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APPLICATION OF GEOGRAPHIC INFORMATION SYSTEM (GIS) AND ANALYTIC HIERARCHY PROCESS (AHP) TECHNIQUE TO STUDY LAND USE CHANGES IN PENDANG, KEDAH

Abdul Ghapar Othman[1], Kausar Hj Ali[2] & Wan Mohammad Fazil Asli[3]

[1,2,3]*School of Housing, Building and Planning*
UNIVERSITI SAINS MALAYSIA

Abstract

Urbanization process has a significant impact on land use planning. It not only affects major cities but also extends to small towns in rural areas where it has a significant role in providing urban services to rural communities. The expansion of urban areas also resulted in the loss of many agricultural lands as well as forests that are rich in natural resources. In both instances, the land use composition is substantially affected. This study uses a "mixed method approach" combining GIS spatial analysis and AHP technique to study land use changes, identify land use growth parameters, determine land use growth suitability areas and identify the direction of urban land use development. The study area is the town of Pendang, which is the main administrative centre for Pendang District, Kedah. The main findings of the study show that changes were not that significant during the period between 2005 to 2012. However, significant land use changes occurred during the period of 2012 to 2020, especially in agricultural land use, vacant land and even water bodies. These land use changes have contributed to the increase in built-up areas. The direction of development is seen heading north, south and southwest of the study area. Accessibility is a major factor influencing the growth of land use and development direction in the study area.

***Keywords**:* Urbanization, land use change, land use suitability, GIS and AHP

[1] Lecturer at Universiti Sains Malaysia. Email: ghapar@usm.my

INTRODUCTION

Urbanization is a global phenomenon that can be observed in many countries. Worldwide urbanization has recorded rapid growth in urban population from 751 million in 1950 to 7.7 billion in 2019 and is projected to continue to increase to 9.7 billion by 2050 (United Nations, 2019). Rural areas located in the suburbs are also evolving in terms of development as a result of the urbanization process. Small towns which can be found within a short distance of many metropolitan areas are important because of the functions they play in providing access to rural communities in obtaining urban services (Rostam et al., 2010; Saleh et al., 2012). They are the drivers of economic growth and to ensure balanced economic growth, regional development strategies were employed to address the imbalanced development between urban and rural areas (Saleh et al., 2014). Through good infrastructures, access to basic facilities and amenities in rural areas can be upgraded to provide better access to health, education, water, and electricity. In addition, good road networks, cheaper land prices, and peaceful living areas are among the major factors that drive new developments, especially housing and commercial areas, into the neighboring regions and smaller towns (Samat et al., 2019).).

This paper aims to study land use changes for the period of 15 years, from 2005 to 2020, in Pendang; which is the administrative centre for the Pendang district in the state of Kedah. The results of this land use change study will be used to identify the suitability of land use for development and the direction of urban land use development in Pendang.

URBANIZATION AND LAND USE GROWTH

PLANMalaysia (2016) defines urbanization as a process of change and application of urban characteristics to an area. This process involves the migration of rural populations to urban areas that generates changes in social and economic activities, values and lifestyles. Urbanization also impacted physical development which can be clearly seen in terms of land use change that occurs in rural areas (Saleh et al., 2014). This process of urbanization often results in sporadic development beyond the city boundaries and into the fringes of urban areas and smaller towns creating pressure on natural resources, environment as well as the communities (Malik et.al, 2018). According to Amir (2004), urbanization has a direct impact on rural areas where existing agricultural land use is preferred for urban development purposes and is increasingly experiencing the development pressure of changing land use activities due to its low-price. Thus, developmental pressures faced by rural land uses where traditional growth patterns used to change organically have now become more systematic (Salleh et al., 2013).

A study conducted by Yaakup et al. (2008) found that some of the main factors that can contribute to urban growth are physical, social, economic and land use factors. The study also found that extensive transportation systems and road networks, such as highway development and transit transportation systems, were major factors influencing the overflow of rapid urban growth. García et al. (2007) meanwhile found that proximity to the road transport system and existing built-up areas determine the factors in shaping the structure of a city and the direction of future growth. Mahamud et al. (2016) on the other hand, identified three main factors that stimulate urban development: physical, socio-economic and environmental factors. More specifically, distance to the workplace, cheap housing and distance to public facilities.

Factors and sub-factors influencing the growth of urban land use, which have been discussed above, will be adapted to the context of the study area and used as parameters in the analysis of this study. The four main factors to be adapted are environmental, economic, social and physical, while a total of seven sub-factors have been identified. They are topography, distance from the river, distance from the commercial centre, distance from the industrial area, distance from institutional & public facilities, distance from infrastructure & utility and distance from transportation networks. The restructuring of these parameters is in line with the context of the study area, where environmental factors need to be taken into account to ensure urban land use can be developed more sustainably. A weighting value is assigned to each of the sub-factors above so that it can be measured and given priority. This will help produce a dynamic urban land use growth model for the study area.

GIS and AHP

The integration between geographic information system (GIS) and multi-criteria decision-making (MCDM) method is capable of creating a dynamic land use modelling. Rad & Haghyghy (2014) implied that the application of GIS alone cannot overcome the problem of balancing expert opinions in evaluating and assigning relative importance to each criterion considered in land use suitability analysis. MCDM techniques should be used in conjunction with GIS tools to obtain concrete research findings. Rusydiana & Devi (2013) describe MCDM as a method of decision making by determining the best alternative from a number of existing alternatives based on several criteria set in accordance with the context of the study. The stated criteria are usually in the form of parameters or standards that can be measured in decision making. Analysis and evaluation of the criteria is done to obtain a set of measurements and then used as a tool to compare the best criteria in the study.

The Analytic Hierarchy Process (AHP), one of the techniques in MCDM, is utilized in this study over other techniques as it requires accurate

numerical values to express the strength of expert choice in decision-making for land use analysis findings. A study by Mosadeghi et.al (2015) that compared the results of two techniques namely AHP and Fuzzy found out that when identifying future land use suitability and development direction, the simple AHP method is already sufficient in conducting the analysis.

STUDY AREA

Pendang (N5.99237, E100.47770) is a rural town located in Pendang District, Kedah, Malaysia (Figure 1) and is the administrative centre for this district. It is divided into two town sections with a total area of approximately 3,791 acres. Pendang has good accessibility to major towns and cities in the state of Kedah. It is connected to a good road network, namely the state road K128 towards City of Alor Star, the towns of Pokok Sena and Kuala Nerang, and K147 towards Gurun. It is also close to the North-South Expressway interchange (4km) and the Kobah train station (4.7km), located southwest of the town. The opening of the Pendang Toll Plaza in 2006 has made it easier for North-South Expressway users from the south going through Pendang to Pokok Sena and Kuala Nerang without having to go through the City of Alor Star.

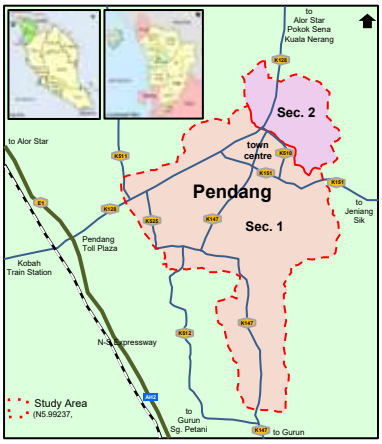

Figure 1: Location of Pendang, Kedah

METHODOLOGY

This study utilizes land use data from three time periods to analyze changes from 2005 to 2012 and 2012 to 2020. The 2005 land use data was obtained from the Pendang District Council while the 2012 data was extracted from satellite images dated 2012. The 2020 land use data was derived from fieldwork. Land use changes are analyzed using ArcGIS 10.4, by applying overlay technique and interpreted through matrix tables. The AHP technique is applied to analyze and

produce a land suitability map for development in the study area. Each sub-factor identified in the literature above is weighted based on its suitability in influencing land use growth by using a pairwise comparison method. Pairwise Comparison is a comparative matrix assessment that estimates the weighting values of parameters used in AHP technique based on probability measurements. For each stage in the hierarchy, it is important to know whether 'Pairwise Comparison' is consistent in receiving weighting results. This study follows the procedure outlined by Saaty (1987) and Wind & Saaty (1980) using the scale of importance of each sub-factor. The Pairwise Comparison method generates weight and compares each sub-factor to distinguish the level of importance in influencing the land use growth in Pendang. The first step is to compare the sub-factors based on the scale of importance. The next step is to do a "Normalize Pairwise Matrix," which produces a matrix shown in Table 1 below.

	1	2	3	4	5	6	7	Total / No. of Sub-Factor	Weightage of Sub-Factor
1	0.0345	0.0108	0.0339	0.0141	0.0213	0.0213	0.0651	0.20098/7	0.0287
2	0.1379	0.0430	0.0339	0.0429	0.0213	0.0213	0.0651	0.36541/7	0.0522
3	0.2069	0.2581	0.1996	0.2572	0.3404	0.3404	0.1535	1.75608/7	0.2509
4	0.1034	0.0430	0.0339	0.0429	0.0213	0.0213	0.0651	0.33092/7	0.0473
5	0.1379	0.1720	0.0499	0.1715	0.0851	0.0851	0.0930	0.79456/7	0.1135
6	0.1379	0.1720	0.0499	0.1715	0.0851	0.0851	0.0930	0.79456/7	0.1135
7	0.2414	0.3011	0.5988	0.3000	0.4255	0.4255	0.4651	2.75748/7	0.3939

Table 1: Calculating Weightage of Sub-Factor based on Normalize Pairwise Matrix
1=Topography condition 2=Distance from river 3=Distance from commercial center 4=Distance from industrial area 5=Distance from institution & public facilities 6=Distance from infrastructure & utility 7= Distance from transportation network

To ensure that the weightage of each sub-factor generated in Table 1 above is relevant, the 'Consistency Ratio' (CR) should be calculated and not exceed the value of 0.10. The CR calculated in this study is 0.077 and all evaluations made on the sub-factors are acceptable. The seven sub-factors are further analyzed using the Euclidean distance method in GIS to produce a suitability level map in raster format for each sub-factor. The generation of this suitability level map is based on the distance/aspect that has been adjusted accordingly, in line with the guidelines and planning standards from PLANMalaysia. To rank the distance/aspect to the appropriate suitability level, the Reclassify method in ArcGIS is applied and the result is used as input to the Weighted Overlay method in ArcGIS to produce a land suitability map of the study area (See Figure 6).

DATA ANALYSIS AND FINDINGS

This section will discuss data analysis and findings on land use change patterns, land use suitability and development direction of Pendang based on land use data

from 2005 to 2020. The altered spatial landscape of the town can be identified by studying land use changes at several time periods.

Pattern of Land Use Changes

As shown in Table 2, agricultural land use was the most dominant land use in 2005 followed by residential and open space and recreational land uses. However, there was a decrease in land acreage for several land uses in 2012 including open space and recreational, agricultural, commercial and industrial, which this has indirectly contributed to increase in land area for housing, transportation, institutional and public facilities and others. From 2012 to 2020, agricultural land use still dominated the study area while other land uses that were experiencing major increase in land area include infrastructure and utilities, open space and recreation, institution and public facilities and others. The land use change scenario recorded a drastic decrease in land acreage for vacant land (-198.20) and water body (-30.21). However, agricultural land use is no longer declining during that time, because the available vacant land has been re-cultivated with agricultural activities.

Table 2: Land Use Changes in Pendang (2005 - 2012 - 2020)

Land Use	Year						Changes			
	2005		2012		2020		2005-2012		2012-2020	
	Area (acres)	%	Area (acres)	%	Area (acres)	%	Area (acres)	%	Area (acres)	%
Housing	640.92	16.90	723.11	19.07	763	20.12	82.19	12.82	39.89	5.52
Commercial	48.29	1.27	43.75	1.15	50.13	1.32	-4.54	-9.40	6.38	14.58
Industry	9.85	0.26	9.13	0.24	10.21	0.27	-0.72	-7.31	1.08	11.83
Mix Devt			4.43	0.12	2.06	0.05	4.43		-2.37	-53.50
Inst & Pb Fac.	162.46	4.28	186.65	4.92	223.88	5.90	24.19	14.89	37.23	19.95
Opn Spc & Rec	334.45	8.82	22.12	0.58	30.96	0.82	-312.33	-93.39	8.84	39.96
Vacant Land			372.13	9.82	173.85	4.59	372.13		-198.28	-53.28
Transport	233.38	6.16	263.89	6.96	288.93	7.62	30.51	13.07	25.04	9.49
Infra & Util.	22.56	0.60	24.85	0.66	89.66	2.36	2.29	10.15	64.81	260.80
Agricultural	2269.66	59.86	2066.12	54.49	2113.71	55.75	-203.54	-8.97	47.59	2.30
Water Body	69.85	1.84	75.24	1.98	45.03	1.19	5.39	7.72	-30.21	-40.15
Total	**3791.42**	**100.0**	**3791.42**	**100.0**	**3791.42**	**100.0**				

The results of this time-series land use analysis from 2005 to 2012 and 2012 to 2020 show that there are significant changes to the three types of land use in Pendang, namely agricultural land use, vacant land and water bodies. From 2005 to 2012, land acreage for agriculture had decreased because of conversion into the development of new housing areas and for upgrading the transport system. Between 2012 and 2020, the land acreage for agriculture has increased but the vacant land was experiencing a rapid decline of -53.28%. Since vacant land usually does not bring any returns and is easy to develop, it has mostly been used for developing new housing areas, for upgrading the transport system and for re-

cultivating more productive agricultural activities. The land area for water bodies had increased from 2005 to 2012 but decreased to 45.03 acres in 2020, contributing to the increase in transportation and agricultural land uses. If compared between the two time-series, the analysis found that land use change activities were more rapid from 2012 to 2020 compared to 2005 to 2012 (see Figure 2).

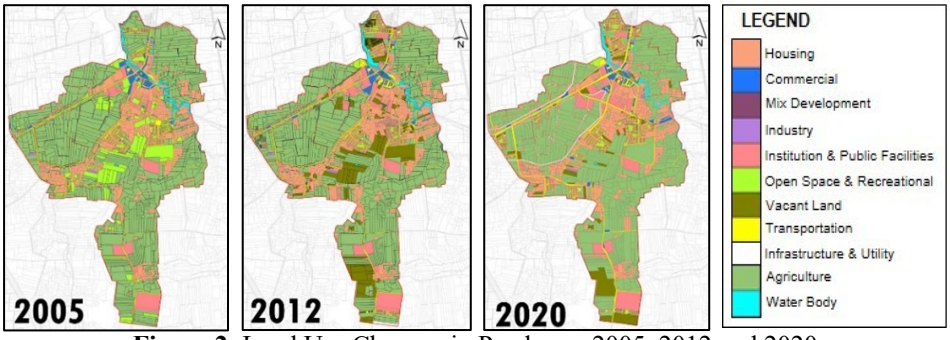

Figure 2: Land Use Changes in Pendang - 2005, 2012 and 2020
Source: Pendang District Council, Google Maps & field work

Table 3: Matrix of Land Use Changes in Bandar Pendang (2012-2020)

Land Use		Land Use 2020											
		House	Comm	Ind.	Mix Devt	Inst & Pb Fac	Op Spc & Rec	Vcnt Land	Trans-port	Infra & Util	Agr	Water Body	Total
Land Use 2012	Housing	613.89	8.19	0.31		5.60	5.75	9.32	56.35	3.18	19.58	0.94	723.11
	Comm	1.20	30.17			1.89	0.09	0.22	9.49	0.59	0.08	0.02	43.75
	Industry	0.08		6.22	0.07			2.26	0.22	0.15	0.07	0.06	9.13
	Mx Devt	0.20			1.74	0.03	0.10	0.07	1.58	0.50	0.17	0.04	4.43
	Inst & Pb Fac	1.00	0.30			174.04	0.13	1.79	5.70	1.13	2.53	0.03	186.65
	OpnSpc & Rec	0.17				0.21	19.61	0.06	1.63	0.27	0.09	0.08	22.12
	Vacant Land	55.75	3.70	1.50		19.80	0.35	101.10	14.71	2.06	173.04	0.12	372.13
	Transport	26.74	4.08	0.73	0.23	5.99	1.85	6.12	162.30	35.97	18.54	1.34	263.89
	Infra & Util	0.15				0.23	0.11		1.72	21.80	0.44	0.40	24.85
	Agricultural	57.68	3.28	1.39		15.19	2.92	52.65	31.76	17.57	1881.13	2.55	2066.12
	Water Body	6.14	0.41	0.06	0.02	0.90	0.05	0.26	3.47	6.44	18.04	39.45	75.24
	Total	763.00	50.13	10.21	2.06	223.88	30.96	173.85	288.93	89.66	2113.71	45.03	**3791.42**

Table 3 above shows the details of each land use change illustrated on the matrix of land use changes for the period between 2012 to 2020 (Note: the land use change matrix for 2005 to 2012 is not shown because the changes that occur are not so drastic compared to land use changes in 2012 to 2020). Vacant land use has declined drastically during this period, being converted to other land uses. Furthermore, land area for water bodies also declined due to the development of agricultural, infrastructure and utility, housing and transportation land uses. In addition, although agricultural land area shows an increase from 2012 to 2020, it is still experiencing a significant transition to other land uses during this period. Infrastructure and utilities and institutions and public facilities land uses rapidly

developed from 2012 to 2020. Along with other land uses, they are responsible for the declining land uses of vacant land, water bodies and agriculture. This clearly shows the rapid growth of land use for the development of Pendang from 2012 to 2020.

Land Use Suitability

The suitability of land use growth is analysed by integrating GIS and AHP applications. Figures 3 shows the suitability level maps for the seven sub-factors derived from the methodology discussed above.

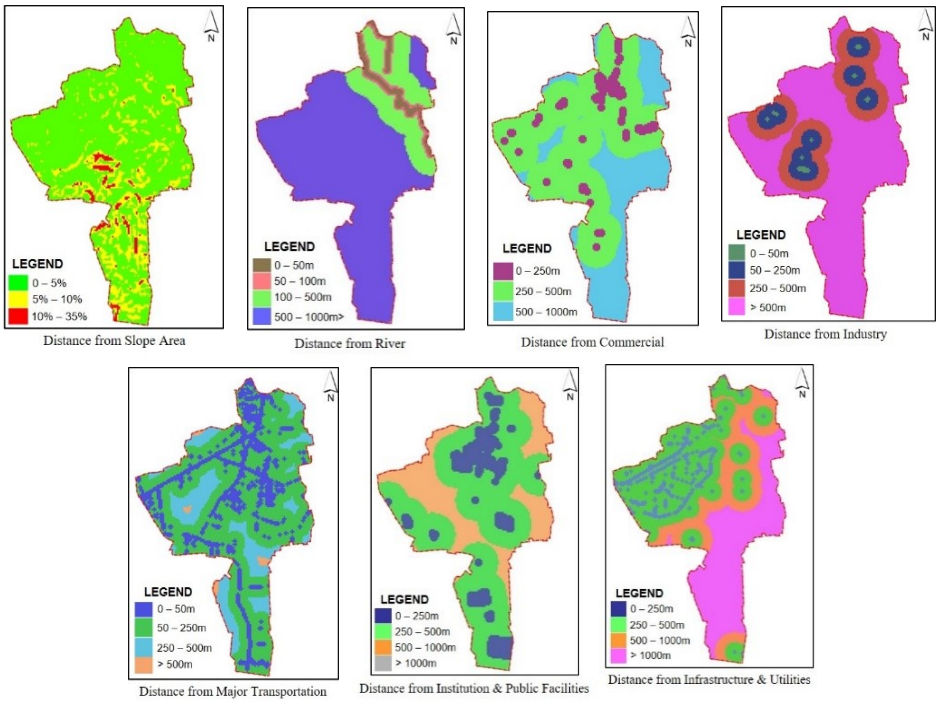

Figure 3: Land Suitability Map by Sub-Factor

The results of the land suitability analysis as shown in Figure 4 indicates that the southwest and southern parts of the study area are the potential areas for future development. These areas are strongly influenced by factors that normally contribute to the growth of towns such as excellent accessibility (e.g., close to commercial centres, proximity to public facilities) and having better infrastructure development and transportation networks. Furthermore, the analysis also shows that land development sprouts parallel with the transport corridor that connects Pendang to nearby towns in a more radial pattern. The development of existing built-up areas is also a factor that contributes to the

growth of other land uses surrounding it. The dispersal of land use occurs because the built-up area will inflict development pressure on the non-built-up area adjacent or near it.

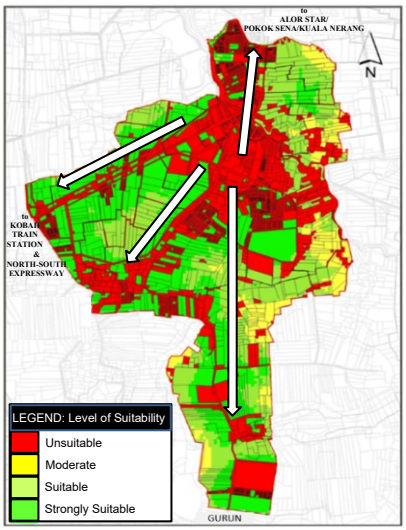

Figure 4: Land Suitability Map and Direction of Land Use Development (2020)

Direction of Development

The results from the land use changes and land use suitability analyses indicate that the development of Pendang between 2005-2020 is aligned along the main transport corridor. Figure 4 above shows the development direction of Pendang is towards the north, south and southwest of the study area. This is due to the strong accessibility factor where linear development is taking place along the main roads leading to the North-South Expressway and the Kobah's train station in the southwest as well as to the City of Alor Setar, Pokok Sena and Kuala Nerang in the north and Gurun in the south. The concentration of existing built-up land uses in the Pendang town centre has also encouraged other urban land use development to spread and grow along the main roads.

DISCUSSION

The land use changes emerged as a result of the distribution of urban activities where central areas perform economic, political, institutional and cultural functions (Rodrigue, 2020). The findings from this study show that accessibility is a major factor that contributes to the change of land uses in Pendang where its development is affected by the growth of the City of Alor Setar, Pokok Sena and Gurun. Pendang is also strategically connected to the North-South Expressway and the double-track railway lines that facilitate the movement of population between Pendang and the towns surrounding it. The pattern of land use changes also shows an increase in

built-up land uses such as housing, institutions and public facilities, infrastructure and utilities, as well as transportation. Significant changes have also occurred, particularly in the use of agricultural land, vacant land and water bodies. The pattern of agricultural land use changes which used to mature gradually has now become more planned (Amir, 2004). This has happened around Pendang since 2006, where agricultural land use has been converted to planned housing such as Taman Setia, Taman Murni Pendang, and Taman Sri Seberang. Pendang is categorized as a local town and is the administrative and service centre for Pendang District (PlanMalaysia, 2017). To strengthen the functionality of this town in the context of settlement hierarchy, land use changes have taken the form of education as well as institutions and facilities, such as Mara Science Junior College (MRSM), Land and District Office, and District Police Headquarters. A newly completed Pendang People's Bazaar Building has also been built on vacant land near the bus station.

The land use transformation can also be studied through the direction of land use growth. The development of a systematic transportation system, especially the development of highways and railways, plays an important role in influencing the pattern and flow of future development (Yaakup et al., 2008). The direction of urban land use growth is heading towards the southwest of Pendang along the K128 state road to the North-South Expressway and the Kobah railway station. This road is used by motorists to enter and exit the North-South Expressway via the Pendang Toll Plaza near Kobah. Before the operation of this toll house in 2006, travellers on the expressway exited at the City of Alor Star to go to Pokok Sena, Kuala Nerang and other parts of eastern Kedah. But now, travellers exit the expressway and take the K128 road that passes through the town of Pendang to reach the eastern part of the state. This shortcut route saves them the additional toll and avoids traffic congestion in Alor Setar. The increasing traffic on K128 state road especially during festive seasons has attracted the development of commercial and supporting services along this road. This is in line with the development strategy in the Pendang District Local Plan, which is to focus the development of vacant lands along major roads including the Pendang-Kobah corridor (PLANMalaysia, 2011). The findings of the study also found the declining land use of water bodies which is turned into agricultural land use, transportation and especially for infrastructure and utility development. This is mainly due to the implementation of a state flood mitigation program where it involves upgrading the Pendang River and flood diversion through the MADA (Muda Agricultural Development Authority) central canal (PlanMalaysia, 2017). As a result, this program has created unused water body areas that have the potential to be developed for other land use activities.

As outlined in the Second National Urbanization Policy, Pendang is a local town and an administrative centre for Pendang District, and the town performs many functions (PLANMalaysia, 2011). The changes in land use and the direction

of development in Pendang require the local authority to effectively plan, manage and monitor development to preserve the overall quality of the landscape and its environmental system.

CONCLUSION

Development along transport corridors in Pendang has triggered built-up land uses such as housing, transportation, institutions and public facilities as well as infrastructure and utilities. At the same time, land use changes in rural areas also contribute to the loss of agricultural land being converted to other type of urban land uses. This study has shown the land use changes that occurred in Pendang based on space and time and measured through the GIS and AHP technique. The pattern of change and the suitability of land use is a phenomenon that needs to be studied to produce a comprehensive scenario of suburban/urban land use in rural areas. Measurement of parameters that can contribute to land use changes also needs to be determined accurately so that factors that drive land use changes can be evaluated more effectively. Land uses that are easy targets of development pressure such as agriculture, vacant land and water bodies, need to be planned, managed and monitored so that sustainable land development can be achieved. Indeed, the complex relationship between transport and land use suggests the need for various analyses in spatial interactions in our effort to understand urban activities and their spatial impact on land use.

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