RUBBER ACREAGE CHANGE DETECTION USING LANDSAT TM: LINKAGES TO POLICIES

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ABSTRACT

Quantification and characterization of change patterns in land use/cover is necessary to understand land cover dynamics. Despite the number of studies which recognized the loss of land use/cover as a national problem, very little is understood about the relationships between the primary drivers and policies that induce changes in any given resource type. In order to gain a better understanding of the complex policy environment driving land-use change, the primary drivers affecting policies that relate to land use/cover change in south Selangor, Malaysia were identified. The primary focus was change in rubber acreage, and examination of linkages between policies and this change, recorded from Landsat TM between 1989 and 1999. Evidence from this case study suggested that some linkages between policies and the change in area of rubber plantations exist. The relatively poor price of natural rubber was one of the primary drivers that determined the formation and implementation of rubber policy instruments, thus affecting subsequent changes in rubber acreage. Federal government policies and state policies operating within the federal context explained the rapid urbanization and development of infrastructure. These activities, driven by demographic expansion, subsequently determined the change in rubber acreage in the study site.

INTRODUCTION

Land use/cover change is increasingly being recognised as an important indicator of global environmental change (Turner *et al*. 1994; Lambin 1997; Mertens and Lambin 1999). Despite the number of studies which recognised the loss of land use/cover as a national problem, very little is understood about the relationships between the primary drivers and policies that induce changes in any given resource type on a regional or local scale. This paper was concerned with the connections between primary drivers, policy response, and rubber area change in the geographical setting of south of Kuala Lumpur in the State of Selangor. Within this setting, two issues were addressed around an examination of two key relationships. First, to illustrate how primary drivers influence policy formation and implementation, thus affecting the change in rubber areas. Second, to demonstrate how policy analysis can be effective in highlighting the key dimensions of the linkages between policies and rubber area change.

MATERIALS AND METHODS

A Case Study Area

To analyse the changes in land use/cover and rubber area activities, a case study area was chosen located about 20 km south of Kuala Lumpur, between 101^o 25'and 101^o 45' E latitudes and 2^o 50' and 3^o 05' N longitudes, covering about 250 km^2 (Figure 1). The study area consists of part of three districts namely Petaling, Sepang, and Kuala Langat (collectively referred to in this paper as area south of Kuala Lumpur). The southern part of the area is mainly flat and represents a typical rural landscape with heterogeneous agricultural land cover and villages. Crop types are primarily rubber and oil palm plantations, as well as varying sizes of mixed crops. The mixed crops are characterised by diverse intercropping of traditional home garden systems, with a mixture of coffee, cocoa, coconut, banana, shrubs, and herbaceous plants (Suratman *et al*. 2000). The selected study area is a representative of the ecological and land use/cover conditions throughout the State of Selangor. The area has been a focus of large-scale changes in land use over the last decade. Rapid rates of land cover changes and land use conversions were due to developments of the new Federal Government Administration Centre (previously in Kuala Lumpur) known as Putrajaya started in 1994, covering an area about 4,400 ha.

Satellite Image and Reference Data

The remote sensing data consisted of three full scene images of the State of Selangor, Malaysia from the TM sensor on Landsat-5 acquired in 7th February 1988, 26th February 1993, and 11th February 1999, respectively. Available reference data to support this work consisted of ground truth data; a 1999 State of Selangor map at a scale of 1:125,000 (series 9101); and 1990 topographic maps at a scale of 1:50,000 (sheet numbers 3756 and 3757), both produced by the Department of Survey and Mapping, Malaysia. Also, a 1995 land use map at a scale of 1:125,000, and a 1966 soil map at a scale of 1:253,440, were used. Both topographic and soil maps were obtained from the Department of Agriculture, Malaysia.

Figure 1. A case demonstration area in south of Kuala Lumpur, Malaysia (TM bands 5, 4, and 3 - path 127, row 58)

Image Pre-Processing

To allow meaningful detection of land use/cover change based on all images, the common radiometric response among them were restored. Radiometric normalization techniques described by Joyce and Olsson (1999) were used to minimise the effects of atmospheric conditions, illumination angles, and seasonal variation among TM images. The 1999 TM image was selected as the reference image to which the 1989 and 1993 images were normalized.

Land Use/Cover Classifications for 1989, 1993, and 1999

Supervised image classifications based on the maximum likelihood algorithm were performed in this study to classify the 1989, 1993, and 1999 Landsat TM images. Eight land use/cover classes were identified: (1) water; (2) forest; (3) oil palm; (4) mixed crops; (5) grasslands; (6) rubber; (7) cleared areas; and (8) urban areas. The accuracy of the classified products was assessed by comparison with independent test areas using the standard procedures (Congalton 1991). Change matrices containing information on the number of change and no change pixels for each land use/cover class (i.e., “from 1989 to 1993” and “from 1993 to 1999”) were then developed.

Change Analysis of Rubber Plantation Area

The primary goal of this analysis was to quantify the reduction rate, to study the trend of conversion, and to map changes in areas of rubber plantations between the periods of 1989 to 1993 and 1993 to 1999 that would prove useful for examining change activities as well as temporal and spatial distribution of rubber area. The reduction rate of rubber area refers to both permanent and temporary removal of the area under rubber production, and for a given land area was calculated as follows (Mertens and Lambin 1997):

$$\text{Reduction rate (\%, per annum)} = \frac{\dfrac{(R_1 - R_2)}{R_1}}{N} \times 100$$

where R_1 is rubber area at the beginning of reference period, R_2 is rubber area at the end of reference period, and N is number of years in reference period.

Change Detection Accuracy

The change detection accuracy was estimated using the joint classification methods described by Stow *et al*. (1980), Singh (1989) and Lunetta (1998), where the change accuracy for each time interval was approximated by multiplying the accuracies of each individual classification based on the entire. Similarly, for the change in each class, the resulting accuracy was a product of individual class accuracies.

Information Sources

In order to find additional policy relevant information, relevant data on policies relating to the processes of land use/cover change, secondary data, both published and unpublished, at the national or regional scales were examined. National and state data on demographic, economics, and social status were readily available; however, local information proved to be more difficult to access. Major information was gained through formal interview with small landholders Some assistance was provided by district offices, while supplemental information was obtained through interactions with rubber related agencies.

The analysis in this chapter involved an interdisciplinary approach, using concepts and methods such as economics, sociology, and politics to address issues in the public policy arena. In short, an integrated assessment technique was employed, and this required the following steps (Majchrzak 1984; Bardach 1996):

1. gather and review government policies, relevant legislation, and government reports;
2. develop a conceptual framework for linkages between policy drivers, policy response, and rubber area change;
3. analyse the historical land use/cover, and national/state rubber and rubberwood statistics;
4. analyse the country/state/district census information;
5. assess thematic patterns of land use/cover maps;
6. interview officials from related implementing agencies during field data collections;
7. conduct formal interview with small landholders in the study area and its proximity, and
8. review the theoretical rationales in the literature.

RESULTS AND DISCUSSION

Conceptual Framework for Linkages

Recognition of the need for linkages between policy and land use/cover change is well documented (e.g., Janz and Persson 1998; Sharifah *et al*. 2000; Sharifah 2001); however, in most land use/change studies, the linkages remain very weak. Figure 2 shows a conceptual framework to examine how one can link land use/cover change or monitoring information from Landsat TM data, to national/state policy issues.

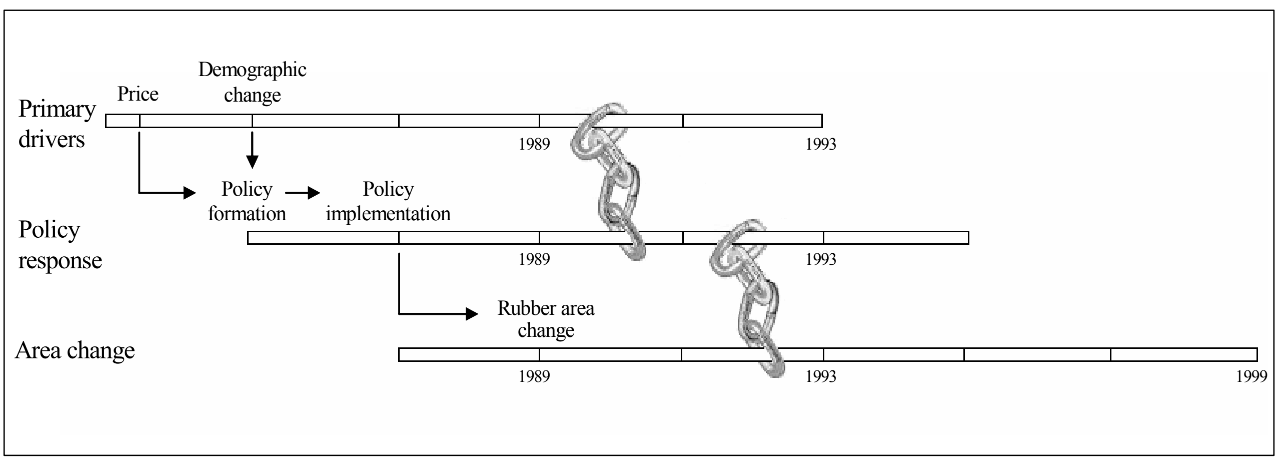

Figure 2. Conceptual framework: Linking rubber area change information from three dates of Landsat TM data to primary drivers and policies.

Conceptually and practically there is a time lag between primary drivers, policy formation and implementation, and subsequent land use changes that can be detected by remote sensing. The policies examined in this context relate to land resources (with a primary focus on rubber), land use, land development, and infrastructures that could have impacts on changing the area of rubber plantations. Based on the rubber area change statistics and thematic maps generated for 1989, 1993, and 1999, and secondary data available for this area, linkages were established by gathering the evidence on the effects that policy instruments can have on rubber plantations. While the change statistics are only estimates and primarily used to demonstrate the application of area change information to policy analyses, they provide insights into examining evidence of linkages between rubber area change and policy response in the study area.

Evidence of Linkages

One of the pertinent questions to ask is why rubber area conversion in the area south of Kuala Lumpur occurred at such a rapid rate? To answer this, it is necessary to examine the factors driving policy formation and implementation that may have had a direct impact on the change in area of rubber plantations in the study area.

Decrease in natural rubber prices and demographic change are the two primary drivers that may affect the policy formation and implementation in the study area. The three policy instruments that may be linked to the rubber area changes in the study area are:

1. rubber policies;
2. land use and development polices; and
3. infrastructure and utility policies.

To facilitate this discussion, the evidence of linkages is illustrated in Table 1 and correspondingly, their components are described in the next sections.

Table 1. Linkages between the primary drivers, policies, and rubber area changes for the area south of KL (Petaling, Kuala Langat, and Sepang districts of Selangor).

Primary drivers	Policies (year of implementation)	Post-rubber land uses	Rubber area conversion (%/annum)	
			1989–1993	1993–1999
Decrease in natural rubber prices	Rubber policies: • Crop diversification (1985) • Replanting grants (1991) • Trade planting (1991)	Mixed crops Oil palm	3.9 0.8	1.4 0.6
Demographic change	Land use and development policies: • Look east policy (1981) • Vision 2020 (1991) • Multimedia Super Corridor (1994) Infrastructure and utility policies (early 1990s)	Cleared areas and urban development Man-made lakes	4.2 0.2	6.2 0.8
Conversion to minor land uses			3.3	1.8
Total gross rubber area reduction (%/annum)			12.4	10.8

Decrease in Natural Rubber Prices

The estimated gross reduction of rubber plantation areas from 1989 – 1993 was 12.4% per annum, with an average of 3.9% per annum due to conversion into mixed crops (Table 1). During this period, the natural rubber industry of the country experienced rapid structural changes as a result of the federal government's policy response to fluctuating prices for natural rubber (Figure not shown). The price of the three grades of Malaysian natural rubber (i.e., Standard Malaysian Rubber (SMR) and Ribbed Smoked Sheets (RSS)) showed a decrease from an average of US$ 0.62/kg in 1983 to a lowest level of US$ 0.48/kg in 1985. The price of rubber has declined due to a combination of factors, including: (1) competition with the global synthetic rubber market, which is about twice the size of the natural rubber market; (2) reduced demand following the Asian financial crisis; and (3) an excess of supply due to the establishment of new plantation areas in Indonesia, Thailand, Vietnam, and India (Tomasso 2000). These poor natural rubber prices adversely affected small landholders.

Rubber Policies

Included in the Malaysian government's resolution mechanisms was the crop diversification policy. This mechanism was implemented in 1985 to encourage more efficient use of present agricultural land in order to increase productivity rate through flexible management and replanting grants (Ahmad 1992; Mahmud 2002). In addition, the policy was implemented to diversify export earnings from the agricultural sector and strengthen the income of small landholdings. This policy resulted in an increase in agricultural land use in areas where small landholders have chosen to expand their area of cultivation and/or diversify their crops (Table 1).

The federal government, through RISDA, introduced rubber replanting grant subsidies to small landholders in 1952. From the period of 1981 – 1990, replanting grants were US$ 1,430/ha for small landholdings of less than 4.05 ha. By 1991, the grants had increased to US$ 1,626/ha, or a 14% increase (RISDA 2002). While there was no indication of any positive growth in area of rubber plantations in the study area following the replanting grants increment, rates of rubber area reduction and conversion into mixed crops decreased from 1993 – 1999 (Table 1).

The lack of positive growth in area of rubber plantations could partly be attributed to the introduction of the replanting trade policy by the government in 1991 (Rojas 2002). With this policy, the government supported the production of palm oil by allowing the use of rubber replanting grants for planting oil palm. Modified post-classification image analyses revealed that 3.4% (280 ha) and 3.8% (200 ha) of rubber plantation areas were converted into oil palm from 1989 – 1993 and 1993 – 1999, respectively (Tables 2 and 3). This translates into an average conversion rate of 0.8% and 0.6% per annum, respectively (Table 1).

Table 2. Change matrix of land use/cover from 1989 to 1993.

From 1989	To 1993								
	Water	Forest	Oil palm	Mixed crops	Grass-lands	Rubber	Cleared areas	Urban	Total (ha)
Water	**453.2**	4.1	4.9	11.8	5.9	16.7	113.5	43.2	653.2
Forest	11.3	**2,533.5**	90.0	484.5	317.3	352.5	230.1	27.5	4,046.8
Oil palm	14.4	160.5	**2,253.7**	580.5	181.8	177.3	83.9	18.9	3,470.9
Mixed crops	13.0	5.6	42.8	**528.2**	159.8	56.2	171.0	26.5	1,003.0
Grasslands	20.6	35.7	66.9	746.3	**921.9**	294.7	688.1	391.6	3,165.7
Rubber	58.2	389.3	279.9	1,294.1	714.4	**4,195.6**	1,164.6	215.3	8,311.4
Cleared areas	81.1	16.4	32.6	244.5	185.9	153.7	**1,746.9**	373.7	2,834.8
Urban	24.4	4.0	12.6	36.1	25.7	17.6	321.8	**922.9**	1,365.0
Total (ha)	676.3	3,148.9	2,783.3	3,926.0	2,512.7	5,264.3	4,519.9	2,019.4	24,850.8

Note: The bold values show the unchanged area in each category.

Table 3. Change matrix of land use/cover from 1993 to 1999.

From 1993	To 1999								
	Water	Forest	Oil palm	Mixed crops	Grass-lands	Rubber	Cleared areas	Urban	Total (ha)
Water	**398.6**	3.8	0.0	27.9	31.3	18.8	151.7	44.1	676.3
Forest	115.2	**1,808.8**	72.2	174.0	52.2	421.2	419.5	85.9	3,148.9
Oil palm	422.8	273.4	**619.1**	210.6	73.4	139.1	604.0	440.9	2,783.3
Mixed crops	191.2	303.4	289.6	**937.7**	367.5	432.9	948.2	455.6	3,926.0
Grasslands	131.5	42.4	114.1	531.4	**677.8**	359.1	462.0	194.5	2,512.7
Rubber	255.9	295.1	199.9	448.1	273.3	**1,845.9**	1,404.1	542.0	5,264.3
Cleared areas	158.5	31.9	54.5	230.7	332.5	119.4	**2,126.2**	1,466.4	4,519.9
Urban	94.1	19.4	7.5	42.5	57.1	32.6	404.6	**1,361.7**	2,019.4
Total (ha)	1,767.8	2,778.2	1,356.8	2,602.8	1,865.1	3,369.0	6,520.1	4,591.0	24,850.8

Note: The bold values show the unchanged area in each category.

At the state level, the Department of Agriculture (2002) estimated the growth rate of oil palm plantations was at 5.2% per annum from 1991 – 1999, which is slightly lower than that reported nationally within the same period (i.e., 7.3% per annum) (Department of Statistics 2000).

Demographic Change

Changes in land use/cover have been portrayed as going from less intensive to more intensive management over time, driven by a human population growth (Boserup 1981). It is also assumed that this process occurs gradually over long period (Reid *et al*. 2000). While the direction of change in land use/cover in south of Kuala Lumpur showed a positive trend from a less to a more intensive system, land use/cover changes in this area rapidly occurred over a short period. The most striking changes were towards land development and urbanization. This land use change process could partly be driven by demographic change. This section focuses on four aspects of demographic change, population size, density, net migration, and urbanization rates in the study area during the study periods. Comparisons between the study area and state and national levels of demographic change were also made.

Within the last two decades, the population of south of Kuala Lumpur and its vicinity (i.e., Kuala Langat, Sepang, and Petaling districts grew by an average of 41% from 1981 to 1991, and 71% from 1991 to 2000. This translates into an average growth rate of 4.1% and 7.9% per annum, respectively. These rates were slightly lower than that of the state level (6% and 8.2%) and higher than the national level (3.4% and 3.6%) (Department of Statistics 2002; Government of Selangor 2002). At the national level, the average birth and death rates between 1991 and 2001 were 26/1000 persons and 4.6/1000 persons, respectively (EPU 2002b).

During the 1994 population enumeration, the Government of Selangor reported that the population in the three districts was 1.03 million people. In 2000, the population reached 1.47 million people. This represents an annual average increase of 73,000 people since 1994, which leads to urban residential expansion within the area. This dynamic in the speed and direction of change may help to predict future changes within this area.

The population growth rate and urbanization in this area is expected to increase in the coming year once Cyberjaya is fully completed in 2011. Therefore, population growth may serve as the driving force for urbanization leading to rubber area decreases, as might be expected.

Changes in land use/cover as a result of urbanization driven by population growth have been common in developed countries as well (Wang and Moskovits 2001). For example, between 1972 and 1991, Tokyo reported a loss of 50% vegetative cover within a 30 km radius, with the population expanding by about 5% per annum (Hashiba *et al*. 1998).

As Table 4 shows, the population density in the three districts of interest, state, and country increased between 1991 and 1999 with Petaling district recorded the highest increase. Kuala Langat (32.9%) and Sepang (24.5%) districts also experienced similar increases in population densities. Although the Sepang district recorded the lowest increase, it is expected that the growth rate will dramatically increase with on-going physical development, such as new townships, housing areas, highways, and industrial enterprises in the vicinity of this area.

Table 4. Change in population density in three districts, Selangor, and Malaysia between 1991 and 1999.

District/State/Country	Population density (persons/km^2)		% increase
	1991	1999	
Petaling	1,308	1,834	40.2
Kuala Langat	149	198	32.9
Sepang	94	117	24.5
Selangor	289	401	38.8
Malaysia	53	67	26.4

Source: Asmah and Mokhtar (2000).

Increase in population size in the study area was a result of the migration of populations for a variety of reasons, mainly economic (Asmah and Mokhtar 2000). A migration pattern study from 1980 – 1991 indicated that Petaling, Kuala Langat, and Sepang experienced net migration rates of 10.2%, 0.1%, and 4.8%, respectively (Table 5). During these periods, Petaling was experiencing rapid development, both physically and socio-economically, due to the effects of the development of Kuala Langat, whereas population migrations in the other two districts were growing at slower rate.

Table 5. Percentage of urban population and net migration rate for three districts, Selangor, and Malaysia from 1980 – 1991.

District/State/Country	Urban population (%)	Migration rate (%)		
		In	Out	Net
Petaling	92.9	16.7	6.5	10.2
Kuala Langat	28.8	2.7	2.6	0.1
Sepang	0.0	7.5	2.7	4.8
Selangor	75.2	12.7	5.9	6.8
Malaysia	50.7	6.6	6.6	0.0

Source: Department of Statistics (1995).

Petaling was a highly urbanised district, with 93% of its population being urban. This high degree of urbanization may explain the high migration rate. While Sepang was a rural area in 1991, it experienced a net migration of + 4.8%. This could be attributed to the attraction of new opportunities created in the area as a result of being chosen as the location for the new international airport during that time.

Land Use and Development Policies

Although there are many possible policy instruments that drove land use/cover change, one of the main factors may be the implementation of land use and development policies as in response to demographic change. In this context, the following discussion is focused on how government affects the allocation of resources in society through its land use and development policies.

The Malaysian government has been securing its political and social stability by sustaining consistency within the ruling government and development policies. For instance, the current National Alliance ruling party, led by Prime Minister Mahathir Mohammad, launched the “Look East Policy” in 1981. This was an important federal government strategy to encourage Malaysians to acquire new ethical values from Japanese and South Koreans. This successfully provided short- and long-term industrialisation plans for the country. Also, more recently, the “Vision 2020”, announced by the federal government in 1991, was designed with the main objective of transforming Malaysia into a developed and informational society by the year 2020 (Prime Minister’s Office 2002).

The creation of the Multimedia Super Corridor (MSC) project in 1994 is the federal government’s core strategy for the country to realise Vision 2020 (Prime Minister’s Office 2002). The MSC, located to the south of the capital city KL in the State of Selangor, is 15 km wide and 50 km long. It stretches from Kuala Lumpur’s central business district, including the Kuala Lumpur City Centre (KLCC) and Petronas Twin Towers, to the Kuala Lumpur International Airport (KLIA) in the south. At the centre of the zone there are two new ‘intelligent’ cities: Putrajaya, the new government administrative capital, and Malaysia’s Silicon Valley, Cyberjaya, its private sector counterpart. Putrajaya houses the Prime Minister’s Department, 16 ministries, and a range of other federal and state agencies.

The MSC project, Putrajaya, and Cyberjaya encompass a 14,780 ha area within the Petaling, Sepang, and Kuala Langat districts of Selangor. As a result of this land development, 4.5%, 1.7%, and 0.8% per annum of rubber areas were converted into cleared areas, urban areas, and man-made lakes from 1993 – 1999, respectively (Table 1). The newly created water bodies as shown in the 1999 classified image in Figure 3c include the 600-ha man-made lake, Putrajaya Lake, which is the centrepiece of the development in Putrajaya. This lake was built for discharging major storm drains from surrounding urban growth and from streams within its catchment areas. Additionally, all new lakes play a role in enhancing the aesthetics of the whole development, including promoting various water-related recreational activities. It was estimated that 43% (226 ha) of the lakes were built at the expense of rubber plantations in 1993 to 1999 (Table 3 and Figures 3b and c).

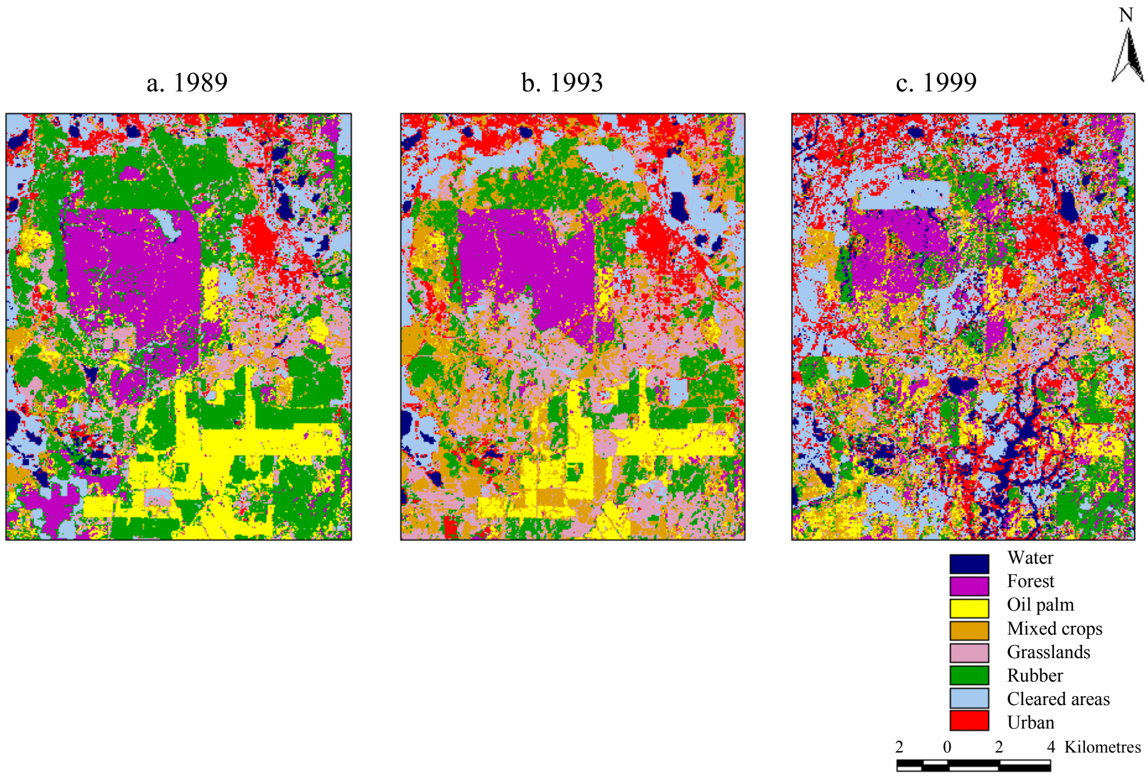

Figure 3. Land use/cover classification maps of the demonstration area produced by the supervised classifications of Landsat TM images

The classified land use/cover map sequence in Figure 3 shows alarming changes of the Ayer Hitam Forest Reserve area. Despite being gazetted as an area consisting of research forests for the UPM Faculty of Forestry, as recognised in the NFP 1978 (Revised 1992), there has been dramatic area depletion in the period of 1989 to 1999. Within ten years, the depletion rate of forests in this region was estimated to be 46%, or an average of 4.6 % per annum (Table 6). The underlying factor for this change appears to be lax forest policy implementation by the state government, which owns the research forests. This supports the usefulness of up-to-date thematic images from land use/cover change analysis for detecting land use/cover conversion. In this regard, there is a need for the Government of Selangor to focus their attention on this matter as the state is reported to have less than 30% forested areas remaining (Selangor Forestry Department 2002), which is 17% lower than the current amount reported by the NFP.

Table 6. Observed land use/cover area for 1989, 1993, and 1999 and annual rate of changes for the periods of 1989 – 1993, 1993 – 1999, and 1989 – 1999.

Land use/cover classes	1989 (ha)	1993 (ha)	1999 (ha)	Average rate of change (%)		
				1989−1993	1993−1999	1989−1999
Water	653.2	676.3	1,767.8	-3.5	-161.4	-63.1
Forest	4,046.8	3,148.9	2,778.2	22.2	11.8	45.7
Oil palm	3,470.9	2,783.3	1,356.8	19.8	51.3	155.8
Mixed crops	1,003.0	3,926.0	2,602.8	-291.4	33.7	-61.5
Grasslands	3,165.7	2,512.7	1,865.1	20.6	25.8	69.7
Rubber	8,311.4	5,264.3	3,369.0	36.7	36.0	146.7
Cleared areas	2,834.8	4,519.9	6,520.1	-59.4	-44.3	-56.5
Urban	1,561.4	2,019.4	4,591.0	-29.3	-127.3	-66.0

In south of Kuala Lumpur, initiatives at the federal level had a bigger impact on land use/cover conversion than state or local levels, especially in areas of land use and development programming. Most land use decision making in this region occurs at the federal level. Federal government is responsible for land use planning in the study area, resulting in development land use with directives coming from the new administrative centre of the federal government of Malaysia, situated within the MSC.

Infrastructure and Utility Policies

Malaysia ranked fourth in economic growth in Asia by achieving an overall 8.3% GDP growth in 2000 (Economist.com 2001; EPU 2002a). In order to sustain economic growth, it is essential to have well-developed and integrated infrastructures and utility networks. Provisions in these networks include transportation, telecommunication, postal, electricity, water supply, and gas pipelines. It is necessary for the government to expand the infrastructure network into rural areas to allow progress there. To provide better network connections, the upgrading of existing roads and the construction of new toll highways have been on-going since the early 1990s (Asmah and Mokhtar 2000).

Therefore, the last decade, especially the period from 1993 – 1999, can be considered a period of government intervention for major infrastructure activities in this area. The development of infrastructure and network connections, without a doubt, has direct impacts on rubber area change in this region. Although quantitative evidence was not provided in this analysis, the impacts from infrastructure development and network activities can be observed visually from linear features detected in classified images (Figure 3).

The rubber changes in south of Kuala Lumpur do not appear to be guided to a large extent by state land use planning measures, although this is where the power to do so resides. Land use planning control, especially from 1993 – 1999, appears to rest with the federal government, given the trends shown in this analysis.

Conversion to Minor Land Uses

The estimated conversions of rubber plantation areas to minor land uses (e.g., grasslands and recreational parks) from 1989 – 1993 and 1993 – 1999 in the study area were 3.4% and 1.8% per annum, respectively (Table 1). With the rise in the level of income among the general population, there is an increasing tendency towards the enhancement of people's quality of life (EPU 2002b). This is seen by the shift from subsistence economies to other related value-added activities, such as services and high technology-dependent industries. As such, the population consumer demand becomes more sophisticated, with increasing consumerism habits and tastes (EPU 2002b). This includes leisure demands such as golf club memberships, holiday homes, state parks, theme parks, etc. The development of leisure areas requires vast tracts of land (Sharifah 2001). For example, the increase of a vibrant leisure-related sector was evident in the high number of golf courses built within the last few years. A study conducted by the Department of Environment in 1993 indicated that there were more than 20 golf courses in Selangor, accounting for 26% of the total golf courses within the country (Asmah and Mokhtar 2000). The department reported that 70% of the golf courses were formerly agricultural lands, 20% were secondary forests, and 10% were former mining lands. The high demand for hill resorts in a highly urbanized state like Selangor created a significant economic demand and justified land use/cover conversions (Li and Chew 2002). As a consequence, such developments are catalysts factor for the conversion of agricultural fields and forest cover into other forms of land development.

Limitation of Linkages

The changes in rubber areas were triggered through the complex intervention of multiple policies either acting singly or concurrently. Some of these policies were not easily linked to rubber area changes, and sufficient information was not readily available to provide evidence for linkage. Therefore, to understand and link policies to the changes in rubber area, it was essential to reduce the complexity of the linkages by focusing on a single or reduced number of policies, rather than on a multitude of simultaneously acting or related policies.

In this study, it was also shown that rubber area decline was determined by a combination of cause and effect in varying geographical and historical contexts. Some policy linkages are geographically robust (e.g., increased oil palm plantations as a result of the implementation of trade planting policy), although some are regionally specific (e.g., urban expansion a result of land use and land development policies).

Other limitation in this study was that reported changes in land use/cover were only estimates and were affected by possible errors. As an example, the amount of rubber plantation areas actually affected by the crop diversification policy could be because overestimated. Nevertheless, this information is useful in providing insights on the magnitudes of the change and how it links to policies.

Inherently, time lags in the response of rubber area change to the implementation of policies and the driving forces exist making it difficult to relate certain patterns to an observed variable, especially over the short term. Studies over longer periods or longer temporal comparisons may help.

Proposed Utility of Study Approach

Based on the explanatory factors of rubber area change that were examined, there are several relevant points that can be made in terms of how the observations from this work can be utilised. First, the linkages made in the study area can provide guidelines to facilitate policy development and implementation in other jurisdictions. Second, this study provides relevant information to demographic influences on land use change. Third, the analysis explains the post-land uses after rubber plantation removal. Fourth, data and analysis illustrate the complex interactions between policies between various political jurisdictions and regulatory agencies involved in land use management. Finally, this study provides information on government responds to prices changes or market.

CONCLUSIONS

This chapter demonstrates the role of primary drivers in the linkages between policy and rubber area change. Additionally, it was shown that a critical concern of policy analysis must be to understand the incentives that determine the conversion of rubber areas into other land use/cover types. To design better policies to guide both rubber tree and other land resource conversion, one must begin with a better understanding on how existing public policies and programs affect the resource management and decisions of small landholders.

Although policy – rubber area change linkages may be pervasive throughout the country and pose daunting and formidable challenges to policy makers, such problems are not insurmountable. One can find ways to examine such linkages provided that one carefully analyses the markets, institutions, and policies in the region in order to improve their understanding of the complex structures of policies that drive land use/cover change.

A time series of satellite imageries are useful in providing area change information of rubber plantations. Evidence from this case study suggests that some linkages between policies and the change in area of rubber plantations exist. For example, this study indicates that the relatively poor price of natural rubber was one of the primary drivers that determined the formation and implementation of rubber policy instruments (i.e., crop diversification, replanting grants, and trade planting), thus affecting subsequent change in rubber areas in the study area.

Federal government policies (i.e., Look East Policy, Vision 2020, and MSC development) and state policies (i.e., land use and development policies) operating within the federal context were explanatory factors for the rapid urbanization and development of infrastructures in south of Kuala Lumpur. These activities, driven by demographic expansion, subsequently determined the change in rubber area in the study site.

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