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Forest fragmentation and its correlation to human land use change in the state of Selangor, peninsular Malaysia

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Abstract

In many tropical countries forest fragmentation caused by changes in human land use activities is of primary concern for sustainability. In Malaysia this relationship is usually described without any quantitative measurement to show the implications for land use planning and management. To understand this relationship, this study developed a single forest fragmentation index based on a combination of three landscape metrics, i.e., non-forest area, forest edge bordered by human land use and patch size coefficient of variation, using the state of Selangor, Malaysia as a case study. Two defined natural landscapes; wetland and forest landscapes were used as a basic unit of analyses of pattern change of forest fragmentation and its relationship to human land use in three temporal years of 1966, 1981 and 1995. Results showed that forest fragmentation in the state of Selangor generally increased during the time periods studied. Multiple regression analysis showed that human land use is an important determinant of forest fragmentation, but the significance of several land uses as explanatory variables to forest fragmentation changed temporally. Oil palm and rubber plantations were apparently the major contributors to forest fragmentation. Differences in fragmentation pattern occurred between the two natural landscapes. Forest fragmentation increased in the wetland landscape, whereas not much change was observed in the forest landscape. Oil palm plantation appeared to be the major contributor to forest fragmentation in the wetland landscape, whereas rubber plantation was the major factor in the forest landscape. This study also revealed that knowledge of forest fragmentation through a single index in different natural landscapes provides a pathway for identifying which forested areas are highly threatened and must be given priority in strategic planning of nature conservation. In conclusion, it is vital to understand the relationship between changes in human land use and degree of forest degradation measured by a single index in order to describe the implications for land use planning and management.

Keywords: Development policy; Forest fragmentation index; Fragmentation; Malaysia; Landscape; Tropical rain forest

1. Introduction

In developing tropical regions, forest fragmentation is occurring at an alarming rate (Rudel and Roper, 1997; Laurance, 1999; Sánchez-Azofeifa et al., 2001). Since the last few decades of the 20th century, spatial and temporal change of land utilization by human activities has become more prominent as a proximate factor that catalyses forest fragmentation in the region (e.g., McMorrow and Talip, 2001; Ochoa-Gaona, 2001). Rapid economic development, as well as pressure on development from increasing human populations, are among the major underlying factors that created these circumstances (Tole, 1998; Koop and Tole, 2001; Uusivuori et al., 2002).

Malaysia is one of the developing tropical countries where both proximate and underlying causes of land use play a major role promoting forest fragmentation. From the 1950s to the 1970s, most of the natural forests were converted into agricultural land, mainly for rubber and oil palm plantations (Wong, 1974). However, prosperity from economic development due to emphasizing on the manufacturing sector since the 1980s, catalysed land development for other land uses, such as housing, new urban areas and industrial estates. But, at the same time, land development for these land-uses also intruded into forested areas. Increasing pressure on natural forest areas by human land use activities has led to diverse environmental problems, including landslides (Wan et al., 2000) and river sedimentation (Yusuf and Nordin, 2003), which are naturally

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related to the degradation of forest areas. However, the relationship between human land use change and forest fragmentation has always been described without any quantitative measurement to show the implications for the existing land use planning and management with regards to forest conservation.

In tropical regions, many studies have shown that human intervention in land utilization has changed forest cover over time (e.g., Kammerbauer and Ardon, 1999; Millington et al., 2003; Van Laake and Sánchez-Azofeifa, 2004). Forest fragmentation has also been measured to show the condition or trends of forest loss in a particular area or region (Dirzo and Garzia, 1992; Sierra, 2000; Trejo and Dirzo, 2000; Imbernon and Branthomme, 2001). However, these studies have not examined the correlation between the degree of forest fragmentation and human land use. In these studies, forest fragmentation was measured using multiple landscape metrics or indices.

Landscape metrics, such as mean patch size, edge density, mean shape index, contagion and mean nearest-neighbour distance, are usually used to describe forest fragmentation (O'Neill et al., 1988, 1999; McGarigal and Marks, 1995; He et al., 2000; Jaeger, 2000). However, not all the fragmentation metrics can capture the entire extant of forest fragmentation in a particular landscape (Cain et al., 1997). One of the major reasons is that most of the metrics are highly correlated to each other and some of them are redundant (McGarigal and Marks, 1995; Turner et al., 2001). In addition, landscape metrics are also sensitive to changes in levels of forest loss (Trani and Giles, 1999), which highlight the importance of awareness of their application for assessing and monitoring forest fragmentation. Thus, multiple landscape metrics cannot feasibly be correlated to human land use statistically. Therefore, an explicit single forest fragmentation index that can be correlated to human land use must be developed.

Recently, the landscape context has received much attention in land use planning and management (Brandt et al., 2002; Romero-Calcerrada and Perry, 2004), especially concerning forest and biodiversity conservation (Fukamachi et al., 2000; Nakamura and Short, 2001). Nevertheless, to augment the effectiveness in land use planning and management for the sustainability of land development, the concept of landscape type has been developed (Aubrecht et al., 2001). Landscape type can be used principally as a spatial reference unit for any further step of land evaluation with respect to nature conservation (Banko et al., 2003). Therefore, the concept provides other options to develop an approach for assessing levels of forest fragmentation through a single index and its relationship to human land use change. This can subsequently be integrated into land use planning and management for forest conservation.

Therefore, the objectives of this study are to develop a single forest fragmentation index to describe the degree of forest fragmentation and to understand the relationship between forest fragmentation and human land use change, using the state of Selangor, Malaysia as a case study. Forest fragmentation as defined here is caused directly by changes in human land use and excludes natural fragmentation and temporary human land use activity, such as logging.

2. Study area

The state of Selangor, which extends along the west coast of peninsular Malaysia, is located between 2°35′ and 3°60′N and between 100°45′ and 102°00′E. Selangor, the most rapidly developing state in Malaysia, has an area of approximately 800,000 ha and borders the state of Perak to the north, the state of Negeri Sembilan to the south, and the state of Pahang to the east (Fig. 1).

Having the highest gross domestic product per capita, particularly since the late 1980s, Selangor has become the richest state in Malaysia. From being mainly dependent on tin mining and rubber production from the 1950s to the 1970s, its economy has shifted towards the manufacturing sector since the late 1980s. The impact of the transition is reflected by the fact that in 2000 the state contributed the most to Malaysia's gross domestic product in the manufacturing sector; approximately 34.5%. However, other sectors such as agriculture, forestry, commerce and tourism are also becoming increasingly important in contributing revenue to the state. The population of the state is the highest in the country. The state's development in terms of socio-economics has been mainly influenced by the Federal Territory of Kuala Lumpur, which was officially separated from the state in 1974 (Fig. 1). In this study, Kuala Lumpur was included in the analyses.

3. Methods

3.1. Data set

The pattern change of forest fragmentation and its relationship to human land use were analysed in 1966, 1981 and 1995. In this study the classification scheme of land use/cover categories in the state of Selangor as developed by Abdullah and Nakagoshi (2006) were used (Table 1). This classification was based on digitised (vector version) land use/cover maps of these years, produced by the Institute for Environment and Development (LESTARI), Universiti Kebangsaan Malaysia. These digitised maps were produced based on land use maps (scale 1:250,000) by the Soil Management Division of the Department of Agriculture Malaysia. The base maps were developed by the department, through interpretation of aerial photos (scale 1:40,000) and field survey for rectification. In this study, all except forest and wetland forest and marshland were defined as human land use/cover categories.

The year 1966 was used as the reference year to evaluate the changes, and the landscape type approach was applied in the analyses. In 1966, four landscape types (wetland, forest, semi-natural and cropland landscapes) occurred in the state of Selangor (Table 2) (Abdullah and Nakagoshi, 2006). These results were based on their analysis on 100 grid squares (10 km × 10 km dimension) that cover the study area. The grid size represents about 1% of the total study area, which is appropriate for a regional scale study (a case study involving