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GIS AND REMOTE SENSING TECHNIQUES FOR MEASURING AGRICULTURE LAND LOSS IN BALIK PULAU REGION OF PENANG STATE, MALAYSIA

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Abstract

Currently, Malaysia like other Asian countries has experienced rapid expansion of urbanization due to economic development, industrialization, massive migrations as well as natural population growth. This expansion particularly unplanned consumed a huge amount of arable land in the urban milieu and in its surrounding areas. This paper aims to measure arable land loss due to massive urbanization in Balik Pulau region of Penang State, Malaysia. Landsat TM (Thematic Mapper) images of 1992 and 2002 at the resolution of 30 m and Landsat ETM (Enhanced Thematic Mapper) 2010 have been used to measure the rate of urban expansion and its impact on agricultural land. The integration of Remote Sensing and Geographical information system GIS were used to quantify the conversion of arable land to built-up areas in Penang State. The result reveals that built-up areas have expanded rapidly during the last four decades at the expense of agricultural land in Balik Pulau Region. Built-up areas had increased from 1793.22 ha in 1992 to 3235.38 ha in 2002, while agricultural areas decreased from 6171.32 to 4727.83 ha during the same period. The expansion of Built-up area is directed towards low-lying areas with less topographical barrier causing heavy loss in productive land and environmental degradation. In order to safeguard the environment and maintain arable land, urbanization should be controlled and rationalized through legislative measures, wise policy and public awareness. More attention should be given to the areas that have witnessed massive urbanization and coordination between various sectors involved in development is a must.

Keywords: Agriculture, urbanization, land use changes, GIS, remote sensing, Malaysia

1. INTRODUCTION

Currently, urbanization and its impact on agriculture have received considerable attention by planners, researchers, and policymakers (Elhadary *et al.,* 2013) due to it is negative impact on livelihood and food security. This idea supported by Massar (2001) who stated that urbanization has impacted negatively on socio-economic development of the countries. This has led several authors to define urbanization as the transformation of rural communities into urbnized society, and often being associated with changes in livelihoods (Atmis *et al.,* 2007; Martinuzzi *et al.,* 2007; UN, 2008). For Liu *et al.* (2005) urbanization is the process of transforming rural land uses into urban activities

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and thus put huge pressure into rural communities. Despites all these, urbanization has become one of the leading factors that transform landscape all over the world (Price *et al.*, 2006).

The speed of urbanization looks different between continents as it reached 42.4% in Africa, 42.7% in Asia, 74.2%, in Europe, 79.4%, in Latin American and Caribbean, 82.3% in North America and 73.7% in Oceania (United Nation, 2003). Like Western nations, several Asian countries including Malaysia have adopted industrialization policies to foster economic growth (McGee, 1989; Simon *et al.*, 2004). Accordingly urbanization has spread very rapidly even faster than that experienced in the developed countries (Deng *et al.*, 2009; Barraclough, 2005) and become hard to control particularly in some Asian countries (Quang, 2005). For example, urbanization in some Asian cities has increased from 17.8% in 1950 to 40% in 2000s and it has been projected to reach 60 % by 2030 (Atmis *et al.*, 2007). In Malaysia, the share of the national population living in urban areas increased from 27.6% in 1970 to 65.4% in 2000, and it is projected to reach 75.0% in 2020 (Ghani 2000). This rapid urbanization has occurred at the expense of agricultural land and is considered as one of the most prevalent causes in transforming rural areas to urban areas (Dewan and Yamaguchi, 2009a).

The shift of economy from a mainly agriculture to an industry based economy in early seventies (Ghazali, 1999; Drakakis-Smith 2000; Sathiamurthy, 2010) is one of the major driving forces behind the seed up of urbanization in Malaysia (Ghani, 2000; Ghazali, 1999; Samat *et al.*, 2011). This has led manufacturing activity to increase in the metropolitan periphery, exurban areas and even in rural areas (Hutton, 2004). Other factors include population growth, massive rural–urban migration, economic development, governmental policy and good transportation network (Yuan *et al.*, 2005; Çakir *et al.*, 2008; Koomen and Stillwell, 2007). This rapid and unplanned expansion has created heavy pressure on agricultural land (Saleh and Al, 2007) and caused conversion of massive farming lands into urban activities (Fazal, 2000; Overbeek and Vader, 2003). The expansion at the expense on farming activities has generated socio-economic pressure on land in urban spaces as well as at the peri-urban areas (Ma and Xu, 2010) leading to socioeconomic and planning problems in the urban and rural areas (Tran, 2006).

The aim of this article is to measure the rate of urban expansion and the loss of agricultural at Penang Island of Malaysia, particularly in Balik Pulau district. The paper has started by mapping the changes in land use at Penang Island from 1840 to 2000 based on data derived from an old topographic map. Then, remote sensing images of 1992; 2000 and 2010 integrated with Geographical Information System GIS techniques have used to monitor land cover changes and quantify agricultural land loss in Balik Pulau.

2. GEOGRAPHICAL SETUP OF THE STUDY AREA

Balik Pulau literarily means back of the island, is located at the southwest district of Penang State and was chosen as the study area. This area has experienced urban development pressure since 1970, when Malaysia had embarked on industrialization policy as catalyst of economic growth (Chan, 2010). The study area lies between 5° 24' 27" and 5° 18' 46" N and 100° 11' 35" and 100° 14' 21" E. It covers an area of approximately 86 km^2, accounting for 28% of the total land area in Penang Island (Figure 1). The number of population was approximately 29,218 in the 2000 and it has increased to 34,219 in 2010 (Department of Statistics, Malaysia, 2001; 2010). The topography of this area ranges from sea level to over 4,000 m. Balik Pulau is located 20 km from Bayan Lepas International Airport, 22 km from Bayan Lepas Free Industrial Zone and approximately 22 km from the capital state of Georgetown.

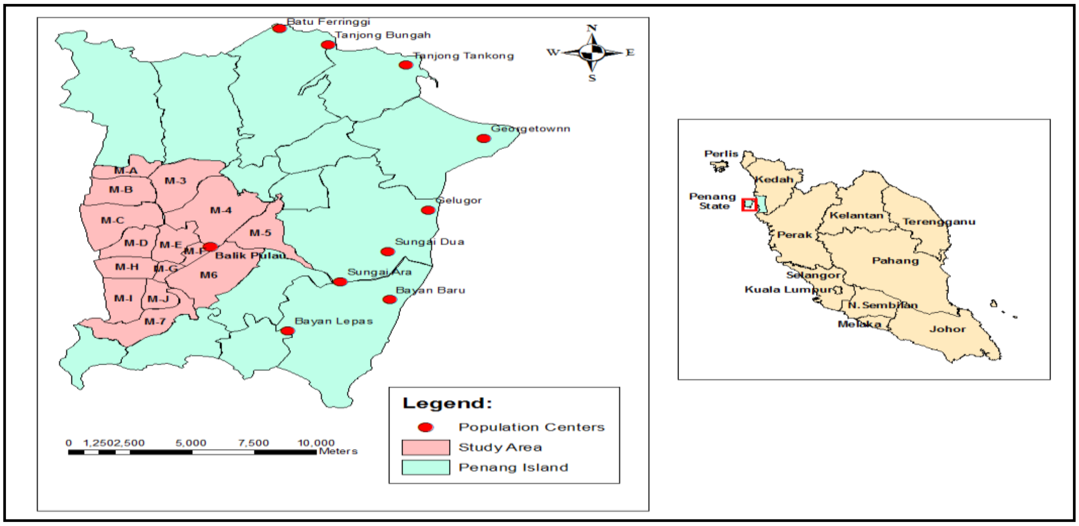

Figure 1: Location of study area: Southwest of Penang Island

Balik Pulau is self-sufficient township with basic municipal facilities including hospital, a police headquarter, a fire station and a post office. It is one of the major touristic areas in Penang Island. Balik Pulau is undergoing rapid urbanization due to the high demand residential area and urban development. Accordingly rice and fruits which are the famous production in the study area are now under threat due to urbanization. This offers the study an opportunity to measure the loss of productive land and thus facilitate decision makers in formulating rational policies to protect agricultural land. Another reason for selecting the Balik Pulau is due to data availability. Data availability is an important issue in monitoring land use changes since data input and database creation is time consuming and costly (Samat, 2006).

3. MATERIALS AND GENERAL PROCEDURE S OF DATA PROCESSING

3.1. Data for GIS application

This article is based mainly on the use of Geographical Information System GIS and Remote Sensing RS techniques. Regarding GIS part, the study depends mainly on the use of the three land use maps (1967, 1974, and 2010) with the scale of 1:150,000. These maps were collected from various sources; the maps of 1967 and 1974 were gathered from University of science in Malaysia USM, and the map of 2010 was collected from the Federal Department of Town and Country Planning (JPBD) office. While, the roads network and elevation data with the scale of 1:150,000 were also gathered from USM. Other digital maps such as Penang cadastral lots and Penang district which are in GIS format (Arcview Shapefiles) were obtained from GIS laboratory at the School of Humanities, Universiti Sains Malaysia. To enhance the quality and ensure better result all maps were converted into GIS format and having the same projection and scale. All analogue maps have been scanned and digitized to match the maps in GIS format. ArcGIS 9.3 software was used to perform spatial analysis and generate shape files layers. The availability of old based maps provides the study a chance to examine the expansion of built-up areas in Penang state since early 1840 to 2000. With the helping of spatial analysis tool in ArcGIS, a time series of such expansion and its climax has been shown in (figure 3).

3.2. Data for remote sensing

Satellite images of 1992; 2000 and 2010 have been used to investigate land cover changes and measure agriculture land loss in Balik Pulau. Landsat data (TM (Thematic Mapper) 1992, ETM (Enhanced Thematic Mapper) 2002) acquired from United States Geological Survey (USGS) remote sensing website and Thailand Earth Observation System (THEOS) 2010 were acquired from School of Physics, Geophysics section, USM. The collected images are used to measure the rate of urbanization in the study area. The evaluation of land use\ land cover changes were conducted through the use of Multi-temporal remote sensing image of 1992, 2002 and 2010. Two major sources of images data set have been used in this study. These were Landsat images with 30 meter resolutions, and THEOS image with 15 meters resolution. More details on these images are given in Table 1. Section below provides details information on image processing (correction, classification and ground control points).

Table 1: Remote sensing data source

Data availability	Date	Source	Existing format
Landsat 5Satellite image	24-06-1992	USGS	7bands soft copy
Landsat 7Satellite image	1/4/2002	USGS	7bands soft copy
THEOS1Scene level 2A Satellite image	29-01-2010	USGS	4bands soft copy

3.3. Geometric correction and satellite image classification

The study adopted Anderson *et al.* (1976) classification system level II. This Level is appropriate for regional land use and land cover compilation and mapping (Lillesand *et al.*, 2004). Figure 2 explains the flowchart used to perform image classification and to detect land cover/use changes. The first step is geometric correction which was carried out using 35 ground control points (GCPs) from maps in Universal Transverse Mercator (UTM) to geocode the image of Landsat TM image of 2002, then this image was used to register all the other images. By doing so, the study ensures that all images have the same projection and properly matches to each other for better classification and visual interpretation.

The purpose of the image classification method is to automatically organize all pixels in the image into land cover classes or themes (Lillesand and Kiefer, 1994). The paper adopted USGS classification techniques as recommended by Lillesand *et al.* (2004) in landuse/cover classification. For the classification method the study implemented Maximum Likelihood (ML) procedure as introduced by Fan *et al.* (2007). Supervised classification was done using PCI 9.1 software using 30 ground checkpoints and the digital topographic maps of the study area.

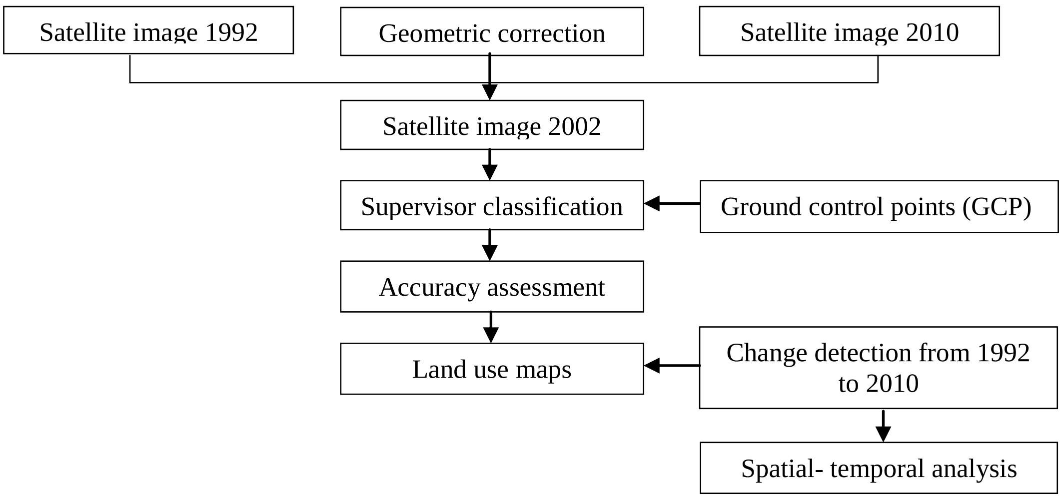

Figure 2: Flowchart of image classification and change detection analysis

Several steps have been adopted for image classification. The first step was the adoption of first order polynomial fit then all reflective bands in the images were resemble into thirty meters pixels using the nearest neighbour method. Accordingly, eight classes of land use were recognized. These classes include mixed agricultural land, farming land, built-up areas, bare land, sand, mangrove, forest and water). To eliminate error and ensure high quality, the study adopted accuracy assessment technique.

4. ACCURACY ASSESSMENT

Accuracy assessment was carried out using PCI 9.1 software. This software provides all necessary statistical reports and very efficient in analyzing the classification result. This study used the sampling scheme appropriate and standard techniques adopted by (Fan *et al.*, 2007) to evaluate the accuracy. Practically, the paper select 30 points randomly from classification result. The output was performed using error matrix to uncover the truth of the ground in comparison. Kappa coefficient is used to examine the difference between classified image and actual data (Congalton, 1991). The overall accuracy derived for data was 86.75 %, 80.35 % and 90% for the images of 1992, 2002 and 2010 respectively as shown in Table 2.

Table 2: Accuracy and kappa statistics of satellite imagers

Satellite image	Year	Overall accuracy	Overall kappa
THEOS1Scene level 2A satellite image	2010	95%	0.928%
Landsat 7, ETM	2002	81 %	0.703%
Landsat 5, TM	1992	87%	0.794%

4.1. Land use land covers change detection

This section highlights the analysis undertaken based on spatial data obtained from topographic maps and satellite images. GIS technique was used to determine the expansion of urban areas in Penang Island during 1840 to 2000. The type of land use/land cover change between two periods was calculated using equation 1 below (Samat, 2010) and the rate of changes were calculated by using equation 2 as given by Ma and Xu (2010).

$$\Delta LU_{i,j,r}^{t \to t+1} = LU_{i,j,r}^{t+1} - LU_{i,j,r}^{t} \qquad \text{…...……………… (1)}$$

Where,

$\Delta LU_{i,j,r}^{t \to t+1}$ = changes of land use type *r* at location *i* and *j* from *t* to *t* + *1*,

$LU_{i,j,r}^{t+1}$ = land use type *r* at location *i* and *j* at time *t* + *1*, and

$L_{i,j,r}^{t}$ = land use type *r* at location *i* and *j* at time *t*.

$$LUDI = \frac{Ua - Ub}{Ua} \times \frac{1}{T} \times 100\% \qquad \text{………………….. (2)}$$

Where,

LUDI= the annual rate of change in area for land use classes.

Ua = certain land use class at time a

Ub = certain land use class at time b and.

T = denotes the length of time from time a and time b, when T is in a unit of year,

5. RESULTS AND DISCUSSION

5.1. Analysis of historical urban expansion in Penang Island from 1840 to 2000

The Built up area as indicator was used by this study to measure the rate of urbanization. Several authors have adopted such techniques in measuring urban expansion (Ma and Xu, 2010; Li *et al.*, 2010; Dewan and Yamaguchi, 2009b; Yu *et al.*, 2010). Our analysis has shown that built-up area in Penang Island increased by 36.7% between 1840 and 2000 (Figure 3). Moreover, the built-up area has increased by 21.2 % between the year 1960 and 2000. While during 1960 and 1980 the built-up area has expanded very rapidly at rate of 8.1% annually, an increase of 2447.1ha. However, the rate of urbanization has decreased sharply between 1980 and 1985 by a ratio of 0.616, which is equivalent to 185.8 ha. The expansion has increased very rapidly between 1985 and 2000 at a percentage of 12.5%, an increase of 3761.9 ha (see Table 3). This shift in urbanization is due to the rapid economic development that has taken place in Penang Island during such period (Beng and Lee, 2010; Hutton, 2004; Ismail and Lim, 1991). Three points need to be highlighted to understand the areas that have witnessed rapid urban expansion in Penang Island. These points include:

(1) Several cities have been found between 1960 and 1980. These cities include Georgetown suburbs, the coalescing of Butterworth–Bukit Mertajam, and the subsequent urban sprawl from both metropolitan areas (Ismail and Lim, 1991; Samat, 2002). During such period the built- up area of Penang Island has extended by 2447 ha at an annual average rate of 112. 4ha.
(2) During the year 1980 and up to the year 1985, the annual rate of built-up area in Penang Island was 185.9 ha at an annual average rate of 37.2 ha per year. The expansion in this period was slow compared with the earlier period as shown in (table 3 and Figure 3).
(3) While during the year 1985 and up to 2000, the built-up area of Penang Island expanded by 3761ha at an annual average rate of 250.8. Our analysis has confirmed that this period had witnessed very rapid expansion of urbanization in the study area. This is due to the adoption of large-scale urban industrial complexes and increased of manufacturing activities within the metropolitan periphery, exurban areas, and even rural zones (Hutton, 2004).

Figure 3: Different historical periods of urban expansion in Penang Island from1840 to 2000

Table 3: Quantification of urban expansion in Penang Island from 1840 to 2000

Years	Built-up Area/ha	%
1840	132.4	0.438
1900	1071.2	3.5
1960	4583.6	15.2
1980	7031.1	23.3
1985	7216.9	23.9
1995	8146.7	27.1
2000	10978.8	36.4

Table 4 reflected clearly the remarkable increase of built-up areas in Penang Island. It shows that the percentage of built-up area has increased from 0.4% in 1840 to 36% in the year 2000. This implies that one third or more of the total area has been occupied by urbanization. Moreover, the table explains that in four decades particularly from the year 1960 to 2000 built-up areas has increased by 21.2%. During this period built- up area of Penang Island expanded by 2447 ha, at annual average rate 112.4 ha in this period. Urban expansion has grown in Georgetown suburbs and the subsequent urban sprawl from this metropolitan area (Ismail and Lim, 1991). This rapid expansion might be due to rapid economic development in the Penang Island as indicated by (Beng and Lee, 2010; Hutton, 2004; Ismail and Lim, 1991). Or to the large-scale urban industrial complexes and manufacturing activity that have taken place in metropolitan periphery, exurban areas and even rural zones (Hutton, 2004). The adoption of industrlization since 1970s has impacted negatively to agricultural sector in urban as well in countryside.

Table 4: Urban expansion rates of Penang Island in different periods

Items	Periods		
	1960-1980	1980-1985	1985-2000
Urban expansion area /ha	2447.1	185.9	3761.9
Urban expansion percentage (%)	8.1	0.616	12.5
Annual average rate /ha	112.4	37.2	250. 8

The analysis has shown that built -up area has expanded over the land used for agriculture. Nearly 20% of agricultural land was converted to industrial sector and residential area (Ismail and Lim, 1991). This explains the sharp decline in agricultural production (only 3.3%) to the economy of Penang Island. The historical dynamic increase of built-up areas in Penang Island is shown in Figures 4. The figure indicated that built-up areas have continued to increase between the years 1980 to 2000 and expected to increase up to the year 2020. The following section provides details on the current land use changes in Balik Pulau.

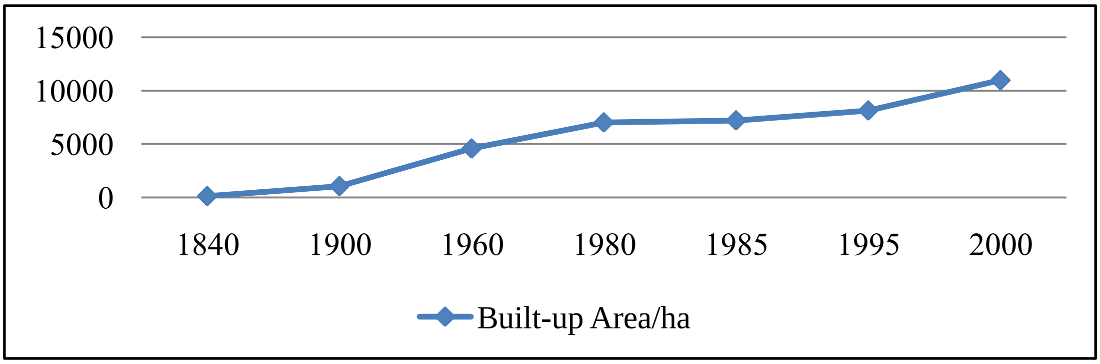

Figure 4: Dynamic of urban expansion in Penang, 1840-2000

5.2. Dynamic changes in Balik Pulau from 1992 to 2010

Balik Pulau which is a part of Penang Island has faced the same destiny in urban expansion during the last two decades. The land use conversion matrix in table 5 has shown that Balik Pulau has witnessed dramatic land use changes during the period 1992-2002; in 1992 almost half of the total area was agricultural lands 6171, 32ha representing 53.79% of the total area, it has been decreased to 4727, 83ha by the ratio of 42.08% in 2002. The study obviously demonstrates that there had been a drastic change in urban areas (highly built-up areas), which increased by 109.03% over the 8-year period; the urban area increased from 31.23 to 65.28 km^2. This implies that agricultural sector has lost roughly 1443, 49 ha in 10 years between 1992 and 2002. This finding appeared in the examination of the classification result of 2010 imagery. Meanwhile, the total changes of these 18 years that is mostly in the farming areas, decreased by the 37% with 2288ha. Also, urban uses increased by the ratio of 123.7% with 2193ha as shown in Tables 5 and 6 (see Figures 5 and 6).

Table 5: Repartition of agricultural lands and built-up areas in balik pulau of years 1992, 2002 and 2010

Class	Surfaces 1992		Surfaces 2002		Surfaces 2010		Total percentage of changes among 18 years	
	ha	%	ha	%	ha	%	ha	%
Agricultural lands	6171.3	53.8	4727.83	42.1	3883	35.8	- 2288	37.0
Built-up areas	1793.2	15.6	3235.4	28.2	3987.8	34.9	+2193	123.7

The analysis has shown that built-up areas have expanded very rapidly comparing to agricultural areas. It has increased from 1793.2 ha in 1992, which encompassed 15.6% of the total of study area to approximately 3235.4ha in 2002; so the proportion on of urban uses is by the ratio of 28.2 % (as shown in Table 6), and an increase of 1442.2 ha during this 10 years with an annual rate of 144.21 ha. This exactly constitutes the rate of annual loss in agricultural lands. This figure confirmed that 98% of urban expansion has occurred on areas that were used for farming activities. The analysis of the images has reached to the same result, within the years between (2002 and 2010) built-up areas also increased by 752.4 ha by at the ratio of 6.7% (as shown in Tables 6) and (Figure5).

Table 6: Land cover percentage and total changes for each cover class between 1992 and 2010

Cover class	1992 %	2002 %	2010 %	% Changed from 1992to 2002	% Changed from 2002 to 2010
Built-up areas	15.63	28.20	34.9	+ 12.57	+6.7
Forest	10.58	11.66	15.74	+ 1.08	+4.8
Agricultural	53.59	42.8	35.8	- 10.79	-7.0
Mangrove	4.29	2.53	_	- 1.76	_
Sand	1.37	0.52	_	- 0.89	_
Barren land	1.41	6.27	_	+ 4.86	_

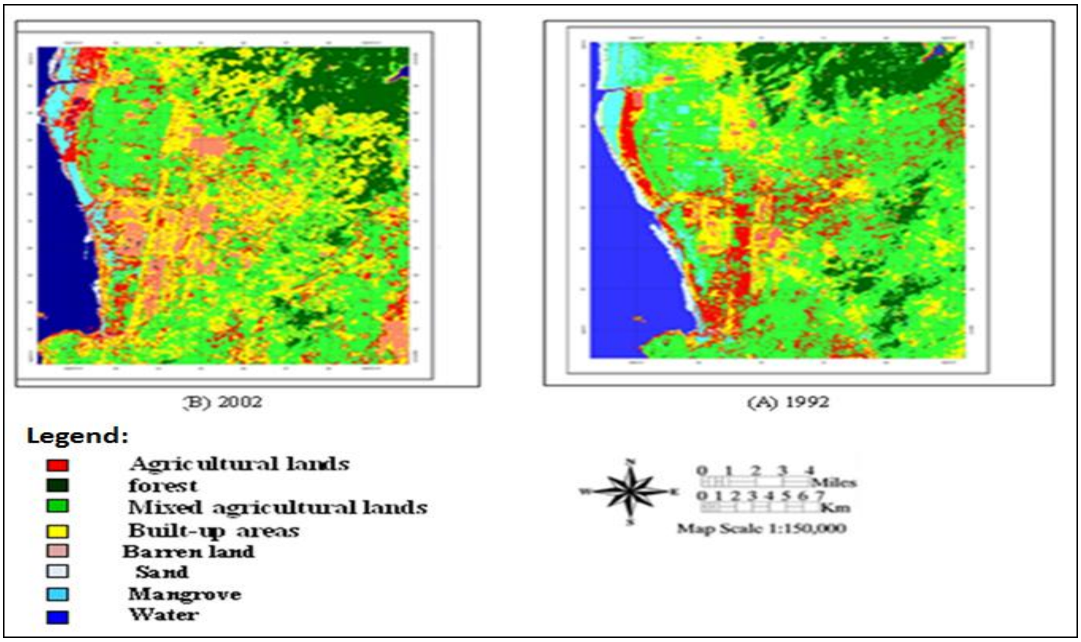

Figure 5: Land cover classification of Balik Pulau 1992 and 2002

Our analysis has confirmed that urbanization has expanded rapidly at the expense of agricultural lands particularly from 1992 to 2002 and during 2002 to 2010 (Table 6). The findings have shown that built-up areas have increased while other land use classes remained without change or at least stable. Astonishingly, the analysis has indicated there is increase in forest area. It has been increased from 10.58% in 1992 to 11.66% in 2002 an average increase of 1.08%. From 2002 until 2010 the forested area increased by average of 4.8% (Table 6 and Figure 6).

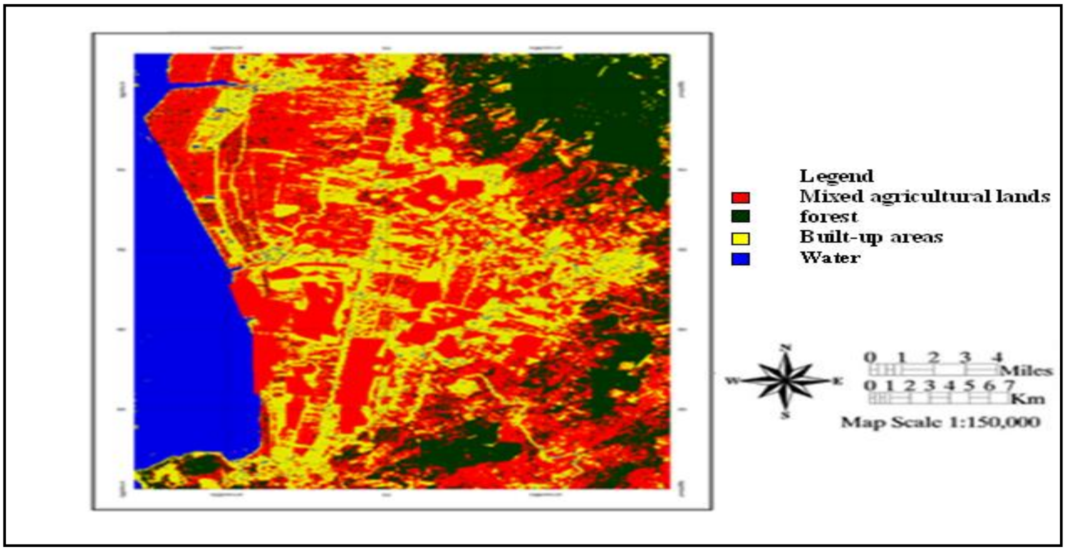

Figure 6: Land cover classification of Balik Pulau–2010

Our analysis has shown that a built-up area has increased as compared with others land use types. The percentage of built- up areas has shifted from 15.63% in 1992 to 28.20% in 2002 (see Figure 6, and Table 6) of an average increase of 12.57%. While during 2002 to 2010 the built-up areas has continued to increase with an average of 6.7% (Table 6 and Figure 6). It important to note that, agricultural land has decreased sharply as presented in the classified image. It decreases from 53.58 in 1992 to 42.8 in 2002 and to 35.8 in 2010. Not only that, urbanization has impacted negatively even on mangrove. The results clearly indicated that mangrove decreased from 4.22% in 1992 to 2.5 in 2002.

6. CONCLUSION

Urbanization in both Penang Island and Balik Pulau has expanded rapidly during the last four decades. This expansion has impacted negatively on agricultural sector leading to a massive loss of arable lands. Penang Island has shifted sharply from only 3% in 1900 up to 36% in 2000. Our analysis has shown that in Balik Pulau agricultural land has decreased from 53.6% in 1992 to 42.8 in 2002 and to 35.8 in 2010. The major driving forces behind the lost of arable lands are believed to be the fast economic growth, industrialization and good network infrastructure. Available literature on urbanization has shown that industrialization is the major factor behind the decline of most productive land particularly paddy fields in the country. A serious and urgent action is needed to control and manage urbanization in order to minimize the great loss of productive land and to sustain food security in Malaysia.

Geographical Information System GIS and Remote Sensing have proven its efficiency in providing up to date information and large details in urban expansion. These tools alone would not give clear picture about urbanization and its consequences. Integration of socioeconomic, political and developmental studies is highly needed to fill in the gap and support the spatial findings.

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