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# LAND USE CHANGE AND SOIL LOSS RISK ASSESSMENT BY USING GEOGRAPHICAL INFORMATION SYSTEM (GIS) AND USLE EQUATION IN IPOH STATE, MALAYSIA

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**ABSTRACT**

Soil erosion is among of the most acute issues facing in the world, from the loss of soil to natural resources and crop farmers. The main objectives of this study were to analyze and Land use Changes from year 2000 to 2015 and possible soil erosion rate in the future. All spatial analysis work has been carried out in GIS Environment using ArcGIS version 10.3 all data that use in this study were obtained from Department of Agriculture in Malaysia. The total area was 1227.80 $Km^{2.}$ Results showed that the proportion of agriculture land in the study area increased significantly from 2000 to 2015 (30% to 34.35% of the total study area, The forest area in the study area has been decreased from 45.1% in 2000 to 42.5% in 2015 because exploited and transformed into u urban area, where the urban area was recorded from 14.34% in 2000 to 17.93% in 2015 with values of 183.1 $km^2$ to 216.16 $km^2$of study area. Using the USLE equation and GIS technology is a useful and effective tool for predicting the long-term erosion potential and assessing the effects of soil erosion in large areas. Finally, the USLE equation used to calculate the annual average soil loss rate (A) in ton/ha/year for the Ipoh Area. In order to predict the annual average soil loss rate, the R, K, LS, C and P factors from the earlier estimations multiplied using the raster calculator function tool for ArcGIS10.3.

**Keywords:** Soil erosion, ArcGis, Usle, Ipoh, Soil erodibility

## Introduction

Soil erosion is one kind of soil degradation and typically associated with additional issues which can resemble low levels of organic matter within the soil, loss of soil acidity and soil structure. Singer and Munns (1999) construed soil erosion as a natural phenomenon that includes transit and deposition of soil molecule from one (Morgan, 2005)position to another. It has the ability to contribute to a myriad of complications as it occurs because of human activities despite being deemed as a natural phenomenon. According to Morgan (2005), regarding land preservation, humid and tropical regions have the tendency to encounter soil erosion habitually due to agricultural activities. Such activities encompass the crop yield, declining the quality of water and expansion of carbon and biodiversity. Tropek et al (2014) claimed that this occurrence happens because of increasing rainfall intensity, ill-advised management of land use and impoverished conditions of soil. At present, soil erosion contributes to the severity of natural assets reduction around the world. Marsh (1984), Oldeman et al (1990), and Stott and Sullivian (2000) concluded that the development of industries in a country or region on a wide scale, deforestation, overgrazing, fuelwood and agricultural activities are instrumental to the 3 most severe soil erosion complications.

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**Soil erosion**

Soil erosion is the displacement of the upper layer of soil, one form of soil degradation. This natural process is caused by the dynamic activity of erosive agents, that is, water, ice (glaciers), snow, air (wind), plants, animals, and human activities. In accordance with these agents, erosion is sometimes divided into water erosion, glacial erosion, snow erosion, Soil erosion may be a slow process that continues relatively unnoticed, or it may occur at an alarming rate causing a serious loss of topsoil. The loss of soil from farmland may be reflected in reduced crop production potential, lower surface water quality and damaged drainage networks.

**Study area - Ipoh**

Ipoh is in the state of Perak, which is in the northern part of Peninsular Malaysia. . Located by the Kinta River, it is nearly 180 km (110 mi) north of Kuala Lumpur and 123 km (76 mi) southeast of George Town in neighboring Penang. Ipoh contained a population of more than 657,892, making it the third largest city in Malaysia by population. The size of the city is about 643 square km (Figure 1).The city is in the middle of the Kinta Valley, on the bank of the Kinta River and the Sungai Perak, the second longest river in Malaysia, The Kledang mountain range stretches from the north to the west of the city. This range runs parallel to the Bintang mountain range with the Perak River flowing on its left bank and the Kinta River to its right. Ipoh sees high precipitation throughout the year with an average of 200 mm (7.9 in) of rain each month and averaging 2,427.9 mm (95.59 in) of rain per year. The wettest month is October where on average 297.2 mm (11.70 in) of rain is seen. Ipoh's driest month is January which has 132.3 mm (5.21 in) of rainfall on average. With high intensity of tropical rainfall and short durations the erosivity of rain and runoff are main causes for loosening the soil, weakening slopes and ultimately leading to mass movements of solid and semi-solid materials such as soil creep, land slips and landslides.


Figure 1. Peninsular of Malaysia

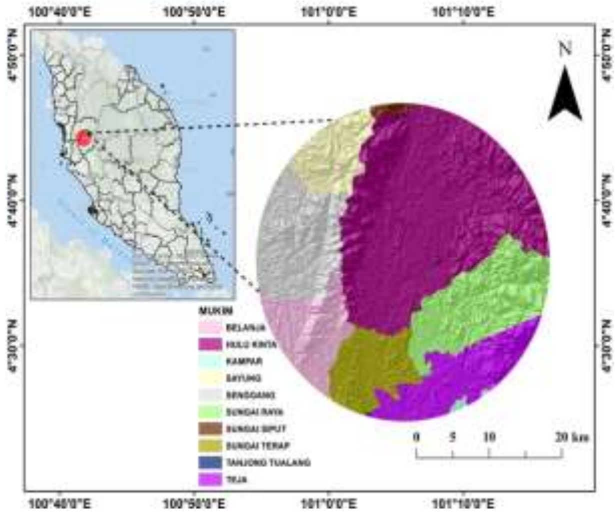


Figure 2. The location map of the study area.n

**Universal Soil Loss Equation (USLE)**

The use of universal soil loss equation (USLE) index model is highly acknowledged in both agricultural and hilly watersheds because of its beneficial points as compared to the others tool to desegregate disparate data sets and in a position to evaluate any dynamic system like soil erosion. It is the primarily favored analytically based model used worldwide for soil erosion prediction and management, also the USLE can redict the long-term average annual soil loss associated with sheet and rill erosions. The USLE incorporates improvements in the factors based on new and better data but keeps the basis of the USLE equation.

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Additional research and experience have resulted in an upgrade of the USLE from the past 30 years.The USLE was enhanced by revising the weather factor, the soil erodibility factor depending on seasons, revising the gradient and length of slope and developing a new method to calculate the cover management factor. The USLE assumes that detachment and deposition are controlled by the sediment content of the flow. Erosion is limited by the carrying capacity of the flow but is not source limited (Munodawafa, 2007)Detachment will no longer take place when the sediment load has reached the carrying capacity of the flow. The USLE equation is shown below (Lu *et al.*, 2004):

**A = R ´ K ´ LS ´ C ´ P**

Where:

**A** – Annual soil loss, in tons per hectare per year

**R** – Rainfall erosivity factor, an erosion index for the given storm period in MJ.mm/ (ha.hr. year)

**K** – Soil erodibility factor, a measure of soil particle susceptibility to detachment and transport by rainfall and runoff.

**LS** – Topographic factor which represents the slope length and slope steepness. It is the ratio of soil loss from a specific site to that from a unit site having the same soil and slope with a length of 22.1 meter

**C** – Cover management factor, which represents the protective coverage of canopy and organic material in direct contact with the ground. It is measured as the ratio of soil loss from land cropped under specific conditions to the corresponding loss of tilled land under clean-tilled continuous fallow conditions.

**P** – Support practice factor which represents the soil conservation operations or other measures that control the erosion. It is measured as the ratio of soil loss with a specific support practice to the corresponding loss with ploughing up and downslope(Kouli *et al.*, 2009) .

**Data Collection**

Three main types of data used in this study are satellite data, land use maps, and topographic map.

**Rainfall Erosivity Factor (R)**

Rainfall and runoff considered a vital role in the progression of soil erosion and are together usually expressed as the R factor. The larger the intensity and duration of the rainstorm, the higher the erosion potential (Prasannakumar *et al.*, 2011).The rainfall erosivity factor (R factor) represents the erosion potential caused by rainfall. The rainfall erosivity factor (R factor) for the particular locality is the average annual total of the storm EI30 values for that locality. The R factor is considered to be the most highly correlated index to soil loss at many sites throughout the world; (Wischmeier and Smith, 1978) . In this study the Rainfall data was obtained from the Hydrological Station of the Department of Irrigation and Drainage (DID) Malaysia. (10) Rain gauge stations selected of study area to get the annual average of rainfall at study area

In this research, Arnoldus equation was applied to compute the R factor equation

**R=P×0.5**

In this equation

R= rainfall and runoff erosivity factor in MJ mm ha_1 year for 10 rain gauge stations of the study area.

P= mean annual rainfall in mm . (Devatha *et al.*, 2015).

**Soil Erodibility Factor (K)**

$$K = \frac{2.1\, M \times 1.14 \times 10-4 \times (12-OM) + 3.25 \times (S-2) + 2.5 \times (P-3)}{100 \times 0.317}$$

Where:

K = Soil Erodibility.

M = product of (% Silt + % Very Fine Sand) × (% Fine Sand + % Medium.Sand + % Coarse Sand).

OM= the percent of Organic Matter.

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S = Soil Structure Code.

P = Soil Hydraulic Permeability Class.(Elsheikh *et al.*, 2015)

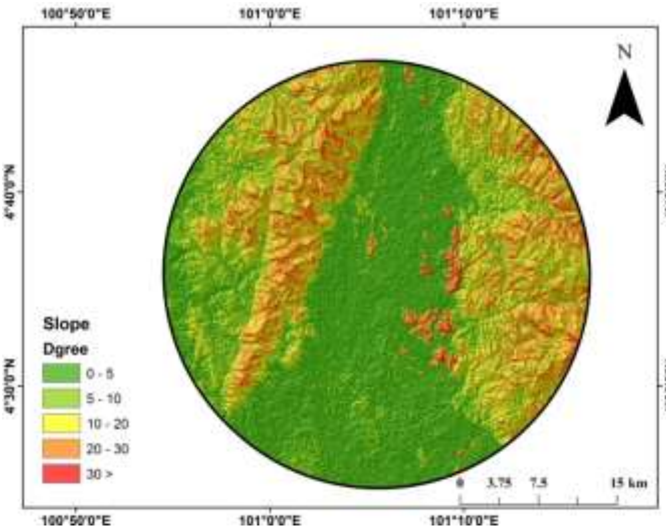
The soil erodibility factor (K factor) measures the susceptibility of soil particles as affected by intrinsic soil properties(Wade *et al.*, 2012). Also, it is detachment from the amount of rainfall and runoff input (Renard, *et al.*, 1997). It is known that the most easily eroded soil particles are silt and very fine sand and the less erodible. K factor depends on the organic matter and texture of the soil, its permeability and profile structure. It varies from 70/100 for the most fragile soil to 1/100 for the most stable soil. It is measured on bare reference plots 22.2 m long on 9% slopes, tilled in the direction of the slope and having received no organic matter for three years.soil particles are aggregated soils because they are accrued together making it more resistible.(Wischmeier and Smith, 1978) the USLE model was applied and K factors of each soil series were considered as constant values during a year.

This result depicts that the area with very low soil erosion has the K-factor of 0.012. This implies that it has high resistance of soil detachment. Whereas, the area with the highest K-factor is the area with very high soil erosion at the value of 0.075. It indicates that the land can be easily destroyed, has the tendency to crust as well as induces high rate of runoff.

**Slope Length and Slope Steepness Factor (LS)**

The Slope Length and Steepness Factors (LS) factor represent erodibility due to mixtures of slope length and steepness relative to a standard unit plot. It expresses the effect of topography, specifically hillslope length and steepness, on soil erosion. Enlarge in hillslope length and steepness results in enlarge in the LS factor The slope length factor (L) is defined as the distance from the source of runoff to the point where either deposition begins or runoff enters a well-defined channel that may be part of a drainage network.(Jamshidi *et al.*, 2012)

There are many relationships available for estimation of LS factor. Among these, the best suitable relative for integration with GIS is the theoretical relationship proposed by Moore and Wilson 1992 based on unit stream power theory given below. Slope shape, the interaction of angle and length of slope, has an effect on the magnitude of erosion. As a result of this interaction, the effect of slope length and degree of slope should always be considered together.(Zhang *et al.*, 2013)



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The outcome of L-factor and S-factor, ensuing the combination of LS-factor, is depicted in figure 7. It can be deemed that the LS-factor varies from 0 to greater than 32.087 in the catchment area. A large portion of the catchment presents low LS-factor values. However, some particular areas with steep slopes such as slopes across the rivers and the foothill structures present alongside the top of the mountains, have comparatively substantial LS-factor values.

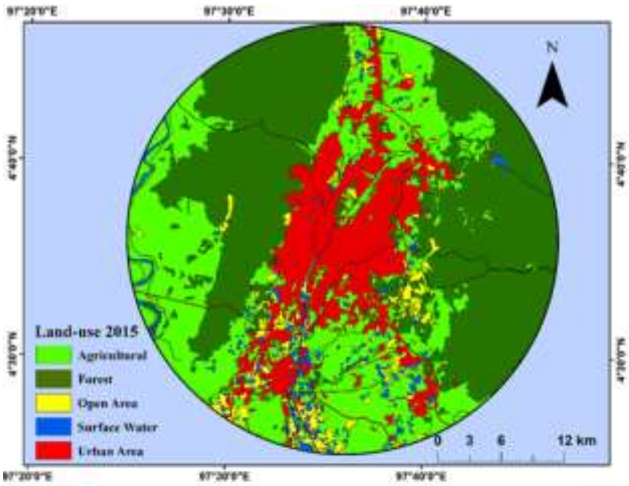
**Cover Management Factor (C) and Support Practice Factor (P)**

The Land Cover Management Factor (C) is used to express the effect of plants and soil cover. Plants can decrease the runoff velocity and defend surface pores. The C-factor measures the combined effect of all interrelated cover and management variables, and it is the factor that is most readily changed by human activities. It varies from 1 on bare soil to 1/1000 under forest, 1/100 under grasslands and cover plants, and 1 to 9/10 under root and tuber crops. and it is defined as the ratio of soil loss from specific crops to the equivalent loss from tilled, bare test-plots (Gitas *et al.*, 2009) (Ganasri and Ramesh, 2016). The value of C depends on vegetation type, stage of growth and cover percentage.

The support practice factor P represents the effects of those practices such as contouring, strip cropping, terracing, etc. that help prevent soil from eroding by reducing the rate of water runoff. The P value range 0 to 1 where 0 represents very good manmade erosion resistance facility and 1 represents no manmade erosion resistance facility.

**Result And Discussion.**

The final results of the land use map in the study area showed that the highest percentage of land use in the region is forests, where about 386 km2, The second larges of the total area used in the study followed by agricultural land where the final percentage was 575.18 km2. And then the rivers and water in the study area, where about 30.23km2 of the total area and the results also showed that open areas are the lowest proportion in the region, as we noted that the region is experiencing the development of urban land and agricultural recently.




| Land-use type | Land-use in the study area | |
|---|---|---|
| | Area km$^2$ | Area % |
| Agricultural | 386.9 | 30.3 |
| Forest | 575.2 | 45.1 |
| Open Area | 118.7 | 08.3 |

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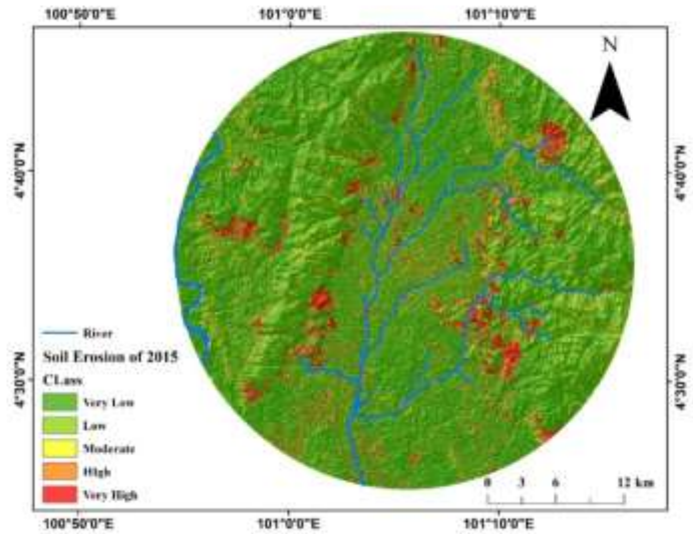
| | | |
|---|---|---|
| Surface Water | 30.2 | 02.4 |
| Urban Area | 183.1 | 14.3 |
| **TOTAL** | **1276.7** | 100 |

**Table 1.** Soil erosion potentia potentials are categorised into 5 different classes.

| Erosion Class | Erosion Rate(ton/ha/yr) | Soil Erosion Potential | Area (km2) |
|---|---|---|---|
| 1 | 0-1 | Very Low | 115329.2 |
| 2 | 1-5 | Low | 4656.5 |
| 3 | 5-10 | Moderate | 1994.5 |
| 4 | 10-20 | High | 1141.6 |
| 5 | 20-100 | Very High | 3676.7 |
| | | **TOTAL** | **1267.98** |




The table above shows that by year 2015, the area with very low possibility of soil erosion has expanded to 115329.2 hectare. Whereas, the area with low possibility of soil erosion has enlarged to 4656.5 hectare by the same year. The area with moderate possibility of soil erosion has extended to 1995.4 hectare while the areas with high and very high possibility of soil erosion have grown to 1141.6 hectare and 3676.7 hectare respectively. This implies that due to high value in P-factor which denotes adequate land protection and conservation received, the expansion of very high risk area has reduced substantially. This can also be seen in the graph in figure 8. The extremely risky areas are located at the foothills whereas the minimal risk areas includes a significant amount of land the in the catchment.

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