FINAL REPORT
SHORT-TERM GRANT 304/PHUMANITI/634031

Title:

An Assessment of the Effect of Development on the Vegetation Coverage of Pulau Langkawi Using Landsat Thematic Mapper.

(Penilaian Kesan Pembangunan Terhadap Litupan Vegetasi di Pulau Langkawi Dengan Menggunakan Landsat Thematic Mapper)

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# Acknowledgement

The researchers of this project would like to thank the Research & Development Department of Universiti Sains Malaysia for the support and provision of research fund. We fully appreciate the support given by the research committee of School of Humanities, USM for this project.

The research and report of this project would not have been completed without the enormous help provided by the following organizations and individuals:

- The Malaysian Centre for Remote Sensing (MACRES) for the provision of satellite data
- The Meteorological Department of Malaysia for the provision of meteorological data
- USM Technical Staffs for helping out in the preparation, logistic and fieldwork
- Undergraduate and postgraduate students from School of Biological Sciences and Centre for Marine and Coastal Studies for the willingness to carry out the tasks during field work.
- All other individuals whom we may have not mentioned for helping in one way or the other.

We owe you our gratitude and heartfelt thanks.

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Abstract

This research was conducted for north Langkawi with an objective of identifying the landuse/cover changes occurring within a pristine environment undergoing progressive land development pressure to provide a preliminary perspective towards the changes taken place forming an invaluable asset in an integrated ecosystem research, planning, management and monitoring to ascertain the environmental status of the research area. This research was conducted using Landsat-TM and Landsat-ETM images dated 10 March 1989 and 11 November 2000 respectively to detect changes during an 11-year period, i.e. from pre-development in 1989 to developing phase in year 2000. Preliminary results showed that the changes projected varying degree of affected areas, which were the primary forest, the mangroves, and the cultivated land. Grassland and urbanised areas had increased considerably within these years. Computed statistics showed that from the year 1989 to 2000, primary forest had decreased from 41.8% to 33.9%; the mangroves decreased from 23.9% to 23.6%; sandy areas decreased from 8.9% to 7.4%; grasslands had increased from 5.8% to 14.2%; cultivated land decreased from 5.5% to 3.0%; and urban areas increased from 5.2% to 11.4%. The use of satellite data in this research study has proved to be invaluable and cost-effective in providing a broader perspective over the changes in landuse/cover detected for north Langkawi within a short time frame. The preliminary stage of this research has produced a meaningful picturesque view of the effect of development on north Langkawi natural ecosystem and also grounds for further in-depth research crucial in the planning and implementation of management and monitoring studies to ascertain the environmental status of Langkawi.

1.0 INTRODUCTION

This research focuses on an 11-year change detection analysis of the terrestrial environment of north Langkawi using the advancing technology of remote sensing. The changes detected over the period of 1989 and 2000 will provide a preliminary perspective over the impact of development based on eco-tourism.

The selection of north Langkawi as the research area was because Pulau Langkawi had been declared a free port on January 1987. Since then the development on the island has rapidly progressed. This coincided with the increase in infrastructure development especially with those development related to the tourism industry (Lee, 1994). Since then the image of Langkawi is synonymous with eco-tourism and a healthy lifestyle (Yasin *et al.*, 2001). Initially the focus of the development was in Kuah; the largest town in Pulau Langkawi located in the southeastern part of the island. Later development spread to the coastal areas to support the tourism industry basically relying on the natural beauty of the island coastline (Abdullah *et al.*, 2001).

Although the scale of development in the northern region of Langkawi is relatively small, the development dissects a location of sensitive environmental ecosystems such as land areas adjacent to coral reefs, the fragile mangroves and virgin tropical rainforest. Langkawi, still considered to be in its pristine environmental status, is rich in its natural resources hence earning its name in the world of eco-tourism. Conventional methods alone have been proved insufficient to provide a synoptic view on the scale and impact of development. It is also often time-consuming and costly. The advancing remote sensing technology is currently the trend in such studies. It not only provides a synoptic view of the research area but the combination of remote sensing and conventional data will project an integrated picture of the status of an environment and to preview the impact of development on the natural ecosystems.

The investigation and study of landuse patterns and the detection of changes are very important for economic planning and development. This is because each geographic region needs its own unique data, and remote sensing is well suited for providing such specialized information. The use of remote sensing data for the establishment of a landuse map of areas showing landuse changes is advantageous because it allows timely detection of changes. This demand cannot be satisfied by traditional methods alone.

Land is a vital resource for the simple existence and survival of humankind and other living things. Land is always structured as a mosaic which can be seen on satellite images and from aerial photographs. Mosaic patterns are found on all spatial scales (landscapes, regions, continents, etc.) and may on any of these scales be composed of patches, corridors and matrix, which are the three basic spatial elements of any pattern on land.

Landscape patterns are created through several mechanisms: Substrate heterogeneity, such as hills, wet spots, and different soil types, cause vegetation patchiness. Natural disturbances, including fire, storms, and pest explosions, create heterogeneity. Human activity, such as ploughing fields, cutting woodlots, and building roads, creates patches, corridors, boundaries and mosaic patterns. Various biological processes commonly modify or enhance these patterns.

On the one hand, patches of different size habitats with merging borders and edges promote species richness of an area. On the other hand, large areas are indispensable habitat for some species (birds, for example, are especially patch-size sensitive) and for the maintenance of important ecosystem functions, fragmentation therefore represents a major threat to biodiversity and the health of ecosystems.

Studies on landscape patterns and habitat fragmentation can help to better understand the linkages between species richness and habitats and therefore help planners and conservationists to better preserve biodiversity through the conservation of favourable habitat conditions.

1.1 Aspects of Tropical Development: *Threats from Humankind*

There are two major types of wet tropical forest: equatorial evergreen rainforest and moist forest, which includes monsoon forest and montane/cloud forest. Equatorial rainforests, often considered the "real rainforest" is characterized by more than 6.5 feet of rain annually spread evenly throughout the year. These forests have the highest biological diversity and have a well developed canopy "tier" form of vegetation. Roughly two-thirds of the world's tropical wet forests can be considered the equatorial type. These forests are near the equator where there is very little seasonal variation and the solar day is a constant length all year round. The greatest expanses of equatorial rainforest are found in lowland Amazonia, the Congo Basin, the Southeast Asian islands of Indonesia, and Papua New Guinea.

Tropical moist forests are found at a greater distance from the equator where rainfall and day length vary seasonally. These forests get "only" 4-12 feet of rain annually and are markedly distinguished from equatorial rainforest by a cooler dry season. During this dry season, many trees shed some or even all their leaves, creating a seasonal reduction of canopy cover and allowing more sunlight to reach the forest floor. The increased sunlight reaching the forest floor allows the growth of vigorous understory vegetation not found in lowland equatorial forest. Such moist forest is found in parts of South America, the Caribbean, West Africa, and Southeast Asia especially Thailand, Burma, Vietnam, and Sri Lanka.

The greatest cause of tropical rainforest destruction today comes from human activities, which unlike natural damage, are unrelenting and extremely thorough. Although much of this deforestation is driven by national and international economic forces, the majority serves no long-term purpose; it results from subsistence activities on a local level. Many of the effects from human-induced destruction of the rainforests are probably irreversible with in our time.

The role of humans in the deforestation of the world's forests is considerable and extensive. Many activities contribute to this loss including subsistence activities, oil extraction, logging, mining, fires, war, commercial agriculture, cattle ranching, hydroelectric projects, pollution, hunting and poaching, the collection of fuelwood and building material, and road construction. Under current practices, extractive industries (timber, oil, and mineral) promote the development of short term booms that encourage permanent settlement. These booms and resulting settlements can attract large numbers of poor seeking a better life. They clear the surrounding land for agriculture and livestock. Meanwhile, the forest resource, whether it be oil, timber, or minerals, is rapidly depleted with little consideration for the long term consequences. Once the resource is exhausted, the industry moves on to new areas, leaving behind settlements dependent on the resource extraction for survival and a degraded environment. The only resort for the settlers is to practice subsistence agriculture by clearing what forest remains. Most extractive processes in the rainforest are not sustainable as currently practiced.

Like most environmental assets, rainforests are endangered by their status as open access resources or as common property (Though designating rainforests as open access resources is not entirely accurate, in light of the lack of formal property rights in certain countries and the limited capacity of many governments to manage and regulate the rainforest lands, treating rainforest as such is adequate for this discussion). Under open access, no group has exclusive use of rainforest resources, but essentially everyone enjoys access to the resource. There is little incentive for conservation with the "If I do not get the resource someone else will" mentality under these conditions and forest is depleted by industry and small farmer alike. In addition, economic incentives like subsidies and tax breaks for forest developers distort the direct costs of harvesting and converting tropical rainforests. The result is market failure, where the prices for tropical timber products and other goods derived from rainforest destruction do not reflect the full environmental costs of the loss of goods and services provided by the ecosystem. Therefore, by offering these incentives, the government effectively makes it profitable for firms to convert forest for development purposes where it normally would not be profitable.

Another contributor to commercial forest destruction is the outstanding debts of developing countries, which causes them to seek quick ways to raise revenue to make debt payments. However, the elemental underlying cause of deforestation is population growth; both in developing countries which depend on forest lands for sustenance, and in developed countries, which place more demand on forest products with their high standard of living.

We (humans) have always cleared the forest for our own interests, but in the past, the process was slow and only limited regions were deforested, generally for subsistence agriculture. However, today, humanity is far more efficient at clearing the forest with our advanced technology and machinery and the drive to earn profits in the near term.

1.2 Atmospheric Role of Forests

Rainforests play the important role of locking up atmospheric carbon in their vegetation via photosynthesis. The vegetation and soils of the world's forests contain about 125% of the carbon found in the atmosphere. When forests are burned, degraded, or cleared, the opposite effect occurs: large amounts of carbon are released into the atmosphere as carbon dioxide along with other greenhouse gases (nitrous oxide, methane, and other nitrogen oxides). The burning of forests releases almost one billion tons of carbon dioxide into the atmosphere each year.

The buildup of carbon dioxide and other gases in the atmosphere is known as the "greenhouse effect." The buildup of these gases is believed to have altered the earth's radiative balance meaning more of the sun's heat is absorbed and trapped inside the earth's atmosphere, producing global warming. The largest anthropogenic contributor to the greenhouse effect is carbon dioxide gas emissions, 73-92% of which comes from the combustion of fossil fuels, 13-23% of which is attributed to deforestation, and the final 1% coming primarily from energy costly production activities like the manufacture of concrete, steel, and aluminum. Preindustrial atmospheric concentration of carbon dioxide was 280 ppm, though today levels have risen to 360 ppm, a 28.6% increase. Climatologists estimate that a level 450 ppm may result in an eventual 2.5-3C (4.3-5.4F) increase in temperature. Even though we appear to be coming to an end of an interglacial period, some climatologists predict that global warming will produce a sharp upswing in global temperatures followed by a deep plunge into a glacial period several thousands years from now.

The extent and effect of global warming has been long debated by scientists, industries, and politicians. In 1995 leading scientists, the Intergovernmental Panel on Climate Change (IPCC) concluded that global warming had been detected and that "the balance of evidence suggests a discernible human influence of global climate." Their evidence included a 0.5-1F (0.3 to 0.6C) increase in average global temperature, a 4.5F (2.5C) degree increase at the Earth's poles, the breaking up of the Antarctic ice sheets, the receding of glaciers worldwide, the longest El Niño ever recorded, a record number of hurricanes in 1995, a record number of heat waves, and an increase of epidemics attributed to global climate change including dengue fever, malaria, hanta virus, and the plague. According to scientists at the National Oceanic and Atmospheric Administration 1997 was the warmest year on record . . . until 1998, which was even warmer. A British study at the University of East Anglia suggested that 1998 may be the warmest year in over 800 years. The 1990s have been the warmest decade of the millennium and the past decade has witnessed nine of the eleven hottest years this century. In the 900 years before the twentieth century, temperatures dropped an average of 0.02 degrees C (0.04 degree F) per century.

In the past 150 years, the carbon dioxide level has increased from 280 ppm to 360 ppm (28.6% increase) and may double within the next 60 years. Although the effect of global warming can only be anticipated, the consequences are believed to include increased violent weather like hurricanes, melting of polar ice translating in a decline in krill populations which are critical to the ocean food chain, a rise in global sea levels which would inundate low elevation cities like Cairo, Lagos, New Orleans, and Amsterdam, the migration to cooler regions or extinction of species sensitive to changes in temperature like amphibians, the heightened danger from human pollutants like ozone, and the spread of tropical disease into cooler climates.

The projected rise in sea level from ocean water expansions and ice melt (sea ice in the Artic is shrinking by an average of 14,000 square miles per year and is strongly correlated to greenhouse gas and aerosol emissions) corresponding to global warming varies, though there is a good chance that oceans will rise from 10" (25 cm) to 20" (50 cm) within the next century if greenhouse gas emission rates continue at present levels. Such a rise in sea level does not sound like much, but it would have profound effects on both humankind and natural systems. Note that any sea level increase would be magnified during tides, storm surges, and hurricanes and have a devastating impact.

Island nations like the Maldives and scattered South Pacific republics face extinction. The sea is a tremendously important resource for man: our greatest cities lie along the coast for trade and commercial fishing. Any rise in sea level would directly effect these metropolises, causing flooding and the failure of sewage and transit systems, along with inundating neighboring agricultural plots. A change in sea levels will also affect coastal ecosystems like river deltas, wetlands, swamps, and low-lying forests, which play an important role in providing services for mankind, in addition to housing biological diversity. Though sea levels have been higher in the past, today there is less room for species affected by flooding since buildings and concrete now occupy the areas that were once extensions of their environment. Modern humankind is so dependent on existing conditions that a change in sea level, even if it is 10-20" (25-50 cm) will have a drastic effect on our species. Global warming is as much a social problem as it is an environmental one.

1.3 Statement of the problem

The past decade has seen Malaysia develop at an unprecedented rate with dire consequences for the environment. The country is becoming industrialized and urbanized, and a growing majority of Malaysians are becoming mentally disconnected from the source of their sustenance - the land. As a result, a large proportion of Malaysians seem to be indifferent about the long-term impacts of development on the land which has potential to stunt future growth and undermine our present achievements. History has shown that one of the main reasons that cause societies to collapse is the self-destruction of their resource-base, primarily the soils that support agriculture (Hyams, 1952), hence our vegetation in general. It is imperative that we bear this lesson in mind when choosing our path to development in this current economic climate. The "balanced development" sought by the government to achieve Vision 2020 should ensure that the use of our land and its related resources can be sustained for generations to come.

It is critical for us to understand that every action, every activity that is carried out on land will carry its impact either on a short-term basis, intermediate or even on a long term basis. It is crucial to investigate and to predict this validation if we are moving towards the era of "sustainability". Too rapid a development will prove immediate detrimental to the environment for a long term basis. This, however, will be inevitable if there is no proper planning where development is concerned.

Having these in mind, it is the main goal of this research to study the impact of development on the vegetation, since the era of "sustainability" will also require the environment to provide green lungs for its dependents.

1.4 Objectives of the Study

(1) To evaluate the extent of development and its effect on the vegetation coverage of Pulau Langkawi between 1990 and 2000.
(2) To produce landuse/cover changes map of Pulau Langkawi between 1990 and 2000.
(3) To assess possible impacts development has on the vegetation coverage.

The project shifted its focus on the northern section of Pulau Langkawi because north Langkawi is a pristine environment undergoing progressive land development pressure. This research will provide a preliminary perspective towards the changes that had taken place which is an invaluable asset in an integrated ecosystem research, planning, management and monitoring to ascertain the environmental status of the research area. The period of change detection study will be based on pre-development phase (1989) and developing phase (2000).

1.5 Approach to the Study

This study applies Environmental Remote Sensing to the vegetation coverage of Pulau Langkawi in Peninsular Malaysia. There are three major components involved in this research study and these are landuse/cover monitoring, remote sensing, and impact studies. This research study is basically divided into five phases and these are given in a flow chart in Figure 1.

The methodology adopted in this study utilizes both conventional and advancing remote sensing technology to assess the existing coastal environment. The use of a remote sensing technique will provide a broad synoptic view of the distribution and location of landcover types.

Landcover types, vegetation types in particular, can be a visible indicator of development impacts if there is improper planning, erosion or even soil loss. Remote sensing can provide the synoptic view of the landscape necessary to locate and monitor areas with significant development impact or problems.

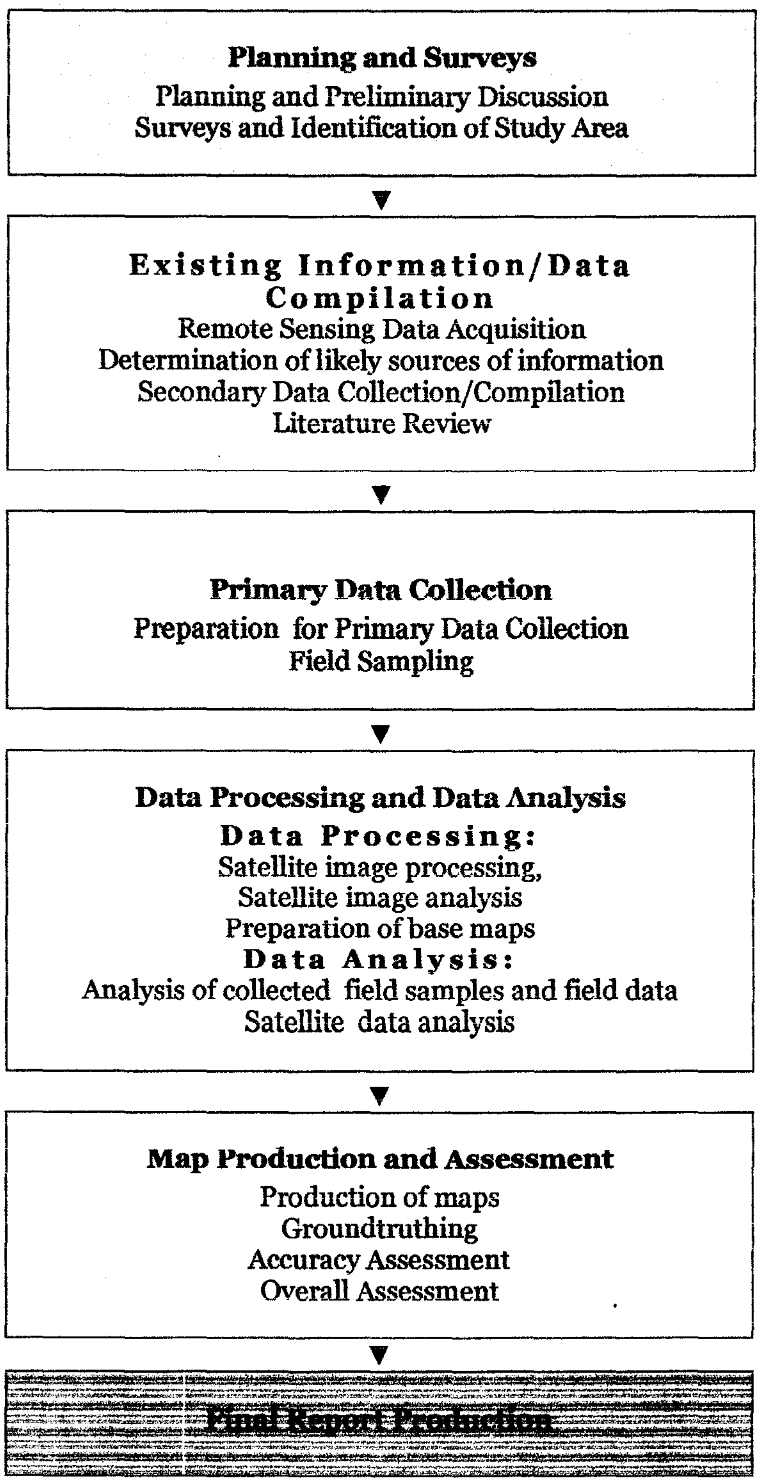

Figure 1. The Research Study Phases.

2.0 THE STUDY AREA

The island of Langkawi is located at the northeast of Peninsular Malaysia (6° 10'N – 6° 30'N and 99° 35'E – 100° 00'E). This is about 30 km from the mainland port of Kuala Perlis, which is the main entry point to the island. The main island itself covers an area of 32,180 ha divided into six administrative districts. The study area *i.e.* north Langkawi, transcends five of the six districts which are Mukim Padang Mat Sirat, Mukim Bohor, Mukim Ayer Hangat, Mukim Ulu Melaka and Mukim Kuah. The study area of north Langkawi covers approximately 950 km^2 of land surface. The location of the research area is shown in Figure 2.

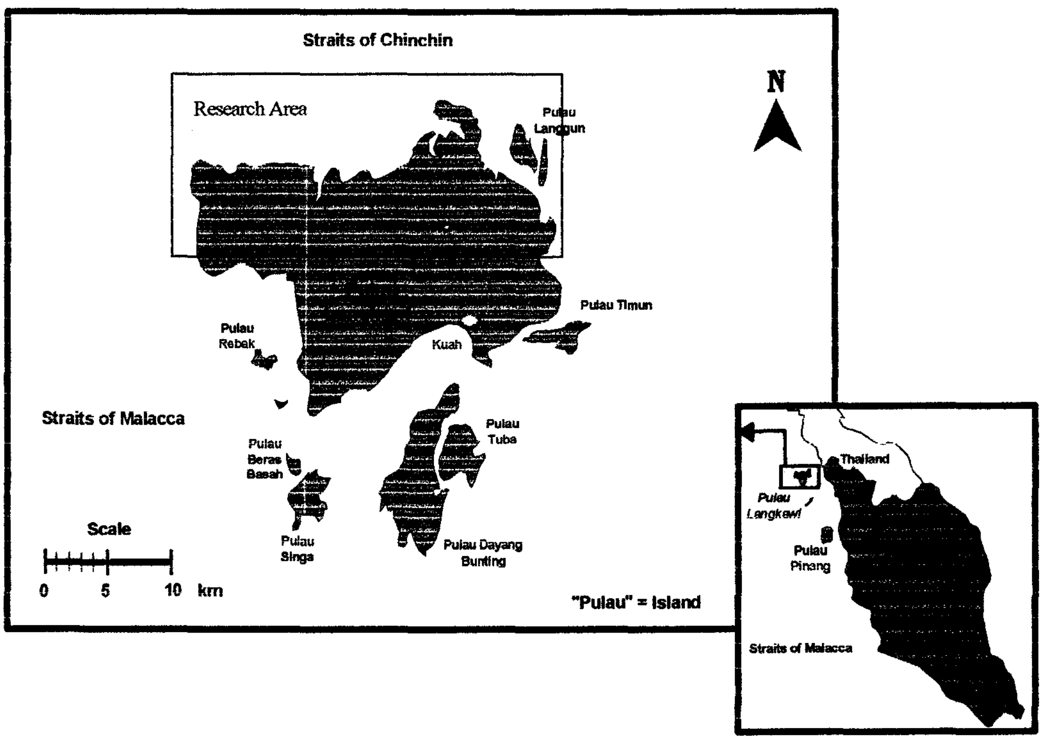

Figure2. The location of the study area.

3.0 METHODOLOGY

Two sets of Landsat images were utilized in this research, which are:

1. Landsat-TM of path/row ID: 128/56 dated 10 March 1989
2. Landsat-ETM of path/row ID: 128/56 dated 11 November 2000

The imageries used in this study are shown in Figures 3 and 4.

The Landsat-TM image was obtained from the archives courtesy of Reef Research Group of Universiti Sains Malaysia, while the Landsat-ETM image was obtained from the Malaysian Centre for Remote Sensing (MACRES). The satellite images were processed using ERDAS Imagine 8.3.1 image processing software.

There were 8 landuse/cover (LUC) classes used in the classification process and they were:

(i) Mangrove Forest
(ii) Limestone hilly ourcrops
(iii) Primary Forest
(iv) Secondary Forest
(v) Grassland
(vi) Open/Dry Bare land
(vii) Build-up Areas

The above 8 LUC classes were chosen mainly because these classes would easily differentiate from one with the other since the objective of the research was to determine the amount of changes development has impacted on the vegetation coverage. Differentiation of categories of build-up areas would serve no purpose for this project. An error matrix is computed to calculate the overall accuracy for the maps produced from Landsat Thematic Mapper imageries.

The following sub-sections will describe the image processing procedures that were used in this research to produce the landuse/cover maps of north Langkawi, and the change detection analysis.

Figure 3. Landsat TM p/r: 128/56. date 1989. Displayed in r/g/b:4/5/3.

Figure 4. Landsat ETM p/r: 128/56. date 2000. Displayed in r/g/b:4/5/3.

3.1 Image Processing Procedures: Production of landuse/cover maps of north Langkawi

- **Georeferencing**

The raw data of Landsat images were georeferenced to conform to the Malayan Rectified Skew Orthomorphic Projection system. In this process, each raster cell was resampled to a cell size of 30m x 30m (x,y) giving the number of units per cell as $900m^2$. Resampling of cell size is important and necessary for generating statistics of the research area.

- **Subset**

The research area was cut out from the georeferenced image. The cut-out image leaves only the northern region of Langkawi. Due to the inevitable shifts of the satellite path, the irregular coverage of the western region of north Langkawi was cut appropriately to form a more defined research area. The total size of the research area is 430 rows x 1020 columns *i.e.* inclusive of the sea area, which will be omitted in the landuse/cover classification process.

- **Classification**

Supervised classification method, a process that relies on the analyst's knowledge of the research area, was employed in this research to produce the landuse/cover maps from the Landsat-TM and -ETM images. Prior to the classification process, the landuse/cover classes or scheme was defined as described in Table 1.

The classification scheme was based on the Malaysian classification system used in its standard map production. Only nine classes were chosen because:

1. The northern region of Langkawi has not yet undergone heavy facelift in development and therefore do not have too complicated landuse/cover types.
2. Too many landuse/cover classes would create a very complex and meaningless landuse/cover map.

The most homogenous possible training samples were selected to best represent the classified classes and their signatures evaluated before being used in the classification process. Maximum Likelihood classification was the preferred decision rule or hardclassifier. With Maximum Likelihood a full multidimensional probability function is evaluated to determine the likelihood that any pixel belongs to a given class. By default, each pixel is assigned to the most likely class, regardless of how likely or unlikely that maximum may be. This is the most advanced and most accurate of all classifier techniques in ERDAS Imagine system because it takes the most variables into consideration. However, it is also the most time-consuming computation where the computation time increases with the number of input bands.

Table 1. Landuse/cover classification scheme.

Class	Description
Primary forest (PF)	This class include all undisturbed virgin forest.
Belukar (BE)	A local Malay term used for mixed forest types which include open, disturbed or re-growth forested areas
Mangrove (MG)	Forests of intertidal zones
Grassland (GR)	Grass coverage of more than 50%.
Cultivated land (CL)	Land areas having agricultural activities *e.g.* rubber plantation, padi fields
Build-up areas (BA)	Settlement areas and other infrastructures like roads, railways and industrial areas.
Baresoil/land (BS)	Bare land with more than 50% exposed soil/land or land with very low vegetation coverage.
Sandy areas (SA)	Beaches or other sandy areas usually occurring within the coastal region.
Water bodies (WB)	This class represented both natural and man-made lakes, reservoirs, and does not include the sea or the rivers in the research area.

3.2 Image Processing Procedures: Change detection analysis of north Langkawi

The MATRIX module was used in the computation of change detection analysis of the resultant images of year 1989 and 2000. Newly-formed landuse/cover classes based on changes between the two dated maps will be generated as indicated in the matrix where the columns in the matrix were specified as landuse/cover classes of 1989 while the rows were specified as landuse/cover classes of 2000. Theoretically the total possible number of combination classes for the newly generated matrix will now be 81. However, the final result may not cover the maximum number of classes here because the output will depend on the category of changes that had taken place and detected through remote sensing. The theoretical matrix is shown in Table 2. Numbers 1 to 81 in the matrix indicated newly generated landuse/cover classes. For example, the new class 10 showed that the original primary forest class in 1989 had been converted into *belukar* in 2000. The shaded diagonal classes indicated that no change had occurred in the landuse/cover class from 1989 and 2000, *i.e.* original landuse/cover classes of 1989 that remained unchanged in 2000.

Table 2. A theoretical matrix of newly generated landuse/cover classes for 1989-2000 change detection.

		1989								
		PF	BE	MG	GR	CL	BA	BS	SA	WB
2000	PF	1	2	3	4	5	6	7	8	9
	BE	10	11	12	13	14	15	16	17	18
	MG	19	20	21	22	23	24	25	26	27
	GR	28	29	30	31	32	33	34	35	36
	CL	37	38	39	40	41	42	43	44	45
	BA	46	47	48	49	50	51	52	53	54
	BS	55	56	57	58	59	60	61	62	63
	SA	64	65	66	67	68	69	70	71	72
	WB	73	74	75	76	77	78	79	80	81

Computation of Error Matrix / Accuracy Assessment

Basically, the general LIT survey method was also employed in the ground truthing process with one exception - points were selected at random. Ground truthing which is carried out after map production mainly means verifying information extracted from remote sensing data (stereograms, and photographs). From ground truths, accuracy assessments for reef maps were also calculated. This assessment was based on a set of reference points selected randomly on the study area as it is not practical to ground truth or test every unit area of the study region. A classification accuracy table is also generated from the ground truth results and two kinds of reports were derived, the error matrix and the accuracy report. The accuracy report refers to the calculated statistics i.e. the percentages of accuracy based upon the results of the error matrix.

The error matrix is the most common way to represent classification accuracy of remotely sensed data as in this study. An error matrix is a square array of numbers that expresses the number of points assigned to a particular category relative to the actual category as verified on the ground. The columns usually represent reference data or the observed data while the rows indicate the classified data generated from the remotely sensed data. An error matrix is a very effective way to represent accuracy because the accuracies of each category are plainly described along with both the error of inclusion (commission errors) and errors of exclusion (omission errors) present in the classification or mapping.

The error matrix can be used as a starting point for a series of descriptive and analytical statistical measurements. The simplest descriptive statistic is overall accuracy, computed by dividing the total correct points or correct occurrences (*i.e.* the sum of major diagonal) by the total number of points or occurrences in the error matrix.

The total number of correct points in a category divided by the total number of points of that category as derived from the reference data (the column total) indicates the probability of a reference point being correctly classified and is really a measure of omission error. It is also known as "producer's accuracy" because it indicates how well a certain area can be classified. On the other hand, if the total number of correct points in a category is divided by the total number of points that were classified in that category, the result is a measure of commission error or the "user's accuracy". This is also a measure of reliability indicating the probability that a point classified on the map or image actually representing that category on the ground. A summary of the error matrix computation is as follows:

		Columns (Reference data)			
Rows (Classification data)		1	2	k	Row total
	1	n_{11}	n_{12}	n_{1k}	n_{1+}
	2	n_{21}	n_{22}	n_{2k}	n_{2+}
	k	n_{k1}	n_{k2}	n_{kk}	n_{k+}
	Column total	n_{+1}	n_{+2}	n_{+k}	n

$$\text{Overall Accuracy (\%)} = \frac{\text{Sum of correct occurrences } (n_{11} + n_{22} + \ldots n_{kk})}{\text{Sum of occurrences (n)}} \times 100$$

Producer's accuracy for class 1 (%) = $(n_{11} / n_{+1}) * 100$
User's accuracy for class 1 (%) = $(n_{11} / n_{1+}) * 100$

The ground truthing and generation of error matrices for this study were carried out by the author.

3.3 Map Production

Final maps with complete composition were then generated as the 11-year change detection output.

4.0 THE ANALYSIS OF CHANGES OF NORTH LANGKAWI

4.1 The Landuse/cover changes for year 1989 and 2000

The landuse/cover map produced using Maximum Likelihood as hardclassifier in the supervised classification for year 1989 is given in Figure 5 while for year 2000 in Figure 6. Distribution of the various landuse/cover features for years 1989 and 2000 are represented in pie charts as shown in Figure 7. A more detailed breakdown of area coverage of each landuse/cover class and the changes are given in Table 3. Generally, most classes had deceased in its size except two classes, which are grassland and urbanised areas.

Statistics calculated for the research area showed a total land area of 958.94 km². It was obvious from both maps that the largest group of landuse/cover classes were the primary forest and the mangroves. Primary forest within this region was found on the mountainous and hilly areas of Gunung Machincang, Gunung Raya and Bukit Sawak ranges. Mangroves were found on the two major mangrove forest regions of Kubang Badak in the west and Ayer Hangat – Kuah in the eastern side. *Belukar,* which is a Malay term for open and mixed forest, were found fringing some parts of the foothills of Bukit Sawak and Gunung Raya in year 1989. *Belukar* coverage decreased considerably from 7.8% in 1989 to 5.6% in 2000.

In 1989, the cultivated land was quite extensive composing of 5.5% of the total research area. By year 2000 the area was reduced to a mere 3.0%. The urbanised areas (5.2%) in 1989 were more aggregated compared to year 2000.

Sand-covered areas were larger in 1989, *i.e.* 8.9%, while this was reduced to 7.4% in year 2000. Most sandy areas covered the strips of beaches along the Tanjung Rhu to Teluk Ewa region and much less amongst the urbanised region in 1989. The decrease of 1.5% of sand-covered areas in year 2000 may not be entirely due to conversion into another landcover class. There could be some beach erosion and sand transportation seawardly.

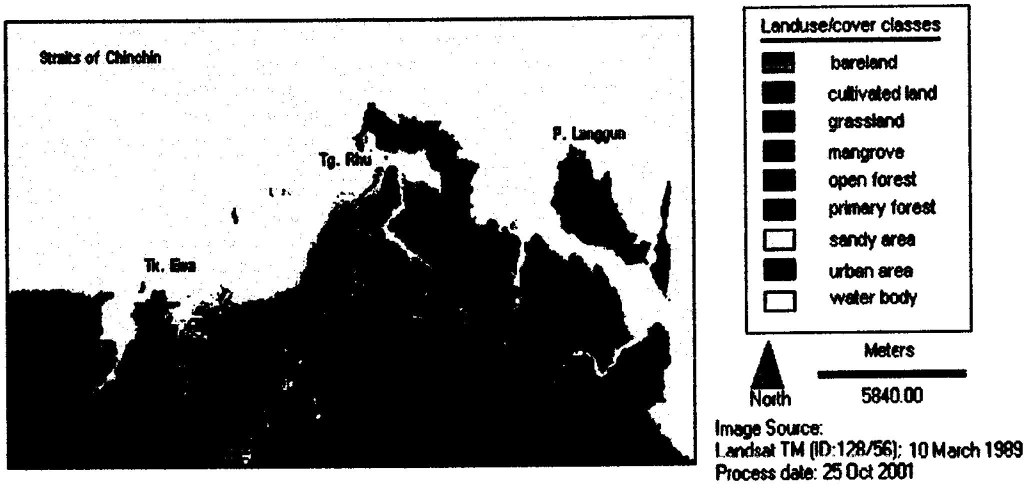

Figure 5. Classified map of landuse/cover of north Langkawi in 1989.

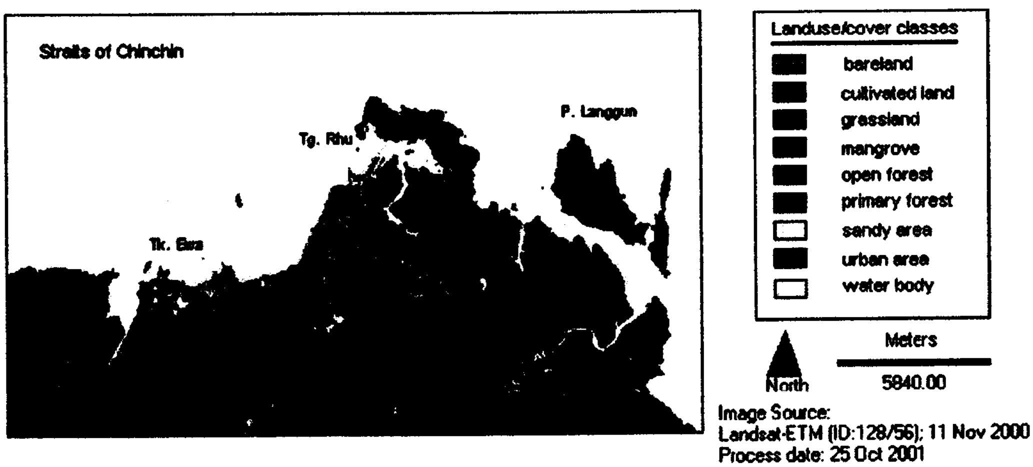

Figure 6. Classified map of landuse/cover of north Langkawi in 2000.

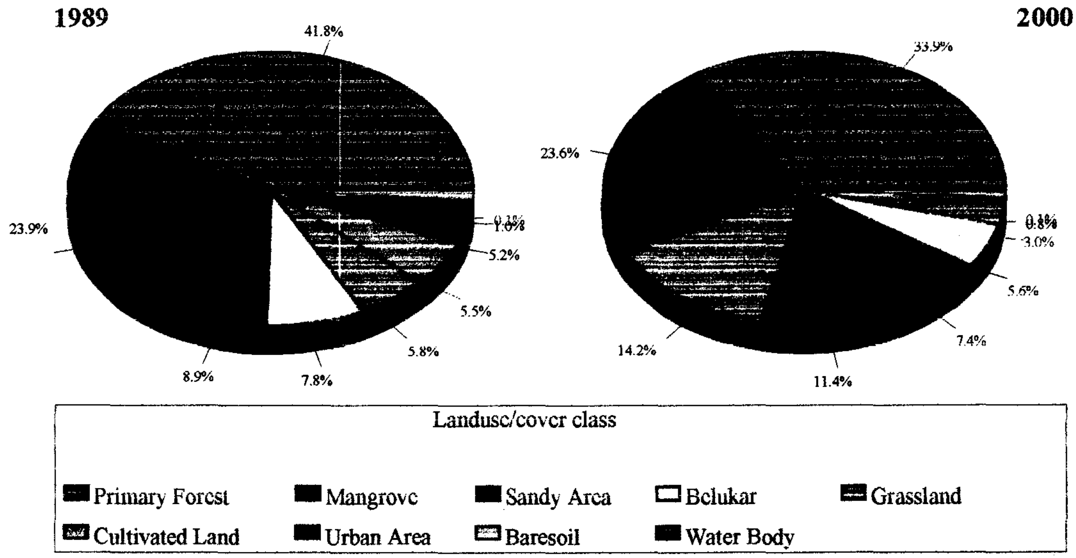

Figure 7. Composition of classified landuse/cover of north Langkawi in 1989 and 2000

Table 3. Computed statistics of area cover extracted from landuse/cover classification of north Langkawi for year 1989, 2000 and the changes between 1989 and 2000.

	Area (km²)		
Landuse/cover class:	1989	2000	Change in area from 1989 to 2000
Baresoil/land	9.73	7.72	(-) 2.01
Cultivated Land	52.63	28.81	(-) 23.82
Grassland	55.70	225.06	(+) 169.36
Mangrove	229.53	135.18	(-) 94.34
Belukar	74.80	52.99	(-) 21.81
Primary Forest	400.63	323.16	(-) 77.47
Sandy Area	85.50	70.69	(-) 14.81
Urban Area	49.41	108.77	(+) 59.36
Water Body (in-land)	1.02	1.02	0.00
Lost area		*5.55*	*5.55*
Total area (km²)	958.94	958.94	N/A

Note:
(+) an increase in area (-) a decrease in area N/A : not applicable

The size of grass-covered land had changed considerably between 1989 and 2000. An increase of 8.4% of the total area from 5.8% in 1989 was observed. Most of the conversion centred within the previously cultivated land.

Areas of baresoil/land underwent a 0.2% decrease from 1.0% in 1989 to 0.8% in 2000. Similarly to grassland, the change occurred within previously cultivated land. The differences between grassland and baresoil/land may be indistinguishable if the density of grasses is low. In the remote sensing perspective, low-density grass-covered land may appear to look like baresoil/land because of the high spectral reflectance.

From Table 3, there was a 5.55 km^2 of area that was categorised as lost. This is partially true because beach erosion and sand transportation that could not be accounted for may be present and had contributed in this lost area category. Apart from this it is also important to consider that these classifications were based on satellite data and slight shifts in the orbit or satellite path is inevitable. The shifts no matter how small it is *e.g.* one pixel size (30m) could produce changes in varying degrees.

4.2 The 11-year landuse/cover change

Based on an overlay analysis between the maps of 1989 and 2000 had resulted in another map showing areas that had undergone changes in greater detail. A batch of 18 newly classified classes was produced as shown in Figure 8.

The original 9 classes remained as areas undergoing no changes between the 11-year period. Regions where most changes had taken place were lying within the flat land areas in between the mountain ranges of north Langkawi.

Although most of the forested areas within north Langkawi *i.e.* the primary forest and the mangroves, are reserves, there were still changes in the landuse/cover particularly around the fringes of the reserves. There normally appear to have no distinct boundary between the forested reserve areas and the corridor vegetation. The occurrence of this has in fact resulted in quite a considerable change in its area coverage. Primary forest had lost approximately 77.47 km^2 to mainly urban areas, grassland, and baresoil/land; while the mangrove reserves had lost approximately 94.34 km^2 to similar landuse/cover class conversion over the 11 years.

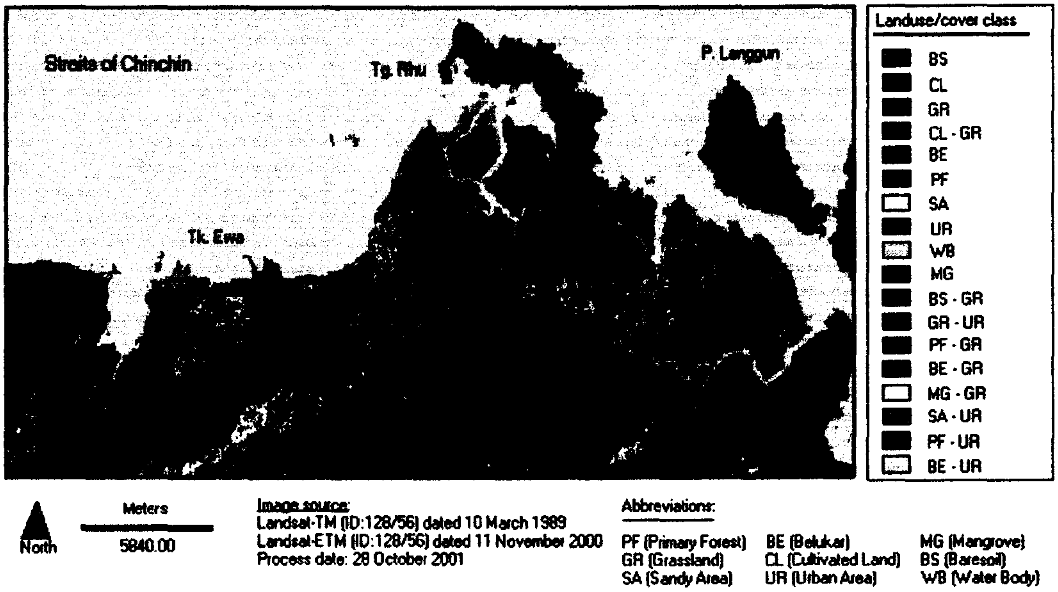

Figure 8. The mapped changes in landuse/cover of north Langkawi between 1989 and 2000.

Most cultivated land has been converted into grassland, baresoil and particularly into urban areas. It would be important to note that in 1989, Langkawi was beginning to experience rapid progress of development and during that time majority of its local population was still depending on their traditional agricultural practices as their main economical trade. Therefore most flatlands had been utilized as padi fields, coconut and rubber plantations, and other mixed-sundry orchards. Gradually over the years, with the eco-tourism trade being strongly imposed on the island had generated greater influx of tourists and outsiders (*i.e.* the non-locals). This had possibly created a sense of awareness amongst the locals that relying on the traditional agricultural practices alone no longer proved to be economically profitable in the short run. Although there is still a fraction of the islanders whom were still practising the traditional agricultural trade, most of them had somehow abandoned their traditional practices and resorted to tourism-related industry.

The other factor being that the islanders or locals may have been forced indirectly to abandon their agricultural land. This is simply because following the declaration of Langkawi being a free port and later an eco-tourism state, the rapid progress of land development had in itself created environmental problems to the agricultural land to some degree. The uncontrolled or improper control of erosion from the developing land had taken its toll by causing destructive flash mud-floods. Traditional irrigation method was then no longer functional and the locals were forced to seek other means of livelihood. The 'wasted' agricultural land was then urbanised, bought over and filled for future development or simply left abandoned as observed at the present state.

Table 4 summarises the details of changes detected between the landuse/cover classes between 1989 and 2000. Most changes indicated a decrease in coverage with the exception in the grassland and urban area categories, which in itself reflected the transition of Langkawi from a formerly traditional non-free port and non-eco-tourism state in the 1980's into a free port and major eco-tourism state at present. Although the major development of Langkawi has been concentrated mainly on the southern region and much less within the northern region of the island, the degree of development certainly has its effect imprinted on the changes that had taken place in the north.

Table 4. Computed statistics of acreage extracted from landuse/cover classification of north Langkawi based on change detection analysis during an 11-year period.

Landuse/cover class	Area (km^2)	Landuse/cover class	Area (km^2)
Baresoil/land	7.72	Baresoil/land → Grassland	2.25
Cultivated Land	28.81	Cultivated Land → Grassland	24.68
Grassland	55.70	Mangrove → Grassland	94.34
Mangrove	135.18	Belukar → Grassland	11.12
Belukar	52.99	Primary Forest → Grassland	36.97
Primary Forest	323.16	Belukar → Urban Area	8.40
Sandy Area	70.69	Grassland → Urban Area	3.69
Urban Area	49.41	Primary Forest → Urban Area	37.85
Water Body (in-land)	1.02	Sandy Area → Urban Area	9.41
		Lost area	*5.55*
(Total area : 958.94 km^2)			

Note: → indicates change of one landuse/cover to another.

5.0 DISCUSSION

5.1 Accuracy Assessment

As resources become scarce, they become more valuable. Value is evidenced both by the increasing prices of resources and by problems in resource allocation and management. From forest harvesting and landuse conversion, to the fragmentation and loss of tropical habitats, acid deposition in continents and environmental degradation and pollution, the ecosystems of the world have been significantly altered. Expanding population pressures continue to cause the price of resources to increase and to intensify conflicts over resources allocation and availability.

As resources become more available, the need for timely and accurate information about the type, quantity, quality and extent of resources increases. Allocating and managing the Earth's resources requires knowledge of their distribution across space. For example, to improve the habitat of endangered species such as much sought-after specific herbal plants, or the *jati* trees, we need to know what the species habitat requirements are, where that habitat exists, where the plants exist, and how changes to the habitat and surrounding environments will affect species distribution and population viability. To plan and conserve for the future requires decisions, and each decision (including the decision to do nothing) impacts (1) the status and location of resources and (2) the relative wealth of individuals and organizations that benefit from the resources. Knowing the location of resources and how they interact spatially is critical to their effective management.

Thus, effective decisions about resources require maps of known accuracy. If the accuracy of the map is known, the known expectations of accuracy can be incorporated into planning and contingency plans can be prepared for situations when the accuracy is low. This type of knowledge is critical for decisions such as endangered species preservation, resource allocation, emergency response, and management responses.

Remote sensing is the collection and interpretation of information about an object from a remote vantage point. Because there is high correlation between variation in remotely sensed data and variation across the earth's surface, remotely sensed data provides an excellent basis for making maps of landuse, landcover, and of pollution spread.

From the advent of the first aerial photographs to the launch of the latest satellite imaging system, the use of remotely sensed data has become an increasingly important and efficient way of collecting map information. Remotely sensed data are used to make maps because they:

1. are usually less expensive and faster than creating maps from information collected on the ground,
2. offer a perspective from above, allowing for a better understanding of spatial relationships, and
3. permit the capturing of types of data that humans cannot sense, such as the infrared portions of the electromagnetic spectrum.

The widespread acceptance and use of remotely sensed data has been and will continue to be dependent on the quality of the map information derived from it (Congalton and Green, 1999). However, map inaccuracies or error can occur at many steps throughout any remote sensing project. Figure 7.1 shows the schematic diagram of the many possible sources of error. Accuracy assessment is conducted to understand the quality of map information by identifying and assessing map errors.

Accuracy assessments enabled the quality of the map information to be improved by identifying the sources of errors to be corrected. Analysts often need to compare various techniques, algorithms, analyses, or interpreters to test which is the best. Finally, if the information derived from the remotely sensed data is to be used in some decision-making process, then it is critical that some measure of its quality be known.

Accuracy assessment determines the quality of the information derived from remotely sensed data. Accuracy assessment can be qualitative or quantitative, expensive or inexpensive, quick or time-consuming, well-designed and efficient or haphazard. The purpose of *quantitative* accuracy assessment is the identification and measurement of map errors. Quantitative accuracy assessment involves the comparison of a site on a map against reference information for the same site. The reference data is assumed to be correct.

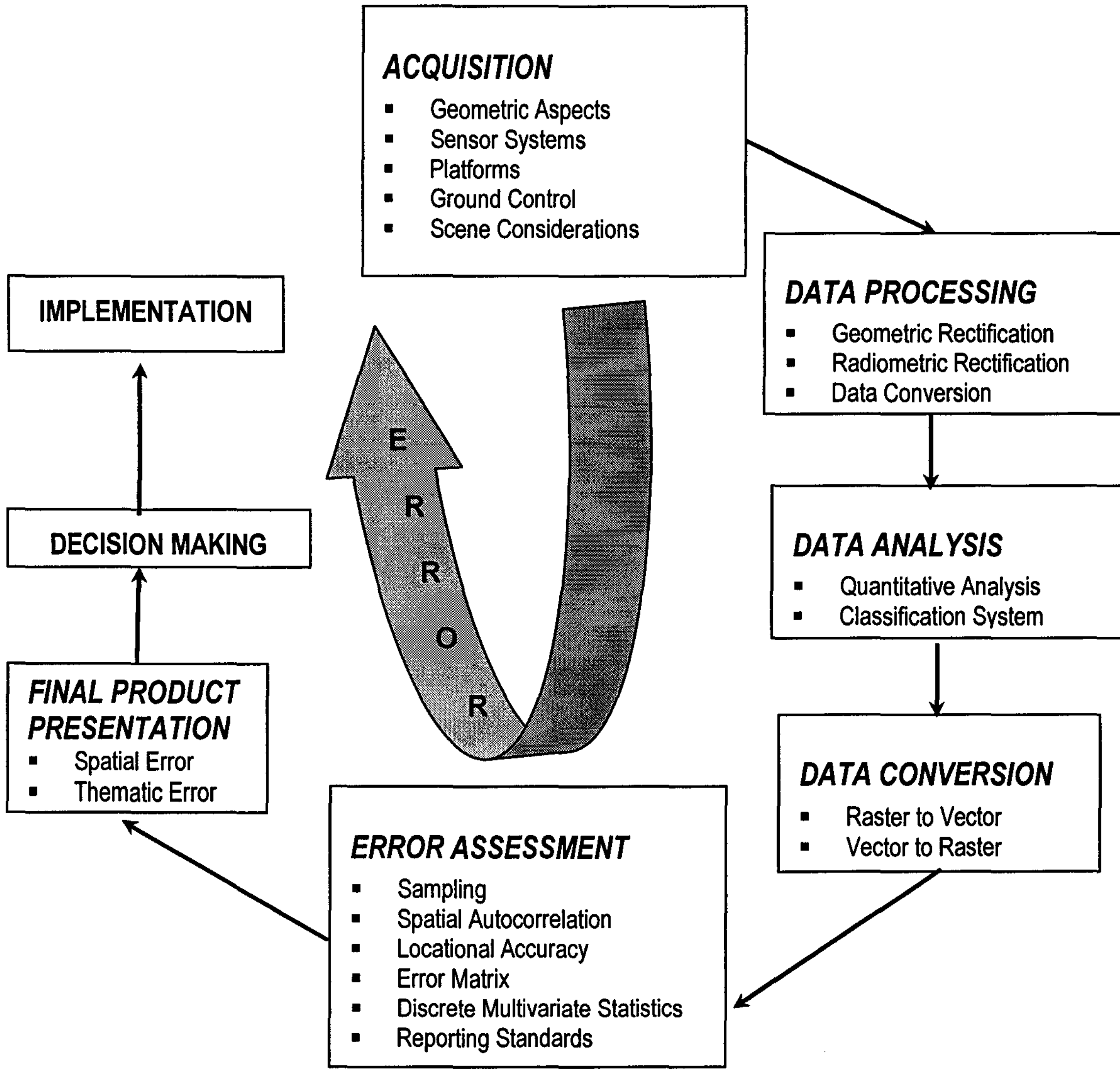

Figure 9. Sources of error in remotely sensed data. (Source: Lunetta *et al.*, 1981)

Usually funding limitations preclude the assessment of every spatial unit on the map. Because comparison of every spatial point is impractical, sample comparisons are used to estimate the accuracy of maps. Accuracy assessment requires:

i. the design of unbiased and consistent sampling procedures, and
ii. rigorous analysis of the sample data.

How a map is sampled for accuracy will partially be driven by how the information on the map is distributed across space by map category. This distribution will, in turn, be a function of how the categories of features of the earth being mapped are chosen – referred to as the *classification scheme.*

Map categories are specified by the project's classification scheme. Classification schemes are fundamental to any mapping project because they create order out of chaos and reduce the total number of objects (i.e. classes) that must be dealt with to some reasonably small number (Cowardin *et al.* 1979). The detail of the scheme is driven by (1) the anticipated uses of the map information, and (2) the features of the earth that can be discerned with the data (e.g., aerial photography, satellite imagery) being used to create the map. If a rigorous classification scheme is not developed before mapping begins, then any subsequent accuracy assessment of the map will be meaningless because it will be impossible to definitively state that an accuracy assessment sample area is of one class or another.

A classification scheme has two critical components: (1) a set of *labels* (clear water, turbid water, mangrove, etc.) and (2) a set of *rules* or definitions for assigning labels (Congalton and Green, 1999; Congalton, 1991). Without a clear set of rules, the assignment of labels to types can be arbitrary and lack consistency.

In addition to having labels and a set of rules, a classification scheme should be:
(1) *mutually exclusive,* and
(2) *totally exhaustive.*
Mutual exclusivity requires that each mapped area fall into one and only one category or class. A totally exhaustive classification scheme results in every area on the mapped landscape receiving a map label; no area can be left unlabeled (Congalton and Green, 1999; Congalton, 1991).

If possible, it is also advantageous to use a classification scheme that is *hierarchical.* In hierarchical systems, specific categories within the classification scheme can be collapsed to form more general categories.

There two basic analysis techniques in accuracy assessment and these are:
(1) Non-site Specific Assessments, and
(2) Site Specific Assessments.

In a non-site specific accuracy assessment, only total areas for each category mapped are computed without regard to the location of these areas. In other words, a comparison between the number of acres or hectares of each category on the map generated from remotely sensed data and the reference data is performed. In this way, the errors of omission and commission tend to compensate for each other and the totals compare favourably. However, nothing is known about any specific location on the map or how it agrees or disagrees with the reference data.

For site specific assessment, there was a need to know how the map generated from the remotely sensed data compared to the reference data on a locational basis.

5.2.1 Factors or limitations affecting accuracy assessment of remote sensing data

There are several factors that need to be considered during accuracy assessment and these are:

(1) Size of study area

The size of the study area is very important in relation to the resolution or pixel size of the satellite imagery in use. It would not be appropriate to have a study area the size of 1500m x 1500m (1.5km x 1.5km) when one uses Landsat TM data for remote sensing studies. The small area of 1500m x 1500m area will contain only 50 x 50 pixels in a Landsat TM data because each pixel is 30m x 30m. A relatively large area would be more appropriate and cost effective for satellite imagery. Schematic examples for a small study area (A) and a large study area (B) using Landsat TM data are shown in Figure 10.

(2) Feature recognition

The existing features recognizable in satellite imagery play a very important role as well. It would not be appropriate to map an area that contained features that are too small to be distinguished in the mapping process. Recognizable features on the satellite imagery provide further aid in speeding up the mapping process and reduce unnecessary error.

(3) Surrounding influences – neighbouring pixel effect

If a general study area is large enough, but some features are too small, there tends to be a neighbouring pixel effect. An example is from this study itself which was mentioned in the earlier subsection (Section 7.4) where the width of certain sections of Sungai Padang Lalang was too narrow relative to the pixel size. The effect of the surrounding features (in this case the vegetation along the river banks) would have empowered the reflectance value detected and measured by the satellite concerned. This, in fact, is an error by itself but one that is unavoidable because of the way the sensor was designed.

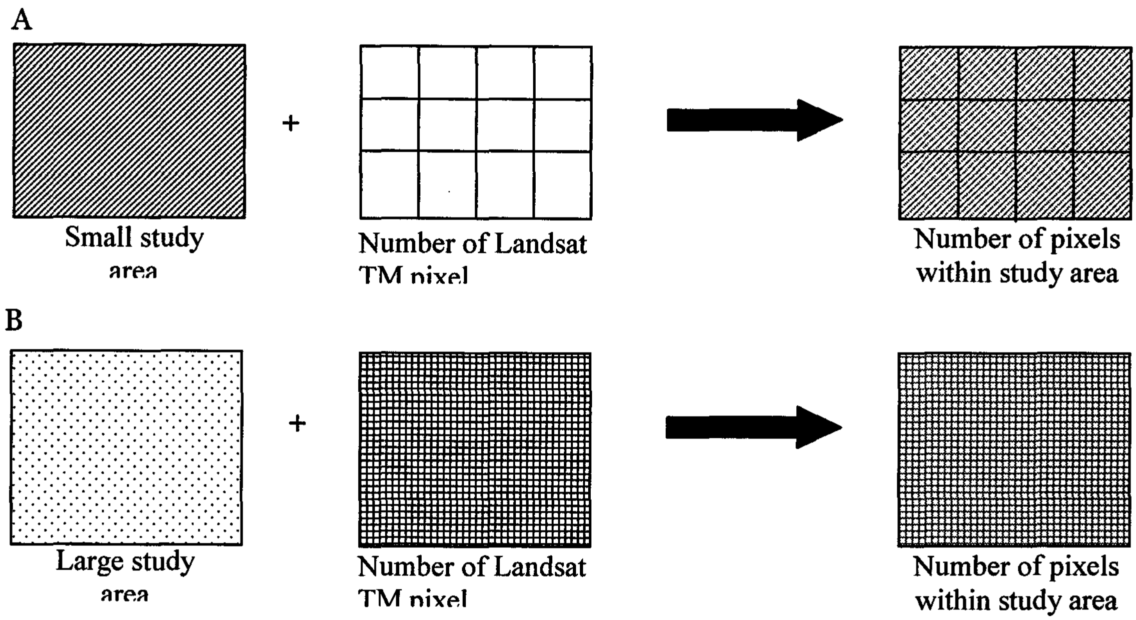

Figure 10. A schematic representation for a small study area (A) and a large study area (B) using Landsat TM data.

(4) *Classification scheme.*

The formation of larger groups for the categories in the classification process can also contribute errors. This is particularly true for water quality classification with the application of an algorithm. For example: The dynamic nature of the coastal and marine system would have contributed the changes and errors for the map produced. An area classified as having 50.5 mg/L TSP may no longer fall within the 0 – 50 mg/L category but placed in the 50 – 100 mg/L category. Logically an additional 0.5 mg/L shall not be a concern but if accuracy assessment was to be done, this will already be considered a classification error. If the original value were rounded up to 50 mg/L and not 50.5 mg/L, then this area will be classified within the 0 – 50 mg/L category in the predicted map and the accuracy assessment would have been correct. Basically the classification scheme chosen in the image processing procedure will depend on the degree of detail required.

(5) *Resource limitations for detailed sampling in the process of accuracy assessment.*

Another major factor affecting accuracy assessment is the availability of resources to compute more detailed and systematic ground truthing points. The higher the number of ground truthing or accuracy assessment points, the higher the probability of obtaining higher accuracy maps (Figure 11).

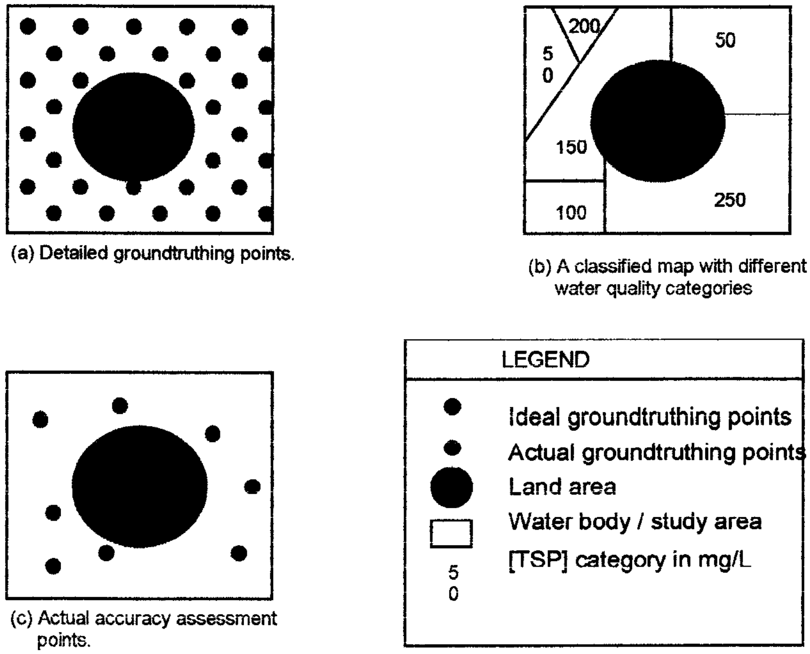

Figure 11. A schematic representation of resource limitation factor for detailed sampling in an accuracy assessment process.

(6) Time and date of data acquisition

To achieve higher accuracy in a classification or mapping process, the time and date of both measured and satellite data should be identical or as similar as possible. However, this may not always be the case for coastal and marine systems because of limited access to the study area, which could be seasonal, or even the resources available. The time and date factor would be applicable to the terrestrial mapping purpose such as land use and land cover.

5.3 Land being left idle

In Langkawi, a lot of land, agriculture land, had been left idle since the island was first declared a free port in January 1987. This was more so seen in the early to mid 1990's after the Visit Malaysia Year declaration in 1990 by our former Prime Minister. This happened to coincide with the prolific result of the Sixth Malaysian Plan (1991-1995). During these times job opportunities were abundant particularly of tourism. Most farmers, young farmers, were easily lured into these business ventures associated with the tourism industry - of opening up chalets, tour operators either on land or by the sea, forming chains of vehicle rental business, and the likes. Such businesses require less effort compared to farming exposing them directly under the prickly hot sun, drenching in their own sweat or rain, in short – hardwork and hard-earned money. With the tourism industry, money-making seemed to be an easier option. Perhaps the involvement in tourism-related industry would impact their social status. With the emigration of particularly younger farmers, farming labour shortage would be inevitable resulting in land abandonment. By nature of the problem, the phenomenon of idle land is not likely to be a result of just a single factor. In most cases, it is the result of a combination of many factors – with one factor interacting with another, and usually the happenings are the results of a triggering factor which in this case would be tourism industry.

5.4 Land Development and Environmental Impacts

Conversion of forest land for agriculture and infrastructure development has resulted in widespread deforestation. Apart from reducing the amount of pristine forests and biodiversity of the forest and wildlife, deforestation has also contributed to soil erosion, siltation, slope failures and landslides in Malaysia. Continued deforestation and forest degradation in catchment areas will gravely affect the yield and quality of water resources, impede the capability of groundwater recharge, and cause more serious flooding in lowland areas. This will ultimately affect the lowland vegetation and further the impact of indirect deforestation.

The expansion of urban areas and industrial development have directly caused a greater degree of modification to the natural ecosystem compared to forestry and agricultural development.

5.4.1 Consequences of Deforestation

People may wonder why we should care about deforestation of the rainforests. What is the difference if a few plants, animals, mushrooms, and microorganisms perish? For most people, the forests are not all that pleasant to visit: they are hot and humid, difficult to reach, insect ridden, and have wildlife that is relatively hard to see. Actually the concern should not be about losing a few plants and animals. Humanity will lose much more: by destroying the tropical forests we risk our own survival, the stability of the planet, the existence of other species that share our rights to life, and the valuable economic assets provided by biological diversity.

While in most areas environmental degradation has yet to reach a crisis levels where entire systems are collapsing, it is important to examine some of the effects of existing environmental impoverishment and to forecast some of the potential repercussions of forest loss. Continuing devastation of natural systems could make human activities increasingly vulnerable to ecological surprises.

The consequences of deforestation can be broken down into local and global sectors, with some overlap. The most immediate consequences from deforestation are evident on the local level, while many of the global consequences are predictable to occur in the long run, but not fully demonstrable in the short term.

5.4.2 Habitat Fragmentation

Habitat fragmentation is the breaking up of a continuous habitat, ecosystem, or land-use type into smaller fragments, which is considered to be one of several spatial processes in land transformation. It is commonly used in relation to the fragmentation of forests. Habitat fragmentation is mainly caused by human activities such as logging, conversion of forests into agricultural areas and suburbanization, but can also be caused by natural processes such as fire.

5.4.3 Edge Effects and Habitat Fragmentation

The environmental contrast when one walks from an open field towards a forest edge and then into a forest is great but the transition from one another is not abrupt and may be spread over 50-100 m. The transition from open ground to forest is marked by a set of environmental gradients: increased moisture both in air (humidity) and in the soil; increased amounts of leaf litter and hence soil organic content; and decreased light availability, wind speed, temperature, noise, and pollution. This zone of transition is the forest edge. It offers a unique set of habitats and is often an area of considerable species richness.

The plants of deep forest are specialists that thrive under dark, cool, moist conditions, so not surprisingly many species fail to survive in either the open areas or the edge habitats. Some forest species, the least demanding in terms of habitat requirements, will be able to survive in the edge. Similarly, plants of the open ground will be unable to compete in the shaded conditions of the forest, but some will be able to live in the edge. Consequently, the edge of the forest will contain a mixture of both forest and open ground plants. Animals are dependent on plants for food, so the edge will support a blend of forest and the proximity of fields or grasslands for foraging will suit some animals. The edge supports a portion of the flora and fauna of both open ground and deep forest, and consequently, it may actually have a higher species diversity than either.

Species that can live under edge conditions are those with a broad environmental tolerance. These species are likely to be the species we are most familiar with, because so many of the habitats that humans create are edge-like: parklands, gardens, hedgerows, and farms. The species that are most threatened by our changes in land use are those with very narrowly defined niches and precise habitat requirements, e.g. the Cycads.

If the edge effect is so important, the next logical question is, "How far does edge effect extend into the forested area?" The answer will vary accordingly to the edge factor that one is considering. For example, wind speed, light, and humidity are probably affected within 100-300 m of the edge. The smaller the habitat fragment, the greater will be the proportion that is influenced by the edge effect (Figure 12). In an extreme case, where the reserve is only 100 m across its narrowest axis, the whole area will be an edge. In such areas, no habitat is left for the indicator species, and it will be missing.

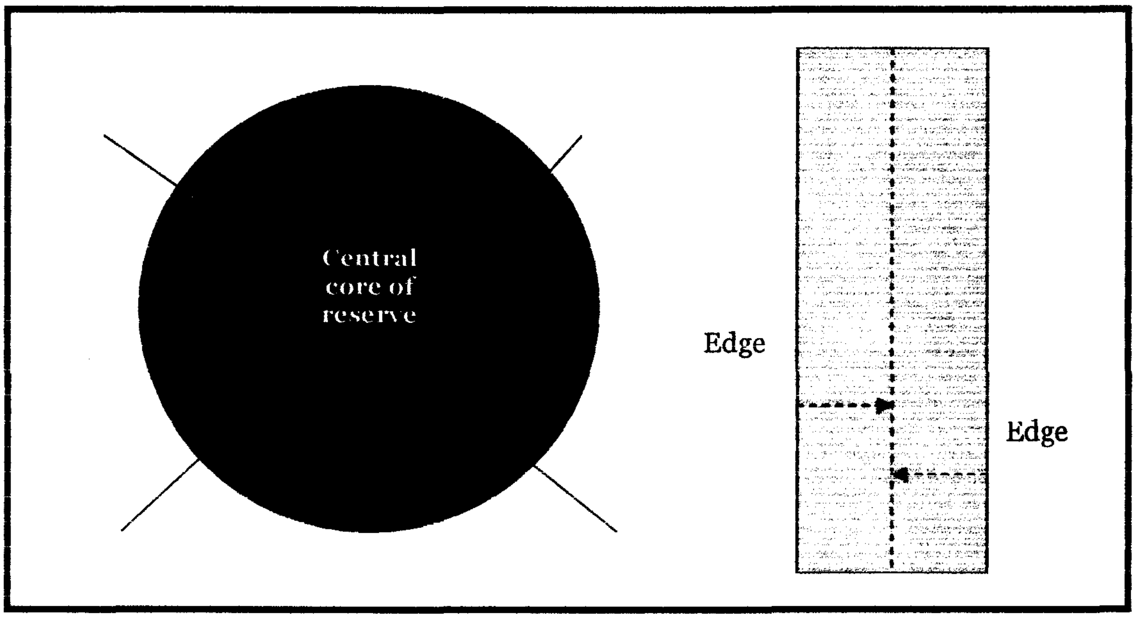

Figure 12. The effects of edges on small nature reserves of equal area but different shape.

5.4.4 Habitat Fragmentation and Global Warming

According to scientists at Brazil's National Institute for Research in the Amazon, the conversion of rainforest into fragments contributes to global warming. Studies have shown that fragments experience a considerable die-off of trees attributed to drying winds and storms. As the vegetation dies, more carbon is added to the atmosphere. In addition, forest fragments are characterized by "weedier" fast-growing species which store less carbon per volume than longer-lived trees with high density wood. Therefore such fragmented and disturbed forest has a lesser carbon storage capacity than undisturbed primary rainforest. Fragmentation is a problem worldwide as more than two-thirds of the world's remaining forests are fragmented.

5.4.5 Habitat Fragmentation and Degradation

In addition to wholesale habitat destruction, many habitats are being negatively affected by fragmentation. Habitat fragmentation not only reduces the area of available habitat but also can isolate populations and increase edge effects. Habitat fragmentation may also make habitats more susceptible to other forms of habitat degradation such as overexploitation of valuable species, the introduction of exotic species, and contamination. Understanding the possible consequences of habitat fragmentation has become of great concern to conservation biologists, since almost all natural habitats have become fragmented at some scale.

Costa Rica represents a prime example of the need to understand the consequence of habitat fragmentation since the majority of remaining natural habitat exists in isolated parks and reserves. Are these parks large enough? What types of species are most effected by habitat fragmentation? Can knowledge about the influence of habitat fragmentation be used to improve the conservation of protected areas or mitigate its negative effects?

The rate of tropical deforestation exceeds fifteen million hectares annually. Human-induced deforestation is not a new phenomenon: since the beginning of an agrarian society, indigenous peoples have always harvested the forests to raise their crops. The main difference between these ancient practices and current deforestation is the difference in scale and rate of increase. In the past, indigenous peoples generally slashed and burned small patches which quickly grew back upon abandonment. The results were patches of fields in a larger forested landscape. Current trends are the opposite, in which we are left with remnant forest patches in a sea of severely altered and degraded landscape. In this lecture, we will present some concepts of forest ecology, emphasizing the importance of these ecosystems on a local and planetary level. We will then discuss how habitat fragmentation, and in general, degradation, can severely compromise the function of tropical landscapes, and inquire into the future of tropical landscapes in the face of continued fragmentation.

Tropical forests, especially rainforests, are one of the most productive and diverse ecosystems on the planet. The high productivity is due to a very tight coupling between production and decomposition: "turnover" rates are very high, and minerals are recycled quickly and efficiently. Part of this is a result of high biodiversity: an incredible host of organisms have adapted to form a tight interconnecting loop coupling production and decomposition. There are many mutualistic, symbiotic and parasitic relationships which take advantage of this energy flow (e.g. lianas, bromeliads, mycorhizae). As a result, tropical forests are very productive despite typically having poor soils.

This production is very beneficial globally insofar as it sequesters large amounts of carbon dioxide in the trees and soils of the forest. Production is very important on a local scale for the crops and medicines that humans can harvest from the forests. Biodiversity is a related issue in terms of potential genetic material that can be used to generate disease-resistant crops, or cures for diseases.

When the larger forested ecosystem is destroyed, patches of remnant forest remain. There are many issues related to the ecology of forest patches. A very important concept is that of species-area curves, which simply states that, all other things being equal, a greater number of species can survive in a larger area. However, nothing is equal. Habitat range sizes are not constant throughout the plant and animal world. Some species may be perfectly capable of surviving in a remnant forest patch –many others may not. A forest patch is not the same as a piece of original forest: edge effects may now encroach, or even traverse the whole patch. Weedy species may invade. Some species' populations may become separated, leading to inbreeding depression. Whatever the combination of biotic and abiotic changes, the forest patches generally can no longer sustain the production or biodiversity that it once had as part of the larger forest.

What can we do? Current efforts are aimed at somehow linking remnant forest patches such that genetic information can cross from one patch to another. Animals that require larger home ranges can travel from one fragment to another while remaining within the natural forest matrix that it requires. Biological corridors also help educate the public, giving them an ideal example for understanding the interconnectedness of organisms (including ourselves!) and their natural environment.

5.5 Destruction of Renewable Resources

Deforestation can rob a country of potential renewable revenues while replacing valuable productive lands with virtually useless scrub and grassland. Tropical forests provide important renewable resources that can significantly contribute to national economic growth on a continual basis.

One of the largest "renewable resources" provided by tropical rainforests is ecotourism. The booming market brings tens of billions of dollars annually to tropical countries around the world. Ecotourism suffers with deforestation - few tourists, let alone ecotourists, want to travel in order to see polluted rivers, stumps of former forest, barren wasteland, gorilla carcasses, and relics of recently assimilated forest dwellers. Recently, the smog or haze created by the Indonesian forest fires caused tourist arrivals in Singapore, Malaysia, and Indonesia to drop significantly.

Forest products play a crucial role in the economy of developing countries. In 1994, exports of primary forest products were US$114 billion, of which at least 10% were secondary, non-wood forest products. These figures do not include the value of these products to local consumers who use timber to build houses and collect nuts and fruits from the forest for food. Short-term economic exploitation through deforestation is devastating to the long-term economy of developing countries not only by annihilating vital ecosystems that afford important services, but also by destroying potential forest products. Already, revenue from tropical hardwood exports are down 25% from 1980 levels and are expected to drop below 75% of 1980 levels by the turn of the century. As these countries develop their economies, they will continue to deplete their forest stocks, and may, in the foreseeable future have to import wood from temperate regions like the former Soviet Union, Canada, and the United States. Malaysia has seen a 60% decline in log exports, while the Philippines (a major exporter of logs during the early 1980s) has seen a virtual cessation in log exports. In both cases, the declines are due to dwindling harvestable forest resources. By 2000, only 10 of the 33 tropical countries that export timber will still be able to export. The new tropical log exporters, at least until their reserves are exhausted, are Latin America, Papua New Guinea, the Solomon Islands, Cambodia, and parts of Africa including Cameroon, Gabon, Ghana, and Congo.

Besides timber products, tropical countries lose potential earnings from renewable forest products like the nuts from Brazil nut trees, durian fruit from Southeast Asia, and iguana farming from Belize. In 1996, the value of non-wood forest products, accounting for the domestic consumption value and the international trade value, was estimated at US$90 billion. Many rainforest products cannot exist without a fully functioning rainforest system. Thus by deforestation, developing countries are jeopardizing their renewable forest resources and an important part of their economic future.

5.6 Natural Conflicts With Wildlife

As their habitat dwindles, many animals are forced to forage outside their traditional forest range and move into areas populated by humans. Fatal encounters with wild animals like elephants, venomous snakes, and big cats are increasing in the tropics at an alarming rate. Forest elephants have made news recently with their deadly conflicts (for both humans and elephants) in Asia. Several countries have embarked on innovative plans to keep elephants away from crops, while providing for their safety, though many farmers believe it easier to simply kill the offending animals.

5.7 Landuse Trends in Malaysia

To understand better the trends in land development and utilization in recent years, it is necessary to look at the economic background and scenario that have fostered or fanned such trends.

The opening pages of the Seventh Malaysia Plan (7MP) boast of the period of the Sixth Malaysia Plan, 1991-1995, as being a “momentous period of rapid growth”. Such was the country’s economic achievement that 1996 itself represented the eighth consecutive year of rapid growth (of 8.9% per annum).
In the words of the 7MP, the high economic growth during that period was very much due to and accompanied by these factors:

- A tremendous structural transformation of the Malaysian economy which resulted in the gradual shift from one relying on the production and exports of primary commodities to a more modern industrial economy;
- The increasing role of the private sector as the engine of growth;

- The implementation of the government's privatization programme which led to corporate expansion, and the private sector's accelerated participation in economic activities, particularly in developing infrastructure (which was once the domain of the public sector);
- The further expansion, upgrading and improvement of the country's network of infrastructure and utilities - which led to additional capacity in roads, ports, airports, telecommunications, and water supply and sewerage. Highways facilitated the emergence of new industrial zones, housing estates, recreational facilities and townships.

Spurred on by the economic successes of the day and bent on pushing its privatization programme through, the government went even as far as "reviewing various legislation which inhabited the privatization process", resulting in the enactment of a number of new legislation as well as amendments made to existing legislation (7MP).

Indeed - during the years preceding the present financial crisis – one could see that never before had this land felt the pulsating push and pace of development, in every possible nook and corner. At times it seemed as though the patriotic cry of "Merdeka!" on this land had unconsciously been replaced by "Mega!" , given the growth in scale of development projects.

The government would of course from time to time remind the nation of the importance of spiritual and social values, whilst equating "sustaining growth" to "sustainable development".

In spite of the momentous growth, it soon became very obvious to the powers that there was another side to the buoyant economy which the 7MP has so enthusiastically highlighted – one which could be described as close to a social and environmental tragedy.

For the sake of growth – priority was given to solving unemployment and other economic problems – social and environmental integrity would have to wait or even be sacrificed. Yet growth rates do not prove anything when economic success isolates social equity and environmental sustainability. The 7MP may have considered the year 1996 as "representing the eights consecutive year of rapid growth", but statistics mean little to those ordinary people facing lack of basic amenities and a myriad of livelihood problems.

Ironically, there was a general and strong consensus that the environment in Malaysia was in a state of crisis, indicating that the various components of the environment, such as land, water, forest and soil – whether it be on highland or lowland, wetland or island – had been exploited far beyond their maximum sustainable limits.

This was the result of – and a reflection of – the rather warped notion of "development" amongst some of the country's politicians and authorities: one which views forests and jungles, or Nature as such, as "undeveloped" – therefore constituting the potential for commercial development.

And in the rush to unleash the processes of industrial development, the adverse, and at times irreversible, consequences were often disregarded or downplayed by the authorities. Also incurred were the severe human costs in the form of land eviction and people having to struggle with the problems related to land degradation and pollution.

As the focus of this study is on land and its greens, we need to take closer looks at the background of a "buoyant economy", at some of the trends related to land development and landuse, and how their impacts have contributed to the environmental crisis that confronts us till this day.

As the country prospered through the years, development priorities became blurred and even distorted. And there is no better example of a distirted priority in landuse than the mushrooming of golf courses or mega golf resorts on prized natural land. Such is the example seen in Langkawi particularly of the Teluk Datai area which is on the pristined land of Machinchang Forest Reserve in Northwest of Langkawi. Hills, islands, beaches, green lungs and parks have been swallowed up by sprawling golf courses, each covering between 100 and 600 acres. In the example of Teluk Datai golf course, the adjacent river, Sungai Tukun, were completely deteriorated, hence impacting on ecosystems entirely depending on it (lee, 1994, Abdullah *et.al* , 2002).

In 1984 there were 45 golf courses in the country. The number sprang up to 72 in 1990 as the craze for golfing mounted. Malaysia was expected to have as many as 200 golf courses by year 2000 and as December 1994, State Governments in the peninsula had approved 10, 524 hectares of land for golf courses alone. Land areas parceled off by State Governments to companies for golf course development are by no means small. For instance, between 1974 and 1994, a total of 30, 732 hectares of for4est reserves were degazetted (New Starits Times) which was 52.4% of reserved forested land to make way for mainly golf courses and quarries. This was about 10 times more than the 1,682 hectares that were exercised for townships and resettlement.

The environmental and social repercussions of golf course development in the country need no elaboration. The evidence is both glaring and global. Perhaps equally harmful is the culture of elitism and exclusivity brazently promoted by the golf industry. The increasing number of golf courses are only enjoyed by a very small percentage of the public. This, coupled with the wasteful utilization of vital resources such as water, will only result in much discontent and even a widening of the rich-poor gap.

5.8 Tourism boomed....but the environment doomed

Perhaps no trend has ever had such an impact on the land than tourism development in the country. Just before closing the Visit Malaysia Year 1990, our former prime Minister had in September of the same year declared that the tourism industry was a "gold mine", that it was the objective of the government to make tourism the country's prime motivator in economic development, and that "there should be no saturation point in tourism." He also added that the hotel industry would be expanded (Star, 20.9.90). Investors in projects relating to the hotel industry and infrastructure were promised pioneer status, tax allowances and other facilities.

What followed was a massive onslaught of multi-million or billion-ringgit tourism projects on the land. Those who had previously shown little care for the environment were suddenly submitting 'eco-friendly" proposals. In pursuit of the tourist dollar, State Governments, local and foreign investors rushed to develop every available hill, highland, beach, island or patch of greens.

It did not take very long for the adverse environmental and social impacts of indiscriminate tourism development to show, not to mention the increasing number of, failed tourism projects. Newspaper articles warned of the death and deterioratyion of corals and a host of other environmental problems on and off popular islands such as Langkawi, Pulau Sipadan and Ligitan, Pulau Redang, Pulau Upeh (Malacca), Pulau Pangkor (Perak) , Pulau Payar and Pulau Tioman. Specific imoacts as researched by the author and affiliates were also proofs of such fenomena (Lee, 1994; Abdullah *et al.*, 2002; Abdullah & Yasin, 2001; Abdullah *et al.*, 2007).

Hill or highland projects have resulted in severe soil erosion, flooding and pollution problems due to siltation, mass movement and slope failure for steep slopes, the destruction of habitats and ecosystems, disturbance to the microclimate and serious hazards that could threaten the safety and livelihood of nearby residents. Perhaps tourism is killing tourism in this country. Damming of it for eco-tourism activities has seen to the choking of vegetation, destruction of marine life, bank erosion, water pollution, among other adverse effects.

In spite of their vital and unique role, over half of the peninsula's wetlands have been destroyed and cleared by agricultural activities and urban development. It took a very long time for the authorities to acknowledge that such a trend had severe repercussions on the environment and local communities in terms of their safety and livelihood. In March 1996 the Cabinet revealed that development, aquaculture and agricultural activities had caused massive damage to the country's mangrove forests. It discouraged further development and agricultural activities in mangrove forests pending research on ways to regenerate diminishing mangrove resources.

The act of regeneration of mangals have been adopted by the eco-friendly concept Radisson Hotel in Northeast Langkawi several years ago when they replanted mangals along its riverine system while infrastructural development was taking place. Such is an example of good practice in order to restore the greens in the vicinity of the hotel. The importance iof wetlands which most people regards as wasteland became very apparent when our country was hit by the 26 December 2004 tsunami. It was too late for areas where original thick mangrove stands were stripped down to a mere 5-10 m corridor. It is sad to see the greens being stripped to make way for concrete jungles without being replaced. Perhaps our country should adopt the 1:4 green concept practiced by some of the European countries like Germany where every single tree felled for development should be replaced with the replantation of 4 trees.

5.9 Enhancing sustainable land development

The pressure on nature and biodiversity has increased over the years with the demand for land development to support economic growth and human settlements. Malaysia has gazetted national parks, nature reserves and wildlife sanctuaries as part of its efforts to protect nature. The living segment of nature has always been the beneficiary of this protection, however, it is still not enough as we can the multi levels of deterioration where nature and its natural resources are concerned. The non-living segment of nature, i.e. the physical form, also needs to be recognized and appreciated for its intrinsic value. The integrity of the physical form has been adversely affected by a range of uses, land mismanagement and benign neglect because its value was not recognized (Crowley, 1997). Unsustainable land development includes the over-exploitation, pollution and destruction of natural resources as well as the resource-base.

Further impacts of forest clearance leading to deforestation can also be seen on other natural environments as well. These elements cannot be ruled out as separate issues since the environment we live in are interconnected in a highly complex manner. It would not be possible to look into the whole web of this interconnectedness, however, a simple chain can be outlined as shown in Figures 13 and 14.

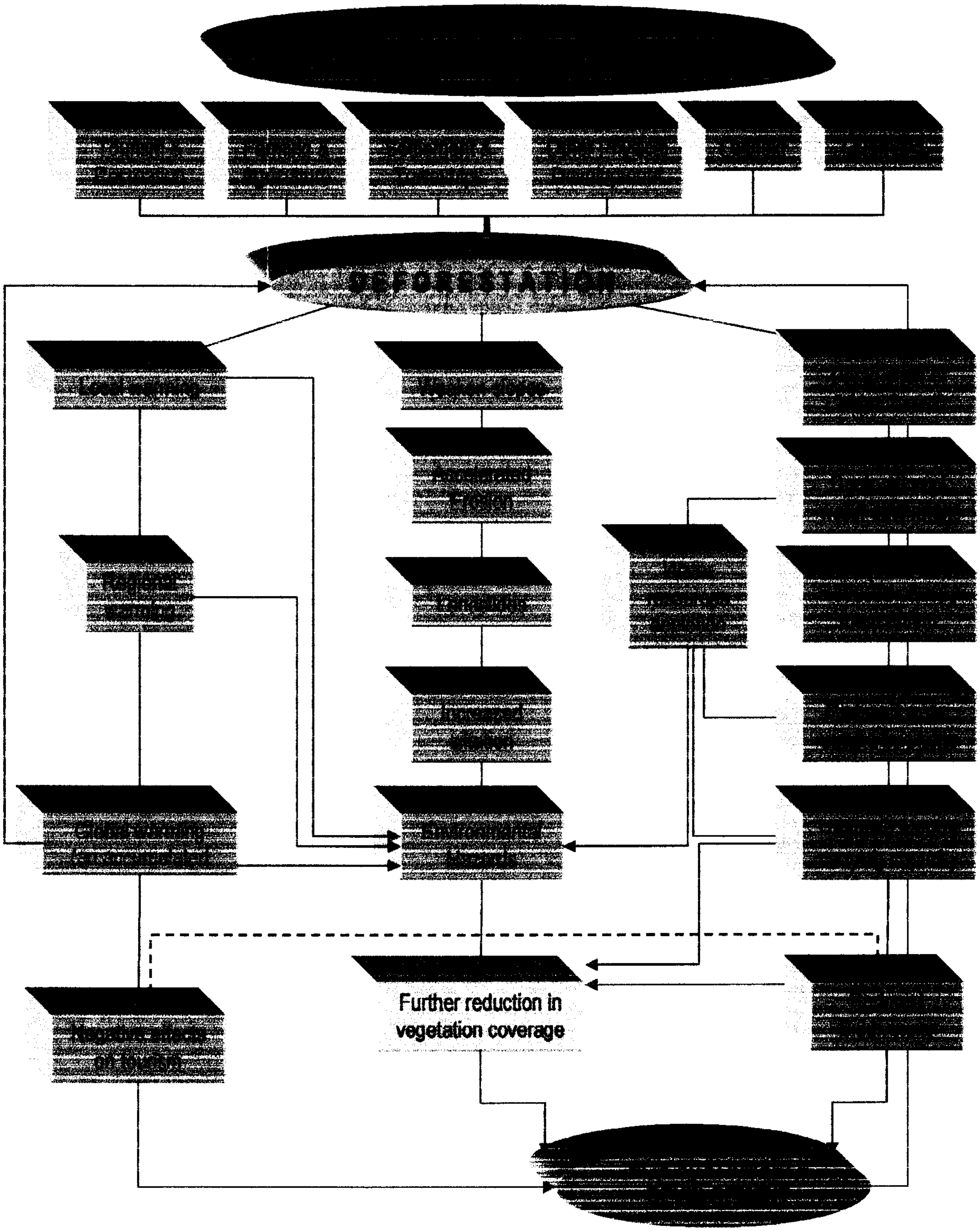

Figure 13. Effects of common land development activities on the natural vegetation leading to environmental degradation and non-sustainable development of the natural resource.

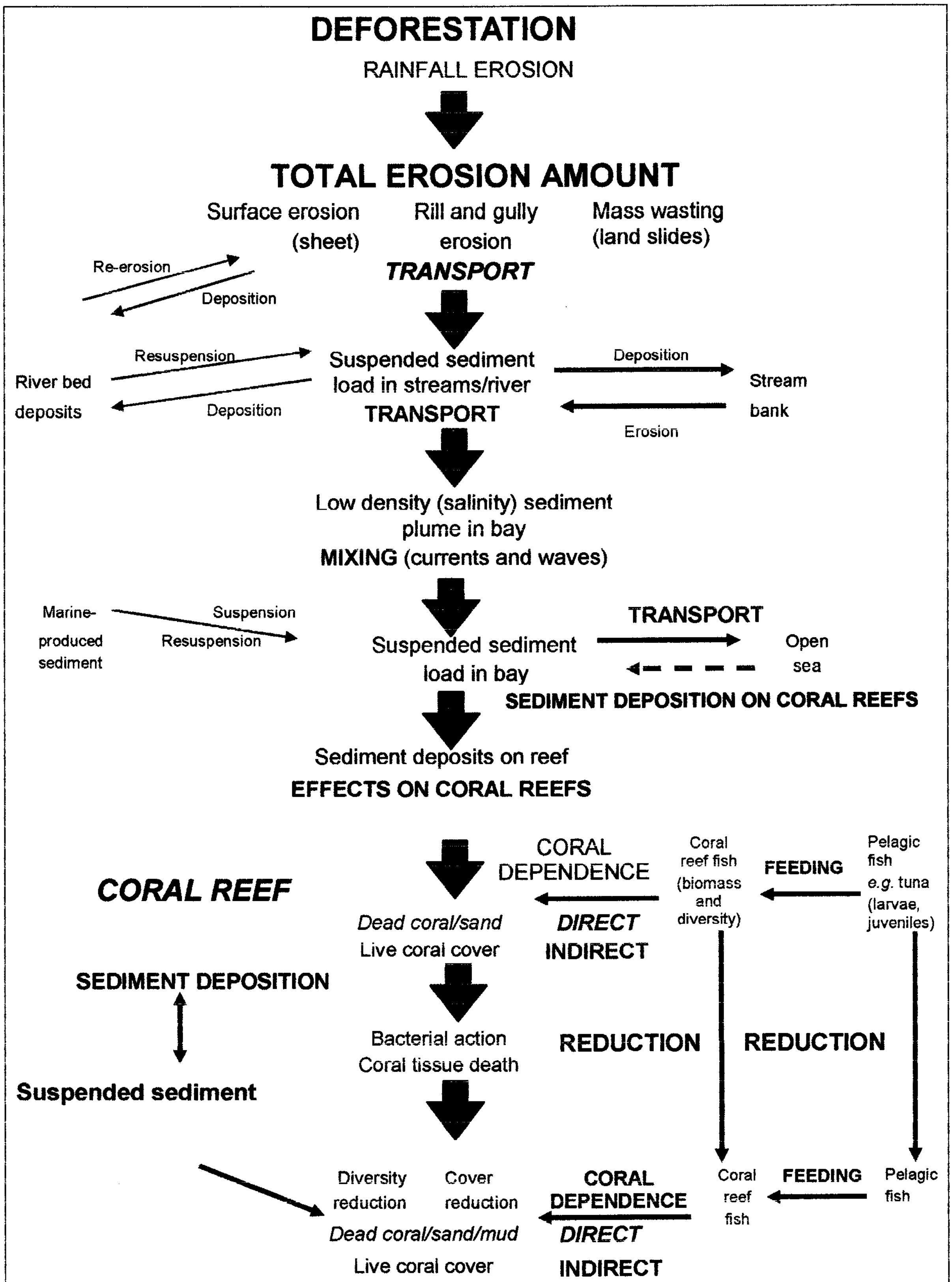

Figure 14. A typical rainfall erosion and sediment pathway from a deforested area to an existing coastal ecosystem. (Modified from Abdullah, 2004)

6.0 SUMMARY

The changes detected over an 11-year period, *i.e.* from the year 1989 and 2000, projected varying degree of changes where most affected areas were the primary forest, the mangroves, and the cultivated land. Grassland and urbanised areas had increased considerably within these years. This preliminary research showed that from the year 1989 to 2000, primary forest had decreased from 41.8% to 33.9%; the mangroves decreased from 23.9% to 23.6%; sandy areas decreased from 8.9% to 7.4%; grasslands had increased from 5.8% to 14.2%; cultivated land decreased from 5.5% to 3.0%; and urban areas increased from 5.2% to 11.4%.

The use of satellite data in change detection analysis has proved to be invaluable and provided a broader perspective over the changes in landuse/cover detected for north Langkawi. It would not be possible to detect these changes cost-effectively within a short time frame if conventional method alone was used. Although this research is at its preliminary stage, it not only had provided a picturesque view of the effect of development on north Langkawi natural ecosystem but also grounds for further in-depth research crucial to the area for the planning and implementation of management and monitoring studies to ascertain the environmental status of Langkawi.

Land is best regarded as resource-base rather than a resource in itself. As a resource-base, land has many facets of usefulness based on its ecological and economic potential, provision of space, and its value as a landscape. The functions of land include its utility for economic activities such as agriculture, forestry and mining; for the space it provides to host housing, industries, commerce, transport and recreation; as well as for its use as a natural ecosystem and as landscape for aesthetic appreciation. The diversity of land's usefulness gives rise to conflicts with regard to the goal of development. The rapid pace of development has made the utilization of land extremely competitive in Malaysia. It has also resulted in poor landuse practices in certain instances. Poor landuse practices can lead to serious problems and pose barriers to development in the long term. Problems that can arise include permanent destruction of the land's capacity to provide economic and environmental benefits, inefficient use of available natural resources, as well as accumulating negative impacts such as the deterioration of biodiversity, species population dwindle, depletion of breeding space, elevation of edge effects and habitat fragmentation, failure in conservation effort and strategies, disruption in food chains and perhaps indirectly on its biogeochemical cycles, environmental problems like global warming and much more.

In the midst of a buoyant economy, rapid growth has been grabbing what little green that is left in our environment particularly our cities. The result is an equally rapid disappearance of green lungs, playgrounds and fields – recreational land - much to the disgust and anger of the public.

From the landuse trends highlighted in part of this research report, several observations on landuse in this country can be drawn:

- The contemporary development model in this country, to which matters concerning landuse and development are so intricately linked, has mainly served the "dominant interests" directly and indirectly, subjugating the interests of a large section of society, who are being deprived of their resource base, crucial for their sustenance and survival. Economic growth and market forces can only deal with material wealth but cannot provide for social equity and environmental sustainability.
- Development can take place only if development is done within the framework of the people. Development styles should be such as to build development around people rather than accommodate people to development. In other words "development" acquires its full meaning and potential only when it is of the people, by the people and for the people. To the extent that these dimensions are lacking it is regressive and even dehumanising. Sustainable development, if it is tobe successful,requires involvement and participation not just from the business sector but public participation should be well encouraged and a diversity of opinions should be sought. We are afterall aware of our needs and are good stewards of environmental resources.

As the densely populated areas in Malaysia increase, land is going to become a scarce commodity. There is a growing need to ensure the optimum use of land. Therefore, a multiple use and sequential land development strategies need to be devised to ensure the best use of each parcel of land. In this regard there is a necessity to formulate a landuse master plan beased on an integrated approach that takes into account optimum utilization of natural resources and its resource-base, prevention of natural and human-induced hazards as well as environmental impacts. There are environmental impacts related to all forms of land developments but the greatest degree of modification to the natural ecosystems has been caused by the expansion of urban areas into suburban and rural areas, and industrial development.

Apart from strengthening the traditional framework of mitigating environmental problems, it is proposed that a landuse master plan be formulated under the auspices of the National Land Council, taking into account optimum utilization of natural resources and its resource-base, prevention of natural and human-induced hazards, as well as environmental impacts. In addition, there is a need to revise, review and intensify research on the effective use of land to encourage sustainable land development with the "green lungs" in mind.

Acknowledgements

The authors would like to thank the Malaysian Centre for Remote Sensing (MACRES) and the Reef Research Group Universiti Sains Malaysia for the provision of Landsat-TM satellite data for this study.

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