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1 This note was written in response to an issue raised by Hemanath Swarna Nantha in studying the opportunity cost of conserving the orangutans.

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ABSTRACT

Analyses the economics of alternative land-use allocations for a forested area that ensure a targeted viable population of a forest-dependent species, such as the orangutan. The alternative of setting aside a sufficient fully protected portion of the forested area allowing the rest to be used for intensive forestry (or another intensive land use) in which the focal species is unable to survive is compared with that of fully protecting none of the forested area but allowing a sufficient portion of it to be lightly logged to ensure the survival of the targeted population of the focal species with the remainder of the land area (if any) being available for intensive use. The conditions for determining the least cost option (the one that minimizes profit forgone) are identified. It is not possible to say a priori which land use is the least cost option. The matter should not be prejudged as some conservationists tend to do.

Keywords: biodiversity conservation, conservation of forest-dependent species, forestry, heavy versus light logging, intensive versus extensive land use and conservation, logging and conservation, opportunity cost and species conservation, orangutan conservation.

JEL Codes: Q23, Q51, Q57
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1. Introduction

Some wildlife species are dependent on the presence of forests for their survival but can survive (albeit often at lower densities) when light logging occurs. The orangutan is one such species. Some conservationists have argued that low-intensity forestry may provide an economic and politically acceptable means of ensuring the survival of such species. Sometimes, light logging is seen as an alternative strategy to one of completely protecting an area in order to conserve the population of a forest-dependent species. However, the problem does not appear to have been analysed systematically. The purpose of this article is to introduce a simple model in order to help resolve the economic issues involved in choosing between the alternative strategies for utilizing a forested area of (1) fully protecting a portion of it of sufficient size to conserve exactly the targeted number, $K$, of a forest-dependent species and allowing the remainder of the forested area to be used for intensive logging or (2) allowing this protected area plus a part of the non-protected area to be lightly logged so as to conserve the targeted number (K) of the focal species with any remainder being available for intensive logging. In the second case, no portion of the forested area is fully protected – all of it is utilized either for light or heavy logging.

First, the nature of the problem is outlined and then a solution to it is specified. After this, the general consequences of the solution are explored and discussed.

2. The Problem

The density of the population of some wildlife species depends on the intensity of logging and so too does the profitability of logging. A problem arises in specifying the relationships involved precisely because the process of logging can be diverse and has multiple attributes or characteristics. For simplicity, however, let us suppose that its intensity can be represented by a variable $x$ which falls in the range $0 < x < 1$ where zero means that logging is absent and 1 implies it is at its maximum intensity.
Suppose that $\lambda$ represents the density per km$^2$ of the focal forest dependent species (for example, orangutans). Then the long-term density of this species as a function of the intensity of logging might be like that shown by relationship ABCD in Figure 1. The long-term density of the species declines as logging intensity approaches $x_1$ and then falls to zero. However, it is conceivable that for some forest species, this density at first rises and then falls because they benefit from some forest disturbance. Also for some species a precipitous decline at a threshold like that of $x_1$ in Figure 1 may not occur – the decline may be more gradual.

![Figure 1: A hypothetical relationship between the density of a focal forest-dependent species and the intensity of logging in its abode](image)

The profit per km$^2$ from logging also depends on the intensity of logging. It is usually higher for conventional (higher intensities of logging) than for low intensity logging. One possible relationship between the profitability of logging and its intensity is shown in Figure 2 by curve DEFG. In this case, logging at an intensity of less than $x_0$ is unprofitable. Profit is positive for intensities of logging greater than $x_0$ and rises as the intensity of logging increases.
In Figure 1, $x_1$ is the maximum intensity of logging compatible with the long-term survival of the focal species. However, in reality, this threshold is likely to be uncertain. Therefore, to be on the safe side if the survival of the species is at stake, it may be wise to opt for a lower intensity of logging than this.

It is not practical to consider all possible intensities of logging and the economic cost of conserving the focal species. Therefore, consider two discrete alternative strategies for the allocation of a forested area for forestry and the conservation of the focal species of a size of $H$ km$^2$. These are:

1. Completely protecting a portion of the area $H$ km$^2$ of the forested area so as to conserve just $K$ of the focal species and allow the remaining portion to be used for high intensity logging.

2. Not completely protecting any part of the forested area and allowing light logging in a portion of it sufficient to conserve a population $K$ of the focal species and permitting heavy logging in the remainder. The level of light logging and heavy logging are assumed to be pre-specified, and the allowed level of heavy logging is assumed to be the same as in Option 1.
Given the two alternative strategies, which is the most profitable alternative?

3. The Solution

In order to visualize the solution, consider Figure 3. The total available forested area for allocation is equal to the area of the rectangle marked A plus that marked B and is shown in the top portion of Figure 3. The area is assumed to be uniform in the quality of its forest and in the density of the focal species it can carry. Option 1 is illustrated by the top large rectangle and Option 2 by the lower one. In case 1, the area of the rectangle identified by A is fully protected so as to conserve K of the focal species and the remainder is used for heavy logging (or it could be used for plantations or other forms of agriculture). In case 2, the protected area is made available for light logging and an area indicated by the rectangle identified by C is withdrawn from heavy logging and used for light logging so as to ensure that the area lightly logged conserves K of the focal species. The rectangular shapes of the forested land area and its uses are assumed for ease of exposition. The solution can be generalized to accord with other land patterns.
Figure 3 An illustration of the alternatives of (1) a combination of a protected area plus a heavily logged area and (2) a lightly logged area plus a heavily logged area (no protected area) as ways of conserving a targeted level of the population of a forest-dependent focal species.

The change in total profit from forestry when Option 2 rather than Option 1 is adopted equals the increase in profit from being able to log area A less the reduction in profit from area C as a result of altering its use from heavy to light logging. If the former amount exceeds the latter amount, profit from forestry rises as a result of the changed strategy for conserving the focal species. On the other hand, if the latter amount exceeds the former amount, profit from forestry falls as a result of the change in strategy.

In order to analyse the matter further, consider a mathematical analysis of the issue. Let K represent the target population of the focal wildlife species, and let $\lambda$ be its density per km$^2$ on protected land and $\theta \lambda$ be that on lightly logged land where $0 < \theta < 1$. The species is assumed to disappear in the long-term on heavily logged land. In this case, if Option 1 is adopted, the required size of protected area A in Figure 3 is $K/\lambda$ km$^2$. If Option 2 is adopted and light logging occurs, the area needed to conserve K of the species (marked A plus C) is $K/\theta \lambda$ km$^2$. [It is assumed here that this $K/\theta \lambda$ km$^2$, is not greater than H km$^2$. If it is, light logging is not an option compatible with the
survival of the targeted level, K, of the focal species. Therefore, the area marked C equals \((K/\theta \lambda - K\lambda) \text{ km}^2\).

Suppose that the profit from heavy logging is \(\Pi\) per \(\text{km}^2\) and that from light logging it is \(\varepsilon \Pi\) where \(0 < \varepsilon < 1\). The total change in returns from logging when Option 2 is adopted rather than Option 1 can be expressed as:

\[
\Delta R = \frac{K}{\lambda} \varepsilon \Pi - \left(\frac{K}{\theta \lambda} - \frac{K}{\lambda}\right) (\Pi - \varepsilon \Pi) \tag{1}
\]

\[
= \frac{K}{\lambda} \varepsilon \Pi - \left(\frac{K}{\theta \lambda} - \frac{K}{\lambda}\right) (1 - \varepsilon) \Pi \tag{2}
\]

The first term on the right hand side of this equation is the increased profit from being able to lightly log the previously protected area and the second term is the reduction in profit from having to forgo heavy logging in an area corresponding to area C in Figure 3.

Other things being held constant, it is observed that the likelihood that \(\Delta R\) is negative (that is that light logging is less financially rewarding than the alternative) increases as \(\varepsilon\) becomes smaller, that is the greater is the reduction in profit per \(\text{km}^2\) from light logging compared to that from heavy logging. Secondly, other things held constant, the smaller is \(\theta\) (that is, the larger the reduction in the density of the focal species when light logging occurs compared to no logging) the more likely is the light logging strategy to give lower returns from logging than Option 1. This is because the coefficient \(\left(\frac{K}{\theta \lambda} - \frac{K}{\lambda}\right)\) increases as \(\theta\) becomes smaller.

4. Discussion and Conclusions

The above analysis identifies conditions under which it is the economically optimal to follow a fully protected land policy for a portion of forested land compared to a light logging type of policy to ensure the survival of a focal forest-dependent wildlife
species. Only a few parameters need to be estimated to complete the analysis. This is a practical advantage.

Note that it cannot be decided *a priori* whether a protected area policy combined with heavy logging or a light logging type of policy is the most profitable land use policy from the point of view of loggers. This can be illustrated by the following simple examples. If both $\theta$ and $\varepsilon$ equal 0.5, Expression (2) reduces to zero. In this case, light logging results in both a halving density of the focal species per km$^2$ and a halving of profit per km$^2$ compared to heavy logging. In Figure 3, it implies that the area marked by C equals the area identified by A.

Now consider the example in which, $\varepsilon > 0.5$, (that is the profit per km$^2$ from light logging in less than half that from heavy logging,) and $\theta = 0.5$ (the density of the focal species is halved compared to that in the absence of logging). The light logging option raises returns from logging compared to Option 1 in this case, other things being unchanged. If $\varepsilon < 0.5$ and $\theta = 0.5$, then the opposite result follows.

Consider now variations in $\theta$ when $\varepsilon$ is set at 0.5. If the $\theta > 0.5$, the density of the focal species falls by less than a half when light logging occurs compared to no logging, and the returns from Option 2 exceed those from Option 1. On the other hand, if $\theta < 0.5$, the returns from Option 2 are less than those for Option 1.

In general, the lower is the reduction in the density of a focal species under conditions of light logging compared to its density when no logging occurs, and the smaller is the reduction in profit from logging per km$^2$ when light rather than heavy logging is practised, the greater is the likelihood that the light logging option (Option 2) gives greater total returns from forestry than the protected area option (Option 1). This is on the assumption that a given targeted level of the focal species is to be conserved. The opposite relationship also holds.

Therefore, whether Option 1 or Option 2 maximizes returns from forestry depends on the circumstances identified. The model presented here is relevant in the context of conserving a single species, such as the orangutan, at minimum economic cost in
terms of profit forgone. Therefore, the analysis should not be construed as a reason for failing to aside protected areas, especially if the aim is to conserve whole ecosystems. Furthermore, there might also be circumstances in which it is socially defensible to support the light logging option even when it is not the least cost one in forms of profit forgone. The light logging option may, for example, ensure greater employment spread over a wider geographical area than setting aside a full protected area and allowing intensive land use outside of it. This may also result in its greater political acceptability in some jurisdictions as a land use option.
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