bates, D., Rudel, T.K., 2000. The political ecology of conserving tropical rain forests: a cross national study. Society and Natural Resources 13, 619–634.

Becker, D., Ostrom, E., 1995. Human ecology and resource sustainability: the importance of institutional diversity. Annual Reviews of Ecology and Systematics 26, 113–133.

Berkes, F., 2003. Rethinking community-based conservation. Conservation Biology 18, 621–630.

Bhattarai, M., Hammig, M., 2001. Institutions and the environmental Kuznets Curve for deforestation: a crosscountry analysis for Latin America, Africa and Asia. World Development 29, 995–1010.

Braatz, S., 2002. National reporting to forest-related international instruments: mandates, mechanisms, overlaps and potential synergies. Unasylva 210, 65–67.

Brockington, 2002. Fortress Conservation: The Preservation of the Mkomazi Game Reserve, Tanzania. Indiana University Press, Indiana, USA.

Brown, K., Corbera, E., 2003. Exploring equity and sustainable development in the new carbon economy. Climate Policy 3S1, S41–S56.

Bruner, A.G., Gullison, R.E., Rice, R.E., Fonseca, A.A.B.D., 2001. Effectiveness of parks in protecting tropical biodiversity. Science 291, 125–129.

Bulte, E., Engel, S., 2006. Conservation of tropical forests: addressing market failure. In: López, R., Stiglitz, J., Toman, M. (Eds.), Sustainable Development: New Options and Policies. Oxford University Press, Oxford, UK.

Chapman, D., 2003. Management of national parks in developing countries: a proposal for an international park service. Ecological Economics 46, 1–7.

Christensen, N.L., Bartuska, A.M., Brown, J.H., Carpenter, S., D'Antonio, C., Francis, R., Franklin, J.F., MacMahon, J.A., Noss, R.F., Parsons, D.J., Peterson, C.H., Turner, M.G., Woodmansee, R.G., 1996. The report of the Ecological Society of America Committee on the scientific basis for ecosystem management. Ecological Applications 6, 665–691.

Contraloría, 2003. Estadísticas y Censos Nacionales. Contraloría General de la República, Panamá, República de Panamá. Available at: http://www.contraloria.gob.pa.

Culas, R.J., 2007. Deforestation and the environmental Kuznets curve: an institutional perspective. Ecological Economics 61, 429–437.

DeFries, R., Hansen, A., Newton, A.C., Hansen, M.C., 2005. Increasing isolation of protected areas in tropical forests over the past twenty years. Ecological Applications 15, 19–26.

Didia, D.O., 1997. Democracy, political instability and tropical deforestation. Global Environmental Change 7, 63–76.

Dudley, R.G., 2007. Payments, penalties, payouts, and environmental ethics: a system dynamics examination. Sustainability: Science, Practice & Policy 3, 24–35.

Ebeling, J., Yasue, M., 2008. Generating carbon finance through avoided deforestation and its potential to create climatic, conservation and human development benefits. Philosophical Transactions of the Royal Society B 363, 1917–1924.

Engle, S., Palmer, C., 2008. Payments for environmental services as an alternative to logging under weak property rights: the case of Indonesia. Ecological Economics 65, 799–809.

Fall, J.J., 1999. Transboundary biosphere reserves: a framework for cooperation. Environmental Conservation 26, 252–255.

Ferraro, P., Simpson, R.D., 2002. The cost-effectiveness of conservation payments. Land Economics 78, 339–353.

Ferraro, P.J., Kiss, A., 2002. Direct payments to conserve biodiversity. Science 298, 1718–1719.

Forner, C., Blaser, J., Jotzo, F., Robledo, C., 2006. Keeping the forest for the climate's sake: avoiding deforestation in developing countries under the UNFCCC. Climate Policy 6, 275–294.

Geist, H.J., Lambin, E.F., 2001. What drives tropical deforestation: a meta-analysis of proximate and underlying causes of deforestation based on subnational case study evidence. Land-Use Land-Cover Change Report Series No. 4. LUCC International Project Office, Louvain-la-Neuve, Belgium.

Gossling, S., 1999. Ecotourism: a means to safeguard biodiversity and ecosystems function. Ecological Economics 29, 303–320.

Gould, K.A., 1999. Tactical tourism: a comparative analysis of rainforest development in Ecuador and Belize. Organization and Environment 12, 245–262.

Grieg-Gran, M., Porras, I., Wunder, S., 2005. How can market mechanisms for forest environmental services help the poor? Preliminary lessons from Latin America. World Development 33, 1511–1527.

Griffiths, T., 2007. Seeing 'RED'? 'Avoided Deforestation' and the Rights of Indigenous Peoples and Local Communities. Forest Peoples Program, Moreton-in-Marsh, UK.

GTZ, 2002. People and Forests: Opportunities for Improving Livelihoods, Alleviating Poverty, and Safeguarding the Environment Through Sustainable Forest Management. Facharbeitskreis Waldwirtschaft, Eschborn, Germany. Available at: http://www.gtz.de/de/dokumente/en-072-gtz-people-forests-en.pdf.

Hammond, D.S., Zagt, R.J., 2006. Considering background condition effects in tailoring tropical forest management systems for sustainability. Ecology and Society 11. Available at: http://www.ecologyandsociety.org/vol11/iss1/art37/.

Hayes, T.M., 2006. Parks, people, and forest protection: an institutional assessment of the effectiveness of protected areas. World Development 34, 2064–2075.

Hayes, T.M., Ostrom, E., 2005. Conserving the world's forests: are protected areas the only way? Indiana Law Review 37, 595–617.

Hellstomöm, E., 1998. Qualitative comparative analysis: a useful tool for research into forest policy and forestry conflicts. Forest Science 44, 254–265.

Hockings, M., Stolton, S., Leverington, F., Dudley, N., Courrau, J., 2006. Evaluating effectiveness: a framework for assessing the management of protected areas. In: Valentine, P. (Ed.), Best Practice Protected Area Guidelines Series No. 14, 2nd edition. IUCN, Gland, Switzerland and Cambridge, UK. Available at: www.iucn.org/dbtw-wpd/edocs/PAG-014.pdf.

Hollings, C.S., Meffe, G.K., 1995. Command and control and the pathology of natural resource management. Conservation Biology 10, 328–337.

Houghton, R.A., 2005. Tropical deforestation as a source of greenhouse gas emissions. In: Mutinho, P., Schwartsman, S. (Eds.), Tropical Deforestation and Climate Change. IPAM (Instituto de Pesquisa Ambiental da Amazonia) and Environmental Defense, Washington, DC, USA.

Igoe, J., 2004. Conservation and Globalization: A Study of National Parks and Indigenous Communities from East Africa to South Dakota. Wadsworth/Thompson, Belmont, USA.

James, A.N., 2001. Can we afford to conserve biodiversity? BioScience 51, 43–52.

James, A.N., Gaston, K.J., Balmford, A., 1999. Balancing the earth's accounts. Nature 401, 323–324.

Kellert, S.R., Mehta, J.N., Ebbin, S.A., Lichtenfeld, L.L., 2001. Community natural resource management: promise, rhetoric, and reality. Society and Natural Resources 13, 705–715.

Koop, G., Tole, L., 1998. Deforestation, distribution and development. Global Environmental Change 11, 193–202.

Kruger, O., 2005. The role of ecotourism in conservation: panacea or Pandora's box? Biodiversity and Conservation 14, 579–600.

Lambin, E.F., Geist, H.J., Lepers, E., 2003. Dynamics of land-use and land-cover change in tropical regions. Annual Review of Environmental Resources 28, 205–241.

Laurance, W., Albernaz, A., Fearnside, P., Vasconcelos, H., Ferreira, L., 2004. Deforestation in Amazonia. Science 304, 1109–1111.

Laurance, W.F., Laurance, S.G., Ferreira, L.V., Merona, J.R.-d., Gascon, C., Lovejoy, T.E., 1997. Biomass collapse in Amazonian forest fragments. Science 278, 1117–1118.

Leach, M., Mearns, R., Scoones, I., 1999. Environmental entitlements: dynamics and institutions in community-based natural resource management. World Development 27, 225–247.

Locke, H., Dearden, P., 2005. Rethinking protected area categories and the new paradigm. Environmental Conservation 32, 1–10.

Luttrel, C., Schrecjenberg, K., Peskett, L., 2007. The implications of carbon financing for pro-poor community forestry. In: Brown, D. (Ed.), Forestry Briefing, vol. 14. Overseas Development Institute, London, UK.

May, P.H., Boyd, E., Veiga, F., Chang, M., 2004. Local sustainable development effects of carbon projects in Brazil and Bolivia. A View from the Field. International Institute for Environment and Development, London, UK. Available at: http://www.rlc.fao.org/foro/psa/pdf/susta.pdf.

MNRE, 2005. Financial Sustainability for National Systems of Protected Areas: Panama Country Support Plan. Ministry of Natural Resources and Environment, Panamá, República de Panamá.

Molnar, A., Scherr, S., Khare, A., 2003. Who Conserves the World's Forests? A New Assessment of Conservation and Investment Trends. Ecoagriculture Partners, Washington, DC, USA.

Naughton-Treves, L., Holland, M.B., Brandon, K., 2005. The role of protected areas in conserving biodiversity and sustaining local livelihoods. Annual Review of Environmental Resources 30, 219–252.

Neely, A.M., 1994. Protected areas for the 21st century: working to provide benefits to society. Biodiversity and Conservation 3, 390–405.

Oates, J.F., 1999. Myth and Reality in the Rain Forest: How Conservation Strategies are Failing in West Africa. University of California Press, Berkely, USA.

Peskett, L., Harkin, Z., 2007. Risk and responsibility in reducing emissions from deforestation and degradation. Forestry Briefing, vol. 15. Overseas Development Institute, London, UK. Available at: http://www.odi.org.uk.

Peskett, L., Brown, D., Luttrell, C., 2006. Can payments for avoided deforestation to tackle climate change also benefit the poor? Forestry Briefing, vol. 12. Overseas Development Institute, London, UK. Available at: http://www.odi.org.uk.

Potvin, C., Guay, B., Petroni, L., 2008. Is reducing emissions from deforestation financially feasible? A Panama case study. Climate Policy 8, 24–40.

Pretty, J., 2003. Social capital and the collective management of resources. Science 302, 1912–1914.

Price, M., 1994. Ecopolitics and environmental nongovernmental organizations in Latin America. Geographical Review 84, 42–58.

PROARCA/CAPAS, 2000. Protected Areas Management Effectiveness Information Module. PROARCA/CAPAS Scorecard Evaluation. Central American Regional Environmental Project/Central America Protected Area System. Available at: http://www.unep-wcmc.org/wdpa/me/PDF/PROARCA.pdf.

Prowse, M., Peskett, L., 2008. Mitigating climate change: what impact on the poor? Opinion, vol. 97. Overseas Development Institute, London, UK. Available at: http://www.odi.org.uk.

Putz, F.E., Blate, G.M., Redford, K.H., Fimbel, R., Robinson, J., 2001. Forest management and conservation of biodiversity: an overview. Conservation Biology 15, 7–20.

Ragin, C.C., Rihoux, B. (Eds.), 2008. Configurational Comparative Methods: Qualitative Comparative Analysis (QCA) and Related Techniques. SAGE, Thousand Oaks, USA.

Ragin, C.C., Sonnett, J., 2005. Between complexity and parsimony: limited diversity, counterfactual cases, and comparative analysis. In: Kropp, S., Minkenberg, M. (Eds.), Vergleichen in der Politikwissenschaft. Wiesbaden. VS Verlag fur Sozialwissenschaften, Heidelberg, Germany.

Rice, R.E., Gullison, R.E., Reid, J.W., 1997. Can sustainable management save tropical forests? Scientific American 276, 44–49.
Richards, K.R., 2004. A brief overview of carbon sequestration economics and policy. Environmental Management 33, 545–558.
Richards, K.R., Andersson, K., 2001. Implementing an international carbon sequestration program: can the leaky sink be fixed? Climate Policy 1, 173–188.
Rihoux, B., 2006. Qualitative comparative analysis (QCA) and related systematic comparative methods. International Sociology 21, 679–706.
Ruschmann, D.V.D.M., 1992. Ecological tourism in Brazil. Tourism Management 12, 125–128.
Sánchez-Azofeifa, G.A., Daily, G.C., Pfaff, A.P., Busch, C., 2003. Integrity and isolation of Costa Rica's national parks and biological reserves: examining the dynamics of land-cover change. Biological Conservation 109, 123–135.
Santilli, M., Moutinho, P., Schwartsman, S., Nepstad, D., Curran, L., Nobre, C., 2005. Tropical deforestation and the Kyoto Protocol. Climate Change 71, 267–276.
Scrieciu, S.S., 2007. Economic causes of tropical deforestation be identified at a global level? Ecological Economics 62, 602–612.
Skutsch, M., Trines, E., 2008. Policy piece: report from the UNFCCC meeting in Bali. African Journal of Ecology 71, 267–276.
Skutsch, M., Bird, N., Trines, E., Dutschke, M., Frumhoff, P., de Jong, B.H.J., van Laake, P., Masera, O., Murdiyarso, D., 2007. Clearing the way for reducing emissions from tropical deforestation. Environmental Science and Policy 10, 322–334.
Smith, J.R., Muir, R.D.J., Walpole, M.J., Balmford, A., Leader-Williams, N., 2003. Governance and the loss of biodiversity. Nature 426, 67–70.
Stern, N.H., 2007. Reversing Emissions from Land Use Change. In: The Economics of Climate Change: The Stern Review, Cambridge University Press, Cambridge, UK.
Swetnam, T.W., Allen, C.D., Betancourt, J.L., 1999. Applied historical ecology: using the past to manage for the future. Ecological Applications 9, 1189–1206.
Thorson, E., Barrera, L., Gray, J., 2007. Petición Reservas de la Cordillera de Talamance-La Amistad/Parque Nacional La Amistad. International Environmental Law Project and Lewis & Clark Law School, Portland, USA. Available at: http://www.biologicaldiversity.org/.
UNEP, WCMC, 2008. World database on protected areas. Available at: http://sea.unep-wcmc.org/wdbpa/.
Vedeld, T., 1996. Enabling local institution-building: reinventing or enclosing the commons in the Sahel. In: Marcussen, H.S. (Ed.), Improved Natural Resource Management—The Role of Formal Organizations and Informal Networks and Institutions. Occasional Paper, vol. 17. International Development Studies, Rosklide University, Denmark, pp. 135–189.
Wells, M.P., McShane, T.O., 2004. Integrating protected area management with local needs and aspirations. Ambio 33, 513–519.
Wells, M.P., Guggenheim, S., Khan, A., Wardojo, W., Jepson, P., 1999. Investing in Biodiversity: A Review of Indonesia's Integrated Conservation and Development Projects. World Bank, Washington, DC, USA.
Wells, M.P., Brandon, K.E., 1993. The principles and practice of buffer zones and local participation in biodiversity conservation. Ambio 22, 157–162.
Wunder, S., Engel, S., Pagiola, S., 2008. Taking stock: a comparative analysis of payments for environmental services programs in developed and developing countries. Ecological Economics 65, 834–852.
Wunder, S., 2007. The efficiency of payments for environmental services in tropical conservation. Conservation Biology 21, 48–58.
Wunder, S., 2005. Payment for Environmental Services: Some Nuts and Bolts. CIFOR Occasional Paper. Center for International Forestry Research, Indonesia. Available at: www.cifor.cgiar.org/publications/pdf_files/OccPapers/OP-42.pdf.
Yaffee, S.L., 1999. Three faces of ecosystem management. Conservation Biology 13, 713–725.