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Targeting and implementing payments for ecosystem services: Opportunities for bundling biodiversity conservation with carbon and water services in Madagascar

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ABSTRACT

Payments for Ecosystem Services (PES) are generating a lot of attention among conservationists because they have the potential to create new funding opportunities for biodiversity protection and other ecosystem services that contribute to human well-being. A number of recent publications have suggested ways to target and implement PES projects in order to maximize their cost-effectiveness and efficiency, and the Heredia Declaration (this issue) sets forth a list of agreed-upon principles concerning the use of PES schemes. One of those principles concerns the "bundling" of joint products of intact ecosystems in PES schemes in order to maximize the benefits to society. There have been several recent studies focusing on the degree of overlap between biodiversity and other ecosystem services and therefore the opportunities and constraints to bundling these services. Building on this idea, the bulk of this paper focuses on developing a method for selecting sites for PES where the main interest is to bundle biodiversity with other ecosystem services. We focus our analysis on Madagascar, a country with globally important biodiversity that is also beginning to explore the utility of PES as a conservation mechanism. Specifically, we assess the opportunities for bundling biodiversity conservation with carbon and water services at the national scale and identify where using PES to protect these areas of multiple benefits would be most cost-effective and efficient. This analysis identifies almost 30,000 km^2 — out of 134,301 km^2 — of natural habitat that could potentially meet biodiversity conservation goals and protect additional ecosystem services through a PES scheme. One of the places identified by our methodology corresponds to an ongoing conservation project that has already begun using payments from carbon emission reductions to protect standing forests and restore important biodiversity corridors — the Ankeniheny-Mantadia-Zahamena Biodiversity Conservation and Restoration Project. This project site was selected for its high biodiversity and carbon values, lending credibility to our spatial targeting methodology and providing a case study to draw insights on how multiple-benefit PES schemes can be implemented in biodiversity "hotspots". In the discussion section of this paper we draw on experiences from this project to consider how many of the principles outlined in the Heredia Declaration affect implementation of PES schemes in Madagascar, providing lessons for similar countries experimenting with PES for biodiversity conservation.

1. Introduction

Payments for ecosystem services[1] (PES) are generating a lot of interest among conservationists and land use managers because they are considered a promising new approach to protect biodiversity and ecosystem goods and services, such as climate regulation, water filtration, and nutrient retention, which contribute to human well-being (Pagiola et al., 2002; Wunder, 2005). PES are defined by five criteria: (1) they are a voluntary transaction; (2) they involve a well-defined environmental service; (3) the service is "bought" by at least one buyer; (4) the service is "provided" by at least one provider; and (5) the transaction is conditional on provision of that service (Wunder, 2005, 2006, 2007). Specific PES tools include direct public payments, direct private payments, tax incentives, cap and trade markets, voluntary markets, and certification programs (Scherr et al., 2005; Ecosystem Marketplace website, 2007). To date, most PES projects have focused on one or more of the following services: biodiversity, carbon, water, or landscape beauty (Landell-Mills and Porras, 2002;

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[1] Also referred to as payments for environmental services in the literature.

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Wunder, 2005). While there are still only a limited number of PES projects in the developing world, the number is growing rapidly, and they range from national programs (e.g., China, Costa Rica), which tend to be government driven, to local PES projects, which are smaller and tend to be financed by the private sector (e.g., Ecuador, Brazil, etc.). The extent to which these projects meet all five of the defining criteria varies considerably, as does the number and type of services being sold, the payment mechanisms being used, and the number of buyers and sellers involved in the transaction (Landell-Mills and Porras, 2002; Landell-Mills, 2002; Wunder, 2005).

In theory, the PES approach can offer several advantages for meeting biodiversity conservation goals over other conservation interventions. First, PES use direct incentives to reach biodiversity targets. This type of direct approach is considered more cost-effective than traditional and indirect conservation policy tools, such as protected areas or integrated conservation and development projects, because it is not as complex to implement and is targeted specifically at project outcomes (Ferraro, 2001a; Ferraro and Simpson, 2001; Ferraro and Kiss, 2002; Pagiola et al., 2005). This means that policymakers should get more biodiversity conservation outcomes per dollar spent. Second, in a time where biodiversity conservation financing is scarce, PES can attract new funding sources (Jenkins et al., 2004; Scherr et al., 2005). The potential inclusion of avoided deforestation in post-Kyoto negotiations represents one of the most tangible opportunities to secure large amounts of financing for the protection of ecosystem services, including biodiversity (Chomitz et al., 2007). Recent proceedings from the thirteenth session of the Conference of the Parties (COP-13) on climate change to explore instruments to "reduce emissions from deforestation and degradation" (REDD) suggest that this may soon become a reality (UNFCCC, 2007). The key for those interested in biodiversity conservation is to ensure that carbon-based PES projects are targeted in areas that also benefit biodiversity protection. Third, PES projects can provide mutual benefits to local people. While PES are not designed to be a poverty alleviation strategy, they can result in more sustainable livelihoods through the provision of cash or in-kind benefits to participants, especially when targeted specifically at rural or indigenous populations (Pagiola and Platais, 2002; Rosa et al., 2003; Pagiola et al., 2005). These direct incentives to local people can be critical in areas where traditional biodiversity conservation strategies have failed and where unsustainable livelihood activities, such as slash and burn agriculture, are one of the major threats to biodiversity (Wunder et al., 2005).

Of course, PES will not be an appropriate tool in all places where biodiversity conservation is warranted, but it is increasingly becoming a preferred policy mechanism given the advantages cited above. While payments can be made exclusively for the provision of biodiversity, another approach that is gaining momentum is to "bundle" biodiversity with one or more additional ecosystem services. Bundling can be advantageous for those interested in biodiversity conservation because biodiversity is often harder than many other services to monetize and thus more difficult to get local and global beneficiaries to pay for directly (Chomitz et al., 1999; Heal, 2002; Robertson and Wunder, 2005). Bundling of services can also be beneficial from the seller's point of view because it can reduce transaction costs and raise price premiums (Landell-Mills and Porras, 2002). However, there are also caveats to trying to bundle multiple services in a conservation program. First of all, our knowledge on many ecosystem functions and services is still rudimentary and obtaining accurate spatial data for these services is even more difficult (Carpenter et al., 2006; Kremen and Ostfeld, 2005). This limits our ability to adequately plan for these services. Second, several recent studies have highlighted the inherent tradeoffs between multiple services (Chan et al., 2006; Egoh et al., 2007; Nelson et al., 2008). The degree of congruence between biodiversity and services such as carbon and water is still relatively unknown (Egoh et al., 2007). Nelson et al. (2008) suggest that we may have to settle for lower levels of services if we are interested in conservation actions that target multiple benefits simultaneously.

With these caveats in mind, conservation practitioners are rapidly building their portfolios of projects that deliver biodiversity plus other ecosystem service benefits. However, to date, there has been no systematic strategy for incorporating ecosystem services into biodiversity conservation projects (Egoh et al., 2007), let alone a method for identifying areas that might make sense for using a market-mechanism such as PES to conserve biodiversity. Therefore, the main purpose of this article is to develop a targeting method that can be used to identify where PES might be an effective and efficient approach to protect ecosystem services that occur in priority areas for biodiversity conservation. We apply our methodology to Madagascar — a country known for its globally important biodiversity and one that is also beginning to explore the use of PES for biodiversity conservation. For this analysis we use spatial data to map where areas important for biodiversity conservation overlap with carbon and water services. We focus exclusively on remaining forests and wetlands in this article because this is currently the main strategy used by international and national conservation organizations to target biodiversity priority areas. Within these forests and wetlands we consider what the level of threat (e.g., probability of deforestation) and opportunity costs are in the areas where biodiversity, carbon, and water services can be bundled to target where PES projects could protect multiple services in a cost-effective and efficient manner.

In the next section, we provide some background on biodiversity conservation and PES in Madagascar. In addition, we introduce one of the first PES projects in the country that has been targeted at biodiversity protection and carbon services — the Ankeniheny-Mantadia-Zahamena Biodiversity Conservation and Restoration Project (referred to as the Mantadia Project in the remainder of the paper). We draw on this project later in the paper to help validate our spatial targeting methodology and to discuss many of the implementation challenges highlighted in the Heredia Declaration (this issue). In Section 3 we discuss the methods and data sources used for our analysis. In Section 4 we present the results from the national-level targeting of potential PES sites; this includes identification of the area corresponding to the Mantadia Project. We discuss the implications of this targeting methodology for Madagascar in Section 5 and provide a brief overview of some of the implementation challenges associated with using PES as a biodiversity conservation strategy in Madagascar. In Section 6 we conclude with a discussion of the opportunities and challenges of using this type of targeting methodology to identify areas to use PES to conserve biodiversity and additional ecosystem services in priority countries for biodiversity conservation.

2. Background

Madagascar is an ideal test case for our spatial targeting methodology of PES schemes aimed at biodiversity conservation because of its global importance as a "biodiversity hotspot" (Myers et al., 2000; Mittermeier et al., 2004). In addition to biodiversity value, ecosystems within the country also provide a number of documented goods and services to local, national, and global beneficiaries (Kramer et al., 1997; Kremen et al., 2000; Carret and Loyer, 2003; Minten and Moser, 2003; Bodin et al., 2006). However, Madagascar is rapidly losing its biodiversity and ecosystem services as a result of deforestation and degradation — 8.6% of all forests were lost between 1990 and 2000 and less than 15% of the island remains in primary forest (Harper et al., 2007). While the drivers of deforestation are complex and can vary across regions (e.g., see Casse et al., 2004 for an example from southwestern Madagascar), one significant factor is the increasing need for agricultural land given high population growth rates and

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unsustainable agricultural practices such as *tavy*[2] (Gade, 1996; Vagen, 2006; Gorenflo et al., forthcoming).

The government of Madagascar has recently pledged to increase the protected areas system from 1.7 million hectares to 6 million hectares, or from 3% to 10% of the country's surface, in an effort to halt forest and biodiversity loss and ensure the continued provision of environmental services.[3] Unfortunately, funding for managing parks is scarce and not sustainable (Carret and Loyer, 2003), protected areas do not necessarily prevent deforestation (Ingram and Dawson, 2005), and the opportunity costs borne by some local communities from the establishment of protected areas are high (Ferraro, 2001b). These conditions suggest that PES could be an appropriate conservation policy tool both within and outside of newly proposed protected areas. Within newly proposed protected areas, PES could provide an important source of financing to improve park management and to compensate local communities. In places that fall outside of the newly proposed protected areas, PES could provide a potentially cheaper and more equitable alternative to parks.

As the Heredia Declaration emphasizes, political will and policy coherence are necessary for any type of PES system to be sustainable over the long term. Fortunately for Madagascar, there is President-level commitment to conserve the environment, as demonstrated by the declaration to set aside a total 6 million hectares of the country as protected areas. President Ravalomanana's political leadership has also led to the declaration that clearing native forest for logging or *tavy* is illegal, and to the establishment of several pilot projects for measuring and protecting important watersheds. In addition, the government already recognizes the potential benefits of tapping into the growing interest in carbon payments by including provisions in the current phase of the National Environmental Program (EPIII) and the Madagascar Action Plan (MAP) to use forest-based carbon projects as a mechanism for funding biodiversity conservation. Thus, scaling up this interest in carbon financing to identify projects that bundle carbon storage services with biodiversity conservation goals, and other ecosystem services, is rapidly becoming a reality in Madagascar.

In addition to political leadership, Madagascar already has some of the legal framework needed to effectively govern the use of ecosystem services in the country. One example is an alignment between logging bans which, if enforced, would further climate policies of reducing emissions from deforestation in natural forests; unfortunately, the funding to fully implement and enforce many of these forestry and environment laws is limited. An additional limitation of the current system in Madagascar is that the government ministries required to support ecosystem service projects (e.g., forests, water, agriculture, energy, mining, protected areas) are often focused on different priorities, and there is currently limited cooperation on cross-cutting issues such as PES at the national level (Randimby and Razafintsalama, 2006). Creating this type of policy and ministerial alignment is critical to fostering national-level political motivation to move forward on ecosystem service conservation (Rodriguez, 2007). For example, Costa Rica's national PES program was greatly facilitated by the consolidation of funding and management of ecosystem service projects into one institutional body, FONAFIFO (the National Forestry Financing Fund).

Thus, overall, Madagascar is on the right track to successfully use PES as a mechanism to finance biodiversity conservation, but there are still improvements in policy alignment and capacity building to be made. A handful of incipient projects that fit many of the criteria for PES have already been implemented or are being discussed in Madagascar (Randimby and Razafintsalama, 2006), and overall interest in the PES approach is growing rapidly. One of these projects is the Mantadia Project[4]. The Mantadia Project is a 30-year project formally endorsed and launched by the Minister of Environment, Water and Forests (MEEF) in Madagascar in 2004. The primary ecosystem services being generated in this project are carbon emission reductions and biodiversity existence value. These services are being generated through reduced deforestation on over 420,000 ha of primary and degraded forests. In addition, natural forest restoration and rehabilitation on 3000 ha are intended to form a corridor between the forests. These reforestation activities should generate additional local ecosystem service benefits in the way of reduced soil erosion, nutrient depletion and off-site sedimentation in the associated watersheds. The entire area has now been designated a multiple-use protected area, with 80,000 ha put under strict protection and the remaining forest designated as a community-use zone. Partners in this project include government agencies (e.g., MEEF), quasi-government organizations (e.g., the National Association for the Management of Protected Areas), and non-government organizations (e.g., Conservation International and several local facilitating organizations[5]).

In the Mantadia Project, the government is the actual “seller” of the carbon emission offsets — this is because the government owns the rights to forestland and therefore carbon emissions under current Malagasy environmental laws — but the actual funds and benefits are being allocated for reforestation and forest management of the corridor areas, and to alternative livelihood activities across 2000 additional hectares that are meant to provide incentives to surrounding communities to protect the forests. The initial “buyer” of the carbon emission reductions is the World Bank's BioCarbon Fund. Because carbon funding covers only a portion of the 30-year project activities (specific reasons to be discussed in Section 5), additional funding is provided by a consortium for biodiversity conservation and sustainable development including the Government of Madagascar, Conservation International, and the U.S. Agency for International Development.

The Mantadia Project represents a voluntary agreement between the “sellers” and the “buyers” of carbon, and local communities living in the area are willingly participating in the project[6]. Payments to the government for carbon offsets are contingent on periodic monitoring and verification of carbon emission reductions. The incentives being received by local communities for forgoing *tavy* in the protected forests and reforested corridors are clarified land tenure, sustainable agricultural plots, and employment benefits for a limited number of people. Thus, while carbon payments to the government are conditional on provision of the service, the ability to rescind on “payment” between the project and the communities is more difficult if the communities decide not to respect the agreement or if they request additional benefits in the future. Despite these complications, this project is using payments from provision of a specific ecosystem service to increase environmental protection and local livelihood benefits in the area, providing a local PES case study from which to draw insights about the principles outlined in the Heredia Declaration.

[2] We use *tavy* in this article to refer broadly to the practice of slash-and-burn agriculture in the country; however, technically, *tavy* refers to slash-and-burn agriculture for rice cultivation and the term is used mainly in the east, while hatsake (which usually involves maize) is the term used in the southwest (Gorenflo et al., forthcoming).

[3] The President of Madagascar made this pledge at the 2003 World Parks Congress.

[4] This project has two main components, an avoided deforestation component and a natural forest restoration and rehabilitation component. For simplicity, we refer to these two project components jointly as the Mantadia Project throughout this paper.

[5] Local facilitating organizations include Guide Association of Andasibe (AGA), “Ecophysiology” at University of Antananarivo (Ecophi), Man and the Environment (MATE), MITSINJO (Malagasy for “Care for the Future”), Groupe d'Etudes et de Recherches des Primates de Madagascar (GERP), and Sampan'Asa Fampandrosoana/Church of Jesus Christ in Madagascar (SAF/FKJM).

[6] Negotiations with the communities began four years before the project was implemented and has involved a substantial education campaign aimed at informing communities about the benefits they would receive from the project.

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3. Methods

3.1. Targeting PES for biodiversity conservation

Currently, we know very little about where higher concentrations of ecosystem services such as carbon or water regulation occur in most countries, what the opportunities are for bundling these services with biodiversity conservation projects, or where PES might be a cost-effective and efficient conservation approach. In this exploratory analysis we focus on the provision of biodiversity, carbon, and water services in existing forests and wetlands in Madagascar. There are, of course, a number of other services important in both Madagascar (e.g., see Bodin et al., 2006 for a description of pollination services) and other biodiversity-rich countries. We concentrate on these three services because they are the most cited in the literature for having potential PES buyers (Landell-Mills and Porras, 2002; Wunder, 2005) and are also the services where spatial data is easily attainable at the national scale.

In mapping these three services we measured both the magnitude of the service provided and, when applicable, the demand or "value" for the service by beneficiaries. Ecosystem services imply that people benefit from ecosystem processes, so in targeting conservation projects it is necessary to capture differences in the value of services across space (i.e., one watershed may have more beneficiaries than another watershed). There are several methods one could use to measure the value of services to humans, such as monetary valuations or qualitative indexes of people's preferences. In this analysis we follow Boyd and Wainger (2003) and generate an index of the degree to which benefits are provided to people by a particular piece of land and use this as a proxy of the value of that land for ecosystem service generation for humans. Since we are specifically interested in identifying where services are complementary in space, we map services individually and then combine them to give an indication of the opportunities for bundling biodiversity conservation with other ecosystem services.

In our assessment of where PES might be the best approach to protecting biodiversity and ecosystem services, we drew on several recent studies aimed at improving the efficiency and cost-effectiveness of targeting PES schemes. For example, it has been recognized that including information on the level of threat to service provision (Alix-Garcia et al., 2005; Muñoz-Piña et al., 2005; Wünscher et al., 2008) and the opportunity costs of the land (Wunder, 2005, 2007;

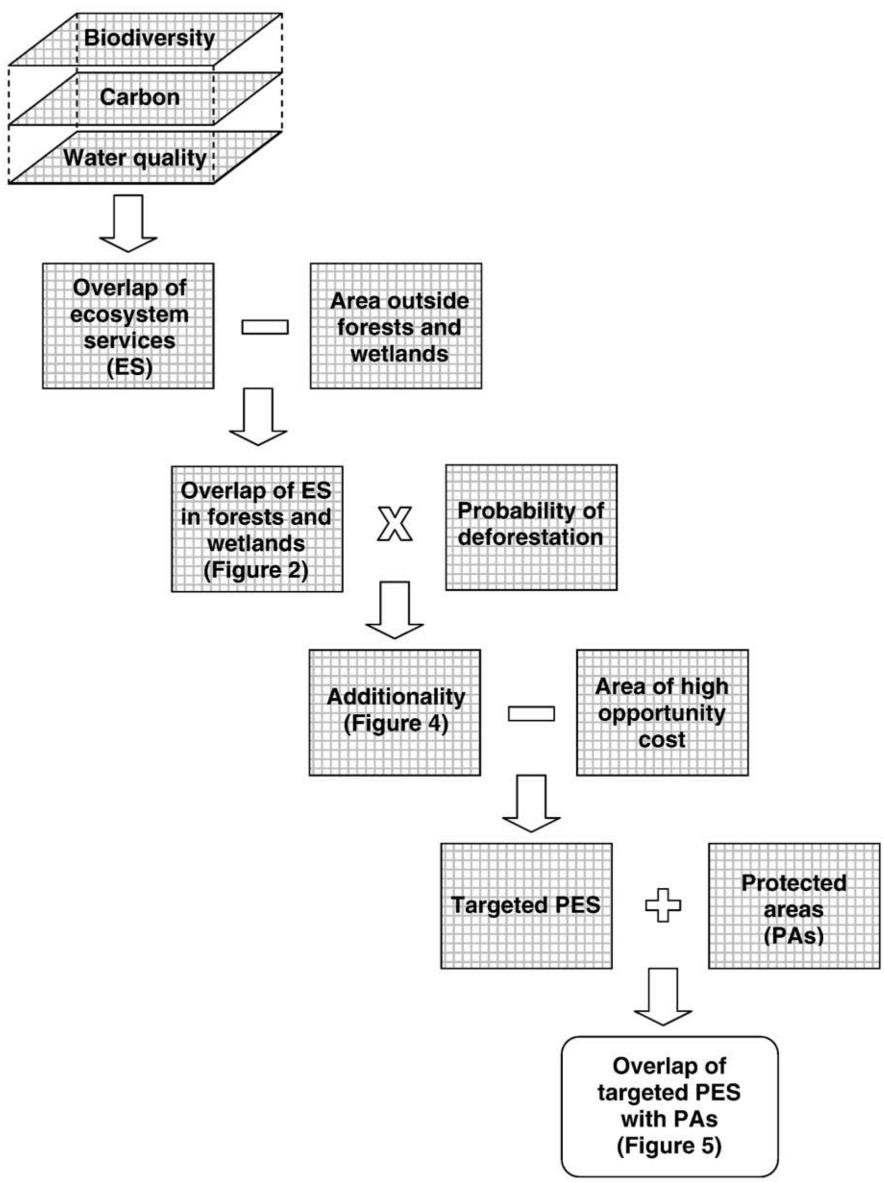

Fig. 1. Spatial targeting methodology (subtraction sign stands for spatial masking; addition sign stands for spatial overlay. Figures in the paper corresponding to steps in the methodology are referenced).

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Wünscher et al., 2008) are necessary for efficient and cost-effective PES systems. Recent evaluations of Costa Rica's and Mexico's PES programs have suggested that not including the level of threat or opportunity costs into targeting payments has lowered additionality[7] (Sierra and Russman, 2006; Sánchez-Azofeifa et al., 2007; Sills et al., forthcoming) and efficiency (Alix-Garcia et al., 2005; Wünscher et al., 2008). The idea of geographically targeting high threat/low opportunity cost lands for conservation is not new, and is already used to maximize the cost-effectiveness of many protected areas and reserves (Newburn et al., 2005; Naidoo et al., 2006). Being primarily interested in PES from a biodiversity conservation perspective, including information on the threats and opportunity costs of the land allows us to identify where the level of threat justifies intervention and where PES might be more cost-effective than alternative conservation approaches in mitigating these threats. We have depicted the general methodology we use to target sites for PES in Fig. 1.

3.2. Data

3.2.1. Ecosystem services

3.2.1.1. Biodiversity. To create a non-binary index for biodiversity value we used currently available global vector data on species ranges of mammals (Baillie et al., 2004), birds (BirdLife International, 2006), and amphibians[8] (IUCN, 2006) and weighted them by their threat status as defined by IUCN's Red List (IUCN website, 2007). For the weighting we used the "equal-steps" weights described by Butchart et al. (2004) to assign specific values to threat status with the following modifications: we added 1 to all categories in Butchart et al. (2004) to include the categories "not evaluated" and "data deficient" in the analysis and gave a value of 0 to species labeled "extinct" or "extinct in the wild" to exclude them from the analysis. We chose the equal-steps method over other ranking systems that give higher priority to significance of threat for its simplicity and the fact that using this method allows the index to be driven by a relatively larger number of species, leading to a more robust and representative index (Butchart et al., 2004). We converted this vector data to a 30 arc second grid (approximately 1 km at the equator) to facilitate further analysis. We did not include a proxy for demand across space for biodiversity — we assumed that demand for species protection is equivalent across the country. This is supported by a recent study in Costa Rica that found similar willingness to pay values for biodiversity in remote areas and highly accessible areas of the country (Bienabe and Hearne, 2006).

3.2.1.2. Carbon. In the 1980s, Olson et al. (1983, 1985) developed a global ecosystem-complex carbon stocks map of above- and below-ground biomass following more than 20 years of field investigations, consultations, and analyses of the published literature. The original data characterized the use and vegetative cover of the Earth's land surface with a 0.5 arc degree grid (approximately 55 km at the equator). Gibbs (2006) extended Olson et al.'s methodology to more contemporary land cover conditions using remotely sensed imagery and the Global Land Cover Database (GLC, 2000). For this analysis we used the 5 arc minute data (approximately 9 km at the equator) created by Gibbs (2006), and resampled this grid to 30 arc second to facilitate further analysis. We did not include a measure for demand since carbon storage from one forest should have the same number of global beneficiaries as another forest.

3.2.1.3. Water quality. We focused on water quality (versus water supply or regulation) in our analysis since the relationship of this hydrological service with natural forest cover is not contested (Aylward, 2004; Bruijnzeel, 2004; Calder, 2005). In addition, studies in Madagascar have established a direct relationship between deforestation and downstream sedimentation (Rakotoarison, 2003; Albietz, 2006), providing local empirical support. To proxy for the supply of sediment-free water we used population distribution data obtained from the LandScan™ 2004 dataset (Bright et al., 2005), a land cover/land use map of Madagascar (FTM, 1997), and water flow directional information derived from the HydroSHEDS dataset (Lehner et al., 2006). To measure water quality benefits we devised three spatial indices: the first captured drinking water benefits by weighting areas that provided hydrological services by the downstream population's need for quality drinking water; the second captured the irrigated rice benefits by weighting areas that provided silt-free water by downstream area of irrigated rice fields; and the third captured the importance for mangroves by weighting areas that provided hydrological services by the area of mangroves downstream (Honzák et al., 2006). Our final water quality index was a linear combination of these three datasets plus an index of slope[9], with equal weight given to each dataset. We converted the initial 15 arc second resolution grid to a 30 arc second grid to facilitate further analysis. Note that this layer does not incorporate variables that might affect the quantity of water at these locations (e.g., precipitation, evapotranspiration, or soil infiltration).

3.2.2. Probability of deforestation

Quantifying the probability of deforestation is a complex task. Acknowledging the disadvantages of using national-level data and cross-sectional data (Kaimowitz and Angelsen, 1998), we derive a simplistic model of deforestation probability in Madagascar based on the same assumptions as identified by Gorenflo et al. (forthcoming). Based on their analysis we estimated a similar multivariate probit model of deforestation where the dependent variable was whether deforestation occurred between 1990 and 2000 and the independent variables included distance to footpaths, distance to roads, elevation, slope, population density, mean annual per capita expenditure, household income inequality[10], presence of protected areas (established before 1990), and five regional dummies to account for differences in agroclimatic factors. We used the estimated coefficients from this model to predict the probability of deforestation from 2000 to 2010 assuming a business as usual scenario.

3.2.3. Opportunity costs

To proxy for opportunity costs in Madagascar we use data on the opportunity costs of agriculture and livestock produced by Naidoo and Iwamura (2007). Naidoo and Iwamura (2007) compiled information on crop productivity and distribution for 42 crop types, livestock density and estimates of meat produced from a carcass, and producer prices to measure the gross economic rents of agricultural land across the globe. We clipped this global data to Madagascar's boundaries. Gross economic rents ranged from 0 to 529 USD per hectare for Madagascar, with a mean value of 45 USD ha^{-1} $year^{-1}$. We used the value of 91 USD ha^{-1} $year^{-1}$ (one standard deviation) as the cutoff to

[7] Additionality is defined here as achieving an outcome (in this example, maintaining forests and wetlands and the associated ecosystem services) that would not have occurred without the PES intervention.

[8] These three taxa are considered a credible proxy for the "value" of biodiversity given that most tourism in the country is directed at viewing lemurs, birds and amphibians. We therefore assume that a person's willingness to pay would be higher for these more "charismatic" species. Plants also represent biodiversity value locally through medicinal uses and globally through bioprospecting; however, there is no spatially explicit database to our knowledge that highlights important medicinal plants in Madagascar. Despite excluding data for plants and other taxa in our index, a visual comparison of the areas with high biodiversity value shows significant overlap with the Key Biodiversity Areas (KBAs) identified as conservation priorities for Madagascar by Conservation International (Langhammer et al., 2007). KBAs provide a binary index of conservation value in the country and therefore could not be used to compare the relative value of one area to another.

[9] Information on slope adds extra weight to the fact that vulnerability to soil erosion is higher for steeper slopes; slope data come from Globe (1999).

[10] This was measured as the Gini coefficient at the firaisana level. The Gini coefficient was calculated from the 1993 census data (Mistiaen et al., 2002).

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exclude areas of high opportunity costs. We converted the initial 5 arc minute grid to a 30 arc second grid to facilitate further analysis.

While the Naidoo and Iwamura (2007) dataset provides a global overview of agricultural opportunities, it does not do a great job of capturing regional variations in production for Madagascar. The caveats to using this dataset for regional and local analyses are laid out explicitly in Naidoo and Iwamura (2007). In scrutinizing this dataset for Madagascar several anomalies were found. For example, a few isolated spots of high opportunity cost were found in the arid southern region of the country; despite the fact that it is one of the poorest regions in Madagascar with livelihoods predominately centered around animal husbandry. Unfortunately, there are no national or local datasets on opportunity costs for Madagascar, and so we use this dataset in our analysis but advise caution in interpreting the results associated with this layer. In addition to the limitation of using a global dataset for agricultural rents, mining and logging are direct threats to biodiversity conservation goals in Madagascar but are not included in the Naidoo and Iwamura (2007) data. We were not able to acquire spatial data on the current or future productivity and economic value of these industries across Madagascar, and so have not included this information in our opportunity costs layer. We acknowledge this omission and suggest verifying locally whether mining or

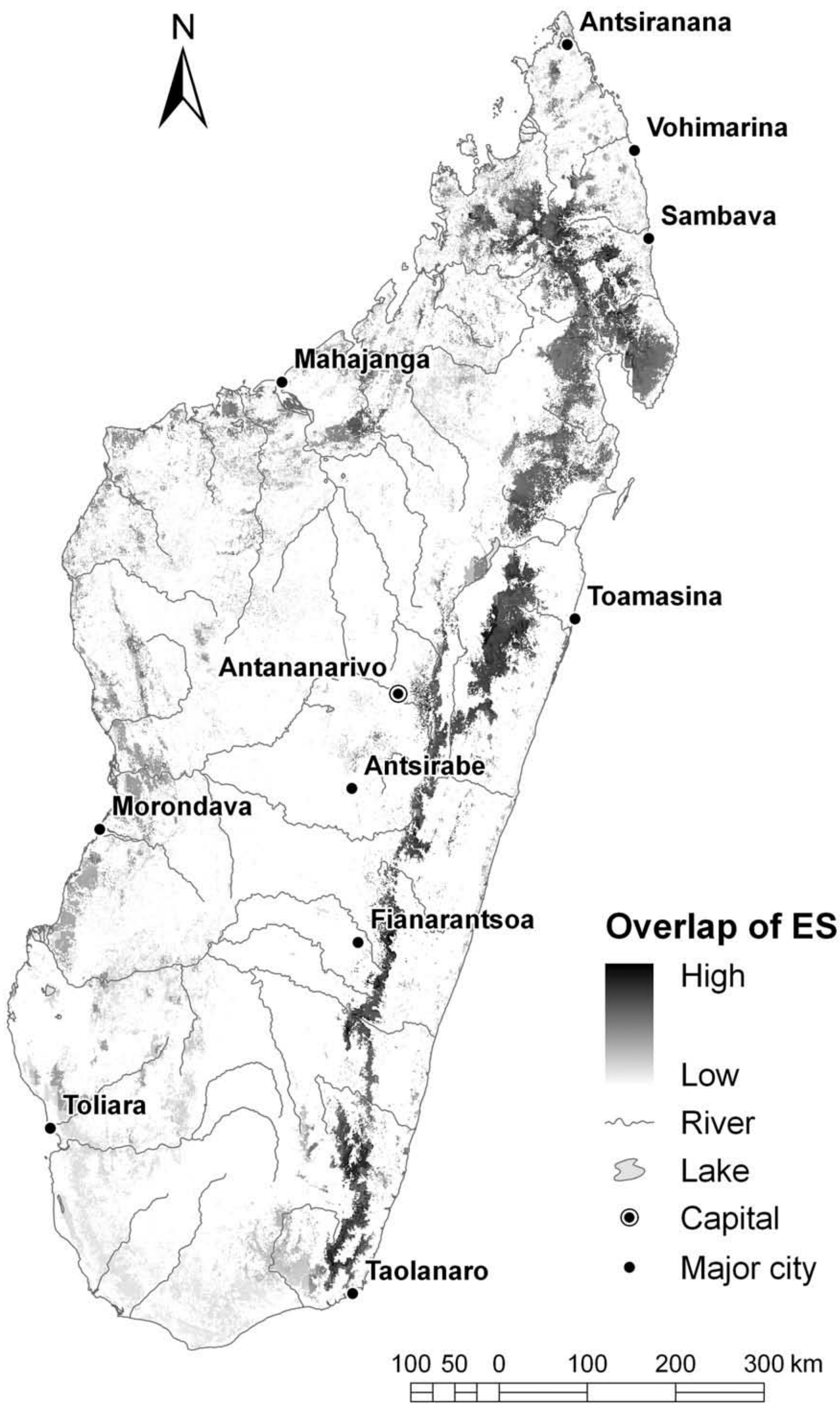

Fig. 2. Overlap between multiple ecosystem services (ES) in forest and wetlands (the relative strength of the overlap is depicted in shades of gray ranging from white (low) to black (high)).

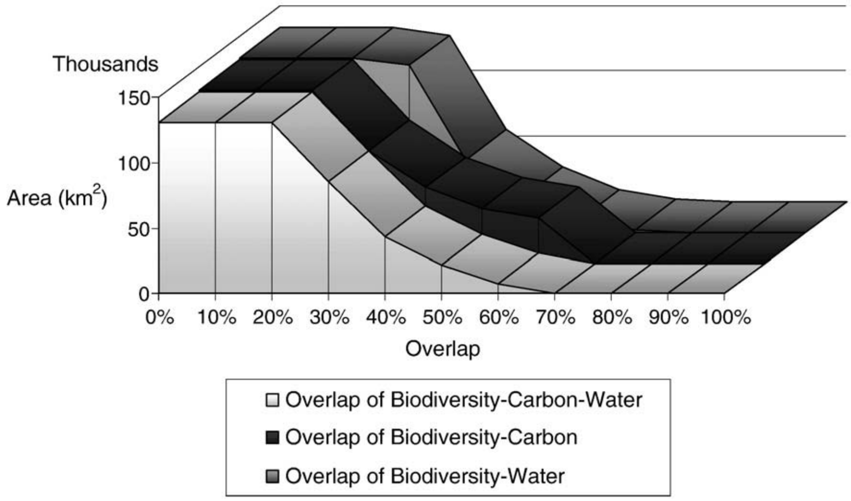

Fig. 3. Overlap between multiple ecosystem services (the relative strength of the overlap is expressed by summing the area in each percentile class).

logging interests would pose a direct challenge to the potential PES areas identified in this analysis.

4. Results

4.1. National targeting

To produce a national map of PES targets we first restricted our analysis to remaining forests and wetlands by clipping vegetation classified by Kew Gardens (2002) as forest or wetlands from other land cover classes; this gave us a total area of 134,301 km^2[11] that was used as a mask in all subsequent analyses. For the three ecosystem services we followed the methodology used by Wünscher et al. (2008) and applied a *z*-normalization to each data feature to normalize the service values (mean = 0 and standard deviation = 1) so that we could combine the individual layers. During the normalization process we identified extreme outliers in the water quality layer — about 1.4% of all cells had a value greater than three standard deviations. To be consistent we chose to limit values for each ecosystem service layer to within three standard deviations from the mean of that service. We then linearly rescaled the individual service values to between 0 and 1. In our biodiversity index of forested areas and wetlands in Madagascar we found a minimum value of 0.234, an average value of 0.499, and a maximum value of 0.937. The minimum value for total stored carbon in forested areas and wetlands was 0.284, the average value was 0.499, and the maximum value was 0.668. The minimum value for water quality in forested areas and wetlands was 0.307, the average value was 0.498, and the maximum was 1.00. To combine the three services we used a simple Weighted Linear Combination (WLC) method. We gave equal weight to each layer.

Next, we quantitatively assessed the ability to bundle biodiversity with carbon and water by measuring how much of each service was found within each square kilometer of forest or wetland where overlap occurred (Fig. 2). We summed the area where bundling of more than 0% of each service was found, where more than 10% of each service was found, and so forth, up to 90% or more (Fig. 3). We found strong spatial overlap between all three services up to a value of at least 30% of each service. The area of overlap decreased rapidly as we moved higher along the spectrum, with zero overlap occurring at a value of 70% and higher; the limiting factor for this value was the maximum value of carbon. Turning to just biodiversity and carbon we found higher levels of bundling than between all three services, especially at values greater than 40%. Bundling between biodiversity and water was also slightly higher than between all three services, with some areas having over 70% of overlap.

We then estimated the additionality of protecting forests that provided these multiple services. While we could consider numerous scenarios from Fig. 3 as sufficient measures of bundling of multiple services, we limited this analysis to areas where at least 40% of each service was found — this gave us an area of 43,510 km^2 or 32.4% of the total area considered. To measure the additionality of protecting these 43,510 km^2, we followed Wünscher et al. (2008) and multiplied the sum of ecosystem service values in that area by the probability of deforestation. Our estimated deforestation values (not shown) ranged between 0 and 1, with an average probability of 0.317. Fig. 4 shows the added value of protecting forests and wetlands for ecosystem services as compared to a scenario where deforestation occurred as predicted in our model. The areas shown in Fig. 2 that no longer appear in Fig. 4 represent areas of no additionality — this could be due to having low values of ecosystem services (Fig. 2) and or low probabilities of deforestation. This means that areas having low probabilities of deforestation but extremely high values of ecosystem services are retained in Fig. 4.

While the additionality layer by itself can indicate potential areas of intervention by showing where protection might result in more biodiversity and ecosystem service conservation as compared to areas with low ecosystem service values or low deforestation rates, comparing these values to the opportunity costs of the land can give perspective on which areas might be more cost-effective to implement PES projects. To do this we isolated areas where additionality is reasonably high (we took the top three quarters of values from Fig. 4) and subtracted out areas where opportunity costs are high to determine targeted sites for PES. This leaves 29,343 km^2 of forest and wetlands that might be appropriate for a PES scheme barring additional suitability analysis. Finally, given the president's declaration to triple the size of the protected areas system in Madagascar, we considered where the most suitable sites for PES identified by our analysis correspond to existing and proposed protected areas in the country and where they fall outside of these areas (Fig. 5).[12]

[11] This number encompasses all natural forest/vegetation types occurring in Madagascar including humid forest, western humid forest, western sub-humid forest, western dry forest, southwestern dry spiny forest-thickets, littoral forest, tapia forest, mangroves, and wetlands. The total area in this article is therefore higher than analyses that classify land only as forest/non-forest (e.g., Harper et al., 2007).

[12] It is important to remember that our unit of analysis for opportunity costs is 5 arc minutes compared to 30 arc seconds resolution of the additionality depicted in Fig. 4. Within each 5 arc minute block there could be considerable variation in opportunity costs; our analysis is likely to miss these subtleties and could therefore omit some areas that might be competitive for a PES scheme.

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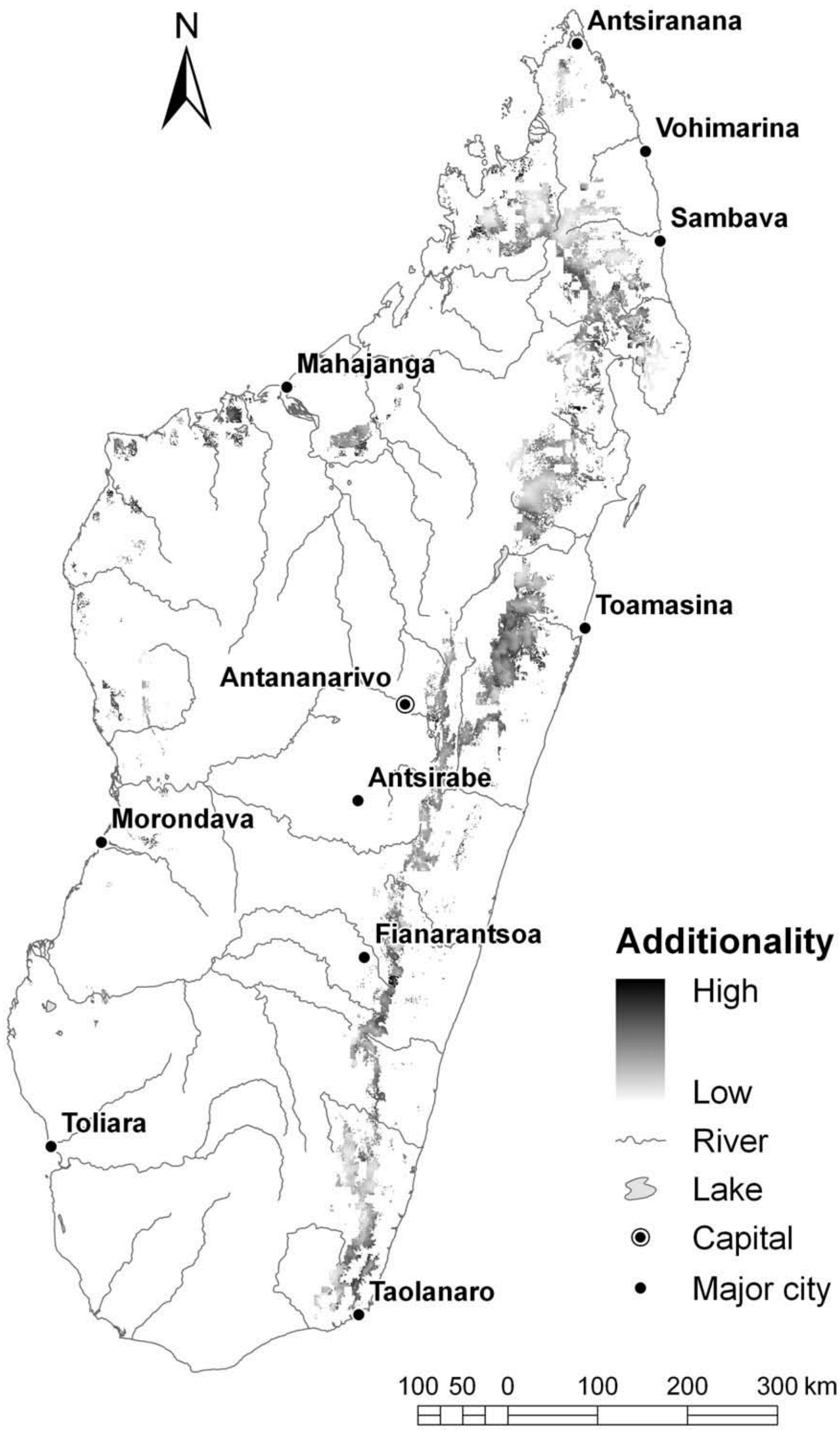

Fig. 4. Additionality of protecting multiple ecosystem services (the relative strength of the added value of protecting forest and wetlands is depicted in shades of gray ranging from white (low) to black (high)).

We found that 37% of the areas identified in our analysis are already protected areas[13] (as of 2006), 23% are in areas proposed for new protected areas, 20% are in areas proposed for new forest reserves that would allow for sustainable timber management, and 20% did not overlap with any existing or proposed conservation intervention (Table 1).

[13] While in theory targeting existing protected areas for PES would not offer any additional ecosystem service protection, these areas were retained in the targeting analysis because of their extremely high values of ecosystem services and the fact that in reality they are still susceptible to threats – protected area status in Madagascar does not necessarily translate to lower deforestation rates. So in practice, there could be "additional" ecosystem service protection gained from generating revenue through a PES scheme within existing protected areas.

4.2. Local targeting

To attempt to ground truth our national targeting analysis, we compared the amount of overlap in the national map (Fig. 5) to the boundaries of the Mantadia Project. As mentioned before, the Mantadia Project was designed to protect biodiversity and carbon services; project administrators have also noted hydrological benefits in the project area. We found that 71.2% of the land in the Mantadia

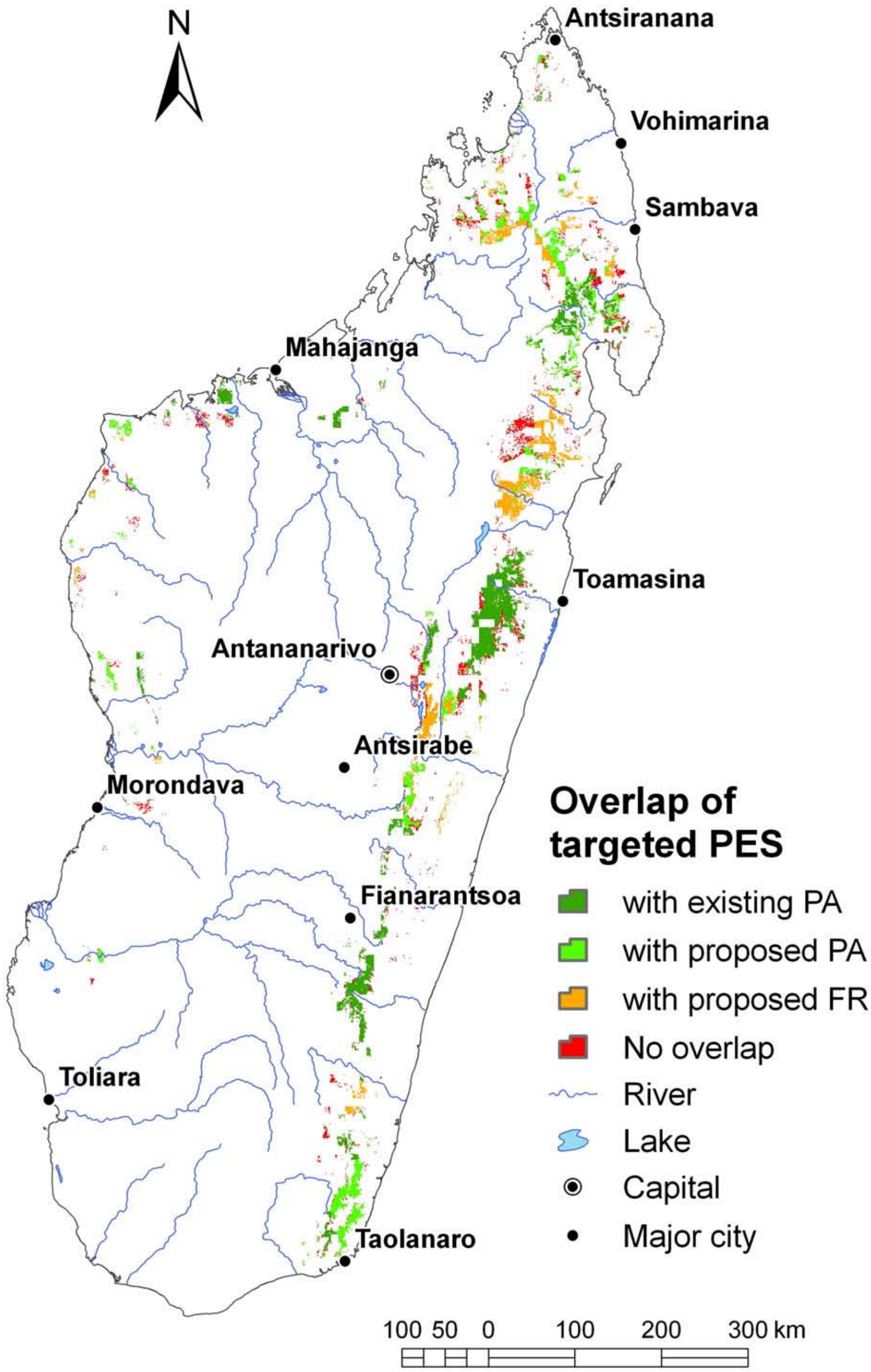

Fig. 5. Overlap of targeted PES and existing and proposed conservation interventions (PA=protected area, FR=forest reserve).

Project overlapped with our national analysis (Fig. 6). This is a considerable amount of overlap and suggests that the areas in Fig. 5 represent reasonable approximations of where multiple benefit ecosystem service projects could be undertaken.

4.3. Limitations of spatial analysis

While our spatial analysis targeted potential sites for PES in Madagascar, these maps should be interpreted with the following caveats in mind. First, due to inconsistent resolutions in our spatial data on ecosystem services, the accuracy of our PES targets is limited to 9 km in some places. This is because the initial resolution of the carbon and opportunity costs layers was 5 arc minutes (approximately 9 km at the equator) and because species ranges were delineated by hand. Places where this limitation applies appear coarse in the figures. Second, we use global scale data for many of the layers in our analysis.

Table 1
Overlap of targeted PES sites and existing and proposed conservation interventions

	Area (km2)	% of total area targeted for PES
Existing protected areas (2006) with PES overlap	10,786	37%
Proposed protected areas with PES overlap	6851	23%
Proposed forest reserves with PES overlap	5923	20%
PES with no overlap	5783	20%

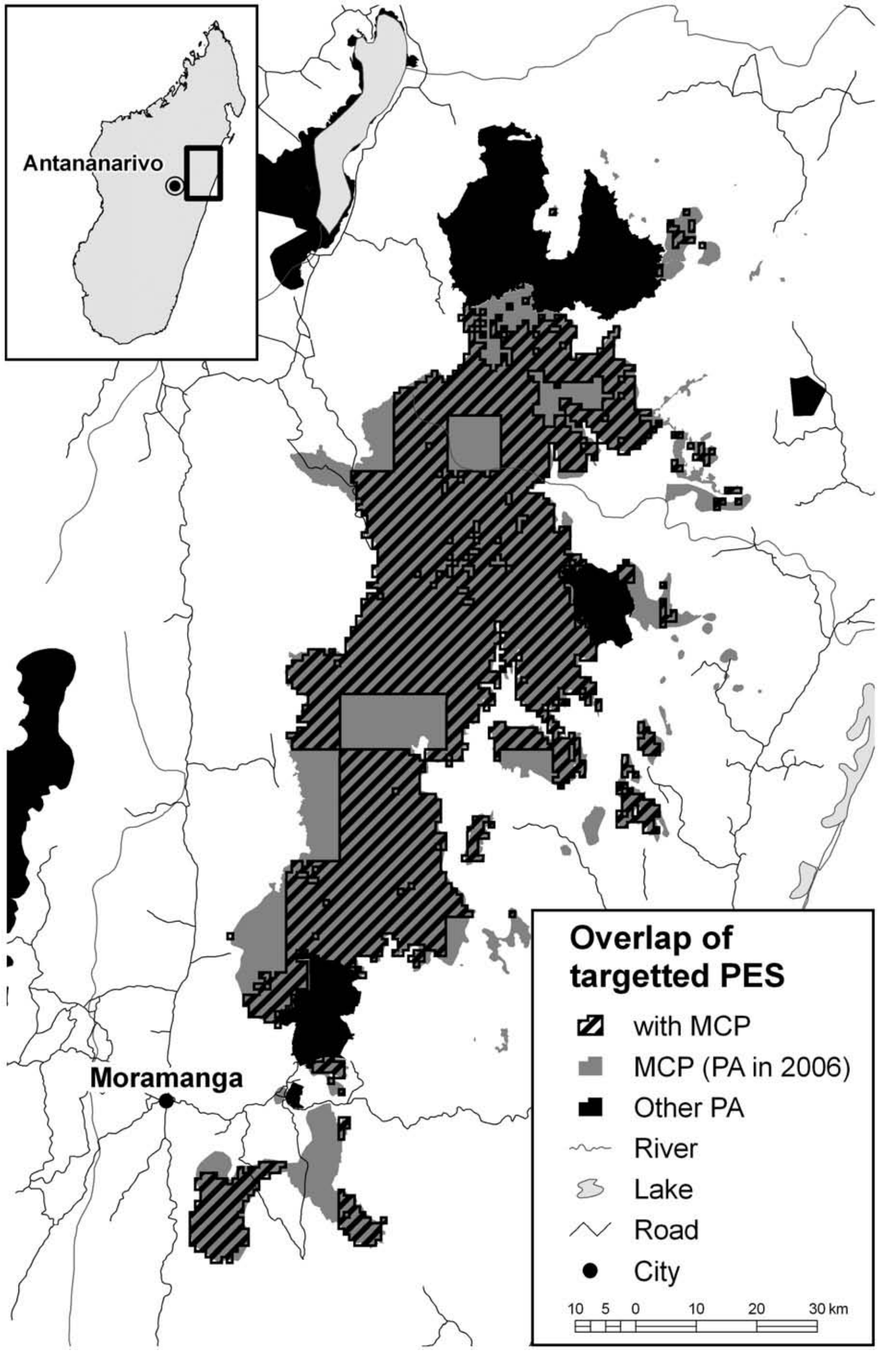

Fig. 6. Overlap of targeted PES and Mantadia Corridor Project (MCP).

While this is the best data that exist for Madagascar in many cases, detailed analyses of these data suggest several inconsistencies with what is happening on the ground (e.g., the opportunity costs dataset), and the accuracy of our results are affected accordingly. Global scale data should only be used for local and regional planning activities if rigorous assessments of its validity can confirm its accuracy. Third, due to outliers in the water quality layer we chose to limit each of our ecosystem service data layers to within three standard deviations. In doing this we may have excluded potentially high opportunity sites for PES. Fourth, we decided to combine the individual service layers using equal weights to facilitate bundling of all three services; combining these services using different weights could result in slightly different targeted PES sites in Fig. 5. Additionally, altering the assumptions made in other parts of this analysis could affect the results presented in Fig. 5. Fifth, in the case of the probability of deforestation, Casse et al. (2004) argue that the traditional econometric approach that we adopted (i.e., multivariable regression using distance to roads, etc.) to explain causes of deforestation in the southwestern part of Madagascar may be flawed. After scrutinizing our probability of deforestation layer we confirmed that this regression approach probably does underestimate threats in certain regions of the country. Sixth, our analysis was limited to ecosystem services where data existed at the national scale. We were therefore not able to identify what other services might exist within forests and wetlands, and what the potential tradeoffs would be between these services (see Chan et al., 2006 for more detail on potential tradeoffs between services). Seventh, with the exception of our measure of the probability of deforestation, this analysis is static, and so does not account for the potential temporal changes in ecosystem service provision, demand for services, and opportunity costs of land, or the

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interactions of these variables across space. This is also a limitation in previous conservation planning analyses (Naidoo et al., 2006). A dynamic model that can account for the feedback between ecosystem service provision and demand, climate change, opportunity costs, and deforestation would eliminate this shortcoming.

5. Discussion

5.1. Implications for targeting PES in Madagascar

Sixty percent of the areas identified for PES in this analysis overlap with existing or proposed protected areas. This is not too surprising given the high biodiversity values and amount of forest cover found in these areas. Given the limited funding for protected areas management (Carret and Loyer, 2003), the fact that protected area status does not ensure against all deforestation (Ingram and Dawson, 2005), the opportunity costs borne by local people around protected areas (Ferraro, 2001b), and the increasing encroachment on forests for agricultural needs (World Bank, 2003; Gorenflo et al., forthcoming), PES could serve as a viable source of funding to improve the management and protection of existing protected areas and to establish new protected areas that provide more equitable benefits to surrounding communities. While existing protected areas are not typically considered high threat areas, and thus do not provide "additionality", research in countries like Madagascar (e.g., Ingram and Dawson, 2005) suggest that many protected areas are failing to prevent deforestation and poaching within their boundaries. Thus, while legally "protected", these areas could benefit substantially from increased management funds and personnel. PES-type programs could be used to generate these types of management funds.

Twenty percent of the places targeted for PES in this paper overlap with areas proposed for sustainable forestry management. The high ecosystem service values found for these areas suggest that the Government of Madagascar and local communities might receive additional economic and social benefits if these areas were conserved through PES or other conservation approaches as opposed to being used strictly for timber management. Finally, in 20% of the areas targeted for PES in this study, we find no overlap with existing or proposed conservation interventions. These are the places where PES could be a viable strategy on their own to protect areas important for biodiversity and additional ecosystem services that have local (water) and global (biodiversity, carbon) value.

As shown by the correspondence between our national targeting and an existing PES project — the Mantadia Project — many of the places highlighted by our analysis could prove conducive to PES schemes on the ground. However, within these targeted areas, it will still be necessary to ground truth these results and add more detailed analysis before a PES project is determined to be the best conservation strategy. This type of local analysis would be important to explore the tradeoffs between the ecosystem services considered in our analysis and others that accrue at the local level (e.g., pollination services). Additionally, the proxies we used for opportunity costs were compiled at the global scale and do not necessarily reflect production activities on the ground. Thus, more detailed information on local conditions is needed to assess the feasibility of using PES in specific areas. With these limitations of the data in mind, this type of national-level spatial targeting should provide a rough proxy within Madagascar of the places where PES could be used as a viable strategy for biodiversity conservation that also provide additional ecosystem service benefits. However, to move forward with conservation and ecosystem service planning in a more rigorous and detailed fashion, more time and money will need to be invested in acquiring national-level data on ecosystem services, the opportunity costs of agriculture, mining and logging, and threats to ecosystem integrity. With better data in hand, this type of targeting methodology could be replicated nationally or at a regional or local scale.

5.2. Implementing PES for successful biodiversity conservation

In addition to identifying spatially where PES is a potential conservation strategy it is also necessary to determine whether the capacity and willingness to implement and monitor these types of programs exists. As the Heredia Declaration emphasizes, some of the conditions needed for the PES approach to be effective include appropriate property rights, policy coherence among institutions, political will, engagement and education of stakeholders, and sustainable funding. We described in Section 2 the political will and policy coherence that exists within Madagascar. In this section we discuss how some of these other issues are impacting and being addressed on the ground in the Mantadia Project, one of the first projects in Madagascar to meet many of the criteria outlined by Wunder (2005) for PES.

A primary concern for implementing the PES strategy in many developing countries is the issue of land tenure (Wendland, 2008). Reviews of the PES approach have warned that without secure property rights "buyers" will be reluctant to join into contracts with land owners, and land owners will not be able to exclude others from accessing their land (Chomitz et al., 1999; Greig-Gran et al., 2005; Pagiola et al., 2005). As the Heredia Declaration states, this does not necessarily mean that ecosystem services must be privatized to be marketed, but that some form of management system must be established that recognizes rights at the individual or communal level. This is particularly important for carbon projects that require the transfer of emission reduction rights to international investors.

In the Mantadia Project, dealing with land tenure and the clarification of property rights has been a challenge. Part of the complexity in the Mantadia case has stemmed from the fact that while most of the land is state-owned (97%), individual and communal claims exist on the other 3%. Implementing forest restoration on this 3% of land is critical to the success of the corridor project, but a lack of formally documented property rights in Madagascar has led to a number of conflicting land claims, making it difficult to sort out who has legal rights. To deal with this issue, the project is leveraging the work of the Program National Foncier[14] (PNF) to establish a "fast track" process to clarify and document land rights of communities or individual farmers in the project area. This involves setting up and funding participatory processes to document and clarify land tenure that resolve conflicting claims equitably. As a result of land tenure complexities, the aggregation of the selling of carbon emission reductions directly through the government actually helped simplify some project activities and reduce transaction costs. However, this centralization of payments created other complexities in that the government must then redistribute project benefits in an equitable and transparent manner to the local communities.

These types of land tenure issues are not just a problem for Madagascar, as many areas important for biodiversity conservation lack formal property rights or the state maintains *de jure* land rights while local people practice *de facto* land rights. For Madagascar, there is some indication that the land tenure system is changing. The PNF, and a land tenure process operating through the Millennium Challenge Account, are both addressing the need to strengthen property rights in the country as a key development objective. In addition, the government's well-established *transfer de gestion* process, which allocates forest management rights to local communities, could potentially be used to negotiate temporary rights to or compensation from ecosystem service projects.[15] Regardless of the

[14] PNF is currently supported by various donors, including the United States' Millennium Challenge Account and the European Union.

[15] In order for this to work, some aspects of this process would need to be modified, particularly to more closely match the long-term stewardship required to address "permanency" requirements of carbon credits and other environmental services with the length of contracts provided by the transfer de gestion process, which are currently short (three years) with an option for renewal of 10 years.

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mechanism, one of the main lessons learned from the Mantadia Project is that clear and secure aggregation of ecosystem service rights must be established as early as possible in project design for individuals and local communities to effectively access global carbon and local PES market incentives.[16] If clear and secure property rights do not exist at the project level, then PES schemes should expect to invest significant time and money in clarifying these issues.

One of the purported advantages of PES over other biodiversity conservation approaches is the potential mutual benefit that can be provided to local people. While the objective of PES is not poverty alleviation, in many areas, PES can bring substantive income and non-income benefits to participants (Pagiola et al., 2005; Wunder, 2005). In the Mantadia Project, the local communities are receiving incentives in the form of sustainable livelihood alternatives to *tavy*, land tenure clarification, and in some cases employment opportunities, for agreeing to protect lands allocated to carbon sequestration and storage (BioCarbon Fund website, 2007). Recognizing that many of the incentives received by local communities in this project are indirect and are not conditional, limiting the ability to rescind on "payments", we first describe these incentives further and their contribution to livelihoods and second, offer insight from other experiences in Madagascar on conditional and direct approaches.

The *tavy-savoka* shifting agricultural cycle, currently the most common land-use activity in the project area, consists of producing rice on hillsides, followed by short fallow cycles to recover lost nutrients. While this may have seemed sustainable at one time, increasing land pressures have decreased the fallow period, leading to low yields, and soil exhaustion and erosion (World Bank, 2003; Gorneflo et al., forthcoming). The Mantadia Project is directly addressing this issue of declining agricultural yields by supporting more sustainable, diversified, and stable food practices, providing technical assistance for enhanced fallows for rice cultivation and agricultural alternatives, and establishing forest and fruit gardens that will be used for income sources, wood products, fuelwood, and food production (BioCarbon Fund website). The success of this sustainable livelihoods component is still to be determined, but it is expected to provide higher agricultural returns than the alternative *tavy* system and avoid many of the long-term environmental problems associated with *tavy*. Additionally, one of the most cited benefits of the project by local communities has been the process of clarifying land tenure. As described above, this process is being both expedited and partially funded by the project, and is essential to project success. In addition to these community-wide benefits, over 200 community members will receive employment opportunities to do forest corridor restoration and maintenance. For these individuals, income benefits are provided, but these employment opportunities are temporary, lasting for an approximate nine to twelve-year planting and maintenance period. However, the silvicultural knowledge being generated on native tree species by the project should benefit future restoration projects throughout the country. Finally, this project is contributing to local capacity building, leading to stronger institutions and social networks; this is helping facilitate the implementation of national- and commune-level development plans in the project area.

Direct and conditional incentives are currently being used in a Conservation International project funded by Fondation Ensemble[17] to reach biodiversity conservation targets in Madagascar. This project, started in 2006, uses conservation incentives in the form of small grants for development projects to "award" winners of community-level competitions to protect biodiversity. All participating communities receive incentives equal to their opportunity costs and the winner receives additional award amounts. While this project does not focus on the provision of ecosystem services in addition to biodiversity conservation, it suggests that direct and conditional incentive structures can work in Madagascar with great success. Other research in Madagascar suggests rice might be an appropriate in-kind payment mechanism (Minten, 2003). Experiences from Mantadia suggest that more research on the types of incentives that are most appropriate for PES projects, and preferred by local communities, would be beneficial, as large monetary transfers can be socially disruptive in communities that lack appropriate institutions and transparency (Wunder, 2007).

A last issue that has been extremely important in the Mantadia Project and that is highlighted in the Heredia Declaration is funding for PES projects. While there are many opinions on who should pay for protecting ecosystem services — from the global community (Farley et al., in this issue) to local beneficiaries (Geoghegan, 2005) — at this point in Madagascar it is very unlikely that local people can or will pay for ecosystem services, even if they are the direct beneficiaries (Carret and Loyer, 2003), so funding will have to come from somewhere else. Currently, carbon financing from international carbon markets holds the largest potential for funding implementation of PES projects in Madagascar. Investments in the regulated and voluntary markets[18] are growing substantially, and Madagascar has already piloted the concept of "Conservation Carbon" projects[19] through the Mantadia Project, attracting millions of dollars in funding commitments for projects that provide climate change mitigation simultaneously with community and biodiversity benefits. The other large "buyers" of ecosystem services at this time are biodiversity conservation organizations and the government — both are already investing significant amounts of money in biodiversity conservation in the country, and some of this money could be used to implement PES projects aimed at protecting biodiversity plus additional ecosystem services. Other potential "buyers" include the tourism industry (Carret and Loyer, 2003), which is directly dependent on biodiversity and scenic beauty, and large, private sector water users. These various funding sources can only be integrated if projects are designed explicitly to spatially bundle multiple ecosystem services such as carbon, water, and biodiversity conservation, as illustrated by our analysis in Section 2.

The ecosystem service payments in the Mantadia Project come primarily from carbon emission reductions. Two key financing issues have arisen: 1) the need for upfront funding to establish the project and 2) that carbon payments do not cover the full 30-year costs of the project. In particular, the Mantadia Project has required tens of thousands of dollars in start-up funding to implement technical analyses for estimating and monitoring carbon benefits to meet strict Kyoto Clean Development Mechanism (CDM) requirements; community engagement activities such as nursery establishment, outreach programs and demonstration plots for the reforestation and agroforestry components; to assist policymakers and local government officials with the technical training and capacity to help implement the PES project; and to negotiate the complex legal and financial arrangements required to create and sell carbon emission reductions, particularly for compliance under the CDM. Payments for ecosystem

[16] Clarification of property rights is still ongoing in the Mantadia Project and the lack of resolution of conflicting claims has impeded the progress of some project components. Thus, the importance of clarifying and recognizing some form of property rights as described in the Heredia Declaration cannot be overstated.

[17] This project is a joint initiative between the government, multilateral institutions, and several non-governmental organizations in the country. For information on this project see: http://www.fondationensemble.org/index.php/fr/programmes/renforcement_des_-communautes_pour_la_protection_de_la_biodiversite.

[18] Some of the other carbon projects in the country are: the Wildlife Conservation Society's project in Makira Protected Area, a Japanese project called Oji Paper Inc Plantation, and a project run by the Swiss Foundation for Development and International Cooperation.

[19] Conservation Carbon projects mitigate the impacts of climate change, as well as protect and restore native habitats, thereby providing multiple benefits, including biodiversity protection, community development, conservation of watersheds, and the restoration of fragmented habitats. For information on Conservation Carbon projects see: http://www.conservation.org/xp/CELB/programs/climate/conservation_carbon.xml.

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services such as carbon emission reductions are often received only after the service is "delivered", therefore up-front financing is required to get a project designed and launched. A second reason that the project has not been able to rely exclusively on carbon payments is that current market prices are relatively low — \$3–\$10 t^{-1} CO_2 — and highly volatile[20]. For these reasons, carbon financing only covers about 30–50% of the total 30-year implementation and transaction costs of the project, requiring the project to develop multiple revenue streams to ensure financial viability.

To overcome these constraints in the Mantadia Project multiple revenue sources are being leveraged. The sale of carbon emission reductions account for a projected 36% of funding; the Government of Madagascar, corporate donations, non-profit organizations, and development assistance are being used to meet the sustainable development goals (24%); and government and non-profit funding is being used for targeted biodiversity activities (15%). Twenty-five percent of the project is still unfunded. Several options exist to meet this project shortfall, including potential revenue from philanthropic sources and additional tourism fees since this region is one of the most visited ecotourism destinations in the country. The lesson from Mantadia is that for most PES projects in Madagascar, and other areas important for biodiversity conservation, to be financially sustainable, additional sources of funding to match the ecosystem service payments will be required. This is because land tenure may need to be clarified, local capacity will have to be strengthened, and upfront costs for establishing the project might exist.

6. Conclusions

In this paper we have laid out a method that those interested in biodiversity conservation can use to target PES projects in areas that protect biodiversity and provide important additional ecosystem services, such as carbon and water. The main objectives of this method are to identify potential sties that are beneficial from a biodiversity conservation perspective and that are cost-effective and efficient from an economic perspective to be considered for PES. As our analysis highlights, PES will not be the right approach for every situation where biodiversity conservation is warranted, or where ecosystem service protection is needed. This is because high levels of congruence between biodiversity targets and marketable ecosystem services might not exist (Chan et al., 2006; Egoh et al., 2007), and because other factors such as threats or opportunity costs might deem the PES strategy ineffective. Additionally, in many situations where PES might be an appropriate approach to biodiversity conservation, the institutional frameworks and in-country capacity to implement these types of projects are still developing (Landell-Mills and Porras, 2002; Jenkins et al., 2004).

In light of these complexities, the type of spatial methodology outlined in this paper represents one type of analysis that biodiversity conservation practitioners could use to conduct preliminary investigations into where PES could be implemented for conservation of biodiversity and ecosystem services. There is, of course, room for improvement and extension of the targeting analysis presented here. At the most basic level, improvements in our knowledge about ecosystem functions and the tradeoffs between services (Kremen and Ostfeld, 2005; Chan et al., 2006; Egoh et al., 2007; Nelson et al., 2008) will help improve this type of targeting mechanism. A second improvement would be to move beyond the focus on existing forests and wetlands and consider where PES could be a viable strategy for biodiversity and additional ecosystem services in degraded and deforested landscapes. As these forces continue to wreck havoc on global biodiversity and human livelihoods, PES for restoration and rehabilitation activities in countries where biodiversity priorities exist could provide significant benefits to both biodiversity and people.

Finally, from our brief overview of the Mantadia Project, important challenges and opportunities for implementing PES projects within Madagascar and other countries critical for biodiversity conservation were identified. These included the need for capacity building with local organizations and government agencies, alignment of government institutions for better policy coherence, and clarification of land tenure before securing PES opportunities. These experiences suggest that upfront investments in PES "infrastructure" will be necessary to create the enabling conditions to implement PES successfully; this in turn will increase the funding required to make these schemes work. Challenges aside, there are many factors that suggest that PES for biodiversity conservation can be done successfully both within and outside of Madagascar. Two of the most significant steps that can be taken at the national level include having a country commit itself toward biodiversity and ecosystem service conservation, as was done in Costa Rica in the past and is being done in Madagascar today, and having a country realign institutions and policies to facilitate multiple ecosystem service conservation.

[20] Financial planning for carbon projects must be accomplished in the presence of an unpredictable market price for forestry-based offsets given the special nature of temporary crediting, current exclusion of forestry-based CDM credits from the EU Emissions Trading Scheme, exclusion of crediting emissions from avoided deforestation, and the unclear future for the Post-2012 Kyoto Protocol regime.

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