ISSN 1327-8231

ECONOMICS, ECOLOGY AND THE ENVIRONMENT

Working Paper No. 175

Selective Logging and the Economics of Conserving Forest Wildlife Species e.g. Orangutans

by

Clem Tisdell

September 2011

THE UNIVERSITY OF QUEENSLAND

ISSN 1327-8231

WORKING PAPERS ON

ECONOMICS, ECOLOGY AND THE ENVIRONMENT

Working Paper No. 175

Selective Logging and the Economics of Conserving Forest Wildlife Species e.g. Orangutans*

by

Clem Tisdell†

September 2011

* This article is an extended version of Working Paper No. 168 in this series and a version of it was presented at the 9th Biennial Pacific Rim Conference of the Western Economic Association International on April 26, 2011.

† School of Economics, The University of Queensland, St. Lucia Campus, Brisbane QLD 4072, Australia
Email: c.tisdell@economics.uq.edu.au

WORKING PAPERS IN THE SERIES, *Economics, Ecology and the Environment* are published by the School of Economics, University of Queensland, 4072, Australia, as follow up to the Australian Centre for International Agricultural Research Project 40 of which Professor Clem Tisdell was the Project Leader. Views expressed in these working papers are those of their authors and not necessarily of any of the organisations associated with the Project. They should not be reproduced in whole or in part without the written permission of the Project Leader. It is planned to publish contributions to this series over the next few years.

Research for ACIAR project 40, *Economic Impact and Rural Adjustments to Nature Conservation (Biodiversity) Programmes: A Case Study of Xishuangbanna Dai Autonomous Prefecture, Yunnan, China* was sponsored by the Australian Centre for International Agricultural Research (ACIAR), GPO Box 1571, Canberra, ACT, 2601, Australia.

The research for ACIAR project 40 has led in part, to the research being carried out in this current series.

For more information write to Emeritus Professor Clem Tisdell, School of Economics, University of Queensland, St. Lucia Campus, Brisbane 4072, Australia.

Selective Logging and the Economics of Conserving Forest Wildlife Species e.g. Orangutans

ABSTRACT

Analyzes the economics of alternative allocations of forested land for uses (dominant-use vs. multiple use) to ensure the survival of a viable population of a forest-dependent species, e.g. the orangutan. The alternatives are (1) setting aside a sufficient fully protected portion of the forest and allowing the rest to be used for intensive logging and (2) fully protecting none of the forested area but allowing a sufficient portion of it to be lightly (selectively) logged to ensure the survival of the population of the focal species with the remaining land (if any) being available for intensive use.

Keywords: biodiversity conservation, conserving of forest species, forestry, logging and conservation, opportunity cost and conservation, orangutans.

JEL Codes: Q23, Q51, Q57

Selective Logging and the Economics of Conserving Forest Wildlife Species e.g. Orangutans

1. Introduction

Several wildlife species depend for their existence on the presence of forests. Most forest species depend on the forest for the type of food they need and for shelter. The locomotion of some (such as the orangutan) is facilitated by the presence of a tree canopy. However, the ecological relationship between forest-dwelling species and forests varies, and the populations of some are less sensitive to forest disturbance (such as occurs for example as a result of logging) than others. Furthermore, their sensitivity varies with the type of forest disturbance that occurs.

Forests are continuing to disappear as forested land is converted to non-forest uses (such as agriculture) and many natural forests continue to be heavily logged, often as a prelude to the conversion of the land to agriculture. This is a threat to the conservation of forest species. For example, the survival of the endangered orangutan continues to be threatened by deforestation in Borneo and Sumatra and the conversion of the forested land to agricultural use, mostly the cultivation of oil palm (Swarna Nantha and Tisdell 2009). However, orangutans (and several other forest species) can survive in selectively logged land or land that is logged but not heavily logged (Husson et al. 2008). In view of this relationship and the fact that strong political pressure exists in many developing countries to commercially use forested land and not lock it up in protected areas, some conservationists support non-intensive logging as a land use (for example, Payne and Prudente 2008). Payne and Prudente (2008, p.145) state, for example: “Orangutans can survive and breed happily in natural forests that are well managed for timber production. This has already been proved since the 1990s in the 55,000 hectare Deramakot Forest in Sabah [Malaysia] certified under Forest Stewardship Council principles and criteria.” They go on to point out that this “forest sustains one of the highest recorded populations of densities of orangutans is logged lowland dipterocarp forest” and advocate the adoption of similar procedures for managing the logging of forests sustainably in other areas where orangutans occur. While not the best ecological solution, selective or low-intensity forestry enables some forest species to survive whereas virtually all will perish if forested land is converted to agricultural use.

The environmental requirements for the survival of the orangutan (*Pongo* spp.) are of particular interest because these species require a very large continuous forested area for their survival *in situ*. Therefore, the economic opportunity cost of conserving the orangutan by completely protecting forested areas is high. At the same time, because of their human-like features (see Plous 1993; Tisdell, Wilson, and Swarna Nantha 2005), there is probably strong support for conserving the orangutan amongst residents of higher income countries whereas in the developing countries where it occurs support for conserving it by fully protecting forest areas is likely to be limited because of the high economic sacrifice involved. Rikjsen and Meijaard (1999) estimated that a minimum viable meta-population of 5,000 adult orangutans is needed for the survival of the species. They are of the view that this would require about 10,000 km^2 of suitable habitat. Orangutans are very sparsely distributed in their habitats and densities in Borneo range from 0.1 to 3.6 per km^2 (Soehartono et al. 2007, p.8). On the other hand, Singleton et al. (2004) state that a single population of at least 500 orangutans is needed for its long-term viability. If the carrying capacity of the conserved habitat is on average one orangutan per km^2, 500 km^2 is required and if it is two on average 250 km^2 of suitable habitat is needed to reach the target suggested by Singleton et al. (2004).

This means that the amount of forested area required to conserve this species is considerable and the opportunity cost of protecting it can be high. For example, if all the land involved is suitable for oil palm production, the pre-tax profit from oil palm production forgone is likely on average to be US$528-790 annually per ha (Swarna Nantha and Tisdell 2009, p.490).

While some of the ecological aspects of selective logging have been explored for particular species, for example, by Lindenmayer and Possingham (1994) for the Leadbeater's Possum, little attention has been given to the economics of selective or low-intensity logging as a strategy for conserving forest species but considerable attention has been given to spatial ecology and the optimization of managed ecosystems (for example, by Hof and Bevers 1998). This is not to say that this problem has been entirely neglected by economists. For example, Bowes and Krutilla (1989, pp. 32-34 and pp. 36-37) compare the dominant-use management of forested areas with their multiple-use management and suggest that in many cases the latter type of management is superior. The general nature and implications of possible trade-offs between timber harvests and wildlife services in multiple use situations are considered at the forest stand level (Bowes and Krutilla 1989, pp. 71-87). Somewhat later, Vincent and Binkley (1993) argued that efficient multiple-use forestry may require land-use specialization. They argue that when a fixed level of management effort can be allocated between identical forest stands, economies in the management of the stands should tend to favor specialization in their purpose. “Multiple products are produced at the forest level, but management at the stand level tends towards dominant use” (Vincent and Binkley 1993, p.373). Boscolo and Vincent (2003) develop this theme further arguing that nonconvexities in timber production, biodiversity provision and carbon sequestration are important. They find that joint production of biodiversity and timber is likely to be less economic than the allocation of the forested area by dominant use. They find, using some data from Malaysia, that dominant use allocation of forested land, “is often likely to be superior to uniform management for the production of biodiversity and timber” (Boscolo and Vincent 2003, p. 266)

The model developed here is not concerned per se with the conservation of biodiversity in a forest stand but rather with the economics of conserving a single forest wildlife species such as the orangutan. It can also be extended to include specific additional species.

The type of logging considered here is logging that is modified to assist the conservation of a focal wildlife species. It can be regarded as a form of reduced impact logging, but it is reduced impact in relation to the conservation of a particular species (or set of species). While this type of selective logging involves a modification of conventional logging, it is unclear whether this type of selective logging would be as financially demanding on loggers as reduced impact logging (RIL) generally or sustainable forest management (SFM), the economics of which is reviewed by Putz et al. (2008) and by Garciá-Fernández, Ruiz-Pérez, and Wunder (2008, p.1468). In some instances, this type of selective forestry could be less of an economic burden on loggers than RIL or SFM but this is an empirical matter.

This article focuses on determining the minimum cost of conserving a minimum viable population (MVP) of a forest dependent species. Previous economic studies have not considered this specific matter. It considers whether it is more economic to conserve a focal forest species by

1) Setting aside a fully protected area that enables a minimum viable population (or some other target-level of population) of it to survive and then allow heavy logging of the remainder of the land or

2) Not to set aside a protected area and allow light (selective) logging (multiple use) over sufficient area to maintain a minimum viable population of the focal species.

Note that the level of population of a species constituting a minimum viable population is not certain but usually the probability of survival of a species increases with the level of its population which is supported by its environment (Hohl and Tisdell 1993).

More specifically, this article introduces a simple model in order to help determine the economics of 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 (selectively) 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 (selective) or heavy logging.

A further feature of the model introduced in this article is that it can be used to determine the opportunity cost (profit forgone) of relying on light or selective logging to conserve a targeted level of population of forest species rather than allowing the heavy logging of an entire forested area resulting in the local extinction of the forest species. The formula for determining this opportunity cost is specified in this paper and factors that influence its size are identified.

Note that the simple models considered here are linear ones. This makes their application tractable and they may approximate non-linear systems.

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

2. The Initial Problem

The density of the population of some wildlife species depends on the intensity (or the selectivity) 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. An alternative possible interpretation is that zero corresponds to an extremely high degree of selectivity so the survival of the focal species is not adversely affected by its changed habitat whereas one corresponds to a situation in which no selectivity is practised in removing trees.

Suppose that y 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. Furthermore, the relationship involved may be non-linear.

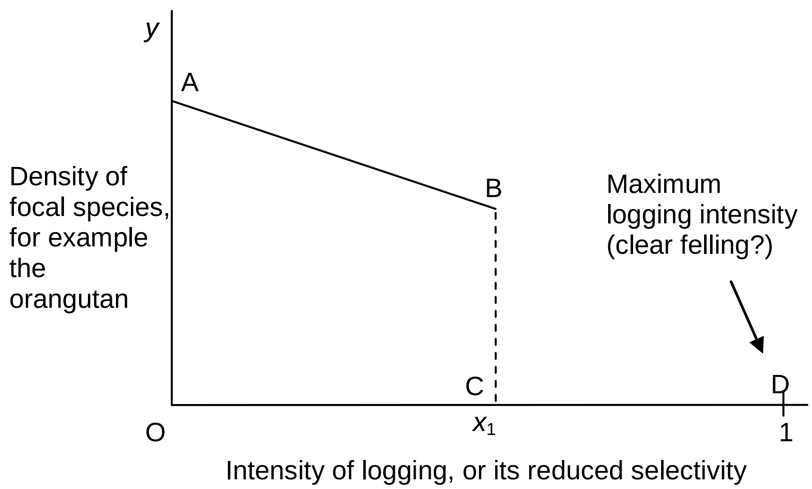

Figure 1: A hypothetical relationship between the density of a focal forest-dependent species and the intensity of logging (or its reduced selectivity) in its abode.

As mentioned above, alternative types of logging can be very diverse in their characteristics. Even light logging can be quite disadvantageous to some species if it targets the harvest of trees on which these species depend. It is implicitly assumed above that at a low intensity of logging, the loss of forest resources on which the focal species depends is low but increases with the intensity of logging. Husson, et al. (2008, p.92) found from their analysis that orangutan "densities are lower in moderately to heavily logged forest than in unlogged areas of comparable habitat, in accordance with the majority of studies already published on this subject". In general, they find that logged sites have a lower density of orangutans than unlogged sites (Husson et al. 2008, p.93). However, there appears to be little difference between orangutan density in unlogged areas and those that are 'lightly' logged because when light logging occurs in the habitats of the orangutan, it is usually of trees of the Diptercarpaceae family which are not an important food source for primates, including orangutans (Husson et al. 2008, p.83). Husson, et al., come to the qualified conclusion that "a well-managed, selective-logging operation that only removes those species of trees and does minimal damage to the surrounding forest may not significantly alter the forest structure and food availability from an orangutan's perspective". (Husson et al. 2008, p.83).

A similar situation sometimes occurs in other places and for other species. For example, John Williams, Commissioner, New South Wales Natural Resource Commission, in discussing an earlier version of my paper presented at the 9th Biennial Pacific Rim Conference of the Western Economic Association International on April 26, 2011 pointed out that cypress trees (*Callitris* spp.) used for timber production in New South Wales and other parts of Australia are not an important source of food and habitat for most animal species present in such forests but that other plant species interspersed within these cypress forests (such as acacia and grasses) are. Therefore, selective logging of cypress can be compatible with the conservation of several animal species that show little or no dependence on cypress.

Husson et al. (2008) in studying the relationship between orangutan density and the intensity of logging adopt the following scale of logging intensity: (1) unlogged, (2) lightly logged, (3) moderately logged and (4) heavily logged. To some extent, their scaling of logged areas into the different categories is subjective. For example, Husson, et al., (2008, p.95) state: "While it was difficult to empirically compare logging intensity between all the sites included in this study, sites with well-managed selective-logging operations were typically classed as lightly logged, and those subject to uncontrolled illegal logging as heavily logged". They go on to point out that mechanized logging is more destructive of a forest than is hand logging.

The profit per km^2 from logging also depends on the intensity of logging or how selective it is required to be. 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 ODEFG. 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.

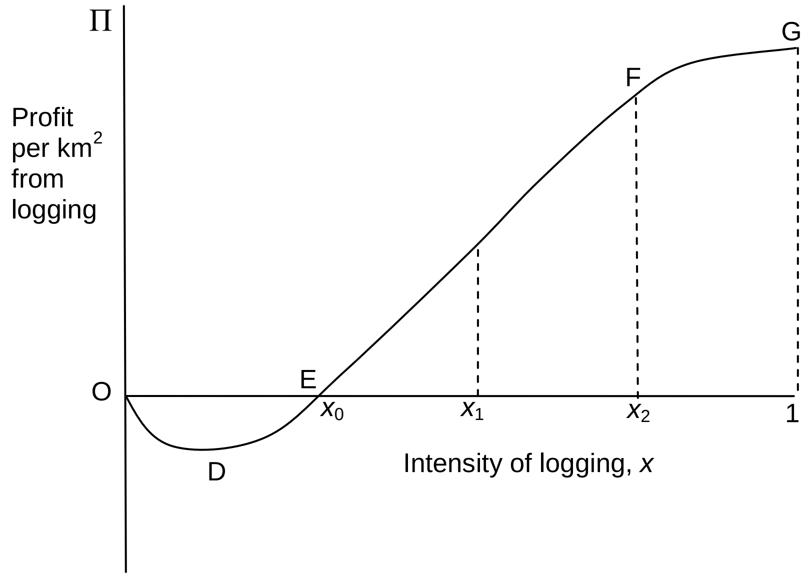

Figure 2: A possible relationship between the profitability per km^2 from logging and its intensity (or reduced selectivity).

In Figure 1, x_1 is the maximum intensity of logging potentially 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.

Note that it is assumed that heavy logging is sufficiently heavy to extinguish the focal species. Further, it is supposed that light logging (which might also be designated moderate logging) reduces the density of the focal species compared to no logging.

Given the two alternative strategies listed above, which is the most profitable alternative?

3. The Solution to the Problem Mentioned Initially

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.

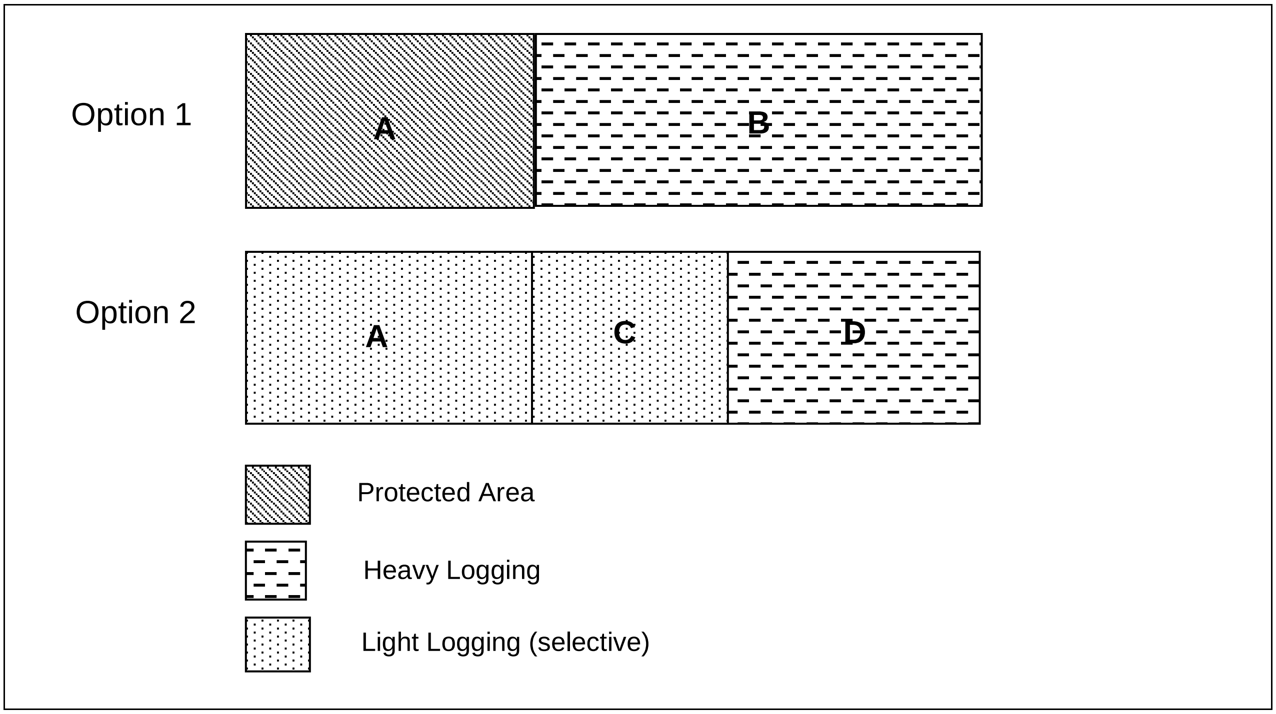

Figure 3: An illustration of the alternatives of (1) a combination of a protected area plus a heavily logged area and (2) a lightly logged (selective) area plus a heavily logged area (no protected area) as ways of conserving a targeted level of the population of a forest-dependent focal species.

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 analyze the matter further, consider a mathematical analysis of the issue. Let K represent the target population of the focal wildlife species, and let λ 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/λ 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/θλ 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/θλ − Kλ) km^2.

Suppose that the profit from heavy logging is Π per km^2 and that from light logging it is εΠ where 0 < ε < 1. The total change in returns from logging when Option 2 is adopted rather than Option 1 can be expressed as:

$$\Delta R = \frac{K}{\lambda}\varepsilon\Pi - \left(\frac{K}{\theta\lambda} - \frac{K}{\lambda}\right)(\Pi - \varepsilon\Pi) \quad (1)$$

$$= \frac{K}{\lambda}\varepsilon\Pi - \left(\frac{K}{\theta\lambda} - \frac{K}{\lambda}\right)(1-\varepsilon)\Pi \quad (2)$$

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 ΔR is negative (that is that light logging is less financially rewarding than the alternative) increases as ε becomes smaller, that is the greater is the reduction in profit per km^2 from light logging compared to that from heavy logging. Secondly, other things held constant, the smaller is θ (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 co-efficient $\left(\frac{K}{\theta K} - \frac{K}{\lambda}\right)$ in Equation (2) increases as θ becomes smaller.

4. Discussion of the Above Results

The above analysis identifies conditions under which it is 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 θ and ε 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 θ when ε 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 practiced, 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 a side 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 fully 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.

5. The Opportunity Cost of Replacing Heavy Logging by Light (or Selective) Logging to Conserve a Targeted Level of the Population of a Forest Species.

Another economic issue worth investigating is the opportunity cost of replacing heavy logging by light (selective) logging of just sufficient area to conserve a targeted level (K) of the population of a forest species. The opportunity cost in this case is the profit forgone by not being able to heavily log the area that is to be lightly logged to achieve the conservation objective. Where ξ is the density per km^2 of the focal species (e.g. orangutans) on lightly logged land, the lightly logged area needed to achieve the conservation objective is ξ/K. Given that Π is the profit per km^2 from heavy logging and $E\Pi$ is that from light logging where $0<E<1$, the profit forgone by adopting this conservation strategy is

$$L = K/\xi\ (\Pi - E\Pi) \qquad (3)$$

It follows that, other things held constant, the loss in returns from forestry when light logging is practiced to conserve the focal species (1) increases with the targeted level of the population of the forest species (2) is higher the lower is its density on lightly logged land and (3) is higher the lower is the profit per km^2 from light logging compared to heavy logging.

6. Further Discussion and Conclusions

The simplified relationship (illustrated in Figure 1) showing the density of a forest species as a function of the intensity of logging needs to be extended to take account of the passage of time and to allow for the spatial dimensions of environmental change. For example, the relationship ABCD shown in Figures 1 and 4 might apply to the density of orangutans soon after an area has been logged. However, after a longer period of time, the forest will start to regenerate and a relationship like that shown in Figure 4 might apply. In addition, if migration of members of the forest species, e.g. orangutans, from other areas is possible, then after enough time elapses, the relationship shown by AEFG in Figure 4 is possible. The detailed study of Husson et al. (2008) of the impacts of forestry on the density of orangutans might have been usefully extended by taking such factors into account. Failure to do this, limits the conclusion that can be safely drawn from their cross sectional statistical analysis of the relationship between the intensity of logging and the density of orangutans.

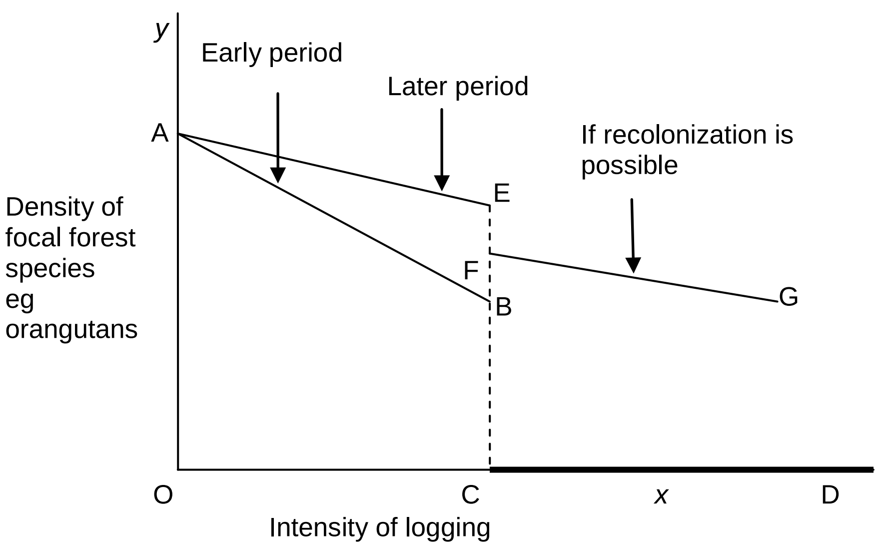

Figure 4: Diagram used to highlight the fact that the density of a forest species following logging depends on the passage of time and the scope for a species to recolonize a logged one.

Ideally spatial and dynamic factors should be incorporated in the above analysis. For example, the conservation of selected small fully protected reserves in logged landscapes can be valuable in facilitating recolonization of a logged area once it begins to regenerate. While these refugia may not (on their own) support minimum viable populations of focal forest species in the long-term, they may support the populations for sufficient time to enable recolonization of nearby logged areas to occur. Consequently, they can increase the chances of survival of the species locally. The provision of such refugia can be regarded as another form of selective logging and is also amenable to economic analysis. The appropriate selective spatial conservation patterns will, however, vary with the ecology of the forest species to be conserved. Therefore, extension of the analysis is probably best done by specifying the requirements for the conservation of specific forest species or groups of these in logging environments rather than by listing the myriad of general abstract possibilities.

Available evidence indicates that light-to-moderate logging which is selective does not endanger the orangutan. However, logging which is intense, rapid and present over a large area is a serious threat to its survival as is the geographical spread of agriculture (Tisdell and Swarna Nantha 2008; 2009). The spread of agriculture in Indonesia is often associated with the occurrence of forest fires which also negatively impact on orangutan populations which are slow to reproduce. Climate change does not appear to be a major threat to this species, although as a result of sea level rise, the land mass available for its population would be reduced. Measures to subsidize forests to sequestrate carbon will only be of advantage to this species if the areas involved include the species of trees on which the orangutan depends for food. This species will not benefit from subsidies to forest plantations because this will probably lack the food trees and tree canopies required by this species. Since biodiversity is socially valuable, measures to reduce global warming (for example, to encourage the continuous provision of forests) should also take account of their consequences for biodiversity conservation. Policies to reduce greenhouse gases should serve multiple objectives.

There are also forest species other than the orangutan for which selective logging is compatible with their conservation. As the number of different forest species to be conserved at a minimum viable population when selective logging is practiced increases, the economic returns from selective logging are likely to decrease. A stage is therefore, likely to be reached where selective logging is no longer a viable economic option for conserving the species and dominant use at the landscape level is likely to be a more economic solution. Note that this article does not provide a complete social cost-benefit analysis of the economics of conserving forest species by means of selective logging. Most forests have uses other than for logging and wildlife conservation and the economic value of these can be expected to vary with the intensity and selectivity of logging. For example, forests provide ecoservices (such as hydrological services, carbon sequestration), may cater for ecotourism, in some cases have visual value (see, for example, Haight, Monserud, and Chew 1992) and can provide subsistence products to local villagers in developing countries. While intense logging is likely to reduce the economic value of these services substantially, this need not be the case if light selective logging is practiced when multiple-use values are many, optimizing forest use, even at the landscape level, can be quite complicated as the study by Haight et al. (1992) shows.

Overhead costs (not considered in my simple model) can also be important as pointed out by Boscolo and Vincent (2003) and Vincent and Binkley (1993). They suggest that overhead costs are likely to favor the allocation of forested land by dominant (specialized) use rather than multiple use at the landscape level. For example, the cost of building access roads to extract timber are likely to be higher where light logging is practiced, and administration costs may also increase. On the other hand, employment intensities in logging are likely to be higher than in fully protected areas and light logging would spread employment over a wider geographical area than heavy logging than would occur if the dominant-use allocation of forests is adopted. This may be politically important in the case of the orangutan which can require 250-500 km^2 of suitable fully protected forest habitat to survive (Singleton et al. 2004).

The United Nations Earth Summit held in Rio de Janeiro in 1992 stated in Chapter XI of Agenda 21 "the need for sustaining the multiple roles and functions of forests, and for enhancing their protection, sustainable management and conservation. This need was further reaffirmed in 2000 in the United Nations Millennium Declaration (Chapter IV) and at the second Earth Summit held in Johannesburg in 2002 …." (Sist, Garciá-Fernández, and Fredericksen 2008, p.vii). While the development of methods for reduced impact logging (RIL) pays some attention to these objectives, this development pays little or no attention to the conservation of species. Sist et al. (2008, p.vii) observe: "Most RIL operations are still based, as all other selective logging systems operating in the tropics, on a very simple rule: the minimum diameter cutting, which is applied to all other commercial species. These cutting limits are set to accommodate processing technologies and market demands, rather than the biology and conservation of the harvested species (Sist et al. 2003).” In addition, RIL methods fail to take account of the conservation of non-harvested species, such as forest wildlife species; some of which may nevertheless indirectly benefit from RIL. Therefore, an even more holistic approach to managing tropical forest than that envisaged by Sist et al. (2008) is called for.

7. Acknowledgements

This is a revised and extended version of a paper presented at the 9th Pacific Rim Conference of the Western Economic Association International on April 26, 2011 in the session “Fisheries, Forests and Species Survival”. The revision has benefited from comments received on that occasion particularly those of Dr. John Williams, New South Wales Natural Resources Commissioner and of Professor Darwin Hall, California State University, Long Reach. I also thank Hemanath Swarna Nantha for discussing the original ideas with me. The usual *caveat* applies.

REFERENCES

Boscolo, M., and J. R. Vincent. "Nonconvexities in the production of timber, biodiversity and carbon sequestration." *Journal of Environmental Economics and Management* 46, 2003.251-263.

Bowes, M. D., and J. V. Krutilla. *Multiple-use Management: The Economics of Public Forestlands*. Washington, D.C.: Resources for the Future. 1989.

Garciá-Fernández, C., M. Ruiz-Pérez, and S. Wunder. "Is multiple-use forest management widely implementable in the tropics?" *Forest Ecology and Management* 256, 2008.1468-1476.

Haight, R. G., R. A. Monserud, and J. P. Chew. "Optimal harvesting with stand density targets in managing Rocky-Mountain conifer stands for multiple forest outputs." *Forest Science* 38, 1992.554-576.

Hof, J. G., and M. Bevers. *Spatial Optimization for Managed Ecosystems*. New York: Columbia University Press. 1998.

Hohl, A., and C. A. Tisdell. "How useful are environmental safety standards in economics? The example of safe minimum standards for protection of species." *Biodivers. Conserv.* 2 (2), 1993.168-181.

Husson, S. J., S. A. Wich, A. J. Marshall, R. A. Dennis, M. Acrenaz, R. Brassey, M. Gumal, A. J. Hearn, E. Meijaard, T. Simorangkir, and I. Singleton. Orangutan distribution, density, abundance and impacts of disturbance. In *Orangutans: Geographical Variation in Behavioural Ecology and Conservation*, edited by S. A. Wick, S. S. U. Atmoko, T. M. Setia and C. P. Scheik. Oxford: Oxford University Press. 2008.

Lindenmayer, D. B., and H. P. Possingham. *The Risk of Extinction: Ranking Management Options for Leadbeater's Possum Using Population Viability Analysis*. Canberra, ACT: Centre for Resource and Environmental Studies, Australian National University. 1994.

Payne, J., and C. Prudente. *Orangutans: Behaviour, Ecology and Conservation*. London: New Holland Publishers. 2008.

Plous, S. "Psychological mechanisms in the human use of animals." *J. Soc. Issues* 49, 1993.11-52.

Putz, F. E., P. Sist, T. Fredericksen, and D. Dykstra. "Reduced-impact logging: challenges and opportunities." *Forest Ecology and Management* 256, 2008.1427-1433.

Rijksen, H. D., and E. Meijaard. *Our Vanishing Relative: The Status of Wild Orangutants at the Close of the Twentieth Century*. Dordrecht: Kluwer. 1999.

Singleton, I., S. A. Wich, S. J. Husson, S. S. U. Atmoko, M. Leighton, N. Rosen, K. Traylor-Holzer, R. Lacy, and O. Byers. *Orangutan population and habitat viability assessment: final report*. Apple Valley, MN, USA: IUCN/SSC Conservation Breeding Specialist Group. 2004.

Sist, P., R. Fimbel, R. Nasi, D. Sheil, and M.-H. Chevallier. "Towards sustainable management of mixed diptorcorp forests of South East Asia: moving beyond minimum diameter cutting limits." *Environmental Conservation* 30, 2003.364-374.

Sist, P., C. Garciá-Fernández, and T. Fredericksen. "Moving beyond reduced-impact logging towards a more holistic management of tropical forests." *Forest Ecology and Management* 256, 2008.vii-ix.

Soehartono, T., H. Djoko Susilo, N. Andayani, S. S. Utami Atmoko, J. Sihite, C. Saleh, and A. Sutrisno. *Strategi dan rencana aksi konservasi orangutan Indonesia 2007-2017*. Jakarta, Republik Indonesia: Direktorat Jenderal Perlindungan Hutan dan Konservasi Alam 2007.

Swarna Nantha, H., and C. A. Tisdell. "The orangutan-oil palm conflict: economic constraints and opportunities for conservation." *Biodiversity Conservation* 18, 2009.487-502.

Tisdell, C. A., and H. Swarna Nantha. Conservation of the proboscis monkey and the orangutan in Borneo: comparative issues and economic considerations. In *Perspectives in Animal Ecology and Reproduction, Volume 5*, edited by V. K. Gupta and A. K. Verma. Delhi: Daya Publishing House. 2008.

———. Supply-side policies to conserve biodiversity and save the orangutan from oil palm expansion: An economic assessment. In *Handbook of Nature Conservation - Global, Environmental and Economic Issues*, edited by J. B. Aranoff. New York: Nova Science Publications Inc. 2009.

Tisdell, C. A., C. Wilson, and H. Swarna Nantha. "Association of public support for survival of wildlife species with their likeability." *Anthrozoos* 18 (2), 2005.160-174.

Vincent, J. R., and C. S. Binkley. "Efficient multiple-use forestry may require land-use specialization." *Land Economics* 69, 1993.370-376.

PREVIOUS WORKING PAPERS IN THE SERIES

ECONOMICS, ECOLOGY AND ENVIRONMENT

For a list of working papers 1-100 in this series, visit the following website: http://www.uq.edu.au/economics/PDF/staff/Clem_Tisdell_WorkingPapers.pdf or see lists in papers 101 on.

101. Knowledge and Willingness to Pay for the Conservation of Wildlife Species: Experimental Results Evaluating Australian Tropical Species, by Clem Tisdell and Clevo Wilson, May 2004.
102. Antarctic Tourists, Wildlife and the Environment: Attractions and Reactions to Antarctica, by Clem Tisdell, May 2004.
103. Birds in an Australian Rainforest: Their Attraction for Visitors and Visitors' Ecological Impacts, by Clem Tisdell and Clevo Wilson, May 2004.
104. Nature-Based Tourism and the Valuation of its Environmental Resources: Economic and Other Aspects by Clem Tisdell, May 2004.
105. Glow Worms as a Tourist Attraction in Springbrook National Park: Visitor Attitudes and Economic Issues, by Clem Tisdell, Clevo Wilson and David Merritt, July 2004.
106. Australian Tropical Reptile Species: Ecological Status, Public Valuation and Attitudes to their Conservation and Commercial Use, by Clem Tisdell, Clevo Wilson and Hemanath Swarna Nantha, August 2004.
107. Information and Wildlife Valuation: Experiments and Policy, by Clem Tisdell and Clevo Wilson, August 2004.
108. What are the Economic Prospects of Developing Aquaculture in Queensland to Supply the Low Price White Fillet Market? Lessons from the US Channel Catfish Industry, by Thorbjorn Lyster and Clem Tisdell, October 2004.
109. Comparative Public Support for Conserving Reptile Species is High: Australian Evidence and its Implications, by Clem Tisdell, Clevo Wilson and Hemanath Swarna Nantha, October 2004.
110. Dependence of public support for survival of wildlife species on their likeability by Clem Tisdell, Clevo Wilson and Hemanath Swarna Nantha, October 2004.
111. Dynamic Processes in Contingent Valuation: A Case Study Involving the Mahogany Glider by Clem Tisdell, Clevo Wilson and Hemanath Swarna Nantha, November 2004.
112. Economics, Wildlife Tourism and Conservation: Three Case Studies by Clem Tisdell and Clevo Wilson, November 2004.
113. What Role Does Knowledge of Wildlife Play in Providing Support for Species' Conservation by Clevo Wilson and Clem Tisdell, December 2004.
114. Public Support for Sustainable Commercial Harvesting of Wildlife: An Australian Case Study by Clem Tisdell, Clevo Wilson and Hemanath Swarna Nantha, December 2004.
115. Endangerment and Likeability of Wildlife Species: How Important are they for Proposed Payments for Conservation by Clem Tisdell, Hemanath Swarna Nantha and Clevo Wilson, December 2004.
116. How Knowledge Affects Payment to Conserve and Endangered Bird by Clevo Wilson and Clem Tisdell, February 2005.
117. Public Choice of Species for the Ark: Phylogenetic Similarity and Preferred Wildlife Species for Survival by Clem Tisdell, Clevo Wilson and Hemanath Swarna Nantha, March 2005.
118. Economic Incentives for Global Conservation of Wildlife: New International Policy Directions by Clem Tisdell, March 2005.

119. Resource Entitlements of Indigenous Minorities, Their Poverty and Conservation of Nature: Status of Australian Aborigines, Comparisons with India's Tribals, Theory and Changing Policies Globally by Clem Tisdell, March 2005.
120. Elephants and Polity in Ancient India as Exemplified by Kautilya's *Arthasastra* (Science of Polity) by Clem Tisdell, March 2005.
121. Sustainable Agriculture by Clem Tisdell, April 2005.
122. Dynamic Processes in the Contingent Valuation of an Endangered Mammal Species by Clem Tisdell, Clevo Wilson and Hemanath Swarna Nantha, April 2005.
123. Knowledge about a Species' Conservation Status and Funding for its Preservation: Analysis by Clem Tisdell, June 2005.
124. Public Valuation of and Attitudes towards the Conservation and Use of the Hawksbill Turtle: An Australian Case Study by Clem Tisdell, Hemanath Swarna Nantha and Clevo Wilson, June 2005.
125. Comparison of Funding and Demand for the Conservation of the Charismatic Koala with those for the Critically Endangered Wombat *Lasiorhinus krefftii* by Clem Tisdell and Hemanath Swarna Nantha, June 2005.
126. Management, Conservation and Farming of Saltwater Crocodiles: An Australian Case Study of Sustainable Commercial Use by Clem Tisdell and Hemanath Swarna Nantha, August 2005.
127. Public Attitudes to the Use of Wildlife by Aboriginal Australians: Marketing of Wildlife and its Conservation by Clem Tisdell and Hemanath Swarna Nantha, August 2005.
128. Linking Policies for Biodiversity Conservation with Advances in Behavioral Economics by Clem Tisdell, August 2005.
129. Knowledge about a Species' Conservation Status and Funding for its Preservation: Analysis by Clem Tisdell, August 2005.
130. A Report on the Management of Saltwater Crocodiles (*Crocodylus porosus*) in the Northern Territory: Results of a Survey of Pastoralists by Clem Tisdell, Clevo Wilson and Hemanath Swarna Nantha, September 2005.
131. Crocodile Farms and Management of Saltwater Crocodiles in Northern Territory: Results of a Survey of NT Crocodile Farmers Plus Analysis of Secondary Information by Clem Tisdell, September 2005.
132. The Environment and the Selection of Aquaculture Species and Systems: An Economic Analysis by Clem Tisdell, October 2005.
133. The History and Value of the Elephant in Sri Lankan Society by Ranjith Bandara and Clem Tisdell, November 2005.
134. Economics of Controlling Livestock Diseases: Basic Theory by Clem Tisdell, November 2006.
135. Poverty, Political Failure and the Use of Open Access Resources in Developing Countries by Clem Tisdell, November 2006.
136. Global Property Rights in Genetic Resources: An Economic Assessment by Clem Tisdell, November 2006.
137. Notes on the Economics of Fish Biodiversity: Linkages between Aquaculture and Fisheries by Clem Tisdell, November 2006.
138. Conservation of the Proboscis Monkey and the Orangutan in Borneo: Comparative Issues and Economic Considerations by Clem Tisdell and Hemanath Swarna Nantha, March 2007.
139. Economic Change and Environmental Issues: Policy Reforms and Concerns in Australian Agriculture, by Clem Tisdell, April 2007.
140. Institutional Economics and the Behaviour of Conservation Organizations: Implications for Biodiversity Conservation by Clem Tisdell, March 2007
141. Poverty, Policy Reforms for Resource-use and Economic Efficiency: Neglected Issues by Clem Tisdell, May 2007.
142. The State of the Environment and the Availability of Natural Resources by Clem Tisdell, May 2007.
143. Economics of Pearl Oyster Culture by Clem Tisdell and Bernard Poirine, July 2007.

144. The Economic Importance of Wildlife Conservation on the Otago Peninsula – 20 Years on by Clem Tisdell, November, 2007.
145. Valuing the Otago Peninsula: The Economic Benefits of Conservation by Clem Tisdell, November 2007.
146. Policy Choices about Agricultural Externalities and Sustainability: Diverse Approaches, Options and Issues by Clem Tisdell, November, 2007.
147. Global Warming and the Future of Pacific Island Countries by Clem Tisdell, November 2007.
148. Complex Policy Choices about Agricultural Externalities: Efficiency, Equity and Acceptability by Clem Tisdell, June 2008.
149. Wildlife Conservation and the Value of New Zealand's Otago Peninsula: Economic Impacts and Other Considerations by Clem Tisdell, June 2008.
150. Global Property Rights in Genetic Resources: Do They Involve Sound Economics? Will They Conserve Nature and Biodiversity? By Clem Tisdell, August 2008.
151. Supply-side Policies to Conserve Biodiversity and Save the Orangutan from Oil Palm Expansion: An Economic Assessment. By Clem Tisdell and Hemanath Swarna Nantha, September, 2008.
152. The Orangutan-Oil Palm Conflict: Economic Constraints and Opportunities for Conservation by Hemanath Swarna Nantha and Clem Tisdell, October 2008.
153. Economics, Ecology and the Development and Use of GMOs: General Considerations and Biosafety Issues by Clem Tisdell, October 2008.
154. Agricultural Sustainability and the Introduction of Genetically Modified Organisms (GMOs) by Clem Tisdell, February, 2009.
155. Notes on Biodiversity Conservation, The Rate of Interest and Discounting by Clem Tisdell, April, 2009.
156. Is Posner's Principle of Justice an Adequate Basis for Environmental Law? by Clem Tisdell, June 2009.
157. The Sustainability of Cotton Production in China and Australia: Comparative Economic and Environmental Issues By Xufu Zhao and Clem Tisdell, June 2009.
158. The Precautionary Principle Revisited: Its Interpretations and their Conservation Consequences by Clem Tisdell, September, 2009.
159. The Production of Biofuels: Welfare and Environmental Consequence for Asia by Clem Tisdell, September, 2009.
160. Environmental Governance, Globalisation and Economic Performance by Clem Tisdell, November 2009.
161. Managing Forests for Sustainable Economic Development: Optimal Use and Conservation of Forests by Clem Tisdell, February 2010.
162. Comparative Costs and Conservation Policies for the Survival of the Orangutan and Other Species: Includes an Example by Clem Tisdell and Hemanath Swarna Nantha, May 2010.
163. Notes on the Economics of Control of Wildlife Pests by Clem Tisdell, May 2010
164. Are tourists rational? Destination decisions and other results from a survey of visitors to a North Queensland natural site – Jourama Falls by Clem Tisdell, June 2010.
165. Conservation Value by Clem Tisdell, June 2010.
166. The Influence of Public Attitudes on Policies for Conserving Reptiles by Clem Tisdell, July 2010.
167. Core Issues in the Economics of Biodiversity Conservation by Clem Tisdell, July 2010.
168. The Survival of a Forest-Dependent Species and the Economics of Intensity of Logging: A Note by Clem Tisdell, August 2010.
169. A Case Study of an NGOs Ecotourism Efforts: Findings Based on a Survey of Visitors to its Tropical Nature Reserve by Clem Tisdell, August, 2010.
170. Sharing Nature's Wealth through Wildlife Tourism: Its Economic, Sustainability and Conservation Benefits by Clem Tisdell, August, 2010

171. Economic Growth and Transition in Vietnam and China and its Consequences for their Agricultural Sectors: Policy and Agricultural Adjustment Issues by Clem Tisdell, September, 2010.
172. World Heritage Listing of Australian Natural Sites: Effects on Tourism, Economic Value and Conservation by Clem Tisdell, October, 2010.
173. Antarctic tourism: Environmental concerns and the importance of Antarctica's natural attractions for tourists by Clem Tisdell, October 2010.
174. Sustainable Development and Intergenerational Equity: Issues Relevant to India and Globally by Clem Tisdell, November 2010
175. Selective Logging and the Economics of Conserving Forest Wildlife Species e.g. Orangutans by Clem Tisdell, September 2011.