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Protected areas: an effective tool to reduce emissions from deforestation and forest degradation in developing countries?

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Prepared by

Sarah Clark, Katharine Bolt and Alison Campbell

UNEP WCMC

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Abstract

Successful implementation of REDD is likely to require the reduction of deforestation rates on a national scale. Designation of new protected areas and strengthening of the current protected area network could form one strategy for achieving this. This review aims to inform the debate through an assessment of the effects of forest designation and management on deforestation rates, and through consideration of the design and management-related factors that influence protected area effectiveness in reducing deforestation. The evidence suggests that protected areas are an effective tool for reducing deforestation within their boundaries. The extent to which this deforestation is displaced to surrounding areas is unclear. Protected areas designated under the more restrictive IUCN categories (I-II) seem to be more effective than those that may include a focus on sustainable use (V-VI). However, there are only a small number of studies on deforestation within category V-VI protected areas. In addition, studies rarely consider the forms of governance that exist within protected areas, or the level of community involvement. Some insight can be gained through analysis of deforestation rates in indigenous lands and community forestry areas, which have also been shown to be successful at reducing deforestation. The evidence suggests that the creation of a protected area network that incorporates all levels of protection, as appropriate for the situation at site level, could be a valuable component of a national REDD strategy. To better inform such planning decisions, further research is required into the factors that influence the effectiveness of protected areas in reducing deforestation; and in particular the interrelationship between protected area status, community involvement and governance.

Introduction

Forests play a key role in the global carbon cycle, absorbing and storing carbon in their biomass and soils. The UN Framework Convention on Climate Change (UNFCCC) discussions on reducing emissions from deforestation and degradation (REDD) in developing countries result from a recognition of the substantial greenhouse gas emissions resulting from deforestation, especially in the tropics. Depending on the method of forest clearing and the subsequent use of the felled trees and land, deforestation not only releases the carbon stored in the above ground biomass, but leads to decomposition of roots and mobilization of soil carbon. Global greenhouse gas emissions from changes in land use, including tropical deforestation, are estimated to make up around 20% of annual global emissions from all sources (IPCC 2007), though there is a high level of uncertainty attached to the precise figure. Forest fragmentation and degradation also increase the risk of forest fires, which release further carbon emissions and increase susceptibility to future fires (Cochrane & Schulze 1999). Retaining and restoring forested areas is therefore a crucial climate change mitigation strategy.

Discussions at the recent UNFCCC's 13th Conference of the Parties focussed on guidance for demonstration (pilot) REDD projects, potential policy mechanisms and incentives for developing countries. While the precise form of any future REDD mechanism as part of a post-2012 emissions reduction agreement is yet to be determined, this review aims to inform the debate by considering protected areas as a prior example of the effects of forest conservation interventions on deforestation rates. This review considers the designation and management-related factors influencing their effectiveness in achieving this.

Forested protected areas

Forested protected areas are established in order to conserve forest of biodiversity value from damaging processes, such as deforestation. Deforestation drivers vary by region and time as well as being mutually re-enforcing (Kaimowitz & Angelsen 1998), but most notably include the demand for timber, and for land for agriculture, settlements, and mining. Land areas with particular characteristics face differing risks of deforestation; altitude, proximity to roads and/or settlements, land gradient, rainfall and soil productivity have all been found to affect the rate of deforestation (Kaimowitz 1995, Cropper *et al.* 2001, Wilkie *et al.* 2001, Deininger & Minten 2002, Linkie *et al.* 2004, Mas 2005, Gaveau *et al.* 2007). It is clear that many factors need to be taken into consideration when assessing the causes of deforestation in or around a given protected area, and that no one management solution is applicable to all situations. This review aims to identify general patterns in the impact of an area's protection status and management on the rate of deforestation.

Broadly speaking, protected areas can be defined as areas of land or sea "dedicated to the protection and maintenance of biological diversity and of natural and associated cultural resources, managed through legal or other effective means" (IUCN 1994). The World Conservation Union (IUCN) describes six management categories (Table 1) for protected areas, according to the reason for establishment. The categories do not specifically determine protected area management and governance (Naughton-Treves *et al.* 2006), and this differs both within and between categories. In general, protected areas with a higher IUCN category (I-II) are more (and sometimes completely) restrictive of resource exploitation and land use change than the lower categories (V-VI).

Table 1 – IUCN management categories

Category	Description
Ia	Strict Nature Reserve: protected area managed mainly for science
Ib	Wilderness Area: protected area managed mainly for wilderness protection
II	National Park: protected area managed mainly for ecosystem protection and recreation
III	Natural Monument: protected area managed mainly for conservation of specific natural features
IV	Habitat/Species Management Area: protected area managed mainly for conservation through management intervention
V	Protected Landscape/Seascape: protected area managed mainly for landscape/seascape conservation and recreation
VI	Managed Resource Protected Area: protected area managed mainly for the sustainable use of natural ecosystems

Several global and regional conventions and agreements provide for the designation of internationally recognised protected areas. For example, World Heritage Sites and Biosphere Reserves are both designated through a process managed by the UN Educational, Scientific and Cultural Organization (UNESCO). World Heritage sites are areas of "outstanding universal value", either of a natural or cultural origin, following the definitions of the World Heritage Convention. Biosphere Reserves, designated under the Programme on Man and Biosphere, constitute areas with a core under protection and a buffer zone allowing human habitation (often tens of thousands of people) and sustainable development. Within the European Community, the Birds and Habitats Directives have ensured the designation of a network of Natura 2000 sites, recognised as of regional conservation importance. These international sites are not assigned an IUCN management category, but often share the boundaries of nationally-designated areas that do have a category.

The IUCN management categories are independent of the ownership of, or management responsibility for, the protected area. Additional distinctions can be made between protected areas in terms of 'governance' type, depending upon whether the area is government managed, co-managed, privately owned, or a community conserved area. Governance types vary within and between management categories. Community-managed forests are increasingly growing in importance as a method of forest conservation. Though they are not always formally designated as protected areas, their goals are often consistent with IUCN management category VI. Similarly, indigenous lands are not typically assigned an IUCN category, as they are not primarily designated for biodiversity protection. As governments accord them a high protection status, both community-managed and indigenous areas are reviewed here to assess their effectiveness in comparison to traditional protected areas.

Are protected areas effective in reducing tropical deforestation?

Protected areas

The evidence reviewed in this report indicates that there is less deforestation within formally protected areas than in the areas surrounding them (Sánchez-Azofeifa *et al.* 1999, 2003, Pelkey *et al.* 2000, Bruner *et al.* 2001, Deininger & Minten 2002, Helmer 2004, Curran *et al.* 2004, DeFries *et al.* 2005, Mas 2005, Naughton-Treves *et al.* 2005, 2006, Sommerville 2005, Bleher *et al.* 2006, Nepstad *et al.* 2006, Chowdhury 2007, Gaveau *et al.* 2007, Oliveira *et al.* 2007, Phua *et al.* 2007; Oliveira *et al.* 2007). A minority of studies report no significant impact on deforestation arising from protection status (Marizán 1994, Cropper *et al.* 2001, Rautner *et al.* 2005, Roman-Cuesta & Martinez-Vilalta 2006).

As deforestation rates are influenced by site-specific factors, it is useful to compare the situation across a range of protected areas. A questionnaire-based study of 93 protected areas in 22 tropical countries compared the rate of land clearing at the time of the protected area's establishment with that of the present day (Bruner *et al.* 2001). All protected areas were 'subject to significant land-use pressure', but it should be noted that the study was not specific to forested areas, and had a focus on biodiversity rather than forest loss. Nevertheless, land clearing is a useful indicator of success in reducing deforestation, and only 17 percent of protected areas had experienced net clearing since their establishment. 97 percent experienced less land clearing than did a surrounding 10 km belt; although the proportion of protected areas faring better than the surrounding areas fell to 80% when logging and fire were also considered. The study suggests that these protected areas are very effective at preventing land use change.

Deforestation studies have often been undertaken with the use of satellite data. In a study of 198 category I & II protected areas and the 50 km zones surrounding them, 500-m MODIS and 8km AVHRR satellite data were used to measure deforestation from 1980-2000 (DeFries *et al.* 2005). Overall, approximately 25% of protected areas experienced some forest loss; with 9% losing over 5% of the forest area. In comparison, there was some forest loss in the 50km surrounding zone of over 68% of the protected areas. The results were summarised by region (Table 2), indicating that Latin American protected areas have defended against deforestation more effectively than Asian or African protected areas, as has been reported elsewhere (Naughton-Treves *et al.* 2005). These figures do not show the absolute area lost by region, or take into account the differing deforestation pressures and management regimes acting upon these forests. It was concluded that protected areas are generally effective in reducing deforestation.

Table 2. Percentage of protected areas with land cover change from 1980-2000. Adapted from supplementary materials provided by Defries et al. (2005)

	1% or more of surrounding 50km zone was lost	1% or more of protected area was lost	5% or more of protected area was lost	Total number of protected areas
Latin America	41%	14%	3%	85
South and Southeast Asia	47%	20%	14%	95
Africa	47%	18%	12%	18

Similar work has been undertaken in Costa Rica. Sánchez-Azofeifa *et al.* (2003) studied deforestation from 1986 to 1997 in and around a network of National Protected areas, Biological Reserves and surrounding zones. Both aerial photography and maps derived from satellite data were used. Deforestation within these protected areas was negligible: 17 out of a sample of 27 protected areas lost less than 100ha, and the maximum loss measured was 324ha. Higher levels of deforestation were observed immediately around the protected areas, with deforestation rates increasing with distance from the parks; from an average of 0.32% per year in the 1 km surrounding zone to 1% per year in a 10 km zone. In some cases, deforestation reached right up to the park boundaries. This raises questions over the effectiveness of protected areas in implementing REDD, as it is difficult to establish the extent to which deforestation is merely displaced to other areas.

Case Study - Kinabalu Park (Phua *et al.* 2007)

Kinabalu National Park in Malaysia is a category II protected area in which only recreational, educational and scientific use is permitted. The park has been strictly managed by the state government since 1984, with substantial fines for encroachment. It has no formal buffer zone but local people are involved in maintaining boundaries and have other job opportunities. Using satellite data and change vector analysis, forest cover was measured in 1973, 1991 and 1996. Overall 1.3% of the park was deforested in this time; from 1973-1991, 2606 ha of forest was lost at a rate of 145 ha/yr; from 1991-1996 the deforestation rate was over three times slower, with 236 ha deforested. To measure the effectiveness of protections against encroachment, deforestation was measured within the 1 km zone inside the park's borders, and zones both 1 km and 10 km outside the park. Over the 23 years, 0.1% of the forest 1 km within the boundary was cleared compared to 1% in the 1 km outside and 1.6% in the 10 km surrounding zone, indicating that protection has been effective.

Of particular interest are studies that have accounted for differences in deforestation pressures inside and outside of protected areas, facilitating assessment of the impact of protection status alone. For example, Mas (2005) measured a deforestation rate of 0.3%/yr within the Calakmul Biosphere Reserve in Mexico, versus a rate of 1.3%/yr in the 10 km surrounding area. Within this surrounding zone, the deforestation rate was measured for the areas of land in which deforestation pressures matched those within the protected zone. The rate in this comparable land outside of the protected area was 0.6%/yr. This suggests that the protection status of the area halved the rate of deforestation relative to nearby land under similar pressures.

Various models have also been developed to measure or predict deforestation rates. Cropper *et al.* (2001) developed a bivariate probit model using land use data collected over a number of years in North Thailand, to predict the probability of deforestation for land with and without protection status. In this region, designation as a national protected area (category II) did not have a statistically significant impact on forest clearing. This is consistent with other findings that protected areas are less effective in Southeast Asia than in other tropical regions (DeFries *et al.* 2005). Conversely, a model for Mexico that used data from digital maps and censuses to forecast deforested areas in 1990 from forest cover in 1980 found that protection had a statistically significant effect at reducing deforestation (Deininger & Minten 2002). Without protection, 43% of plots in protected areas would have been at high risk of being deforested, whilst with protection 'only' 9% of plots were deforested. The influence of the protected area status varied depending upon factors such as forest type and distance from roads.

Many studies have found that protected areas are effective at reducing forest loss related to roads (Wilkie *et al.* 2001, Deininger & Minten 2002, Mas 2005, Ankersen *et al.* 2006, Oliviera *et al.* 2007). In the Peruvian Amazon, 1.15% of the area under protection within 20 km of roads was deforested in a six year period, compared to 4.76% of unprotected forest (Oliveira *et al.* 2007).

Most studies discussed thus far have focused upon comparison of deforestation rates inside and outside protected areas. Whilst protected areas may reduce the rate of deforestation *relative to their surroundings*, forest may still be cleared at high rates. In an extreme example, Gunung Raya Wildlife Sanctuary in Sumatra lost nearly 81 percent of its forest cover between 1972 and 2002. The 2.74% per year deforestation rate was only 0.1 percent less than that in the surrounding unprotected area (Gaveau *et al.* 2007). Deforestation rates in excess of 3-6% within protected area borders have been reported by Linkie *et al.* (2004) and Achard *et al.* (2002). Therefore, although protected areas are generally successful at *reducing* deforestation rates, they may not eliminate deforestation and in some cases the total area of forest loss can still be very high.

Similarly, few studies have taken leakage into account, in which deforestation inside protected areas is simply displaced to surrounding areas. Whilst little information exists for leakage from protected areas, Oliviera *et al.* (2007) have assessed relative changes in and around sustainably managed timber concessions in Peru. Following the assignment of the concessions, deforestation rates in these areas halved while in surrounding areas, deforestation increased by several hundred percent. Overall the deforestation rate remained the same. This study has been cited as the best empirical evidence of the occurrence of leakage to date (Ewers & Rodrigues 2008). The local reduction in carbon emissions resulting from the success of a protected area may therefore be offset by an increase in deforestation outside of the area, indicating that unless a country's protected area network includes a high proportion of remaining forest, it can form only part of a successful strategy for REDD.

Indigenous lands

Within formally declared indigenous lands, local institutions typically govern the use and distribution of forest resources, ensure security of tenure, and provide a mechanism for enforcement and conflict resolution, including through cultural sanctions and beliefs (Pimbert & Pretty 1995). Many such lands prevent deforestation entirely. The protective effect of indigenous people on their traditional lands has often held over centuries, longer than any protected area has been in existence. In Brazil, indigenous lands have an intermediate protective effect between that of national forests and extractive reserves, with deforestation levels over 8 times higher outside the indigenous lands than inside them. (Nepstad *et al.* 2006). In comparison with the few category I and II protected areas that have been designated on the Amazonian agricultural frontier, they were equally as effective at preventing deforestation. These indigenous lands were identified as the most important barrier to deforestation in the Amazon.

In Nicaragua's Bosawas Biosphere Reserve, patterns of land tenure and agricultural practices are influenced by the various cultures of the inhabitants (Stocks *et al.* 2007). Non-indigenous colonists allocate land to private households, whilst the two indigenous groups own land communally. Colonists value and trade pasture land, whilst the indigenous groups largely practice shifting cultivation. Land within the colonist zone was deforested at 16 times the rate observed in the indigenous zones. From 1987 to 2002, 6.7% of a 2 km 'buffer' zone at the edge of the land occupied by colonists was lost, in comparison with 2.3% of a similar zone at the end of land occupied by indigenous people. Patterns of forest cover differed significantly, with a lower percentage cover of primary forest in the colonist region. Thus, indigenous people proved successful at protecting their own forest, whilst the colonist areas became increasingly similar to those outside the reserve. Other studies have also shown indigenous lands to be more successful than National Parks and Community Forests at reducing deforestation (Ruiz Perez *et al.* 2005).

Community forests

Community forest management includes situations in which forests are community governed, and those in which communities participate in management strategies established by the government. In Tanzania, for example, Joint Forest Management schemes divide responsibility between the owner (usually the government) and locals, and can be implemented in either protected or unprotected forests (Blomley *et al.* in press). Meanwhile, in Community Based Forest Management schemes, locals take full ownership and responsibility. In some places, community managed schemes have been initiated by local communities. Formal government recognition of these schemes is thought to bolster the community's ability to confront illegal forest use (Bruner *et al.* 1999).

Several studies indicate that community-based forest management schemes can successfully reduce deforestation and forest degradation (Bray *et al.* 2003, 2004, Ruiz Perez *et al.* 2005, Murdiyarso & Skutsch 2006). In the Morogoro region of Tanzania, three forest reserves under Joint Forest Management (JFM), with restricted access that is controlled by the villages, were compared with three national forest reserves in matched ecological zones. The latter are managed by central government and considered to be open-access (Pfliegner & Moshi 2007). The JFM forests contained 34% more live timber-size trees, 45% more pole-size trees and 55% more withy-size trees than the forest reserves. There are concerns about equity of access to forest resources within villages participating in the JFM scheme, which may jeopardise the long term viability of this arrangement. Another study in Tanzania assessed the effectiveness of the Kimunyu Forest, which has been run by a village environmental committee since 2000 (Murdiyarso & Skutsch 2006). From 2005-2006, tree volume increased, reversing the previous trend, without evidence of leakage of extraction pressure to other areas.

A review of *ejidos* (community forest enterprises) in Oaxaca, Mexico (Bray *et al.* 2003) reported that due to community reforestation and limits on agriculture the forest area had increased by 500 hectares over the preceding 18 years. The extent to which deforestation still took place but was 'balanced' by afforestation in this period is not clear. Similarly, the net deforestation rate of central Quintana Roo in Mexico, an area with many *ejidos* and no protected areas, was 0.4 % per year in 1976-1984, a rate which fell over the next 16 years (Bray *et al.* 2004). This rate compares favourably with those experienced by some of the protected areas reported in previous sections. Most *ejidos* in this area follow practices approved by the Forest Stewardship Council, even if they have not been certified. The area had a much lower deforestation rate than that of the wider unprotected region, lower even than that of protected area-dominated swathes in the broader region (Bray *et al.* 2004). Success with community based forest management schemes has also been noted in India, Nepal, Senegal, Indonesia and elsewhere.

Hayes (2006) compared deforestation in formally protected forest areas with that in areas of forest managed under rules developed by forest users. These rules include regulations on when certain forest products may be harvested, what parts of specific trees may be harvested, who has the right to harvest, and the types of technologies that may be used. These areas of forest were no less effective in reducing deforestation than officially designated protected areas.

It is clear, therefore, that conferring some degree of protection on forest areas is effective in reducing deforestation. Whilst officially designated protected areas have a major role to play, other areas such as indigenous lands and community managed forests can be at least as effective. This raises the question of what makes a particular area effective in reducing deforestation, and the extent to the IUCN management category and level of community involvement influence this.

What do protected areas need to be effective?

It is clear that some protected areas are more effective than others at reducing deforestation. To date there has been relatively little quantitative investigation of the factors influencing success. Those studies which are available have often been based on qualitative data, which can be subject to respondent and survey bias; and the diversity of methodologies used limits the scope for direct comparison between studies. However, some conclusions can be drawn on the importance of site-specific characteristics including protected area status, management, design, and the influence of external factors. These can help inform decisions on the potential use of protected areas as a tool for implementation of REDD, and the potential management strategies best applied outside protected areas.

Protection status

A number of studies have considered the effect of the different IUCN management categories on deforestation rates. Some variation between individual protected areas is to be expected even within the same category, as the level of forest use permitted varies, and management and governance differ. The evidence suggests that in general, protected areas with stricter degrees of protection are more effective at reducing deforestation (Nepstad *et al.* 2006, Jones 1990, Bleher *et al.* 2006, Naughton-Treves *et al.* 2005, Dudley *et al.* 2004, Pelkey *et al.* 2000, Sánchez-Azofeifa 1999). A meta-analysis of literature reported for 49 protected areas across the tropics suggested that categories V-VI appeared to be the least effective in reducing deforestation (Naughton-Treves *et al.* 2005). However, it was acknowledged that only six such areas were included in the analysis.

Nepstad *et al.* (2006) reviewed the success of protected areas within the Brazilian Amazon in reducing deforestation. Federal protected areas prohibiting resource exploitation ('parks') were compared with indigenous lands, extractive reserves, and national forests, all of which allow human residence and subsistence forest use, but have some restrictions on deforestation. For parks, deforestation rates beyond the boundaries were 20 times higher than within them. The equivalent ratio for national forests (IUCN category VI) is 9.5 and for extractive reserves (category VI) is 1.7. This analysis examined 15 parks, 18 national forests, and 10 extractive reserves, along with 121 indigenous areas (as reviewed above). Rates were compared within and around protected areas, but total deforestation figures were not provided. Although a higher rate of deforestation is observed outside the park, the area of land deforested within the park may still be large. As extractive reserves by definition allow some forest use, a lower ratio would be expected between these reserves and their surroundings, potentially as a result of a lack of 'leakage' into surrounding areas. However, these findings do indicate that parks were more effective in reducing deforestation.

More rigorous studies are needed to determine why protected areas with a higher IUCN category tend to be more effective at preventing deforestation. Whilst it has been suggested that protected areas with higher IUCN categories tend to have more effective management (Dudley *et al.* 2004; Bleher *et al.* 2006), a possible confounding factor is that of community versus state governance. Protected areas designated under the same IUCN category can differ widely in their governance and subsequent levels of community involvement and land tenure.

However, protected area governance is rarely reported in deforestation studies, so it has not been possible to extricate its influence upon deforestation rates. An analysis of the conservation impacts of community involvement in protected area management and governance across the IUCN management categories could be helpful in informing REDD decision making.

Protected area management, design, and infrastructure
Protected area management is a major factor influencing the effectiveness of protected areas. Dudley *et al.* (2004) suggests that legal gazettement immediately confers some protective effect, but that active management (including planning, monitoring and evaluation) improves this. Effectiveness in reducing deforestation is commonly linked to the level of funding (Jepson *et al.* 2002, Wilkie *et al.* 2001, Aung 2007). Without adequate funding, protected areas lack the necessary infrastructure and management resulting in "paper parks". Strong involvement by NGOs can be a significant factor in protected area success, probably as a result of their contribution to good management practices and employee accountability (Sommerville 2005). Staff education, training, and salaries are all often listed as weaknesses in protected area management that contribute to reduced effectiveness (Aung 2007).

It is possible that there is a relationship between protected area size and effectiveness in preventing deforestation (Struhsaker *et al.* 2005), but this is a contentious topic (Sommerville 2005), and beyond the scope of discussion here. As not all protected areas have formal buffer zones (surrounding areas which allow some restricted use of forest products to allow for the needs of local people), where boundaries are not strictly enforced, they can become informal buffer zones, shrinking the effective size of the protected area (Cropper *et al.* 2001). The clear demarcation of a protected area's boundaries has been found to have a significant impact on reducing deforestation by reducing unwitting encroachment (Bruner *et al.* 2001, Jones 1992, Browder 2002, Werner 2001).

Another site-specific characteristic widely cited as an important contributor to effectiveness in reducing deforestation is the response to illegal activity within the protected area; including the probability of getting caught and the seriousness of the sanction if caught. (e.g. Bleher *et al.* 2006, Pattanavibool & Dearden 2002, Bruner *et al.* 2001, Jones 1990, Browder 2002, Dudley *et al.* (2004), Pelkey *et al.* 2000, Struhsaker *et al.* 2005, Werner 2001). In many cases there is little active deterrent (Naughton-Treves *et al.* 2006). Well-managed logging operations within those protected areas which allow extractive use may be a useful tool at preventing deforestation (Congo Basin Forest Partnership 2006), simply because there is investment in management and enforcement of regulations. Oliviera et al. (2007) found that deforestation rates within long-term timber concessions in Peru fell by up to 2 orders of magnitude after timber harvest legislation was passed, although there was leakage into surrounding areas. If there is even a relatively low probability of having their concessions cancelled following violations, concession owners are likely to switch to sustainable forest management and protect against encroachment (Kaimowitz & Angelsen 1998).

Level of community involvement
Land tenure and land use rights differ across protected areas, as do the number of people living in and around the area. Thousands of people, indigenous or otherwise, may live within individual protected areas. These protected areas vary in their governance and in the level of community involvement. From a conservation perspective, the rationale for community involvement is that denying locals access to protected area resources or decision-making leads to non-cost-effective tension between protected area officials (where present) and local residents (Hayes 2006). When governmental agencies allocate land for certain purposes without consulting local residents, they may simply ignore the restrictions (Werner 2001), or violent conflict may erupt (Naughton-Treves *et al.* 2006). Overall park effectiveness has been found to be significantly related to the level of compensation received by local communities for any costs incurred (Bruner *et al.* 2001). The effectiveness of community-managed lands

not officially designated as protected areas has been discussed above, but community-based management schemes are also found within some protected areas.

Whilst categories V-VI are most frequently associated with sustainable development and consideration of local livelihoods, protected areas in any category can have some form of community involvement. Integrated Conservation-Development plans (ICDPs), whereby local communities are integrated into/considered in, and expected to gain benefits from, protected area management, have become more common over recent years. These vary widely in design, but generally establish a core restricted-use protected area and encourage local income-generating sustainable-use schemes within a buffer zone (Naughton-Treves *et al.* 2005). Many studies have assessed ICDPs from a conservation perspective, with mixed results.

When seven Ugandan protected areas with community-based management were compared to nine with conventional management (Mugisha & Jacobson 2004), a threat reduction assessment did not differ significantly between the two sets. However, the community-managed areas fared better at reducing bush burning, logging and encroachment, and had clearer boundaries. Similar results have been found in Brazil, where the Alta Juruá extractive reserve (category VI) is a large, sparsely populated forest, with a stable deforestation rate of just under 1% per year by 2000 (Ruiz Perez *et al.* 2005). Its inhabitants have prepared the management plan, allocated different responsibilities for reserve governance, and run all those activities that fall under its jurisdiction. The deforestation rate was slightly higher than that of indigenous lands and a National Park in the region (stable rates of under 0.6% and 0.8% respectively), but substantially less than the rate of 6% for rural development projects under the remit of Brazilian National Land Reform Institute.

Environmental education can help communities to understand the benefits of protected areas and increase local support for their protection. This type of outreach has been found to correlate strongly with management effectiveness (Dudley *et al.* 2004), though not in all cases (Struhsaker *et al.* 2005). The strength of public support has also been correlated with overall conservation success (Struhsaker *et al.* 2005, Mugisha & Jacobson 2004), although again, not in all cases (Bruner *et al.* 2001)

It is clear that governance factors relating to local communities are not adequately reported on in studies of deforestation. Whilst the drivers of deforestation vary from site to site, and local involvement will have limited impact on deforestation rates when external forces are driving deforestation, there is a real need for more research into the extent to which communities can be involved in reduced deforestation; from both a livelihood perspective and that of practical implementation of REDD.

External factors

Protected areas will be under greater threat when conditions favour forest clearance; when forested lands are more accessible, agricultural and timber prices are higher, rural wages are lower, and there are more opportunities for long distance trade (Kaimowitz & Angelsen 1998). Amongst other factors, land speculation, land taxes, credit and fiscal subsidies can all affect the rate at which deforestation occurs (Kaimowitz & Angelsen 1998). In particular, a forest's proximity to roads, and thus access to non-residents and to markets, is known to increase deforestation pressure. In the Peruvian Amazon, 83% of deforestation was found within 20km of roads; although protected areas had some success in countering this increased pressure (Oliveira *et al.* 2007).

The political environment can have both negative and positive impacts on protected areas. Weak laws can make enforcement difficult and dangerous for protected area staff (Aung 2007), particularly when government agencies do not coordinate their policies (Werner 2001, Ankersen *et al.* 2006). In an extreme example, centralised government might award timber concession permits within strictly protected national protected areas which are governed by provincial agencies, as occurred in Bukit Baka National Park in Indonesian Borneo (IUCN category II; Soertato *et al.* 2001). Lack of inter-sectoral communication has been noted as an issue for protected areas in Brazil (Hirakuri 2003), and Costa Rica (Jones 1992); in the latter case creating perverse incentives for forest clearance within a forest reserve. Corruption may also be an issue; with recorded examples ranging from accepting bribes (Laurance 2004) to the military backing of large-scale illegal logging (Werner 2001). For example, WWF employees at Zombitse National Park in Madagascar were feared locally for their willingness to enforce boundaries, while government-employed forest officials were reportedly open to bribes or even encouraged the exploitation of forest resources at night (Sommerville 2005). Brazilian officials have sometimes issued timber permits for non-existent areas of land, the paperwork then being used to falsely legitimize wood harvested from protected areas (Hirakuri 2003).

Conflict or even war can have unexpected benefits for protected areas conservation, halting logging operations or agricultural encroachment. Conversely, the failure of protected area governance in wartime can result in extensive illegal hunting, mining and fuelwood collection. Guerrilla presence in forests can lead to damage, directly or by government troops. The need for fuelwood of refugees during the Rwandan Civil War caused over 8 000 hectares of the Virunga National Park in the Democratic Republic of Congo to be deforested, whilst the conservation value of Kahuzi-Biega National Park suffered significantly from organised mining and hunting operations (Draulans & van Krunkelsven 2002, Yamagiwa 2003). The unpredictability of these influences and their impact upon protected area effectiveness highlights the need to ensure that assessment of the effectiveness of protected areas in reducing deforestation is context-specific.

Conclusion

The drivers of deforestation vary by region, between protected area sites, and over time. Different management and governance strategies tailored to the needs of the area are required to efficiently prevent deforestation. The evidence indicates that protected areas are effective in reducing deforestation relative to their surroundings, even if they do not eliminate it entirely. That said, one issue that studies rarely take into account is that of leakage. While protected areas may effectively reduce deforestation within their borders, there is a risk that deforestation pressures are merely displaced elsewhere. Where studies have not estimated leakage, the true success of the protected area may be overstated, particularly in the context of REDD, where the aim is to reduce total greenhouse gas emissions.

It seems that protected areas designated under more restrictive IUCN categories (I-IV) are more successful at reducing deforestation than those designated under categories with a greater focus on sustainable use (V-VI). However, these conclusions are based on little quantitative information for category V-VI protected areas and do not explicitly take into account the governance of an area; although greater community involvement is implied by the 'sustainable use' element of the designation. Category V-VI protected areas do generally still reduce deforestation relative to their surroundings.

To date, there has been little study into the impacts of different governance approaches and levels of community involvement on deforestation. Some insight can be gained with reference to indigenous lands and community forestry areas outside the formal protected area network. Various studies have shown indigenous lands to be equally effective as protected areas at reducing deforestation, when the local communities have control over their land; community forestry areas to a lesser extent. As the activities of forest users influence forest condition, it stands to reason that these users should be involved in protected area management planning, to contribute their own experience and build understanding and ownership of management objectives. Levels of community involvement within protected areas vary, but there is evidence that it can contribute to conservation where the governance is transparent.

It is clear that there is no 'one size fits all' approach to reducing deforestation within protected areas. Indeed, many different types of protected area will be required to build an effective network to contribute to reduced deforestation and forest degradation. There will be cases where strictly-enforced rules on resource extraction will be the most effective option, such as areas of high conservation value where investment is made in protection, or areas of low resource use pressure; whereas in other areas official recognition of indigenous lands or designation of well-managed and governed extractive reserves will be more suitable. The implementation of REDD on a large scale is unlikely to be feasible without the support of indigenous and local communities. The official recognition and encouragement of community-based forest management is becoming more widespread, and could become a viable component of, or complement to, protected areas in reducing deforestation.

It is also clear that to support decisions on REDD implementation, further research is required into the factors that influence protected area effectiveness. Ideally, new studies should measure deforestation over time both in and around protected areas; particularly focusing on comparisons between areas with similar deforestation pressures. They should take into account differences in habitat condition and management between the interior and surroundings of protected areas, and assess how much leakage of deforestation occurs (Ewers & Rodrigues 2008). Future research should also compare not only the areas' IUCN management category, but the governance type and extent of community involvement. Protected area management categories and governance are not equivalent, and information on both is required to assess the impacts of community involvement in protected areas, and identify those situations in which community involvement is successful in reducing deforestation.

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