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From Forest Landscape to Agricultural Landscape in the Developing Tropical Country of Malaysia: Pattern, Process, and Their Significance on Policy

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Abstract Agricultural expansion and deforestation are spatial processes of land transformation that impact on landscape pattern. In peninsular Malaysia, the conversion of forested areas into two major cash crops—rubber and oil palm plantations—has been identified as driving significant environmental change. To date, there has been insufficient literature studying the link between changes in landscape patterns and land-related development policies. Therefore, this paper examines: (i) the links between development policies and changes in land use/land cover and landscape pattern and (ii) the significance and implications of these links for future development policies. The objective is to generate insights on the changing process of land use/land cover and landscape pattern as a functional response to development policies and their consequences for environmental conditions. Over the last century, the development of cash crops has changed the country from one dominated by natural landscapes to one dominated by agricultural landscapes. But the last decade of the century saw urbanization beginning to impact significantly. This process aligned with the establishment of various development policies, from land development for agriculture between the mid 1950s and the 1970s to an emphasis on manufacturing from the 1980s onward. Based on a case study in Selangor, peninsular Malaysia, a model of landscape pattern change is presented. It contains three stages according to the relative importance of rubber (first stage: 1900–1950s), oil palm (second stage: 1960s–1970s), and urban (third stage: 1980s–1990s) development that influenced landscape fragmentation and heterogeneity. The environmental consequences of this change have been depicted through loss of biodiversity, geohazard incidences, and the spread of vector-borne diseases. The spatial ecological information can be useful to development policy formulation, allowing diagnosis of the country's "health" and sustainability. The final section outlines the usefulness of landscape analysis in the policy-making process to prevent further fragmentation of the landscape and forest loss in Malaysia in the face of rapid economic development.

Keywords Agricultural expansion · Development policy · Forest transition · Malaysia · Oil palm · Sustainable landscape

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Over the last century, two important trends have influenced change in the intensity of human land use. First, land allocated to human use has grown considerably, and second, increases in production of commodities have intensified the use and development of land (Richards 1990; Lepers and others 2005). One of the most important implications of these trends is increasing loss of natural forest or deforestation, which is considered a fundamental environmental concern in land use planning and management. With development, the land use in a particular area or region will continuously change over space and time. This presents land managers and decision makers with the challenge to manage land development sustainability for forest conservation.

By the end of the last century deforestation had become an alarming concern in developing tropical countries (Geist and Lambin 2002; Lambin and Geist 2003; Lambin and others 2003). Historical data have shown that approximately

28% of tropical forest area in Latin America was lost between 1850 and 1985 (Houghton and others 1991). In contrast, the area of croplands, pastures, and fallow land grew from about 357 million to 918 million ha over the 135-year period. In South and Southeast Asia the reduction in forest area over the last 140 years was between 30% and 40% (Houghton and Hackler 1994; Richards and Flint 1994). Remotely sensed data allow the estimate that between 1990 and 1997 approximately 6 million ha of humid tropical forest was lost each year (Achards and others 1991). Although the causes of tropical deforestation vary between countries (Geist and Lambin 2002), most forest loss is associated with agricultural expansion (Benhin 2006). Agricultural activities such as subsistence agriculture, cattle ranching, shifting cultivation, and permanent cash crops have been key drivers of tropical deforestation (e.g., Andersen 1986; Boahene 1998; Geist and Lambin 2002), with permanent cash crops becoming more prominent in recent years (Rasul and Thapa 2003; Hansen and Mertz 2006).

In the developing world, agriculture is a socioeconomic activity commonly driven by technocratic economic planning known as development policy (e.g., Angelsen 1999; McMorrow and Talip 2001; Casse and others 2004; Shively and Pagiola 2004; Pacheco 2006). Economic development policy is viewed as a sector-based process of planning by targets and instruments such as a 5-year planning system which sets out future objectives and programmes (Rist 2000). The planning process for the agricultural sector is mainly state-led, driven by top-down developmentalism. Over time, any consequences of such development policies, such as deforestation, have implications for both overall economic development policy and sector-based land use policy (e.g., Andersson and Gibson 2007), because any changes in land use and land cover also affect the landscape composition and configuration, or landscape pattern, in a particular area (Forman and Godron 1986). Although not all landscape pattern transformations are unfavorable in terms of socioeconomic benefits, there have been cases where adverse effects on the environment have occurred (e.g., Jepsen 2006; Zimmermann and others 2006). Specifically, studies using a landscape ecology approach have shown the linkages between development policies and landscape pattern (e.g., Munroe and others 2005; Nikodemus and others 2005; Kamusoko and Aniya 2007). In corollary, it is proposed that changes in environmental conditions are the results of the interaction between development policies and land use/land cover and landscape pattern change, as illustrated in Fig. 1. Thus far, information about this circular relationship is still lacking, which we maintain is analytically necessary to understand the impact of landscape change on development policy and the broader public policy in any given country. In light of this deficit, this paper attempts to address two interrelated questions: (i) What are the links between development policies and changes in land use/land cover and landscape pattern? and (ii) What are the significance and implications of this relationship for future development policies? The objective is to develop insights on the changing process of land use/land cover and landscape pattern as a functional response to development policies and their consequences for environmental conditions.

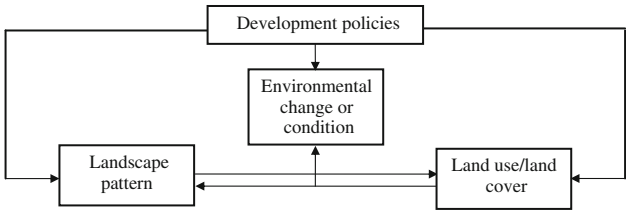

Fig. 1 The relationship between development policies and land use/land cover and landscape pattern change

The paper begins with an overview of the development of cash crops such as rubber and oil palm and their linkages to deforestation and land development policies in peninsular Malaysia. The emphasis on rubber and oil palm is consistent with these crops' importance to deforestation in the country compared to that of other crops. We also define deforestation as total conversion of forested areas to rubber and oil palm plantations. This is followed by a discussion of these two crops' influence on landscape pattern change using the state of Selangor (Fig. 2) as a case study. Selangor is selected because it reflects the likely future of land use/land cover elsewhere in peninsular Malaysia. Its rapid manufacturing-based economic development since the 1980s, which has accelerated the changes in land use/land cover, is beginning to be replicated by development policies in other states in Malaysia. The subsequent section gives an account of the consequences of those changes for environmental conditions. Following this, the paper discusses the significance for development policy by outlining the potential use of landscape ecology as an analytical tool for environment and natural resources management. The last section offers conclusions on the interconnection between the themes discussed earlier.

Overview of Agricultural Expansion, Deforestation, and Development Policies in Peninsular Malaysia

Agriculture is one of the major land uses in peninsular Malaysia (coordinates, 4°0'43"N, 102°18'3"E; total land area, 13.2 million ha) (Fig. 2). For example, by 2000 it represented 46% of the total land area, an increase of 31% from 1974 (Fig. 3). Although agriculture is important to the country's economic development, its expansion has

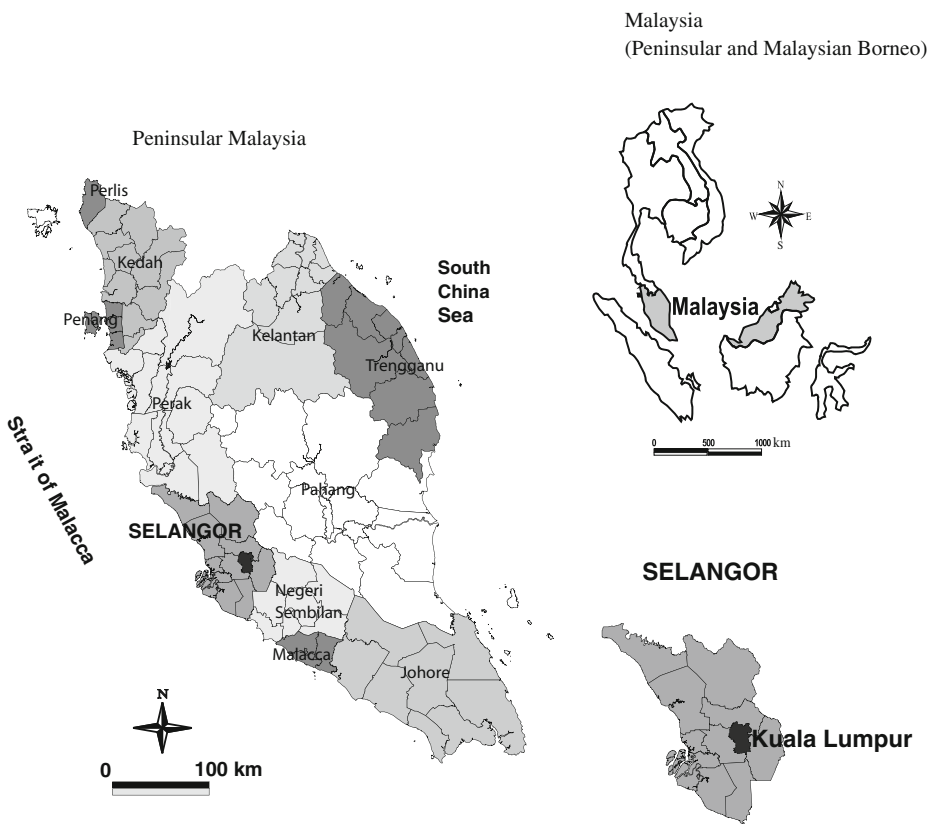

Fig. 2 The geographic location of peninsular Malaysia and the state of Selangor

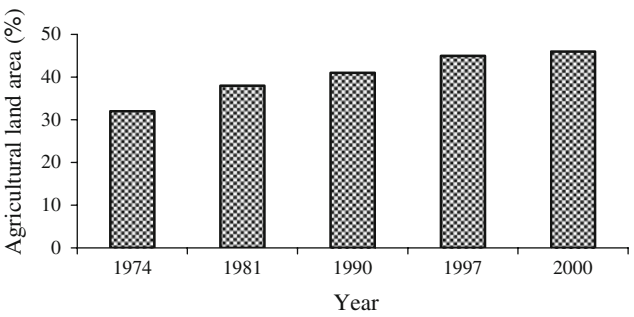

Fig. 3 Percentage of total agricultural land in peninsular Malaysia: 1974–2000. *Source*: Department of Agriculture, Malaysia

caused a considerable loss of forested areas in peninsular Malaysia (Gillis 1988). Of particular importance has been the expansion of rubber and oil palm plantations (Jomo and others 2004).

Conversion of forested areas into rubber crops has occurred since the early 20th century. In 1911, the total area of rubber was 549,000 ha, approximately 4% of the total land area of peninsular Malaysia (Voon 1992, cited in Jomo and others 2004). By the 1950s, the introduction of land development programs and resettlement schemes under the auspices of government agencies such as the Federal Land Development Authority (FELDA) have opened up new land, originally forested, for development, especially rubber plantations (Mahmud 1994). Concern was raised over the extensive clearance of forest for large-scale oil palm plantations (Jomo and others 2004). High prices of rubber and oil palm, compared to, for example, cocoa, coconut, coffee, and tapioca, have concentrated attention on these two crops.

The land use competition between forestry and agriculture in peninsular Malaysia was not determined solely by their relative marginal economic benefits (see Benhin 2006). An equally important proximate driver of deforestation was to overcome the fundamental socioeconomic problems of poverty, low productivity, and unemployment in rural areas. In 1956 when the FELDA scheme was established, about 100,000 ha, or 1%, of the total forested areas had been converted into rubber and oil palm plantations as well as for human settlements (Goh 1982).[1] The implementation of the 1971 New Economic Policy (NEP) for eradicating poverty through rural development programs accelerated the process. Building on the First Malaysia Plan (1965–1970) and the Second Malaysia Plan (1971–1975), the Third Malaysia Plan (1976–1980) and the NEP had both maintained an emphasis on agricultural development. According to Wan (1985), between 1974 and 1981 the expansion of rubber and oil palm together was

[1] The forested area in 1956 is not available. Thus, the estimation is based on area of forest in 1960, which is the nearest year to 1956 for which data were available.

30% (0.4 million ha). This corresponded to the loss of about 0.8 million ha of forested land in about the same period, that is, between 1975 and 1980 (Jomo and others 2004).

The natural resource potential of land in peninsular Malaysia was defined scientifically in terms of the relative economic viability and locational attributes, which differ across geographical conditions (Wan 1985). Two instruments of land use policy are worthy of mention. First was the introduction of a land capability classification (LCC) system by the Prime Minister's Department (Economic Planning Unit 1967) for broad regional planning and resource development. Established in 1967, the purpose of the LCC scheme was to delineate zones of land development for mining, agriculture, forestry, and recreation/wildlife, based on economic criteria that categorize five classes of land uses.[2] The LCC scheme perceived mining as being the most beneficial land use, followed by agriculture, forestry, and recreation/wildlife. The classification excluded factors such as social benefits, natural resource importance, land ownership, and accessibility. The second instrument was a combination of land capability and soil suitability called the Soil-Crop Suitability Classification, which was developed by the Department of Agriculture Malaysia. This system has been valuable in the planning of large-scale agricultural development based on the choice of crops and soil suitability. Nonetheless, there has been a long debate in Malaysia regarding whether or not these systems have influenced the expansion of rubber and oil palm at the expense of forested areas.

Expansion of oil palm continued until the end of the 20th century, driven by high global market prices (Siwar and others 2006) (Fig. 4a). In contrast, the area of rubber decreased due to the fall in prices in the global market since 1965 (Lim 1967, cited in Siwar and others 2006) (Fig. 4b). Furthermore, by the late 1970s peninsular Malaysia had limited land suitable for large-scale plantations, as most potential agricultural land had been brought under cultivation (Jomo and others 2004). As a result the more profitable oil palm was given priority (Mahmud 1994). By 2000 about 15% of peninsular Malaysia's total land area was covered by oil palm, compared to only 4% in 1975 (Fig. 4a).

From the early 1980s there has been a change in the development pattern in peninsular Malaysia. This has been driven by a shift in government development policy to a focus on the manufacturing sector (Brookfield 1994), whose contribution to the national economy has been

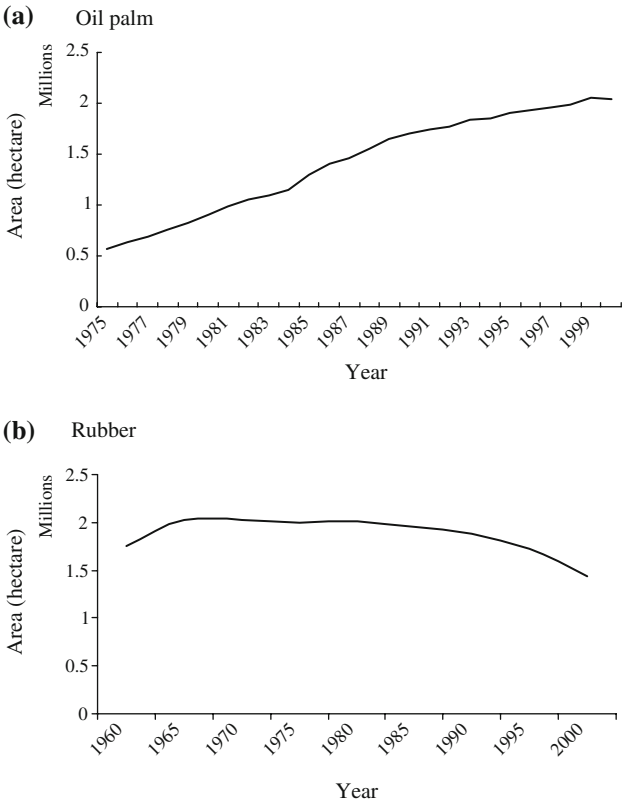

Fig. 4 Total area (ha) of (**a**) oil palm and (**b**) rubber between 1960 and 2000. *Sources*: a, Malaysian Oil Palm Board [MPOB]; b, Ministry of Primary Industry Malaysia, cited in Siwar and others [2006]

growing ever since. By 1987, manufacturing emerged as the premier contributor to economic development in peninsular Malaysia, accounting for 23% of the country's gross domestic product (Economic Planning Unit Malaysia 2004). By 2000, the contribution of the sector to gross domestic product increased to 33% (Economic Planning Unit Malaysia 2001). As a result, national development planning agencies started promoting other sectors, such as infrastructure and commercial development.

By the year 2000, as a cumulative effect of decades of development process, rubber and oil palm plantations together covered about 24% of the total land area of peninsular Malaysia. That notwithstanding, rapid urbanization is being intensively pursued, with further conversion of forest as well as rubber and oil palm plantations, especially in the region of peninsular Malaysia with the highest economic progress.

The Case of the State of Selangor

In the state of Selangor, rubber and oil palm plantations had caused deforestation in two different categories of

[2] Class I, high potential for mining; Class II, suitable for wide range of agricultural crops; Class III, suitable for restricted range of agricultural crops; Class IV, suitable for productive forest; and Class V, not suitable for mineral, agriculture, or forestry but only for catchment area and recreation.

natural forest: (i) inland forest and (ii) wetland forest and marshland (hereafter referred to as wetland forest) (Abdullah and Nakagoshi 2007). Loss of inland forest was mainly associated with the expansion of rubber, whereas oil palm was the major cause of wetland forest reduction. Although rubber plantations still contribute to a large proportion of the total agricultural land in Selangor, its importance as the major driver of deforestation has steadily decreased compared to that of oil palm (Abdullah and Nakagoshi 2007).

The intensification of rubber and oil palm land uses over the last century has changed the features of Selangor's landscape: from one dominated by natural vegetation to a landscape dominated by humans and, in particular, by agriculture (Abdullah and Nakagoshi 2006). Arguably, the primary transition from forest landscape to agricultural landscape in Selangor occurred during the 1960s and 1970s, a period which coincided with government land development programs, particularly FELDA. This is supported by the fact that by 1981 the total area covered by agricultural landscape was higher than that covered by natural landscape, whereas in 1966 the situation was reversed (Fig. 5) (Abdullah and Nakagoshi 2006).

In turn, the 1980s saw the beginning of significant change in the spatial distribution of forested land, rubber, and oil palm, which has gradually modified the landscape of Selangor. Promotion of the manufacturing sector as the engine of economic development by government as reflected in various development policies from 1980 to 2000, for example, the Fourth Malaysia Plan (1981–1985), the Fifth Malaysia Plan (1986–1990), the Sixth Malaysia Plan (1991–1995) and the Seventh Malaysia Plan (1996–2000), affected the pattern of land use/cover and landscape change in Selangor. One of the main consequences was the clearance of forested areas for urban and built-up area development. Our analysis of change was based on three land use maps of Selangor, from 1966, 1981, and 1995, using the GIS application of ArcView (version. 3.2). This showed that between 1981 and 1995 the total forested areas converted into urban and built-up areas increased by about 26% from the period between 1966 and 1981 (Table 1). Furthermore, studies by

Table 1 Conversion of natural forests, rubber, and oil palm into urban and built-up areas during two periods in the state of Selangor, peninsular Malaysia

(a) 1966–1981	
1966	Urban and built-up area (ha): 1981
Forest	2,137
Wetland forest and marshland	1,826
Rubber	14,157
Oil palm	866
Total	18,986
(b) 1981–1995	
1981	Urban and built-up area (ha): 1995
Forest	2,087
Wetland forest and marshland	3,246
Rubber	15,116
Oil palm	6,967
Total (ha)	27,416

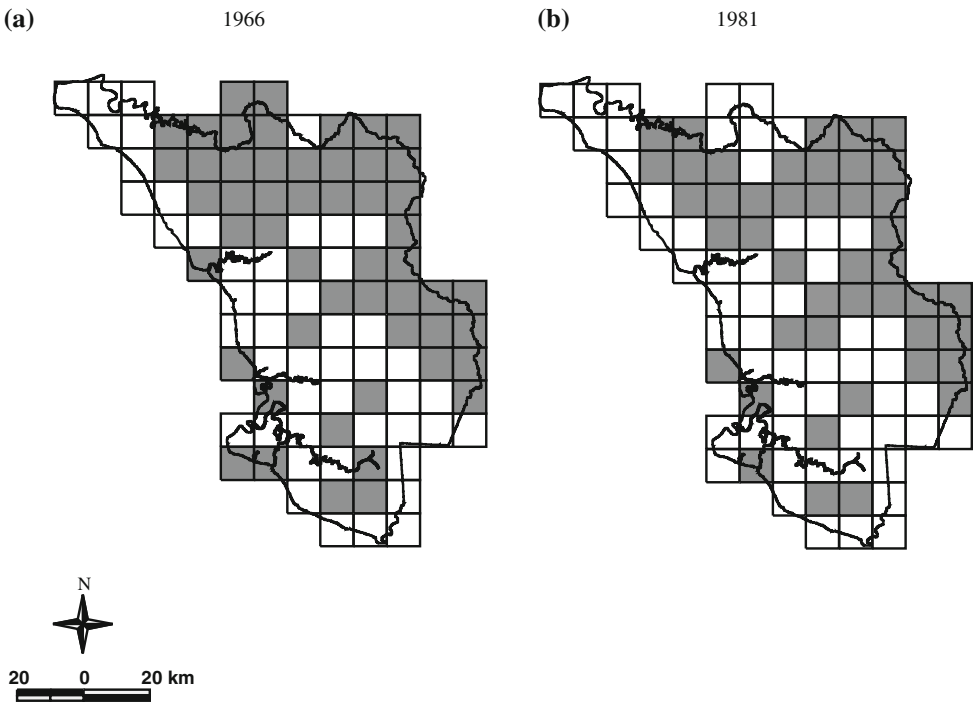

Fig. 5 Distribution of natural and agricultural landscapes in the state of Selangor in 1966 and 1981. Gray areas: natural landscape; white areas: agricultural landscape (Modified from Abdullah and Nakagoshi [2006].)

Abdullah and Nakagoshi (2007) have shown that the loss of forested areas in Selangor is highly correlated with the expansion of urban and built-up areas.

Table 1 shows that rubber and oil palm plantations were also converted into urban and built-up areas, which include housing areas, new townships, and industrial estates. However, the conversion of vast areas of rubber and oil palm plantations into urban and built-up areas did not take place until the mid 1990s. Examples include the development of the new Federal Government administrative center, Putrajaya, the new hi-tech township of Cyberjaya, and the construction of the Kuala Lumpur International Airport. All these areas are located in the Langat Basin of Selangor, where studies by Shaharudin and others (2004) showed that the proportion of agricultural land, which is dominated by oil palm and rubber land uses, decreased by about 7% from 1996 to 2001. Under this scenario, it can be hypothesized that the total land area of oil palm in Selangor will be reduced further in the near-future as was the case with rubber plantations.

The dynamic changes in land use/land cover have influenced the landscape pattern of Selangor (Abdullah and Nakagoshi 2006). Based on the scenario described above we develop a model of landscape pattern change in Selangor during the last century. In this model, the importance of each land use (rubber, oil palm, urban and built-up area) to landscape pattern change is depicted. Based on their importance, the scenario can be divided into three stages (Fig. 6). In the first stage, i.e., from the early years of the 20th century until the 1950s, rubber and oil palm land uses replaced many other types of land use, most notably forested areas, but at this stage rubber was more dominant than oil palm. During the second stage (from the 1960s to the 1970s), apart from forested areas, large tracts of rubber plantation were also removed and replaced with oil palm. However, rubber plantations still have the capacity to cause landscape pattern change, although less intense than that caused by oil palm. In the third stage (from the 1980s to the end of the 20th century), urbanization began to take place, causing significant changes, as the process removed both the agricultural crops and the forested areas. As landscape pattern change involves the fragmentation of land use types, there has been a change in landscape heterogeneity in Selangor. Both landscape fragmentation and heterogeneity are known to have negative environmental impacts (Jepsen 2006; Zimmermann and others 2006).

Environmental Changes

Fragmentation affects the connectivity, isolation, and percentage of edge of patches, whereas heterogeneity depicts the diversity of land uses of an area (Farina 2002). Changes in landscape fragmentation and heterogeneity impact on the integrity of various ecological systems. Shrinkage of natural habitats is commonly linked to landscape fragmentation and heterogeneity (e.g., Saunders and others 1991; Collinge 1996; Vos and Chardon 1998; Olff and Ritchie 2002; Michalski and Peres 2005). In peninsular Malaysia forest loss and fragmentation have affected wildlife diversity, richness, and abundance (e.g., Zubaid 1993; Jasmi 1997; Lim 1997). As wildlife is part of the complexity of ecosystem organization (Rapport 1998), its reduction is one of the immediate indications of ecosystem simplification. The simplification is due to stress caused by anthropogenic activities, and stressed ecosystems generally have less species diversity and richness (Rapport and others

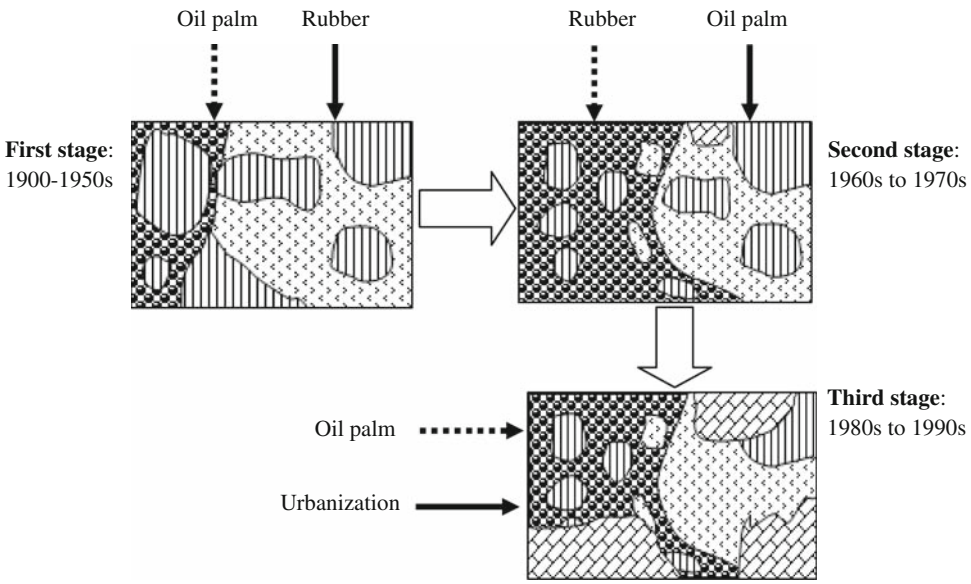

Fig. 6 A schematic view of the causative pattern of landscape fragmentation and heterogeneity in the state of Selangor during the 20th century. Solid black arrow, high intensity; dashed black arrow, lower intensity. Vertically striped areas, natural landscape; black-dotted areas, oil palm; areas with carets (<, >), rubber; brick-patterned areas, urbanization

1985). The intrusion of wild fauna into human settlements is yet another consequence of forest fragmentation, which has resulted in conflicts between humans and wildlife and in damage to crops (Jasmi 1997).

These landscape changes involve forest functional systems and fluctuation of or unstable environmental conditions in surrounding areas, for example, the ambient condition of wind regimes (Hobbs 1993) and hydrological systems (Ziegler and others 2004). In peninsular Malaysia the other obvious impact of simplification is the occurrence of various geohazard incidents such as surface erosion and landslides, especially during the rainy season (e.g., Wan and others 2000). Such incidents have caused severe sedimentation in downstream river systems (e.g., Yusuf and Nordin 2003) and damage to aquatic ecosystems (e.g., Azrina and others 2006).

Transmission or spread of vector-borne diseases to human and livestock animals is the other major consequence of landscape change (Langlois and others 2001; Graham and others 2004; Özer 2005). In peninsular Malaysia, the opening-up of land for rubber plantations has affected the breeding habitat of the mosquito, a key disease vector. If not curtailed, this situation could eventually increase the incidence of lymphatic filariasis (Kwa 2008). The development of oil palm plantations has caused changes in the ecology of mites and rodents, causing an increased frequency of scrub typhus in the human population (Kwa 2008). According to Oaks and others (1983), in the mid 1970s, before the introduction of large-scale oil palm plantations, scrub typhus was not a major problem in Malaysia. The emergence of the Nipah virus outbreak in peninsular Malaysia in 1998 has been suggested to be linked to deforestation (Chua 2003). However, it is uncertain whether the outbreak was associated directly with the clearance of forest for rubber and oil palm. Dengue fever is becoming more common, and is likely to be linked to forest clearance. In peninsular Malaysia, thus far, there is no quantitative analysis to explain the relationship. However, in Sarawak in Malaysian Borneo the clearance of oil palm plantations has been reported to have caused an increase in the dengue vector (Chang and others 1997). The above examples show the importance of assessing the pattern of landscape changes in order to improve the understanding of the implications of land use/cover change.

Policy Significance

Rapid environmental transformation in peninsular Malaysia has proven to be a success in economic terms. For instance, rural development by FELDA has received accolades as a successful policy for bringing about social and economic benefits and, hence, being exemplary to other developing countries (Fold 2000). The incidence of poverty in the country was reduced from 49.3% to 8.9% from 1970 to 1995 and to 5.1% in 2002 (Siwar and Chamhuri 2006). Nevertheless, path-dependency theory posits that when a country is consistently rewarded with economic returns (Pierson 2000), the mainstream path will form a force hostile to change (Hezri and Hasan 2006; Sham 1993). In its simplest form, the theory contends that history matters. Because there is no blank canvas in policy-making, new policy area such as environmental sustainability (which is a new alternative path) will be relegated to a secondary concern compared to the longer-standing and dominant economic development policy. This is true for Malaysia as elsewhere. Until recently, environmental issues were packaged as an independent sector of development planning and policy, with minimal integration across other policy sectors. This led to "end-of-pipe" and uncoordinated environmental management as reflected in the trend of landscape fragmentation in Selangor.

In retrospect, the three stages of landscape pattern change (see Fig. 6) described above were driven by a variety of development (and political) priorities underlined by a combination of domestic and international drivers. Fragmentation of landscapes during the first stage (early 1900–1950s) was understandably low because land resources were utilized only to serve the needs of British colonial rule. Little attention was paid then to any welfare considerations such as eradication of poverty. The second stage (1960s–1970s) saw aggressive agrarian reform, with the government playing an unprecedented interventionist role to correct market failures in the agricultural sector to ensure competitiveness in international trade (Arshad 2007). In addition, "growth with equity" became the guiding development ideology, which has driven the conversion of forests into new cultivation areas, resulting in increasing landscape fragmentation. The increasingly heterogeneous and fragmented landscape pattern produced during the third stage (1980s–1990s) was influenced by the country's need to change its economic structure from reliance on agriculture to reliance on manufacturing to increase export income. This was the period when rapid urbanization took place, bringing about a new set of environmental consequences. We have highlighted the transformation in Selangor as it arguably represents a microcosm of the future trend elsewhere in peninsular Malaysia. This is because a new driver, the development objectives of the Ninth Malaysia Plan (2006–2010), aims to reduce the regional disparity between states in Malaysia by replicating the economic success in Selangor. The government is introducing new "corridors of development" in the northern, southern, and eastern areas of peninsular Malaysia to promote higher economic growth.

There is an urgent need for more proactive planning in Malaysia that anticipates consequences before they occur. Similarly, there ought to be an increased capacity to manage the level of disturbance through ecologically informed plans and strategies. Landscape ecology perspectives may contribute to development policies by providing "informational descriptions" and, thence, a "diagnosis" of the pattern and process of land transformation.

The first potential contribution to development policy is the spatial information of landscape composition and pattern. The focus of landscape ecology analysis on describing the interaction between human and ecological landscapes allows the incorporation of biophysical information into existing land system knowledge. Malaysia's functional-based land management system, the LCC, and other soil maps are mainly informed by the soil-science tradition. This means that there has been little input from wider ecological knowledge which suggests the relationship among various biophysical variables. Another key land policy instrument, the Environmental Impact Assessment system, on the other hand, deals only with individual land-component ecological data. Landscape analysis augments such a locational (often site-specific) land use (ecological) knowledge by utilizing more specific data sets and using multiple such sets to generate functional landscape units of wider areas. Here we have chosen the state of Selangor as a functional landscape to demonstrate the possibility of describing a broader context than do narrow population or community ecology studies.

A related challenge for the developing world is how to combine structure-function ecological analysis with political-economic, or human, considerations. As described earlier, the rural resettlement policy of Malaysia's FELDA scheme represents one of the many culturally varied ways in which landscapes are politically conceptualized by different societies. Such a combination, through visual representation and interpretation, would enable landscape ecology to be an invaluable tool providing an analysis of the pattern of change in a particular cultural context. For instance, information on the state of landscape fragmentation could assist major decision-makers in Malaysia to incorporate ecological considerations in planning regional corridors of development in the less developed states. This would maximize socioeconomic benefits to the population, as done with the FELDA scheme, in tandem with environmental protection.

Description of landscape patterns is incomplete without an attempt to explain and understand the processes that occur within them. As demonstrated in the case of Selangor, landscape changes occur rapidly, so they are fast-moving targets for analysis. This requires factoring in the temporal dimension of landscape analysis in policy planning. The foregoing discussion of Selangor demonstrates that spatial relationships responded differently to a range of management and land use impacts over time. The proximate drivers of transformation from forest to agricultural landscapes can be local, national, or even international, as in the case of commodity prices influencing land use in Selangor. Knowledge of the historical process of transformation is important for a policy system to begin developing a capacity to diagnose its "health" or "sustainability" as a spatial whole.

Desirable as these data may be, Malaysia is constrained by inadequate ecological information as a result of its weak foundation of ecological monitoring. Furthermore, available data are often inaccessible because they are largely fragmented and, in many instances, suffer from patchy ecological and scale-relevant baseline information. Indeed, the indifference of development policy to environmental issues means a corresponding lack of a clear and purposive goal for the generation of environmental information at the national level. More positively, however, the capacity to undertake landscape analysis is made more tractable by the advent of remote sensing and satellite imaging technology. Many government agencies in Malaysia are currently improving their capacity for data acquisition and assimilation, especially the operating technology of data pooling, calibration, and archiving based on remote sensing information.

Once available to users, specific information on landscape processes such as fragmentation and heterogeneity must be communicated to planners and administrators through all stages of planning, from issue identification through implementation and evaluation. Emerging landscape-relevant policy tools such as the Strategic Environmental Assessment (SEA) system could benefit from the application of landscape analysis (von Seth 1999). The interface of landscape information with policy processes is already taking place systemically in countries with very limited land resources such as the Netherlands (van der Valk 2002), and gradually in other developed countries such as Britain and Denmark (Brandt and others 2002). The prospect of interorganization cooperation and coordination using landscape analysis must be explored, given the interdisciplinary and practical nature of landscape ecology. Malaysia could be a unique case study of landscape analysis application because the country's highly centralized development planning bureaucracy is capable of transmitting information to the right agency at the right time, provided that there is the political imperative to do so.

Conclusion

The transformation of land is a trend that will continue to unfold. Throughout the 20th century, the development of

cash crops has changed the country from one dominated by natural landscapes to one dominated by an agricultural landscape. More recently, the country's landscape has changed again with urbanization. The landscape transformation process was caused by the implementation of various policies for agricultural land development and industrial manufacturing. The focus of this article has been to analyze the linkages among changes in land use/cover, landscape pattern, and development policies in peninsular Malaysia. Using the state of Selangor as a case study, a model of landscape pattern change was developed. This model suggests three stages of the process of landscape transformation, with each stage showing a different landscape pattern of fragmentation and heterogeneity. The environmental consequences of change have been depicted through loss of biodiversity, geohazard incidences, and the spread of vector-borne diseases. Spatial-based ecological information could be utilized in development policy to improve the capacity to prevent further fragmentation of the landscape and forest loss. Specifically, the landscape ecology perspective may contribute to development policies by providing "informational descriptions" which could serve as a tool to "diagnose" the pattern and process of land transformation, with sustainability as the overall objective.

Beyond these insights and discussion, additional research may illuminate previously unknown properties of the interactions between landscape change and development policy in Malaysia. Three future research areas are especially relevant. The first is an extension of the case study in Selangor to include the entire peninsular Malaysia. This will answer the question whether the trend seen in Selangor is also generic to other states in the peninsular despite economic, demographic, and biophysical differences. The second research area is a cost-benefit analysis to investigate the connection between the economics of forest loss and landscape pattern change. Related to this is whether the economic returns from past deforestation are causing peninsular Malaysia to reach what is known as the forest transition stage (Rudel 1998). Findings from this research could answer the question of whether past decisions on land use were made using the best available information. This could lead to the third research area, investigating whether or not land resources in Malaysia are approaching an ecological tipping point characterized by low agricultural yield and deteriorating ecosystem services and, thus, will require policy intervention. The analysis and discussion presented in this article should be seen as the first step toward integrating a landscape ecology approach with the study of development processes in the developing world.

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