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Comparative Costs and Conservation Policies for the Survival of the Orangutan and Other Species

ABSTRACT

The extent to which conservation is feasible is constrained by budgets and the financial sacrifice stakeholders are willing to bear. Therefore a possible objective for conserving a species is to minimise the cost of achieving that stated aim. For example, if a minimum viable population (MVP) of a species is to be conserved, the size and type of habitats reserved for this could be selected to minimise cost. This requires consideration of the comparative (relative) opportunity costs of reserving different land types for conservation. A general model is developed to demonstrate this and is applied to the case of the orangutan. In the ecological literature, recommendations for reserving different types of land for conservation have been based on comparisons of either the absolute economic returns they generate if converted to commercial use or on differences in the density of a species they support. These approaches are shown to be deficient because they ignore relative trade-offs between species population and economic conversion gains at alternative sites. The proposed model for orangutan conservation shows that where land conversion may be impending, the selection of habitats (peat forests or dryland forests or combinations of both) for securing an MVP may in fact be different when comparative costs are factored in than if only absolute values are considered.

Keywords: Comparative costs; Conservation *in situ*; costs of conservation; environmental policy; minimum viable populations; opportunity costs; orangutan (*Pongo pygmaeus*).

JEL Classification: Q01, Q13, Q57, Q58.

Comparative Costs and Conservation Policies for the Survival of the Orangutan and Other Species

1. Introduction

The importance of opportunity costs and comparative opportunity costs for the optimal allocation of resources has been emphasised in the economic literature since the early 19th century (Ricardo, 1817). However, the significance of these concepts has not been adequately recognised in the literature focusing on the choice of ecological policies (e.g., Cullen, 2009). This can lead to errors in recommendations for the best allocation of available land for the conservation of wild nature and for commercial use such as for agricultural development.

The World Conservation Strategy (IUCN-UNEP-WWF, 1980) and its successor *Caring for the World* (IUCN-UNEP-WWF, 1991) recommended that the most productive land for agriculture or for similar commercial purposes be set aside for agriculture rather than be conserved. This implies that land having a low productivity from a commercial point of view should be reserved for conservation purposes. However, as pointed out in Tisdell (1991, pp. 29-31; 2005, pp. 34-38), this ignores the principle of comparative opportunity cost, that is, the comparative (or relative) productivity of land when used for alternative purposes. It relies on a comparison of *absolute* opportunity costs (economic returns forgone) rather than *relative* opportunity costs as the basis for determining the purpose for which land is used. Making this distinction is important because the absolute-cost principle does not ensure that conservation goals are achieved at minimum economic costs. Minimising economic costs makes conservation more attractive or palatable to decision-makers; more habitats or a larger population of a species could be conserved for a given amount of resources or for less monetary sacrifice.

Models have been proposed for optimising absolute economic returns and species richness over a given landscape (e.g., Polasky et al., 2008). The purpose of this article however is to show how the economic principle of comparative advantage can be applied to decisions about conserving different types of land and their associated habitats so as to achieve the probable survival of a single species' population at minimum economic cost. The principle is illustrated by taking the survival of the orangutan (*Pongo pygmaeus*) of Southeast Asia as a particular case. After discussing conceptual issues involved in this analysis and its sometimes counterintuitive results, general obstacles to conserving the orangutan are outlined. The economics of reserving different types of land areas for the conservation of the orangutan in Borneo, such as peat swamps and other land types, are then specified. The scope for the general application of this analysis is discussed.

2. Relevant conceptual issues

One aim of this article is to determine how to allocate land for the *in situ* conservation of a minimum viable population of a species so as to ensure that this is achieved at the lowest possible economic cost, where the economic cost is opportunity cost. Opportunity cost in this case is the maximum economic benefit forgone by setting aside the land for the conservation of the species rather than using it for alternative purposes. For example, in Borneo and Sumatra, the private opportunity costs of conserving land and its associated habitat for the conservation of the orangutans are often the returns forgone from not growing oil palm on this land. The social opportunity costs would include environmental externalities in addition to this.

This conservation goal raises several conceptual issues. Firstly, no conservation strategy can ensure the survival of any species forever. Therefore, strictly speaking, there is no completely safe minimum population for ensuring the continuing survival of a species. The best we can achieve are strategies that preserve or increase the chances of survival of a species (Hohl and Tisdell, 1993). In these circumstances, a workable objective is to determine the level of population needed to ensure that a species will survive with a minimum acceptable probability, for instance, 95%, for at least a specified period of time. One then attempts to minimise the economic cost of achieving this objective. This is the approach adopted here in considering the fate of the orangutan.

Second, opportunity costs are not always easy to estimate, and the question needs to be addressed of whether private opportunity costs or social opportunity costs should be used in solving this optimality problem. In practice, it is useful to consider both types of cost. Private opportunity costs are important because private economic returns from land conversion are the main driving force politically for alterations of natural habitats. But they need also to be considered as a part of social opportunity costs. Usually, more reliable information is available about this component of social opportunity cost than about its other components (e.g., environmental costs). Therefore, estimation and consideration of the private opportunity costs of conserving a species is an important step in taking into account the social opportunity cost of its conservation.

The private opportunity cost of conserving a species is highest when simultaneously each member of its population requires a large home range for its survival and the available land gives a high return when used for alternative purposes. This appears to apply, for instance, to the allocation of fertile tropical lowlands for conserving the orangutan.

The orangutan on the island of Borneo consists of three different subspecies and the conservation of populations of all three may be desirable. In such circumstances, it can be very difficult to justify, in terms of cost, the goal advocated by Ciracy-Wantrup (1968) that (at least) one safe minimum level of the population of the species be conserved, and it is unclear whether all subspecies should be conserved at this level. Furthermore, since the opportunity cost of conserving such a species is high, significant economic gain may be made by ensuring that the land area(s) set aside for its conservation is such that the aggregate opportunity cost of reserving this land is minimal.

Although the focus in this article is on the conservation of a single species, in the process of protecting land for its conservation other valued species may also be conserved. Thus the benefit from the conservation of a single species may be greater than the value of (or come at a lower cost than) its own survival, as is especially evident in the case of umbrella species. For example, conserving areas to protect the orangutan also helps conserve the distinctive proboscis monkey (*Nasalis larvatus*) (Tisdell and Swarna Nantha, 2008). Ideally, relevant synergies and associations of this type should be taken into account. At this stage, however, this analysis will only focus on the cost of conserving a single species.

The question arises of whether the conservation of a species should occur in more than one area. Other things held constant, the greater the number of separate areas in which viable populations of a species are conserved, the more likely is the species to persist for a specified period of time (and environmental conditions maintained for ecosystem services) (Luck et al., 2003). However, opportunity costs can be expected to rise as the number of protected areas increase. The analysis presented here initially assumes that only one area is to be set aside for conserving the focal species. Subsequently, consideration is given to the possibility of conserving separate populations of the species.

Bearing in mind the above qualifications, consider some of the economic and related challenges involved in conserving the orangutan, and then drawing on available scientific evidence available in Husson et al. (2008), let us apply the theory of comparative economic advantage (comparative opportunity costs) to identify types of land which if conserved are likely to minimise the opportunity cost of protecting the orangutan.

3. Some relevant background about the orangutan

The general conservation status of the orangutan according to the IUCN Red List is that it is endangered in Borneo and critically endangered in Sumatra. There has been a decline of orangutans of more than 50% in the last 60 years in Borneo and an 80% decline in Sumatra in the last 75 years (IUCN, 2009). Although the orangutan once had a wide distribution in Asia, its remaining populations are now confined to the aforementioned islands, where less than 50,000 and about 6,500 orangutans are found, respectively. In Borneo, large minimum viable populations of the orangutan only exist in Kalimantan (Indonesia) and Sabah (Malaysia). Sarawak (Malaysia) has a border area with Kalimantan that contains orangutan and provides a minimum viable population of orangutan when combined with an adjoining area in Kalimantan. There are no orangutans in Brunei.

The orangutan is a highly specialised hominid which relies primarily on fruits from tropical trees for food (e.g., Rijksen and Meijaard, 1999). This is supplemented by the eating of young shoots, barks and insects. Because of its comparatively specialised diet, each orangutan requires a relatively large land area of diverse flora to provide it with food. Unlike other great apes, it is not gregarious and this appears to be a consequence of the large forested areas that each orangutan requires to provide it with sufficient food.

Another factor that obligates orangutans to living in natural forests is that they find it easiest to travel through a closed forest canopy rather than along the ground. Therefore, they normally occupy the forest canopy and sleep in beds (nests) built high in the canopy. The fact that orangutans are usually solitary and are normally present high in the forest canopy makes them difficult to locate and view. This results in their potential for nature tourism in the wild being much less than for other hominid species, such as the gorilla.

The greatest threat to the continuing survival of the orangutan is believed to be the conversion of forested land to oil palm plantations (Swarna Nantha and Tisdell, 2009; Wich et al., 2008). There are also threats from land conversion for other purposes as well such as for timber plantations and also from large-scale intensive logging that is often illegally done. In many cases, logging is a forerunner to the establishment of oil palm plantations or other types of agriculture. Profits from the initial logging of a forested area can add to the financial viability of converting these lands into oil palm plantations (Clay, 2004). This it can do by reducing initial cash flow problems and providing investible funds. Other things held constant, land areas that give a high and rapid return from logging add to the financial attractiveness of starting oil palm plantations. These large returns from logging have also resulted in cases where lands are abandoned once timber gains are made (Holmes, 2002).

Fires are often lit after logging to dispose of remaining vegetation and residual forest wastes and to return any fertilising nutrients contained in them to the soil. These fires can escape and create forest fires during dry periods. Such fires are a further threat to the survival of orangutans.

An additional problem in conserving the orangutan is that it has the slowest birth rate amongst all mammals. Orangutans reach reproductive maturity only after a period of 8 to 15 years and produce one offspring every 7 to 8 years (e.g., Payne and Prudente, 2008). Consequently, the survival of populations is vulnerable even to the relatively lower rates of orangutan loss that are caused by hunting or by its capture for the pet trade or similar purposes.

4. A model for the application of the theory of comparative advantage to the conservation of a single species

For ease of application and as a first approximation, a linear model is proposed as the basis for determining the most economic allocation of land in order to conserve, *in situ*, a minimum viable population of a species, X. The problem is to find the allocation of land between its reservation for conserving a species, X, and its consumptive use for commercial purposes (such as agriculture) such that this allocation minimises the economic cost (the opportunity cost) of conserving the species. In the next section, this model will be applied specifically to the conservation of the orangutan.

Suppose that $i = 1, \ldots, n$ separate areas of land of varying types of habitat are available and that they are individually suitable for conserving a minimum viable population, K_i, of species, X. The minimum viable population (MVP) of the focal species could vary between land areas. For example, other things equal, the MVP of a species may be higher in regions where its food supply fluctuates more than elsewhere.

Assume that in location i an area of land of $\overline{L_i}$ km^2 is available to support species, X, at an average density of λ_i per km^2 and that L_i km^2 of this land may be allocated to the growing of crops (or other forms of commercial production). Commercial economic production is assumed to provide an average private economic benefit of Π_i per km^2. In the area of land where commercial production occurs, species X is assumed to disappear. There is, therefore, a trade-off between the level of population of X in location i and the use of this land for commercial production. The relationship can be expressed as:

$$Y_i = \lambda_i (\overline{L_i} - L_i) \qquad (1)$$

where Y_i is the population size of the focal species. Private economic benefit, R_i from converting land to commercial production in location i can be expressed as:

$$R_i = \Pi_i L_i \qquad (2)$$

where Π_i is the average private economic benefit (e.g. profit) per km^2 from converted land.

Consequently, the trade-off function between the population of species X conserved at site i and private economic returns can be found. From equation (2):

$$L_i = R_i/\Pi_i \qquad (3)$$

Substituting in equation (1), the trade-off function is:

$$Y_i = \lambda_i \overline{L_i} - \lambda_i R_i/\Pi_i \qquad (4)$$

Letting $\lambda_i \overline{L_i} = a_i$ and $\lambda_i/\Pi_i = b_i$, this can be re-expressed as

$$Y_i = a_i - b_i R_i \qquad (5)$$

The intercept of this line with the Y-axis, a_i, indicates the minimum population of species X that site i is able to sustain in the absence of land conversion and b_i represents the rate at which the size of the population of X at site i is reduced in order to obtain an increase in private benefits from commercial production. It is the rate of trade-off between conservation of the population of X and private economic benefit from land conversion. Its inverse represents the extent to which private economic benefits from land conversion have to be forgone to elevate the size of the population of X. The intercept of the line represented by equation (5) with the R_i - axis is:

$$R_i = a_i/b_i = \Pi_i \overline{L_i} \tag{6}$$

It is the total private return that can be obtained by converting all the available suitable land at site i to commercial production. Note that not all the available land area may be suitable for commercial production and therefore Π_i needs to be adjusted accordingly by a scaling variable. For example, if only 80% of the land is suitable for commercial use, this variable would be 0.8.

Given this approach, knowledge of only two numerical values is needed to estimate the trade-off function. These are the maximum population of species X that site i can sustain and the maximum private economic benefit to be obtained from total economic conversion of land at this site. These values are respectively, $a_i = \lambda_i \overline{L_i}$ and $\Pi_i \overline{L_i}$.

This aspect is illustrated in Figure 1. There line ABC represents the trade-off between the level of population of species X at site i and the private economic benefit to be obtained from converting the land to commercial production. Point A corresponds to the maximum population of X that can be sustained at the site and point C corresponds to the maximum private economic benefit that could be obtained by land conversion. If at site i, the MVP of species X is K_i = OF, this constraint can be met at point B. Hence, a private economic benefit of OD can be obtained by converting some land to commercial production at site i and leaving enough unused land to conserve the MVP of X. The amount of land that needs to be conserved to achieve point B and thereby conserve the MVP of X can be found by substituting K into Equation (1) and rearranging. It is:

$$K_i = \lambda_i(\overline{L_i} - L_i), \tag{7}$$

$$\overline{L_i} - L_i = K_i/\lambda_i, \tag{8}$$

The remaining area land,

$$L_i = \overline{L_i} - K_i/\lambda_i \tag{9}$$

can be set aside for commercial production.

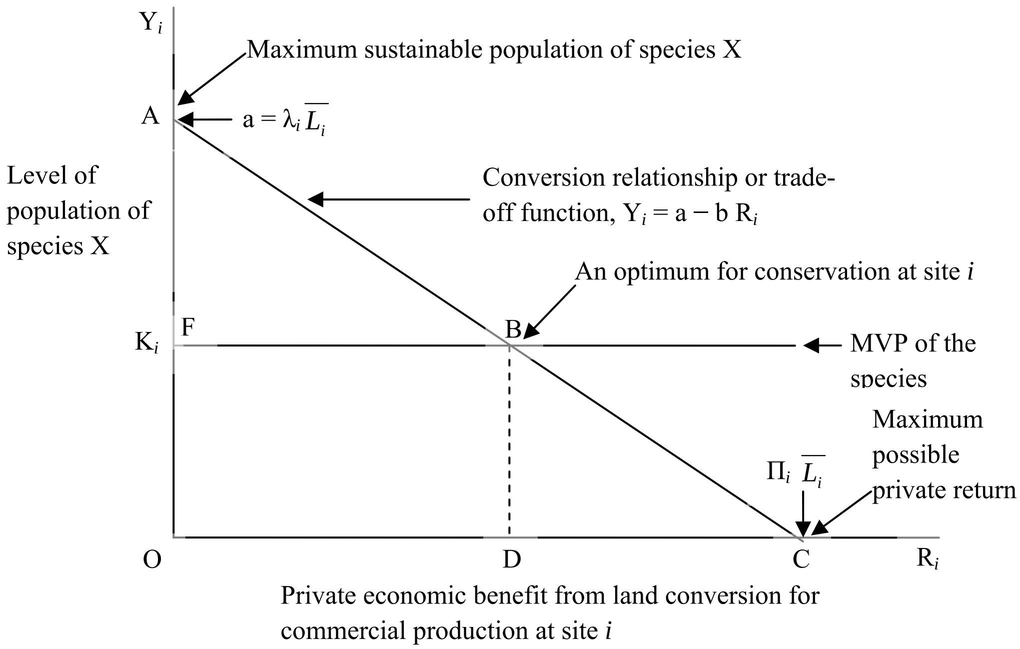

Figure 1: An illustration of the trade-off between conversion of land for private economic gain and the population size conserved of a species. This figure is also used to illustrate the solution of an optimisation problem outlined in the text.

In order to solve the problem of minimising the total private opportunity cost of conserving a MVP of species X (when only a single site is set aside for its conservation), it is necessary to consider the level of private economic benefits forgone at each of the available sites in order to achieve the MVP of species X at each of these sites, that is K_i. This can be found by taking the difference between R_i when $Y_i = 0$ and R_i when $Y_i = K_i$. The site should be singled out for conserving the species for which this difference is lowest. This will minimize private opportunity cost. When $Y_i = 0$, it follows from (5) that

$$Y_i = 0 = a_i - b_i R_i \tag{10}$$

and therefore,

$$R_i = a_i/b_i \tag{11}$$

When $Y_i = K_i$

$$K_i = a - b_i R_i \quad (12)$$

and rearranging,

$$R_i = (a_i - K_i)/b_i \quad (13)$$

Consequently, when sufficient land is set aside at site *i* to conserve K_i of species X the economic benefit foregone, C_i, is

$$C_i = a_i/b_i - (a - K_i)/b_i \quad (14)$$

$$= K_i/b_i \quad (15)$$

where $b_i = \lambda_i/\Pi_i$. This result is of **central importance** for decision-making in this conservation case because the site should be selected for conservation of species X that minimizes K_i/b_i if a single minimum viable population is to be selected so as to minimise opportunity cost.

Some important implications of expression (15) should be noted. First, the location for which K_i/b_i is lowest is the one that minimises the opportunity cost of conserving a minimum viable population of species X. If more than one separate viable population of the species is to be maintained, the private opportunity costs are minimised by adding conservation of the species at other available sites in ascending order of K_i/b_i. Observe that since $b_i = \lambda_i/\Pi_i$, the value of this expression does not depend on the *absolute* densities of species X that can be supported at a site nor does it depend on the average level of economic returns per km^2 yielded by commercial 'development' of a site. Only the *relative* marginal opportunity costs of conserving species X at one site and the required size of its MVP are relevant in this optimisation problem.

It can be seen that, other things held constant, a rise in the required MVP for X at a site increases the opportunity cost of conserving it at that site, and also an increase in marginal opportunity cost does likewise. If the MVP for X is the same at all sites, the site for which b_i is largest (the one for which a reduction in R_i results in the largest increase in population of X) is the one that minimises the opportunity cost of conserving species X. If two sites have a similar value for b_i, the one with the lowest value of K_i minimises the private opportunity cost of conserving species X.

5. A Discussion and extension of the above model

First, it should be noted that the trade-off function in the above model is assumed to be continuous. However, if the MVP for the species X represents a threshold (as it is supposed to) then in reality, the trade-off function has a discontinuity. In Figure 1, for example, once the extent of land conversion is such as to yield a private economic return marginally in excess of OD, the probable survival of species X falls below the targeted level and its population is liable to disappear. Thus, its population may fall to zero for private commercial returns in excess of OD. However, this complication does not invalidate the procedure outlined above for solving the optimisation problem specified.

Note that there is also a qualitative dimension to the above problem which is implicit to the model. The viability of a population does not depend merely on gross land area alone; the *type* of land converted or reserved is also crucial. Scenarios where similar amounts of land are converted but those of differing habitat qualities for the orangutan could have varying implications for orangutan densities and, by extension, the MVP. For example, the conversion of land most conducive for orangutan habitation could have a larger negative impact on survival the conversion of a similarly-sized land that has fewer important food resources. Likewise, the shape and habitat connectivity of the land set aside for conservation also affects the b_i variable (in other words, giving up a specific amount of opportunity costs by conserving habitat could result in a smaller or larger number of conserved orangutans depending on the mentioned qualitative factors).

Secondly, in practice, the optimal solution presented in the model is unlikely to be achieved because of political pressures. Other things equal, the greatest political pressure will be applied to allow conversion of natural areas to commercial use that give the largest private economic gains. Their relative productivity for conserving a focal species is likely to be given scant consideration. As a result, the private opportunity cost of conserving a species may not be minimised.

This can be illustrated by Figure 2. Consider two sites, I and II. Compared to site I, site II is assumed to conserve more of species X per km^2 (e.g., it has a higher density of orangutans on average, λ_i) if left in its natural state and is also assumed to give greater private profit per km^2 if converted to commercial use. There will therefore, be greater commercial pressure to develop site II than site I. For example, in Figure 2, ABC might represent the trade-off function between the level of population of species X and private profit at site I and $A'B'C'$ might represent that at site

II. Given that K is the MVP of species X at both sites, private opportunity costs are minimised by conserving the species at site II rather than site I. The opportunity cost of conserving a MVP of the species at site I is equal to DC whereas it is only D′C′ at site II. The latter is smaller in amount because A′C′ declines more sharply than AC. The rate at which profit has to be forgone at site II to increase the population of X is less than at site I. On the other hand, a higher absolute amount of profit per km^2 is foregone if site II is used to conserve the species. Such a choice is likely to generate considerable political opposition by commercial interests.

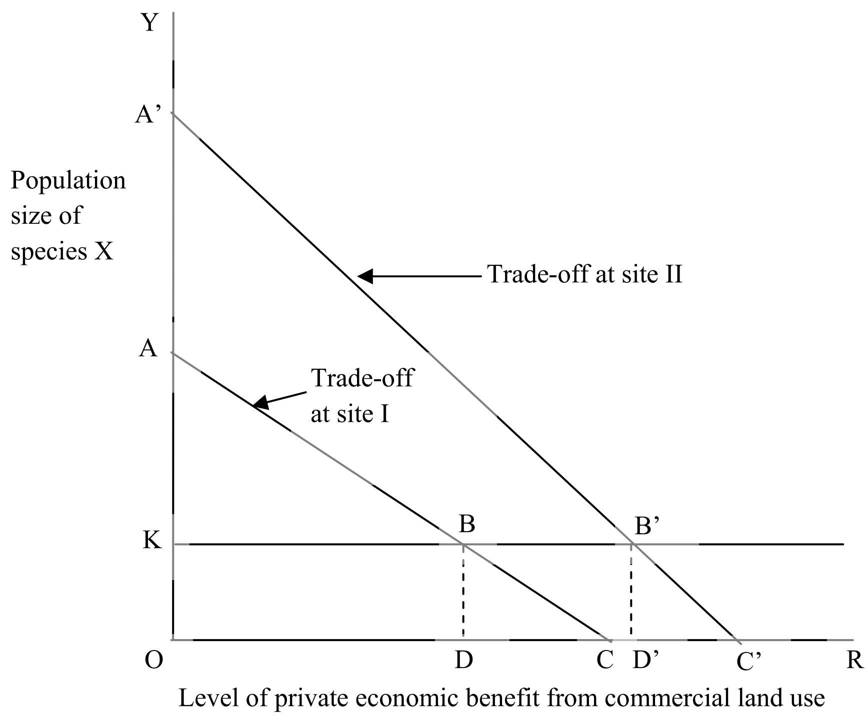

Figure 2: Sometimes conserving a species on land that has the greatest commercial value minimises opportunity costs as is explained in the text and illustrated above. The opportunity cost of conserving a MVP of the species at site I in the above case is DC but it is D′C′ at site II, which is a lower cost.

The above exposition indicates that even if private economic gains are the only consideration, social pressures can result in land conversion that does not minimise the private opportunity costs of conserving a species. Furthermore, economic failure is even more likely if the goal is to conserve the focal species in a way that minimises social opportunity costs. The social economic gains from land conversion are likely to vary with the location of the land and its properties, and in most cases it differs from private economic benefits. Ideally, the social opportunity costs of conserving a species should be minimised, although it needs to be noted that social opportunity costs are difficult to measure and there can be considerable differences in opinion about their magnitude. However, the concept is important. For example, if there are two different areas where a MVP of species X can be conserved for a similar private opportunity cost, socially one may not be indifferent about the area to select for their conservation. For example, the negative externalities generated by commercial production in one of these areas may be greater than in the other. Therefore, it would be socially desirable to conserve the species in the area which would generate the least negative spillover when used commercially. This type of issue arises in setting aside areas for the conservation of the orangutan as will become evident in the next section of this paper.

Note also that, as explained earlier, in many cases it is not just the size of an area reserved for the conservation of a species that is important but also its spatial characteristics. Areas conserved for the orangutan basically need to be compact and continuous and not disjointed and scattered, i.e., fragmented. In addressing the above issue, the spatial requirements of a species cannot be disregarded but it adds to opportunity costs.

Finally, the model presented here is a linear one and more complexity could be introduced into it, such as curvilinearity to reflect changes in comparative cost variations in thresholds relating to the type and intensity of land-use, the biological sensitivity of the species to habitat modification, and curves of varying slopes to reflect financial dynamics (e.g., the rate of return may decline as large amounts of land becomes converted for production due to, e.g., a supply-side glut).

6. Selecting areas for conserving an MVP of orangutans

Can any lessons be learnt from the above modeling about selecting areas for the conservation of orangutans so as to ensure that the conservation areas selected minimise economic cost and ensure that a MVP of orangutan is achieved? Husson et al. (2008) identify differences in orangutan densities supported by different types of landforms. On the whole, they found that densities were highest in descending order in mosaic landscapes (peat and dry forests), peat swamps, dry forests, and karst forests. However they state that while they found that peat-swamp forests support higher mean densities of orangutan than dry forest habitat, the difference was not statistically significant, contrary to what they had initially predicted (Husson et al., 2008, p. 93).

It is therefore not yet entirely clear whether orangutan densities tend to be strictly higher in peat-swamp forests than in dryland forest.

If we assume that these densities are much the same, and we consider two areas (one consisting of peat swamps and the other of dryland forest) both of which are capable of sustaining a MVP of orangutan, the economic choice of which habitat to select for a reserve will hinge on the relative opportunity cost of providing the reserve. The private economic returns from growing oil palm on areas of peat swamp are likely to be somewhat lower per unit area of land (and for a given density of planting) than from the cultivation of palms on dryland forests with mineral soils. Palms grown on peat likely require heavier rates of fertiliser application (e.g., phosphate, copper and zinc) and it can be more difficult to sustain yields (Andriesse, 1988, p. 99; Mutert et al., 1999; Singh, 2008). Higher densities of palm per hectare may need to be planted on deep peat, which could mean additional production costs. Therefore, reserving peatlands for orangutan conservation is likely to involve lower marginal private opportunity costs than doing this in areas of dryland forest.

Furthermore, from several perspectives, the use of peatland rather than dry forest habitat for growing oil palm involves higher negative externality costs. Agricultural use of peatland is associated with greater levels of release of CO_2 to the atmosphere and a greater frequency and duration of wild fires. Moreover, exploiting only a part or certain sections of a peat swamp for oil palm planting could still jeopardise overall peat swamp ecological and hydrological stability leading to its systemic collapse (FAO, 2008). These negative externalities suggest that the social economic benefit of reserving peatland for conservation purposes is higher than for dryland forest. Nevertheless, it is likely to be desirable to conserve both habitats if biodiversity conservation is a prime consideration.

The relative economic benefit of preserving karst forests is unclear. While karsts host significant species endemism, they support low orangutan densities and are not considered an important focus for orangutan conservation (Marshall et al., 2007). Although some, not all, karst forests have rich and productive soils suitable for agriculture such as for rice production and oil palm, they most valued economically for mining and are quarried for cement, marble and lime for agriculture (e.g., to reduce the acidity of peat soils) (Schilthuizen et al., 2005). In any case, the necessary trade-offs are unknown at this time between orangutan populations and the development of agriculture on karst lands.

7. Concluding comments

More research is urgently required to estimate accurately the opportunity costs, private and social, of conserving different types of habitat for orangutans. This will improve decision-making about the selection of sites for the conservation of this species. Greater attention should be given to the approach of ecological economics, which combines ecological and economic consideration, in order to improve choices about the conservation of species.

This is underlined by the main implication that Husson et al. (2008) draw from their well-researched ecological results about populations of orangutans. From their findings, they conclude that "sites with the highest density of orangutans should be prioritized for conservation (together with the largest remaining populations), and we show these to be sites with a mosaic of habitats. It is therefore essential to preserve this habitat heterogeneity, in particular by protecting riverine habitat and by preventing peatland damage" (p. 96).

As is evident from the model outlined in this article and as detailed below, focusing on conserving habitat that contains the highest density of a species does not necessarily minimise opportunity cost of protecting it. It will, however, reduce the area of land required to achieve a given targeted population of the species. Nevertheless, the amount of land saved may have little ecological and economic significance in itself. For example, high densities of orangutans may be successfully conserved in a relatively smaller space but overall biodiversity and ecological functioning may be compromised. The opportunity to conduct sustainable forestry over an adequate amount of area may also be reduced. Although conserving sites containing the largest remaining population of a species should raise the probability of the survival of the species it could also be a costly strategy. It ignores the economics of conservation.

Using the theory outlined above, Figure 3 can be used to illustrate the point that the criterion of Husson et al. (2008, p. 96) does not necessarily minimise the cost of conserving the orangutan. Once again, assume that there are two alternative sites I and II where the orangutan can be conserved. Suppose that they are of equal size and that site II can support the highest density of orangutans. Suppose also that a higher rate of profit per km from conversion can be obtained at site II than at site I but that the rate of reduction in the population of orangutan at site II for increased profit is less at site II than site I. Also assume that the MVP at both sites is K. If it is decided to conserve an MVP of orangutans at site II rather than site I (as the Husson et al. criterion recommends), the opportunity cost would be higher than if the opposite choice was made. A line like ABC in Figure 3 can be drawn to represent the trade-off at site I and A'B'C' can be drawn to illustrate that of site II. Should enough orangutans be conserved at site II to satisfy MVP = K, the opportunity cost is equivalent to D'C' whereas if it is done at site I, it is DC. The latter amount is less than the former one because the trade-off function ABC is steeper than A'B'C'. This drives home the point that differences in the absolute densities of the population of a species able to be supported by dissimilar areas and differences in the profitability of converting these areas to commercial use cannot be relied on to determine the reservation of land to minimise the cost of conserving a species.

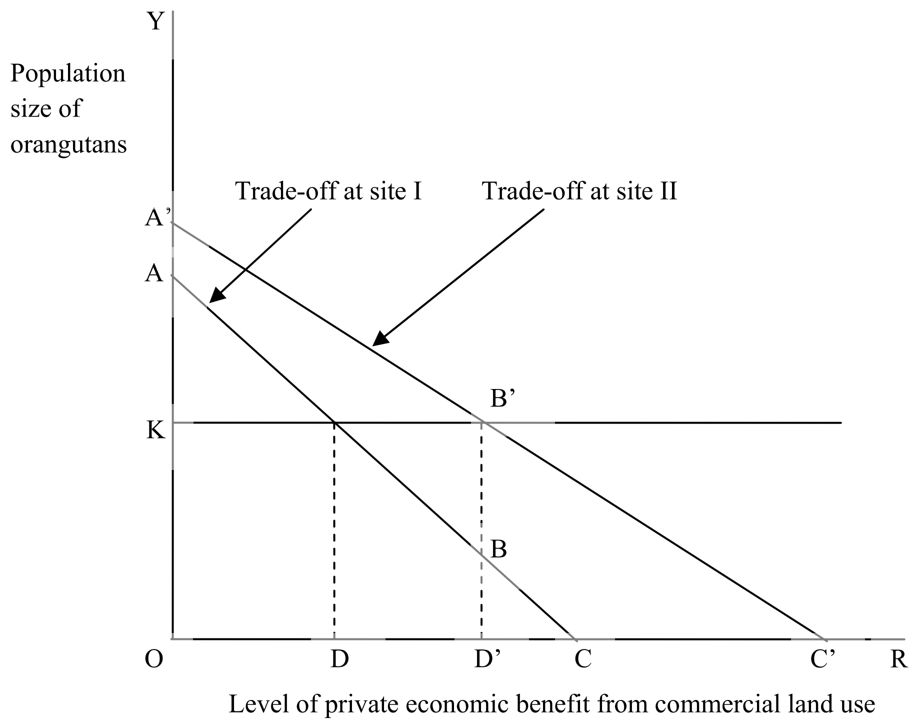

Figure 3: An illustration that the criterion of Husson et al. (2008, p. 96) may fail to minimise the economic cost of conserving the orangutan.

Clearly more attention needs to be given to the goals or objectives to be pursued in conserving species and these should be stated specifically. In most cases, economic constraints and considerations need to be taken into account in formulating objectives for nature conservation and this will influence the strategies satisfying the objectives. In formulating ecological and biological policies for conservation, greater attention should be given to economic principles if changes in resource use are recommended. This can result in more efficient conservation choices.

References

Andriesse, J.P., 1988. Nature and Management of Tropical Peat Soils. FAO, Rome.

Ciracy-Wantrup, S.V., 1968. Resource Conservation: Economics and Policies (3rd ed.). Division of Agricultural Science, University of California, Berkeley.

Clay, J., 2004. World Agriculture and the Environment: A Commodity-by-Commodity Guide to Impacts and Practices. Island Press, Washington DC.

Cullen, R., 2009. Is economics being outcompeted in environmental decision-making? Connections, Paper #98. Available from: http://www.agrifood.info/connections/2009/Cullen.pdf. Accessed 3 February 2010.

FAO, 2008. Oil-palm estate development in Southeast Asia: consequences for peat swamp forests and livelihoods in Indonesia. Pp. 81-86 in FAO, Scoping Agriculture–Wetland Interactions: Towards a Sustainable Multiple-response Strategy. FAO, Rome.

Hohl, A. and Tisdell, C.A., 1993. How useful are environmental safety standards in economics? The example of safe minimum standards for protection of species. Biodiversity and Conservation 2: 168-181.

Holmes, D.A., 2002. Where Have All the Forests Gone? Environment and Social Dvelopment, East Asia and Pacific Region Discussion Paper Series. The World Bank, Washington DC.

Husson, S.J., Wich, S.A., Marshall, A.J., Dennis, R.A., Acrenaz, M., Brassey, R., Gumal, M., Hearn, A.J., Meijaard, E., Simorangkir, T. and Singleton, I., 2008. Orangutan distribution, density, abundance and impacts of disturbance. Pp. 77-96 in S.A. Wich, S.S.U. Atmoko, T.M. Setia and C.P. van Schaik (eds.), *Orangutans: Geographic Variation in Behavioral Ecology and Conservation*. Oxford University Press, Oxford.

IUCN-UNEP-WWF, 1980. The World Conservation Strategy: Living Resource Conservation for Sustainable Development. IUCN, Gland, Switzerland.

IUCN-UNEP-WWF, 1991. Caring for the World: A Strategy for Sustainable Living. IUCN, Gland, Switzerland.

IUCN, 2009. The IUCN Red List of Threatened Species. Available from: www.iucnredlist.org. Accessed 4 January 2010.

Marshall, A.J., Salas, L.A., Stephens, S., Nardiyono, Engstrom, L., Meijaard, E. and Stanley, S.A., 2007. Use of limestone karst forests by Bornean orangutans (*Pongo pygmaeus morio*) in the Sangkulirang Peninsula, East Kalimantan, Indonesia. American Journal of Primatology 69: 212-219.

Mutert, E., Fairhurst, T.H. and von Uexküll, H.R., 1999. Agronomic management of oil palms on deep peat. Better Crops International 13: 22-27.

Luck, G.W., Daily, G.C. and Ehrlich, P.R., 2003. Population diversity and ecosystem services. Trends in Ecology & Evolution 18: 331-336.

Payne, J. and Prudente, C., 2008. Orang-utans: Behaviour, Ecology and Conservation. New Holland Publishers, London.

Polasky, S., Nelson, E., Camm, J., Csuti, B., Facker, P., Lonsdorf, E., Montgomery, C., White, D., Arthur, J., Garber-Yonts, B., Haight, R., Kagan, J., Starfield, A. and Tobalske, C., 2008. Where to put things? Spatial land management to sustain biodiversity and economic returns. Biological Conservation 141: 1505-1524.

Ricardo, D., 1817. The Principles of Political Economic and Taxation (1955 reprint). Dent, London.

Rijksen, H.D. and Meijaard, E., 1999. Our Vanishing Relative: The Status of Wild Orang-utans at the Close of the Twentieth Century. Kluwer Academic Publishers, Dordrecht; Boston.

Schilthuizen, M., Liew, T-S., Elahan, B.B. and Lackman-Ancrenaz, I., 2005. Effects of karst forest degeneration on pulmonate and prosobranch land snail communities in Sabah, Malaysian Borneo. Conservation Biology 19: 949-954.

Singh, G., 2008. Sustainable development of peatland for oil palm. In: *The International Symposium on Tropical Peatland*, Kuching, Sarawak, Malaysia, August 2008. Available from: http://www.geog.le.ac.uk/carbopeat/kuchingcontents.html. Accessed 3 February 2010.

Swarna Nantha, H. and Tisdell, C., 2009. The orangutan–oil palm conflict: economic constraints and opportunities for conservation. Biodiversity and Conservation 18: 487-502.

Tisdell, C.A., 1991. Economics of Environmental Conservation (1st ed.). Elsevier, Amsterdam.

Tisdell, C.A., 2005. Economics of Environmental Conservation (2nd ed.). Edward Elgar, Cheltenham, UK and Northampton, MA, USA.

Tisdell, C.A. and Swarna Nantha, H., 2008. Conservation of the Proboscis Monkey and the Orangutan in Borneo: Comparative Issues and Economic Considerations. Pp. 225-250 in V. K. Gupta and A. K. Verma (eds.), Perspectives in Animal Ecology & Reproduction, Vol. 5. Daya Publishing House, Delhi.

Wich, S.A., Meijaard, E., Marshall, A.J., Husson, S., Ancrenaz, M., Lacy, R.C., van Schaik, C.P., Sugardjito, J., Simorangkir, T., Traylor-Holzer, K., Doughty, M., Supriatna, J., Dennis, R., Gumal, M., Knott, C.D., and Singleton, I., 2008. Distribution and conservation status of the orang-utan (*Pongo* spp.) on Borneo and Sumatra: how many remain? *Oryx* 42: 329-339.

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