Landscape management in tropical regions based on an assessment of ecosystem services

Mazlan Hashim (UTM)
Ab. Latif Ibrahim (FDNS)
Mahdan Bongkik (FDNS)
Roslan Rani (FDNS)
Keiichiro YOSHIDA (JSPS - NIES)
Toshinori OKUDA (NIES)
Sen NISHIMURA (FRIM)

INTRODUCTION

Deforestation in tropical regions is now widely acknowledged to be both a regional and a global problem. There are no restrictions on the conversion of tropical forests into land for human use, because agricultural land is perceived as having higher economic value than tropical forest (Peters et al. 1989). However, tropical forests provide numerous "ecosystem services," which are the benefits that humans derive, directly or indirectly, from ecosystem functions (Costanza et al. 1997). Decision-making processes have generally not considered the loss of indirect benefits from ecosystem services when tropical forests are converted and degraded. These indirect benefits are considerably greater than the benefits from economic products, including timber and agricultural yield. In many countries, the degradation of natural resources has restricted sustainable economic development. Therefore, for sustainable development to work in tropical regions, landscape management must include both economic activity and ecosystem services. Moreover, modifying the landscape management of tropical regions can improve the efficiency of natural resource use, so that tropical forest conservation can be a priority while maintaining high economic returns.

In order to determine how sustainable landscape management can take place with low economic risk, it is necessary to compare the benefits of produced goods with the benefits from ecosystem services across a range of competing land uses. However, many ecosystem services benefit human societies without passing through the monetary economy (Guo et al. 2000), and therefore, we must assess the economic delivery of multiple services.

The economic value of nonmarketed ecosystem services is difficult to estimate accurately (Balmford et al. 2002), but recently, a number of studies have evaluated various ecosystem services (for review, see Bishop 1999; Emerton 2001). Kundhlande et al. (2000) assessed savanna ecosystems and noted the significant economic value of their ecological services, in particular from carbon sequestration and water supply. The economic value of the Danube floodplains has also been calculated (Gren et al. 1995). Further, Costanza et al. (1997) evaluated the world's ecosystem services and natural capital.

The economic value of ecosystem services from some tropical forests has also been estimated. For example, the total economic value of tropical forests in Mexico has been calculated (Adger et al. 1995). Two other studies have focused on Amazonian rainforests: Peters et al. (1989) evaluated non-timber products and proposed a strategy for rainforest use in the region, while Torras (2000) assessed economic losses as a result of deforestation based on the total economic value of tropical forest in Brazil. Awang Noor et al. (1999) also estimated the economic value of forest goods and services of Ayer Hitam Forest in Peninsular Malaysia. These studies, however, made suggestions for improvements in forest conservation

and/or management (e.g., logging methods) that are not applicable to landscape management on a regional scale. For example, previous studies could not answer the questions of whether we should conserve tropical forests or how much tropical forest can be replaced by alternative agricultural land uses. This type of information is important if decision makers are to achieve sustainable development through appropriate land use in tropical regions.

In this study, we quantitatively assessed the economic value of ecological services at Pasoh Forest Reserve (Pasoh FR), which is located in the Pasoh Forest Region on the Malaysian Peninsula (2°43' - 3°15' N, 102°03' - 102°35' E). In addition, we propose a model of landscape management that encompasses the least economic risk. The specific objectives of this study were: (1) to estimate the economic value of ecological goods and services delivered by a biome when it is relatively intact, and when it has been converted to other land uses, including logging and oil palm plantations; (2) to compare the economic value of tropical forest with alternative land uses and evaluate the economic risks of deforestation in Pasoh FR; (3) to develop an appropriate land-use model based on a comparison of the economic values of both ecosystem services and commercial products from tropical forests, logged forests, and oil palm plantations using a Geographic Information System (GIS). This study provides important information for landscape management and conservation of tropical forest ecosystems in the region.

STUDY AREA AND METHODS

The Pasoh Forest Region has an area of 3600 km^2 (60 X 60 km), and is located from 40-90 km southeast of Kuala Lumpur, Malaysia. The mean annual rainfall from 1983 to 1995 at the Federal Land Development Authority (FELDA) in Pasoh Dua, located in the center of the Pasoh Forest Region, was 1810.7 mm (Noguchi et al. 2003). The topography of Pasoh Forest Region consists mainly of flat alluvial areas in the east and hilly areas in the west.

Until recently, tropical forests on the Malaysian Peninsula were being converted into agricultural land at a rate of 2.2% yr^{-1}, which was higher than the deforestation rates in insular and continental Southeast Asia (1.2-1.5% yr^{-1}) (Okuda et al. 2003). By the early 1980s, most areas where oil palm plantations could be easily developed had been deforested, and by 1996, most remaining forest was distributed only over the hilly parts of the region.

The Pasoh FR is an old-growth, lowland forest, which is characterized by a high proportion of species in the family Dipterocarpaceae (Symington 1943; Wyatt-Smith 1961, 1964). The reserve is generally homogeneous, with no evidence of major disturbance, and is considered to be a representative example of lowland forest in the south-central Malaysian Peninsula (Kochummen et al. 1990; Manokaran and LaFrankie 1990).

We calculated the economic values for Pasoh FR under three scenarios: the primary forest remains intact, the reserve is logged, and the forest is replaced by oil palm plantations. The economic value for each land use option, expressed as the net present value (NPV, the 10% discount rate, and the 100-yr rate), was calculated as the sum of the value of all ecosystem services and commercial products:

$$\mathrm{NPV} = \sum_{t=0}^{t} \frac{B_t - C_t + E_t}{(1+r)^t}$$

where *Et* is the economic value of services derived from an ecosystem in year *t*, *B* is the gross benefit from commercial products (timber from logging and palm oil from oil palm plantations), *C* is the harvesting cost for commercial products, and *r* is the yearly discount rate (10%). In the case of primary forest, there are no commercial products, so the gross benefit and harvesting cost for commercial products are both zero. The gross benefit (*B*) of commercial products (timber and palm oil) was estimated based on market prices. The economic valuation of ecosystem services (*E*) considered carbon accumulation, carbon sequestration, erosion control, and existence value. Since the 1970s, several studies have been carried out at the Pasoh FR, focusing on the ecosystem services of lowland tropical forest, forest structure and composition, productivity, and biodiversity (e.g., Yoshida et al. 2002; Ashton et al. 2003). We used results from these studies to evaluate ecosystem services.

We also developed a land-use model using GIS in the Pasoh Forest Region based on the NPV estimate of economic value from logging and oil palm plantations. The performance of each management scenario was judged according to two criteria: commercial products and ecosystem services. The analysis accounted for spatial variation in the economic cost of soil erosion, and direct costs for forest road construction and transport of products to the nearest market. We did not have data to consider the spatial variation in other ecosystem services or the productivity of commercial products.

RESULTS AND DISCUSSION

Figure 1 shows the economic value of the three land use strategies in the Pasoh FR. The economic value of primary tropical forest ($15,524 US ha^{-1}) was 25% greater than that of logged forest ($12,025 US ha^{-1}), and 50% greater than that of oil palm plantations ($9,868 US ha^{-1}). Therefore, land conversion to logged forest or oil palm plantations requires that the difference in economic value from primary tropical

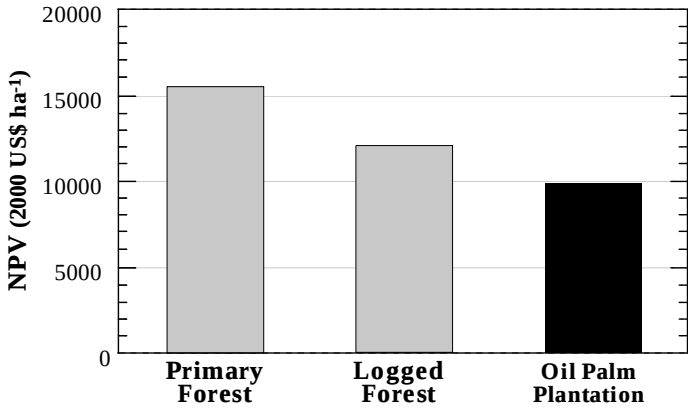

Fig. 1 The net present values for three land use options (primary forest, logged forest, and oil palm plantations) in the Pasoh FR.

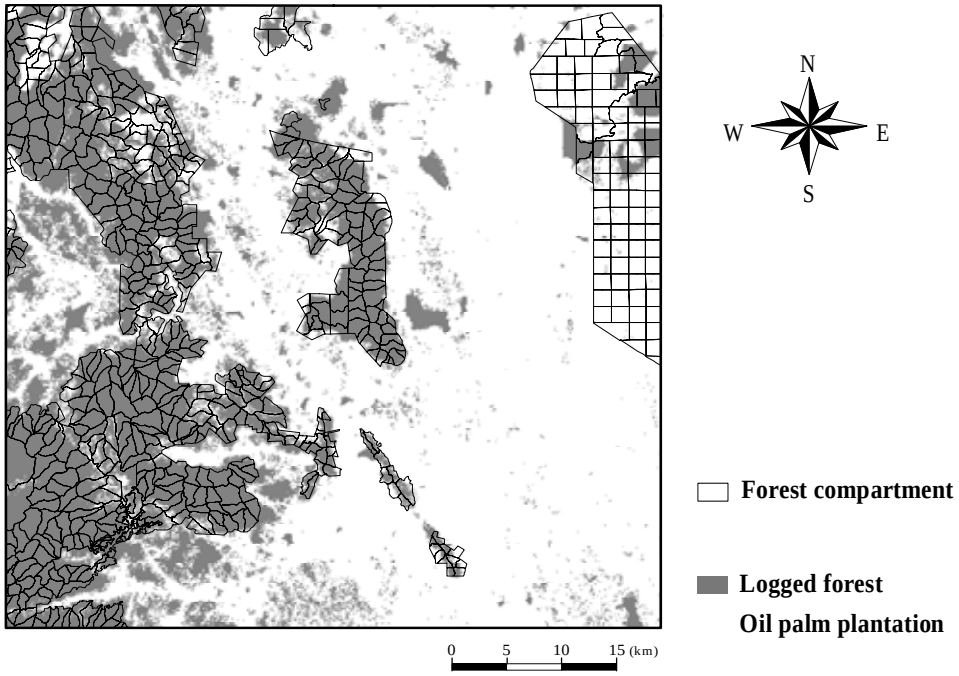

Fig. 2 A land-use model based on the economic value derived from commercial products and ecosystem services in Pasoh Forest Region.

forest be absorbed.

The results demonstrated that there are sufficient economic reasons for conserving primary tropical forests in the Pasoh FR. Logged forest and oil palm plantations provided more benefit from commercial products than did primary tropical forest, but these land uses reduced social and global benefits because of lost ecosystem services.

Comparing the benefits of commercial products and ecosystem services among land use options is an economically reliable method of landscape management, because it presents the economic risk not only for local residents but also for regional and global society. Kumari (1996) compared the values of timber, a suite of nontimber forest products, and several ecosystem services for three logging methods in Selangor, Malaysia. The results showed that there are sufficient economic reasons at both local and national levels to shift to low-impact logging. Working in Cameroon, Yaron (2001) noted that the social and global benefits, and overall value, of sustainable forestry were greater than those of small-scale farming and plantations. As with these two studies in tropical regions, our study also found that there are economic reasons for conserving primary tropical forests in Pasoh FR.

A land-use model was developed using GIS for the Pasoh Forest Region (Fig. 2). The model shows which land use option, logged forest or oil palm plantations, provides the higher economic value of commercial products and ecosystem services within each 100-m quadrat in the Pasoh Forest Region. Although primary tropical forests may provide the highest economic value for the entire area, they were not included in this analysis because most forests in the Pasoh

Forest Region are actively logged. The area of forest with logging operations in the land-use model closely overlapped with actual land use in 1996. However, the hilly western areas of the Pasoh Forest Region, where oil palm plantations are now distributed, may face higher economic risks than the logged forests; land use in these areas is therefore considered irrelevant.

CONCLUSION

Despite limited data, our results indicate that conservation of the Pasoh Forest Reserve represents a lower economic risk than its conversion to other human-dominated land uses.

The economic value of ecosystem services has been estimated using various approaches during the last decade. However, our study differs from previous studies in two important aspects. First, our analysis depended solely on data from the Pasoh FR. Pasoh FR has provided many opportunities for researchers to study lowland tropical forests, and is now the leading center for international field research in Asian tropical forests (Ashton et al. 2003). Other analyses of the economic value of ecosystem services from a particular biome generally have had to gather data from geographically diverse sites, and therefore, frequently encounter deficiencies in the data (e.g., Torras 2000). Second, we considered the economic trade-offs between commercial products and ecosystem services, and addressed the spatial variation of potential economic risk with conversion of tropical forests at the landscape level. Existing studies that compare the economic value of ecosystem services between land uses have focused primarily on the implications of conserving the remaining natural resources through sustainable use. The method of landscape management proposed in this study should be helpful to decision makers, and we anticipate that it will allow more cost-effective landscape management in tropical regions.

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RESEARCH OUTPUT

Publications

Okuda, T., Yoshida, K., & Adachi, N. 2002. Studies on Ecological Services of Tropical Forest. -Laying the groundwork for ecological studies and integrated ecosystem management- TROPICS 11: 193-204 (in Japanese with English abstract)

Conference/Symposia

Yoshida, K., Okuda, T., Adachi, N., Mazlan H., Mahdan B. 2003. Ecosystem management of tropical forest based on an assessment of ecosystem services. The Study Meeting of the Association of Japanese Geographers, Tokyo, Japan, March 2003. (in Japanese)

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