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# Modelling Landslide Using GIS and RS: A Case Study of Upper Stream of Langat River Basin, Malaysia

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*ABSTRACT*

*Increasing pressure for development in Malaysia in recent years due to rapid population growth and urbanization has caused numerous environmental related problems such as landslide and soil erosion. Increasing landslide event in Malaysia has caused degradation to properties, life and environment. This paper describes a study to develop landslide model by using logistic regression approach, partly to measure the significance of each causative factor that contributes to landslide. In this study causative factors are divided into physical, human activities and location. This model is based upon the model developed by a number of researchers. Landslide events in the Hulu Sungai Langat sub-basin, which is the upper stream of Langat Basin, Selangor, Malaysia were used to develop the model.*

*ABSTRAK*

*Peningkatan tekanan untuk pembangunan di Malaysia kebelakangan ini yang disebabkan oleh pertumbuhan penduduk yang pesat dan pembandaran telah menyebabkan beberapa masalah yang berkait dengan alam sekitar seperti tanah runtuh dan hakisan tanih. Peningkatan kejadian tanah runtuh di Malaysia telah menyebabkan degradasi terhadap harta benda, nyawa dan persekitaran. Kertas ini menerangkan kajian untuk membangunkan model tanah runtuh dengan menggunakan pendekatan regresi logistik, sebahagiannya mengukur signifikan bagi setiap faktor penyebab yang menyumbang kepada kejadian tanah runtuh. Dalam kajian ini, faktor penyebab dibahagikan kepada aspek fizikal, aktiviti manusia dan lokasi. Model ini adalah berasaskan kepada model yang dibangunkan oleh beberapa orang pengkaji. Kejadian tanah runtuh di sublembangan hulu Sungai Langat yang terletak di bahagian hulu Lembangan Langat, Selangor, Malaysia digunakan untuk membangunkan model ini.*

## INTRODUCTION

Increasing pressure for development in Malaysia in recent years due to rapid population growth and urbanization has caused numerous environment-related problems. One of the problems is landslide. Between 1993 to 2002, there were 26 cases of landslide reported by the newspapers. Such events had caused 150 deaths, 30 others injured and thousands were evacuated, resulting in an average of more than five deaths for each case.

Landslide activities are related to various factors such as geology, geomorphology, soil, lithology, rainfall and land cover. Studying the relationship between landslides and causative factors not only helps to tackle and understand the mechanism of the landslide itself, but also form a basis for predicting landslides in the future. Recent advancement in geographical information technologies (such as GIS, GPS and RS) enhances the study of landslide by providing numerous abilities for collecting, analyzing, modelling, viewing and storing the landslide data.

Presently in Malaysia, classic studies of landslide events at the national level mainly focused on determining causative factors after the events had happened rather than developing model to determine and measure the significance of each causative factor. Modelling landslide using Geographical Information System and Remote Sensing is important to determine and measure the spatial factors that contribute to landslide events. Such information is very useful to the authority to manage the hazard.

The purpose of this article is to report the preliminary results of our research to develop spatial model of landslide event in Malaysia using Langat River sub-basin as the study area. GIS and remote sensing techniques were used to generate the database and logistic regression was used to develop the model.

## LITERATURE REVIEW

Basically there are five types of analyses that can be used to analyze landslide: distribution analysis (Huma & Radulescu 1978), quantitative analysis (Stakenborg 1986; Kingsbury et al. 1992), statistical analysis (Carrara et al. 1978, Carrara 1988), deterministic analysis (Brass et al. 1989; Hummond et al. 1992) and frequency analysis (Ayalew 1999). Table 1 summarizes examples of methodology and causative factors used by previous researchers in landslide modelling.

Table 1. Summary of spatial variables and methodology used for modeling landslide

| Researcher | Methodology | | | | | | Causative Factors | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Factor of Safety | Statistic | Expert System | Aerial Photo | Remote Sensing | GIS | Soil | Hazard | Drainage System | Meteorology | Hydrology | Water Table | DEM | Slope | Topography | Geomorphology | Discontinuity | Geology | Land Cover | Geotechnic | Past Landslide |
| Al-Homoud & Tahtamoni (2000) | * | * | * | | | | * | * | * | * | * | * | | * | * | | | * | | * | * |
| Kerle & van Wyk de Vries (2001) | | | | * | * | | | * | | * | * | | * | * | * | * | * | * | | | * |
| Nilsen (2000) | * | * | | | | | | * | | | | * | | * | * | | * | | | * | |
| Van Asch & Buma (1997) | * | | | | | | * | | | * | * | * | | | | | | * | | * | |
| Luzi et. al (2000) | * | * | | | | * | | * | | * | * | * | * | * | * | | | * | | * | * |
| Aleotti & Chowdhury (1999) | * | * | | | | * | * | | | * | * | * | * | * | * | * | * | * | | * | * |
| Pachauri et al. (1998) | * | * | | * | * | | | * | | | * | | | * | * | * | | * | * | * | * |
| Dai & Lee (2001) | | * | | * | * | * | | * | * | * | | | * | * | | | | * | * | | * |
| Nagarajan et al. (2000) | | | | | * | | * | | * | * | * | | * | * | * | * | * | * | * | * | |
| Miles & Ho (1999) | * | * | | | | * | * | * | | | | * | * | * | * | * | * | * | | * | |
| Gökceoglu & Aksoy (1996) | * | * | | * | * | | * | | * | | | | * | * | | | * | * | * | * | * |
| Ercanoglu & Gokceoglu (2001) | | | | | | * | | | | | | * | | | * | | | * | * | | |

## SETTINGS AND DESCRIPTION OF STUDY AREA

Hulu Sungai Langat sub-basin is selected as the study area for this research. It is the upper stream of a large scale Langat River Basin ecosystem and covers an area of about 69258.2 hectares. It expands from grid 400, 000 metres E to 440, 000 metres E and grid 310, 000 metres N to 370 000 metres N. It is located in the state of Selangor and surrounded by Pahang River Basin to the east, Klang River Basin to the north and

Linggi River Basin to the south. The study area covers five administrative districts, i.e. Hulu Langat, Kajang, Dengkil, Cheras and a small part of Petaling.

## METHODOLOGY

The methodology for this study is shown in Figure 1. Twelve causative factors are identified and then divided into physical, human activities and location. Physical characteristics consist of topography, geology, river density, geological structure density, soil type, degradation zone, slope,

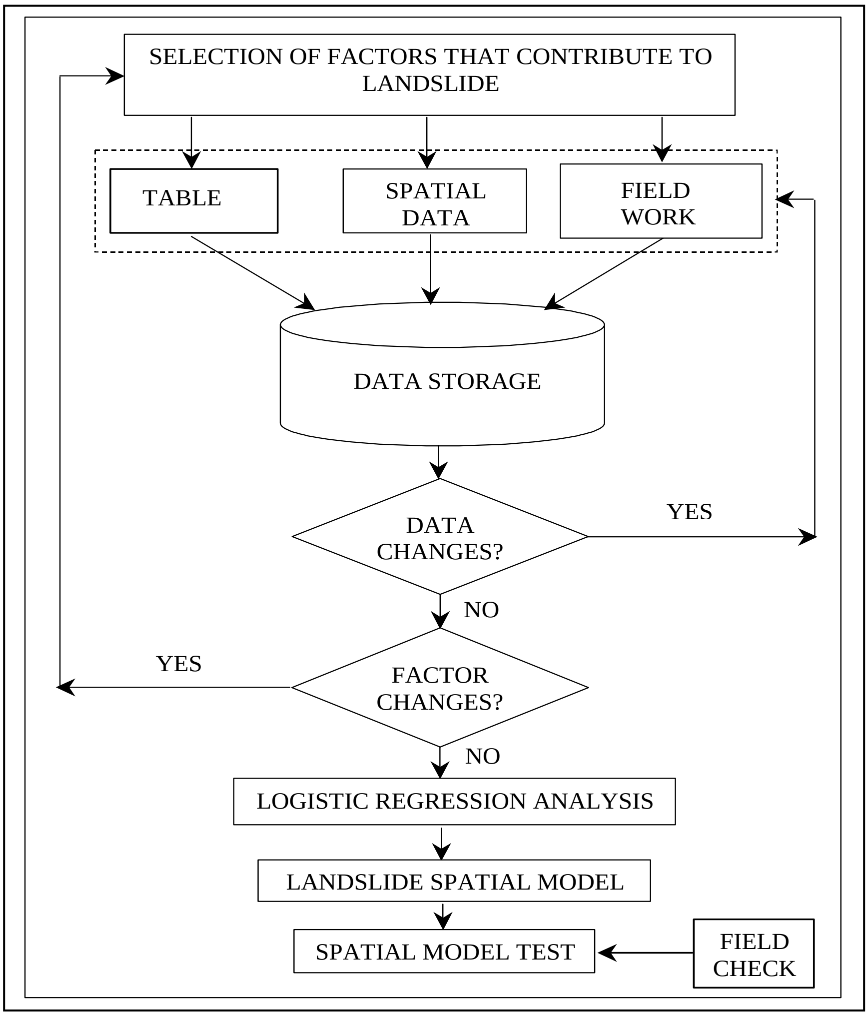


Figure 1. The methodology of this study

underground water level, erosion risk and rainfall, whereas land cover is considered as human activities, and distance from landslide to road declared as location factor.

**Data Gathering and Development of Spatial Database**

Records of past landslide were captured through the interpretation of aerial photographs while records of recent landslide were collected through field work. All the 12 factors contributed to landslide were mapped and converted to digital format using IDRISI32 for Windows. There were 70 landslide locations recorded in this study. Landslide locations are captured as point objects and declared as dummy variable. Random points are selected using IDRISI32 software to get the non landslide locations. Table 2 shows the sources of data and measurement level of the factors. Overlay function is used to get a clear relationship of every single landslide to their causative factors.

Table 2. Data sources information and processes

| No | Layer | Data Sources | Measure-ment Level | Process |
|---|---|---|---|---|
| 1 | Landslide code | RS and GIS processes | Nominal | Modelling (RS and GIS processes) |
| 2 | Distance from landslide to road | GIS processes | Scale | Near function |
| 3 | Topography | Dept. of Survey and Mapping | Ordinal | Digitize |
| 4 | Geology | Minerals and Geoscience Dept. | Ordinal | Digitize |
| 5 | River density | GIS process | Ordinal | |
| 6 | Soil type | Dept. of Agriculture | | Digitize |
| 7 | Degradation zone | GIS process | Ordinal | Digitize |
| 8 | Slope | GIS process | Ordinal | Tin to lattice (grid) |
| 9 | Groundwater level | GIS process | Ordinal | Contour |
| 10 | Rainfall | GIS process | Ordinal | Contour |
| 11 | Discontinuity | GIS and RS processes | Ordinal | Lineament trace from TM Landsat Band 4, gray scale, using specific filter, lineament gridding |
| 12 | Erosion | Dept. of Agriculture | Ordinal | Digitize |
| 13 | Land cover | RS Process | Ordinal | Supervised Classification |

**The Development of Landslide Spatial Model**

Since the dependent variable is categorical, logistic regression analysis is used to derive the spatial model of the landslide. The dependent variable (Y) is a categorical binary presence or absent event whereas the independent variables are combination of metric and non metric data (Hair et al. 1995). The general equation (Hair et al. 1995) used in this study is shown in equation (1).

$$p=E(Y)=\exp(z)/(1-\exp(z)) \quad (1)$$

$$z = a_0 + a_1 X_1 + a_2X_2 + a_2X_2 + a_3X_3 + \ldots\ldots\ldots + a_nX_n + e \quad (2)$$

Where $p$ is the probability of landslide event, $E(Y)$ the expected value of the binary dependent variable $Y$ (landslide occurrence), $a_0$ is a constant to be estimated, $a_1 \ldots a_n$ are the coefficients to be estimated for each independent variable $X_1 \ldots X_n$, n is the number of variables (factors) and $e$ is the prediction error. The logistic function can be transformed into a linear response with the transformation:

$$p' = \log_e\left(\frac{p}{1-p}\right) \quad (3)$$

hence,

$$p' = a_0 + a_1 X_1 + a_2X_2 + a_2X_2 + a_3X_3 + \ldots\ldots\ldots + a_nX_n \quad (4)$$

The statistical analysis was carried out using SPSS for Windows.

RESULTS AND ANALYSIS

The result of the model fitting is shown in Table 3. From 12 causative factors, only 9 factors are significance to this study. The factors are distance from landslide to road, topography, geology, river density, soil type, degradation zone, slope, groundwater level and rainfall. From this result, the probability of landslide occurrence can be estimated using the following equation:

$$p' = -6.933 - 0.004X_1 + 2.722X_2 + 3.122X_3 - 1.355X_4 - 0.883X_5 - 2.802X_6 - 1.275X_7 - 1.442X_8 + 1.535X_9 \ldots\ldots (5)$$

The spatial model has an accuracy rate of about 77 %.

Table 3. Results of the logistic regression analysis

| Variables | Description | B | S.E | Wald | Sig. | Exp(B) |
|---|---|---|---|---|---|---|
| X1 | Distance from landslide to road * | -0.004 | .001 | 24.115 | .000 | .996 |
| X2 | Topography * | 2.722 | .915 | 8.849 | .003 | 15.206 |
| X3 | Geology * | 3.122 | .769 | 16.500 | .000 | 22.698 |
| X4 | River density * | -1.355 | .395 | 11.759 | .001 | 3.877 |
| X5 | Soil type * | -.883 | .360 | 6.002 | .014 | .414 |
| X6 | Degradation zone * | -2.802 | 1.097 | 6.526 | .011 | .061 |
| X7 | Slope * | -1.275 | .476 | 7.160 | .007 | .280 |
| X8 | Groundwater level * | -1.442 | .471 | 9.385 | .002 | .237 |
| X9 | Rainfall * | 1.535 | .495 | 9.608 | .002 | 4.640 |
| X10 | Continuity | -1.50 | .691 | .047 | .828 | .861 |
| X11 | Erosion | -.569 | .417 | 1.865 | .172 | .566 |
| X12 | Land cover | -.424 | .309 | 1.882 | .170 | .654 |
| | Constant | -6.933 | 2.757 | 6.324 | .012 | .001 |

* - significant at 0.05 level.

## DISCUSSION

The most significant factors are distance from landslide to road, geology, river density, groundwater table, rainfall, topography, degradation zone and soil type (Figure 1).

From the equation 5, if the distance from road to landslide increases, the possibility for the occurrence of landslide is low. Road construction is one of the activities involving slope cutting, and land clearing. This can render the slope unstable and susceptible to slide. In the study area, most of the landslide happened in moderate high (20m – 500m) due to rapid urbanization. Highly weathered granite and metamorphic foliation play a very important role to increase the landslide susceptibility. The increase in river density does not indicate landslide susceptibility. Groundwater level is related to rainfall. High rainfall produces high groundwater table which increases susceptibility to landslide.

Increase of rainfall signals more landslide occurrences. Rainfall acts mainly as agent of sliding by decreasing resistance between soil mass and increasing soil water content. Increasing slope and degradation zone may cause landslide, but in this case in zone 1 where slopes are at higher level, forest cover plays an important role in changing the situation.

## CONCLUSION

Modeling landslide is very important to measure the relationship between each causative factor with every single landslide location. The relationship between landslide and their causative factors vary according

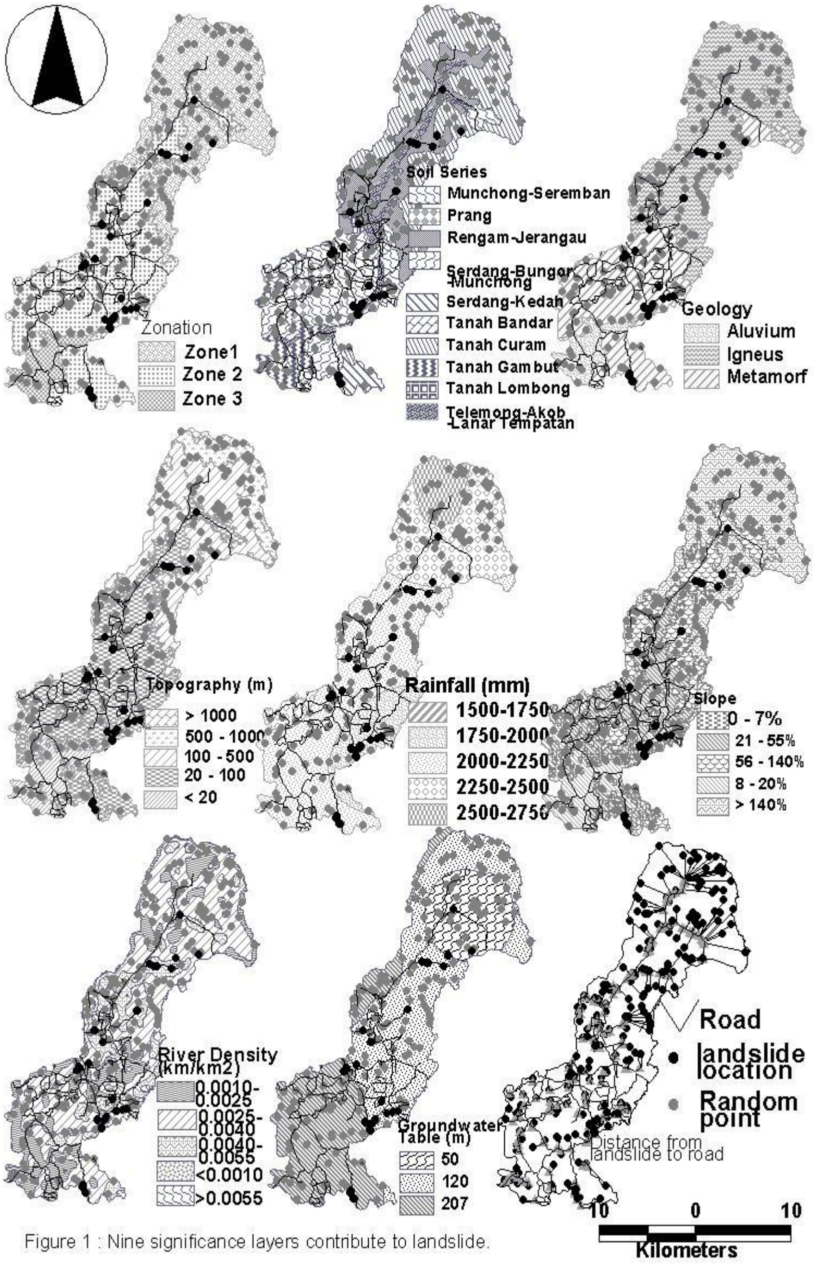


Figure 1. Nine significant layers contributing to landslide

to area, time and climate. By modelling landslide, the inherent characteristics of landslide activities can be quantified. This is very important in order to identify which causative factor plays a major or a minor role. Such information can then help the authority to plan the activities and land use in areas susceptible to landslides.

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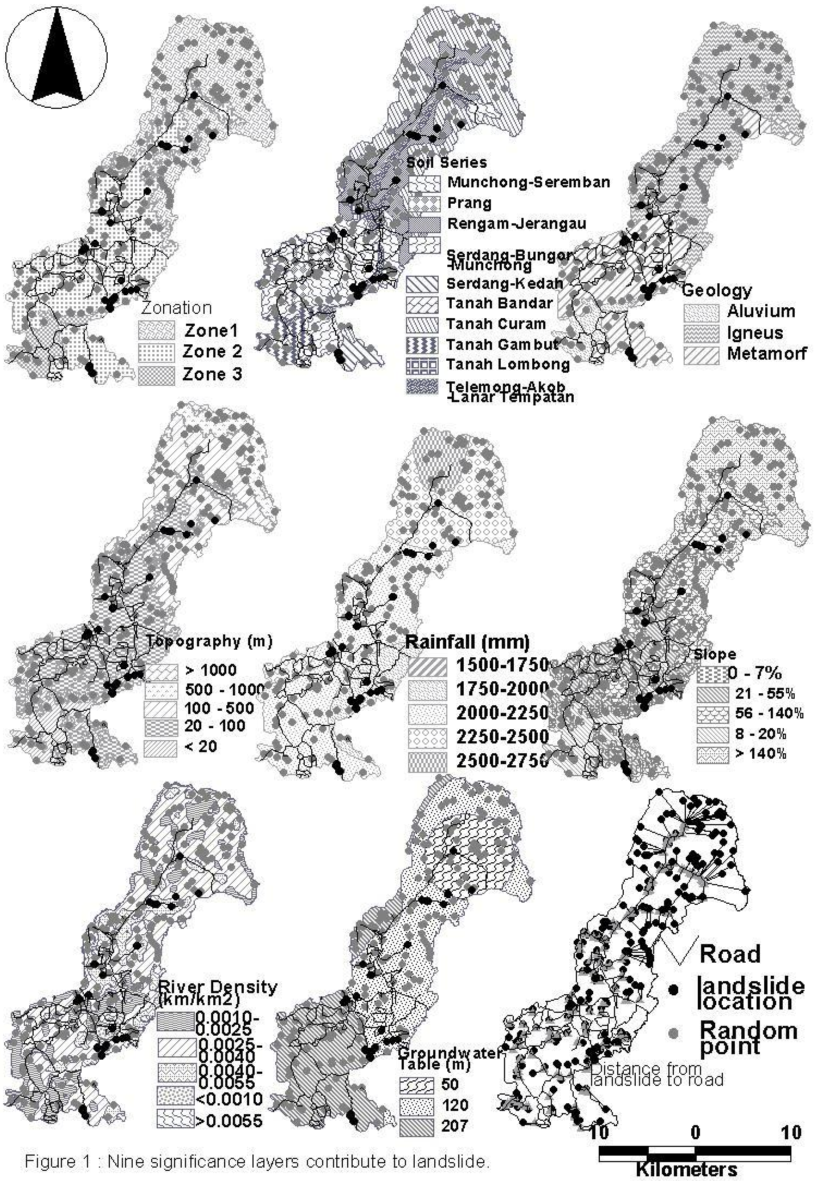


Figure 1 : Nine significance layers contribute to landslide.