Using remote sensing and GIS for observation Land use land cover Changes and quantifying arable land loss in Penang Island – A case study of Balik Pulau

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Abstract

Urban development caused by economic growth in Malaysia during the past few decades has had a significant impact on natural and arable lands. This phenomenon has become a main concern for both planners and urban managers.

Penang Island, as an example, has different urban development features, which probably results from the high economic growth at the state. However, the island is characterized by limited open space because 50% of the island is mountainous. Flat areas are generally used for urban development to satisfy the demand for housing and other infrastructures. This study evaluates urban development pressures by observation land use land cover changes and quantifying arable land loss in Balik Pulau, Penang. Land sat TM data between 1992 and 2002 at a resolution of 30 m are used. GIS analysis is used to monitor the conversion of arable land to built-up areas. The results indicate that large proportions of farmland and grassland had been converted to built-up areas over the 10-year period. Specifically, urban areas increased from 1793.22 ha in 1992 to 3235.38 ha in 2002, while agricultural land decreased from 6171.32 to 4727.83 ha during the same period. Urban land expansion has been largely driven by elevation, population growth , economic development, Road Networks and land value Rapid urban expansion through infilling of low-lying areas and clearing of vegetation resulted in a wide range of environmental impacts, including habitat quality. Further studies need to be undertaken to ensure that urban development does not produce negative consequences to society, space, and the environment.

Keywords: Land use changes, Urban development, Driving Factors , GIS, Remote Sensing, Balik Pulau,

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1. Introduction

1.1. Background

Urban development in East and Southeast Asia, in many cases, occurred much faster than the governmental and urban planners could manage. In Malaysia, urban expansion increased from about

25% in 1960 to 65% in 2005; in 2020, expansion is expected to reach 70 %(Norizan and Zikiry, 2011). Thus, developments at the outskirts of the city are difficult to control, leading to chaotic land use patterns (Vu Phong, 2005). Scholars and local planners are becoming increasingly more interested in the contribution of tourism, rather than industrial, economic, and social development (Albalate and Bel, 2009).

Discussions on the relationship between rural and urban areas and the role of urban pressure are not new. Gradually, more diversification in rural cultures has occurred as a result of the impact of urban development (Overbeek and Vader, 2003). Rapid development is often the cause of enormous pressure on the rural and natural environments. In 1920, the population in urban areas rose to 14% of the world's entire population, and then to 25% in 1950. Between 1950 and 1985, the urban population nearly tripled (United Nations Development Programme, 1991).

Older industrial cities seem less affected by these trends because population growth and the rate of migration from rural to urban areas have become stable. The most notable phenomenon in developing countries is the large number of cities and millions of homes. The population growth rate in urban areas between 1950 and 1990 was much larger in developing countries, where growth rates rose from 17% to 34% and migration from rural to urban areas remained high (Weber and Puissant, 2003). Therefore, during the last century, population growth caused rapid urban growth pressure on land and resources, more so in urban areas than in rural ones (Erdogan et al., 2007).

Although the economic growth and rising living standards lead to increased demands for a larger number of jobs. They also lead to the conception of plans, upon the authorization of the authorities, to preserve the traditional pattern of spatial discrimination in urban and green areas. However, an assessment of recent policies suggests that the government does not have enough power to resist the social dynamics that cause an increase in the demand for housing, infrastructure, and industrial sites. Urban demands for green squares in rural areas also include the demand for recreational opportunities and improved qualities of life. Demands existing in rural areas include, among others, employment and services. Processes involved in these demands tend to share economic activities and flows with each other. The consequences of this exchange and the complexity of operations and demands is that the urban and rural areas rely heavily on each other (Overbeek and Vader, 2003).

Although such programs have been essential to the development of the manufacturing industry in the Asia-Pacific region and other cities over the past half century, the service industries are increasingly important tools for urban growth and change (Thomas and Hutton, 2004). As population continuously increased, economic growth and rapid urban and infrastructure developments were exacerbated and exerted an unprecedented pressure on the coastal environment and agricultural land (Wu et al., 1998; Farooq and Ahmad, 2008; Millington et al., 1999).

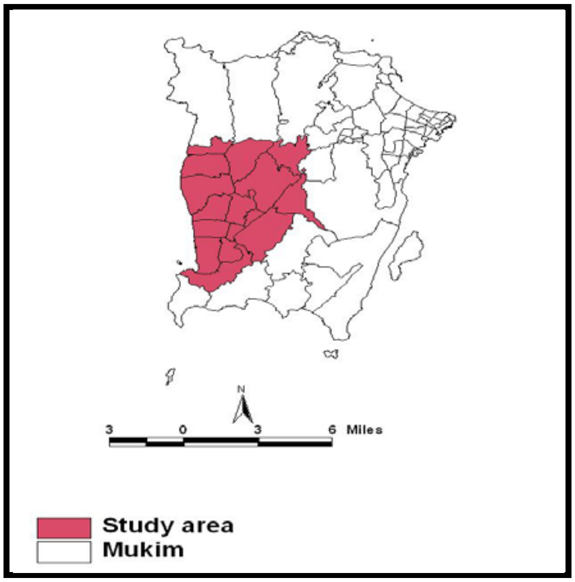
The growth of urban areas tends to be characterized by sprawling suburban development, converted agricultural land, and cultural and open spaces on the margin between urban and rural areas (Maruani and Cohen, 2009). Semi-urban areas in rapidly growing cities are under great pressure due to the demands of land for urban development, leading to the loss of arable land, environmental degradation, and social exclusion of village communities (Zhenshan et al., 2009). Urban development became inevitable over the next two decades. The bulk of this growth occurs in less developed countries. This represents a formidable challenge for planners and managers (Masser, 2001).

1.2 Study area

The designated study area was Balik Pulau, a district located at the southwest district of Penang Island. Geographically, Balik Pulau is located between 5° 24' 27" and 5° 18' 46" N and 100° 11' 35" and 100° 14' 21" E. It covers an area of 86 km^2, accounting for 28% of the total land area in Penang. The population here was approximately 29,218 in the 2000s. The study area included 14 Mukims that vary in terms of land area and population density, with the least densely populated Mukim having a population of 154 and the most densely populated having a population of 2523 (Rahman, 2000). The topography of this area ranges from sea level to over 4,000 m.l Balik Pulau is a district surrounded by industrial and housing estates, and the process of urbanization in the surrounding areas is rapidly moving towards Balik Pulau. Demand for industrial and housing land has been so great that rates of land reclamation and conversion of agricultural land has become more rapid. There has been a reduction in agricultural areas resulting from urban expansion and the development of industries, especially at the periphery of the urban centers. The Balik Pulau area is threatened by urban growth, causing concerns for the future of this area. Therefore, we highlight

Balik Pulau to determine a number of important issues that arise from the negative effects of urbanization. The most important of these issues is the degradation of agricultural land because 90% of the agricultural lands in Penang is located in the Balik Pulau area. Secondary issues include the environmental degradation of habitats, water, soil, and air. Furthermore, urbanization processes threaten the rural community's culture. These issues combined led us to choose Balik Pulau as the study area.

Figure1. Location of study area: Southwest of Penang Island



2. Materials and methods:

2.1. Data

Land sat data (TM, ETM) were acquired and used for study of urban expansion. Multi-temporal remote sensing and multi-temporal city maps were collected to evaluate land use, land cover changes, and urban expansion in South East Penang Island. In this study, the preliminary processes to prove the theoretical framework will use satellite image data of the two scenes, the resolution of the tow images is at 30 m.

2.2. Maps processing

Five Digitalized maps of different historical periods were encoded into GIS software (Arcview 3.2). The maps were geometrically inter-matched and converted to (UTM) map projections. A land use map from 1974 was employed with these five maps as the base maps for this study. The urban area borders in the different periods were determined to calculate the extension rate. Fig. 1 shows the urban areas of Penang Island at different historical periods between 1840 and 2000. The use of historical maps to extract the boundaries of the city to investigate the patterns of urbanization is relatively simple and can show information from pre-industrial times. Although in accuracy may be present, the fact that the areas have been mapped using the same scale of 1,250,000 will cause the impact of these changes to be a minimal view of the relatively coarse time scales used in this study. The first step is to determine the proportion of urban expansion on Penang Island for the periods from 1840 to 2000, and, depending on the base maps of urban expansion that have been obtained from (BGIS), the areas are digitized and made as separate layers using Arcview 3.2 to easily measure the rate of urban expansion between different periods. Thus, determining the periods of rapid urbanization and associating them with the reasons for this expansion will enable the preparation of a standard head to determine the scope of satellite images. This scope will be subsequently used in this search for the integration of GIS and remote sensing data, as shown in Table 2.

Fig 2. Different historical periods of urban expansion in Penang Island between 1840 and 2000.

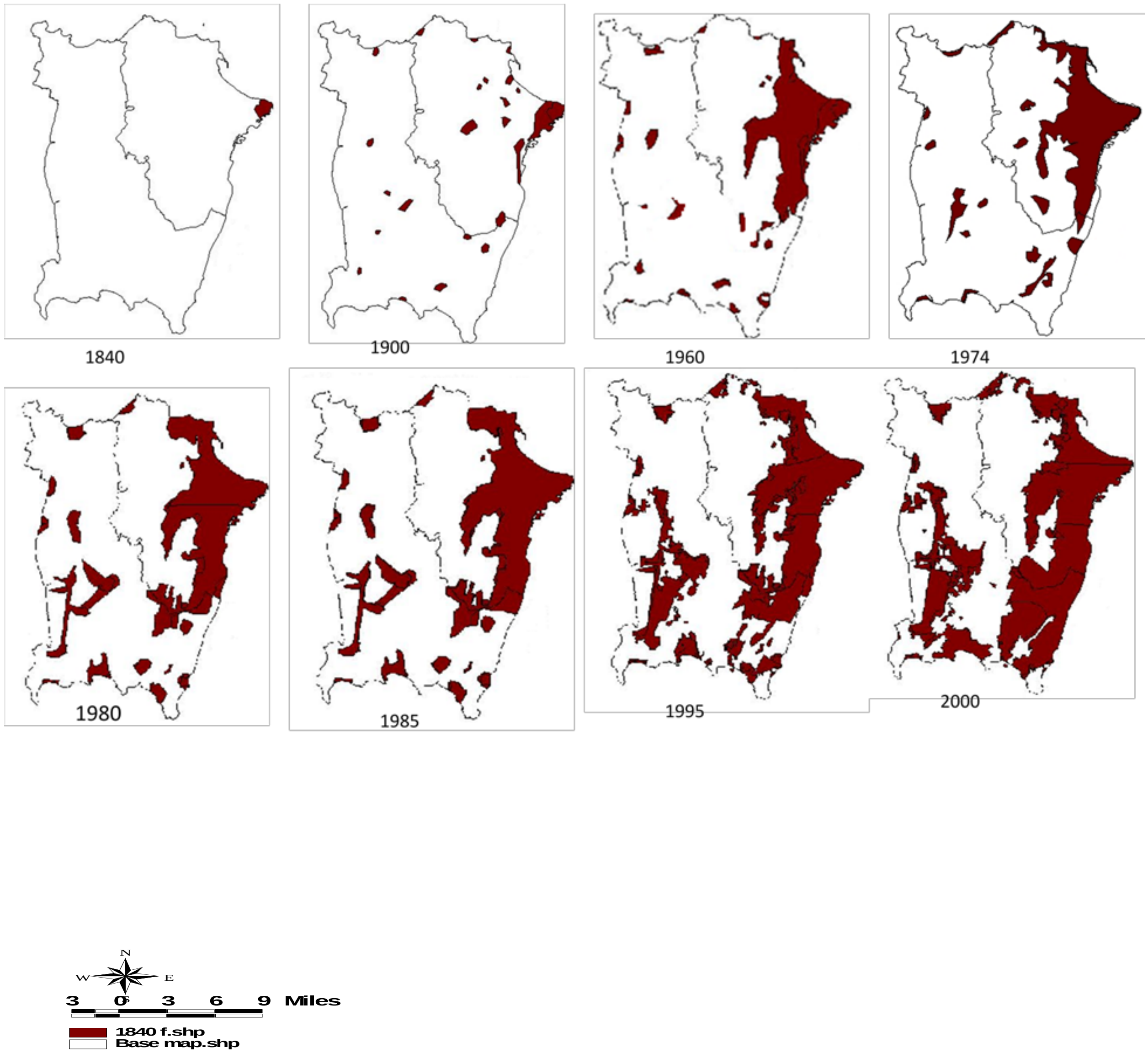


Table 1. Quantification of urban expansion in Penang Island between 1849 and 2000

years	*Built-up Area/ha*	*%*
1840	*132.378*	*0.438*
1900	*1071.189*	*3.548*
1960	*4583.614*	*15.182*
1980	*7031.0890*	*23.289*
1985	*7216.9250*	*23.905*
1995	*8146.709*	*26.985*
2000	*10978.799*	*36.366*

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

The rate of urbanization varies over time and results in changes in the dynamic structure of the spatial city, where land-use changes from time to time. urbanization factors are the evidence of an increase in the category specific and low for another, and this is a key indicator that may be used to measure and assess the spatial variability of urban expansion in accordance with previous studies (Ma and Xu, 2009; Li et al., 2009; Tretz and Rogan, 2004; Tan et al., 2005; Dewan and Yamaguchi, 2009; Yu et al., 2010). Therefore, we can compare and measure the size of urban expansion quantitatively (Hu et al., 2007; Xaio et al., 2006; Ma and Xu, 2009) based on the following formula:

$$\mathrm{LUDI} = \frac{\mathrm{Ua} - \mathrm{Ub}}{\mathrm{Ua}} \times \frac{1}{\mathrm{T}} \times 100\%$$

2.4. GIS Results

Simulation results and calculations show that the total built-up areas in Penang Island amount to 36.366%, increasing between the years 1840 and 2000. The change in the urbanization of Penang, especially between 1960 and 2000, was 21.184% for the 40-year period, and the expansion of the urban areas occurred rapidly for the period from 1960–1980 at 8.107%, an increase of 2,447,475 ha. However, urban expansion gradually slowed in the 5 years between 1980 and 1985 by a ratio of 0.616, which is equivalent to 185.836 ha. Urban expansion again occurred rapidly between 1985 and 2000 at a percentage of 12.461%, an increase of 3,761,874 ha (Table 2), indicating the rapid economic development in Penang Island (APEC, 1998; Hutton, 2004; Ismail and Lim, 1991). We can describe the expansion of the urban area in Penang in different periods as follows (Table 3):

(1) In 1960–1980, the built- up area of Penang expanded by 2,447,475 ha at an annual average rate of 122,373 ha. Urban expansion included the growth of the Georgetown suburbs, the coalescing of Butterworth–Bukit Mertajam, and the subsequent urban sprawl from both metropolitan areas (Ismail and Lim, 1991).

(2) In1980–1985, the built-up area of Penang expanded by185,836 ha at an annual average rate of 37,1672 ha. The expansion in this period was slow compared with the earlier period (Fig1, Table 2).

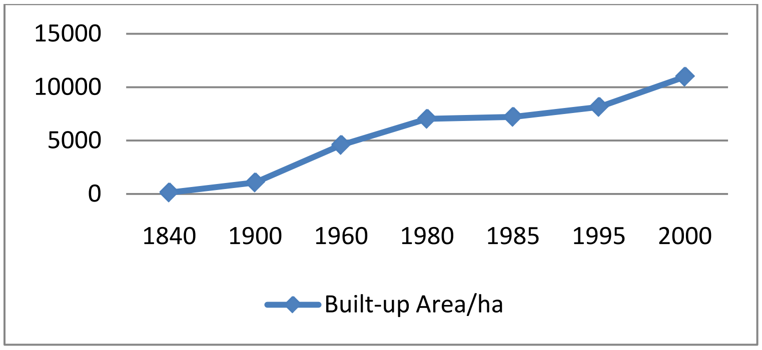
(3) In1985–2000, the built-up area of Penang expanded by3,761,874 ha at an annual average rate of 250,7916. This period had the highest average urban expansion, and beyond the large-scale urban industrial complexes, manufacturing activity increased within the metropolitan periphery, exurban areas, and even rural zones (Hutton, 2004).

Table 2. Area expansion rate and change rate for urban expansion of Penang Island in different periods.

Items	**Periods**		
	1960-1980	1980-1985	1985-2000
Urban expansion area /ha	2,447,475	185,836	3, 761,874
Urban expansion percentage (%)	8.107	0.616	12.461
Annual average rate /ha	122,373	37,167	250, 791

Agricultural sector contribution had declined to 3.3% in terms of land use in Penang Island. The economic growth in Penang since 1970 based on the development of the manufacturing program for export, led to the abandonment of agricultural lands. Agricultural land including nearly 20% of its territory for benefit of the industrial sector and residential, (Ismail and Lim, 1991).

Fig3. Dynamics of urban expansion in Penang, 1840-2000



2.5. Image classification

The maximum likelihood (ML) procedure was chosen as the classification method because of its ready availability and the fact that it did not require an extended training process, (Fan et al., 2007). In addition, using the ML algorithm yields the highest accuracy of classification compared with other algorithms. Geometric correction was performed on all images using a Land sat TM image of the same area from 2002 as reference. At least 35 ground control points (GCPs) were used to register the images to the Universal Transverse Mercator (UTM) system. A first order polynomial fit was applied, and the images were made to resemble 30-m output pixels using the nearest-neighbor method. All reflective bands were used in image classification, except for the thermal band, which was excluded.

The classification process was as follows: (1) based on the maps, references, and visual interpretations of each subset- images were created, (2) a supervised classification was performed using an ML algorithm, and (3) 9 classes of land use were identified, including mixed agricultural, agricultural, industrial, commercial, residential, bad land, mangrove, forest, water, and sand. However, several classes were incorrectly classified into the supervised category of land use land cover because of the presence of similar random sample points in the accuracy assessment. Moreover, some unplanned points came between two types of land use, which were difficult to distinguish because of the low resolution of the satellite images.

2.5.1. Accuracy assessment

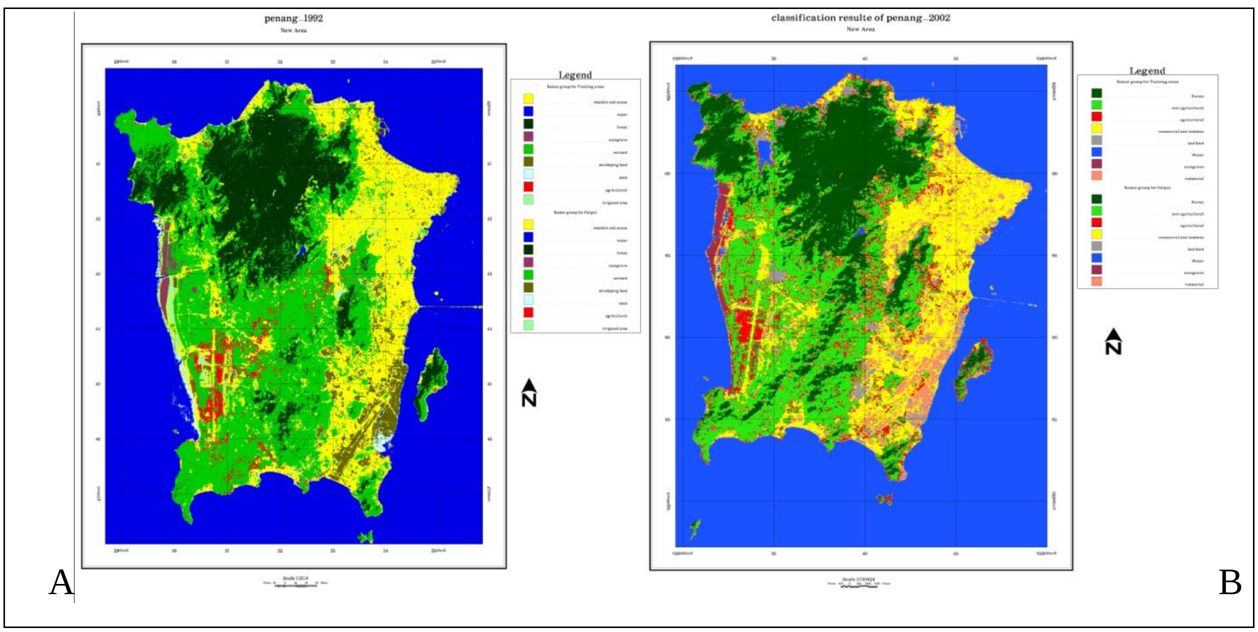
To obtain information on land use conversion, post-classification was conducted using PCI 9.1 software with classification images from between 1992 and 2002. Generally, classification accuracy refers to the extent of correspondence between the remotely sensed data and reference information (Dewan and Yamaguchi, 2009) and the accuracy of the critical evaluation of the map produced from any remote sensing data. The focus of many studies on the sampling scheme was the use of appropriate and standard techniques for assessment (Fan et al., 2007).

Random sampling can be used to evaluate accuracy and compare the results to detect real changes on the ground. It can also be used to build an matrix that refers to the compatibility of the results of change with the true ground conditions. Many measurements were suggested to improve the interpretation of the meaning of the error matrix. Among these methods, the Kappa coefficient is one of the most popular ones used to address the difference between this agreement and the actual opportunities. This is the most common way to represent the inaccuracies in the form of an error matrix that can be used as a starting point for a series of descriptive and analytical results of statistical analysis (Congalton, 1991). The total accuracy assessments of the Land sat-derived LULC data were 88.75.5% and 90.35.5%, respectively, for the images from 1992/TM and 2002/ETM.

2.5.2. Change Detection

Satellite remote sensing has been widely applied for the detection of LULC changes (Weper, 2003; Treitz and Rogan, 2004; Tan et al., 2005; Xiao et al., 2006; Fan et al., 2007; Bahattarai and Conway, 2008; Dewan and Yamaguchi, 2009; Deng et al., 2009; Ma and Xu, 2009; Li et al., 2009; Zhao et al., 2010), especially urban expansion (Lopez, 2001; Schneider et al., 2003; Ma and Xu, 2009; Li et al., 2009; Weng, 2002, 2002, 2003, 2004; Deng et al., 2009; Dewan and Yammaguchi, 2009; Xiao et al., 2006; Fan et al., 2007). Therefore, the use of satellite remote sensing in several studies has been proven to detect a change in the post-classification method to be more suitable for the detection of land use change. In the post-classification technique, two images from different dates are independently classified (Singh, 1989; Jensen, 1981). Preliminary classification was performed on the 1992 and 2002 images. The classification of the 1992 and 2002 images with the highest overall accuracy will be used in the change detection process. Image classification and post-classification techniques are iterative and require further refinement to produce more accurate change detection results (Fan et al., 2007).

Fig 4. A and B classification results of satellite images from between 1992 and 2002.



2.5.3. Remote Sensing Results

The supervised classification allows the identification of 8 classes of both images in terms of land use categories, as shown in Figs4. A and B and as detailed in Table 4.

Globally, the percentages of the agricultural lands decreased between the two dates. Table 4 and Figs. 2 A and B show a comparison of the surface land uses between 2002 and 1992.

Some confusion exists in the repartition of the agricultural and natural land cover categories because the vegetation is not in the same phonologic phase in the 1992 and 2002 images. Moreover, the poor radiometric quality of the images also contributes to the confusion between these two types. This confusion is taken into account in the interpretation of the change detection results.

Table 3. Repartition of the land cover categories between1992 and 2002

Class	Surfaces 1992		Surfaces 2002	
	Ha	%	Ha	%
Agricultural lands	6171,32	53.79	4727,83	42.08
Urban uses	1793,22	15.63	3235,38	28.20

2.5.3.1. *Spatial-temporal dynamics and evolution of land use changes from 1992 to2002*

Penang has undergone rapid urbanization, which has caused fundamental land use changes over the last 40 years. The land use conversion matrix for the areas that underwent change during the period 1992–2002 is shown in Table 4. In 1992, the agricultural land covered 617,132 ha of the total study area or 53.79%, but it decreased to 472,783 ha or 42.08% in 2002 because of rapid urbanization processes. The area of agricultural lands lost was approximately 144,349 ha over 10 years, equivalent to 23.39% of agricultural land being converted to urban use in study area, with an average annual increase of 144.34 ha.

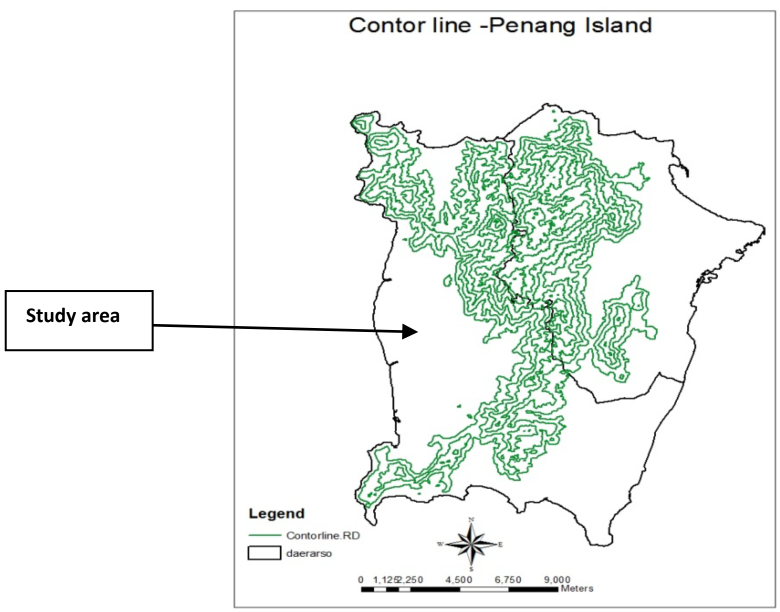
In contrast, urban land areas have increased significantly from 1793.22 ha in 1992, constituting 15.63% of the total of study area, to approximately 3235.38 ha in 2002. Therefore, the percentage of urban use increased to 28.20%(Table 4), with an increase of 1442.16 ha during the 10 years and an annual rate of 144.21 ha. This is equal to the rate of annual loss of agricultural lands, and this confirms the land use change or urbanization accounts for 98% of the agricultural lands. Thus, we have proven the scientific concept of the study.

3. Discussion

3.1 land use land cover changes and driving factors

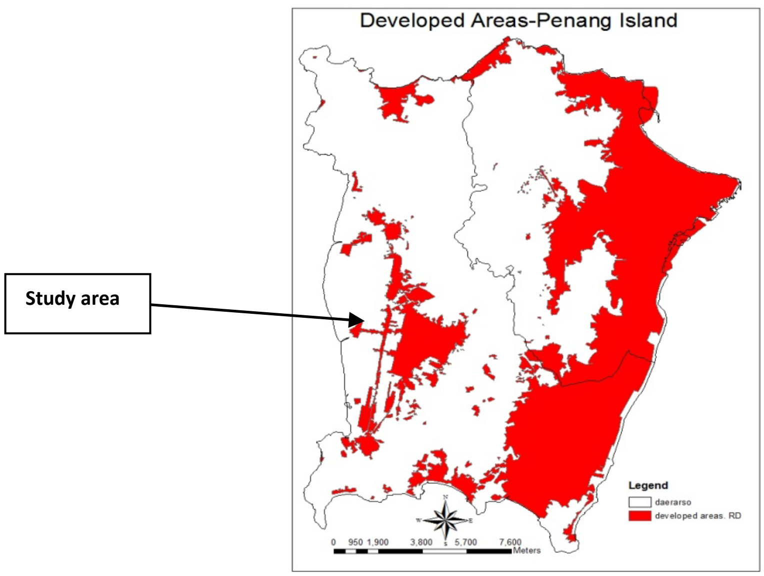
The rate of expansion of land in urban areas has become a concern because of the social turmoil and unrest it generates in rural areas (Lichtenberg and Ding, 2009). Urban expansion reflects structural transformations on the lives of the people brought about by social development, which result from industrialization and modernization (Gulgun et al., 2009). Indicators, that impacts in this urban development pressure in Penang Island , Extensive urban expansion occurred between 1990 and 2002 in the study area, driven by topographical elements (physical properties) , water bodies as important factor to centralization of urban phenomena and socio-economic elements, lead to population growth, economic development and its impact on land value , and road networks development (Ma and Xu, 2009; Tan et al., 2005; Fan et al., 2007). One of most important factors that are dominated on urban expansion trends physical properties, Due 50% of Penang Island mountains. So balik Pulau has the baggiest open space in this time in Penang Island, and due the demanding land to face rapid development, so urban development highlight toward Balik Pulau (Fig 5).

Fig 5. Contour line of Penang Island



The growth of urban areas tends to be characterized by sprawling suburban development, converted agricultural land, and cultural and open spaces on the margin between urban and rural areas (Maruani and Cohen, 2009). Semi-urban areas in rapidly growing cities are under great pressure due to the demands of land for urban development, which leads to the loss of arable land, environmental degradation, and social exclusion of village communities (Zhenshan Yang et al., 2009). Urban development is inevitable over the next two decades. The bulk of this growth occurs in less-developed countries. This represents a formidable challenge for planners and managers (Masser, 2001),Fig 6.

Fig 6. Urban areas in Penang Island



Since 1950, urbanization has become a worldwide phenomenon. Although the pace of changes has varied considerably between countries and regions, virtually every country in the third world has undergone rapid urbanization (Michael, 2005, 2001). Southeast Asia has long been recognized as a region of many diverse cultures, varied political systems, and different levels of economic development. Malaysia is part of Southeast Asia, and has undergone urbanization on different tracks (Terry, 2009) (Table 1).

Table 4. Southeast Asia levels of urbanization from 1950 to 2000

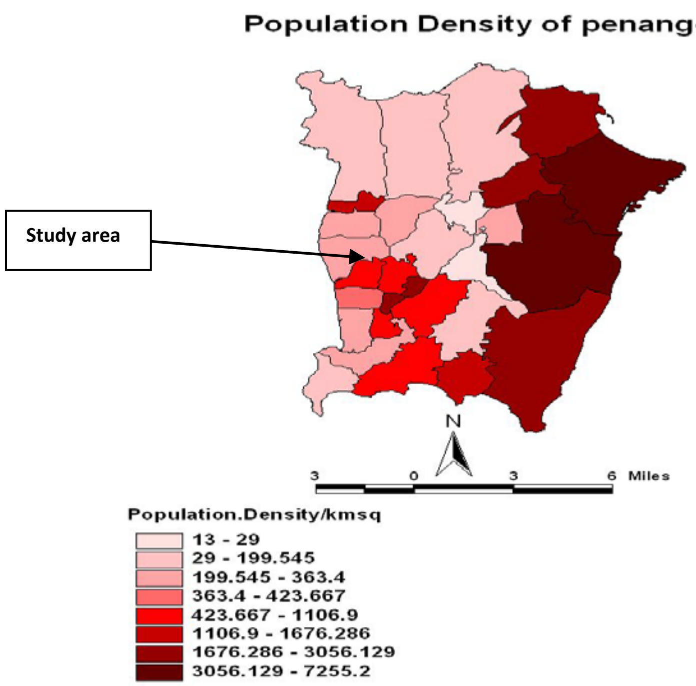
Country	1950	1960	1970	1980	1990	2000
Brunei	43.4	42.8	44.0	49.7	n.a	n.a
Singapore	98.0	100.0	100.0	100.0	100.0	100.0
Indonesia	12.2	14.9	17.1	22.2	30.6	40.3
Malaysia	24.5	30.0	33.5	42.0	49.8	57.5

Philippines	19.8	21.4	33.3	37.5	48.8	59.0
Thailand	10.0	11.4	20.8	24.5	32.5	40.0
Vietnam	n.a	n.a	18.3	19.2	19.9	22.3
Myanmar	12.9	14.3	22.8	24.0	24.8	28.4

Source: (Terry M, 2009)

In Penang State, for example, urban population has increased from 51% to 86% between 1970 and 2000. This significant increase in the urban population is the result of the Malaysian government's industrialization policy that started in the 1970s (Samat, 2006), Fig 7.

Fig 7. Population Density of Penang Island



Penang State has become a growth center in the Northern Region and a leader in manufacturing activities (economic development) in Malaysia. Urban areas in Penang State are rapidly increasing. In 1990. 2005 was a brilliant year for Penang as the State successfully secured RM4.81 billion worth of total approved manufacturing investments. Approved manufacturing investments had increased by more than two-fold in 2005 whereby total capital investments surged from a modest RM2.03 billion in 2004 to a remarkable RM4.81 billion in 2005(PEM.,2006). So urban areas covered 668.2 ha, but 2000 the area increased to 1,016.2 ha (52%) because of industrial transformation (PDC, 2000). Therefore, these are Variety causes factors that influence the increased level of urbanization in

Penang State (Table 5).

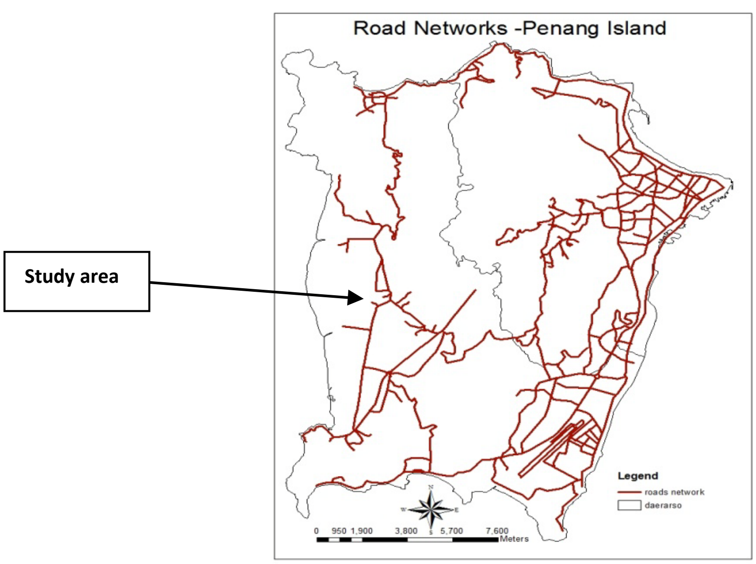
Table 5. Urbanization Level by State, 1970, 1980, 1991, 1995, and 2000.

State	Urbanization Level				
	1970	1980	1990	1995	2000
Johor	26.3	35.2	48.0	51.8	56.4
Kedah	12.6	14.4	33.1	36.9	42.1
Kelantan	14.1	28.1	33.7	35.7	39.4
Melaka	25.1	23.4	39.4	44.0	49.8
Negeri Sembilan	21.6	32.6	42.5	44.7	47.6
Pahang	19.0	26.1	30.6	31.9	33.7
Perak	27.5	32.2	54.3	60.5	67.8
Pedis	-	8.9	26.7	30.4	35.3
Pulau Pinang	**51.0**	**47.5**	**75.3**	**80.6**	**86.1**
Sabah	16.9	19.9	32.8	35.2	38.2
Sarawak	15.5	18.0	38.0	43.4	50.5
Selangor	39.5	34.2	75.0	82.6	89.4
Terengganu	27.0	42.9	44.6	45.1	45.7
Kuala Lumpur	100.00	100.00	100.00	100.00	100.00

Source: Department of Statistics, Malaysia (1996; 2000).

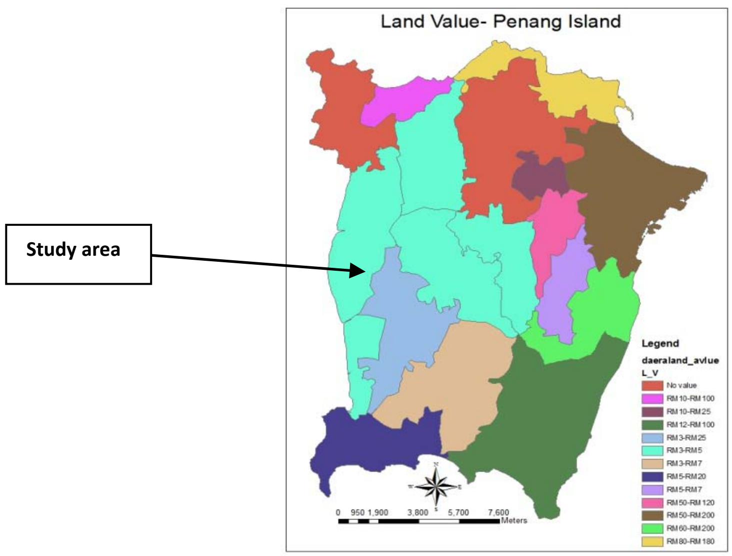
Urban population growth has resulted in increased pressures on land for housing and related services (Devas and Rakodi, 1993). Development of transportation services, which include the Penang airport, road networks, and commercial harbors, is an important factor that influences the level of urbanization in Penang and causes the loss of agricultural and natural lands. (Fig 8)

Fig 8. Road networks of Penang Island



Although land value is the primary cause for rapid urbanization. The land value in Penang island has historical changing depending on the site or neighborhoods development that's mean the price of land limited by development level of zones .So main city centers, industrial and commercial zones have the highest value in Penang Island as the south east part, in this case the new or small investment's are looking to new suitable areas with low cost. Look to Fig 9, will see the big different in land prices between Balik Pulau and another parts in the Island, This different will motivation the government planners and local, out said investments for more development in study area.

Fig 9. Land value of Penang Island



Acknowledgement

We would like to thank the Geography Department, School of Humanities, University Sains Malaysia, BGIS, and the Department of Statistics, Malaysia, for their support as the main sources of our research data.

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