INTEGRATED REMOTE SENSING AND GIS MODELING IN DETECTING LAND USE CHANGES OF EX MINING LAND

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INTEGRATED REMOTE SENSING AND GIS MODELING IN DETECTING LAND USE CHANGES OF EX MINING LAND

By

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LIST OF ABBREVIATIONS

AHP	Analytic Hierarchy Process
AOI	Area of Interest
DEM	Digital Elevation Model
DIME	Dual Independent Map Encoding
DNs	Digital Numbers
DXF	Digital Exchange File
GCPs	Ground Control Points
GIS	Geographic Information System
GMS	Geostationary Meteorological Satellite
HFA	Hierarchical File Architecture
Landsat	Land Satellite
MSS	Multi Spectral Scanner
NDVI	Normalized Difference Vegetation Index
NOAA	National Oceanic and Atmospheric Administration
PCA	Principal Component Analysis
RBV	Return Beam Vidicon
RMSE	Root Mean Square Error
SDTS	Spatial Data Transfer Standard
Shp	Shape File
SPOT	Systeme Pour I'Observation de la Terre
SVR	Synthetic Variable Ratio
TM	Thematic Mapper
URISA	Urban and Regional Information Systems Association
USGS	United State Geological Survey
UTM	Universal Transverse Mercator

MODEL PERSEPADUAN PENDERIAAN JAUH DAN SISTEM MAKLUMAT GEOGRAFI (GIS) DALAM PENGESANAN PERUBAHAN GUNA TANAH DARI KAWASAN BEKAS LOMBONG

ABSTRAK

Kawasan bekas lombong merupakan salah satu sumber alam yang perlu diuruskan disebabkan kerana kegiatan perlombongannya yang lalu. Kawasan bekas lombong ini telah menyebabkan pelbagai impak ke atas alam sekitar seperti kemusnahan pemandangan landskap, pemendapan dan hakisan. Oleh itu tanah-tanah bekas lombong perlu dipulihkan apabila ianya tidak lagi produktif. Justeru itu, maklumat-maklumat terkini berhubung dengan tanah lombong menjadi amat berguna dan penting untuk tujuan pentadbiran, pengawasan dan penyelenggaraan di dalam membuat keputusan dan perancangan.

Kaedah penderiaan jauh dan Sistem Maklumat Geografi (GIS) memainkan peranan yang kritikal di dalam proses pengecaman dan pembuatan peta bertujuan untuk memperolehi maklumat ruang dengan lebih efektif untuk dikemaskini atau dirujuk kembali. Penyelidikan ini dijalankan adalah bertujuan mengesan tren perubahan kawasan lombong untuk model semasa bagi kawasan yang berpotensi untuk dibangunkan. Memandangkan keputusan penganalisaan liputan tanah akan menerangkan realiti penggunaan tanah, ianya telah menjadi begitu penting di dalam penterjemahan peta-peta penggunaan tanah. Objektif penyelidikan ini adalah untuk menilai kelebihan-kelebihan yang ada pada data-data bersepadu yang dikesan secara penderiaan jauh dengan menggunakan Sistem Maklumat Geografi (GIS) untuk penentuan perubahan liputan tanah. Objektif spesifik penyelidikan ini adalah untuk memperoleh kuantiti, memodelkan dan mengecam potensi tanah-tanah lombong untuk tujuan pembangunan seperti pembinaan kawasan perumahan dan kemudahan awam di daerah Kinta.

Dalam usaha memperolehi data perubahan liputan tanah, imej satelit Landsat TM untuk tahun 1991, 1996 dan 1998 telah diperolehi dan diproses dengan perisian Erdas Imagine. Kategori-kategori liputan tanah diterjemahkan kepada peta-peta dan ketepatan peta-peta adalah dinilai kepada data rujukan dan data sebenar bumi. Ketepatan penganalisaan menunjukkan bahawa ketepatan peta liputan tanah tahun 1991, 1996 dan 1998 adalah masing-masing 92.38 %, 90.95 % dan 87.62 %. Pengimejan bertindih dan kaedah pengindeksan telah menunjukkan teknik yang lebih baik di dalam pengenalpastian perubahan masa ke semasa. Ianya dicirikan dengan kebarangkalian untuk memasukkan lebih dari dua pengimejan di dalam proses tunggal dengan keputusan dengan keputusan-keputusan yang dapat diinterpretasikan.

Keputusan-keputusan kaedah ini juga menunjukkan kebarangkalian untuk mengawasi aktifiti-aktifiti perlombongan bertujuan untuk menghindari pengoperasian tidak sah. Keputusan muktamad menunjukkan bahawa sebanyak 81.53 km^2 kawasan lombong adalah amat sesuai sebagai kawasan pembangunan manakala 49.85 % dari pada kawasan tersebut adalah sesuai sementara 2.02 % km^2 lagi dari pada kawasan tersebut adalah tidak disarankan untuk dijadikan sebagai kawasan pembangunan. Keputusan validasi silang dengan penganalisaan kekonsistenan menunjukkan bahawa 31.72 %, 19.67 % dan 16.60 % adalah masing-masing tinggi, sederhana, dan rendah potensinya telah dikenalpasti pada tahun 1998. Kaedah yang digunakan dalam keputusan-keputusan yang diperolehi dengan kuatnya menyokong dan menyarankan bahawa pengaplikasian penderiaan jauh dan Sistem Maklumat Geografi (GIS) memberikan banyak peluang yang lebih cerah di dalam penentuan perubahan liputan tanah dan pengecaman yang seterusnya kepada pemodelan kawasan berpotensi dari pada kawasan-kawasan lombong yang tidak produktif.

ABSTRACT

Ex-mining land is one of natural resources that requires continuous management due to mining operations. Past mining activities sometimes cause various impacts on environment such as destruction of landscape, sedimentation and erosion. Therefore ex-mining land needs to be restored when they become unproductive. The availability of the most recent mining land database is very useful and necessary for administration, monitoring and management for decision making and planning.

Remote sensing and geographic information system (GIS) play a critical role in mapping process to acquire spatial information more efficiently, for updating and rechecking. This research was conducted to detect the mining land cover change trend for initial model of potential built up areas. Since results of land cover analysis will explain the reality of land use, the land cover maps become very important in usage for delineating land use maps. The objective of this research was to assess the advantages of integrating remotely sensed data with GIS for land cover change detection. The specific objective of this research is for quantifying, modeling and mapping the potential of the mining land for built up areas such as housing and other urban infrastructures in the district of Kinta.

In order to obtain land cover change data, Landsat TM images of 1991, 1996 and 1998 were acquired and processed with ERDAS IMAGINE software. Land cover classes were interpreted into maps and the accuracy of the maps were assessed to the reference data and ground truth. The accuracy assessment showed that the accuracy of land cover map of 1991, 1996 and 1998 were 92.38 %, 90.95 % and 87.62 %

respectively. Images overlaying and indexing method has shown a better technique in identifying of multi-temporal changes. It also indicates the possibility to input more than two imageries in a single process with interpretable results.

The result of this method shows the possibility of monitoring mining activities to avoid illegal mining operations. The final results show that 81.53 km^2 of barren mining area is highly suitable for built up area, 49.85 km^2 of the area is moderately suitable, and 2.02 km^2 of the area is not recommended for built up area. The result of cross validation for consistency shows that 31.72 %, 19.67 % and 16.60 % of high, moderate and low potential sites have been validated in 1998. The method used and the results obtain strongly suggest that the application of remote sensing and GIS offer very promising opportunities for land cover change detection and mapping and subsequently for modeling potential sites of present unproductive mining lands.

CHAPTER 1

INTRODUCTION

1.1 Background

Land cover is very important for identifying, delineating and mapping in monitoring studies, resources management and planning activities. The information of land cover is useful in the monitoring and mapping of land use for various objectives. This database knowledge will help develop strategies to balance conservation, conflicting uses of land and developmental projects.

Recently, remote sensing and geographic information system (GIS) have become important tools for monitoring, evaluating and modeling environmental changes. The spatial data from remote sensing can be analyzed using sophisticated GIS hardware and software computer system. These technologies provide faster and more efficient acquisition of the spatial information such as land cover and land use changes.

In addition, the District of Kinta has been selected as a case study site since it was very famous with its mining activities for several decades. These activities and the subsequent activities have been reported to have sometimes caused various impacts on the environment such as urban encroachment, destruction of landscape, sedimentation and erosion and disturbance of watercourses. Therefore, the unproductive mining lands which were reused need to be restored or reclaimed for land use. In this research, predicting and mitigating or modeling the potential sites for future land uses are important factors in the restoration of the unproductive mining lands in the future.

An integrated application of remote sensing and GIS in monitoring and evaluating temporal change and modeling potential sites of mining area for future land use has become one of essential elements for a sustainable development in district of Kinta. This integrated technique also offers the possibility to test the capability of spatial model to actual site selection process in near future (Siddiqui et al., 1996). In this research the GIS spatial validated model has been used to test the reality of potential mining area 1991 in 1998. The imagery of year 1998 was used in the validation due to unavailability of the latest satellite data from MACRES.

The use of remote sensing and GIS tools in identifying such area have become important and indispensable for the effective of resources conservation, management and development, especially for investigation the effect of spatial parameters changes in the site selection study. Many potential problems that may arise can be overcome when special precaution is taken in managing the changes of environment.

1.2 Aim and Objectives of The Research

The aim of this research is to assess the advantages of integrating remotely sensed data with GIS for land cover changes detection for quantifying, modeling and mapping the potential mining lands for built up areas such as housing and other urban infrastructures in the district of Kinta, state of Perak within the period of 1991 to 1998.

To support the aim stated above the following objectives were conducted:

i) To study the use of remote sensing and GIS for ex mining land rehabilitation

ii) To identify the selected study area

iii) To utilize the spatial data analysis

iv) To utilize the remote sensing technique

v) To utilize the remote sensing and GIS in modeling land use change.

1.3 Scope of The Study

This research was conducted to evaluate the integration of remote sensing satellite imagery and GIS (Geographic Information System) to model and predict future land cover and land use for a potential built up area. In this research, the analysis of land cover and land use was focused in mine site rehabilitation. The remote sensing technique has been used for land cover mapping, while GIS has provided spatial information and model. Six criteria were chosen as input to the GIS spatial model to generate the potential mining sites for built up area, which are area (contiguity analysis), accessibility, slope, agriculture soil classes, the center of development, and population density.

The final output, which is a spatial model, can be easily updated for future use. It can also assist a decision maker to decide on policies for a better management of the mine site resources.

1.4 Characteristic of Study Area

The selected study area is District of Kinta, State of Perak, Malaysia. The district is located between $4^{0}20'$ and $4^{0}45'$ N latitude and $100^{0}50'$ and $101^{0}15$ E longitudes, which is shown in Figure 1.1. One of the most prominent features of the District of Kinta is a series of limestone hills bounded by steep cliffs rising from the floor of the valley, which can reach 2000 feet in some areas (Ingham and Bradford, 1960). The main mountain ranges consist of extensive masses of granite whose original sedimentary cover has been removed by weathering and erosion. In addition, characteristic features of the climate in the Kinta are uniform temperature throughout the year (25 ^{0}C–33 ^{0}C), high humidity (28 % - 83 %), and high rainfall (2057.4 mm – 3708.4 mm). Geologically the area is divided into two major distinct zones namely

Devonian sedimentary and metamorphic rock, with the Silurian type covered by acid intrusive rocks (Ingham and Bradford, 1960).

1.5 Population

Based on the 2000 government census, the population in Kinta area was 751,825 with the average annual growth rate of 2%. The distribution of population average annual growth within the period of 1991 to 2000 is shown in Table 1.1.

Table 1.1. Number of Persons and Average Annual Growth Rate (percent) by State and Administrative District, 1980, 1991, 2000

Negeri dan Daerah Pentadbiran *State and Administrative District*	Penduduk *Population*			Kadar pertumbuhan purata tahunan (%) *Average Annual growth rate (%)*	
	1980	1991	2000	1980 - 1991	1991 - 2000
PERAK	**1,743,655**	**1,877,471**	**2,030,382**	**0.67**	**0.87**
Batang Padang	136,473	154,686	152,137	1.14	-0.18
Manjung	143,610	168,331	191,004	1.44	1.40
Kinta	564,886	627,899	751,825	0.96	2.00
Kerian	155,765	148,720	152,651	-0.42	0.29
Kuala Kangsar	146,292	146,684	154,048	0.02	0.54
Larut & Matang	249,550	271,882	273,321	0.78	0.06
Hilir Perak	203,028	202,059	191,098	-0.04	-0.62
Ulu Perak	71,372	81,636	82,195	1.22	0.08
Perak Tengah	72,679	75,574	82,103	0.36	0.92

Source : Department of Statistics Malaysia (2001)

In 1991, the administrative of Ulu Kinta was the highest population area in Kinta. The population in this area was 75 % of the total population in Kinta, while the other administrative areas only have 25 % of the population (JPBD, 1993).

1.6 Land Use of Kinta

The area consists of twelve municipalities with the total area about 1856.62 km^2. The Municipalities are Ipoh, Menglembu, Simpang Pulai, Gopeng, Chemor, Tanjung Rambutan, Batu Gajah, Tronoh, Chenderong, Bali, Malim Nawar, and Kampar.

Generally the land use of Kinta is divided into eight main categories or classes. Reserved forest is the biggest class with 55.58 % of the total area. Mining area and agriculture area are 23.37 % and 16.32 % respectively. The other types of land uses are relatively small such as reserved road and rail area, residential, public services, industrial and commercial are 2.12 %, 1.8 % 0.43 % 0.33 %, and 0.05 % respectively. The detail of land uses composition in Kinta is shown in Table 1.2.

Table 1.2. Temporary Land Use of Kinta

No	Land Use	Area (Ha)	Area (%)
1	Residential	3,341.91	1.80
2	Commercial	98.16	0.05
3	Industrial	609.21	0.33
4	Public Services	792.05	0.43
5	Mining area	43,388.44	23.37
6	Agricultural area	30,304.60	16.32
7	Reserved Road and Rail Area	3,935.58	2.12
8	Reserved Forest	103,191.99	55.58
Total		**185,662.00**	**100**

Source: Jabatan Perancangan Bandar dan Desa (1995).

All of these land uses were based on the allocation given by act no. 172 about "Perancangan Bandar dan Desa" (JPBD, 1995).

1.7 The Criteria of Study Area Selection

This study area was selected because of the following factors:

a) It was a major mining area in the past

b) It has been rapidly developing for the last decades where ex-mining land redeveloped into residential area, commercial area and industrial area.

c) The ready availability of spatial and non-spatial data.

d) This area will be one of economic development expansion target in the period of 2000 to 2020 with predicted economic growth 6.9% to 7.0% (JPBD, 1995).

Therefore, due to these criteria it is become interesting to be observed in order to support its future development. The study area is shown graphically in Figure 1.1.

1.8 Organization of The Thesis

This thesis consists of eight chapters. All of the chapters are based on the format and guidelines as laid out in the Guide to The Preparation of Masters and Ph.D Theses, published by the Institut Pengajian Siswazah (IPS), Universiti Sains Malaysia.

In Chapter One, an introduction to the topic of study with the explanation of background, aim of the research, the scope of the study and the characteristic condition of the study area are presented. It contains the whole general information of the research. In addition, Chapter Two describe the literature review of research that has been done in area of remote sensing, GIS and utilization of ex mining land. Chapter Three and Four describe the fundamental information of remote sensing and GIS used in this research. The spatial data and methodology were explained in Chapter Five, which includes the application of Erdas Imagine Version 8.3.1 for image processing and GIS Spatial Model. The results of the study are presented in Chapter Six in the form of tables, graphics and maps. Finally the conclusions and recommendations are given in Chapter Seven.

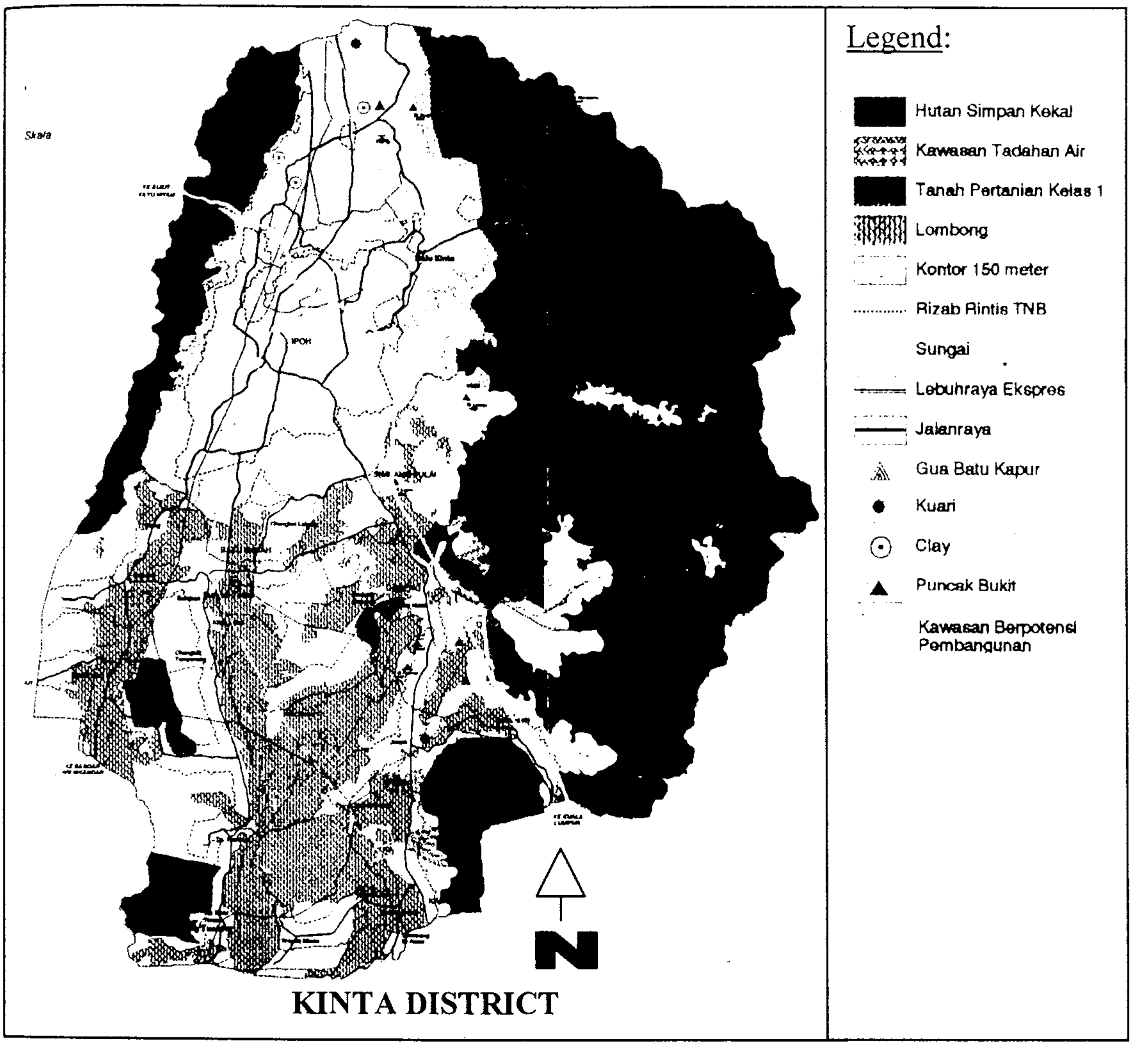

Figure 1.1. Map of Study Area

CHAPTER 2

REVIEW OF LITERATURE

2.1 Introduction to Land Use and Land Cover

The term of land use refers to a series of operation on land, carried out by the authorities, with the intention to obtain product and, or benefit by using land resources. Land use is captured by describing the land use purposes and the operational sequence. Operations are meant to have impact on land so that the aim at land use purposes can be achieved. Finally, a result of land use often influence land cover. Resources used may included such as soil resources, the crops grown and the present natural vegetation; crops grown are part of a land, and thus part of land cover are vegetation (De Bie et. al., 1995).

Land use is also defined as any kind of permanent or cyclic human interaction to satisfy human need for a complex of natural and artificial resources, which together are called land (Vink, 1975). Turner and Ismail (1993) define two linked components of land transformation, namely land cover and land use change. Land cover concern principally of natural sciences and denotes the physical state of the land. On the other side land use denotes human activities and purposes, therefore the land use change may involve a shifting to another or intensification of existing use.

The term of land cover refers to a naturally or man-made materials such as urban infrastructure that occur on an earth surface. Vegetation, bare rock, ice, sand, water, and any material on the earth surface consider as land cover (De Bie et. al., 1995). It therefore the land use and land cover change directly connected to the environment. In the 90's, people start to attempt the strategic formula to control the land use change so that it would minimize the impact on environment.

Longley et. al (1999) stated that the most readily available GIS-data were those from remote sensing, which meant that they were restricted largely to land cover information. Only a very limited amount of land use information can be extracted. Therefore, it is not surprising to find that data contain in GIS in developing countries are primarily concerned with the physical environment and land cover.

2.2 General Land Use Issues

An assessment of the potential environmental consequences of certain development projects has become an integral part of a planning process. There has also been growing international pressure to adopt a more strategic approach to the integration of conservation and development consistent with the global objective of ecosystem maintenance and the sustainable utilization of resources (IUCN, 1980). The ability to characterize, quantify and evaluate the potential environmental implication of the change at local or strategic levels has been hampered by shortage of information on environmental resources and by lack of appropriate analytical techniques.

An appropriate approach is very important to determine the requirement of the geographical information to solve the land use problem. Many users such as government and private sectors involve as policy makers in a certain phenomena. It has been indicated by 80 % of task in government, private and individual sectors had been related to landscape design for such site selection study or environment assessment and modeling (Rainis and Shariff, 1998). Handling the land use a good care will reduce the risk to health and viability of ecosystems in the wc___.

2.3 Methods in Land Use Assessment

Generally, land use distribution can be determined by conventional or modern methods. The conventional method is the assessment process without the use of any automated computing hardware and software such as transparent plastic overlaying and hand-mapping. In contrary, the modern method uses advance methods in computing, cartography, and photogrammetry. These methods have laid the technological foundation for automated Geographic Information Systems (Star and Ester, 1990).

Previously, geographers found many difficulties in the analysis of spatial data. The analysis of maps and spatial data format was more complex than the analysis of numerical data. The manual processes of management, comparison and measurement of data for mapping were resources consuming, limitation in analytical ability and very sensitive to human error. These factors have blocked the use of spatial data (Rainis and Shariff, 1998).

The automated GIS has enable integrating data from a variety of sources, manipulating the sets of data for analyses, and enabling them to provide information for resources planning and management decision process (Star and Ester, 1990). Since the ability to integrate data from many sources, the automated GIS can work with satellite imagery data to provide the latest land use and land cover information.

2.4 Remote Sensing and GIS for Integrated analysis of Land Cover Change Detection

Change is normally described as something of significant that happens. The detection of changes generally links with those representing time. Therefore change can be distinguished in term of their temporal pattern into four types, namely continuous (going on throughout some interval of time), majorative (going on most of the time), sporadic (occurring some of the time), and unique (occurring only one) (Longley et. al., 1999). Figure 2.1 shows the representing of time in the change pattern.

Since the space and time are continues, it is necessary to divide the time into discrete unit of variable length for purposes of measurement such as minutes, day and year (Longley et. al., 1999).

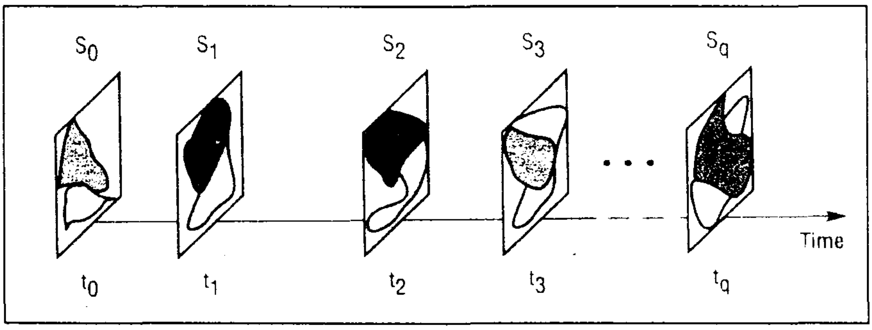

Figure 2.1. The Snapshot as the representing of time in the Change
Source : Longley et. al (1999)

For change analysis, it is necessary to carry out data manipulation in several steps involving preprocessing, processing and color display. Land use changes have been detected by image differencing, ratioing, and differencing of NDVI (normalized difference vegetation index) (Prakash and Gupta, 1998). Some land cover types do not change over the time (static) but some land cover is dynamic, changing rapidly. It is important that such changes can be inventoried accurately so that the physical and human process at work can be more fully understood (Jensen, 1996). Therefore, it is not surprising that significant effort has gone into the development of change detection methods using remotely sensed data.

Many studies that have been conducted shown that the integration of remote sensing and GIS is powerful to determine and detect the change of land use/cover. Kwarteng and Chaves (1998) have studied change detection of Kuwait City using multi-temporal Landsat TM data. This research used a relatively large kernel (201 pixels by 201 pixel) to enhance high frequency information in both bright desert and dark urban area. Color composite were applied for analyses using bands -2, 3, 4 and 2, 4, 7. The two multi-temporal images were geometrically and radiometrically corrected and used as an input to an automatic change detection procedure. The result was generated using the TM band 2, 4, 7 to detect and map temporal change dealing with urban development, vegetation, coastal wetland, and sand sheet surface differences caused by the oil spill that occurred during the 1991 Gulf war. In addition, Prakash and Gupta (1998) also reported that false color composites of bands 4,3 and 2, 7,5 and 3, and 5,4 and 2 provided very useful information for land use mapping, while False Color Composite (FCC) of PC 1, PC 2 and PC 3 gave unsatisfactory result.

Bato (2000) has determined the major factor which affected the land use/land cover of Upper Magat Watershed in preparation for land use / land cover change analysis. The images data in this research were taken from different dates of ten years period. Furthermore the imageries were rectified using road and river vector files as a source of ground control points (GCPs). The evident change was selected as sub areas, which are based on the examination of the raw and classified imageries. It is pointed to four major factors that affected the land use/land cover of Upper Magat Watershed. They were climatic, human activities through agriculture, deforestation and reforestation, and natural disasters. Finally, a linear regression analysis was performed; with the year as the independent variable to preview the trend of land use/ land cover classes with the progression of time.

Zhang (2001) has conducted a research to detect detail changes such as urban housing development, using fused-multispectral satellite data. In this study the TM landsat data were registered to the SPOT pan data before the fusion. For a better detection the SVR (Synthetic Variable Ratio) image fusing method was applied to the TM and SPOT pan data. The principle of the SVR is expressed with the following formula:

$$XSP_i = Pan_H (XS_{Hi})/(Pan_{Hsyn}) \qquad (2.1)$$

$$Pan_{Hsyn} = \Sigma \ \varphi_I \ XS_{Hi} \qquad (2.2)$$

Where XSP_i the grey value of the i-th band of the fused TM-SPOT data, XS_{Hi} is the grey value of the i-band of the magnified TM data, which have the same pixel size as the SPOT pan data, Pan_H is the grey value of the SPOT pan data, Pan_{Hsyn} is the grey value of the synthetic panchromatic data simulated with XS_{Hi} and φ_I is the regression coefficient of variable Pan_H and XS_{Hi}.

Giovanni et al (2001) have studied about the integration of socio-economic and environmental data from different sources into GIS as main strategy for the analysis of human population dynamic and the assessment of their impact to ecological system.

Change detection analysis as well as spatial analysis of the landscape is the main issues of these investigations. They use image algebra to detect the change where the intensity and direction of the changes are quantified by differencing or rationing two remotely-sensed images from different time. Those change detection techniques were applied to NDVI (normalized difference vegetation index) variation in 5 years period from Landsat TM scenes. NDVI index has been extensively use to measure vegetation biomass and vigor on a worldwide basis. By comparing changes due to human disturbance in lowland, abandonment of human activities in the mountain and natural phenomena dynamics on short temporal term, the detected changes related to habitat mosaics can be identified. These results stress the need to couple remote sensing techniques with GIS tools in order to generate change detection map that can give policy maker and land information managers to foresee the effect of their land use decision toward the existing processes and risk to biological conservation.

2.4.1 Change Detection Techniques

Many techniques to detect and identify land cover change have been developed. Some of these methods are image differencing, ratioing, principal component analysis, post-classification and conditional, vector change analysis and multi-temporal composite.

Image differencing is one of the most common methods for change detection, and has been used in a variety of geographical environmental research. It involved subtracting the imagery of one date from that of another. The subtraction result will be in the range of positive to negative value in area of radiance change, and the value of relatively near to zero in the area of no change. The critical element of differencing method is to decide where to place the threshold boundary between the change and no change pixel of an image. Jensen and Toll (1982) stated that the detection of residential land use development at the urban fringe was improved from 77 to 81 percent when image differencing applied both TM 5 and texture information. Image differencing has a general weakness such as its sensitivity to misregistration and mixed pixel.

The principal component analysis is a technique to reduce the redundant data from a satellite bands. It is extensively used in remote sensing image analysis for change detection. The principal component is based on the eigenvector of the covariance (unstandardized) or correlation matrices (standardized principal component). Fung and LeDrew (1987) have evaluated the application of PCA to land cover change in Kitchener-Waterloo-Guelp area. They found that eigenvector used for rotation can be vary significantly, depending upon the choice of using standardized or unstandardized data. They recommended that the eigenvector derived from the entire data set is more valid for land cover change detection.

The most intuitive method of change detection is post classification. It is a GIS overlay of two independent images to produce classified images. This technique can be used to identify not only the amount and location of change, but also the nature of change. Mas (1999) stated that post classification was often considered as a priori to be the best for change detection. It therefore used as the standard for evaluating the result of other methods. The disadvantage of this method is the present of every error in the individual data classification in the detection of change. Therefore, it is imperative that the individual data classification maps used in the change detection be as accurate as possible.

Change vector analysis technique is an empirical method of detecting radiometric change between multidate of satellite imagery in any number of spectral bands. This method provides information about the degree and type of spectral change by calculating the vector magnitude and direction in multispectral change space for each pixel (Michalek and Wegner, 1993).

A Multi-Temporal Composite technique involved combining all bands from two or more date, the false color composite and unsupervised classification then applied to visualize the changes.

Many researchers have applied a combination of the change detection methods. Martin (1989) combined simple multi-date composite images, PCA and supervised classification. He stated that supervised classification was the best method. Singh (1989) did image differencing and PCA, and said that image differencing was better than PCA. Mas (1999) applied image differencing, vegetation index differencing, selective PCA, post-classification, unsupervised classification and combination of image enhancement and post-classification. He concluded that post-classification was better than the others. Sunar (1998) applied image overlay, image differencing, PCA and multi-temporal classification, and concluded that image overlay and differencing was better than the others.

2.4.2 Image Algebra for Change Detection

Prakash and Gupta (1998) stated that studying changes of a land use pattern using remotely sensed data was based on the comparison of temporal data. Various phenomena in earth surface can be monitored and evaluated visually or using digital techniques (Garg et. al, 1988). Band ratioing or image differencing is possible method applied in change detection of two imageries from different dates. Image differencing involves subtracting one date imagery to that of another. The result of eight (8) bits data will be in the potential value range of -255 to 255. Normally this result will be transform to positive value by adding a constant (c) (Jensen, 1996). It is mathematically expressed as:

$$D_{ijk} = BV_{ijk}(1) - BV_{ijk}(2) + c \quad \text{.. (2.3)}$$

Where:

D_{ijk} = change pixel value

$BV_{ijk}(1)$ = brightness value at time 1

$BV_{ijk}(2)$ = brightness value at time 2

c = constant (e.g., 127)

i = line number

j = column number

k = a single band (eg. TM band 3)

A different method was indexing, which was applied to enable analyzing multi temporal changes (Nur et. al., 2002). It is a modification of the equation 2.3 which derived from combination of post-classification, multi-temporal composite and image overlay. This method gives an advantage of a possibility to input more than two imageries with the interpretable result. Data of each classified image recoded to a certain value and applied to a mathematical operation such as adding or subtraction. This operational is express as:

$$C_{ijk} = BRV_{ij}(1) \pm BRV_{ij}(2) \pm BRV_{ij}(3) \pm BRV_{ij}(n) \quad \text{........................ (2.4)}$$

Here: $BRV_{ij}(n) = DN_{ijk}(n) * WIF$

Where:

C_{ijk} = change pixel index value

$BRV_{ijk}(1)$ = brightness recoded value at time 1

$BRV_{ijk}(2)$ = brightness recoded value at time 2

$BRV_{ijk}(n)$ = brightness recoded value at time n

DN = digital recoded number

WIF = weighting index factor (e.g., 1, 9 and etc.)

i = line number

j = column number

k = single layer

The application of this method has to consider a spectral resolution of the output image data such as 8 bits and 16 bits to accommodate output result. Figure 5.10 in Chapter 5 illustrates how this method applied.

2.5 Application Remote Sensing and GIS for Initial Site Location Analysis

Siddiqui et. al (1996) carried out studies about landfill sitting using GIS. He stated that using Analytic Hierarchy Process (AHP) would enable the selection landfill site with a wide variety of criteria. The AHP decision making method used in spatial-AHP involved the five steps: identifying issue and objective, structuring them in the decision hierarchy, judging the relative importance of the decision-hierarchy element aggregating the measurement to calculate suitability index of the alternative and ranking the spatial object (polygons or raster) based on the suitability index. This index expressed by:

$$SI = \sum_{i}^{N2}\left[RIW_i^2 \cdot \sum_{j}^{N3i}\left(RIW_{ij}^3\right) RIW_{ij,k}^4\ )\right] \quad (2.5)$$

where SI = suitability index; $N2$ = the number of level 2 decision factor; RIW^2 = the relative importance weight of level 2 decision factor I; $N3$i = The number of level 3 sub factors directly connected to level 2 decision factor I; $RIW^3{}_j$ = the relative importance weight of level 3 sub factors j of level 2 decision factor I; and $RIW^4{}_{jk}$ = the relative weight of level 4 attribute category k of level 3 sub factor j and level 2 decision factor i.

This method was referred to the AHP as the rating method. Two types of general criteria was applied to select municipal landfill namely exclusionary criteria to accommodate government regulation and nonexclusionary for other parameters such as hydrogeology. In addition, Gamino et. al. (1998) and Lay (1999) have started a study about initial site location analysis using GIS model. They used factors such as area, slope, road net and soil types that affect a site for a preliminary analysis for a potential site.

Saha (1998) has designated slope to four classes as terrain hazard factor; low (1-4 %), medium (5 – 10%), high (10 – 15%), and very high for a slope greater than 25 %. In addition, Juliao (2000) stated that to measure the accessibility, regardless if its unit was time, cost, or distance, should be evaluated for the whole territory and not only on the network.

2.6 Regression Analysis

Regression analysis is performed to analyze and illustrate a correlation of two or more variables. The relationship is represented by an equation.. It is necessary to determine a dependent and independent variables before examining a regression analysis. The regression analysis is applied to observe the significance correlation between those variables. There are four possibility of this analysis, namely linear, multiplicative, exponential and reciprocal. The suitability of the regression model is determined by the coefficient of determinant called R square (R^2). In assessing a goodness of equation fit in regression, usually work in term of slightly different statistic, called *adjusted* R^2 (Lea. et. al.,1997). A goodness of fit in a simple regression is called variance accounted for, symbolized by R^2 (correlation coefficient). It is expressed by:

$$1-\frac{(sum\ of\ squared\ deviation\ from\ the\ line)}{(sum\ of\ squared\ deviation\ from\ the\ mean)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2.6)$$

2.7 Population Growth

The population has been increasing in Perak for the past two decades as shown in Table 1.1. It shows that the population of Perak generally increases from year to year with the average of annual growth rate of 0.67 % in the period of 1980-1991 and 0.87 % in period 1991-2000. Among the Districts in Perak, Kinta shows the highest of average annual growth in this period. Using the exponential model, which is based on continuous change (Radcliffe, 2000), it is possible to predict the population of Perak in the future. This model is expressed by the equation 2.7.

$$A(t) = P.e^{rt} \qquad \text{.....(2.7)}$$

Where:

$A(t)$ = amount of population after t years

P = initial population (population in year x)

e = exponential constant (2.718...)

r = annual growth rate (decimal form)

t = time in year (number of years after year x)

2.8 Housing Demand

Jabatan Perancangan Bandar dan Desa has proposed future housing demand based on the population growth. It can be calculated using equation 2.8 (JPBD, 1993).

$$A = (I * P) / (k * hs) \qquad \text{..... (2.8)}$$

Where :

A = Housing demand

I = constant (speculation index)

P = number of population

k = Number of household/housing size

hs = number persons/house

Based on the survey in 1990, number of household/housing size (k) was 1.02 and number person/house (hs) was 4.5.

2.9 Advances of Remote Sensing and Geographical Information System in Malaysia

There are several studies that were conducted to determine and detect the changes within Malaysia such as the study of land use change of Mukim Petaling and Mukim Bukit Raja in Petaling, Selangor, and Gua Musang in Kelantan.

2.9.1 Mukim Petaling case study

Alias (1993) conducted a study to determine the change of land use of Mukim Petaling using two land use maps of 1984 and 1991. A hard copy of Landsat TM 5 image at a scale of 1 : 40000 and black – and – white aerial photograph taken in February 1991 were acquired in this study. The result showed that the Mukim consisted of nine land use classes. The classes were classified with the overall accuracy of 81 % based on the ground truthing.

2.9.2 Mukim Bukit Raja case study

Halim (1993) conducted a study to determine the rate of land use classes changes in Mukim Bukit Raja. A hard copy of black and white 1982 aerial photograph and the Landsat TM image of 1991 were employed to acquire land use change data. The accuracy of this study, which is based on the ground trust, is 84 %. Based on this study it is strongly suggest that remote sensing technology offers more promising tool for land use change analysis.

2.9.3 Gua Musang case study

The study of land use change in Gua Musang has identified and generated ten land use classes in northern part of this district. In this study, the remote sensed data is taken from 1990 and 1997 at a scale of 1 : 150.000. The GIS system was used in this study to assist land use mapping which transform the remote sensed data into detail information with good quality data.

The major changes that were detected in this study are the replacement of disturbed and undisturbed forest areas to oil palm, rubber and shrub areas with the percentàge of changes reach 36 %. The total overall accuracy assessment of this land use classification, which based on the visualized-sample point, was 86.54 % (Senthavy, 2000).

2.9.4 Kinta case study

Since 1993, Jabatan Perancangan Bandar dan Desa Negeri Perak has applied Geographic Information System to Structural Design of Kinta District. This design was proposed to provide land use information, to improve environment quality and to develop socio-economic sector, which was based on act no. 172, year 1976. In this design, the land uses were plotted base on the general land requirement regardless land accessibility and demand factors. Some criteria, which were used in this design:

a. The development area was 150 m above sea level.

b. The area was not in natural conservation area

c. The slope less than 20 degree

d. The area was not in water catchments area

e. The area was not in agricultural soil

f. The area was not in a historical place

Although some important criteria excluded in this design, but it has been used as a platform for landscape design in Kinta.

Another study of land use in some parts of Kinta District using integrated remote sensing and GIS was also conducted by Azlin et. al (2002) and Azlin et. al (2003). In this study, they detect 19.57 km^2 of the mining area around Ipoh and 1.74 km^2 of the mining area in Sungai Raya catchments have change to urban area. They concluded that remote sensing and GIS techniques provide an efficient and scientific way to monitor land use and land cover change.

2.10 Conclusion

Application of remote sensing and GIS is a powerful tool to provide information of temporal changes due to the temporal resolution of satellite imagery and spatial information system of GIS. Many researchers have conducted study about change detection by implementing various methods. Due to the inability of image differencing, ratioing and principal component analysis (PCA) to cope multi-date data for change detection in a single process, application of Post Multi-date-Classification, and Image overlay and indexing may give a better result for change detection of multi-date imagery.