Saving Sumatra's Species:

Combining economics and ecology to define an efficient and self-sustaining program for inducing conservation within oil palm plantations

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Abstract

The paper presents results from a four year study of the economic and ecological potential for implementation of conservation schemes within the rapidly expanding palm oil plantations of South East Asia. Unparalleled access to financial records combined with a highly intensive ecological data gathering exercise allows us to develop spatially explicit cost effectiveness models for optimising conservation efforts. This is integrated with a further study of the price premium potential of conservation-grade palm oil to yield insights into the optimal design of schemes for delivering biodiversity within existing plantations

Introduction

The world is beset with tradeoffs between biodiversity conservation and economic returns to human activities (Balmford et al 2002, Green et al. 2005). The overwhelming cause of loss of biodiversity and species populations is land conversion (Tilman 2001, Foley et al. 2005) with the most dramatic losses being within tropical forests, which are being lost at up to 12 million hectares per year (DeFries et al 2002). While the agents of deforestation are often

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local of regional, the underlying drivers are global demands (Geist and Lambin, 2002) such as for timber, soy, beef and now palm oil. The result of these losses is most dramatically witnessed by recent figures suggesting that 1 in 4 terrestrial mammals are now threatened with extinction (Schipper et al 2008). Such a telling tale begs the question of ‘why is this happening?’ – with the obvious answer being that conservation activities can incur large costs – in particular lost economic opportunities (Ando et al 1998; Naidoo et al 2006). Understanding this trade-off requires us to ask two essential questions:

- Where is it most cost effective to undertake conservation interventions within a human dominated landscape?
- Can the costs and economic losses associated with conservation be compensated for?

While it is clearly essential to prevent further loss of virgin undisturbed tropical forest, the fact that the earth’s land surface is increasingly dominated by human activity means that it is essential to investigate the potential for improving the biodiversity potential of such lands. This paper provides the first results from a four year field study investigating the biodiversity conservation of one of the fastest growing land use types in the world; oil palm plantation. Palm oil is the world’s number one vegetable oil (HGCA 2008) and 80% of production comes from Southeast Asia. This is an area experiencing some of the highest rates of deforestation (Sodhi et al. 2004) and encompasses some of the world’s most important areas for biodiversity (Myers et al. 2000). With expanding world food consumption and the advent of biofuels, demand for palm oil continues to rise. Concerns regarding biodiversity impact have in part led to the recent creation of the Roundtable on Sustainable Palm Oil (RSPO; *www.rspo.org*) which operates a certification scheme for producers undertaking conservation measures. However, to date only a minority of producers have joined the voluntary conservation scheme.

Our study combines unique, spatially referenced economic data, provided through unprecedented access to the accounts of a major oil palm producer, with primary ecological data collected through over 1000 kilometres of species observation transects. These data are modelled and integrated into a spatially sensitive cost effectiveness analysis indicating the optimal locations within a plantation for conserving biodiversity. However, such schemes still incur costs to the producer and so we utilize stated preference valuation techniques to examine the viability of a price premium for certified conservation grade palm oil. Integration of these findings with our cost-effectiveness results indicates the various conditions which have to hold in order that participation within a certified conservation scheme yields net benefits to the producer. These results suggest that a reorganization of conservation efforts incorporating the strategies underpinning recent conservation-grade and Fairtrade production movements would provide an economic incentive for a majority of plantations to see conservation as an economically beneficial undertaking; a condition which we feel is vital for the successful large scale uptake of conservation schemes.

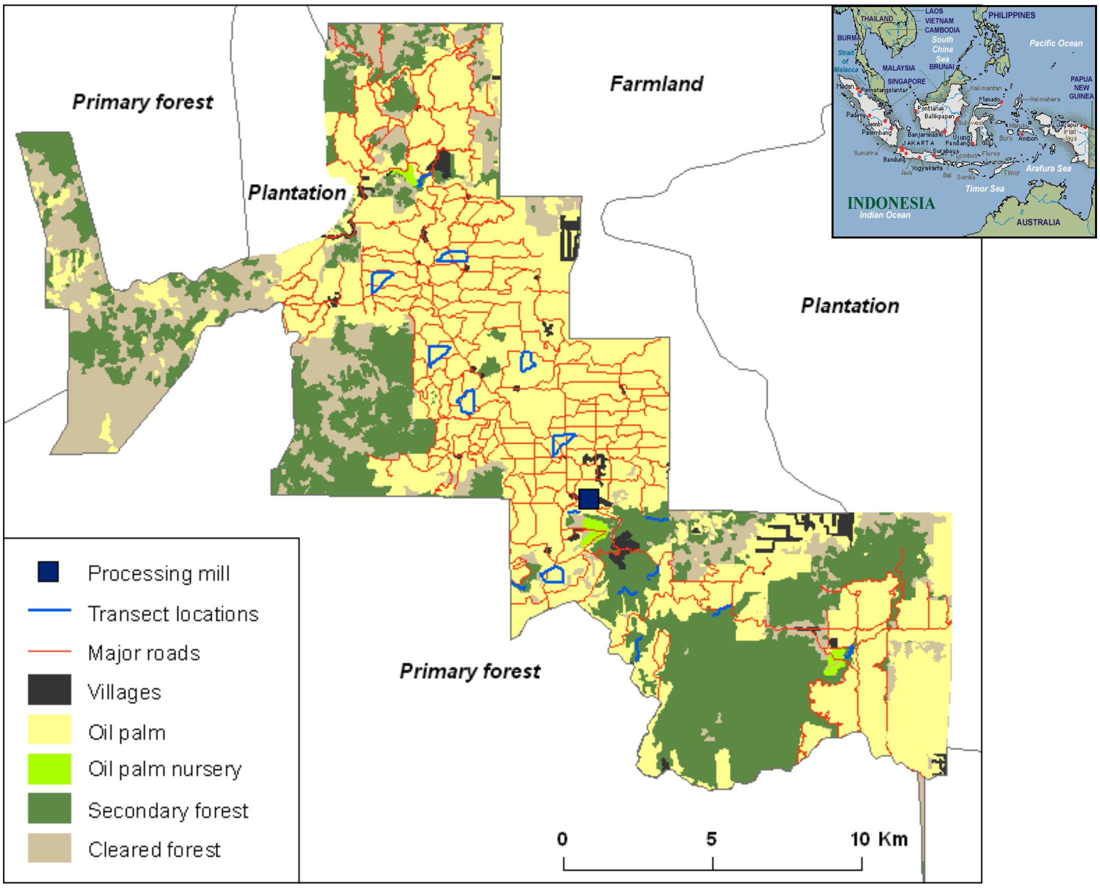
The remainder of the paper is organized as follows. In Section 1 we apply the basic principles of agricultural economics (Hill, 1990) to undertake an economic assessment of the gross margins associated with the production of crude palm oil (CPO). We then extend this analysis to assess the opportunity costs of conservation (OCC). Section 2 presents details of a three year field exercise systematically collecting data on mammal presence through repeated transect analyses. The spatially referenced data collected is then analysed to yield models of the probability of mammal presence across the plantation with respect to a variety of locational and habitat variables, including distances to differing habitat types, human intrusion, etc. Section 3 combines findings from the previous two sections to undertake a cost effectiveness analysis of alternative strategies for allocating land to conservation across the plantation. This shows marked spatial variation in the distribution of cost-effectiveness values. While Section 3 highlights both optimal and sub-optimal solutions to the conservation problem, if left uncompensated all conservation schemes impose net costs upon plantations and are likely to be rendered ineffective by long term competitive pressures. In Section 4 we propose a new approach to solving this problem within the palm oil context. While we are sceptical of the validity of studies directly attempting to estimate economic willingness to pay values for biodiversity (believing that the preferences underlying such exercises frequently lack economic theoretic consistency), we do recognise the price premium accorded to Fairtrade and Conservation Grade products. Therefore we adapt non-market valuation methods to the estimation of such a premium for products made with ‘Conservation Grade’ palm oil, showing that such a price uplift is a robust feature of both high and low grade products. Section 5 completes our analysis by examining the degree to which a price premium might generate net benefits to palm oil producers from a decision to embark upon conservation schemes within their concessions. Section 6 concludes.

1. **The study site, economic assessment of palm oil production, and the opportunity costs of conservation.**

Oil palm is a perennial crop primarily grown in extensive plantations. Seedlings are initially grown in nurseries for the first two years of their life after which they are planted out into management blocks of around 30 hectares at a density of between 130-143 palms per hectare. Once planted out the young palms are classed as immature until they start to produce fruit, usually 3 years after planting out. The fruit is composed of large compact bunches of fruitlets each approximately the size and shape of a plum. Fruit is produced continually throughout the year and harvested at regular intervals of between 5 and 12 days. Oil palms remain productive throughout their life but blocks are generally replanted between 15 and 20 years after planting – by which time the palms have grown too tall to harvest effectively. Continuous upkeep and maintenance of the crop is required, most of which is conducted by manual labourers. This involves fertilizer regimes, weeding, pruning and pesticide application. Once harvested the oil needs to be processes quickly in order to minimise the rapid esterification of the oil content of the fruit. For this reason large plantations will often have a primary processing mill on site or nearby; as is the case in our study site. In the mill the fruit is pressed to extract the crude palm oil (CPO) which is the primary sale product.

Data for both our financial and ecological analyses were collected from an oil palm concession in central Sumatra. Full access was granted to all cost and revenue data broken down to the smallest field unit for the years 2001-2006. Due to the commercial confidentiality of this data we do not provide full details of the name or precise location of this concession which covered more than 30,000ha of mixed mature and immature oil palm plantation, secondary forest and bamboo-dominated scrub land. A commercial logging enterprise bordered the southern edge of the plantation. To the northern edge, transmigration settlements and government oil palm plantations create an agricultural mosaic. Figure 1 illustrates the land use types both within and bordering the concession.

Figure 1. Distribution of habitat types within the case study concession showing existing roads and the location of ecological survey transects.



Data provided by the plantation management consisted of highly disaggregated, spatially referenced, financial and physical quantity information, environmental characteristics and meteorological condition records for each of the nearly 400 sub-compartments (each of about 30ha) of the plantation (planted and unplanted). In total more than 90 variables were provided for each sub-compartment with these data being collected at least every month throughout the study period, yielding a total of approximately 2.5million data records covering the period from 2002 to 2006[4]. This is an unprecedented level of detail permitting great accuracy within our economic modelling.

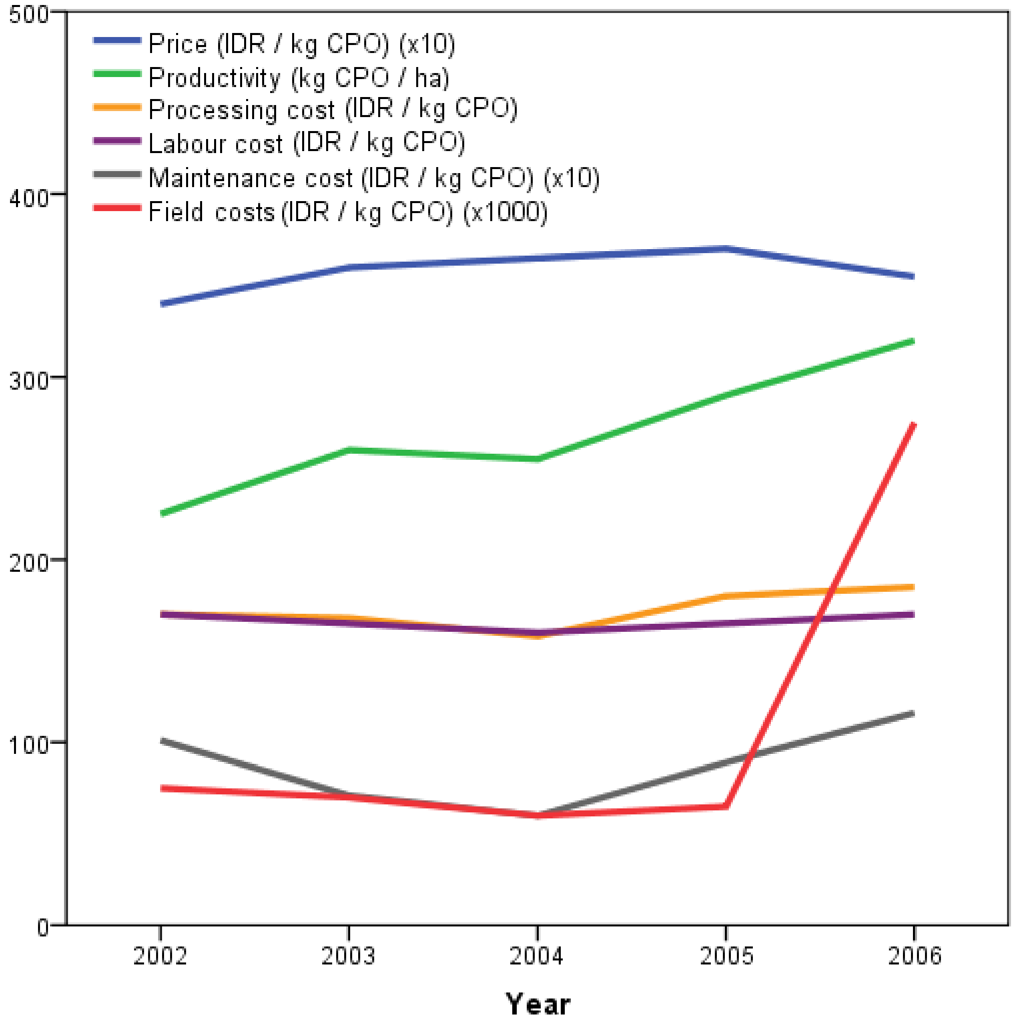
Analysis of these financial data supported a contention from the present plantation management that the data period embraced two very distinct levels of production intensity; a

[4] These data included: Average price at which the plantation sold its CPO; Total number of kilograms of FFB harvested in a given month; Total number of kg of CPO the plantation sold; Total income from CPO sales; Total costs incurred by the central administrative office headquarters; Fixed costs incurred by the processing mill; Financial income and outgoings unspecified but probably resulting from debt servicing; Cost of producing CPO from FFB at the onsite processing mill; General agricultural costs such as pruning, weeding, fertilizing, and censuses; Cost harvester wages and transport of FFB to the processing mill; Costs associated with the field offices (field offices co-ordinate the daily agricultural activities for subdivision of the plantation); Total hectarage of mature (productive) palms.

low input regime at first changing to a high input system after a change of ownership in 2005 (resulting in an almost 50% increase in the per hectare productivity of mature palm areas). Given the large volume of data available we decided to focus upon records from 2002 and 2006 but to omit the intervening transitional period. We subsequently refer to these as “low productivity” and “high productivity” regimes, a distinction which provides us with a clear measure of the impact of this change in production intensity and hence enhances the transferability of results to other contexts.

In order to establish the opportunity costs of conservation we first need to follow basic principles of agricultural economics to establish the distribution of gross margins across the concession for our two periods. Gross margins differ from profits in that they omit fixed costs. For several decades now, gross margin analysis has been the standard approach for assessing agricultural operations (Gittinger, 1982; Tiffin, 2006) as fixed cost levels can vary very substantially across operations often for historical reasons and prevent the generation of generalisable results. The basic data required for calculation of gross margins is summarised in Figure 2 which clearly demonstrates the noticeable increase in productivity over the period.

Figure 2: Plantations level trends in price, output and costs of palm oil production, 2002-2006



Units: Productivity is measured in kg CPO per hectare per month.

All other variables are measured in Indonesian Rupiah (IDR) per month.

The gross margin calculations were undertaken using monthly figures for enhanced accuracy. Prior to calculation of revenues, an analysis of yield data showed no significant spatial variation across the plantation. Despite the size of the plantations this was not surprising as in occupies a relatively flat area with homogenous soils and environmental conditions. We therefore do not spatially differentiate revenues. By taking data on the proportion of fruit mass converted to oil we calculate output of CPO in kilograms produced per month. Bringing in data on monthly prices then yields our revenue estimates, details of which are given in

Fitzherbert (2009). All values were initially calculated in nominal Indonesian Rupiah (IDR) and subsequently deflated to 2006 values[5].

Costs include inputs, maintenance, field administration, wages, plant nursery, development and planting costs as well as processing charges, all of which do not vary spatially. However, this is clearly not the case for harvesting costs which have a substantial transportation element. As harvesting costs were not disaggregated to individual sub-compartments we used a geographical information system (GIS) to calculate the least cost routing from each plot along the available harvester and other roads to the processing plant which was located in the centre of the plantation. Transport costs were then allocated to each sub-compartment based upon this distance measure.

Comparison of revenue and cost streams provides our assessment of gross margin within currently planted areas. This declines with increasing distance from the processing plant due to higher transport costs. However, this does not give us our estimate of the opportunity cost of conservation (OCC) within such areas as existing palms would have to be felled, the land ploughed and restored and a variety of costs incurred to encourage the re-establishment of high quality forest cover. Estimates of restoration costs were taken from Nawir et al. (2007) who also supplied indications of the relevant time profile for such projects allowing us to annuitize costs using discount rates for Sumatra given in Menz & Grist (1996) and Wise & Cacho (2005)[6]. Adding this restoration cost to the foregone gross margin gives us our estimates of OCC within presently planted areas.

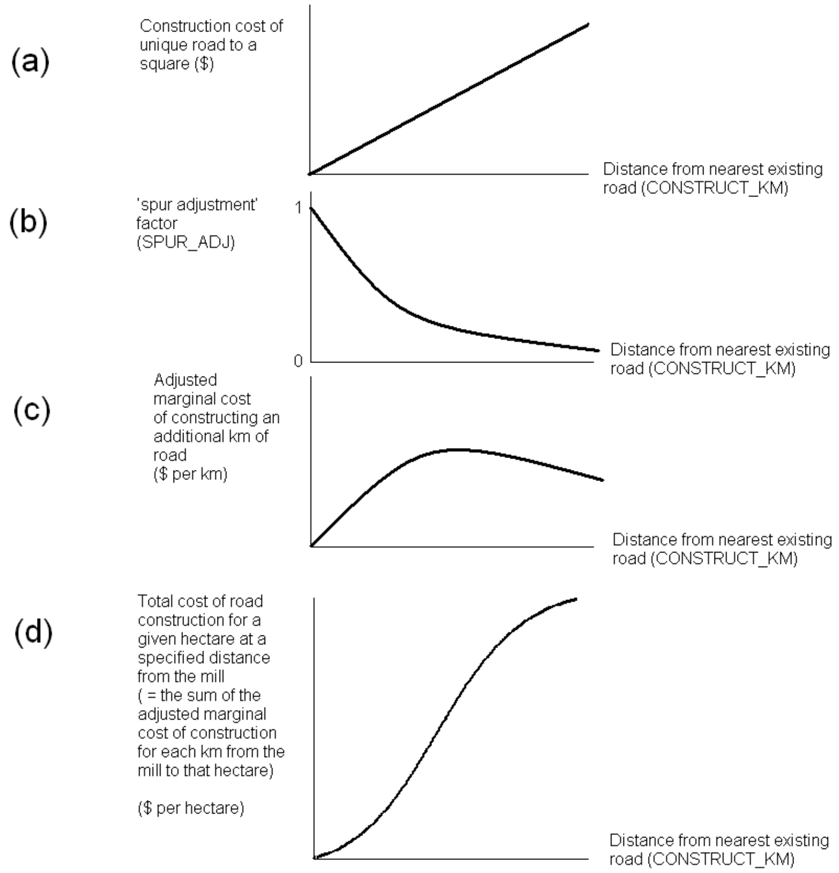
Of course it is likely that any plantation manager will be loath to rip up mature palms if there are unproductive areas within their concession. However, the OCC for such areas is far from zero. They also have a potential gross margin (recall that we included planting costs within the assessment of the latter). This will also vary spatially because of the transport costs described previously. However, often the reason why these areas are currently unplanted is because at present they do not have roads running to them[7]. Therefore the potential gross margin of presently unplanted lands has to be adjusted for the need to extend the road

[5] Total inflation was 12 % between January 2002 and December 2006.
Source: http://indexmundi.com/commodities/?commodity=palm-oil&months=120
[6] Both sources apply a 10% discount rate. Annuity formulae given in Brealey and Myers (1984).
[7] Indeed road density is closely linked to land development, habitat fragmentation, deforestation and the disappearance of wild-lands and wildlife (Chomitz & Gray, 1996; Wilkie et al., 2000).

network to reach those areas. To estimate these road construction costs we again consulted the wider literature taking values from the Indonesian studies of Winkelmann (1999)[8] and annuitizing as before. A problem in this calculation is to allow for the fact that as an unplanted area is developed new roads will spur off each other. Therefore calculating the cost of constructing a unique, new road to any given unplanted area risks overestimation of those costs. This size of this error will vary with distance from the processing plant, being smaller in those cells closest to existing roads and largest further away when the probability that an area would require a unique new road declines in favour of taking a spur off another road developed on the way to that site. Expected relationships are sketched as Figure 3. Here in panel (a) we show total construction costs for a unique new road to a given area assuming constant marginal costs per kilometre and no spurring from other roads that might be create in the interim. Panel (b) shows an adjustment factor which is 1-(probability of spurring); reflecting the increasing probability of spurring as we consider a progressively more distant area. Panel (c) multiples the functions given at (a) and (b) to give the adjusted marginal cost of road construction. Note that at shorter distances from an existing road this reflects the fact that all of the road to that area is likely to need to be constructed afresh. However, as we look at more distant areas the marginal cost declines reflecting the greater likelihood of spurring from other roads. Panel (d) cumulates these marginal values to show the total construction cost to any area.

[8] This suggested a capital cost of constructing earth roads in Indonesia of around US$ 1500 per kilometre. Although of differing quality, plantation roads are genrally earth with the primary roads covered in palm kernel shells a by product of the CPO extraction process. Our case study plantation did have one stretch of tarmac running across it but this was constructed and (questionably) maintained by the local government.

Figure3: Sketch of relationships adjusting for spurring effects in road construction costs.



Parameterisation of the functions sketched in Figure 3 requires the calculation of a road construction adjustment factor (SPUR_ADJ). In order to define the functional form of this adjustment factor (SPUR_ADJ) we modelled the proportion of oil palm contained within a 1 km^2 buffer around each grid cell mid-point (PROP_OPALM) using the single explanatory variable LnDIST_MILL (the natural logarithm distance in kilometres from each grid cell to the processing mill). Because PROP_OPALM is measured as a proportion we used a Tobit regression model to estimate this relationship (Haab & McConnell, 2002). The results of the Tobit regression model are reported in the upper part of Table 1 with adjusted linear predictor values (Greene, 1990) given in the lower part of this table.

Table 1. Tobit regression model of the proportion of oil palm PROP_OPALM in areas as distance from the processing mill varies.

	Coefficient	St. E	t	Sig. (p)	Lower 95% CI	Upper 95% CI
Unadjusted parameters						
LnDIST_MILL	-0.264	0.0075	-35.02	0.0001	-0.279	-0.249
Constant	0.9792	0.0165	59.27	0.0001	0.9468	1.0116
Sigma	0.4411	0.004			0.4332	0.1012
N = 8180						
LL = -5546.76						
Adjusted values						
	dF/dx	St.E	Z	Sig. (p)	Lower 95% CI	Upper 95% CI
LnDIST_MILL	-0.219	0.0062	-35.02	0.0001	-0.2315	-0.207
Constant	0.8135	0.0137	59.27	0.0001	0.7866	0.8404

The models shown in table 1 confirm that the proportion of oil palm to unplanted land falls significantly and logarithmically as distance from the processing mill increases. This provides the shape for our SPUR_ADJ function which can then be used to calculate road construction costs as sketched in Figure 3. These were annuitized as previous.

We can now estimate the OCC for any given area i at any time period t as per Equation (1):

$$OCC_{it} = GM_{it} - Trans_{it} - Construct_{it} + Restore_{it} \tag{1}$$

where:

OCC_{it} = opportunity cost of conservation for area i at time t.

GM_{it} = the (potential) gross margin for area i at time t

$Transport_{it}$ = Transport cost from area i to the processing mill at time t

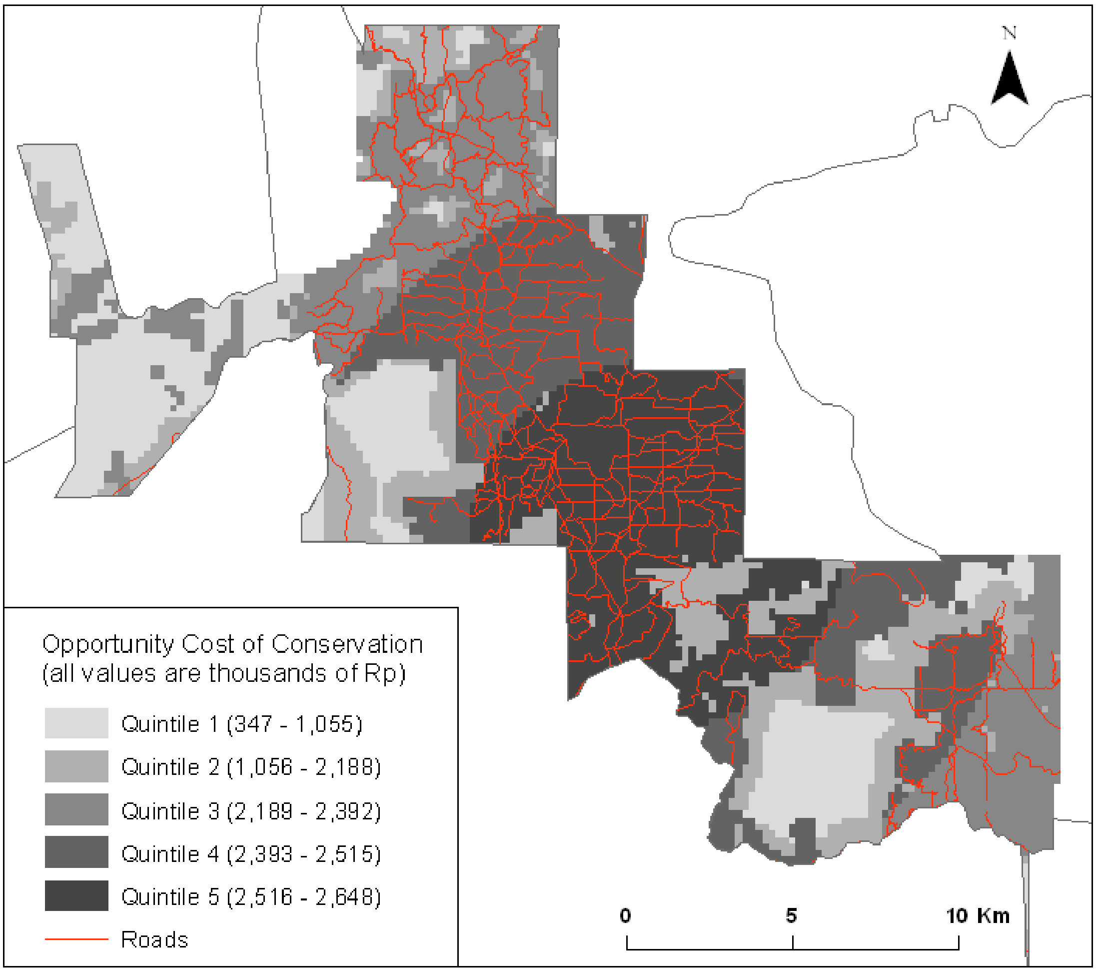
$Construct_{it}$ = Annuitized cost of road construction from existing road network to area i at time t adjusted for spurring probability (=0 for existing oil palm plantation)

$Restore_{it}$ = Restoration cost for grid cell i at time t (= 0 for currently unplanted areas)

Calculating an OCC_{it} value for each grid cell describes the spatial distribution of costs of setting aside each cell across the plantation for conservation. In the next subsection we re-introduce measures of the biodiversity effectiveness of different set aside options for conservations and contrast these with our opportunity cost measures to deliver a cost-effectiveness analysis of those options.

By taking spatially referenced data on the location of planted areas, other habitat types, roads and the processing mill we can use a GIS to transfer Equation (1) so as to generate an OCC cost surface for the entire concession. Assuming the high productivity scenario we obtain the OCC results illustrated in Figure 4. Results for the low productivity scenario were also calculated.

Figure 4. The opportunity cost of conservation for each grid cell across the oil palm concession calculated using Equation (1). Assumes high productivity management regime.



Studying Figure 4 we can see that the opportunity costs of moving land into conservation are highest within existing palm plantation (see Figure 1 for location; restoration costs are incurred here) and near to the processing plant (which is central to the concession; where transport costs are lowest). We can also see that the presence of existing roads also raises OCC as there is less need for road construction in such areas and so (potential) gross margins are higher.

We now move from considering the costs of conservation to assessing its benefits in terms of its impacts upon endangered species.

2. A spatially explicit analysis of the biodiversity effectiveness of conservation areas on oil palm plantations

Our objective here is to assess the species richness that could be supported by conservation land within oil palm concessions and to identify those areas that would provide the greatest conservation benefits. This required primary data collection on a substantial scale and a four year project was launched during which well over 1000 km of transect line walks were undertaken (transect lines being shown on Figure 1).

Species richness varies considerably across the plantation depending on the availability of supportive habitats, water resources, and human disturbance. Our transect based sampling methodology allowed us to record all mammals observed. Fifteen transects were set-up across the plantation covering a variety of land uses including oil palm, cleared forest, secondary forest, and those adjacent to primary forest and farmland (Figure 1). Each transect was walked on a minimum of 20 occasions, during both the day and the night, through 2005 and 2007.

The transect analysis recorded numerous different species (including leopard cats and wild pigs; a major element of tiger diets). However, here we focus solely upon IUCN red list mammals including Agile Gibbons (*Hylobates agilis*), East Asian Porcupines (*Hystrix brachyuran*), Pig-tailed Macaques (*Macaca nemestrina*), Long-tailed Macaques (*Macaca fascicularis*), Pangolins (*Manis javanica*), Siamangs (*Smphalangus syndactylus*), and Smooth-coated Otters (*Lutrogale perspicillata*). The location of sightings were recorded in the field using a Global Positioning Systems device. These GPS points were subsequently used to map the mammal locations within a Geographical Information System (ArcGIS v9.2, ESRI, California) to a precision of approximately 3 metres.

In order to associate the number of IUCN red list mammals observed with potential predictors of presence (e.g. habitat type, distance to secondary forest, availability of water resources, presence of human disturbance, etc.), each transect was divided into 200 metre sections. Examining the distribution of mammals at this resolution allowed the number of mammals sighted within each section, during any given transect walk, to be related to the predominant environmental characteristics of the transect segment. Mammal numbers were assessed in relation to the conditions on the survey day (season, weather, time of day), the habitat that each mammal was observed within, distance to surrounding habitats, area based measures of habitat availability (the area of each habitat type present within a 1km^2 zone around each transect segment which approximates the mammals' home range zone), availability of water resources, and measures of human disturbance. Details of the variables that were calculated under each of these categories are provided in Table 2. Some of these variables were recorded during the transect walks and were estimated by visual observation by a researcher. The remaining variables were measured in GIS and were identified from satellite images and Jambi Government GIS data.

Analysis

As no more than one red list mammal was sighted within each transect segment during the walks, the presence of mammals was modelled in relation to environmental characteristics using step-wise binary logistic regression. The dependent variable was presence of a red list mammal within a 200 m transect segment. Independent variables were selected to represent each of the categories in Table 2 based on the strength of their association with presence of a mammal and were retained if they remained statistically significantly at least $p=0.05$ and their direction of effect was as expected.

To identify areas within the plantation that would be likely to support the highest numbers of IUCN red list mammals if converted to set-aside, the logistic regression mammal model was used make predictions of the likelihood of sighting a red list species across the study area. To do this, the plantation was divided into 200 metre by 200 metre grid cells in GIS, to correspond with the spatial resolution of the regression model. The distance of every grid cell from each habitat type was calculated in GIS and the slope coefficients from the model were used to predict the probability of sighting a mammal within every cell.

Table 2: Description of explanatory variables used to examine variation in mammal numbers across the plantation, including the data sources from which they were derived within GIS.

Variable Categories	Variable Names	Units	Sources of Data
Season	Rainy season	0=no 1=yes	Weather data was obtained from plantation records. The rainy season was defined as the wettest months of the year from October to April.
Weather conditions	Rain Heavy rain	0=no 1=yes	Estimated in the field by visual observation.
Time of day	Night	0=no 1=yes	Estimated in the field by visual observation.
Predominant habitat within each transect segment	Oil palm Cleared forest Secondary forest	0=no 1=yes	The distribution of habitats was identified from satellite images[1] and Jambi Government GIS data[2]. The predominant habitat of each transect segment was calculated in GIS.
Distance based habitat measures	Distance to edge of the plantation Distance to oil palm Distance to cleared forest Distance to secondary forest Distance to primary forest Distance to the nearest tree nursery Distance to farmland	kilometres	The distribution of habitats was identified from satellite images[1] and Jambi Government GIS data[2]. All distances were calculated in GIS.
Area based habitat measures (area of each habitat type within a 1km^2 zone around each transect segment)	Area of oil palm within home range Area of cleared forest within home range Area of secondary forest within home range Area of primary forest within home range Area of tree nurseries within home range Area of farmland within home range	kilometres^2	The distribution of habitats was identified from satellite images[1] and Jambi Government GIS data[2]. The area of each habitat within the home range was calculated in GIS.
	Presence of oil palm within home range Presence of cleared forest within home range Presence of secondary forest within home range Presence of primary forest within home range Presence of tree nursery within home range Presence of farmland within home range	0=no 1=yes	The distribution of habitats was identified from satellite images[1] and Jambi Government GIS data[2]. Habitats present within the home range were identified using GIS.
Availability of water resources	Distance to rivers Distance to seasonally flooded areas	kilometres	Rivers were identified from satellite images[1] and Jambi Government GIS data[2]. All distances were calculated in GIS.
Measures of human disturbance	Distance to major roads Distance to minor roads Distance to harvest roads Distance to settlements	kilometres	Roads and settlements were identified from satellite images[1] and Jambi Government GIS data[2]. All distances were calculated in GIS.

[1] Satellite images were obtained from the plantation management.
[2] Jambi Government GIS data were obtained under licence from the Jambi Government.

Results

Mammals were observed during 14% of the transect segment sampling occasions. Table 3 presents the best fit logistic regression model obtained for presence of mammals. The model accounts for 8% of the null deviance. The results show that the presence of mammals varies with distance from the edge of the plantation, with the likelihood of sighting a mammal being lower in the middle of the plantation which furthest from natural habitats, in particular primary forest. Habitats within the mammals' home range were also important. Notably, the area of secondary forest within the home range was found to be a strong predictor and this is likely to be because this is the predominant natural habitat that exists within the plantation. As expected, mammal sighting were less frequent during the night when these species, which are predominantly herbivores, are less active.

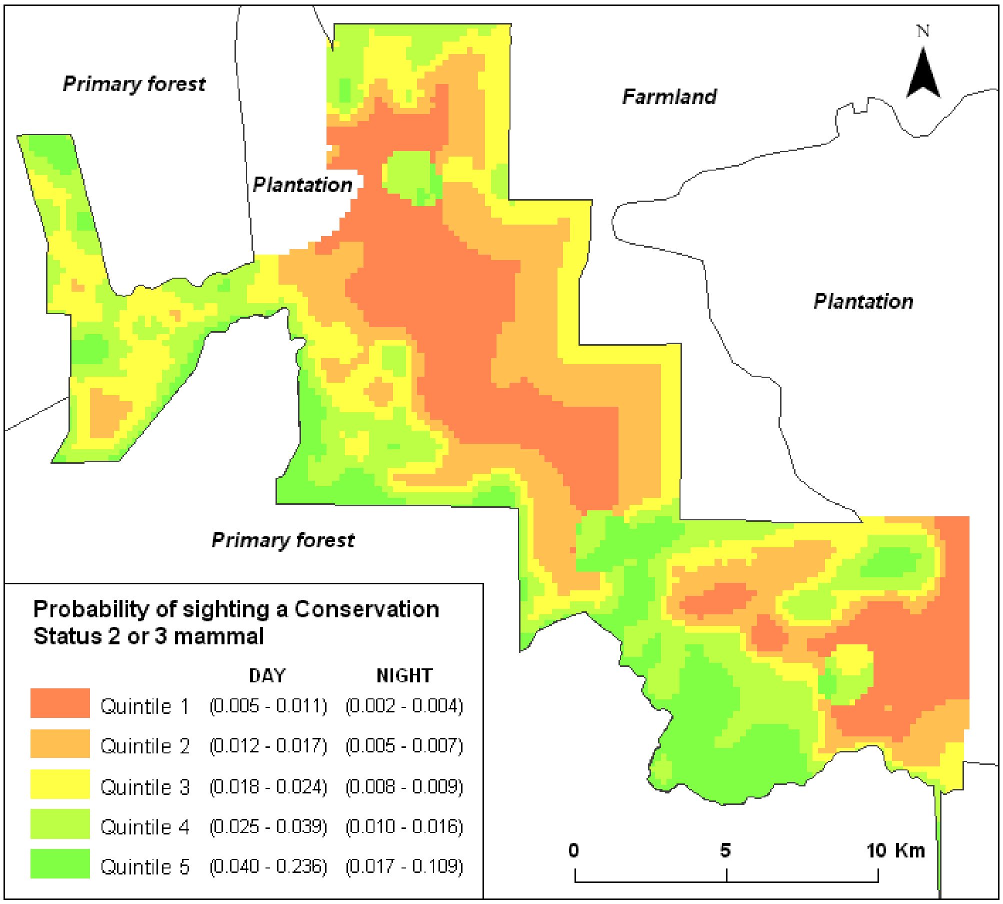
Table 3: Odds ratios for sighting an IUCN red listed mammal in relation to habitat availability.

Independent variables	**Slope coefficient (β)**	**SE for (β)**	**Odds ratio**	**95% CI**		**p-value**
				lower	**upper**	
Night (n=0, y=1)	-0.93	0.36	0.37	0.19	0.81	0.11
Distance to edge of the plantation (km)	-0.35	0.17	0.7	0.51	0.97	0.03
Area of secondary forest within home range (km^2)	1.41	0.55	4.01	1.39	11.95	0.01
Presence of tree nursery within home range (n=0, y=1)	1.23	0.54	3.42	1.18	9.9	0.02
Constant	-3.78	0.45	0.02			< 0.001

Degrees of freedom = 3314, log likelihood = 352.

Figure 5 shows the probability of sighting an IUCN red listed mammal across the plantation. The map illustrates there is a relatively low probability of sighting a threatened or vulnerable species within the centre of the plantation where the main oil palm crops are planted (<1% probability during the day). However, the presence of red list mammals increases around the edge of the plantation (>24% probability of sighting during the day) where there is higher availability of natural habitats including a greater proportion of secondary forest and better access to primary forest.

Figure 5: Probability of sighting an IUCN red list mammal across the plantation during the day and at night.



3. Cost-effectiveness analysis of oil palm conservation schemes: spatial targeting of optimal areas.

In essence the cost-effectiveness task is straightforward in that we compare the cost surface generated in Section 1 with the conservation impact surface produced in Section 2. However, in order to yield true conservation benefits the total area of set aside must be large enough to support those species in question (Brühl et al. 2003). Different species have different area requirements. Jetz et al. (2004) develop mechanistic scaling models linking animal body mass and trophic level to population density and home range size. We used these models to define three different total conservation areas that would theoretically support a predefined minimum population of all the red list species recorded within the plantation concession area. Results from this analysis showed that a minimum conservation area of 5000 ha (14% of the total concession) would be expected to retain a minimum of 22 individuals of all local species of conservation significance. A total of 11500 hectares of land was set as our mid range area scenario. This would theoretically retain a minimum of 50 individuals of all species of conservation concern. Although much debated, it has been suggested that a minimum population size of 50 individuals is required to ensure ecological integrity in wildlife populations (Franklin 1980). To explore the cost of setting aside a larger conservation area a third scenario in which 21,000 ha was conserved was also considered. Table 4 details the predicted population size for each of the relevant Red List species under each of the conservation area scenarios.

Table 4. The predicted population size of each Red List category 2 or 3 species under three conservation area scenarios (based upon models from Jetz et al., 2004).

Species		IUCN Red List Category	Population size within different size conservation areas		
Common name	Latin name		5000 ha	11500 ha	21000 ha
Pangolin	Manis javanica	3	31	72	131
Siamang	Symphalangus syndactylus	3	457	1051	1919
Agile gibbon	Hylobatres agilis	3	1337	3074	5614
Long tailed macaque	Macaca gascicularis	3	1457	3351	6119
Smooth coated otter	Lutrogale perspicillata	2	22	50	92
Pig tailed macaques	Macaca nemestrina	2	749	1723	3146
East Asian porcupine	Hystrix brachyura	2	1019	2344	4281

Aside from conservation area size, two further issues were incorporated into our analysis. First, cost-effectiveness was assessed under both the 'high' and 'low' productivity scenarios set out in Section 1. Second we investigated the effects of three different routes for choosing which areas to conserve:

(i) Maximum cost effectiveness
(ii) Random allocation of areas
(iii)Worst case (minimal cost-effectiveness)

Table 5 details per hectare OCC values (in both millions of IDR and US$) under these various permutations. As can be seen, under the most appropriate maximum cost-effectiveness scenario we see per hectare OCC steadily rising with the size of the conservation area. This reflects the fact that the plantation manager has a clear incentive to initially target unproductive land situation well away from the processing centre in areas where transport and road construction costs are highest. However, as the size of conservation scheme increases so the plantation manager is forced to place more profitable and even planted land into conservation thus raising the OCC. Note that while this trend would apply to any size concession, the precise values are dependent upon plantation size (here 32,500 ha, a typical concession size) and the matrix of habitat types. We return to consider this issue in Section 5 of this paper.

Table 5. Opportunity cost of conservation (OCC) per hectare for various sizes of conservation scheme

Implementation		Least optimal		Random		Optimal	
Productivity level		Low	High	Low	High	Low	High
‘small’ scheme 5000 ha	IDR (million	0.49	0.611	0.354	0.47	0.101	0.222
	US$	53.87	67.12	38.92	51.69	11.14	13.42
‘medium’ scheme 11500 ha	IDR (million	0.49	0.61	0.36	0.47	0.14	0.267
	US$	53.91	67.24	39.18	51.98	15.83	29.34
‘large’ scheme 21000 ha	IDR (million	0.47	0.58	0.36	0.47	0.28	0.393
	US$	51.71	64.23	39.99	51.84	30.68	43.19

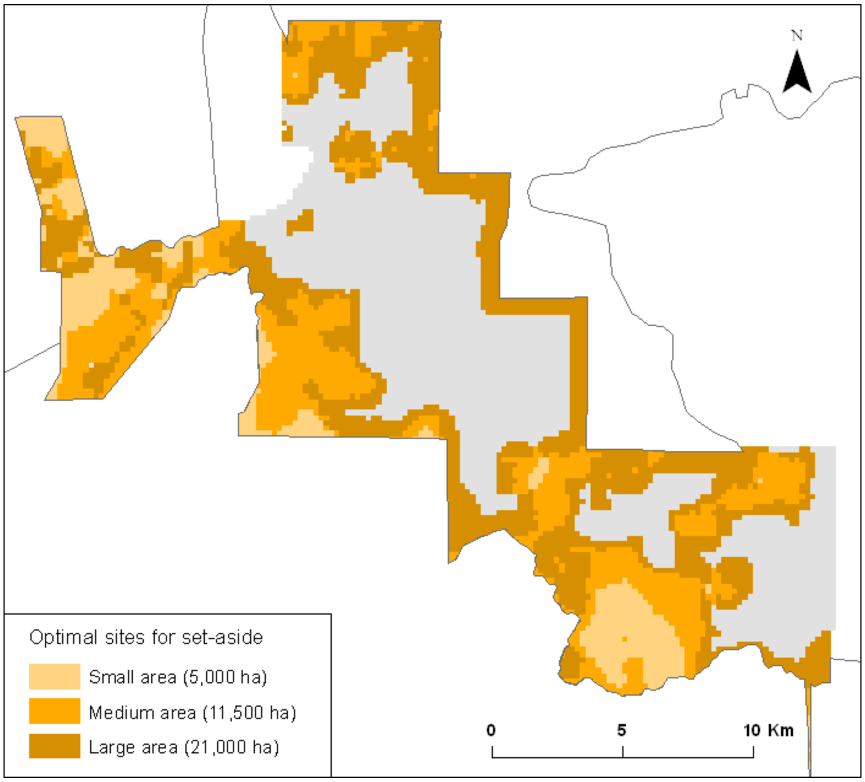
implemented under two productivity levels and via three alternative implementation method.

Figure 6 reproduces the cost-effectiveness map obtained using the optimal (maximum cost-effectiveness) implementation strategy. As can be seen, when the smallest scheme is implemented plantation managers allocate this to the lowest OCC areas. However, as the conservation scheme gets larger this forces the manager to drag more productive, higher OCC land into conservation.

The histogram below this map indicates the biodiversity effectiveness of these various schemes. These are cumulative in that the shading for the intermediate scheme shows the probability mass generated in addition to that provided by the smaller scheme. Note that the smallest scheme (lightest shading) actually is the most effective. This is because the low OCC land is at the fringes of the concession and borders several secondary forest areas which are those preferred by the Red List species. Here then we have a win-win situation in that what is optimal for biodiversity is also best (or at this stage, least cost) for the plantation manger. However, there is an important caveat here. This 'double dividend' would not apply to all species types. We also modelled effectiveness for wild pigs and Leopard cats. While the former have a distribution not too dissimilar to the Red list species (although at a higher frequency) leopard cats reveal almost the reverse distribution. This is in considerable part because they have adapted well to scavenging near to human settlements. While Leopard cats are far from endangered and of no conservation concern it should be remembered that the natural distribution characteristics of a species will play a major part in determining the pattern of cost-effectiveness results.

Figures 7 and 8 report corresponding maps and frequency distributions for the random and least optimal allocations of land into conservation. As expected these perform poorly compared to the optimal approach.

Figure 6. Optimal cost-efficiency allocation of land to three sizes of conservation scheme and corresponding histogram detailing resultant frequency distribution of mammal sighting probabilities.



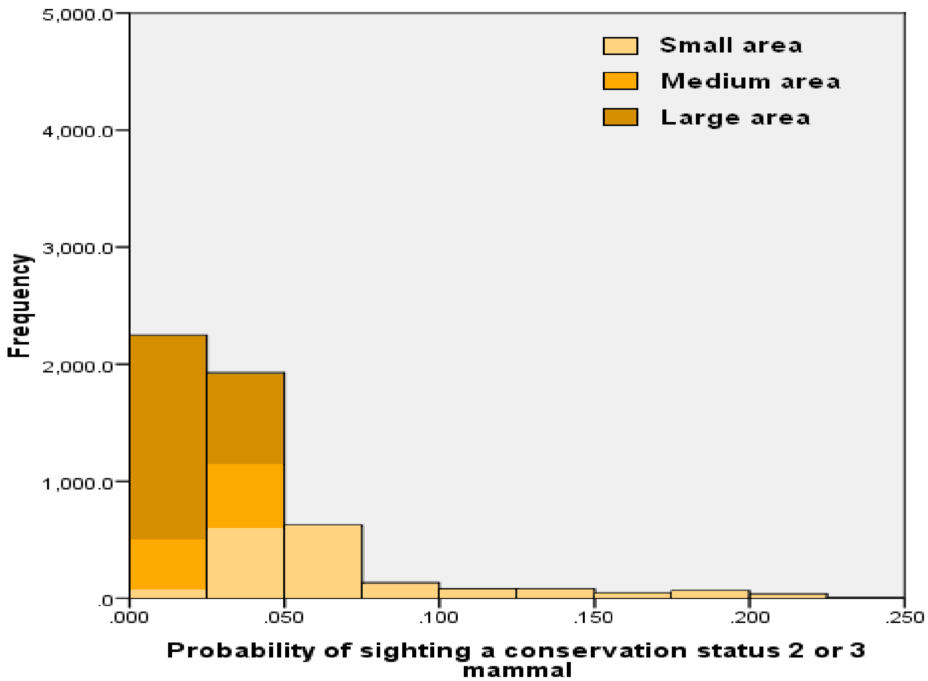


Figure 7. Random allocation of land to three sizes of conservation scheme and corresponding histogram detailing resultant frequency distribution of mammal sighting probabilities.

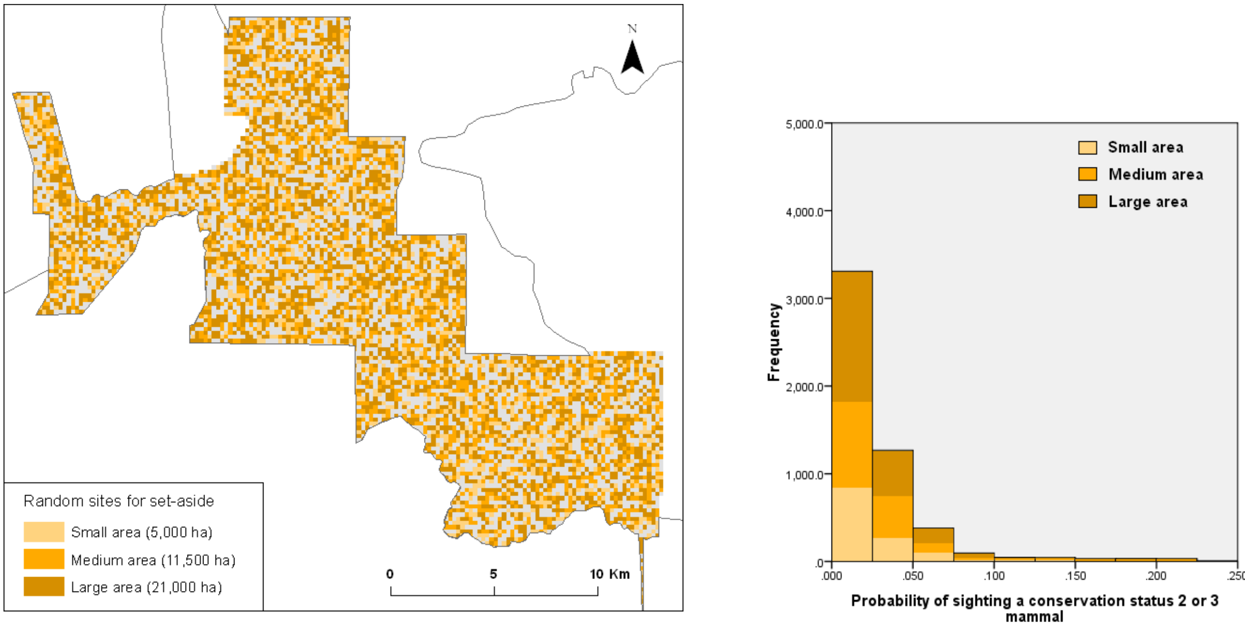
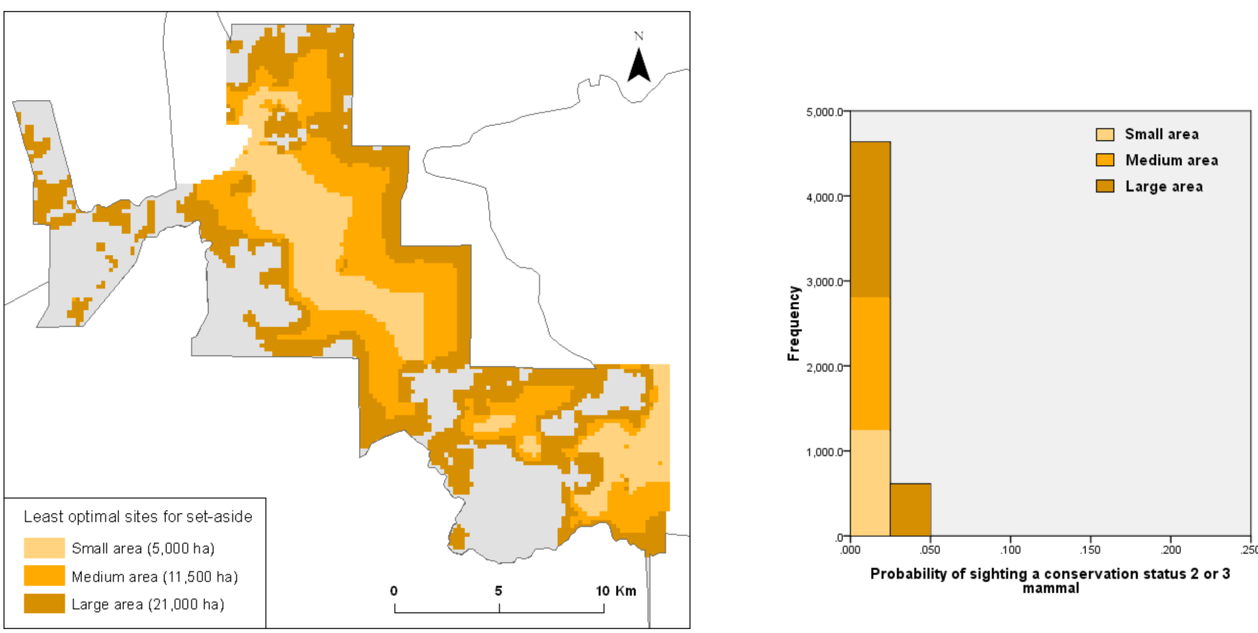


Figure 8. Least optimal (lowest cost-effectiveness) allocation of land to three sizes of conservation scheme and corresponding histogram detailing resultant frequency distribution of mammal sighting probabilities.



4. Assessing the willingness of developed country households to fund oil palm plantation conservation set-aside schemes

We now have a cost-effectiveness tool for optimizing the spatial allocation of conservation land. However, even the most cost-effective scheme still imposes costs upon the plantation. This provides a powerful disincentive for plantations to become involved in conservation. However, we argue that the introduction of the RSPO sustainable production certification scheme offers a potential solution to this problem if such certification leads to consumers being willing to pay a premium for products made with 'conservation-grade' palm oil from plantations engaging in such schemes. In order to investigate the financial viability of such a scheme we undertook a study to investigate the potential for such a price premium.

In 2007 the first RSPO certified palm oil became available on the open market, however there is currently no financial incentive encouraging the remaining producers palm oil companies to both adopt the sustainability criteria and take on the associated financial burden. One mechanism for overcoming this burden may come from tapping "Green" markets where commercial activities are incentivised to engage with conservation objectives (Butler & Laurence 2008; Ferraro et al. 2005). Here we investigate the potential for a price premium for certified palm oil by linking palm oil production with the plight of the Sumatran tiger (*Panthera tigris sumatrae*); one of the world's most endangered and emblematic megafauna (Mills et al. 2007). Extensive areas of Sumatra have been converted to oil palm plantations and the production of palm oil has become a serious threat to tropical forests (Fitzherbert et al. 2008; Kinnaird et al. 2003). Ensuring oil palm does not contribute to deforestation is fundamental in mitigating the worst environmental impacts of plantation development, not only for tigers but for all species.

To find out whether consumers are prepared to pay higher prices for conservation grade palm oil we conducted a field experiment examining the viability and extent of a potential premium for conservation grade palm oil. Using a split sample design we provide clear evidence of the significant influence of varying price, quality and marketing strategies upon this premium through analysis of both the propensity to purchase and willingness to pay for such goods. We conclude that there is a potential price premium for certified palm oil.

Methods

The focus of our study is to estimate the premium that might be attached to a palm oil manufactured under strict sustainability criteria, conservation grade palm oil (CG), as opposed to conventional production methods (CO). We choose a standard size (500g) tub of vegetable margarine as the good to be purchased, because it has high consumer recognition and palm oil is a major ingredient.

We can assess any conservation grade premium via two measures: (i) the propensity of consumers to choose CG over CO and (ii) their WTP for the CG good. While the former yields a discrete choice variable (C*hooseCG*) the latter is continuous (WTP_{CG}). Accordingly we define two dependent variables as follows.

ChooseCG = 1 if the respondent chooses the conservation grade good; = 0 otherwise (chooses the conventional good).

WTP_{CG}= the maximum amount the respondent is willing to pay for the conservation grade good

In subsequent analyses of functional form we also define;

$LnWTP_{CG}$ = natural log of the maximum amount the respondent is willing to pay for the conservation grade goods.

The WTP_{CG} response is elicited through a simple open-ended question. While this is statistically highly efficient, it is open to criticism with respect to the incentive compatibility of responses. However, this criticism does not apply to the take-it-or-leave-it nature of the discrete choice response (Carson & Groves 2007). By asking the choice question prior to the valuation question our study should be immune from criticisms on the grounds of incentive compatibility.

We have two types of treatment variables; (i) those concerning the economic drivers of price and quality and (ii) and those defining the level of marketing. Considering the former, we can define quality simply by informing respondents that the quality of the CG and CO goods is always the same, this quality being signalled by the price of the CO good. We then vary this quality signal across respondents, with one lower price signalling a lower quality product and a second higher price signalling a higher quality product. Based on a supermarket survey we posted a lower quality mean of £0.75 per tub and a higher quality mean of £1.12 per tub. We can therefore define the following binary variable:

HiQuality = 1 where CG and CO are higher quality goods; = 0 otherwise.

The same survey of market data allows us to define a plausible range of prices for the CG good. Again two levels of price were selected (£1.12 or £1.31) so we can therefore define the following binary variable:

HiPriceCG = 1 for higher posted price for CG good; = 0 otherwise.

A split sample design compared all four permutations of CG and CO prices (i.e. respondents had an equal probability of facing any pair of the CG and CO prices). The lower level of the CG price was set to be the same as the upper price level of the CO good. This allows respondents allocated to this pair a costless choice of the CG over the CO good (when both have the same price), while in all other combinations the choice of CG involves a price premium of varying size. The subsequent valuation question (discussed below) allows respondents in all treatments to specify their own maximum willingness to pay for the CG good.

Our second set of treatment variables concerns the level of marketing used for the product. For the purposes of our experiment this was implemented using three nested levels of information, each adding to that given in the lower level. The lowest of these levels (*adLow*) provided individuals with a deliberately general and non-quantified statement suggesting that some of the profit would go towards conserving habitat. The second level (*adMedium*) comprised the former statement and added the quantification of the rate at which the tiger population is being depleted (*from 1000 tigers in 1978 to less than 500 today…*). The final level of information (*adHigh*) comprised both of the above statements and added colour images of Sumatran tiger adults and cubs (Figure 9). Thus we define the following variables:

adLow = 1 if the level of marketing was Low; = 0 otherwise

adMedium = 1 if the level of marketing was Medium; = 0 otherwise

adHigh = 1 if the level of marketing was High; = 0 otherwise

There is ample evidence showing that WTP values are positively related to the level of marketing information presented to individuals (Samples et al., 1986) and we therefore have a clear expectation of a positive impact upon both choice and valuation in this application.

Figure 9. Tiger pictures used in the *adHigh* marketing level

From the above we therefore have two levels of price for the CG good, two quality levels and three levels of marketing. Combining these together defines out twelve distinct experimental treatments. Within each treatment the quality of the CG and CO goods was identical in all respects apart from whether it was produced using conservation grade palm-oil. Low quality was signalled by the lower posted price for the CO good of £0.75 and higher quality was signalled by the higher posted price of £1.12.

Our experimental design allows us examine determinants of choice and value regarding the conservation grade good. Our null hypothesis for values is that WTP for a conservation grade product (WTP_{CG}) is not significantly different from that for a conventionally produced alternative (WTP_{CO}), i.e.:

$$H_o^1 : WTP_{CG} = WTP_{CO}$$

The experiment allows us to examine whether this hypothesis holds as we vary quality and price. In so doing we can also examine whether the hypothesis holds at either the lower and upper end of the market. Our design also allows us to assess the influence of advertising upon this hypothesis. Our alternative hypothesis is directional; that WTP_{CG} exceeds WTP_{CO}.

$$H_a^1 : WTP_{CG} > WTP_{CO}$$

The questionnaire was extensively piloted (n = 150) and field data was collected using survey techniques applied at four towns across England during 2005. Some interviews were undertaken in town centres, others were conducted at supermarkets. ‘Next-to-pass’ interviewing techniques were applied to ensure a random sample. Treatments themselves are randomised such that each respondent has an equal probability of facing any of the twelve permutations of our experiment. Respondents were shown both the CG and CO tubs of margarine and given the marketing package appropriate to the treatment to which they had been allocated. Respondents are then asked to choose between the two products (generating the $Choose_{CG}$ dependent variable) and then asked to state the maximum amount they would be prepared to pay for the CG good (generating the WTP_{CG} variable).

After asking for the choice and valuation response, individuals are asked a number of other questions defining out their socioeconomic and demographic characteristics as well as various other issues which might affect preferences. To rule out variation between treatment samples resulting from external factors we used Analysis of Variance (ANOVA) to test for differences in age, income etc. (detailed Bateman et al., 2008). Given the binary nature of the $Choose_{CG}$ we model these choices using a simple logit regression. Analysis of the WTP_{CG} responses (details *ibid.*) indicated an absence of the truncation problems which sometimes preclude straightforward regression modelling for WTP data. However, specification testing suggested that a log-dependent model substantially outperformed a linear functional form.

Results

A total sample of 600 UK respondents was collected, consisting of 50 individuals facing each treatment. ANOVA showed that there was no significant difference between the characteristics of respondents in each treatment.

Across all treatments some 62.2% of respondents chose the CG good over the CO competitor. However, the $Choose_{CG}$ rate varied very substantially and in expected directions between treatments from 100% in treatment 6 (a high end of market case where both goods are offered at the same price) to just 14% in treatment 3 (where both CG and CO are lower quality with posted prices of £1.31 and £0.75 respectively).

Logistic regression analysis showed that all variables had a significant influence upon the respondent choice. Table 6 reports the best fitting model to these data (Chi-square (4) = 230.1 ($p<.001$); Correct prediction rate = 75.8%; -2 Log likelihood = 565.78; Nagelkerke R^2 = .434).

Table 6: Model of the choice between the conservation grade and conventionally produced good

	$\hat{\beta}$	s.e.	*p*
HiPriceCG	-2.021	.230	.000
HiQuality	2.408	.235	.000
adMedium	0.546	.248	.028
adHigh	1.388	.267	.000
Constant	-0.074	.214	.728

Dep. Var: *ChooseCG*. Base case level of marketing (low) = *adLow*

The negative sign on *HiPriceCG* indicates that, at any given quality level, as the price of the CG good increases so the probability that it is chosen declines. The positive sign on the *HiQuality* variable suggests that as the quality of goods increases so consumers are more likely to choose the CG alternative. The two marketing variables yield expected relations showing that positive information increases the probability of choosing the CG good and that this effect is particularly strong when images of tigers are used as part of that information. Further investigation failed to find any further significant influences upon the choice between CG and CO. Within this choice model convincingly reject the null hypothesis of choice equality between the CG and CO goods with respect to all treatments.

Table 7 reports mean willingness to pay for the CG good under each of the treatments investigated in the experiment (Bateman et al,. 2008 report further detail regarding the WTP distributions and tests of difference between all treatments).

Table 7. Mean WTP for conservation grade margarine; by treatment

	Lower quality product (Lower price for CO good = £0.75)		Higher quality product (Higher price for CO good = £1.12)	
Level of marketing	Lower posted price for CG good (£1.12)	Higher posted price for CG good (£1.31)	Lower posted price for CG good (£1.12)	Higher posted price for CG good (£1.31)

adLow	£1.06*	£0.99*	£1.30	£1.27
adMedium	£1.12*	£1.07*	£1.32*	£1.38*
adHigh	£1.26*	£1.08*	£1.47*	£1.58*

Note: * = significantly different (at p<0.05) from the price of the corresponding conventionally produced tub.

Considering Table 7, in all treatments WTP_{CG} exceeds that of the comparable conventionally produced alternative (WTP_{CO}). With the basic level of marketing (*adLow*) this difference is only statistically significant at the lower end of the market. However, at all other levels of marketing (*adMedium* and *adHigh*) the difference is consistently significant. Irrespective of marketing, a clear quality effect is observable, with WTP_{CG} at the higher end of the market consistently above that at the lower end. The impact of the posted price for CG is more complex. At the lower end of the market respondents react negatively to the excess of the posted price for CG over the price of CO; resulting in WTP_{CG} values which are below the posted price of CG (although still significantly higher than the CO price). However, at the higher end of the market WTP_{CG} is similar to or above the posted price for CG.

While in absolute terms the WTP_{CG} is highest at the upper end of the market, in relative terms the conservation grade premium is greatest at the lower end of the market (>50% compared to 35%). The resulting best fitting log-dependent model analysing the WTP_{CG} responses (detailed Bateman et a., 2008) is reported in Table 8.

Table 8: Model of willingness to pay for the conservation grade good

	$\hat{\beta}$	s.e.	Standardised $\hat{\beta}$	t	*p*
HiPriceCG	-.087	.024	-.176	-3.689	.000
*HiPriceCG * HiQuality*	.109	.033	.189	3.248	.001
HiQuality	.195	.024	.392	8.222	.000
adMedium	.056	.021	.106	2.726	.007

adHigh	.145	.021	.274	7.060	.000
Supermarket	.104	.036	.096	2.862	.004
Constant	.033	.021		1.582	.114

Dep. Var: $LnWTP_{CG}$. Base case level of marketing (low) = *adLow*; F = 48.4 (.000); Adjusted R^2 = .322

Examining the model reported in Table 8 we see a negative relationship between the posted price of the CG good and respondents willingness to pay for that good. However, this has to be interpreted in conjunction with the significant interaction between price and quality captured in the *HiPriceCG * HiQuality* variable. Together these relations indicate that, at the lower quality end of the market respondents react negatively to the higher level of the CG posted price. Examination of the size of the effects (best described by the standardised coefficient estimates) shows that this effect is cancelled out at the upper end of the market when the quality of the goods is high. In effect respondents object to high prices for poor quality goods.

Controlling for the above effect we still see the expected positive relation between quality and WTP_{CG}. Similarly the effect of marketing is as expected. Further investigation identified that WTP_{CG} proved higher amongst those interviewed at supermarkets. Given that other characteristics of respondents proved insignificant (gender, age, household structure, etc.) this suggests that it was the act of shopping and purchasing goods that drove this result (causes remain to be investigated). Given the significant relationships observed within our valuation model, we can again convincingly reject the null hypothesis.

Price premium analysis: Discussions

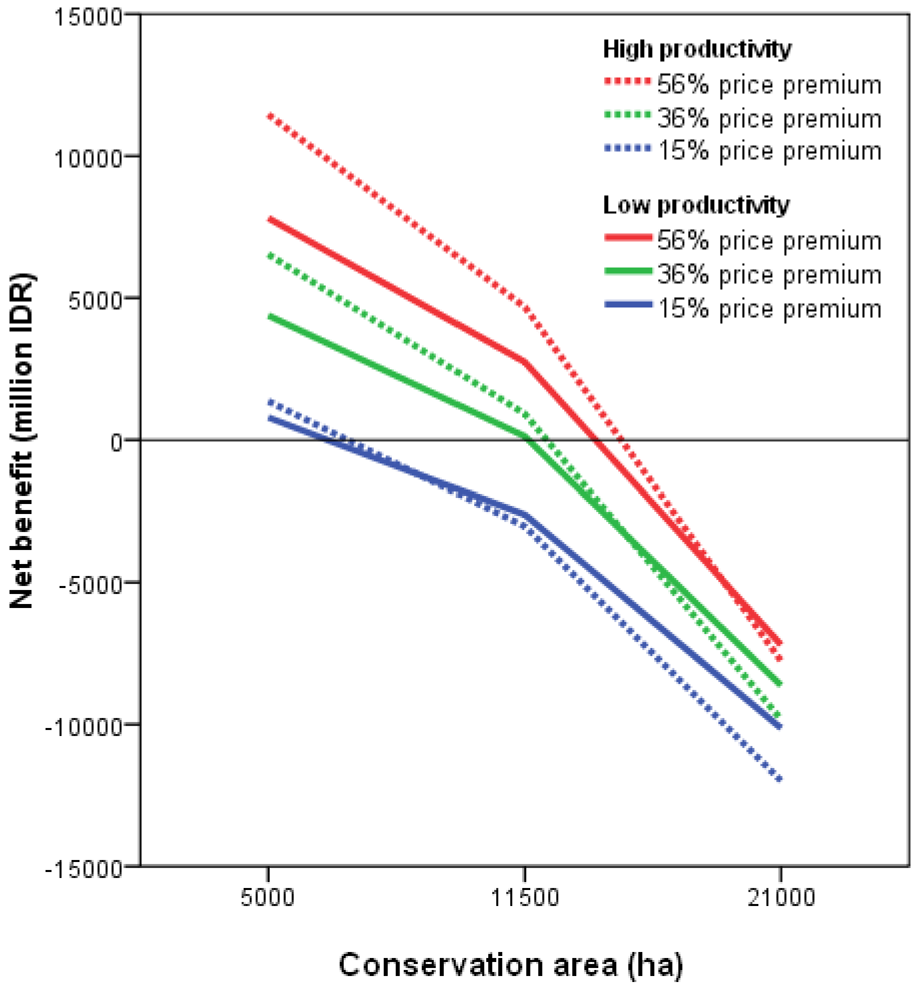
Examining the factors determining the choice of CG goods, we find, as expected, that price and choice are negatively correlated. Also as expected, at the upper (high quality) end of the market consumers are more likely to choose the CG alternative. This quality effect is also found in the valuation responses with WTP_{CG} increasing with the quality of goods. While the net impact of price upon values is negligible at the upper end of the market, this is not the case at the lower end where a high posted price for the CG good seems to trigger respondents concerns that they may be being overcharged for a poor quality good irrespective of its conservation grade credentials. In absolute terms then the premiums associated with conservation grade production are highest at the upper end, but in percentage terms the opposite is true. We also find marketing to be a significant influence on preference and valuation of the conservation good.

These results suggest that such schemes may provide a novel and potentially major route for channelling market forces towards offsetting the cost of integrating conservation measures into palm oil agricultural systems.

5. **Assessing the feasibility and optimal implementation of a market mechanism based approach to conservation within oil palm plantations.**

Our analysis of potential price premiums for conservation grade palm oil indicates a potential solution to the problem that, without an economic incentive, it will only be the most conservation minded of plantations which will adopt biodiversity enhancement schemes. Even then competitive pressures are likely to make such schemes of a minimal nature and probably short lived. To what extent might a conservation-grade price premium provide the incentive for producers to seek RSPO certification and engage in conservation schemes? To answers this question we go back to our gross margin analysis and input the various price premiums estimated in our willingness to pay analysis. Clearly there will be some level of price premium which offsets the associated opportunity costs of conservation and generates net benefits for the plantation. Figure 10 reports results from this analysis for our three sizes of conservation area under the range of price premiums estimated in Section 4 assessed at both levels of productivity.

Figure 10. The Net Benefit accrued by a plantation of a constant size (32,000ha) with varying set aside area and under different percentage price premiums.

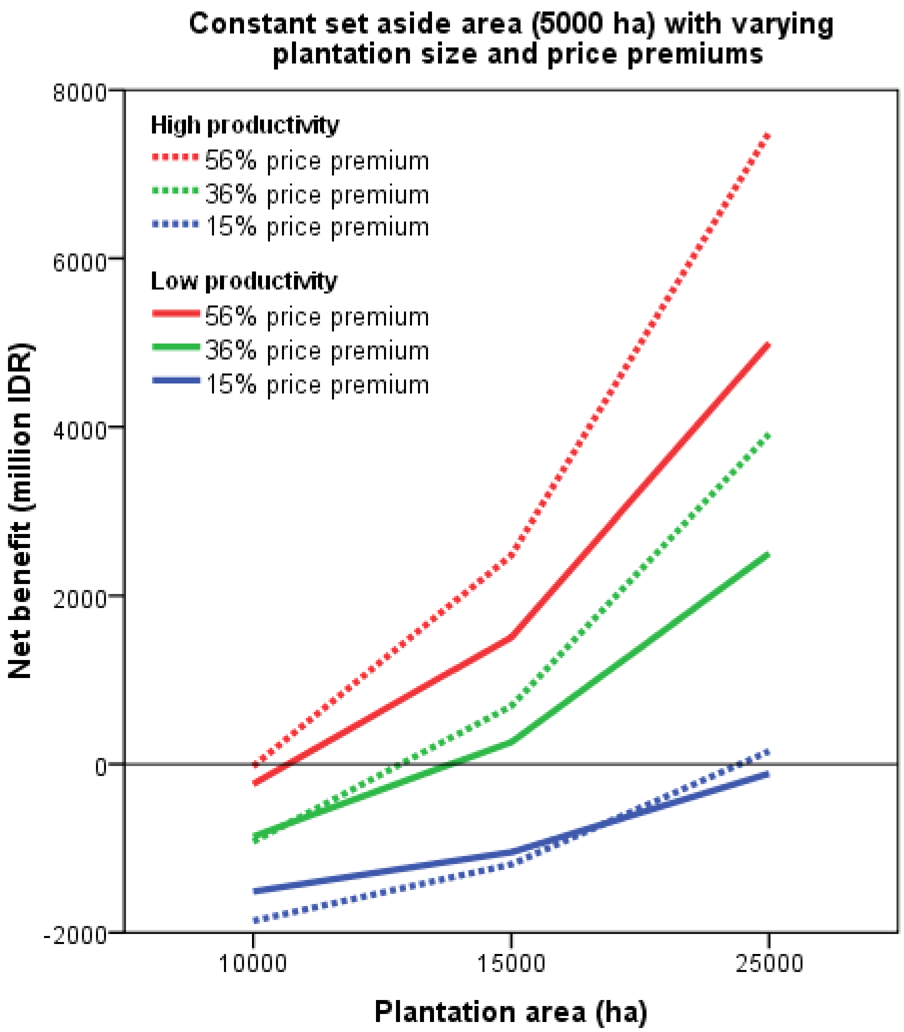


Consideration of Figure 10 shows that, while conservation clearly imposes net costs on the plantation in the absence of price premiums, the smallest conservation area scheme requires only the lowest (15%) price premium to generate a small yet positive net benefit for the plantation. Higher premium levels make such a scheme clearly beneficial for the firm and would clearly induce substantial numbers of plantation to engage in RSPO certified conservation schemes. However, larger schemes are not viable at the lower price premium level, just break even at a 36% premium and are only clearly beneficial at the highest premium levels. This is because such larger schemes require the firm to eat into productive, high profit lands. Indeed irrespective of the price premium the firm makes a net loss from the largest scale moves into conservation. Note throughout that higher productivity levels tends to amplify the net benefit or loss of any scheme.

Note that the above analysis assumes a constant plantation size of around the 30,000 ha of our case study plantation. While this is a typical size it is useful to return to the issue of scale in analyzing uptake of conservations schemes.

Figure 11 reports net benefit results for a single size of conservation scheme (the 5000ha option) as the plantation size varies (the assumption being that the habitat distribution of the concession remains constant in proportional terms). Again we vary price premiums and productivity levels. Results are revealing showing that at all plantation sizes shown (up to 25,000ha) the smallest price premium is insufficient to generate net benefits from conservation for the firm. Recall from Figure 10 that it was only at a plantation size of over 30,000 ha that the smallest price premium made the 5000ha conservation area viable. Indeed for small plantations (10,000ha and below) even the highest price premium fails to make conservation schemes financial attractive. The clear message here is that only large plantations can glean net benefits from conservation schemes. This has a significant message for conservationists who will often demonise large plantation conglomerates. It is precisely these larger organisations who are more likely to be able to make viable gains from conservation schemes when backed by conservation grade price premiums. However, a potential solution for smaller producers is to considered co-operative agreements with similar firms.

Figure 11. The Net Benefit accrued by a plantations of different sizes with a constant set aside area (5000 ha) under different percentage price premiums and plantation productivities



6. Conclusion

A growing body of evidence suggests that in the 21st Century we face a number of pressing and interrelated problems including large-scale conversion of ecosystems and the subsequent loss of biodiversity, along with growing pressure to increase economic growth. Solving these complex and interconnected problems will require knowledge about how and where we can maximize returns to land while minimizing loss of biodiversity and natural habitats. It will require spatially-explicit models of linked ecological-economic systems to feed information to decision makers as to the various options which yield cost-effective outcomes. Here we show both a methodology and result where these spatially-explicit models integrating economics and ecological phenomena can highlight where win-win situations for both species and land users. In our case study, we conclude that there is considerable potential for enhancing biodiversity, including some Red List species, through the adoption of conservation set-aside policies in palm oil plantations and that there exists the economic demand and administrative mechanisms to implement such policies. We think this study can be replicated in a variety of mosaic landscapes, as well as broadened to incorporate a bundle of ecosystem services, for identifying such win-win areas. This undertaking will be crucial in a century with continuing human population and consumption growth are pushing many species to the limits of their existence.

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