ENVIRONMENTAL SCIENCE & POLICY 14 (2011) 697–708

available at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/envsci

Wildlife conservation and reduced emissions from deforestation in a case study of Nantu National Park, Sulawesi
1. The effectiveness of forest protection—many measures, one goal

Ewan A. Macdonald [a,c,*], *Murray Collins* [b,c], *Paul J. Johnson* [c], *Lynn M. Clayton* [c], *Yadvinder Malhi* [a], *Joshua B. Fisher* [a], *E.J. Milner-Gulland* [b], *David W. Macdonald* [c]

[a] *Environmental Change Institute, School of Geography and the Environment, Oxford University Centre for the Environment, South Parks Road, Oxford, OX1 3QY, United Kingdom*
[b] *Department of Life Sciences, Imperial College London, Silwood Park Campus, Buckhurst Road, Ascot, Berkshire, SL5 7PY, United Kingdom*
[c] *Wildlife Conservation Research Unit, Department of Zoology, University of Oxford, The Recanati-Kaplan Centre, House, Abingdon Road, Tubney, Abingdon, OX13 5QL, United Kingdom*

ARTICLE INFO

Published on line 3 April 2011

Keywords:
Protected area
Sulawesi
REDD
Wildlife conservation
Measures of success

ABSTRACT

Discussions on how to reduce carbon emissions from deforestation and degradation have prompted scrutiny of methods for measuring rates of forest loss, as well as discussion of the role of protected area (PA) status in reducing tropical deforestation. This study employs a range of techniques including GIS analyses and local stakeholder interviews to examine the effectiveness of three comparable PAs in Sulawesi, Indonesia in preventing deforestation over a 16-year period. Our analyses demonstrate that all three of the protected areas have proved effective at conferring forest protection to some extent, after controlling for other factors that influence deforestation rates. However Nantu Nature Reserve, the only recipient of broad-based conservation investment, proved to be substantially more effective than the PAs without international investment. In contrast with the recent hopes for integrating conservation with development, interviews with local stakeholders revealed that despite community development projects, the primary contributor to conservation had been the presence of a team of armed park guards. Despite the potentially divisive nature of this situation the villagers recognised the benefits of the forest and looked forward to a time when protectionism might be less necessary and instead villagers would be motivated primarily by the benefits rather than the costs of conservation. The use of remotely sensed data to evaluate conservation effectiveness in this data-poor region has challenges, but we demonstrate that, with the addition of contextualising data from locally based social surveys, it is possible both to quantify the additionality of individual PAs in preventing deforestation, after controlling for other factors, and to understand the reasons behind this success. This type of study will become increasingly necessary as REDD (reducing emissions from deforestation and degradation) implementation progresses.

* *Corresponding author at*: Environmental Change Institute, School of Geography and the Environment, Oxford University Centre for the Environment, South Parks Road, Oxford, OX1 3QY, United Kingdom.
E-mail address: ewan.macdonald@ouce.ox.ac.uk (E.A. Macdonald).

1462-9011/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.envsci.2011.03.001

1. Introduction

Tropical forest conservation programmes are difficult to fund and implement and their efficacy is hard to evaluate. There is interest in funding forest conservation to provide climate services, for example through reduced emissions from deforestation and degradation (REDD; Kremen et al., 2000; Ebeling and Yasué, 2008; Collins et al., 2011). It is yet to be decided how REDD will be implemented, but under potential proposals for a payments for ecosystem services (PES) like approach, payments to service providers would be contingent on demonstrable service provision (Wunder, 2007). Transparent, verifiable demonstration of conservation outcomes has often been neglected or imprecise (Ferraro and Pattanayak, 2006), with few convincing examples (Walker et al., 2008; Linkie et al., 2010; Andam et al., 2008). This is partly because the task of demonstrating success is difficult and available methods are unrefined (Ferraro and Pattanayak, 2006; McDonald-Madden et al., 2009). However, funds are scarce, so it is essential to demonstrate to those investing in conservation that an intervention is effective.

No single metric covers all facets of conservation performance (McDonald-Madden et al., 2009), and inflexible adherence to any one metric is likely to risk short-sighted judgments (Mace et al., 2007). Nonetheless, when a project's original objectives are explicit, success can be measured against these. Stem et al. (2005) review methodologies for evaluating project success. Detailed case-by-case assessments probe important strengths and weakness of a project, acknowledging realities on the ground.

The problems of evaluating and quantifying success apply to any conservation project. However, some cases offer more scope than most for disentangling the relevant factors. Here, we evaluate the conservation success of the Nantu Nature Reserve (Nantu) in Gorontalo, Indonesia; a particularly revealing case study for six reasons. First, the general and specific purposes of this protected area (PA) are clear: to protect pristine rainforest and, within it, an emblematic, endemic large mammal – the Babirusa (*Babyrousa celebensis*; Clayton and Macdonald, 1999). Second, the threats to these purposes are well defined, with Nantu suffering from hunting, illegal logging and agricultural encroachment (Clayton et al., 1997; Clayton et al., 2000). Third, Nantu has an unusually well documented conservation intervention and investment history. Fourth, there are two other parks nearby, with similar habitat and protected area status, but which have either not benefitted from international funding (Panua Nature Reserve gazetted in 1984) or not to the same extent (Bogani-Nani Wartabone National Park gazetted in 1991); comparing them provides a quasi-experiment to reveal the effectiveness of the investment in Nantu. Fifth, diverse conservation interventions have been undertaken at Nantu enabling evaluation of the efficacy of each. Sixth, conservation success at Nantu provides a test case for evaluating the applicability of REDD to protected forests. Therefore, Nantu offers an unusual opportunity (a) to evaluate the effectiveness of forest protection, and various approaches to it (the topic of this paper) and (b) to set this evaluation in the context of payments for ecosystem services such as REDD (see sister paper, Collins et al., 2011).

Here, we investigate the conservation actions taken at Nantu, asking:

(a) Has Nantu been successful at providing additional forest conservation in comparison with two nearby protected areas?
(b) Which of the conservation interventions at Nantu contribute most to project success, in the eyes of local stakeholders?

In particular, we address two issues vital to the potential for REDD; how best to measure additionality regionally (that conservation actions have provided additional benefits compared to a business as usual scenario), and which local-level mechanisms most effectively promote forest conservation. This leads into our linked analysis of the institutional feasibility of operating a REDD scheme in Nantu (Collins et al., 2011).

1.1. Study site

Nantu is located in the Paguyaman forest of Gorontalo Province, northern Sulawesi (0°46′N 120°16′E) (Fig. 1). Sulawesi belongs to the Wallacea 'conservation hotspot'; 57% of mammal and 40% of bird species are endemic (CI, 2010). Nantu was gazetted as a 31,215 ha nature reserve in 1999 and expanded to 52,000 ha in 2004 by the Gorontalonese govern-

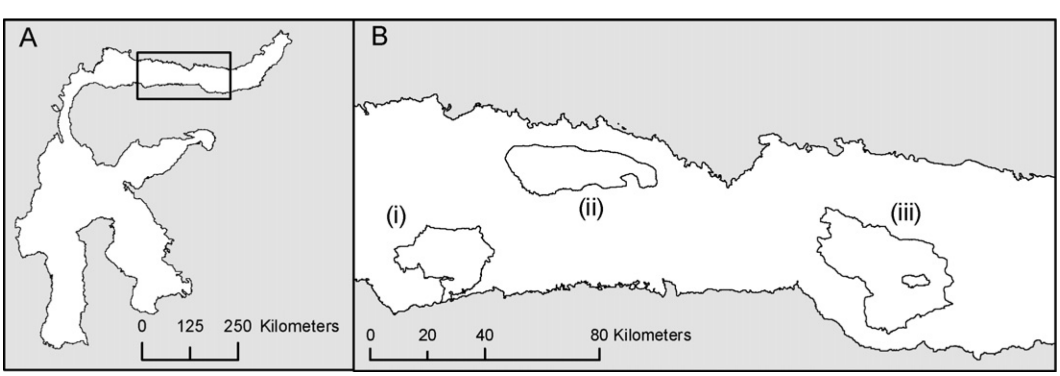

Fig. 1 – Map of the study area showing Sulawesi and the locations of the protected areas. The PAs are: (i) Panua Nature Reserve, (ii) Nantu Nature Reserve and (iii) Bogani Nani Wartabone National Park.

ment, although this is yet to be ratified by the National Government. It is one of few pristine forests in Indonesia, a last stronghold globally of the Babirusa, a wild pig listed as 'Vulnerable' on the IUCN Red List (IUCN, 2009; Clayton and Macdonald, 1999; Clayton and Milner-Gulland, 1999). Other endangered endemics include lowland anoa (*Bubalus depressicornis*), crested black macaques (*Macaca nigra*), red-knobbed hornbills (*Aceros cassidix*) and maleo birds (*Macrocephalon maleo*). The Adudu salt lick makes Nantu unique; it is the only remaining site where babirusa congregations can be observed.

There are five villages immediately on Nantu's boundary, we visited the three of these villages along the southern border: Pangahu, Saritani, and Mohiyolo. These three villages have a combined population of 9700 inhabitants, and a further 25,000 people live downstream in the Paguyaman River watershed. In Saritani and Pangahu the primary agricultural activity is rice cultivation; in Mohiyolo, sugar cane production. Sixty percent of the Gorontalese population depend on fishing, dry-land agriculture and small plantations, and collect timber and non-timber forest products (NTFPs) such as rattan, fruits and wild meat (Kartikasari et al., 2009).

The threats to the Paguyaman forest, including Nantu, have been well documented and include farmland encroachment; illegal logging and mining; NTFP collection and wildlife poaching (Clayton, 1996; Clayton et al., 1997, 2000) all of which are still a concern (LMC personal observation).Nantu has benefitted from three Darwin Initiative grants (1996–2000, 2000–2003 and 2004–2007). This funding and the resulting presence of a conservation researcher (LMC) enabled the project to integrate conservation and development aims by carrying out diverse activities including environmental education, alternative livelihoods provision, community development, forest protection and research (reports available from www.darwin.defra.gov.uk). Specifically 7000 teak and 16,000 cocoa seedlings were provided for villagers; 4 local undergraduate and 3 postgraduate university students from Gorontalo were sponsored to study; local schools were provided with materials. Three students were funded through primary school two of which had now progressed to secondary school, whereas the third had dropped out. The Nantu Protection Unit (NPU) was created and comprises four militarised police (BRIMOB—an acronym of "Brigade Mobil", a division of the Indonesian police force) complemented by four unarmed members of Nantu Initiative staff. NPU patrols the forest in teams of four (two BRIMOB and two project staff) five times weekly.

Of two other protected areas in the province, Panua had received no international funding, whereas Bogani had been the site of a Wildlife Conservation Society project focussing on the conservation of Maleo nesting grounds, and reduction in wildlife trade (Gorog et al., 2005). Neither had received the prolonged, broad based investment in forest protection as at Nantu.

2. Methods

Our approach involved:

(1) Evaluating the additionality of forest conservation with respect to forest cover for each of the three protected areas using remote sensing (RS) and geographic information systems (GIS) analysis, as recommended by the GOFC-GOLD sourcebook (2009).
(2) Evaluating wider measures of success of the interventions at Nantu, using (i) interviews with local stakeholders and (ii) our own observations.
(3) Assessing which activities were perceived as primary drivers of conservation by local stakeholders.

2.1. Assessment of Nantu's additionality with respect to forest cover

Medium resolution remotely sensed images (Landsat and SPOT) were obtained for each of the three parks in the years 1991 and 2007, and classified into four land use classes; 'no data' (areas outside the study area or obscured by cloud), 'forest', 'not forest' and 'unclassified' (clusters that were spectrally indistinguishable between forest and not forest; Fig. 2). Full details of the images used and the pixel classification protocols are detailed in Macdonald (2008). The high levels of cloud cover in some of these images highlights the difficulties of research in such remote but important areas for which it was not possible to obtain high resolution images for use in ground truthing.

We created land use change maps classifying each pixel according to its status in 1991 and 2007: 'forest–forest', 'forest–not forest' and 'not forest–not forest' for each study area from 1991 to 2007 (Fig. 3). Since our aim was to assess the efficacy of forest conservation we excluded the possibility of regeneration; i.e. if a cell was classified as 'not forest' became 'forest' in a later image we treated it as 'not forest' throughout, as there was insufficient time for regeneration for return to primary habitat. Unclassified and No Data areas (6% (Nantu), 26% (Panua) and 63% (Bogani) of the pixels) were excluded from further analysis. The high percentage of excluded cells at Bogani means that we interpret results for this PA cautiously.

We next considered factors hypothesised to influence deforestation rates in a given pixel (Table 1). These factors included topography (slope and elevation derived from Jarvis et al., 2006), access (Euclidean distances from the nearest road and river), population (proxied by Euclidean distance to nearest village) and distance to park boundary. All feature data were manually digitised from paper maps provided by Gorontalo University. Our main hypothesis is that the Nantu conservation intervention led to additional protection over and above the effect of these environmental factors.

Statistical analyses were undertaken to establish whether (1) the protected area status of a pixel had a significant effect on the rate of deforestation when controlling for other factors and (2) whether conservation interventions at Nantu were additional after controlling for other factors.

It is likely that there is co-variation between the variables hypothesised to affect land use change. To summarise this pattern, 5000 pixels were randomly sampled from each of the pixel classes. A Principal Components Analysis (PCA) was then performed based on the environmental variables in Table 1, excluding the variables linked to our hypotheses ("park" and "conservation intervention").

The first two factors explained 37.7% and 22.9% of the variance, respectively (Table 1). Factor 1 appears to be a

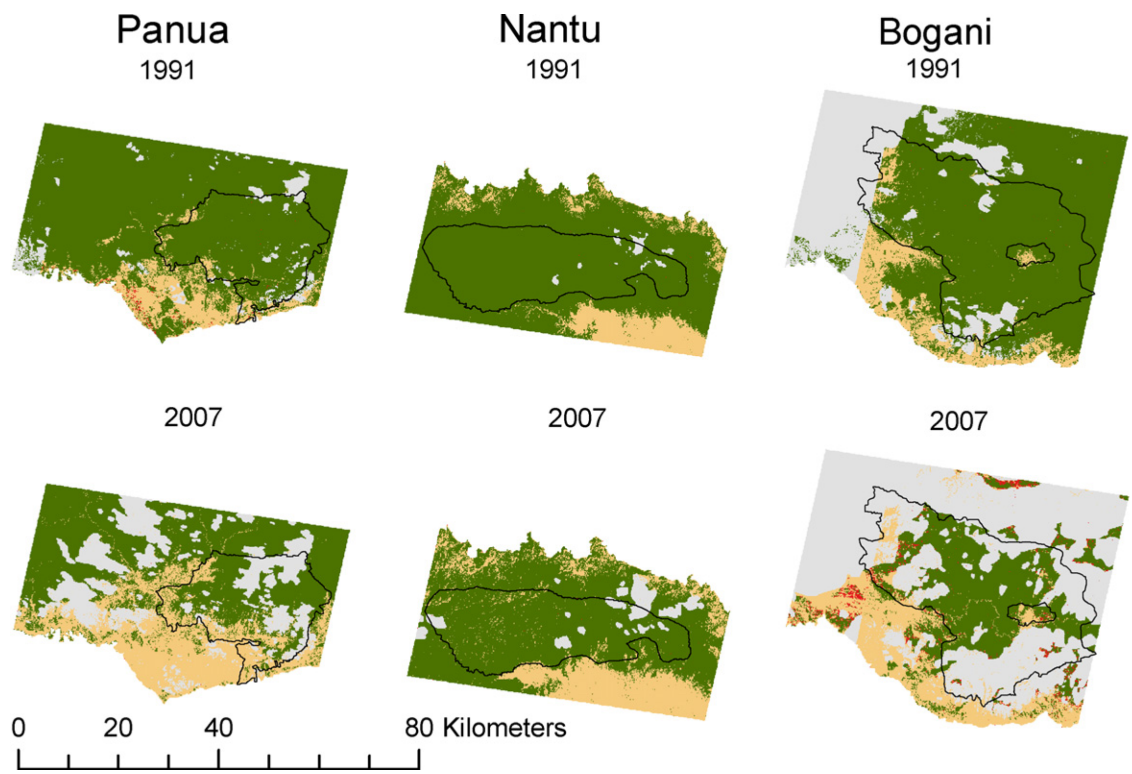

Fig. 2 – Maps of land cover for each of the three protected areas for 1991 and 2007. Green: forest, sandy: not forest, red: unclassified, grey: no data (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.).

function of remoteness (strong positive correlations with distance from nearest village, altitude of the terrain, slope of the terrain, distance from the nearest road). Factor 2 could be a function of protection since it has a strong positive correlation with distance from the park. These two factors were used as predictor variables in subsequent analyses.

2.1.1. *Effect of protected area status on deforestation*

First, we considered all three parks together to ask whether protected status in itself affected the rate of deforestation. We analysed a random sample of 5000 pixels from each land change class, reflecting changes between 1991 and 2007 ['forest–forest' (F–F), 'forest–not forest' (F–NF) and 'not forest–not forest' (NF–NF); Supplementary Material 1] in order to reduce the effect of spatial autocorrelation between pixels.

A multinomial logistic regression (MLR) was used to test the effect of protection status on pixel type (a categorical response variable with levels F–F, F–NF, NF–NF). The output of this produced two binomial functions. The first modelled the effect of our predictors on the probability of a pixel being NF–NF compared with F–F, the second modelled their effect on the likelihood of F–NF compared with F–F. The predictors were

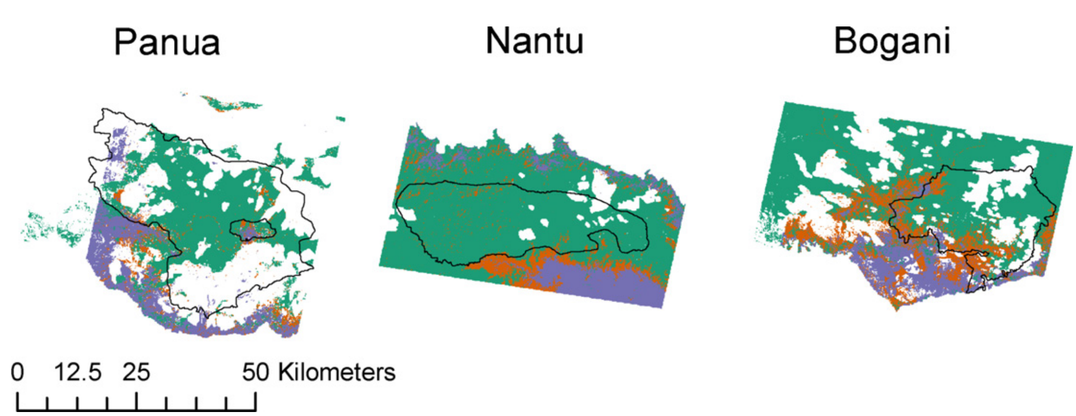

Fig. 3 – Maps of Land use change from 1991 to 2007 for each of the 3 protected areas. Areas of forest–forest are shown in green, areas of not forest–not forest are shown in purple, areas of forest–not forest in orange (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.).

Table 1 – Potential variables that might affect deforestation rates. Factor patterns derived from the principal components analysis are included to show the contribution of each of the continuous environmental variables to the Variance. Factor 1 explained 37.7% of the variance while Factor 2 explained 22.9%. Bold values show those variables that had a strong correlation with each factor.

Type	Name	Description	Factor 1	Factor 2
Topography	Slope	Slope of terrain	**0.57**	−0.46
	DEM	Altitude of terrain (Range: sea level −2856 m)	**0.77**	−0.44
Access	Roaddist	Distance from nearest road	**0.74**	0.45
	Riverdist	Distance from nearest river	−0.21	−0.37
Population	Vildist	Distance from nearest village	**0.87**	−0.32
Distance from park boundary	Parkdist	Distance from park boundary (areas within the park have negative values while areas outside the park have positive values)	−0.12	**0.72**
Protection status	Park	Protected or unprotected	NA	NA
Conservation intervention	Park Name	Proxied by the categorical variable of Park name; only Nantu had received relevant international conservation investment over the study period.	NA	NA

PCA factors 1 (continuous) and status (categorical with levels 'protected' and 'unprotected'). Factor 2 was not used in this analysis as it was strongly correlated with protection status.

2.1.2. *Is Nantu additional?*

To test whether the conservation investment at Nantu had provided any additional protection compared to the other parks, we performed a further MLR excluding all non-protected areas. We took a random sample of 5000 pixels from each land use change class within the protected areas (Supplementary Material 1), and tested the effect of PCA Factors 1 and 2 and park identity (a categorical variable) on the change in land use class from 1991 to 2007. We included distance from park boundary in a further analysis as a continuous predictor (omitting Factor 2), to test if the effect of distance from boundary differed from that of Factor 2.

The statistical analyses were all performed using SAS statistical software (SAS, 1997). In both cases the MLRs were carried out using the CATMOD tool which fits one function fewer than the number of response classes. Model fit was assessed by comparing the model predictions for each pixel with their 'real' values. The predicted values were derived by combining the output probabilities from the two functions comprising each model. The predicted value was deemed to be that with the highest predicted probability of the three pixel types. As the prior probabilities for each type were equal because each class type had the same sample size, model performance was assessed against the null expectation of 33.3%.

2.2. *Evaluation of Nantu's conservation activities from a local perspective*

2.2.1. *Desk-based analysis of reports to funders*

We examined project reports written during the three Darwin Initiative grants (DI; 1996, 2000, 2004). Each was managed locally by LMC, who had been conducting research and conservation at Nantu continuously since 1992 (Clayton, 1996). We condensed the report text into tabulated information detailing project spending, activities and outputs, in order to extract the main conservation activities that had taken place at the PA over the 16 year study period (Macdonald, 2008).

2.2.2. *Interviews with targets of project interventions*

We contextualised the remotely sensed study with field observations of forest status and the local situation at each of the three PAs. As we wished to establish how conservation activities at Nantu may have led to any additionality, as quantified in the GIS study, we conducted interviews with local stakeholders in and around the PA, to explore local perceptions of conservation activities. Interviews were not conducted at the other PAs as they had no comparable conservation interventions.

Fieldwork at Nantu was conducted in June–July 2008, and involved observations of the status of the forest inside and around Nantu's border, and interviews with local villagers and the Nantu Initiative team. In Saritani, Pangahu, and Mohiyolo we conducted semi-structured interviews with 23 focal individuals, each of whom was joined by, and consulted, a group of family members and neighbours, so that the views expressed was tantamount to the consensus of a focus group. In small rural communities, it is hard to be sure what selection process would constitute a random sample of opinion. Indonesian society is focussed upon seniority and status (P. Jepson personal communication). We therefore sought relevant key informants including village heads and their deputies, schoolteachers, administrators, farmers and landowners to act as the principal respondent within the groups. Although only one principal respondent was involved in each interview as a spokesperson for each group, local familial and cultural circumstances meant that his or her answers generally represented the consensus of other family members or companions. Thus, the opinions recorded represent the non-independent views of about 100 people, approximately 1% of the local population.

A list of questions and topics was prepared beforehand. Discussions were led by MC (an Indonesian speaker) assisted by Pak Rahmad Biki (a Natural Resource Conservation Unit

(KSDA) ranger) who translated into local Bahasa Gorontalo where necessary. Questions were intended to reveal the impact on the recipients of various conservation activities. We asked villagers which activities they had been involved in, and ascertained their attitudes towards the park. Interviews were intended to generate conversation anchored around key topics. Where interviewees had received assistance with alternative livelihoods, conversations were extended around a further 10 questions intended to explore the outcome (questions outlined in Macdonald, 2008).

Interview transcripts were condensed into numerical summaries detailing the proportion of participants whose responses were broadly positive or negative with respect to each question. These summaries were integrated with the perceptions captured in our qualitative notes to produce interpreted vignettes regarding each issue.

We also accompanied the Nantu Protection Unit on patrol, which enabled us informally to discuss their opinions on the situation at Nantu.

2.3. *Assessment of the relative contribution of different project activities to additionality at Nantu*

We evaluated the relative effectiveness of different components of the Nantu conservation intervention using stakeholder interviews. A full cost-benefit analysis using quantifiable indicators was neither possible, given the information available, nor desirable, insofar as it would not have captured the nuances of stakeholder perceptions. Hence we asked open-ended, semi-structured questions to local stakeholder groups, aiming to reveal the catalyst for any changes in their behaviour towards the park. These questions were part of the interviews described above. We also interviewed members of BRIMOB, local members of the project staff and Mr. Rahmed Biki (KSDA), to gain alternative perspectives on the reasons for behavioural change.

3. Results

3.1. *Assessment of additionality with respect to Nantu's forest cover*

Between the years 1991 and 2007, 2.57% of the land classified as 'forest' in Nantu was converted to 'not forest'. For the same period Bogani-Nani Wartabone lost 3.22% and Panua lost 15.74% of their 'forest' (Table 2). Rates of deforestation were 6.54 times higher outside the park than inside at Nantu and 1.97 times higher outside at Bogani-Nani Wartabone. At Panua rates of deforestation were 1.12 times higher inside the park than outside. These results need to be interpreted with caution for Bogani, where cloud cover was a particular issue.

3.1.1. *Multinomial logistic regressions*

The probability of a cell being deforested (NF–NF) compared with remaining forested (F–F) was significantly lower for the protected areas than surrounding areas, having controlled for covariates (Table 3). Protected areas were also significantly less likely to become deforested during the study period compared with unprotected areas. This result was to be

Table 2 – Results of the image classification showing the percentage of cells assigned to each class for each of the areas. Average annual rate of forest loss was calculated for each PA by dividing the "% 1991 forest converted to not forest by 2007" by the number of years between the images.

	Nantu Nature Reserve		Nantu surrounding area		Bogani-Nani Wartabone National Park		Bogani-Nani Wartabone surrounding area		Panua Nature Reserve		Panua surrounding area	
	1991	2007	1991	2007	1991	2007	1991	2007	1991	2007	1991	2007
%Deforested	0.01	2.93	22.54	36.1	5.02	9.33	12.27	21.67	5.17	23.59	13.68	29.89
%Forested	97.94	90.53	76.83	59.14	82.76	43.93	51.19	10.85	88.92	49.21	80.42	48.05
%No data	2.04	6.52	0.62	4.74	12.18	45.24	36.51	65.28	5.81	27.16	5.49	22.02
% Unclassified	0.01	0.02	0.02	0.03	0.04	1.51	0.03	2.19	0.1	0.05	0.41	0.03
% 1991 Forest converted to Not Forest by 2007	2.57		16.82		3.22		6.36		15.74		14.08	
Average annual rate of forest loss 1991 → 2007	0.16		1.05		0.2		0.4		0.98		0.88	
Ratio of forest loss outside:inside	6.54				1.97				0.89			

Table 3 – The results of the 3 MLRs used in this analysis. *Note*: **In all models the first function refers to the likelihood of a cell being classified as 'not forest–not forest' (NF–NF) compared to the reference class ('forest–forest'; F–F), and the second function refers to the likelihood of a cell being classified as 'forest–not forest' (F–NF) compared to the reference class (F–F). Hence positive values imply a greater likelihood of remaining forested, compared to either not being forested throughout, or becoming deforested during the period 1991–2007.**

Parameter		Function	Estimate	Standard error	Chi-square	Pr ChiSq	Odds ratio (confidence interval)
Analysis 1: Effect of protected area status on forest cover/deforestation							
Factor 1		NF–NF	−2.3890	0.0433	3038.30	<0.0001	
		F–NF	−1.5814	0.0345	2097.70	<0.0001	
Status	Park	NF–NF	−0.4608	0.0312	217.41	<0.0001	0.63 (0.60:0.67)
	Park	F–NF	−0.1643	0.0257	40.97	<0.0001	0.85 (0.80:0.90)
Analysis 2: Is Nantu additional?							
Factor 1		NF–NF	−1.6151	0.0351	2117.66	<0.0001	
		F–NF	−1.0655	0.0299	1273.38	<0.0001	
Factor 2		NF–NF	0.3584	0.0284	159.06	<0.0001	
		F–NF	0.2708	0.0252	115.41	<0.0001	
Park Name	Bogani	NF–NF	2.7217	0.1401	377.23	<0.0001	8.76 (6.66:11.72)
	Bogani	F–NF	0.0936	0.0363	6.65	0.0099	1.10 (1.02:1.19)
	Panua	NF–NF	0.6394	0.1432	19.93	<0.0001	1.88 (1.43:2.47)
	Panua	F–NF	0.3764	0.0407	85.69	<0.0001	1.46 (1.35:1.58)
Analysis 3: Does the effect of park depend on distance to the park boundary?							
Factor 1		NF–NF	−1.1545	0.0363	1010.16	<0.0001	
		F–NF	−0.8788	0.0345	649.28	<0.0001	
Parkdist		NF–NF	0.000409	0.000064	41.37	<0.0001	
		F–NF	0.000186	0.000015	153.89	<0.0001	
Park Name	Bogani	NF–NF	2.8597	0.2298	154.81	<0.0001	
	Bogani	F–NF	0.0665	0.0636	1.09	0.2957	
	Panua	NF–NF	1.8433	0.2340	62.04	<0.0001	
	Panua	F–NF	0.7899	0.0692	130.34	<0.0001	
Parkdist × Park Name	Bogani	NF–NF	3.165E−6	0.000064	0.00	0.9608	
	Bogani	F–NF	0.000021	0.000018	1.37	0.2417	
	Panua	NF–NF	0.000558	0.000068	66.36	<0.0001	
	Panua	F–NF	0.000093	0.000019	23.24	<0.0001	

Analysis 1: The variable 'Park' indicates the protected status of the pixel, with unprotected as the reference category. Factor 1 proxies remoteness, Factor 2 proxies protection status. *Analysis 2*: Nantu is the reference category, hence positive values suggest a higher probability of either remaining or becoming deforested in the other locations compared to Nantu. *Analysis 3*: Factor 2 is replaced by Parkdist, a measure of distance from park boundary. A positive value implies that the closer to the boundary the pixel is (within the park), the more likely it is to be, or become, deforested.

expected insofar as reserves were sited in pristine areas, however it also shows that when considered together, the three parks provided more protection against deforestation than was typical for sites of comparable remoteness and topography.

The second MLR used only pixels within the PAs to test for additionality of Nantu's conservation activities (Table 3). Both 'F–F' and 'F–NF' pixels were significantly more likely to occur than 'NF–NF' as Factor 2 increased. Since Factor 2 is primarily a function of distance from the park boundary, this implies that already deforested areas are more prevalent near the park boundary. Both Bogani and Panua were significantly more likely to contain non-forested cells than was Nantu. Forested cells in both Bogani and Panua were significantly more likely than Nantu to have become deforested during the study period [Odds ratios: Bogani 1.10 (1.02:1.19). Panua 1.46 (1.35:1.58)]. These two results together suggest that Panua and Bogani were already more degraded than Nantu before this study began, but that they were also more likely to have become further degraded after protection. Thus, Nantu has been significantly more successful in protecting forest than either of the other two parks, evidence for additionality.

The overall effect of distance from park boundary was explored further by asking if there was any evidence that its effect differed amongst the parks. The interaction between distance and park name was significant ($\chi^2 = 169.74$, $p < 0.0001$) suggesting that the distance effect does differ with park. The likelihood of a cell being unforested was very high near to the park boundary, but tailed off towards the interior of the park in both Bogani and Panua, while it was uniformly low in Nantu (Fig. 4a). The likelihood of a cell becoming deforested fell rapidly with increasing distance inside the park in both Panu and Nantu, however it remained reasonably consistent in Bogani (Fig. 4b).

In all three cases the models produced by the MLRs appeared reliable (Table 4). The models were significantly more likely to predict pixel type correctly than would be expected by chance ($\chi^2 = 86.5$, $p < 0.001$).

3.2. Assessment of success using qualitative approaches

3.2.1. Project goal and vision

The synthesis of project reports revealed an international investment at Nantu of c. £826,658 since 1992, or £808,203 over

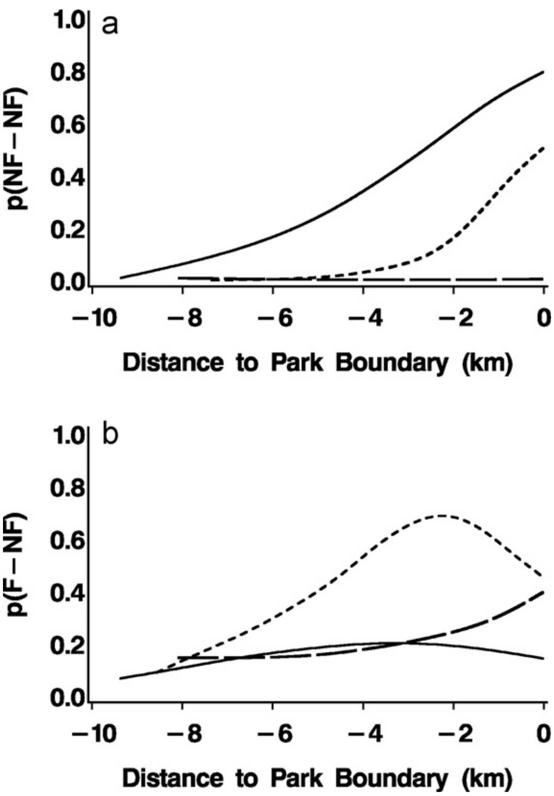

Fig. 4 – Probability plots of deforestation within each of the parks with increasing distance from the park boundary. A value of −10 indicates cells 10 km within the park boundary. Plot (a) shows the probability of a cell being classed as not forest–not forest, while plot (b) shows the probability of a cell being classed as forest–not forest. In both cases the dashed line shows the probabilities for Nantu, the dotted line for Panua and the solid line for Bogani. All lines are smoothed through the predicted probabilities from the model (using the SAS SM option).

Table 4 – Cross tabulation of 'real' land classes observed by the classification and values predicted by each of the multinomial logistic regressions. Percentage values show what proportion of the observed sample (n = 5000) was predicted to belong to each land class. The bold figures show that in each case the models predicted the correct class more frequently than either incorrect class. The null hypothesis is that the predictions should be correct by chance 33% of the time.

Time		Observed land use		
		NF–NF	F–NF	F–F
Land use class predicted	NF–NF	**70.90%**	38.50%	9.54%
by the 1st MLR (Factor 1,	F–NF	22.02%	**42.98%**	15.04%
Factor 2, Park)	F–F	7.08%	18.52%	**75.42%**
		Overall agreement 63.1%		
Land use class predicted	NF–NF	**54.88%**	16.70%	16.06%
by the 2nd MLR (Factor 1,	F–NF	31.30%	**63.38%**	11.46%
Factor 2, Park Name)	F–F	13.82%	19.92%	**72.48%**
		Overall agreement 63.6%		
Land use class predicted	NF–NF	**65.70%**	20.82%	13.40%
by the 3rd MLR (Factor 1,	F–NF	23.36%	**57.36%**	11.38%
Parkdist, Park Name,	F–F	10.94%	21.82%	**75.22%**
Parkdist × Park Name)		Overall agreement 66.1%		

the 12 years spanned by Darwin Initiative funding. The latter represents an average of £67,350 pa, equivalent at the end of 2007 to a cumulative investment over 12 years of £15.54 ha^{-1} then protected (i.e., c. £1.30 ha^{-1} pa^{-1}). The main project activities undertaken over this period were studies of babirusa and poaching, educational outreach, alternative livelihoods and guard patrols (see Macdonald, 2008 for more details).

Neither of the other two protected areas in the province had received long term funding for forest conservation. Bogani had been the site of a Wildlife Conservation Society project focussing on the conservation of Maleo nesting grounds, and reduction in wildlife trade, but Panua had not received any international funding.

3.2.2. *Local perceptions*

3.2.2.1. Information provision. Nantu's proximity and LMC's profile meant all interviewees knew of both the park and its associated projects. 19/23 interview groups had experienced direct contact with the outreach programme. Of these, 16 had received public awareness materials (e.g. posters, stickers, children's books), 10 had participated in public education programmes and 6 received material benefits. Overall, the very high proportion of the community that was aware of, and had had contact with, the project indicated very effective outreach.

3.2.2.2. Perceived benefits and costs of Nantu NR. The extent to which interviewees attributed value to the park, on a five point scale from not at all to very greatly, was extremely high, with 17/23 interview groups valuing the reserve either greatly or very greatly.

Opinion amongst interviewees was consistent as to the reasons why the protected area was valuable. 16 groups cited watershed protection and 10 cited soil fertility as being of major importance, 17 mentioning one or other of these indirect values. Additionally, two interview groups mentioned species protection (one citing babirusa) and one each mentioned the educational and aesthetic value of the forest.

Eleven groups also cited disbenefits to the creation of Nantu; 7 claiming loss of forest products as a source of livelihoods, and 4 citing crop-raiding by pigs and or monkeys. One mentioned fear of BRIMOB.

3.2.2.3. Nantu's role in livelihoods. Interviewees were asked about their current use of the forest (now that it is protected) and their former use of it during the previous 10 years (prior to protection). The spokespeople for 16 interview groups stated that they did not currently use Nantu (a further participant implied the same), and four of the six who claimed to still use the forest did so for educational or aesthetic purposes. Of the remaining two who indicated that they still used Nantu, one collected flowers and the other collected firewood and timber. Insofar as these responses accurately reflect reality, it appears that the protected area is little used. The situation was clearly different formerly; members of 10 groups stated that they had made direct use of Nantu's forest before it was protected, of whom 8 extracted rattan, timber or firewood (other former activities included an instance each of fishing and gold panning).

Members of four groups had been recipients of cocoa and/or teak seedlings from the Darwin Initiative alternative livelihoods programme, all but one of whom reported that they had lost seedlings to ‘‘worms or caterpillars’’ (*ulat-ulat*). Only one of the respondents had so far achieved a harvest (of cocoa) with the others not expecting yields for another 2–6 years. Members of all interview groups felt that they would have liked more follow-up help from the project, particularly pesticides and fertiliser.

3.3. Assessment of the relative contribution of different project activities to success

Interview groups were asked which measures had contributed most to protecting the forest hitherto. They were then asked which of these same measures might be most important in the future. Twenty-one groups offered an opinion (Table 5).

The majority (18/21) of spokespeople viewed enforcement as having been paramount for the past conservation of Nantu. BRIMOB was widely perceived as the most important activity (15/21 groups), with boundary demarcation and prosecution of illegal loggers also important. In one case people mentioned fear of BRIMOB and one respondent referred to an instance of conflict between the guards and local inhabitants sparked by confusion over the location of Nantu’s boundary.

Looking to the future, BRIMOB were still seen as important, although people attributed less importance to policing in the future, hoping that improved education, community involvement and increasing clarity over Nantu’s borders would render BRIMOB less necessary.

Several people thought the future protection of Nantu rested on poverty alleviation, and while there was some discussion of alternative livelihoods, spokespeople of at least four groups alluded to the desirability of payments for not using the forest. There was a general feeling that local people and local government had to get more involved in conservation. One spokesman argued that money spent on BRIMOB should be given to local people who would then guard the forest.

Table 5 – Perspectives of local stakeholder groups on the factors which currently contributed to forest conservation, and the factors they anticipated would become important in the future.

Conservation strategy	Present	Future
BRIMOB must be in the forest to catch illegal loggers	15	8
Publicising conservation in the local area	0	6
Educating local school children about the importance of the forest	2	4
Including local communities in decisions about management of the nature reserve through stakeholder forums.	0	5
Educating local forest users about the importance of the forest	2	3
Marking the Forest Boundaries	3	1
Prosecuting people found breaking the forest laws	2	0
Providing Teak seedlings to local communities	0	1

A recurrent theme was that people living near Nantu, who had formerly exploited the forest, should be compensated for their loss of access. Despite enthusiasm for alternative livelihoods, a prevailing undercurrent was for direct forms of compensation: one villager proposed an ‘unlike’ swap, through provision of a doctor or running an English course, in compensation for lost forest access.

Another recurrent theme was that damage to the forest was done by people other than residents of the respondent’s village. In particular, the teacher at Saritani voiced the widely held view that Mohiyolo’s residents were the culprits. A single interviewee, a schoolteacher from Mohiyolo, suggested that Nantu might be used for ecotourism.

3.3.1. *Alternative livelihoods*

Despite being a beneficiary of the alternative livelihoods scheme, one respondent recorded frustration at needing building materials while living alongside so much prohibited timber. Similarly, another interviewee observed that ‘‘if you live by the sea you take fish, if you live by a forest you take timber’’. Thus, they perceived living beside a protected forest as difficult.

Pangahu’s headman expected that the seedlings he received would be valuable in the future, however he explained that he had had to borrow significant funds to buy the tools and equipment required to tend the teak seedlings provided. He stated that alternative livelihoods were important since BRIMOB kept people out of the forest, though he emphasised the widely expressed view that ‘‘Miss Lynn doesn’t own the forest, it is for the people’’.

All beneficiaries of alternative livelihoods thought the schemes could be extended; one respondent suggested there could be schemes for rice, and corn, another suggested coconuts, coffee and cloves, and a third maize seeds.

Problems with the alternative livelihoods scheme included the opinion that the investment return on teak was longer than anticipated (estimated at 5 years—one interview groups stated 15 years was more realistic). One group mentioned the average family’s need for wood, and explained that if it could not come from Nantu, it must be provided from elsewhere, suggesting that Nantu’s conservation activities may be causing leakage.

3.3.2. *Views of other stakeholders*

Members of BRIMOB said that they were essential to, but insufficient for, forest protection, which required local people’s compliance. BRIMOB judged that the local community was not scared of them, but highly respectful.

The members of the Nantu Initiative staff who worked with BRIMOB in the NPU held the opinion that the only people transgressing Nantu’s boundaries were local Gorontalese rather than transmigrants. Historically, local people used the forest for hunting, but began progressively to harvest timber and rattan. BRIMOB believed that in the absence of patrols this would resume; they also believed the education programme was important and should be expanded.

Mr. Rahmed Biki of the KSDA also emphasised that education programmes had helped local villagers realise the link between forest protection and watershed and soil conservation. He felt more emphasis should be placed on demonstrating the relative efficacy of conserving forest over paying for flood-damaged property. He believed broadly that Indonesia was alert to links between forest loss and climate change. The idea of using religious leaders to promote forest protection was important. In terms of compensation for lost forest access, his opinion was that it is better to give people appropriate material items rather than cash.

4. Discussion

4.1. *Did the protected areas confer actual protection from deforestation?*

Insofar as the rate of deforestation is a proxy for protected area effectiveness, our results show that, having adjusted for the confounding impact of environmental covariates, cells in any of the protected areas were significantly more likely to keep their forest cover than cells in unprotected areas. These covariates were selected on the basis of their likely influence on deforestation rates, for example topography and access (Geist and Lambin, 2002). Hence the three parks taken together appear to provide significant protection from deforestation.

When considering the three parks separately, our analysis suggests that before the study began, both Bogani-Nani Wartabone and Panua were already more degraded than Nantu. Further, during the course of the study, both Bogani-Nani Wartabone and Panua were significantly more likely to become deforested than Nantu when controlling for plausible confounding factors.

Bogani-Nani Wartabone, the only PA with internationally recognised National Park status, was 10% more likely to have been deforested than Nantu. However, while our analysis was compromised by cloud obscuring 45% of Bogani-Nani Wartabone NR and 65% of its surroundings, visits to Bogani by EAM and MC provided qualitative support for our conclusions.

On-the-ground interviews strongly supported the suggestion that conservation investment has made a crucial difference to the conservation of Nantu, leading to clear additionality over the other PAs. While Lee et al. (2005) confirm that the bushmeat trade poses a major threat to many large mammal species in Northern Sulawesi, the cryptic nature of many of the species makes it difficult to quantify this effect in Nantu. BRIMOB and the Nantu Protection Unit patrol the area regularly and have secured a number of convictions, suggesting that these patrols have limited this threat.

4.2. *Which actions have contributed most to conservation success at Nantu NR?*

In recent decades conservation ideology has swung from protectionism, with nature as a priority, to a focus on the human dimension with well-being as a central goal (Macdonald et al., 2007; Swallow et al., 2009; Sachs et al., 2009). The command-and-control, ecocentric concept faces difficulties regarding injustice to people, hence many conservation projects nowadays aim to give local stakeholders a sense of ownership and thereby an incentive to use nature sustainably. Barrett et al. (2001) argue against a one-size-should-fit-all ideology, and conservation interventions at Nantu have combined diverse approaches. It is clear from the interviewees that the Darwin Initiative projects have been highly successful in raising awareness of the park and of issues such as watershed and soil conservation. On the other hand, although the sample of people experiencing the alternative livelihoods schemes was small, all gave the impression that this was at best only a supplement to their livelihood. Most striking was the close to unanimous importance that people attributed to the armed park patrol. We concluded that not only has BRIMOB been essential to protecting the park, but also that the consensus amongst local people was that such a force had probably been the only realistic way of doing so. Nonetheless, people looked forward, with somewhat muted optimism, to a time when this might be less true. We interpret the views expressed as indicating that people felt that for the foreseeable future active enforcement was essential, but that fairness dictated that local people should be given something in exchange for lost access to the park, and that peoples' minds were turning more towards direct compensatory payments than to alternative livelihoods. A striking conclusion from the study is that community involvement mechanisms may, in practice, need to be integrated with more robust protectionist regulation. The local stakeholders also clearly expressed the importance of LMC's continued on-the-ground presence as a powerful force for conservation, though with reservations about her dominance over their relationship with Nantu. Neither finding chimes harmoniously with some contemporary thinking, which is, with good reason, nervous of exclusion and eager more rapidly to hand over responsibilities from expatriate conservationists to local staff (Waylen et al., 2010).

4.3. *Two key challenges for monitoring deforestation rates*

We explore the use of remote-sensing to monitor deforestation. GOFC-GOLD (2009) makes clear the various awkward assumptions, difficulties of consistency and technical hurdles involved in this monitoring. Two broader considerations emerge from our study, one technical and the other philosophical:

4.3.1. *Detecting degraded land*

GOFC-GOLD (2009) recommends that the coarsest spatial resolution of images to be used for national monitoring should be 30 m $\times$ 30 m pixels. However, in our study this scale was inadequate for detection of degradation (and even Souza et al., 2005 method using the Normalised Difference Vegetation Index cannot quantify degradation in the absence of spatial data on logging roads and log landing sites). Local people were the proximate drivers of deforestation so the majority of damage has been small-scale and artisanal in nature. The reason researchers resort to remote sensing in the first place is because places like Nantu are inaccessibly remote, but this means that people use hard-to-detect techniques when exploiting forest resources, so spatially referenced data on forest degradation are hard to secure.

4.3.2. *Additionality*

Our GIS results suggest that Nantu NR has provided effective protection from deforestation, and our interview results support the hypothesis that this is due to the activities funded by the Darwin Initiative. Insofar as this is an outcome that would otherwise not have happened, one might conclude that it constituted additionality, and thus that the protection of Nantu NR might qualify for REDD investment. However Nantu NR has already been gazetted, so the 'additionality' in this case takes the form of protecting an area the threat to which was already illegal—a variant of double jeopardy; is it appropriate to make payments for not doing something that it is anyway illegal?

Recent trends suggest that Indonesia is losing almost 2 million ha of forest a year (FAO, 2005) a trend that if continued implies that sooner rather than later most Indonesian forest will be degraded or felled, protected or not. If so, then any activity that prevents an area being felled might be considered additional. In that sense the enforcement (as distinct from merely gazetting) of a protected area would seem to capture the spirit and intention of additionality. A dilemma is whether the greater benefit to forest and biodiversity conservation lies in claiming additionality for PAs, thereby tacitly acknowledging gazettement in itself is ineffectual, or in demanding that PAs should be treated as legally sacrosanct.

This paper addresses whether protection of Nantu has been effective, and why. In our study area, protected status does appear to provide additional benefit in reducing the risk of deforestation once inaccessibility has been accounted for, but it is significantly more effective when it is supplemented by conservation action on the ground. An important component of that action at Nantu was law enforcement. These results suggest that Nantu NR, and others like it, are potentially valid recipients of REDD funding. However, this raises general questions as to whether the structures exist to enable REDD to be implemented at Nantu in practice. We tackle that question, and its wider implications, in the sister paper by Collins et al. (2011).

Acknowledgements

We gratefully acknowledge the ongoing support of the UK Darwin Initiative to LMC. EJMG acknowledges the support of a Royal Society Wolfson Research Merit award and DWM acknowledges support of the Starr Foundation. EAM was in receipt of the James Teacher Memorial scholarship, a Climate Care bursary and funding from Panthera. We would like to acknowledge the assistance of the Gorontalo Wildlife Protection Agency (KSDA); Universitas Gorontalo and Pak Irwan Bempah for hosting MC and EAM in Sulawesi; Dr Boedhihartono at Universitas Indonesia for help in arranging institutional visits.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.envsci.2011.03.001.

REFERENCES

Andam, K.S., Ferraro, P.J., Pfaff, A., Sanchez-Azofeifa, G.A., Robalino, J.A., 2008. Measuring the effectiveness of protected area networks in reducing deforestation. Proceedings of the National Academy of Sciences 105, 16089–16094.

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

CI, 2010. Biodiversity Hotspots – Wallacea. http://www.biodiversityhotspots.org/xp/hotspots/wallacea/Pages/default.aspx (accessed 05/08/10).

Clayton, L.M., 1996. Conservation biology of the babirusa in north Sulawesi, Indonesia. Department of Zoology, University of Oxford.

Clayton, L.M., Keeling, M., Milner-Gulland, E.J., 1997. Bringing home the bacon: a spatial model of wild pig hunting in Sulawesi, Indonesia. Ecological Applications 7, 642–652.

Clayton, L.M., Macdonald, D.W., 1999. Social organization of the babirusa (*Babyrousa babyrussa*) and their use of salt licks in Sulawesi, Indonesia. Journal of Mammalogy 80, 1147–1157.

Clayton, L.M., Milner-Gulland, E.J., 1999. The trade in wildlife in North Sulawesi Indonesia. In: Robinson, J.G., Bennett, E.L. (Eds.), Hunting for Sustainability in Tropical Forests. Columbia University Press, New York, pp. 473–496.

Clayton, L.M., Milner-Gulland, E.J., Sinaga, D.W., Mustari, A.H., 2000. Effects of a proposed ex situ conservation program on in situ conservation of the babirusa, an endangered suid. Conservation Biology 14, 382–385.

Collins, M., Macdonald, E.A., Clayton, L.M., Dunggio, I., Macdonald, D.W., Milner-Gulland, E.J., 2011. An Institutional Framework for REDD implementation applied to Indonesia. Environmental Science and Policy, doi:10.1016/j.envsci.2011.03.002.

Darwin Project 05-127 (1996–2000) (PI E.J. Milner-Gulland, Warwick).

Darwin Project 09-012 (2000–2003) (PI E.J. Milner-Gulland, Imperial).

Darwin Project 13-028 (2004–2007) (PI D.W. Macdonald, Oxford).

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

FAO, 2005. Global Forest Resources Assessment.

Ferraro, P.J., Pattanayak, S.K., 2006. Money for nothing? A call for empirical evaluation of biodiversity conservation investments. PLoS Biol 4, e105.

Geist, H.J., Lambin, E.F., 2002. Proximate causes and underlying driving forces of tropical deforestation. BioScience 52, 143–150.

GOFC-GOLD, 2009. A sourcebook of methods and procedures for monitoring and reporting anthropogenic greenhouse gas emissions and removals caused by deforestation, gains and losses of carbon stocks in forests remaining forests, and forestation. GOFC-GOLD Report version COP15-1.

Gorog, A.J, Pamungkas, B., Lee, R.J., 2005. Nesting ground abandonment by the maleo (*Macrocephalon maleo*) in North Sulawesi: identifying conservation priorities for Indonesia's endemic megapode. Biological Conservation 126, 548–555.

IUCN, 2009. IUCN Red List of Threatened Species, Version 2009.1. www.iucnredlist.org downloaded on 01 October 2009.

Jarvis, A., Reuter, H.I., Nelson, A., Guevara, E., 2006. Hole-filled seamless SRTM data V3. International Centre for Tropical Agriculture (CIAT), available from http://www.srtm.csi.cgiar.org.

Kartikasari, S.N., Rixecker, S., Espiner, S.R., Colfer, C.J.P., 2009. Seeing the forest as more than its trees: local stakeholders' perceptions of natural forest benefits in Gorontalo Indonesia. International Journal of Environmental Policy and Decision Making 10, 214–230.

Kremen, C., Niles, J.O., Dalton, M.G., Daily, G.C., Ehrlich, P.R., Fay, J.P., Grewal, D., Guillery, R.P., 2000. Economic incentives for rain forest conservation across scales. Science 288, 1828–1832.

Lee, R., Gorog, A., Dwiyahreni, A., Siwu, S., Riley, J., Alexander, H., 2005. Wildlife trade and implications for law enforcement in Indonesia: a case study from North Sulawesi. Biological Conservation 123, 477–488.
Linkie, M., Rood, E., Smith, R., 2010. Modelling the effectiveness of enforcement strategies for avoiding tropical deforestation in Kerinci Seblat National Park Sumatra. Biodiversity and Conservation 19, 973–984.
Macdonald, D.W., Collins, N.M., Wrangham, R., 2007. Principles, practice and priorities: the quest for 'alignment' In: Macdonald, D.W., Service, K. (Eds.), Key Topics in Conservation Biology. Blackwell Publishing, Oxford, pp. 273–292.
Macdonald, E.A., 2008. Evaluating Measures of Conservation Success: The Case Study of Nantu Nature Reserve, Sulawesi. Environmental Change Institute, OUCE, University of Oxford.
Mace, G.M., Possingham, H.P., Leader-Williams, N., 2007. Prioritising choices in conservation. In: Macdonald, D.W., Service, K. (Eds.), Key Topics in Conservation Biology. Blackwell Publishing, Oxford, pp. 17–34.
McDonald-Madden, E., Gordon, A., Wintle, B.A., Walker, S., Grantham, H., Carvalho, S., Bottrill, M., Joseph, L., Ponce, R., Stewart, R., Possingham, H.P., 2009. Environment "true" conservation progress. Science 323, 43–44.
SAS, 1997. SAS/STAT Software: Changes and Enhancements through release 6.12, Cary, NC: SAS Institute Inc., 1997.
Sachs, J.D., Baillie, J.E.M., Sutherland, W.J., Armsworth, P.R., Ash, N., Beddington, J., Blackburn, T.M., Collen, B., Gardiner, B., Gaston, K.J., Godfray, H.C.J., Green, R.E., Harvey, P.H., House, B., Knapp, S., Kumpel, N.F., Macdonald, D.W., Mace, G.M., Mallet, J., Matthews, A., May, R.M., Petchey, O., Purvis, A., Roe, D., Safi, K., Turner, K., Walpole, M., Watson, R., Jones, K.E., 2009. Biodiversity conservation and the millennium development goals. Science 325, 1502–1503.
Souza, J.C.M., Roberts, D.A., Cochrane, M.A., 2005. Combining spectral and spatial information to map canopy damage from selective logging and forest fires. Remote Sensing of Environment 98, 329–343.
Stem, C., Margoluis, R., Salafsky, N., Brown, M., 2005. Monitoring and evaluation in conservation: a review of trends and approaches. Conservation Biology 19, 295–309.
Swallow, B., Kallesoe, M., Iftikhar, U., Noordwijk, M.v., Bracer, C., Scherr, S., Raju, K.V., Poats, S., Ochieng, B., Mallee, H., Rumley, R., 2009. Compensation and rewards for environmental services in the developing world: framing pan-tropical analysis and comparison. Ecology and Society 14, 26.
Walker, S., Price, R., Stephens, R.T.T., 2008. An index of risk as a measure of biodiversity conservation achieved through land reform. Conservation Biology 22, 48–59.
Waylen, K.A., Fischer, A., Mcgowan, P.J.K., Thirgood, S.J., Milner-Gulland, E.J., 2010. Effect of local cultural context on the success of community-based conservation interventions. Conservation Biology 24, 1119–1129.
Wunder, S., 2007. The efficiency of payments for environmental services in tropical conservation. Conservation Biology 21, 48–58.

Ewan A. Macdonald is a DPhil student at the Environmental Change Institute, University of Oxford and collaborator at WildCRU. He is working on the biodiversity conservation co-benefits of carbon finance mechanisms and other financial mechanisms to deliver conservation of, in particular, big cats. He is a Kaplan Scholar funded by Panthera.

Murray Collins is a NERC-ESRC funded PhD student at the London School of Economics and Political Science, and The Institute of Zoology, ZSL. His research focuses on the role of forests in climate change mitigation and wildlife conservation.

Paul Johnson has been the data analyst for the Wildlife Conservation Research Unit since 1991. He joined the WildCRU after a PhD project on the ecology of a group of aquatic oligochaetes (with the Freshwater Biological Association and Reading University). He is also a retained lecturer in quantitative methods at Pembroke College.

Lynn Clayton studied for her DPhil on babirusa with David Macdonald at the University of Oxford, and she has subsequently been a post doc with both the WildCRU and at Imperial, continuing work for two decades on the conservation of the rainforests of Sulawesi. She established the Nantu Initiative in order to protect the forest home of the Babirusa, and continues to devote herself to this conservation work.

Yadvinder Malhi is Professor of Ecosystem Science at Oxford University, and Director of the Oxford Centre for Tropical Forests supported by the Oxford Martin School. His research focuses on the interactions between tropical forests and the global climate system, including natural processes and the influences of deforestation. He conducts research widely in Amazonia, Africa and Borneo.

Joshua B. Fisher is a scientist at the NASA Jet Propulsion Laboratory, California Institute of Technology. He is an ecosystem modeler and ecologist focusing on biogeochemical cycling.

E.J. Milner-Gulland's research interests concern the interactions between human decision-making and ecological sustainability. Her group website is www.iccs.org.uk.

David W. Macdonald is Professor of Wildlife Conservation at Oxford University, and founding Director there of the Wildlife Conservation Research Unit (www.wildcru.org). His research in S.E. Asia began in 1972, and continues today with a spectrum of projects in Sabah, Kalimantan and China, concerned largely with wild felids, their ecology, guild structure and conservation, with a focus on financial mechanisms to deliver biodiversity conservation.