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Land use evaluation for Kuala Selangor, Malaysia using remote sensing and GIS technologies

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Abstract

Land evaluation is the process of predicting the potential use of land on the basis of its attributes and is essential in identifying the best land management practice for sound land use planning. The key objective of this study is to evaluate landuse/cover in Kuala Selangor district, Selangor as the knowledge about land use and land cover has become increasingly important in Malaysia's goal to overcome the problems of haphazard, uncontrolled development, deteriorating environmental quality, loss of prime agricultural lands, destruction of important wetlands, and loss of wildlife habitat. The study integrates remote sensing and GIS technologies for landuse/cover evaluation. In evaluating landuse for sustainable use of natural resources several maps were taken as parameters and obtained from digital classification of SPOT 2005 data by means of supervised modes with maximum likelihood algorithm using necessary ground truth data. The vegetation density using Normalized Differential Vegetation Index (NDVI) of Kuala Selangor was classified into five categories, namely, very high (775.51 km2), high (182.61km2), moderate (67.07 km2), low (77.44 km2), and non-vegetation areas (91.35 km2). Soil suitability map and subclasses were prepared to demonstrate how soil varied in behaviour or suitability for specialised purposes. Three soil types were identified including S2 (42%), S4 (45.63%) and S5 (12.37%). Overlay analyses of landuse and landcover with vegetation density, soil suitability and erosion risk were also presented. The actual distribution and area of the classes in all layers were analysed.

Keywords: GIS, land evaluation, landuse/cover, land use planning, remote sensing, soil suitability

Introduction

In striving to cope with incessant growth of human population that relentlessly transforms the earth, scientists, land managers along with planners are labouring to avert, alleviate, and reverse the consequent loss of species, ecosystems, and landscapes (Rubino & Hess, 2003).

Land evaluation is the process of predicting the potential use of land on the basis of its attributes (landuse/cover, vegetation density, soil suitability and erosion risk). Rossiter (1996) defines Land Suitability as the fitness of a given Land Mapping Unit (LMU) for a Land Utilization Type (LUT), or the degree to which it satisfies the land user. In a more operational sense, suitability expresses how well the LMU matches the requirements of the LUT. It can help optimize land use where our demands and objectives are multiple and often conflicting. It is essential in identifying best land management practices as it is the key process for sound land use planning.

One of the key prerequisites for better use of land is information on existing land use patterns. A modern nation, just as a modern business, must have adequate information on many complex and interrelated aspects of its activities in order to make decisions. Land use is only one such aspect, but for Malaysia knowledge about land use and land cover has become increasingly important as the nation plans to overcome the problems of haphazard, uncontrolled development, deteriorating environmental quality, loss of prime agricultural lands, destruction of important wetlands, and loss wildlife habitat. Land use data are needed in the analysis of environmental processes and problems that must be understood if living conditions and standards are to be improved or maintained at current levels (James *et al.*, 2001). The classification of a study area into different land use/cover types is one of the primary objectives of studies that use remote sensing technology (Ceballos-Silva & Lo´ pez-Blanco, 2003).

Satellite data present a spatially as well as periodic comprehensive view of land vegetation cover. Over the last few decades, several spectral vegetation indices have been developed to assess vegetation canopy biophysical properties (Jiang *et al.*, 2006). Spectral vegetation index data have various rewarding applications. They are utilised to examine the interactions between climate and landscape ecosystems, monitor the consequences of floods, drought, fire and desertification, facilitate land management and sustainability, investigate climate variation and carbon sequestration, and evaluate natural resources, agricultural production and food aid (Seelan *et al.,* 2003; Leeuwen, 2006). Several vegetation indices have been developed of which, NDVI (Normalised Difference Vegetation Index) is still the most widely used vegetation indices and its utility in satellite assessment and monitoring of global vegetation cover has been well demonstrated over the past two decades (Leprieur *et al.,* 2000). In this study, NDVI has been applied to distinguish vegetation from other land cover classes and also to differentiate forest vegetation types.

Since green vegetation differentially absorbs visible incident solar (red) and reflects much of the near infrared (NIR), the satellite-derived NDVI approach is based on the red (low reflectance) and NIR (high reflectance) portions of the electromagnetic spectrum. The NDVI is a normalized ratio of the NIR and red spectral reflectance (NIRred)/(NIR+red) and is well linked with the amount and seasonality of aboveground net primary production (Barbosa, 2006). Therefore, it can be concluded that the more positive the NDVI is the more green vegetation exists within a pixel. Cloud-contaminated measurements also generate lower NDVI values because clouds reflect strongly in both the red and near infrared wave bands (Wang & Tenhunen, 2004).

In the case of SPOT 4 HRVIR sensor remote sensing data, the formula used is:

$$NDVI = \frac{(B_3 - B_2)}{(B_3 + B_2)}$$

Where, *B3*: Near Infrared Band and *B2*: Red Band.

In Malaysia, Phua et al. (2007) compared the usefulness of the NBR, NDWI, and NDVI in an image differencing technique to detect the burned peat swamp forest for Klias Peninsula, Sabah. They concluded that efforts to compile the burned area using medium resolution satellite data over the past El-Nino events should be conducted. The vegetation indices offer an operational technique to accomplish such efforts in other tropical areas.

Soil erosion is a hazard conventionally related to agriculture in tropical and semiarid areas. Its consequence rests in its long-term effects on soil productivity and sustainable agriculture. However, it is a dilemma of a wider implication occurring additionally on land devoted to forestry, transport and recreation. Erosion also causes environmental damage by way of sedimentation, pollution and increased flooding. Distressingly, crises can still develop from quite moderate and frequent erosion events in both temperate and tropical climates. Erosion control is, therefore, essential in nearly all countries under just about every type of land use (Morgan, 2005).

It is critical that the properties of the land and its soils be appraised before we choose the purpose for which the land is to be used, or the types of management practices to be followed. This will avoid mistakes that can be both costly to the user and permanently damage the land itself. Land evaluation can help optimize land use where our demands and objectives are multiple and often conflicting. It is essential in identifying best land management practices as it is the key process for sound land use planning. Each soil unit has its own potentialities and limitations, and each soil use its own biophysical requirements. In this study, soil suitability is used as one of the main factors to evaluate landuse/cover because knowledge of the type of soils to be dealt with and their management requirements will undoubtedly help in feasibility studies prior to development planning and land use evaluation for enhanced sustainability.

The study area

The chosen study area is Kuala Selangor, one of the northern districts of Selangor, which is located 64 km northwest of the city of Kuala Lumpur (see map in Figure 1). The study area lies between 3° 10´N to 3° 34´ N and between 101° 6´ E to 101° 30´ E with an area of 1192.9 km². The development of Selangor state has extended into its surrounding districts, whose natural resources are coming under increasing pressure. The chosen area still has several patches of upland forest, swamp forest and some mangroves. The other major land use in the study area is agriculture, especially oil palm, paddy and coconut plantation. Sungai Selangor (Selangor River) is one of the main rivers in the state of Selangor. It is an important source of water supply for domestic and agriculture use as well as fishing industries for communities along the riverbanks. The Selangor River is still in a pristine and natural state in most places especially in its upstream reaches. It also provides recreational opportunities that pose challenges to the intrepid travellers, ecotourists and adventure-seekers (i.e. river tubing, whitewater rafting and kayaking). Kuala Selangor's mangrove forests are identified as having a potentially high value for wildlife conservation and ecotourism. Interestingly, this riparian mangrove is also home to large colonies

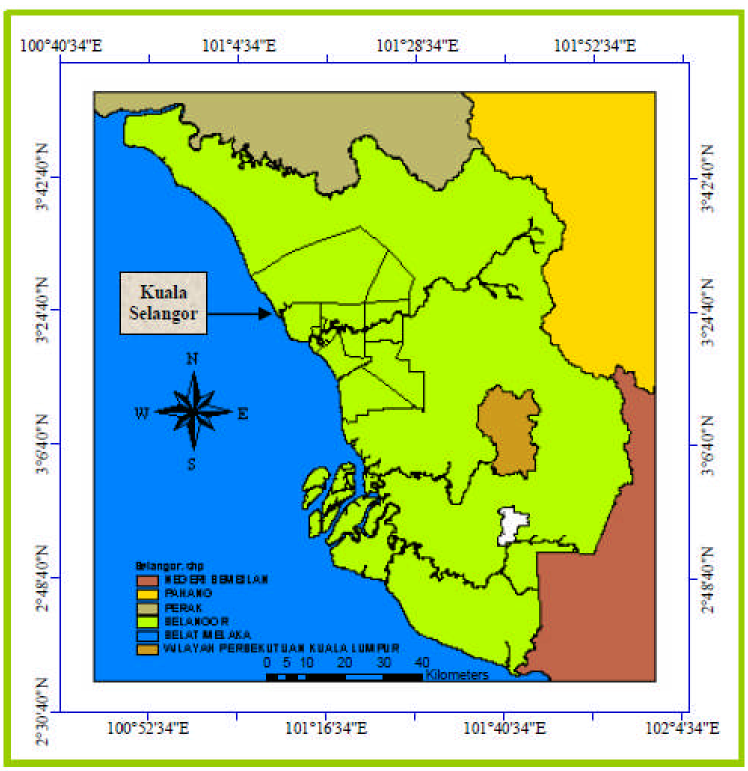

Figure 1. *Location of the study area*

of fireflies that glow in the dark thus providing a brilliant illumination at night. Its nature park is renowned for a variety of flag species of fauna and flora such as the Silverleaf Monkeys, rare species of lizards and birds.

The main land use in the study area is still agriculture, particularly coconut, paddy and oil palm. Oil palm and rubber estates have been established here through forest conversion. Presently, many of these estates are being converted into urban, residential, recreational and industrial areas. Due to the decline in world market prices after the introduction of synthetic rubber, rubber estates in the area are being swiftly converted to either more money-spinning urban areas or more lucrative oil palm estates. Tin mining has a long history in Malaysia and has greatly stimulated its economic development, mainly within the state of Selangor. Found extensively along the study area's Selangor River, most of the tin has already been extracted and many mines have been converted into resort mines and recreational areas.

Methodology

Landuse/cover maps are obtained from digital classification of Satellite Remote Sensing data (SPOT, 2005) by supervised mode with maximum likelihood algorithm using necessary ground truth data. The SPOT 4 imagery used in this study was geometrically rectified to a common local geographical coordinate system of Malaysia – the Rectified Skew Othomorphic (RSO) projection. The GCP chosen are easily distinguishable in both images, for example, road junctions, man-made features, stabilised geomorphic features, small ponds, channel mouths, etc. Eighty GCPs were identified across the image. To rectify the image into map projection (RSO, Modified/ Everest), a polynomial warping function of first order and bilinear pixel re-sampling was used. The total Root Mean Square (RMS) error was 0.2099, which is equal to 4 meters. Once the SPOT 2005 imagery was georeferenced it was compared to the original geo-referenced data to observe how closely it would overlay. The information on the existing land use/land cover pattern and its spatial distribution is a pre-requisite for planning, and for formulating policies and drawing up of micro and macro-level developmental plans. The landuse/cover was classified into nine categories. The 9 land-cover classes considered in this study are derived from the Anderson classification level I, and level II. In this study, the problem of signature extension was encountered when selecting the training data for some land-cover classes. The methodology employed for obtaining the data was a combination of collecting *in situ* information (ground truthing via site visit using GPS) and selecting on-screen polygons of data. Some of the training sites were visited and the centroid coordinates were collected using Global Positioning System (GPS). Table 1 shows the details of the training data sites collection process for each class.

Owing to the inevitable overlap in spectral signatures for the different classes, the outcome of the supervised classification is imperfect and has to be edited and smoothed before any analysis can be performed. Such post classification is the most time consuming stage of the procedure. While cross-referencing with other sources of information, small areas are selected with the certainty that they are of similar land-use type. The area is then designated a specific class using the area fill command. This action is repeated over the entire image, so that larger areas of homogeneous landuse as well as landcover types are formed. The clouds and its shadow in the study area have been eliminated and the actual landuse/land cover on the ground assigned instead of it. Luckily most of the clouds found in the SOPT image of the study area located in the peat swamp forest at the northern part making it an easy task to assign the actual land cover (peat swamp forest) instead of the clouds and shadow. Some of the clouds were found in Tanjung Karang.

Areas other than the paddy field have been removed by random sapling using GPS via ground truthing. The weightage (Eagles 1997) has been used to produce the vegetation density map.

Table 1. The details of the training data sites collection process for each class

Class	Environmental factors leading to signature extension problem	Methodology employed to collect training sites	Centroid coordinates obtained using GPS	Polygons identified with planimetric map
Water Bodies	Differences in turbidity in center of water body and near the shoreline	Selecting onscreen polygons	No	Selangor River, ex-mining Lakes
Mangrove Forest	Relatively homogeneous environmental conditions in the leaves	Collecting *in situ* information.	3° 27' 13.7" N 101° 07' 34.1" E	No
Swamp Forest	Relatively homogeneous environmental conditions in the leaves.	Selecting onscreen polygons.	No	Raja Musa Forest Reserve
Urban and Associated Areas	Environmental conditions change according to the intensity of built up areas: high intensity, low intensity, etc.	Collecting *in situ* information	3° 19' 57.2" N 101° 15' 19.5" E	No
Oil Palm Plantation	Relatively homogeneous environmental conditions in the leaves	Collecting *in situ* information	3° 15' 56.2" N 101° 27' 24.4" E	No
Coconut Plantation	Relatively homogeneous environmental conditions in the leaves	Collecting *in situ* information	3° 23' 41.3" N 101° 12' 59.5" E	No
Upland Forest	Relatively homogeneous environmental conditions in the leaves	Selecting onscreen polygons	No	North Selangor Upland Forest
Paddy Fields	Relatively homogeneous environmental conditions in the leaves	Collecting *in situ* information	3° 28' 25.9" N 101° 07' 53.5" E	No
Mixed Horticulture	Differences related to phenological cycle, plant type, and soil conditions	Collecting *in situ* information	3° 23' 42.8" N 101° 16' 42.3" E	No

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Table 2 reveals different NDVI values and Figure 2 illustrates the methodology flowchart used to produce the vegetation density map (vector data).

Table 2. The different NDVI values

NDVI value	Vegetation density
0.624 – 0.50	Very high
0.496 – 0.353	High
0.348 – 0.201	Moderate
0.0039 – 0.0019	Poor
0.000117-0.000126	Very poor
Less than 0	No vegetation

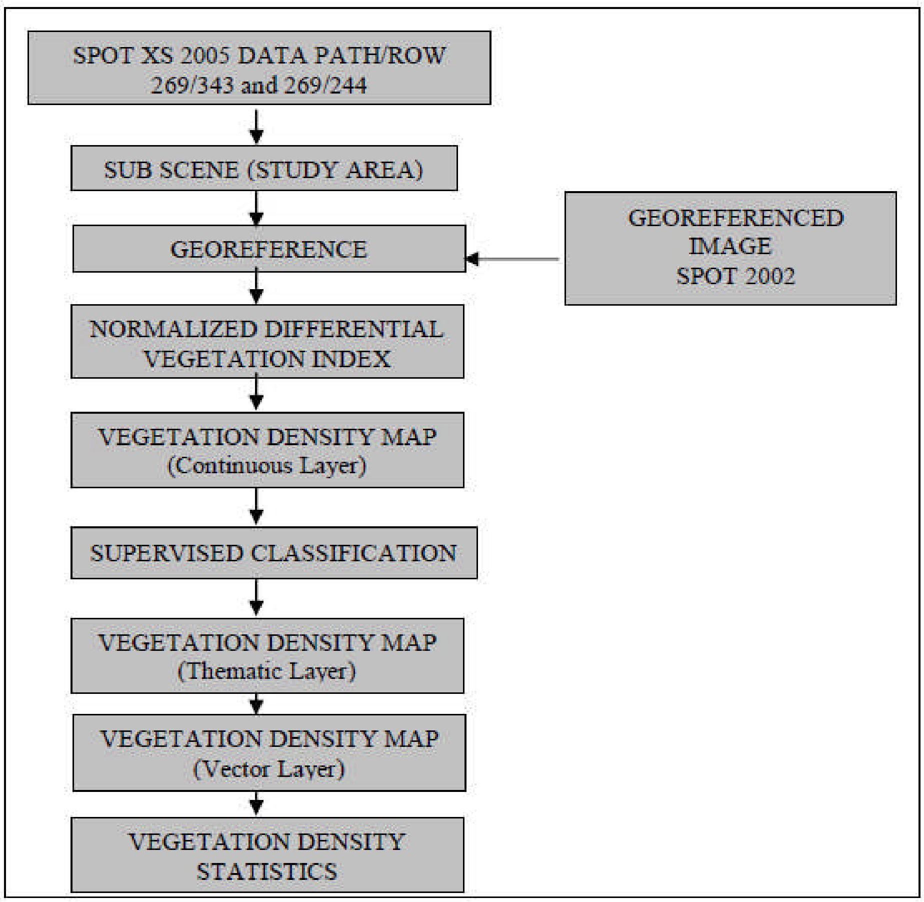

Figure 2. *Methodology flowchart used to produce the vegetation density map (vector data)*

In Malaysia, the high NDVI values are associated with high vegetation density while the minus NDVI values are associated with non-vegetation areas. The vegetation density using Normalized Differential Vegetation Index (NDVI) of Kuala Selangor was classified into five categories of very high, high, moderate, low, and non vegetation areas. NDVI Map has been generated for better distinction of forest and other landuse classes. Soil maps utilized have been prepared by the Agriculture Department, Malaysia. According to this map three types of soil are found in this area. The erosion risk map needs to be prepared as erosion is a problem of high significance, occurring on land dedicated to forestry, transport and recreation. Erosion leads to environmental damage through pollution, sedimentation and increased flooding (Morgan 2005). The analysis has been done using Erdas Imagine 8.4 and ArcGIS 9 softwares. The intersection overlay of landuse/cover with the other parameters (vegetation density, soil suitability and erosion risk) was done and the actual area and distribution of the landuse/cover were given. Figure 3 shows the methodology flowchart.

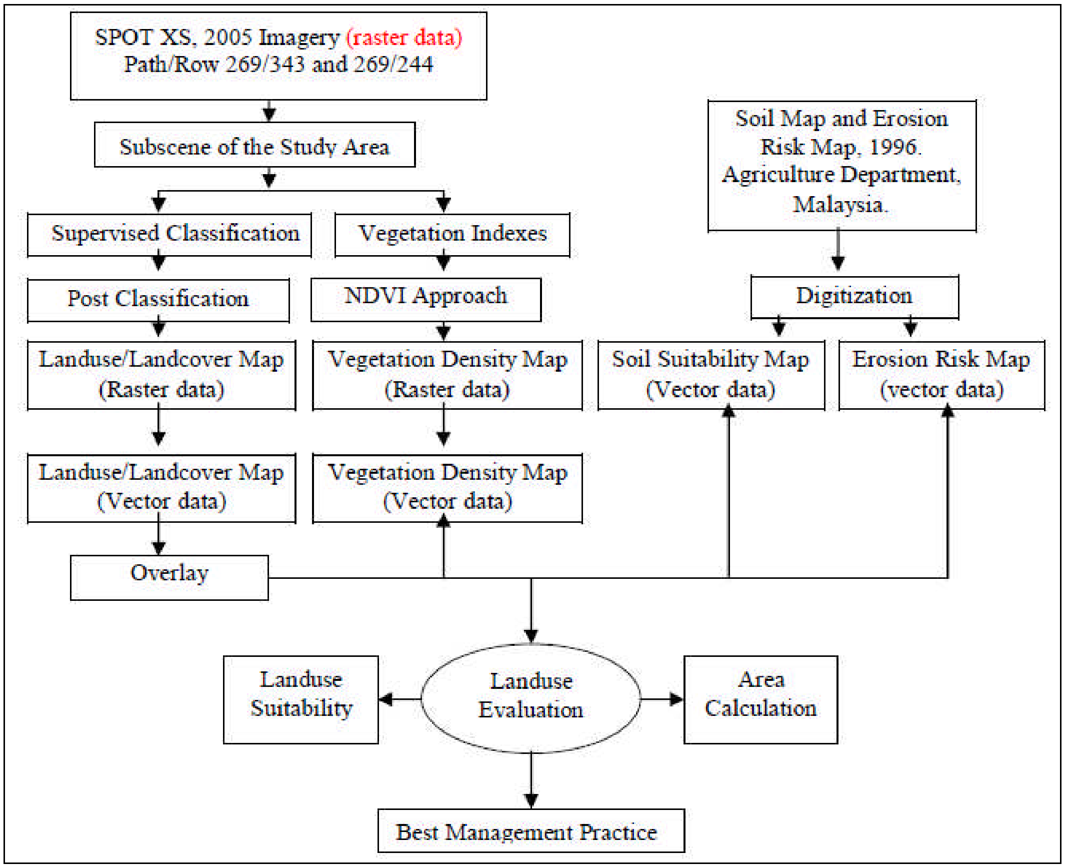

Figure 3. *Methodology framework*

Results and discussion

Landuse/cover analysis

The landuse and landcover of Kuala Selangor was classified into nine categories, namely, peat swamp forest-L1, mangrove forest-L2, urban and associated areas-L3, water bodies-L4, oil palm plantation-L5, mixed horticulture-L6, upland forest-L7, Paddy fields-L8 and coconut plantation-L9. The category of water bodies includes rivers, canals and mining pools. Urban and associated uses include residential area, homestead, industrial and institutional areas. Figure 5 shows the distribution of landuse/cover in the study area.

Table 3 and Figure 4 ptesent the total hectarage of landuse and landcover for the nine categories. Data from the table indicate clearly that within Kuala Selangor, agricultural areas including various types of perennials and seasonal crops (oil palm, coconut, paddy fields and mixed horticulture) are the most extensive. This is followed by forest areas (mangroves, peat swamps, and upland forest) which are found in the northern part and around the Selangor River . Urban and associated areas are rather extensive around the river corridor. The Kuala Selangor district was once a major tin mining area in the country. At present extensive ex-mining pools are used as recreational destinations. This explains the high hectarage of water bodies in the study area.

Table 3. The total hectarage of landuse and landcover in the nine landuse categories

	Landuse/landcover categories		%
L1	Peat Swamp Forest	362.970	30.39
L2	Mangrove Forest	29.7608	2.49
L3	Urban and Associated Areas	89.8322	7.52
L4	Water Bodies	31.9285	2.67
L5	Oil Palm Plantation	453.453	37.97
L6	Mixed Horticulture	39.5140	3.30
L7	Dipterocarp Forest	16.8820	1.41
L8	Paddy Fields	64.1640	5.37
L9	Coconut Plantation	105.911	8.87

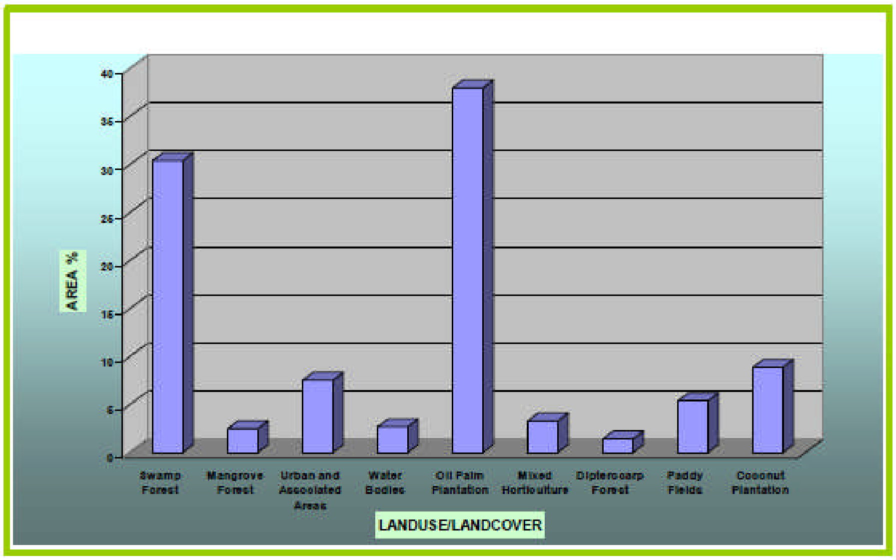

Figure 4. *The total hectarage of landuse and landcover in the nine categories*

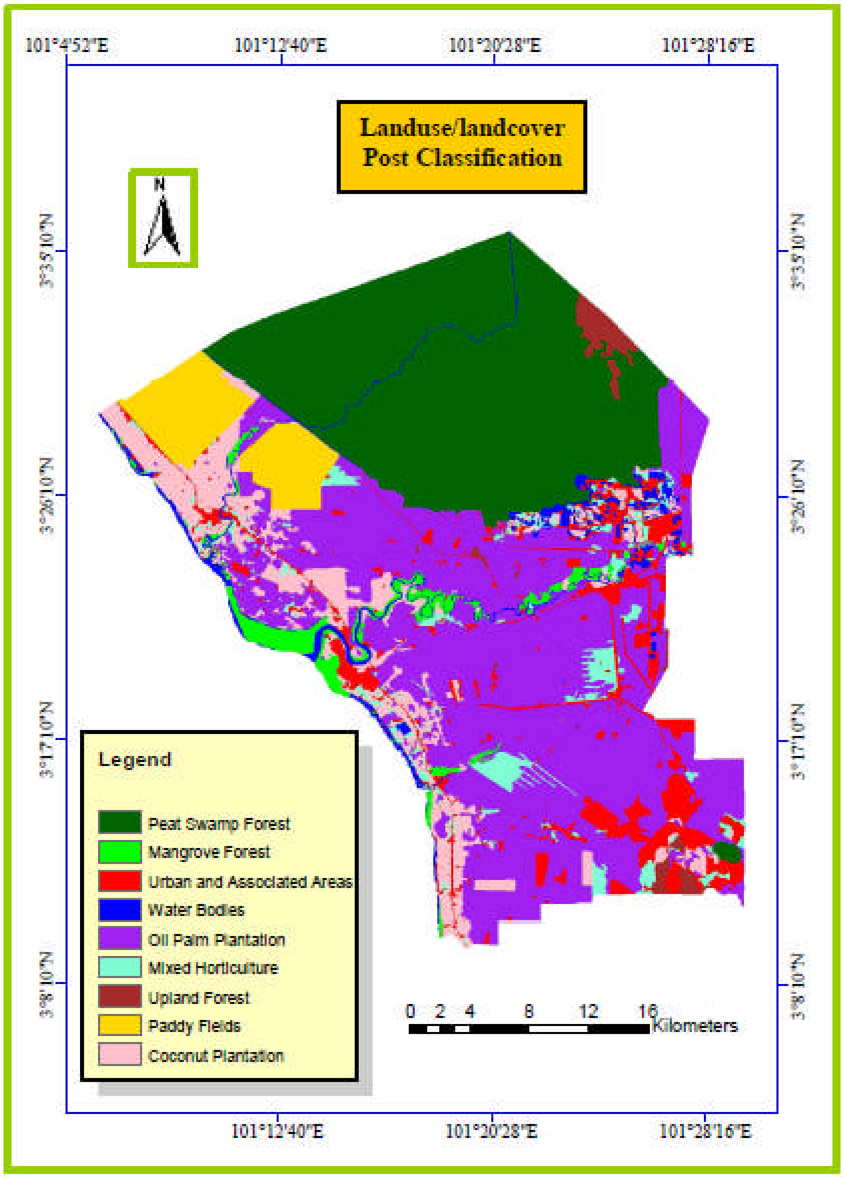

Figure 5. *The distribution of the landuse and landcover classification for Kuala Selangor District*

Results of vegetation density using NDVI approach

Table 4 and Figure 6 indicate the total hectarage of vegetation density in the five categories. Subsequently, data from the Table 4 and Figure 7 (overlay results of LULC and NDVI) indicate clearly that within the study area, a very high vegetation density including the peat swamp forest (328.56 km2), oil palm plantation (360.199 km2) and most of the mangroves (18.97 km2) is found to be the most extensive. It is covering 775.51 square kilometer which represents 64.95 % the entire area. This is followed by high vegetation density areas constituting 15.29 % of the study area and include coconut plantation (34.88 km2) and mixed horticulture (7.652 km2). Most of the moderate vegetation density area make up a total of 67.07 km2. Paddy fields (45.29 km2) lies on the low vegetation density category as it was immature during the time of the image capture. Non-vegetation areas (> 0 NDVI values) include water bodies which total 24.44 km2 (rivers, lakes, pools and canals) and the urban and associated areas which total 38.88 km2 and 91.35 km2 respectively and represents 7.65 % of the study area.

It is noted that some urbanised areas are not classified as non-vegetation areas. This is because the study area is a rural area and local people plant trees especially coconut trees in their yards, road sides and urban green spaces. Figure 8 shows the distribution of the vegetation density classification for the study area.

Table 4. The total hectarage of vegetation density in the five categories using NDVI approach

	Vegetation Density	Area (km2)	%
V1	Non Vegetation	91.35	7.65
V2	Low Vegetation	77.44	6.48
V3	Moderate Vegetation	67.07	5.61
V4	High Vegetation	182.61	15.29
V5	Very High Vegetation	775.51	64.95

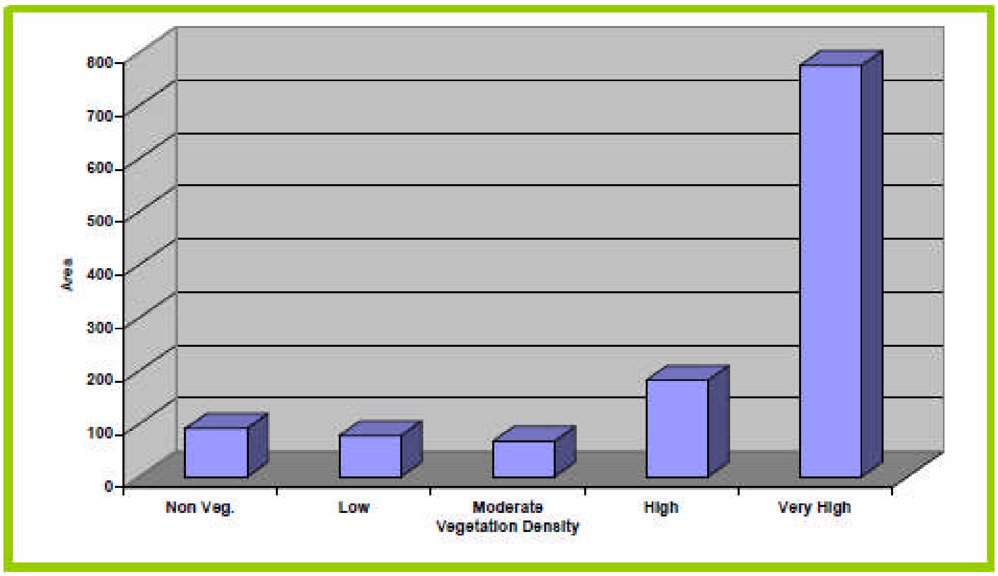

Figure 6. The *total hectarage of vegetation density in the five categories using NDVI approach*

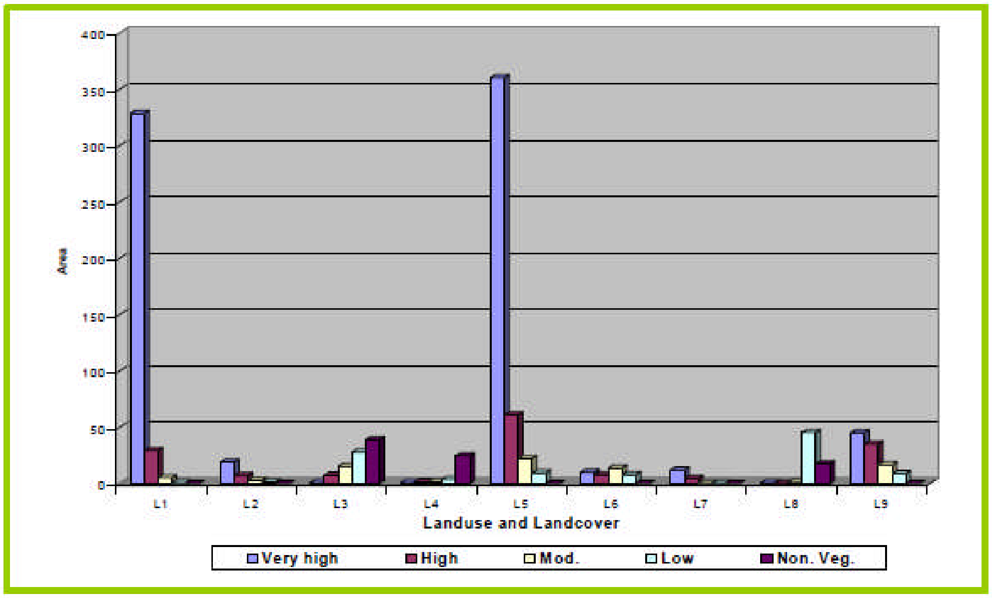

Figure 7. *Overlay results of LULC and NDVI*

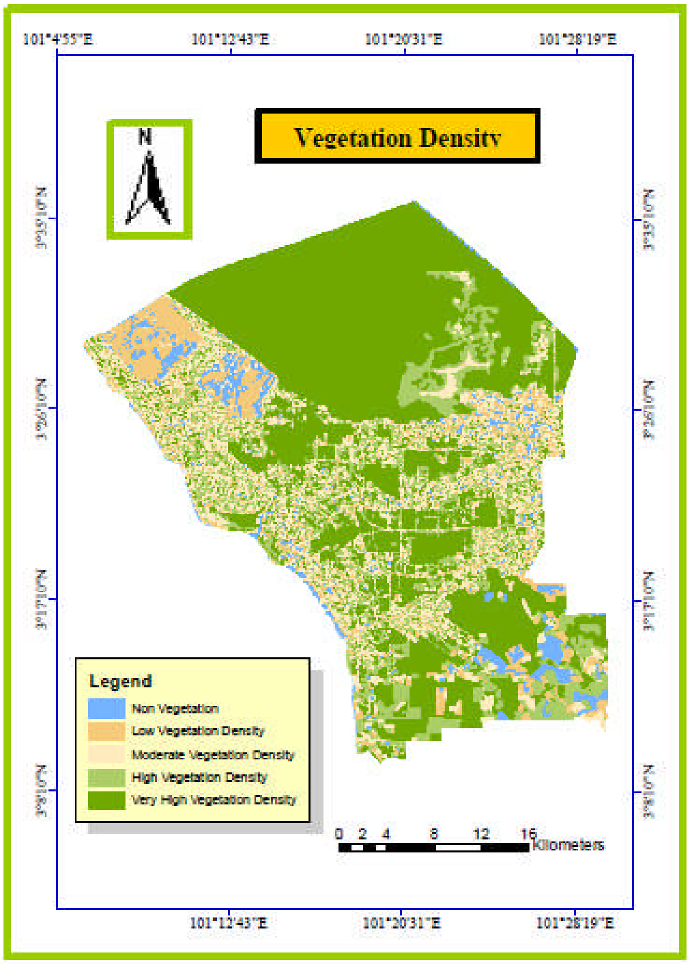

Figure 8. *The distribution of vegetation density categories in vector data*

Soil suitability analysis

There are 3 soil suitability classes in the study area as shown in Figure 9 and described below:

Class 2 (S2): Soils with one or more moderate limitations to crop growth. This class of soil suitability covers an area of 497.598960 Km^2 comprising 42 % of the study area. These soils affect a limited range of crops which may be very sensitive to some soil conditions. For most crops these limitations can be surmounted by proper management practices which may include erosion control measures, minor drainage and irrigation works, or other improvement measures that may result in better tilt and moisture supply.

Class 4 (S4): Soils with more than one serious limitations to crop growth. In having more than one serious limitation these soils are suitable for a very narrow range of crops. Moreover, major conservation or amelioration measures are necessary before they can be cultivated on long term basis. This class of soil suitability covers 541.071269 Km^2 or 45.63 % of the total study area.

Class 5 (S5): Soils with at least one very serious limitation to crop growth comprising 146.632134 Km^2 or 12.37 % of the study . In their present condition these soils are least suitable for crop growth. Where they are not built over for urban and infrastructure development or excavated for mining and quarrying purposes they are best allowed to continue under primary or regeneration forest.

Table 5 represents the suitability classes, area, percentage and suggested management practices for sustainable development of the land use of the study area.

Table 5. The suitability classes, area, percentage and suggested management practices for sustainable development of the land use of the study area

Soil suitability classes	Area (km^2)	Area (%)	Suggested management practices
Class 2 (S2)	497.59	42	1. Erosion control measures 2. Minor drainage and irrigation works 3. Improvements resulting in better tilth and moisture supply
Class 4 (S4)	541.07	45.63	Major conservation or amelioration measures are necessary before than be cultivated on long term basis
Class 5 (S5)	146.63	12.37	They are best allowed to continue under primary or regeneration forest

Results for soil suitability classes in the study area for the eight categories of land use and land cover where the water bodies category is excluded is given in Table 6. They allow for the area calculation of soil suitability classes for each land use and land cover category .

Table 6. Soil suitability classes in the study area for the eight categories of landuse and landcover

Landuse and landcover category	S 2	S 4	S 5
Peat swamp forest (L1)	0.33	359.16	3.32
Mangrove forest (L2)	11.33	0.96	17.21
Urban and associated areas (L3)	42.54	21.99	25.18
Oil palm plantation (L4)	303.19	119.99	30.07
Mixed horticulture (L5)	21.19	6.57	11.71
Dipterocarp forest (L6)	7.45	7.28	2.08
Paddy fields (L7)	46.3	17.86	0.13
Coconut plantation (L8)	64.1	5.2	36.56

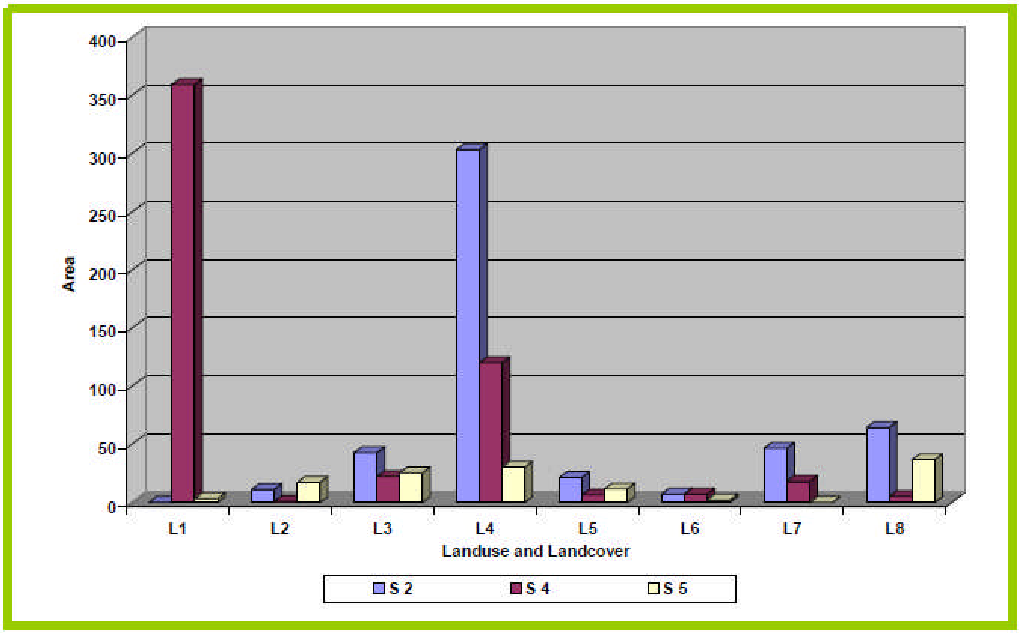

Figure 9. *Soil suitability classes in Kuala Selangor*
Source: Agriculture Department, Peninsular Malaysia

Soil suitability subclasses

Soil suitability subclasses are subdivisions within suitability classes formed on the basis of the kinds of limitation that affect crop growth. While suitability classes are broad classifications the subclasses are more specific on the basis of which it would be possible to make recommendations with regard to specific crops and management practices needed for better planning and sustainable use of the land. In Malaysia, the subdivision of suitability classes into subclasses is based on ten different types of limitations to crop growth (Figure 12).

The results of soil suitability overlays (Figure 11) show that forest areas are distributed on the three types of soil suitability. The dipterocarp forest covers the Class 2 with three moderate limitations (2Gnt) which include gradient limitation (> 6º - 12º slopes), nutrient imbalance (CES = 5 – 10 meq/100 mg soil) and texture and structure limitation (fine to moderately fine textured and weakly structured). The peat swamp covers the S4 where the soil has two serious limitations to crop growth (4do). Since this soil is poorly and very poorly drained and that its organic horizon thickness is more than 125 cm from the surface, it should be conserved and not converted to agricultural areas. The mangrove forest which is mainly located along the western coast stretches into the non-suitable category for agriculture. It covers the S5 (5s (dt)) with one very serious limitation (salinity > 4 mmhos) and 2 minor limitations. Drainage (2º - 6º slopes), texture and structure attributes are minor limitations found in this mangrove area. As such, it is best allowed to remain under primary or regeneration forest for biodiversity conservation. Table 7 shows soil suitability subclasses in the study area for the eight landuse and landcover categories.

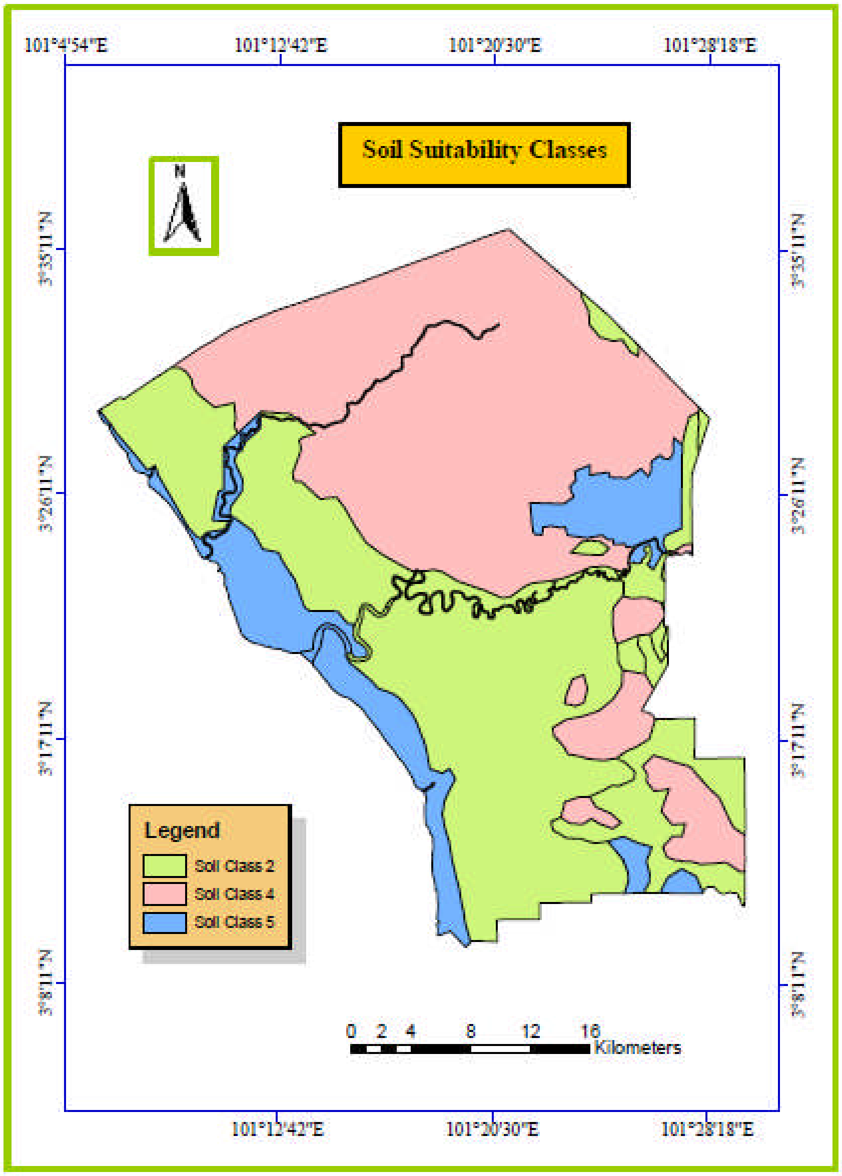

Figure 10. *Soil suitability classes in the study area for the eight landuse and landcover categories*

Agricultural uses in the study area are mainly located in soil suitability Class 2. Most of them covers the soil suitability Subclass 2d where the soil is between imperfectly and somewhat imperfectly drained which is just a minor limitation to crop growth. In addition, this type of soil is useful oil palm plantations to preserve moistures. An extent of 62.953 km² of oil palm, 19.803 km² of paddy fields and 74.138 km² of coconut covers the suitability Subclass 4do. This soil is very poorly to somewhat poorly drained and has an organic horizon of more than 125 cm thickness from the surface. A further 3.6 % of oil palm and 22.5 % of coconut areas are located in soil suitability Class 5 with a slope gradient of more than 20º and a salinity of more than 4 mmhos. In the face of human population growth these lands with the soil suitability Class 5 can be converted to settlement and infrastructure development.

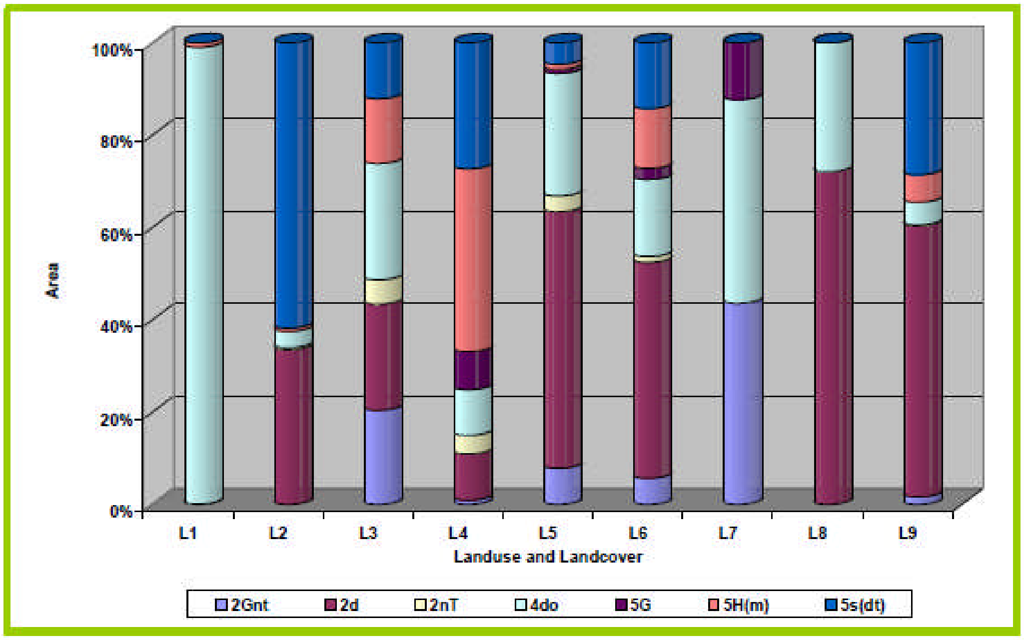

Figure 11. *Soil suitability subclasses for the eight categories of landuse/cover*

Table 7. Soil series classification according to suitability classes in study area

Soil series	Soil suitability subclasses classification by terrain limits					FAO symbol	Area (km²)	(%)	Properties
	0-2°	> 2-6°	> 6-12°	>12-20º	> 20º				
Krangi	5s (dt)					Jt	94.35	7.96	1. Very poor drainage 2. fine textured and massive 3. conductivity above 6 mmhos
Mined land	5H m(n)	5Hm (n)				Ml	43.01	3.62	1. Variable textures 2. Generally lacking in structure and nutrients
Peat	4do					Od	541.07	45.64	1. Extensive (drained peat) 2. Imperfect to very poor drainage 3. variable thickness
Steep land					5G	St	9.26	0.08	Slopes exceed 20º
Telemong -Akob-local alluvium	2nT					Jd-Gd	22.084 547	1.86	Well drained Coarse textured with weak structure CES = 5-10 meq/100 mg soils

Urban and related uses in the study area are exposed to a wide range of soil suitability 38 % of which is found in suitability Class 2 where the soil is suitable for agriculture. Another 19.33 km² of urban and related uses are located in suitability Class 4do and a further 29.9 km ² in suitability Class 5 where a very serious limitations of gradient and salinity exist.

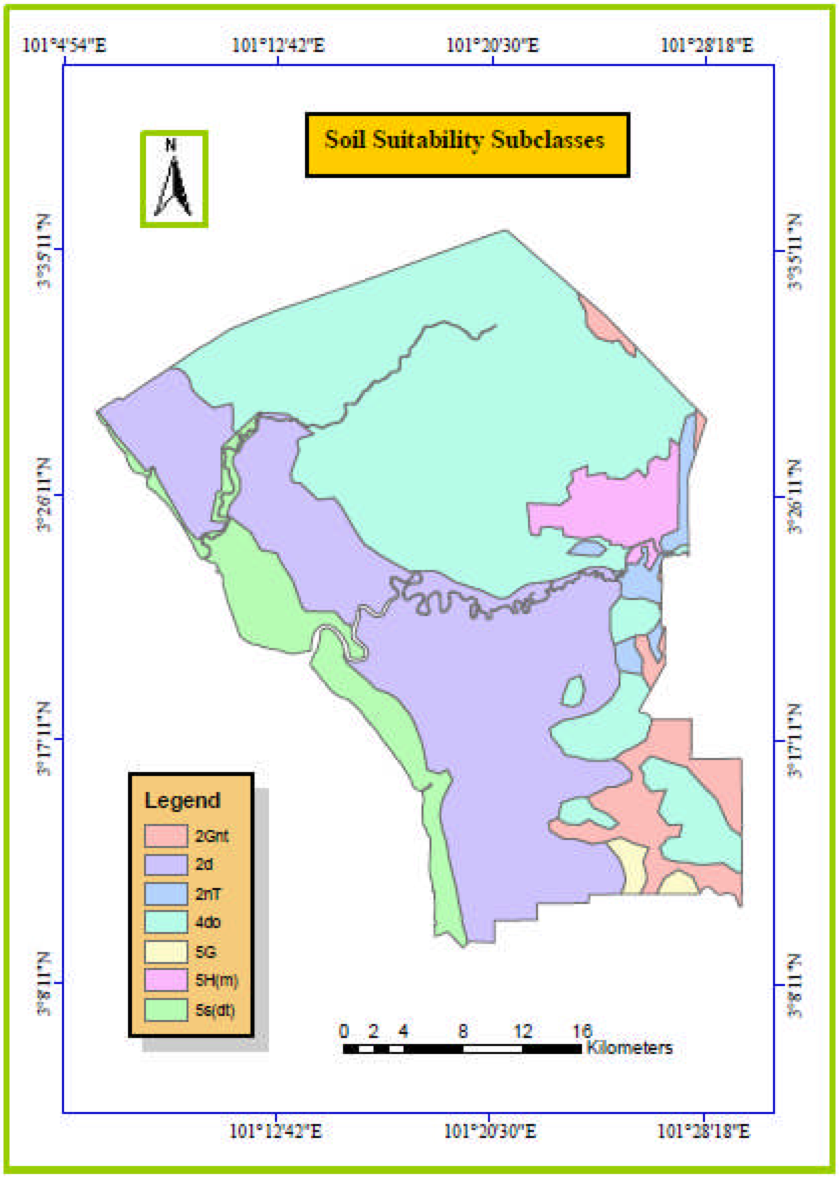

Figure 12. *Soil suitability subclasses for Kuala Selangor*
Source: Agriculture Department, Peninsular Malaysia

Erosion risk analysis

The results of the soil erosion risk map in the Kuala Selangor District are presented in Table 8 and illustrated in Figure 13 indicating that 88.26 % of the study area are located in the low risk zone while 5.49 % are located in the moderate risk zone. As the study area is located on the coast of the Straits of Malacca, it is mostly low lying and that the high and very high risk zones form only 5.13 % of the entire study area.

Results of erosion risk for the whole eight categories of landuse and landcover in the study area are given in Figure 14. The risk factor is translated into the amount of surface soil loss (tons) per ha per year.

Generally low risk areas coincide with lowland area, while the high and very high risk areas are in the highland areas around Jeram and Ijuk. Most of the forest land cover in the study area are found in this low erosion risk area. The areas of low risk cover 367.542 km² and are found in the mangrove swamps in the western part and peat swamps in the northern part of the study area.

The high erosion risk area covers 4.1 km² and is found in the highlands towards the northeastern part where the dipterocarp forest is located.

Agriculture landuse in the study area is exposed to a wide range of erosion risk, mostly in the low risk zone which is about 617.09 km² or 87.5 % of the total area of agricultural landuse in the study area. It should be noted that oil palm, coconut and paddy are grown mainly in big estates that practice a good soil conservation strategy. The good practice is imperative as soil erosion leading to nutrient and organic loss of top soil could prove to be very costly.

The urban land use covers wide risk areas, while the housing settlement associated with high risk areas are those that have been developed in the highland locations around Ijuk and Jeram regions. Other types of settlement are located in the low to moderate risk areas.

Suspended solid (SS) content in the river water is an indicator of the seriousness of water pollution by soil erosion within the catchment area. Most of the water bodies lie within the low to moderate risk zones of the study area.

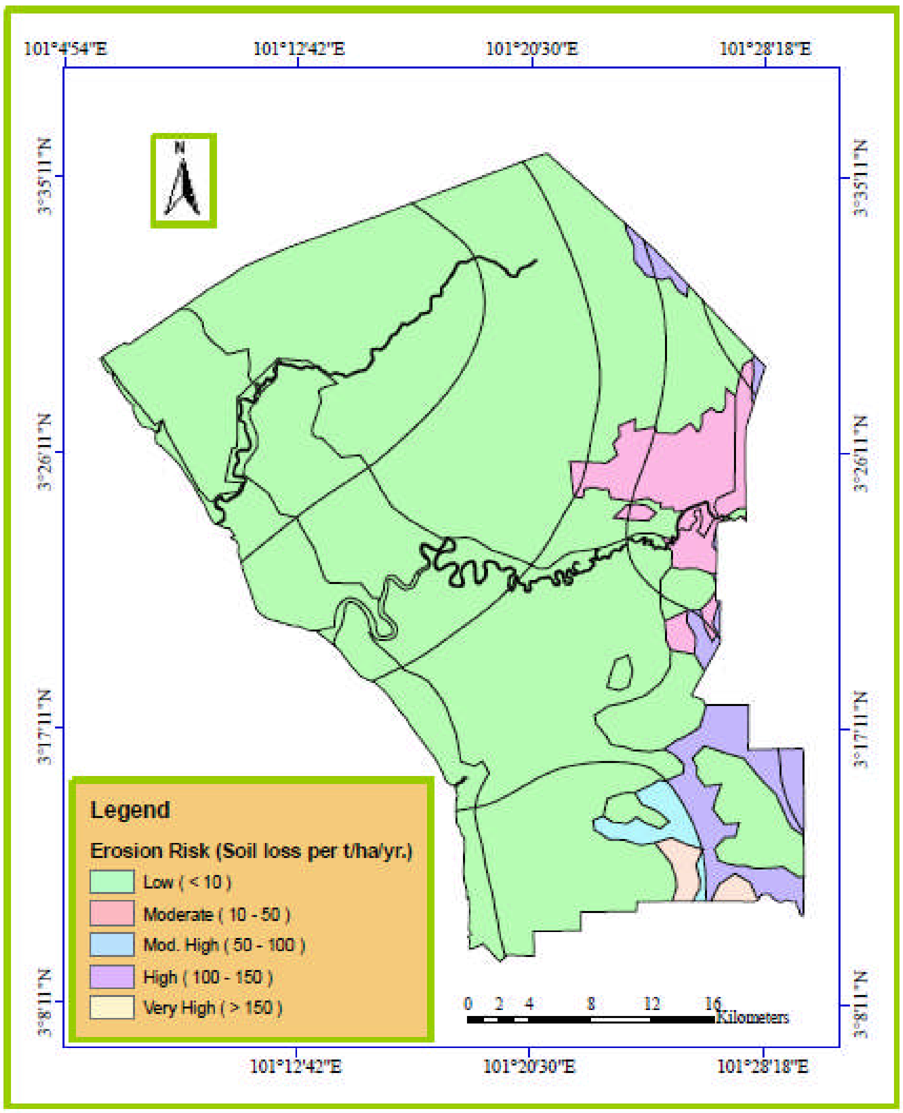

Figure 13. *Soil erosion risk map of Kuala Selangor District*
Source: Agriculture Department, Peninsular Malaysia, 1996

Table 8. Soil erosion risk map of Kuala Selangor District

Erosion Risk (Soil Loss per t/ha/yr.)	Area (km²)	Percentage %	Soil Series	FAO Symbol
Low (< 10)	1045.91	88.26	• Kranji • Selangor-Kangkong • Peat	Jt Bv-Ge Od
Moderate (10 – 50)	65.0996	5.49	• Mined Land • Telemong- Akob- Local Alluvium	Ml Jd-Gd
Moderately High (50 – 100)	13.3674	1.12	• Serdang-Bungor- Munchong	Af
High (100 – 150)	51.6560	4.35	• Serdang-Bungor- Munchong	Af
Very high (> 150)	9.26672	0.78	• Steep Land	St

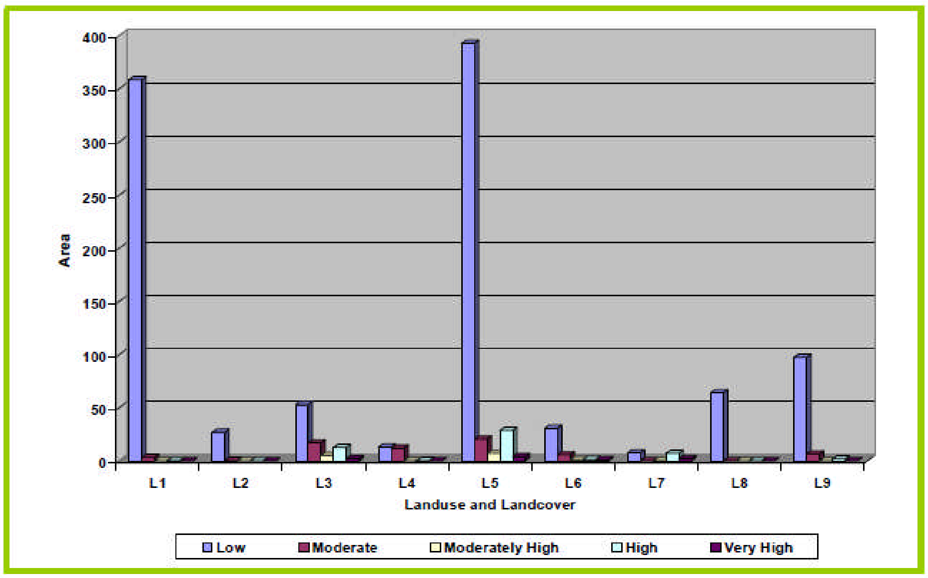

Figure 14. *Erosion risk areas in the study area for the nine categories of the landuse and landcover*

Conclusion

Landuse evaluation is essential in identifying best land management practices as it is the key process for sound land use planning. The knowledge about land use and land cover has become increasingly important for Malaysia's plan to overcome the problems of haphazard, uncontrolled development, deteriorating environmental quality, loss of prime agricultural lands, destruction of important wetlands, and loss of wildlife habitats. In this study the integration of remote sensing and GIS has proven to be powerful tools for landuse/cover evaluation based on the available natural resources.

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