LETTER

Economic benefits of standing forests in highland areas of Borneo: quantification and policy impacts

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Abstract

There exist thousands of valuation studies for environmental goods and services, but the degree to which these have influenced policy is uncertain, especially in developing countries. Here, we demonstrate that a rapid assessment of the benefits of standing forests in the highlands of Borneo is feasible and can provide useful and timely information for conservation policy decisions. We used existing biophysical and economic information to characterize values associated with forests in areas proposed for oil palm plantation development. We focused on three classes of benefits: avoided damages associated with increased greenhouse gas emissions (carbon storage), avoided damages associated with increased fires, and the economic benefits of forest–agriculture mosaics. Carbon storage values dominated the overall value of standing forests and were of similar magnitude to benefits from oil palm plantations. Other values were smaller but nevertheless important to different stakeholder groups. We document how the results were used to influence the Indonesian government's policy on oil palm plantations in the highlands of Borneo. While we cannot quantify the precise policy impact of the valuation work, it appears to have played a role in the decision to shelve the oil palm project.

Introduction

The economic value of natural ecosystems is increasingly recognized by scientists and policymakers (National Academy of Sciences 2004). Examples of these economic benefits that nature provides to humanity ("ecosystem services") include water purification by wetlands (Boyer & Polasky 2004), pollination of important crops by insects (Ricketts *et al.* 2004), and buffering of storm surge by mangroves (Danielsen *et al.* 2005). The value of most of these ecosystem goods and services does not pass directly through existing markets. Nevertheless they do have tangible economic value, and in the last few decades economic techniques to calculate these values have been developed and refined (Freeman 2003). Understanding the economic values of nature is important in order to make rational and informed decisions on policies that affect natural areas; it allows the costs and benefits of both development and conservation to be compared on an equal footing. Too often in the past, the economic benefits of natural habitats have been counted as zero in such decisions. Studies that have directly compared costs and benefits of conservation, however, have found that in some instances conservation can lead to equal or greater economic benefits than development (Balmford *et al.* 2002; Naidoo & Adamowicz 2005). In all instances, not estimating the benefits of ecosystem services can lead to an undervaluation of the natural world by policymakers who may be accustomed to evaluating trade-offs among decisions in terms of dollar values.

Despite the pressing need for economic valuation of ecosystem services and the growing number of case studies thereof, the extent to which valuation has influenced conservation policy is unclear. A number of researchers have reviewed the policy relevance of valuation studies. With particular regard to Europe, it has been suggested

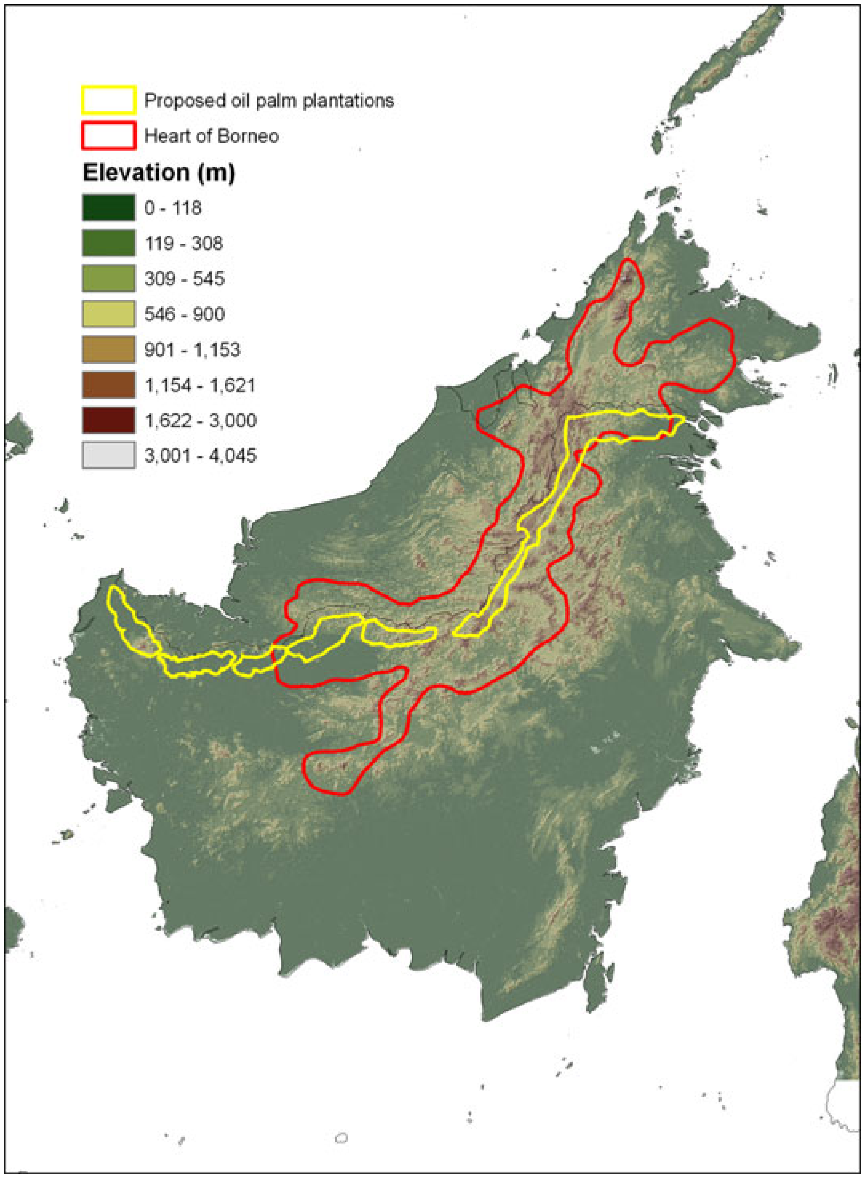

Figure 1 Map of Borneo showing elevation, along with the Heart of Borneo area (red outline) and the proposed oil palm plantations (yellow outline) along the Kalimantan–Malaysia border.

that while great advances in valuation have been made, a number of legal and political issues have inhibited their more widespread use in policy (Pearce & Seccombe-Hett 2000). In a broader review, only a handful of studies were found that assessed multiple ecosystem services values in alternate landscape states, even though these types of studies are the most policy relevant (Turner *et al.* 2003). Finally, at a recent meeting of environmental economists in which the use of economics for tropical conservation was discussed, participants' views on whether economic valuation of the environment can be useful for policymaking were decidedly mixed (Reid & Boyd 2008). Therefore, there appears to be a need for more published case studies that describe the effect of economic valuation of ecosystem services on policy decisions, especially in developing countries.

As an example of a current policy decision with enormous conservation implications, the Indonesian government, with some $8 billion (USD) in backing from Chinese investors, proposed in 2006 to develop a series of oil palm plantations along the Kalimantan–Malaysian border on the island of Borneo (Figure 1). The proposed plantations, which would be the largest in the world, would increase palm oil output and have been touted as a way of providing economic opportunities for an impoverished area of the country (Witular 2005). However, potential economic benefits should be set against the opportunity costs of developing oil palm plantations in the area. The forests in this area, hereafter referred to as the Heart of Borneo (HOB) region, possess high species endemism, species new to science, and are relatively intact (Rautner *et al.* 2005). In addition, the forests provide ecosystem goods and services such as carbon storage, watershed protection, and nontimber forest products, and forest clearance would result in environmental damages such as increased erosion and chemical runoff from the plantations, as well as the ecological, social and economic costs of increased fire frequency (often used when establishing plantations) in the region.

We conducted a rapid assessment of some of the economic benefits provided by standing forests in areas proposed to be converted to oil palm plantations in the Heart of Borneo. We focused on three classes of benefits: avoided damages associated with increased greenhouse gas emissions (carbon storage), avoided damages associated with increased fires, and the economic benefits of forest–agriculture mosaics. These benefits run the gamut of beneficiary scale from international to local. For each benefit type, we used or developed empirical relationships between forest cover and biophysical delivery of the service, then monetized the economic benefits, all using existing data compiled from a variety of sources. We used simple empirical models in our analyses, while recognizing that a deeper treatment of the subject would have required a much more sophisticated modeling approach and many years of research effort. In addition to presenting the results of our analyses, we discuss how these were used in attempts to influence decisions by the Indonesian government regarding the oil palm plantations.

Methods

Plantation areas

We digitized polygons of the proposed plantations into a GIS based on a map of the planned project area provided by WWF Indonesia. The map emanated from a scanned document and was georectified using control points along the Indonesia–Malaysia border and the outer borders of Kalimantan. Root mean square error (RMS) for rectification to a geographical coordinate system was 0.122. The original map and scan were of poor quality and therefore the digitized oil palm plantations and associated calculations must be considered rough approximations only. Government sources indicate that the plantations will cover an area of 1,800,000 hectares (ha), but the digitized polygons had an area of about 2,800,000 ha. We therefore applied a correction factor to all variables so that calculated values arising from summations over polygons were consistent with the 1,800,000 ha figure for plantation area.

Modeling benefits of forests and costs of conversion

We present only a brief summary of the valuation methods we used; detailed methods are available as Supporting Information (Appendix S1). For carbon storage, we used forest plot data (Proctor *et al.* 1983; Yamakura *et al.* 1986; Aiba & Kitayama 1999; Takyu *et al.* 2003; Toma *et al.* 2005) to construct a relationship between elevation and biomass, and used this model to estimate carbon in forest biomass within oil palm plantation areas. We estimated storage values in U.S. dollars using several carbon prices and accounting standpoints and conducted sensitivity analyses by varying these parameters.

For the valuation of health impacts from increased forest fires due to oil palm plantations, we used satellite information on fires and spatial data on landcover and human infrastructure to model the spatial relationship between probability of fire and oil palm plantation development. We modeled the effects of fires on smog in northern Bornean cities using time-series data on fires and visibility at the Brunei airport, and monetized the health effects of increased fires using established relationships between particulate matter and economic costs of increased hospital visits (Vajanapoom *et al.* 2001; Anaman & Ibrahim 2003).

To calculate income lost by local communities due to oil palm development, we used an established relationship between agroforestry dependence and forest cover (Dewi *et al.* 2005). We then used local income statistics to predict agroforestry income loss as a result of forest conversion to oil palm plantations.

Oil palm financial benefits

We collated data from various sources (Wakker 2006; Koh & Wilcove 2007; Fargione *et al.* 2008) to assess the economic benefits associated with the proposed oil palm plantations. We classified benefits according to whether they accrued locally, nationally/regionally, or globally, using information on the oil palm industry and operating procedures from the same sources. Our goal was not to evaluate oil palm financial benefits comprehensively, but to use existing and readily available information to contrast the magnitude of oil palm benefits with the benefits that arise from standing forests. See Appendix S1 for details.

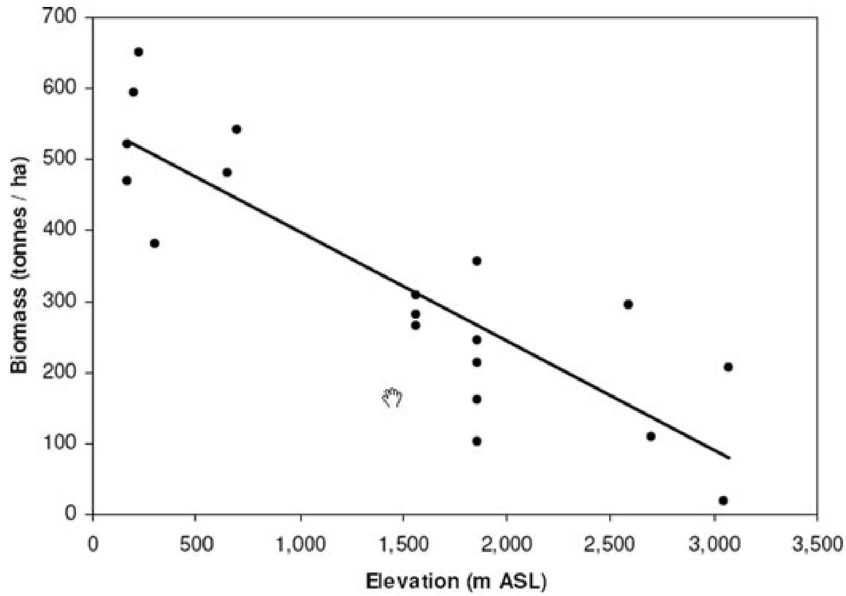

Figure 2 Statistical relationship between biomass (tonnes per ha) and elevation (meters above sea level) for plots throughout forested areas of Borneo (Biomass = −0.15 * Elevation + 552, $R^2 = 0.75$, $P < 0.001$, $n = 19$).

Results

Carbon storage

Forest biomass was strongly correlated with elevation (Figure 2). At the default parameter values, using all forested land in the proposed oil palm plantation area for a carbon storage project would generate $1.7 billion (lCER accounting) or $3.4 billion (social, up-front payment) in hypothetical payments. We identified 27 possible scenarios using realistic low, medium and high values for forest biomass and carbon price, low and medium discount rates (the default estimate of 15% for the discount rate was already relatively high), and both types of accounting stances (lCER vs. social). NPV calculations from these scenarios resulted in a mean carbon storage value of $2.7 billion, (± $1.8 billion), with a minimum of $500 million and a maximum of $7.1 billion (Table 1). Carbon values calculated using the social accounting framework were always higher than those under the lCER stance because payments are provided up-front under the social accounting stance, whereas for lCER payments are delayed into the future and therefore discounted relative to present dollar values.

Health costs from increased fires

The top-ranked model for predicting visibility in Bandar Seri Begawan included moisture variables, wind direction, and the interaction between wind direction and fire pixels (Table 2). The 5-day smoothed average of fire pixel number was a strong negative predictor of visibility, even after correcting for variables such as precipitation, humidity, and wind direction. The effect of fires on visibility was enhanced on days when the wind was from the west and southwest, which is consistent with the position of Bandar Seri Begawan on the north coast of Borneo and hence to the north and east of most of the fires on the island. Overall, the model explained 32% of the variance.

Table 1 Economic values of carbon storage from 27 scenarios based on changes in price, biomass, discount rate, and accounting stance. Units in the "lCER" and "Social" columns, along with summary statistics, are billions of U.S. dollars, with the exception of CV (coefficient of variation) which is unit-less

Price ($/t)	Forest biomass (t/ha)	lCER $d = 0.07$	lCER $d = 0.15$	Social
Low (7)	Low (400)	0.7	0.5	1.0
	Medium (466)	0.8	0.6	1.1
	High (520)	0.9	0.7	1.3
Medium (15)	Low (400)	2.1	1.5	2.9
	Medium (466)	2.5	1.7	3.4
	High (520)	2.8	2.0	3.9
High (25)	Low (400)	3.8	2.7	5.3
	Medium (466)	4.5	3.2	6.3
	High (520)	5.1	3.6	7.1
Mean	2.7			
Std. deviation	1.8			
CV	0.69			
Min	0.5			
Max	7.1			

Table 2 Best model of visibility at Brunei International airport, Bandar Seri Begawan, Brunei

Variable	Estimate	Std. error	*t*-value	$P - value$	% Explained variance
(Intercept)	8.490	0.374	22.69	< 0.00001	–
Fire pixels	−0.006	0.001	−10.56	< 0.00001	42.6
Daily precipitation (inches)	−0.011	0.019	−0.60	0.550	1.24
Relative humidity	−0.014	0.005	−3.06	0.002	1.40
NE wind dummy	−0.073	0.140	−0.52	0.601	2.00
E wind dummy	−0.133	0.103	−1.29	0.198	2.21
SE wind dummy	0.033	0.087	0.38	0.705	2.12
SW wind dummy	0.070	0.047	1.49	0.137	2.31
NW wind dummy	−0.305	0.577	−0.53	0.598	2.09
W wind dummy	−0.027	0.116	−0.23	0.818	1.98
Interaction: fire pixels:NE wind	−0.039	0.066	−0.59	0.555	1.99
Interaction: fire pixels:E wind	−0.003	0.002	−1.66	0.098	3.89
Interaction: fire pixels:SE wind	0.002	0.003	0.71	0.481	1.97
Interaction: fire pixels:SW wind	0.002	0.001	2.91	0.004	29.9
Interaction: fire pixels:NW wind	−0.015	0.032	−0.46	0.642	2.17
Interaction: fire pixels:W wind	0.003	0.001	2.12	0.035	2.10

Residual standard error: 0.5087 on 859 degrees of freedom.
Multiple R^2: 0.3202.
F-statistic: 26.98 on 15 and 859 DF, *P*-value: < 0.000001.

A model that included spatial, biophysical, and human infrastructure variables was ranked highest for predicting the spatial distribution of fires in Borneo (Table 3). From simulation work, the deviance explained (0.33) is roughly equivalent to an R^2 of 0.7–0.9 (Louviere *et al.* 2000), that is, a good fit. Using this model of the spatial distribution of fires, we simulated the effect of oil palm development and associated road networks; this simulation resulted in increases of 500 fire pixels (assuming a road density of 0.33 km/km^2) or 3,156 fire pixels (assuming a road density of 0.62 km/km^2) for a normal year (as typified by 2001). Using information on

Table 3 Best model for the spatial distribution of fire pixels in Kalimantan, Indonesia

Variable	Estimate	Std. error	*z*-value	*P*-value	% Explained variance
(Intercept)	−5113	1411	−3.623	0.0003	
Latitude	90.2	24.8	3.639	0.0003	3.55
Longitude	3.4370	10.1700	0.338	0.7353	5.70
Lat × Long	−0.0238	0.0897	−0.265	0.7910	11.12
(Long)^2	−0.3970	0.1086	−3.656	0.0003	5.61
(Lat)^2	−0.0433	0.1686	−0.257	0.7974	6.03
Elevation	−0.0109	0.0077	−1.415	0.1571	13.69
Annual Precipitation	−0.0016	0.0006	−2.485	0.0129	4.81
Forest	−1.5980	0.7826	−2.042	0.0412	8.64
Distance to forest	9.4820	4.5870	2.067	0.0387	5.48
Distance to river	10.2400	4.8080	2.129	0.0332	2.91
Flooded forest	−0.5012	0.5062	−0.99	0.3221	8.08
Distance to flooded forest	−2.7050	1.1400	−2.372	0.0177	10.65
Distance to roads	−3.9380	2.2150	−1.778	0.0755	3.70
Oil palm plantation	−0.5477	1.0670	−0.513	0.6076	3.83
Population	−0.0004	0.0002	−2.19	0.0285	2.22
Distance to oil palm plantation	0.8435	1.3460	0.627	0.5308	3.92

Null deviance: 368.59 on 2,924 degrees of freedom.
Residual deviance: 245.18 on 2,908 degrees of freedom.
AIC: 325.13.

Table 4 Economic losses ($U.S.) from fires associated with oil palm plantations in the Heart of Borneo

		Road density equal to:			
		"Normal" year		El Nino year	
City	Country	W. Kalimantan	Sarawak	W. Kalimantan	Sarawak
Bandar Seri Begawan	Brunei	37,583	3,097,529	112,749	9,292,586
Kuching	Malaysia (Sarawak)	18,517	1,526,183	55,552	4,578,550
Kota Kinabalu	Malaysia (Sabah)	9,124	751,966	27,371	2,255,897
Pontianak	Indonesia	4,495	370,501	13,486	1,111,503
Total value ($U.S.)		69,719	5,746,179	209,158	17,238,536

area burned on Borneo during 1997–2004 (Bechteler *et al.* 2005), we assumed that fire area in an El Nino year would be about three times greater than in a normal year. Assuming a similar spatial pattern of fires, this means that oil palm development in the HOB would lead to an increase of 2,513 fire pixels (road density of 0.33 km/km^2) and 10,478 fire pixels (road density of 0.62 km/km^2) for an El Nino year. Using the above two models in conjunction, economic damages associated with increased smog from oil palm development in HOB for major cities in northern Borneo are presented in Table 4.

Local values

The proposed 1.8 million ha oil palm plantations will reduce forest cover in HOB by approximately 14.5% from year 2000 estimates. Using "low" and "high" estimates for the proportion of income derived from agroforestry activities, we estimated that the proposed oil palm plantations will cost the HOB region a minimum of $9.9 million (USD) and a maximum of $19.4 million (USD) in annual lost agroforestry revenues (Table 5, Figure 3). For all villages within the study site, per capita income loss ranged from 0% from 84% of total year 2000 income for the "high" estimate (mean 42.2% ± 29) and from 0% from 42.8% (mean 21.5% ± 14.8) for the "low" estimate, depending on the proportion of village-level forest loss. Percent per capita income losses were highest in Malinau and Nunukan, East Kalimantan where losses were approximately 50% of year 2000 income for the "high" estimate and 25% for the "low" estimate. Total economic losses were highest in Nunukan, East Kalimantan where forest cover decreased nearly 70% on average within affected villages (Table 5).

Oil palm plantation benefits

Locally, annual benefits of oil palm plantations vary from $0 (assuming all labor is imported) to $227 million

Table 5 Economic statistics, average agro-forestry dependencies, and "high" and "low" estimates of income loss due to forest conversion for affected villages, by district (Kabupaten). All economic values are given in U.S. dollars

			Average Agroforestry dependence					Average per capita loss	
District (Kabupaten)	Villages (no.)	Per capita GRDP	Year 2000	Projected	Avg. forest loss (%)	Estimate	Total loss	USD	Percent
Kapuas Hulu	43	$376.92	0.50	0.22	57.3	High (100%)	−$3,629,603.54	−$109.25	−29.0
						Low (51%)	−$1,851,097.80	−$55.72	−14.8
Kutai Barat	7	$1,202.95	0.85	0.63	17.5	High (100%)	−$381,946.09	−$257.73	−21.4
						Low (51%)	−$194,792.50	−$131.44	−10.9
Malinau	35	$993.16	0.80	0.31	52.9	High (100%)	−$2,303,387.44	−$482.47	−48.6
						Low (51%)	−$1,174,727.59	−$246.06	−24.8
Nunukan	145	$868.19	0.81	0.23	69.5	High (100%)	−$12,998,704.33	−$428.22	−49.3
						Low (51%)	−$6,629,339.21	−$218.39	−25.2
Sintang	1	$267.60	0.15	0.06	67.2	High (100%)	−$62,851.04	−$23.82	−8.9
						Low (51%)	−$32,054.03	−$12.15	−4.5
Total/Average	231	$741.76	0.62	0.29	52.9	High (100%)	−$19,376,492.43		
						Low (51%)	−$9,882,011.14		

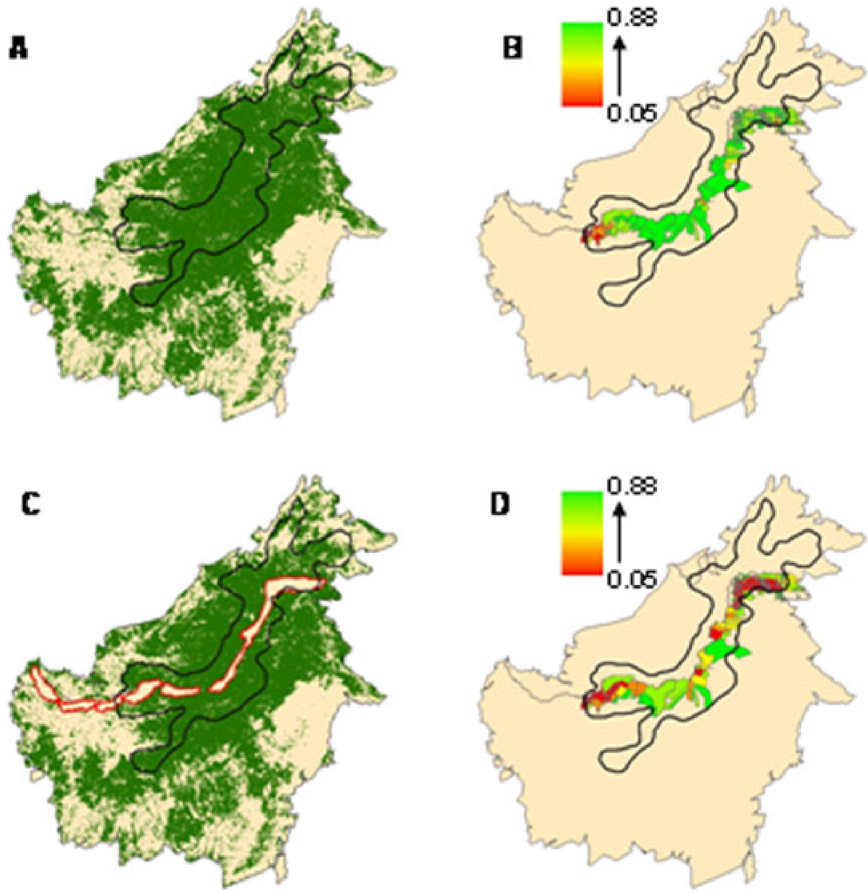

Figure 3 Maps of Borneo showing projected forest loss and resultant change in village-level agro-forestry dependence: (A) Year 2000 forest cover, (B) Year 2000 village-level agro-forestry dependence, (C) Projection of future forest cover, (D) Projection of future village-level agroforestry dependence.

(assuming all labor is locally contracted, wages are 20,000 IDR/day, and workers work 260 days per year). The majority of the benefits of oil palm plantations accrue nationally or regionally to a few palm oil companies (Wakker 2006) and the Indonesian government for a total of $3.7 billion, assuming net profits of $2078 per ha/year once plantations are fully operational (Koh & Wilcove 2007). In addition, an even greater sum would be derived from harvesting the timber on site, which we estimate would provide one-time net revenues of $4.8 billion (see Appendix S1 for calculation details). Globally, benefits of cleaner-burning biodiesel from oil palm plantations (Fargione *et al.* 2008) were minimal (between $4 and $31 million) compared to carbon storage benefits, since only an estimated 2.5% of palm oil production would be used as biodiesel.

Discussion

Using relatively simple statistical models, we characterized relationships between standing forests in areas proposed as oil palm plantations and their economic values for three types of benefits: carbon storage, avoided health costs due to fires, and local forest–agroforest mosaics. As in other studies (Naidoo & Ricketts 2006), carbon storage values dominated the totals, but are currently experienced only at the global scale. Locally, losses of forests from oil palm areas result in economic losses from forest–agroforestry mosaics. At the national–regional level, the increased probability of forest fires due to oil palm development results in negligible health costs to cities in northern Borneo at low future road densities, but costs become considerable at higher future road densities, especially in El Nino years.

Several caveats surrounding these results are worth mentioning. A general caution is that given the rapid nature of the research, all the statistical models presented here are highly simplified abstractions of complex ecological, chemical, and social phenomena. More detailed research that involves primary data collection, simulation modeling, and improved spatial data would have allowed a more accurate estimation of damages. In particular, given the complex nature of atmospheric transport of combustible matter emanating from fires, a more detailed process-based model (Phadnis *et al.* 2001) would be necessary to improve the accuracy of the simple statistical model of fires and health costs.

More specifically, the carbon model we used is clearly a simplification of how elevation influences biomass. In addition, avoided deforestation has only just recently entered UNFCCC negotiations for the next commitment period (to begin in 2012) and all the associated rules and regulations governing how these types of carbon offsets might be counted and traded internationally (if they are counted at all) are as yet unknown. We considered only the effect of fires on Borneo in the relationship between fire and visibility, and so fires from other parts of southeast Asia that may be contributing to reduced visibility in Brunei are not captured. We may also have underestimated the effect of oil palm development on fires in HOB because elevation, precipitation, and human access are confounded on Borneo; the negative effects of elevation and precipitation in our model may just reflect the few people in the highlands. Finally, our local-scale analysis was crude due to a lack of available data at the HOB scale on forest benefits that are important in other areas of Indonesia, such as watershed services, firewood, and nontimber forest product extraction (Pattanayak & Wendland 2007).

Comparing the specific beneficiaries of oil palm plantation development versus retention of standing forests allows for the identification of winners and losers and the quantification of how much stands to be gained or lost. At the global scale, the benefits of not converting forests to oil palm are high due to their carbon storage values. As many others have pointed out, a mechanism is needed to capture such global values and make them relevant to national and local interests and decision making (Pearce 1996; Santilli *et al.* 2005). Conversely, global-scale benefits of oil palm plantation development, through carbon emission reductions from increased biofuel use, were minimal compared to carbon storage benefits; others have noted that the time lag for "repayment" of the carbon debt caused by clearing southeast Asian rainforest for palm oil is on the order of a century (Fargione *et al.* 2008).

Although the oil palm plantations will be developed in Indonesian Borneo, most of the increased fire effects will be felt in Sarawak (Malaysia) and Brunei, because of the plantations' location along the northern Kalimantan border and the direction of prevailing winds in the dry season (from the south and west; (Radojevic 2003). This spillover of health costs associated with increased fire from oil palm development lends an important regional dimension to the issue. While the benefits of oil palm plantations and associated timber revenues will accrue to companies, the government, and those in Indonesia with good connections to both, the costs of such actions will be felt by a more dispersed group of people, including those outside of Indonesia. At this scale, outside of relatively weak international agreements (i.e., a regional transboundary agreement on smog), there is little incentive for the few major beneficiaries of oil palm development to consider the costs that accrue to other regional stakeholders. In contrast, the value of timber alone on the proposed site is suspected to be a major spur for developing the area, regardless of the eventual financial profitability of oil palm cultivation.

Locally, there is the potential to mitigate the loss in agroforestry income via employment opportunities on oil palm plantations. However, large-scale oil palm projects in Indonesia have tended to import workers from outside the area of operation, which fosters social conflict along with typically bitter land tenure battles (Casson 1999; Wakker 2005, 2006); therefore, it is doubtful that such mitigation would occur. In addition, such an offset would entail a radical change in lifestyle for locals who mainly subsist in agroforestry–forest mosaics. This analysis does not take into account "way of life" values that people may hold; this is an important consideration that to date has not received sufficient research attention.

What are the policy implications of this study? The analyses were conducted within a 7-month timeframe during which results were relayed to stakeholders as they were completed (carbon first, then fire results, then local values). The analyses were used to highlight the economic values of standing forests (as opposed to the better known benefits of oil palm plantations) to a variety of stakeholders, including within the Indonesian Ministries of Forestry, Economics, Agriculture, Environment and Planning, and Public Works, as well as with local government officials, community and indigenous groups, and Indonesian nongovernmental organizations. These discussions resulted in recommendations sent to the President of Indonesia by the National Planning Agency as a template for national policy. The World Wildlife Fund (WWF) also met directly with the President and during the discussion the estimated values of ecosystem goods and services were one of the reasons mentioned for not clearing the vast areas of forest. The value of ecosystem services was also included as one of the references by the Ministry of Agriculture, Ministry of Defense and West Kalimantan Provincial Government when they declared that the oil palm development would not go forward because the Heart of Borneo "is a resource of life for Kalimantan." It is nevertheless difficult to quantify the precise impact of this valuation work on the policy decision because it was used in conjunction with other arguments for shelving the proposal, including the poor growth potential of oil palm in the highland areas slated for conversion, and the identification of idle, already degraded lands as potential alternative sites.

We have demonstrated that it is feasible, within tight time and resource constraints, to quantify the economic benefits of forest conservation and present these to decision makers. We are aware of few published studies detailing how the results of environmental valuation studies have been used to influence conservation policy in developing countries. Our study shows that time sensitive estimates on the economic benefits of nature can be estimated and used to inform policy decisions on conservation issues. While the context was unique and isolating the policy impact of our valuation work versus effects of other arguments is not possible, there appears to be at least some role for the economic valuation of ecosystem services to influence conservation policy in developing countries.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Appendix S1.

Please note: Wiley-Blackwell is not responsible for the content or functionality of any supporting materials supplied by the authors. Any queries (other than missing material) should be directed to the corresponding author for the article.

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