DETERMINATION OF R, LS, C AND P FACTORS IN UNIVERSAL SOIL LOSS EQUATION FOR KUANTAN RIVER BASIN

VIVIAN LEE KAH YEE

B. ENG (HONS.) CIVIL ENGINEERING

UNIVERSITI MALAYSIA PAHANG

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VIVIAN LEE KAH YEE

Thesis submitted in fulfillment of the requirements
for the award of the
Bachelor Degree in Civil Engineering

Faculty of Civil Engineering & Earth Resources

UNIVERSITI MALAYSIA PAHANG

JUNE 2018

ACKNOWLEDGEMENTS

Firstly I would like to thank my parents, Lee Foo Ming and Ti Teow Ai who have been supporting me mentally and financially for all the love showered upon me. Without my parents, I will not be who I am today. Next, I would like to express my gratitude to my Final Year Project supervisor, Dr Ngien Su Kong for his guidance. He was very resourceful and always gives me constructive feedback. Lastly, I would like to thank everyone who had helped me in completing this project.

ABSTRAK

Universal Soil Loss Equation (USLE) digunakan untuk menganggarkan purata hakisan tanah yang dijana dari Kuantan River Basin. Penggunaan USLE baru-baru ini semakin popular dalam industri untuk mendapatkan purata kehilangan tanah dan keberkesanan amalan kawalan pelan di kawasan tadahan pertanian integrasi Sistem Maklumat Geografi (GIS). Kajian ini dilakukan untuk meramalkan risiko hakisan tanah oleh kaedah USLE / GIS untuk merancang langkah pemuliharaan di tapak. Faktor erositi hujan(R), faktor topografi (LS), faktor pengurusan perlindungan (C) dan Faktor Amalan Pengurusan Hakisan (P) dikira dari data hujan, peta dan penggunaan tanah. Faktor erositi hujan dihasilkan dengan menggunakan peta erositi hujan di Guideline for Erosion and Sediment Control Malaysia dan didapati bahawa Faktor R di kawasan dekat dengan pantai lebih tinggi daripada Faktor R di kawasan dalaman Seterusnya, faktor LS dikira dengan menggunakan persamaan di mana panjang dan kecerunan diekstrak dari peta topografi. Akhir sekali, faktor C dan P setiap kawasan dijana dengan menggunakan perisian ArcGIS. Nilai-nilai C dan P diekstraksi dari kajian-kajian terdahulu dan diberikan kepada setiap poligon yang unik berdasarkan sifat-sifat pengurusan tanah dan pengurusan hakisannya. Kalau Faktor C dan P dekat dengan 1, maka kurang berkesanlah pengurusan tanah dan pengurusan hakisan dalam mengurangkan hakisan. Keputusan menunjukkan bahawa kadar hakisan tahunan berbeza antara 0.24 hingga 400.61ton/ ha/ tahun mengikut USLE.

ABSTRACT

The Universal Soil Loss Equation (USLE) model is used to estimate average soil loss generated from Kuantan River Basin. Use of the USLE has recently been extended for predicting soil loss and plan control practices in agricultural catchment by the effective integration of Geographic Information Systems (GIS) based on procedures to estimate the factor values in a grid cell basis. This study was performed to predict the soil erosion rate using the USLE/GIS methodology for planning conservation measures in the site. Rainfall erosivity (R), topographic factor (LS), cover management factor (C) and erosion management practices factor (P) values for the model were calculated from rainfall data as well as topographic and land use maps. Rainfall erosivity factor was generated by using rainfall erosivity map in Guideline for Erosion and Sediment Control Malaysia and it is found that the nearer is the location to the coast, the higher is the R factor. Next, LS factor is calculated by using an equation where the slope length and slope steepness are extracted from the topography map. Lastly, C and P factors of each sub basin are generated by using ArcGIS software. C and P values are extracted from previous studies and are assigned to each unique polygon base on their landuse and landcover properties. The closer are the C and P factors to 1, the less effective are the landcover and erosion control practices in reduce erosion. The results show that annual erosion rate for each sub basin in Kuantan River Basin varies between 0.24 to 400.61t/ha/year according to USLE.

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LIST OF SYMBOLS

e_r	Unit Kinetic Energy (MJ/ha.mm)
V_r	Total Rain Depth for Rth Interval (mm/hr)
i	Intensity (mm/hr)
E	Total Kinetic Energy
L	Slope Length Factor
λ	Sheet Flow Path Length (m or feet)
φ	72.6 foot for Imperial Units or 22.13m for SI
A	Annual Soil Erosion Rate
R	Rainfall Erosivity Factor
K	Soil Erodibility Factor
LS	Slope Length and Slope Steepness Factor
C	Cover Management Factor
P	Erosion Control Practices Factor

LIST OF ABBREVIATIONS

USLE	Universal Soil Loss Equation
WEPP	Water Erosion Prediction Program
RUSLE	Revised Universal Soil Loss Equation
MUSLE	Modified Universal Soil Loss Equation
MSMA	Manual Saliran Mesra Alam
JUPEM	Jabatan Ukuran dan Pemetaan Malaysia
LULC	Landuse and Landcover
FAO	United Nation Food and Agriculture Organisation
KRB	Kuantan River Basin
DID	Department of Irrigation and Drainage
GIS	Geographical Information System
OM	Organic Matter
LOI	Loss On Ignition
PSD	Particle Size Distribution

CHAPTER 1

INTRODUCTION

1.1 Background

Malaysia is a country located strategically near to the equator, which provide equatorial climate with both ample sunshine and precipitation. The average rainfall Malaysia receives annually is approximately 250mm from 1901 to 2015 ("Malaysia Average Precipitation," n.d.). However, different parts of the country will receive different amount of precipitation. The highest precipitation recorded in a year is 5687mm of rainfall which took place at Sandakan, Sabah during year 2006 whereas the lowest recorded is at Tawau with precipitation volume of 1151mm recorded. With an annual average precipitation volume of 4159mm and 279 rainy days in a year, Kuching of the state of Sarawak is considered the wettest state of Malaysia, whereas Sitiawan, Perak is called the driest with annual average rainfall of only 1787 mm ("MetMalaysia: Laporan Tahunan," n.d.).

As an important component in the water cycle, rainfall happens very frequently here in Malaysia. Not only it nourishes the ground and brings life to greens, rain water continues to replenish our ground water table, which keeps the ecology system working properly. When rain water fall onto ground, the moisture undergo a process called infiltration where rainwater seeps into soil. Parts of this moisture stored in soil will replenish soil minerals and part of it will contribute to groundwater table. However, there are chances when rainfall cannot be infiltrated into soil, and surface runoff is formed. Surface runoff will wash away loose soil particles and transport them to downstreams of rivers. It is one of the major reasons that contribute to soil loss in Malaysia. Moreover due to the increasing effect of global warming, the occurrence of heavy precipitation also increased (Pour, Harun, & Shahid, 2014). Estimation of soil loss of Malaysia in the year 1995 showed an average of 7.97 tonne/hour/year and the average soil loss for the year 2003 was 6.83 t/h/year, a decline of 15 percent (Said, 2008).

Soil erosion is a process of detachment and transport of soil particles from one place to another (Michael J. Singer; Donald N. Munns, 2006; Roose, 1996). Although soil erosion is a natural phenomenon, it can bring serious problems if not managed properly. One of the most serious that can be brought by soil erosion is land degradation. Based on the report by United Nations Food and Agriculture Organization (United Nations Food and Agriculture Organization (FAO), 2008), there are approximately 1.5 million people in this world who may starve because of lack of crop yields due to land degradation. This is why prevention and control of soil erosion rate is an important topic in soil conservation issues nowadays.

1.2 Problem Statement

The negative impacts brought by soil erosion rate can be divided into two categories, on-site effects and off site effects. Loss of soil is one of the on-site effects, where kinetic energy caused by rainfall will create a splatter effect on the ground, removing the soil particles on the surface layer of ground. This will cause over-exposure of roots of plants. Other than that, there are some non-renewable minerals in soil and soil nutrients that might be washed away by surface runoff (Guo, Liu, Xie, Liu, & Yin, 2015). Consequently, these will result in reduced yields of crops.

On the other hand, soil erosion can bring some off-site effects too, including pollution of waterbodies downstream, disruption of the ecosystem and disappearing water table. After detaching loose soil particles from ground, loosened soil particles will float in this moving stormwater and be transported by surface runoff to downstream areas. Consequently, this will adversely affect the water quality. Also, since these soil particles are opaque and will not dissolve in water, it will block the vision of aquatic organisms. Other than that, these particles might restrain plants respiration as they are floating in the water and might be inhaled into the organism. As time pass, loosened soil particles in the water will slowly settle down and become sediment. As a result, the water depth will decrease.

In this era, land degradation is a major issue all over the world as the rate of soil formation is a lot slower than the rate of soil erosion, especially with disturbance from human activities like deforestation and construction (Addis & Klik, 2015). There are a few methods developed to determine soil loss rate, namely the WEPP, RUSLE, MUSLE and USLE. Using the USLE model, the annual soil loss rate can be calculated based on a few parameters, which are rainfall erosivity, soil erodibility, slope length and slope steepness, crop management applied and lastly the practice and erosion control applied. There are many soil loss assessment conducted in different parts of Malaysia by utilising USLE (Khosrokhani & Pradhan, 2014; Mir, Gasim, Rahim, & Toriman, 2010a; Rizeei, Saharkhiz, Pradhan, & Ahmad, 2016) and the results varies spatially with different soil properties, human activities and slope. By using soil erosion data obtained from this study, areas prone to soil erosion can be identified and authority can rectify this problem accordingly.

1.3 Objective of Study

The objectives of the study are:

i. To determine the soil erosion rate in sub river basins of Kuantan River Basin.
ii. To develop soil erosion risk map for Kuantan River Basin.

1.4 Scope of Study

The scope of this research includes determination of annual surface soil erosion rate due to water erosion in Kuantan River Basin using the USLE. In this study, samples are collected from different sub basins in the Kuantan River Basin for computation of factors involved in USLE. The rainfall erosivity factor, R is obtained from the Rainfall Erosivity Map of Peninsular Malaysia published in Manual Saliran Mesra Alam 2.0 (MSMA 2) while the slope length and slope steepness factor, LS is generated from topography map of Kuantan River Basin obtained from JUPEM. Other than that, ArcGIS software is also used to determine the sampling locations and to analyse areas of different land use and land cover. The land use and land cover will be used to determine Cover Management Factor, C and Erosion Control Practice Factor, P.

1.5 Significance of Study

In December of year 2014, the state of Pahang has encountered a massive flood. There are many reasons this flood took place, such as lack of vegetation cover, rise of ground water tables and so on. The objectives of this study are to determine the annual soil erosion rate and develop the soil erosion risk map of sub basins of Kuantan River Basin. This soil erosion risk map can contribute in predicting areas of high flood risk.

CHAPTER 2

LITERATURE REVIEW

2.1 Background

Generally, soil erosion models can be divided into two categories, namely empirically based and process-based models. Process-based models, also known as physically based models are based on theoretical understandings of processes of the same nature classified together to get a framework to incorporate specific responses under different circumstances (Chandramohan, Venkatesh, & Balchand, 2015). One of the examples of process-based soil erosion models is the WEPP.

Empirical based models are based on experience and observation of large amount of field data, usually without regarding on theory. USLE is derived from large amount of field data. The USLE equation is the first empirically based soil erosion model created that is not limited by the experiment locations. Hence the title of the equation, "Universal" Soil Loss Equation. USLE is presented in Equation 1:

$$A = RKLSCP$$

Equation 1

Where A = Annual Soil Loss Rate

R = Rainfall Erosivity Factor

K = Soil Erodibility Factor

LS = Slope Length and Slope Steepness Factor

C = Cover Management Factor

P = Erosion Control and Practice Factor

Limitations of USLE are listed as follows:

1. Only considered sheet erosion and rill erosion but not gully erosion.
2. USLE is only applicable for average data that is over 20 years. It is not valid for individual storm events. (Department of Irrigation and Drainage, Malaysia; Ministry of Natural Resources and Environment, 2010)

2.1.1 Rainfall and Surface Runoff

When rain falls on the ground, some parts of the stormwater will be infiltrated into the ground and absorbed as moisture for soil. Dry soil as a porous medium is a good infiltration medium in nature. Eventually, as more moisture is absorbed, soil is more saturated, and will slow down the infiltration process. When the stormwater flowing rate is greater than the infiltration rate of soil, excessive stormwater that is not infiltrated into soil will continue to flow on the ground and form surface runoff (Department of Irrigation and Drainage, Malaysia; Ministry of Natural Resources and Environment, 2010).

Other than that, surface runoff is also formed when the ground is impervious. Stormwater will then flow following the gravity to the surrounding soil for infiltration. This phenomenon is especially frequent in developed areas where soil is usually covered by roads and building. If surface runoff is not managed properly, it can cause urban floodings and result in damage of building and infrastructures.

Surface runoff is a major component of the water cycle. It however, is also the culprit of soil degradation and erosion. Soil erosion is one of the major hydrological problems in tropical country (Wijitkosum, 2012). There are a few stages of erosion: the first stage being splash erosion followed by sheet erosion, then rill erosion and finally gully erosion.

2.2 Formation of Soil Erosion due to Rainfall

2.2.1 Splash Erosion

Splash erosion is the first stage of the soil erosion process. Splash erosion happens when rain droplets fall on the bare ground. The kinetic energy of rain has a splashing effect, breaking the surface of the soil and creating a small cavity. The separated soil particles are splashed onto the surrounding soil surface, and consequently form a layer of crust that reduce infiltration rate. Splash erosion is the least severe among the four stages of soil erosion (Department of Irrigation and Drainage, Malaysia; Ministry of Natural Resources and Environment, 2010).

2.2.2 Sheet Erosion

Sheet erosion is a form of soil redistribution and it can be defined as the uniform removal of detached soil particles over a large area by overland flow and travel from the surface of the profile (Heung, Bakker, Schmidt, & Dragićević, 2013). It does not follow any definite channels. Although the loss in soil is usually very minimal, the cumulative amount will bring an adverse effect to the soil (Department of Irrigation and Drainage, Malaysia; Ministry of Natural Resources and Environment, 2010). Sheet erosion often results in removal of an extensive area of topsoil and if left unattended, it can result in loss in organic soil nutrients and eventually adversely affect soil productivity. Symptoms of sheet erosion are instant water puddling as rain falls, bare areas without any vegetation and exposed root of plants.

2.2.3 Rill Erosion

Sheet erosion will eventually develop into rill erosion, where runoff will move into a system of small channels. Rills can be defined as micro-drainage which are less than 0.3m deep (Department of Irrigation and Drainage, Malaysia; Ministry of Natural Resources and Environment, 2010). They are formed when runoff are concentrated down a slope and will wash the soil away. Rill erosion is the intermediate stage between sheet erosion and gully erosion.

2.2.4 Gully Erosion

Gullies are channels that are deeper than 0.3m. Gully erosion happens when stormwater from rill erosion accumulates and flow rapidly into channels, removing soil to a considerable depth greater than 0.3m (Department of Irrigation and Drainage, Malaysia; Ministry of Natural Resources and Environment, 2010). Gully erosion is the presentation of catchment instability (Ionita, Fullen, Zgłobicki, & Poesen, 2015). It can erode the soil layer deep enough to reach subsoil layers. Therefore, if not controlled, it can damage the surrounding infrastructures like road and building. Deforestation and substitution by crops are among the contributing factors for development of gully and soil loss (García-Ruiz, 2010). Figure 2.1 shows the development of erosion from sheet erosion to gullies erosion.

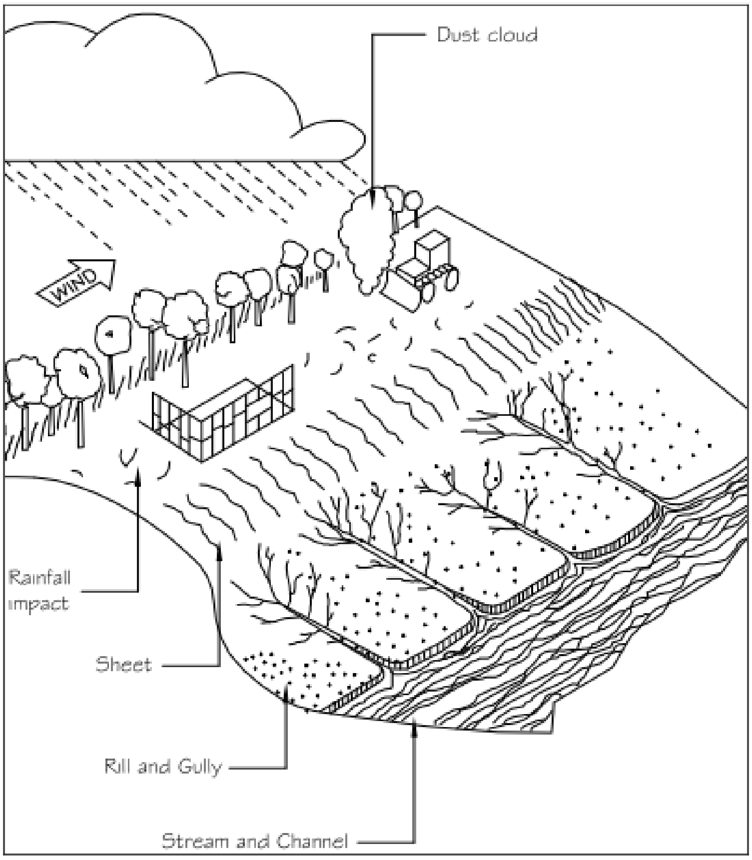


Figure 2.1: Types of Erosion Occurring at Construction Site (Department of Irrigation and Drainage, Malaysia; Ministry of Natural Resources and Environment, 2010)

2.3 Rainfall Erosivity Factor, R

The Rainfall Erosivity Factor, R represents the impacts of kinetic energy brought by rain when raindrops fall on the ground. Different R values represent different intensities of climate erosivity. In most cases, the primary agent of erosion is rainfall. During a rainstorm event, rain droplets fall on the ground, creating a striking force that consequently have a splashing effect on the soil, loosening the soil on the ground surface.

Some of the moisture from rainfall will infiltrate and percolate into the ground, until the soil reaches 100% saturation. The leftover rain will become surface runoff, washing away and bringing loosened soil particles downstream. When the soil particles has stopped moving and remained at one location, usually where the slope gradient is the flattest, it is called deposition of soil. Deposition of soil particles can happen at downstream or at mid-stream where the slope gradient is still decreasing. R factor also reflects the runoff amount and rate associated with rainfall. Figure 2.2 shows the development of soil erosion.

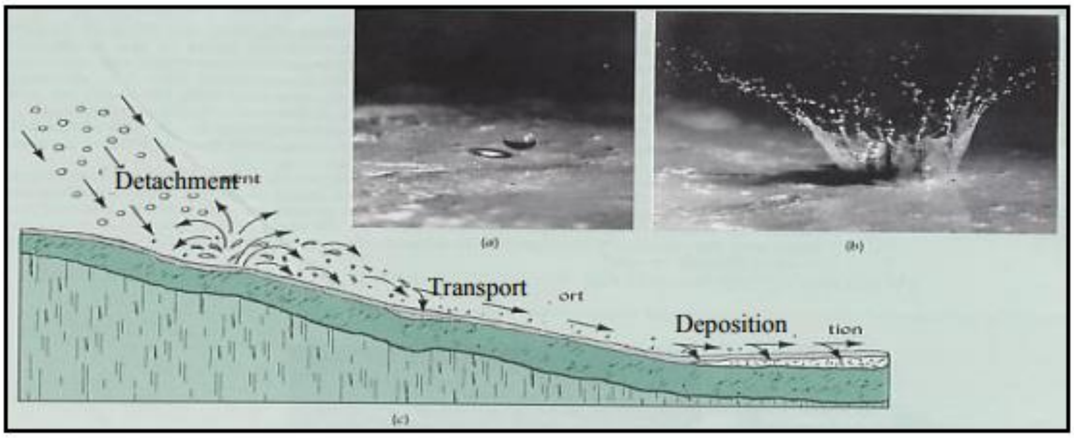


Figure 2.2 Mechanics of Soil Erosion (Weil, Raymond R; Brady, 2016)

The rainfall erosivity (R) can be defined as the product of event kinetic energy (E) and the maximum rainfall intensity in 30 minutes, I_{30} (Wischmeier, Smith, Wischmer, & Smith, 1978). When other factors affecting soil erosion rate are held constant, soil losses are assumed to be directly proportional to this product. The kinetic energy from rainfall, E reflects the volume of rainfall and runoff. A slow but long rain may have the same E value as a shorter but heavier downpour (Renard, Foster, Weesies, & Porter, n.d.) On the other hand, I_{30} represents the prolonged peak rates of detachment and runoff in a storm. Other than that, it is understood that R factor is calculated based on the mean annual precipitation.

2.4 Slope Length and Slope Steepness Factor, LS

The L and S depict the influence of slope length and slope gradient on the soil erosion rate on a slope, respectively. The L factor is the ratio of field soil loss from a slope relative to that of a standard slope. The slope length, L is the horizontal distance between where the overland flow starts to flow and the point where the slope gradient reduce until deposition of runoff is possible, or when runoff concentrates in a defined flow (Wischmeier et al., 1978).

The slope steepness factor, S represents the effect of slope gradient on field soil erosion. S factor is the ratio of soil loss of field slope steepness relative to that of a standard plot, which is a plot with 9 percent steepness, under otherwise identical conditions.

Table 2.1: Slope Length and Slope Steepness Factor, LS

Slope Steepness, s (%)	Slope Length, λ (m)											
	2	5	10	15	25	50	75	100	150	200	250	300
0.1	0.043	0.052	0.059	0.064	0.071	0.082	0.089	0.094	0.102	0.108	0.113	0.117
0.5	0.055	0.067	0.076	0.083	0.092	0.106	0.114	0.121	0.131	0.139	0.146	0.151
1	0.057	0.075	0.093	0.405	0.122	0.150	0.170	0.185	0.209	0.228	0.243	0.257
2	0.089	0.117	0.144	0.163	0.190	0.234	0.264	0.288	0.325	0.354	0.379	0.400
3	0.100	0.144	0.190	0.224	0.275	0.362	0.426	0.478	0.563	0.631	0.690	0.742
4	0.135	0.195	0.257	0.302	0.371	0.489	0.575	0.646	0.759	0.852	0.932	1.002
5	0.138	0.218	0.308	0.377	0.487	0.688	0.843	0.973	1.192	1.376	1.539	1.686
6	0.173	0.273	0.387	0.474	0.612	0.865	1.059	1.223	1.498	1.730	1.934	2.119
8	0.255	0.404	0.571	0.699	0.903	1.277	1.564	1.806	2.212	2.554	2.855	3.128
10	0.353	0.559	0.790	0.968	1.250	1.767	2.165	2.499	3.061	3.535	3.952	4.329
15	0.525	0.909	1.378	1.757	2.388	3.619	4.616	5.486	6.997	8.315	9.506	10.605
20	0.848	1.470	2.228	2.841	3.860	5.851	7.463	8.869	11.311	13.442	15.368	17.145
25	1.249	2.164	3.279	4.183	5.683	8.613	10.986	13.055	16.651	19.788	22.623	25.239
30	1.726	2.991	4.533	5.782	7.855	11.906	15.185	18.046	23.017	27.353	31.272	34.887
40	2.911	5.045	7.646	9.752	13.250	20.083	25.614	30.440	38.824	46.139	52.749	58.846
50	4.404	7.631	11.567	14.753	20.044	30.382	38.749	46.050	58.733	69.798	79.798	89.023
60	6.204	10.751	16.296	20.784	28.239	42.802	54.590	64.875	82.744	98.333	112.420	125.416
70	8.312	14.404	21.833	27.846	37.833	57.344	73.138	86.917	110.856	131.741	150.615	168.026
80	10.728	18.590	28.177	35.938	48.827	74.008	94.391	112.174	143.070	170.025	194.383	216.854
90	13.451	23.309	35.329	45.060	61.221	92.793	118.350	140.648	179.386	213.182	243.723	271.898
100	16.482	28.560	43.289	55.212	75.014	113.700	146.016	172.337	219.803	261.214	298.637	333.159

2.5 Crop Management Factor, C

Crop Management Factor, C represents different types of covers provided to protect and prevent the bare ground from the impact of rain splashing. C factor can be considered as the most important factor in USLE (Rizeei et al., 2016). It is a combination of all the effects of all related cover and management variables. Vegetation gives protection to the soil by dispersing the kinetic energy from rain drop before they reach the soil surface. (Karaburun, 2010).

Under semi-arid climate, plant cover exceeding 60% can significantly reduce soil erosion (Sauer & Ries, 2008). The bigger is the C factor, the less effective the cover management is in reducing soil erosion rate. When C factor is 1, the effect of the particular soil cover used in soil erosion is close to negligible.

2.5.1 Plant Height

Soil erosion rate depends not only on the percentage of plant coverage, but also on the height of plants above the ground. Different plant heights on the ground can decrease the impact of rainfall to the land (Grant, 2016; Said, 2008). For instance, when the plant cover is 100% but the plant is 5m high, the erosion rate will be 75% of that on a bare plot. However, if the plant height is reduced to 2m high, the erosion rate will decrease drastically to 50% of a bare plot. It can be seen that in cases where plants are higher, raindrop energy falling from tall plants is similar to those falling directly from the sky. Therefore, it can be deduced that the effect of tall plants in preventing soil erosion can be considered as negligible.

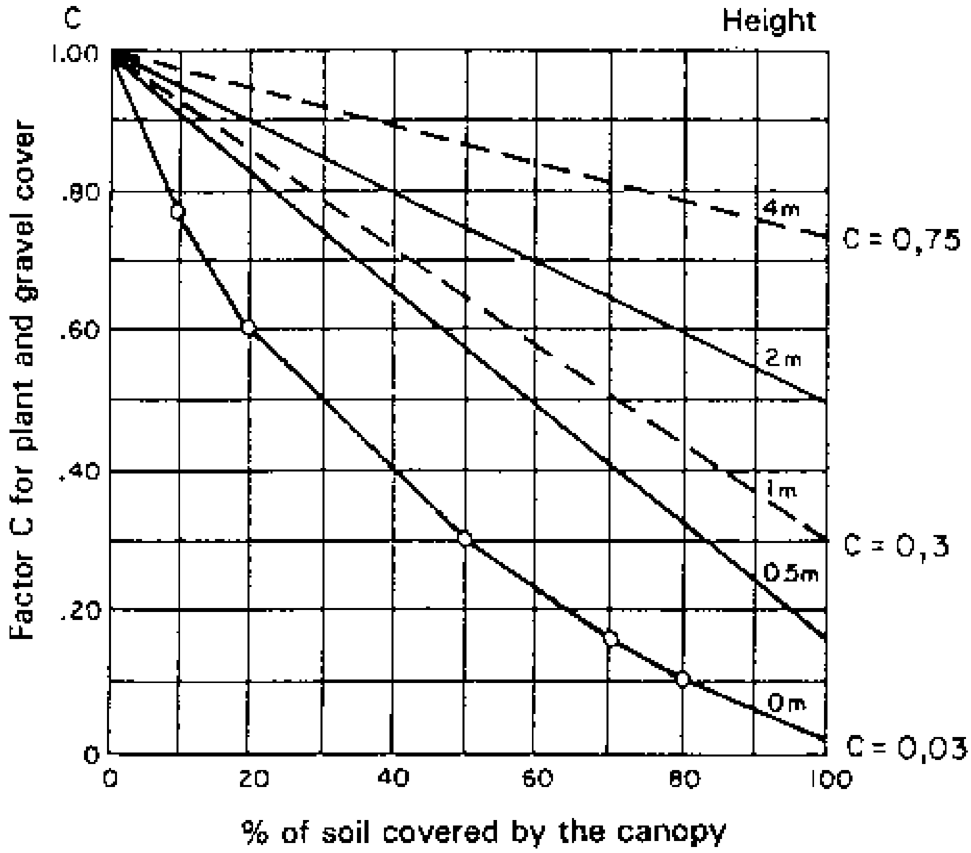


Figure 2.3: : Types of Erosion Occurring at Construction Site (Department of Irrigation and Drainage, Malaysia; Ministry of Natural Resources and Environment, 2010)

From Figure 2.3, the cover height is inversely proportional to the Crop Management Factor. At 100% soil coverage, a 4m high plant will bring a C factor of 0.75 whereas a 2m high plant will only have a C factor of 0.5. This means that the higher is the plant height, the bigger is the C Factor, that is, the less effective is the plant in reducing soil erosion rate, as the raindrops pick up fresh energy.

To provide better plant coverage in areas with greater plant height, mulching is introduced. Mulching is a layer of material put on the surface of bare soil to cover the soil. It helps in reducing soil erosion rate by holding raindrops during the event of a storm and hence reducing splattering and soil erosion rate. In this case, it is the mulch which absorbs the energy from raindrops and runoff. Mulch is usually but not exclusively organic. Together with canopy created by taller plants, mulching can greatly reduce soil erosion rate. Figure 2.4 shows how vegetation on the ground helps to reduce erosion.

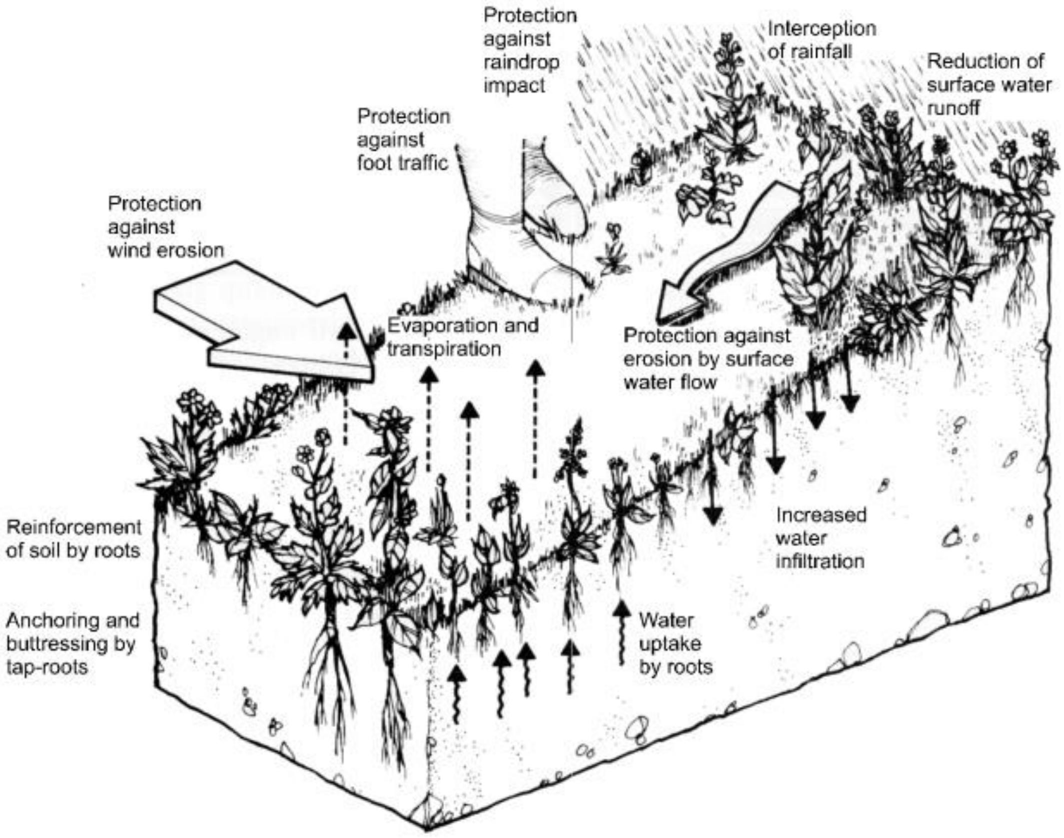


Figure 2.4: Effect of Vegetation on Erosion (Coppin & Richards, 2007)

2.5.2 Plant Architecture

The architecture of plants in this case represents the sculptural organization of the plant above the ground, including the pattern of the branching system, size, shape and position of leaves and flowers. During the event of a rainstorm, raindrops will first fall on plant covers and then to the ground. Therefore, the plant architecture definitely will affect the development and the intensity of soil erosion caused by rainstorm.

Umbrella-like plants, like cassava and banana will not retain the rain droplets. Instead, they will disperse the raindrops energy as rain droplets flow down outwards the leaves (Roose, 1996). Consequently, the soil erosion rate will be greatly reduced.

For trees with leaves and with greater height, rain droplets will flow towards the tree trunk. Finally, the water will accumulate at the foot of the trunk and form a gully. This occurs particularly with pineapple, but also - to a lesser extent - with maize.

Other than plant architecture, the roots formation of plants will also bring great influence to the soil erosion rate. Fasciculate roots can help to reduce soil erosion rate by holding the soil on the ground surface. Taproots on the other hand, will occupy the soil macropores when they grow in volume, and consequently reducing infiltration of stormwater into the soil (Roose, 1996). However, when taproots rot, they will leave hollow spaces stabilized by organic matter, which will later help in encouraging infiltration rate.

In MSMA, C factors for each type of land use are tabulated. These values are modified from previous studies.

Table 2.2: Cover Management, C Factor for Agricultural and Urbanized Areas (MSMA 2nd Edition, 2012)

Erosion Control Treatment	C Factor
Mining Area	1.00
Agricultural Area	
- Agricultural crop	0.38
- Horticulture	0.25
- Cocoa	0.20
- Coconut	0.20
- Oil Palm	0.20
- Rubber	0.20
- Paddy (with water)	0.21
Urbanized Areas	
- Residential	
▪ Low density (50% green area)	0.25
▪ Medium density (25% green area)	0.15
▪ High density (5% green area)	0.05
- Commercial, Educational and Industrial	
▪ Low density (50% green area)	0.25
▪ Medium density (25% green area)	0.15
▪ High density (5% green area)	0.05
- Impervious Parking lot, road, etc)	0.01

Table 2.3: Cover Management, C Factor for BMPs at Construction Sites (MSMA 2nd Edition, 2012)

Erosion Control Treatment	C Factor
Bare Soil/ Newly Cleared Land	1.00
Cut and Fill at Construction Site	
Fill - Packed, smooth	1.00
- Freshly disked	0.95
- Rough (offset disk)	0.85
Cut - Below root zone	0.80
Mulch	
Plant fibers, stockpiled native	
materials/chipped	0.25
- 50% cover	0.13
- 75% cover	0.02
- 100% cover	
Grass-seeding and sod	
- 40% cover	0.10
- 60% cover	0.05
- ≥ 90% cover	0.02
Turfing	
- 40% cover	0.10
- 60% cover	0.05
- ≥ 90% cover	0.02
Commpacted Gravel Layer	0.05
Geo-cell	0.05
Rolled Erosion Control product:	
- Erosion control blanket/ Turf reinforcement mats	0.02
- Plastic sheeting	0.02
- Turf reinforcement mats	0.02

Note: The values are compiled from Kuenstler, 2009; Layfield, 2009

Table 2.4: Cover Management, C Factor for Forested and Undisturbed Land (MSMA 2nd Edition, 2012)

Erosion Control Treatment	C Factor
Rangeland	0.23
Forest/Tree	
- 25% cover	0.42
- 50% cover	0.39
- 75% cover	0.36
- 100% cover	0.03
Bushes/Scrub	
- 25% cover	0.40
- 50% cover	0.35
- 75% cover	0.30
- 100% cover	0.03
Grassland (100% coverage)	0.03
Swamps/mangrove	0.01
Water body	0.01

Note: The values are compiled from Layfield, 2009

In this study, C factor values are extracted from the Tables 2.2, 2.3 and 2.4. The values were used in the soil loss assessment in Kuala Lumpur (Khosrokhani & Pradhan, 2014) and Penang Island (Pradhan, Chaudhari, Adinarayana, & Buchroithner, 2012). In these studies, the researchers identified the landuse and landcover by applying the support vector machine method on a satellite image with 10m spatial resolution. Four classes were indentified from this application, namely: water body, urban and settlement, bareland and vegetation (Table 2.5). Other than that, these C values are also extracted from other USLE assessment in Peninsular Malaysia (Mir, Gasim, Rahim, & Toriman, 2010b; Obaid & Shahid, 2017).

Table 2.5: C Factor Values

Landuse and Landcover Properties	C Factor Values
Water Body	0
Urban/Settlement	0.0015
Vegetation	0.0004
Bareland	1

2.6 Erosion Control Practices Factor, P

Erosion Control Practices Factor, P represents the ratio between the soil loss rate on a piece of land treated by management practices and that of a standard plot. It is a factor that presents the effects of a particular conservation practice in soil, like contour furrowed surface, terracing and silt fencing (Mir et al., 2010a). These management practices will affect soil erosion rate by altering the flow pattern and direction of moving stormwater and rainfall runoff and consequently affect the soil infiltration rate. The higher is the P factor, the less effective is the conservation management applied on the ground. For areas without any support practice applied, P factor can be taken as 1 (Simms, Woodroffe, & Jones, 2003). In soil loss assessment of Semenyih watershed (Rizeei et al., 2016), P factor was generated from landcover maps.

Biological conservation management tends to have a better resistance toward soil erosion rate than mechanical techniques like terracing and ridging. Examples of biological conservation practices are soil cover, plants cover, correct tillage and mulching. However, it is understood that the mechanical methods are more expensive than biological methods. Nevertheless, mechanical techniques receive much fuller treatment in soil conservation manuals, and are advocated more often than not without prior adaptation studies (Roose, 1996). In addition, it is more difficult to implement biological methods in drier area, therefore mechanical methods should be performed as soon as possible so that plants cover can be developed and help to replenish the ground as quickly as possible.

In MSMA, P factors for each type of land use are tabulated. These values are modified from previous studies.

Table 2.6: Support Practice, P Factor for BMPs at Construction and Development Sites (MSMA 2nd Edition, 2012)

Support/Sediment Control Practice		P Factor
Bare Soil		1.00
Disked Bare Soil (rough or irregular surface)		0.90
Wired Log/Sand Bag Barriers		0.85
Check Dam		0.80
Grass Buffer Strips (to filter sediment laden sheet flow)		
Basin Slope (%)		
- 0 to 10		0.60
- 11 to 24		0.80
Contour Furrowed Surface (Maximum Length refers to Downslope Length)		
Slope (%)	Maximum Length (m)	
1 to 2	120	0.60
3 to 5	90	0.50
6 to 8	60	0.50
9 to 12	40	0.60
13 to 16	25	0.70
17 to 20	20	0.80
>20	15	0.80
Silt Fence		0.55
Sediment Containment Systems (Sediment Basins/Traps)		0.50
Berm Drain and Cascade		0.50
Terracing		
Slope (%)		
- 1 to 2		0.12
- 3 to 8		0.10
- 9 to 12		0.12
- 13 to 16		0.14
- 17 to 20		0.16
- >20		0.18

Note: The values are compiled from Kuenstler, 2009; Layfield, 2009

2.7 Research Gap

In the previous studies investigating annual soil erosion rate using USLE equation, there are many countries that are studied, including some states in Malaysia like Johor. However, there are no research that focus on studying annual soil erosion rate for Kuantan River Basin. Therefore, this study will be the first study to investigate annual soil erosion rate from Kuantan River Basin.

Also, every study has its purpose of studying soil erosion, some are to determine the best erosion prevention practice, some are to reduce land degration that will affect yielding of crops. This study is to create a soil erosion risk map that will contribute to flood prevention.

CHAPTER 3

METHODOLOGY

3.1 Introduction

There are two different parts of computation method needed in this study. Firstly, samples to retrieve required soil information for Soil Erodibility Factor, K are collected. Other than that, GIS was used to compute the following factors. Figure 3.1 shows the sub basins in the study area.

a. Cover Management Factor, C

b. Erosion Control Practices Factor, P

Some of the factors or index required to compute soil erosion rate using USLE are very complex and require data of long time span. Therefore, database developed by the previous studies was utilised to obtain the information needed. For example

a. Rainfall Erosivity Factor, R

b. Soil Erodibility Factor, K

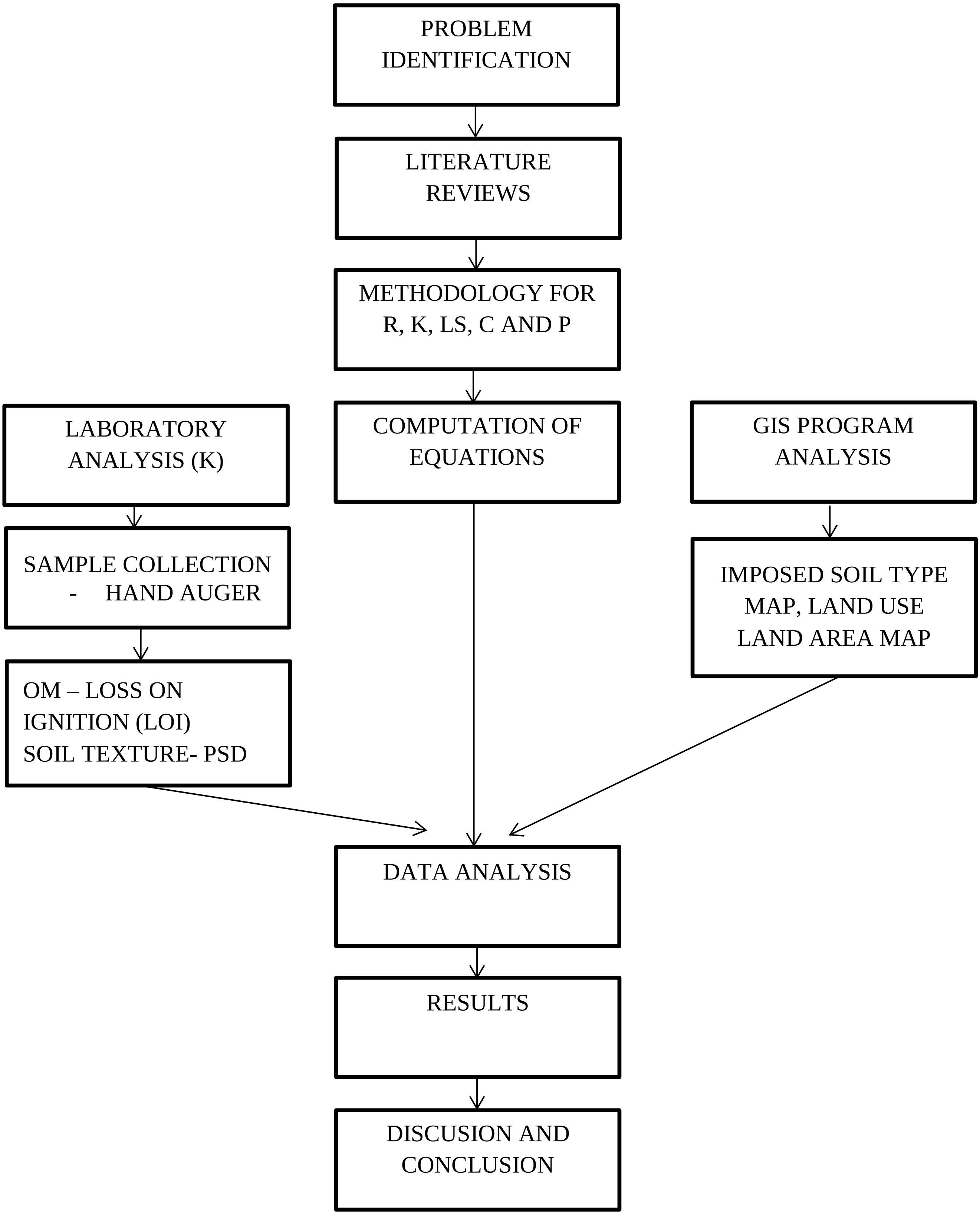
c. Slope Length and Slope Steepness Factor, LS

d. Cover Management Factor, C

e. Erosion Control Practices Factor, P

Figure 3.1: Kuantan River Basin

3.1.1 Process Flow Chart



3.2 Rainfall Erosivity Factor, R

Soil loss and EI_{30} have a linear relationship, which means the summation of EI_{30} values for a given period is the numerical measure of rain erosivity intensity within that period. R factor can be determined by Equation 2:

$$R = \frac{1}{n}\sum_{j=1}^{n}[\sum_{k=1}^{m}(E)(I_{30})_k]$$

Equation 2

Where, R = Rainfall Erosivity Factor (MJ.mm/ha.year)

E = Total Storm Kinetic Energy (MJ/ha)

I_{30}= Maximum 30 Minutes Rainfall Intensity (mm/hr)

j = Index for the Number of Years Used to Compute the Average

k = Index of the Number of Storms in Each Year

n = Number of Years to Obtain Average R

m = Number of Storms in Each Year

Since R factor cannot be based on temporal precipitation and only can be computed using mean yearly precipitation, rainfall gauge are installed to retrieve the rainfall data hourly. In long term, this could be a massive batch of data to be analyzed and organize. In addition, calculation of R factor is a complex and time consuming process as years are spent on data collection and the calculation is complex. Therefore, isoerodent maps (Wischmeier et al., 1978) were developed to simplify the computation, where the respective rain erosivity factor can be generated according to the area selected directly. Isoerodent maps are developed using Equation 3 and Equation 4

$$e_r = 210 + 89log_{10}(i_r), \qquad i_m \leq 7.6\ cm/hour$$

Equation 3

$$e_r = 288.4, \qquad i_m > 7.6\, cm/hour$$

Equation 4

$$R = EI_{30} = e_r V_r I_r$$

Equation 5

Where, e_r = Unit Kinetic Energy (MJ/ha.mm)

V_r = Total Rain Depth for Rth Interval (mm/hr)

i = Intensity (mm/hr)

The rainfall erosivity map, presenting R factor in Peninsular Malaysia is shown in Figure 3.2:

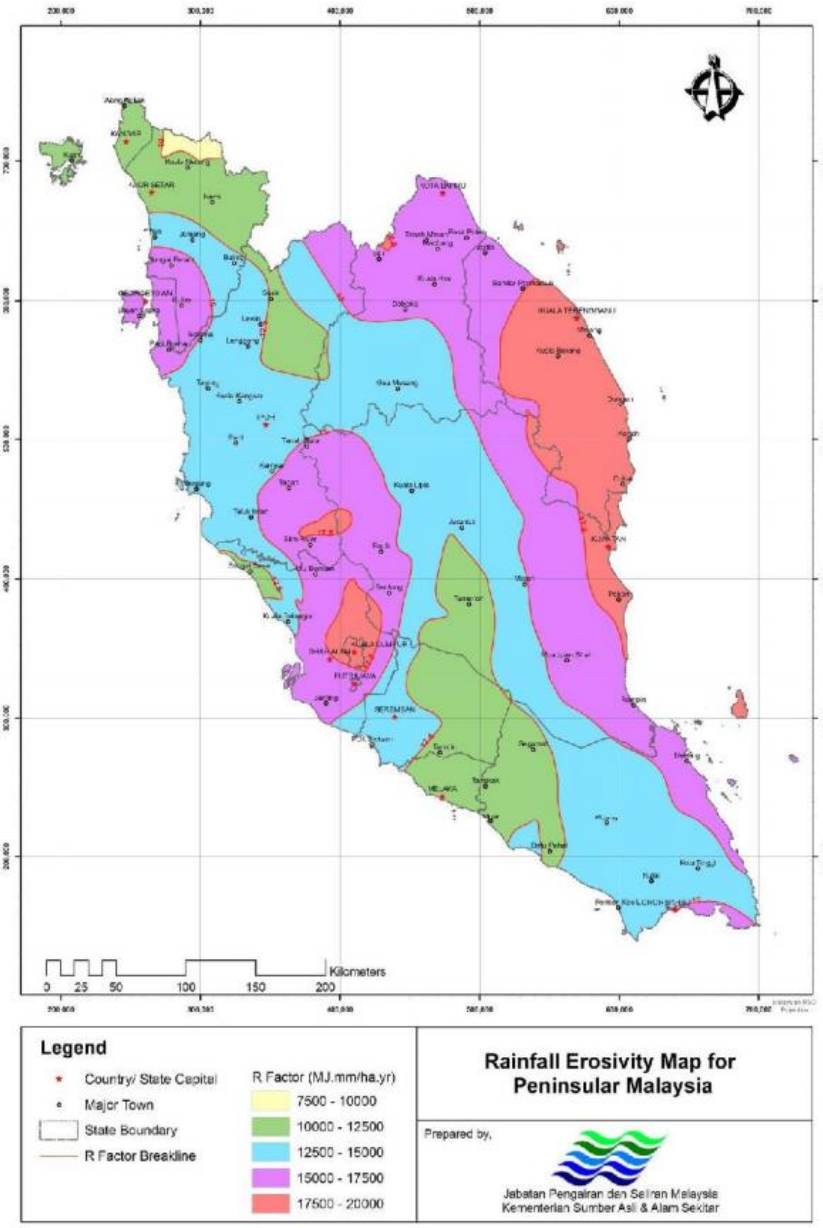


Figure 3.2: Rainfall Erosivity Map for Penisular Malaysia (Guide for Sediment Control and Erosion in Malaysia)

Analysing the rainfall erosivity map it can be deduced that the R factor for each sub basin in Kuantan River Basin ranges from 17,500 MJ.mm/ha.yr to 20,000 MJ.mm/ha.yr approximately.

3.3 Slope Length and Slope Steepness Factor, LS

L factor can be computed by using Equation 6:

$$L = (\frac{\lambda}{\varphi})^m$$

Equation 6

Where

L = Slope Length Factor

λ = Sheet Flow Path Length (m or feet)

φ = 72.6 foot for Imperial Units or 22.13m for SI

The slope length and slope steepness of field will bring large effect on soil erosion rate. These two factors are usually evaluated separately, and represented by two different factors, L and S in academic studies. However, it is more convenient to consider these two factors as one and only look at a unique topographic factor, LS in real life application (Department of Irrigation and Drainage, Malaysia; Ministry of Natural Resources and Environment, 2010). The LS factor can be determined using Equation 7:

$$LS = (\frac{\lambda}{\psi})^m \times (0.065 + 0.046s + 0.065s^2)$$

Equation 7

Where, m = Location Factor

= 0.2 for $s < 1$;

= 0.3 for $1 \leq s < 3$;

= 0.4 for $3 \leq s < 5$

= 0.5 for $5 \leq s < 12$ and

= 0.6 for $s \geq 12\%$

To ease the process of computation for field application, the values obtained using the equation using the Equation 7 is tabulated as shown in Table 2.1. With this table provided, LS can be generated by determining the slope length in percentage and the direct distance from the origin of runoff to its point of interest.

For this studies, the topography maps of the state of Pahang from JUPEM which contain the contour lines and stream lines of the sub river basins of Kuantan River Basin are obtained. This information is then interpreted to get the LS factor from Table 2.1.

3.4 Computation of Cover Management Factor, C and Erosion Management Practices Factor, P Using ArcGIS Software

Both the C and P factors are very dependent on the land use area of the location studied. C focus on the cover management of soil, where the index is evaluated based on condition of the soil surface; whereas the P factor stress on the measures taken or any prevention applied to the soil to reduce soil erosion. In both situations, it is very vital to first observe the land use in order to accurately determine the C or P factor.

To manage these massive data, ArcGIS software was used. Firstly, information on types of soil of each area and types of land use is imposed into the map of Kuantan River Basin. After that, cut the soil maps accordingly to types of land use. Finally to compute C and P factors, weighted areas of each soil types are determined.

3.4.1 Insert information in ArcGIS for analysis

Open a new file and activate the layer of the map data frame. Right click on the selected layer in the Table of Content. Click Add Data to add shapefiles into the activated map data frame. Continue adding until all necessary shapefiles are inserted into the activated data frame. In order to determine the C and P factor for Kuantan River Basin, we need to obtain information in different shapefiles, including, mainstream line of Kuantan River, soil type, land used and land cover of Kuantan River Basin.

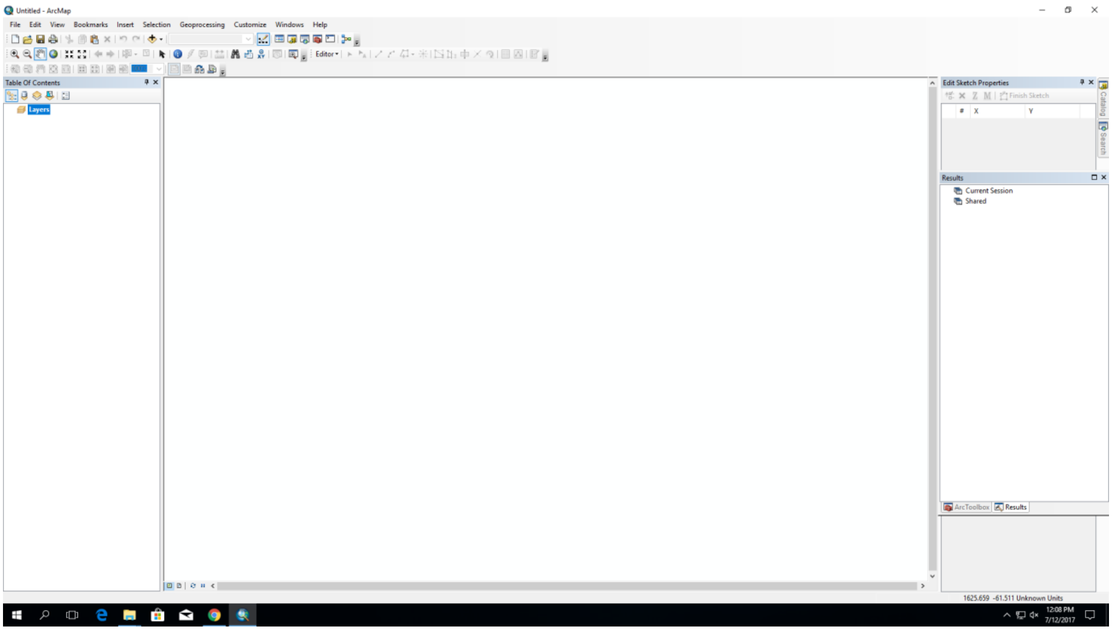


Figure 3.3: Open a new file and activate the layer of the map data frame.

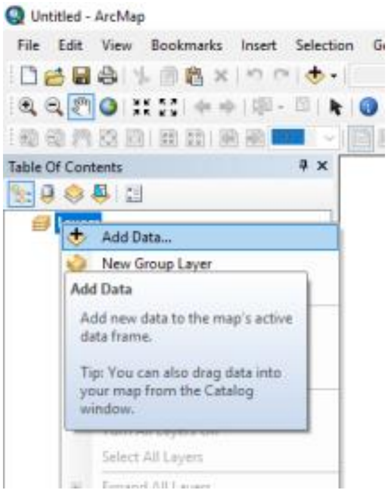


Figure 3.4: Add the required shapefiles.

Step 3:

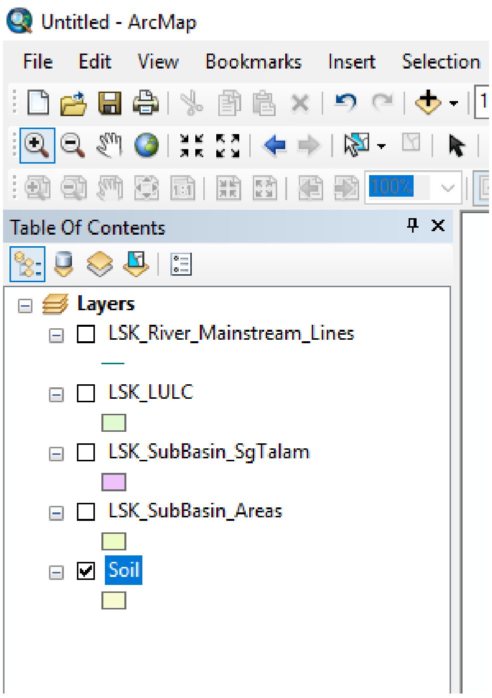


Figure 3.5: All the shapefiles needed.

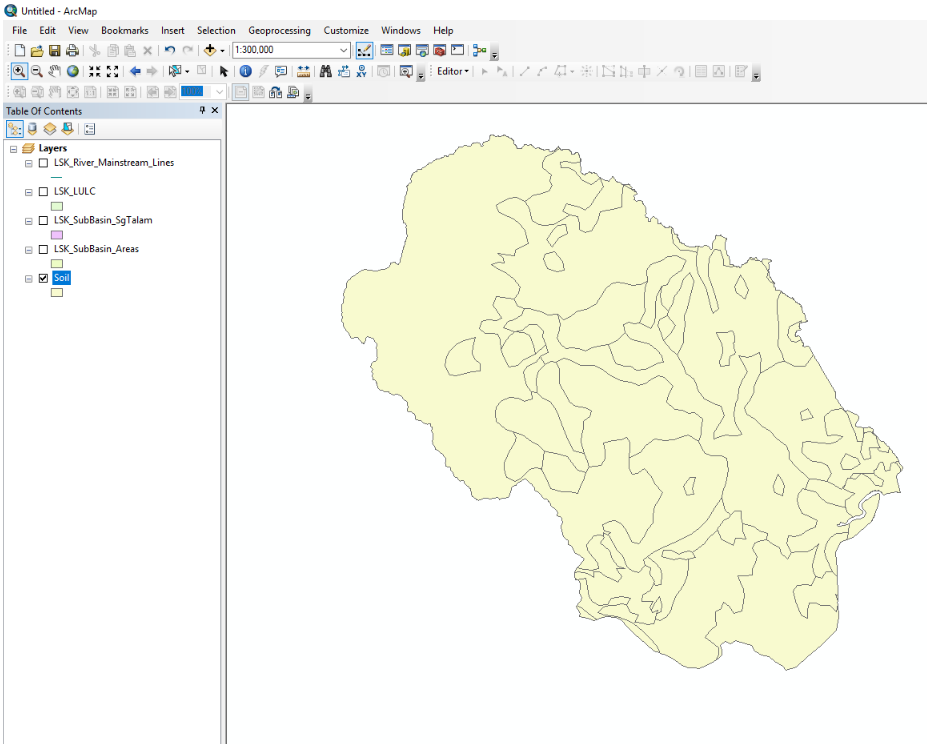


Figure 3.6: Soil Map of Kuantan River Basin

Determine centroid of each polygon in order to pin point sampling location of each type of soil at different area. Arc Toolbox is utilized to find centroid. Expand the Data Management Tree and select the Feature to Point Feature.

Then, insert the shapefile required. In this case, the sampling location of each type of soil are to be determined, so the soil type shapefile is selected. Then, create a name for the centroid shapefile to be saved and exported.

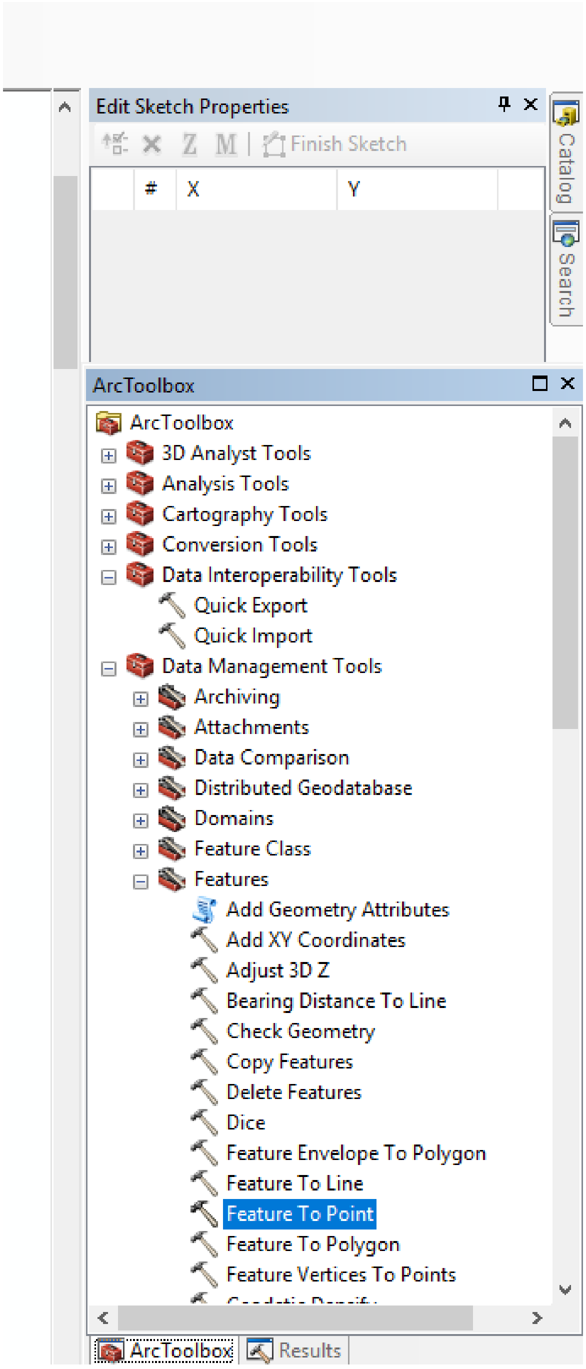


Figure 3.7: Use the "Feature to Point" function to locate the centroid of each polygon

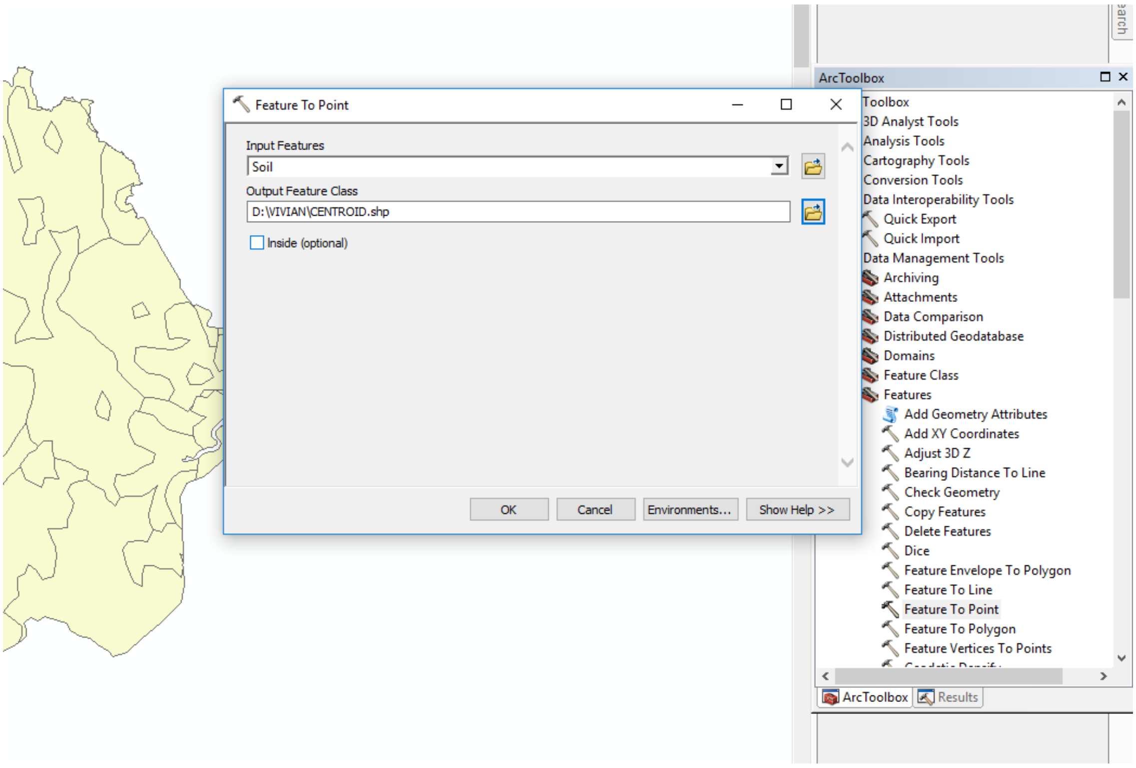


Figure 3.8: Save the soil map polygons centroids as a shapefile

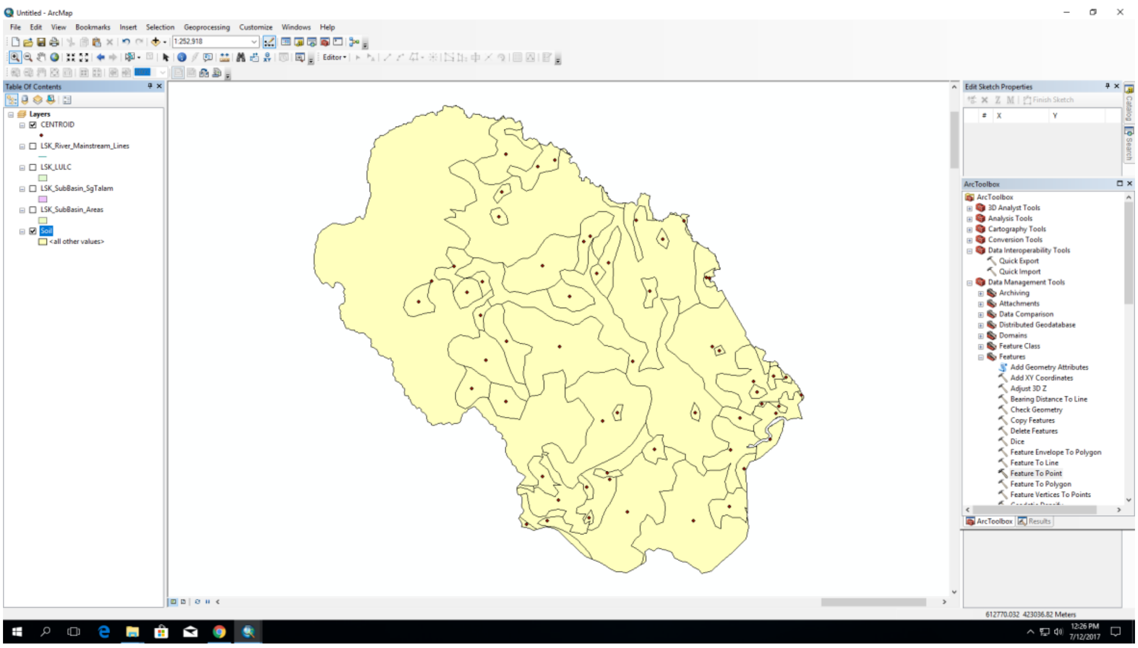


Figure 3.9: Centroids are located.

In order to view the shapefiles better, colour codes can be assigned to each unique polygons. Other than soil map, another important factor affecting the soil erosion rate is the land use and land cover properties. Therefore, to interpret these two sets of data simultaneously, the LULC shapefile is imported and overlayed on the soil map. However, the LULC map are set as hollow (colourless with black outline) so that the colours from the soil map can be seen.

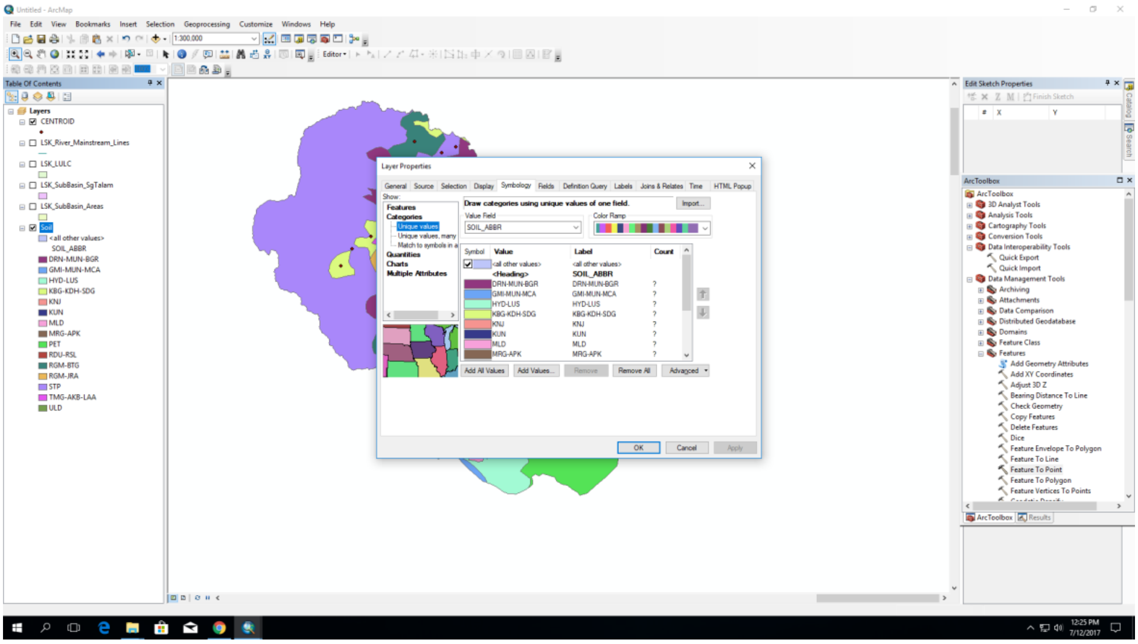


Figure 3.10: Set up colour code for different types of soil.

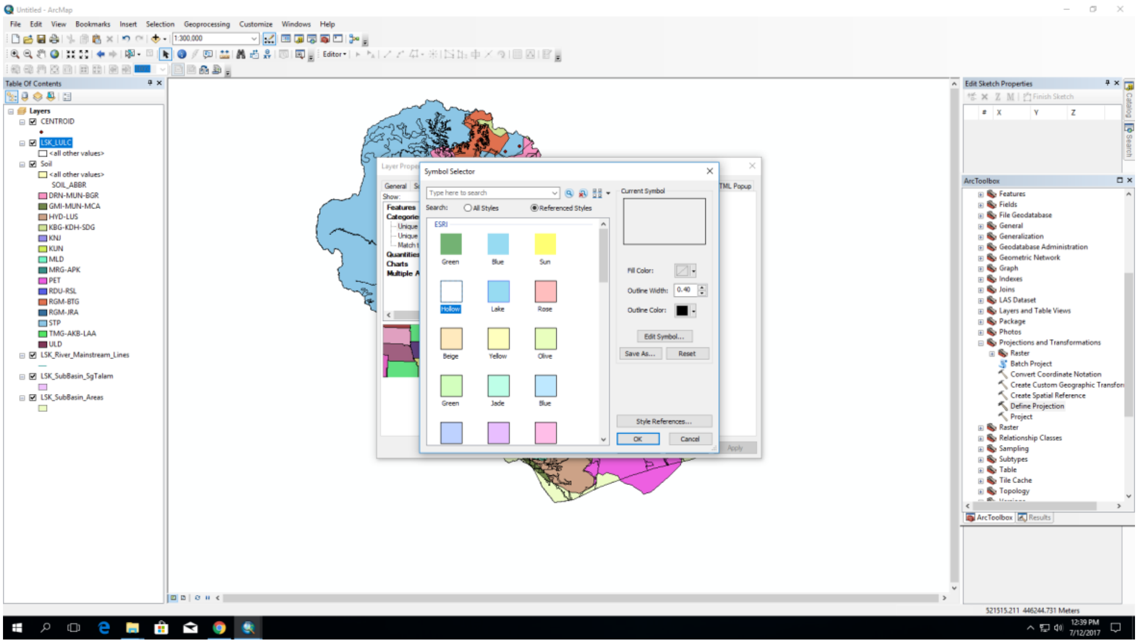


Figure 3.11: Set LULC map as ‘Hollow’(colourless with black outline)

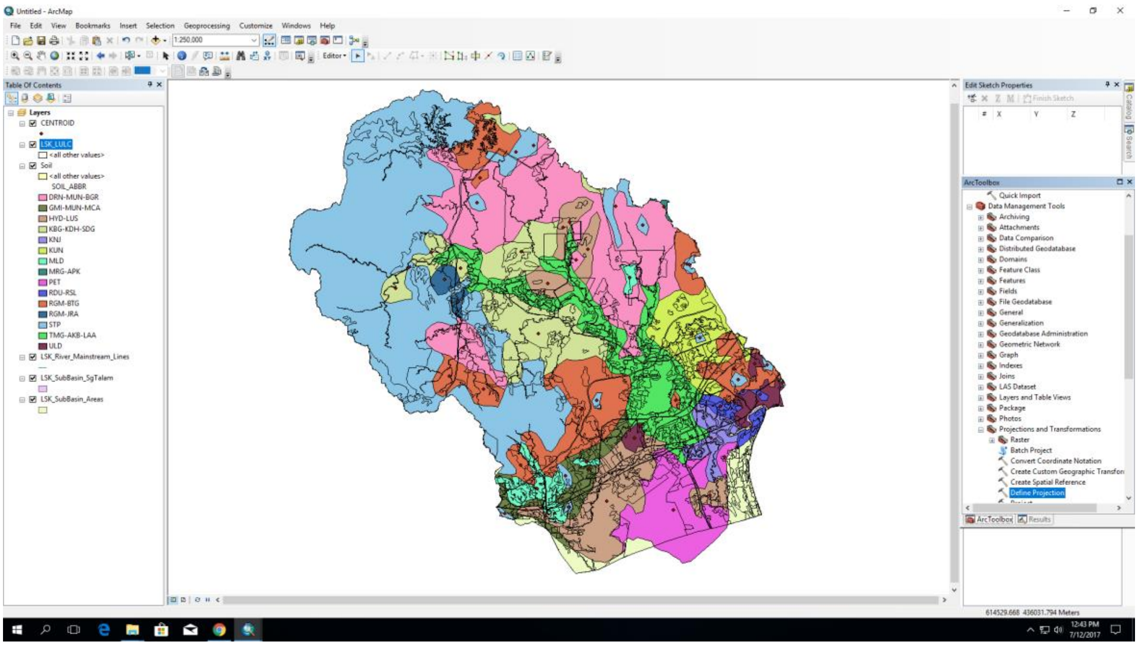


Figure 3.12: Final Outcome

3.4.2 Assign C and P Values to each Unique Polygon

Merged all the unique polygons of same landuse together to each operation. Then, C and P values are assigned to each unique polygons based on the LULC properties.

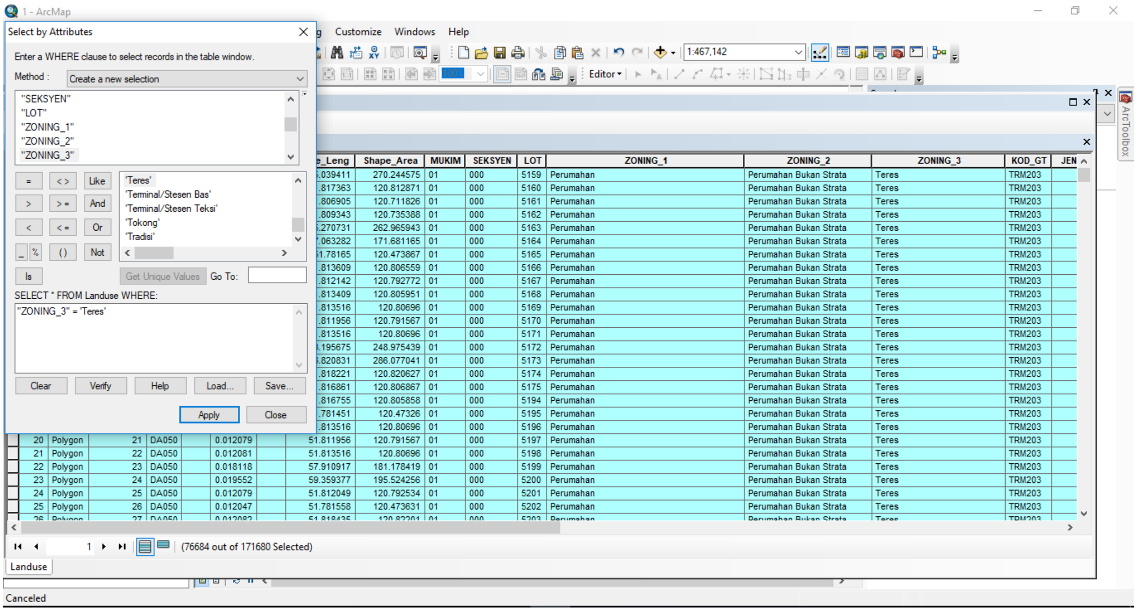


Figure 3.13: Select polygons based on Zoning 3 properties.

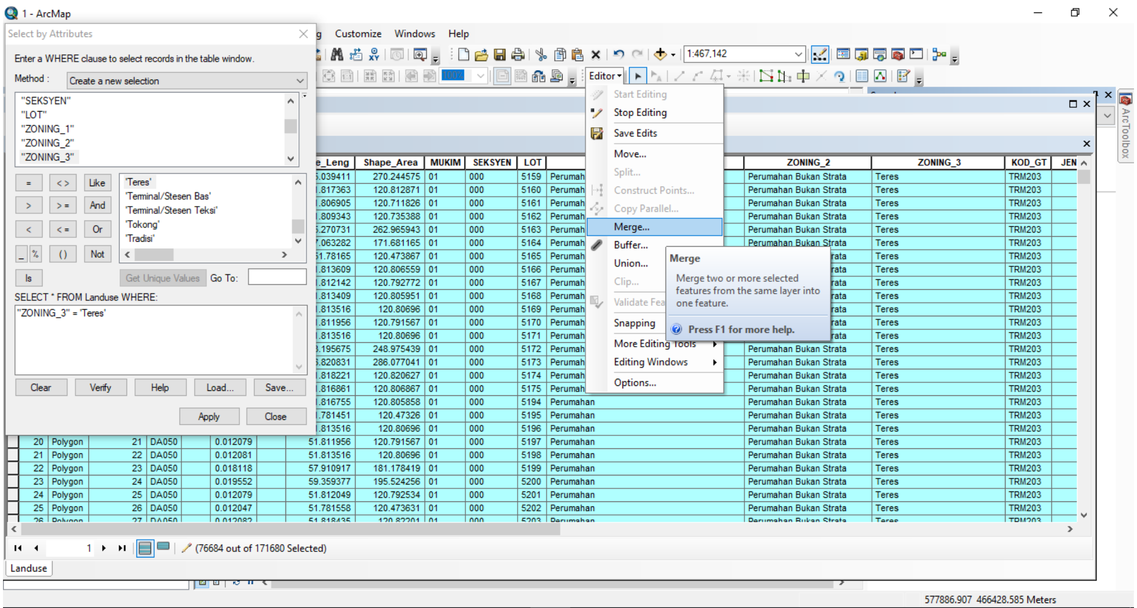


Figure 3.14: Merge all polygons with similar properties together.

Table

Landuse2035

ZOC	Shape_Leng	Shape_Area	MUKIM	SEKSYEN	LOT	ZONING_1	ZONING_2	ZONING_3	KOD_GT
	7.53421	504143.690918	01	000	5627	Tanah Kosong	Tanah Pembangunan	Lain-lain	TTK204
	20.922931	74644.189933	04	000	48183	Komersial	Runcit	Lain-Lain	TPD114
	23.226448	22.942831	04	000	112226	Tanah Kosong	Tanah Tidak Diusahakan	Tapak Projek Terbengkalai	TTK102
	23.65821	29570.108067	01	000	2199	Tanah Kosong	Tanah Tidak Diusahakan	Berumput/Semak/Belukar/Tanah Terbiar	TTK101
	24.374143	141239.782808	01	000	5604	Infrastruktur dan Utiliti	Bekalan Elektrik	Pencawang Elektrik (PE)	IFU110
	34.017886	690.526779	41	020	1517	Infrastruktur dan Utiliti	Bekalan Elektrik	Bekalan Elektrik	IFU110
	42.649859	10757.584643	04	000	30071	Komersial	Pasar	Lain-lain	TPD403
	45.073282	3826.796781	04	000	30062	Institusi dan Kemudahan Masyarakat	Pendidikan	Taska	TIS101
	47.322549	1040.279587	41	017	2929	Komersial	Stesyen Minyak	Stesyen Minyak	TPD2001
	49.936619	149.190465	04			Infrastruktur dan Utiliti	Bekalan Elektrik	Lain-lain	IFU111
	51.795676	198755.416999	01	000	3728	Komersial	Perkhidmatan	Lain-lain	TPD513
	51.843599	1371.359444	04	000	104933	Komersial	Runcit	Runcit	TPD113
	54.381845	858.991949	04	000	123342	Infrastruktur dan Utiliti	Pembetungan	Lain-lain	IFU804
	54.455657	137.611435	41	033	1035	Perumahan	Runcit	Kedai Pejabat	TPD112
	56.056887	4030.218784	03	000		Komersial	Runcit	Peralatan dan Bahan Binaan	TPD109
	56.057002	1898.514858	03	000		Komersial	Perkhidmatan	Klinik Swasta	TPD504
	56.065744	143.957528	03	000		Komersial	Perkhidmatan Peribadi dan Isirumah	Dobi	TPD701
	56.087083	268.538214	03	000		Komersial	Perkhidmatan Peribadi dan Isirumah	Kedai Jahit	TPD702
	56.091379	66935.239182	04	000	39050	Industri	Industri Ringan	Gudang (tempat simpan barang secara sementara, seperti gudang geta	TIN110
	56.104065	161666.775921	03	000		Komersial	Runcit	Barangan Keperluan Harian	TPD101
	57.644129	612.374433	04	000	127122	Komersial	Borong	Peralatan Kenderaan	TPD206
	57.884943	122581.126586	04	000	135241	Perumahan	Perumahan Strata	Rumah Berbilang Tingkat	TRM101
	58.202262	45911.051648	02	000	5544	Perumahan	Perumahan Bukan Strata	Rumah Kos Rendah	TRM205
	59.964826	6563.302153				Komersial	Runcit		
	60.322048	18186.906736	04			Institusi dan Kemudahan Masyarakat	Kemudahan Awam	Perpustakaan Awam	TIS804
	60.338208	1128812.02124	04	000	60987	Industri	Industri Sederhana	Lain-lain	TIN230
	60.923836	15641.340673	04	000	121596	Komersial	Makanan dan Minuman	Restoran Makanan Segera	TPD805
	60.940415	383.533916	06	000	4244	Komersial	Perkhidmatan	Syarikat Insurans/Kewangan	TPD502
	61.473307	163196.718353	01	000	10014	Tanah Lapang dan Rekreasi	Kawasan Hijau	Lain-lain	TLR402
	62.11894	32843.924489	04	000	100014	Komersial	Perkhidmatan	Perkhidmatan Profesional	TPD508
	63.374327	78130.301561	04	000	112506	Komersial	Perkhidmatan	Hospital/Pusat Rawatan Swasta	TPD503
	64.214369	253.532797	06	000	30616	Institusi dan Kemudahan Masyarakat	Kesihatan	Klinik 1Malaysia	TIS205
	64.440664	159.182078	04	000	100016	Komersial	Runcit	Produk Makanan dan Minuman	TPD102
	64.656573	692018.079654	01	000	10028	Komersial	Runcit	Rumah Kedai	TPD113
	65.039411	9741594.46287	01	000	5159	Perumahan	Perumahan Bukan Strata	Teres	TRM203
	65.860196	20042.154542	03	000		Komersial	Runcit	Peralatan Rumah/Pejabat	TPD103
	66.03139	257.953709	41	031	15633	Komersial	Pendidikan Swasta	Tadika	TPD601
	66.529661	51433.001646	01	000	4146	Komersial	Kompleks Perniagaan	Lain-lain	TPD305

1 (0 out of 287 Selected)

Landuse2035

Figure 3.15: Merging completed.

In the Land Use and Land Cover Map, the land use data is categorized into 3 zonings, where zoning 1 is the general field of the land use (e.g.: Industry, Agriculture), zoning 3 is the specific and detailed data of the land use properties such as primary schools, rubber trees plantation. Zoning 2 is the intermediate grouping.

Zoning 3 is used in the merging. However, Zoning 1 and Zoning 2 have to be considered as there might be information missed out in Zoning 3. In some developing areas, there might be some missing data in Zoning 2 and Zoning 3. Therefore, Google Streetview can be used as extra reference.

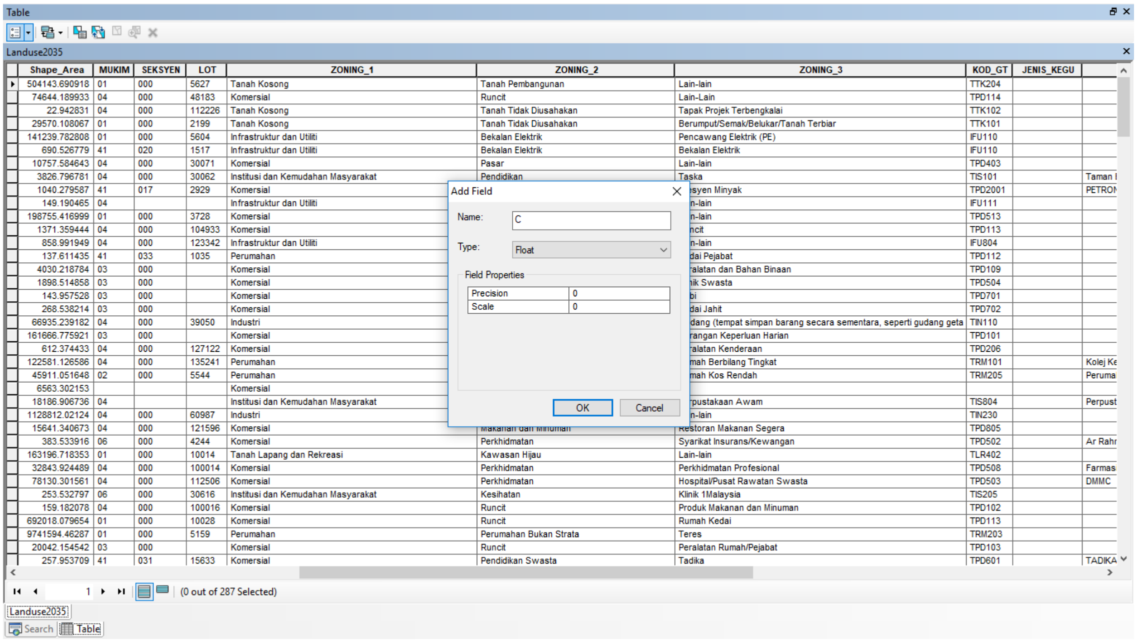


Figure 3.16: Add a new column each for C and P factors.

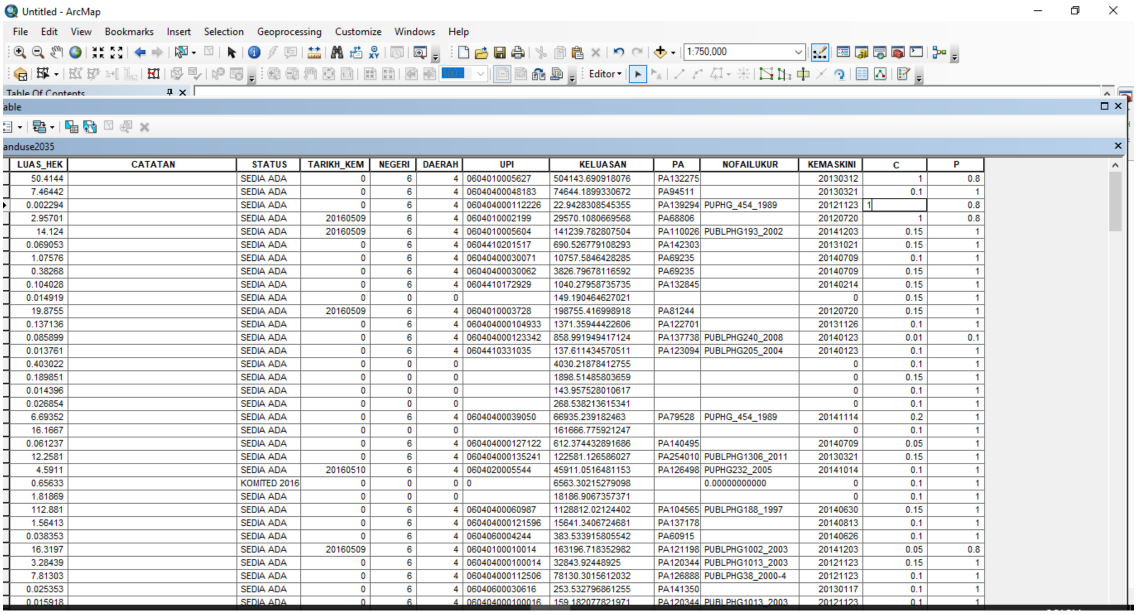


Figure 3.17: Assign C and P values to each of the polygons base on its properties.

In order to generate C and P factors for each sub basin, all the merged polygons of same LULC properties are clipped according to shapes of sub basins. Finally, data is extracted in the form of each sub basins into Microsoft Excel

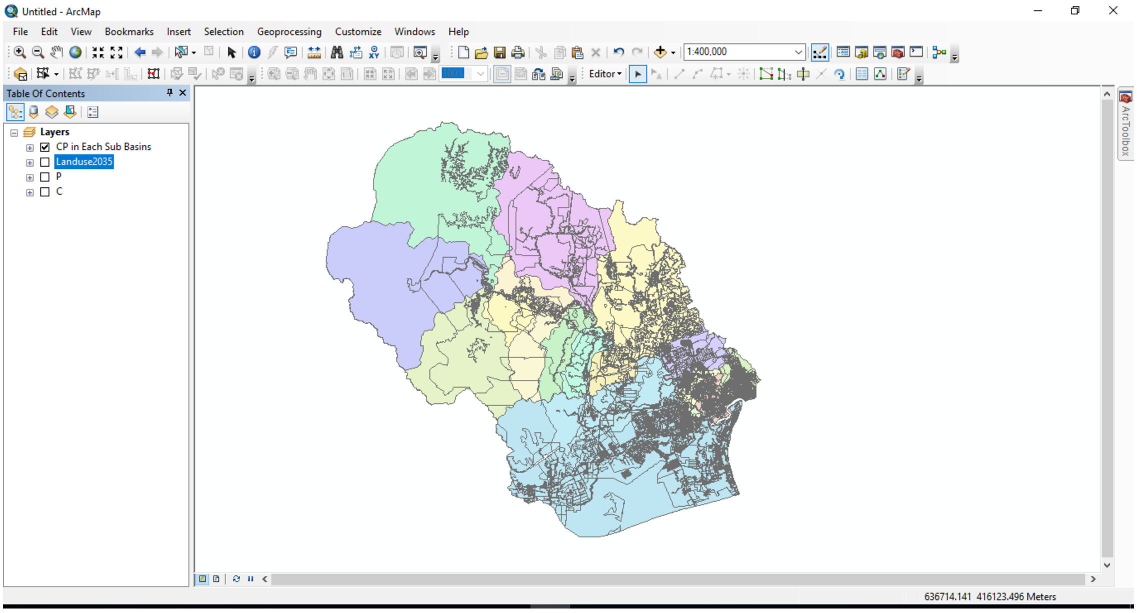
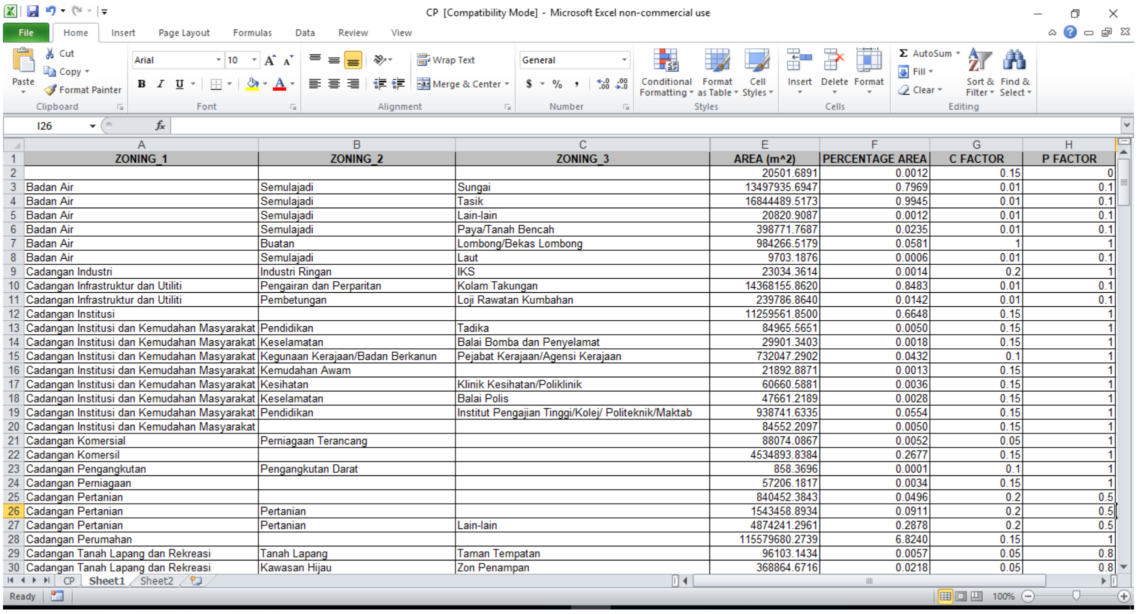


Figure 3.18: Clipped the Landuse and Landcover shapefile according to shapes of sub basins



	ZONING_1	ZONING_2	ZONING_3	AREA (m^2)	PERCENTAGE AREA	C FACTOR	P FACTOR
2				20501.6891	0.0012	0.15	0
3	Badan Air	Semulajadi	Sungai	13497935.6947	0.7969	0.01	0.1
4	Badan Air	Semulajadi	Tasik	16844489.5173	0.9945	0.01	0.1
5	Badan Air	Semulajadi	Lain-lain	20820.9087	0.0012	0.01	0.1
6	Badan Air	Semulajadi	Paya/Tanah Bencah	398771.7687	0.0235	0.01	0.1
7	Badan Air	Buatan	Lombong/Bekas Lombong	984266.5179	0.0581	1	1
8	Badan Air	Semulajadi	Laut	9703.1876	0.0006	0.01	0.1
9	Cadangan Industri	Industri Ringan	IKS	23034.3614	0.0014	0.2	1
10	Cadangan Infrastruktur dan Utiliti	Pengairan dan Perparitan	Kolam Takungan	14368155.8620	0.8483	0.01	0.1
11	Cadangan Infrastruktur dan Utiliti	Pembetungan	Loji Rawatan Kumbahan	239786.8640	0.0142	0.01	0.1
12	Cadangan Institusi			11259561.8500	0.6648	0.15	1
13	Cadangan Institusi dan Kemudahan Masyarakat	Pendidikan	Tadika	84965.5651	0.0050	0.15	1
14	Cadangan Institusi dan Kemudahan Masyarakat	Keselamatan	Balai Bomba dan Penyelamat	29901.3403	0.0018	0.15	1
15	Cadangan Institusi dan Kemudahan Masyarakat	Kegunaan Kerajaan/Badan Berkanun	Pejabat Kerajaan/Agensi Kerajaan	732047.2902	0.0432	0.1	1
16	Cadangan Institusi dan Kemudahan Masyarakat	Kemudahan Awam		21892.8871	0.0013	0.15	1
17	Cadangan Institusi dan Kemudahan Masyarakat	Kesihatan	Klinik Kesihatan/Poliklinik	60660.5881	0.0036	0.15	1
18	Cadangan Institusi dan Kemudahan Masyarakat	Keselamatan	Balai Polis	47661.2189	0.0028	0.15	1
19	Cadangan Institusi dan Kemudahan Masyarakat	Pendidikan	Institut Pengajian Tinggi/Kolej/ Politeknik/Maktab	938741.6335	0.0554	0.15	1
20	Cadangan Institusi dan Kemudahan Masyarakat			84552.2097	0.0050	0.15	1
21	Cadangan Komersial	Perniagaan Terancang		88074.0867	0.0052	0.05	1
22	Cadangan Komersil			4534893.8384	0.2677	0.15	1
23	Cadangan Pengangkutan	Pengangkutan Darat		858.3696	0.0001	0.1	1
24	Cadangan Perniagaan			57206.1817	0.0034	0.15	1
25	Cadangan Pertanian			840452.3843	0.0496	0.2	0.5
26	Cadangan Pertanian	Pertanian		1543458.8934	0.0911	0.2	0.5
27	Cadangan Pertanian	Pertanian	Lain-lain	4874241.2961	0.2878	0.2	0.5
28	Cadangan Perumahan			115579680.2739	6.8240	0.15	1
29	Cadangan Tanah Lapang dan Rekreasi	Tanah Lapang	Taman Tempatan	96103.1434	0.0057	0.05	0.8
30	Cadangan Tanah Lapang dan Rekreasi	Kawasan Hijau	Zon Penampan	368864.6716	0.0218	0.05	0.8

Figure 3.19: Data extracted and exported into Microsoft Excel

3.4.3 Weighted Area Method

After imposing the necessary information in the ArcGIS program, the next step is to analyse the data by each section differentiate by soil type. To determine the C and P factors, the land cover and land use information are interpreted respectively. Therefore, the land use and land cover information is also to be accommodated with the soil type file. To consider the effects of ground cover and erosion management on each segment, cut the soil segment polygons accordingly with the land use land cover borders and calculate the weighted area C and P factors.

Example below demonstrates how to determine the weighted area C and P factor.

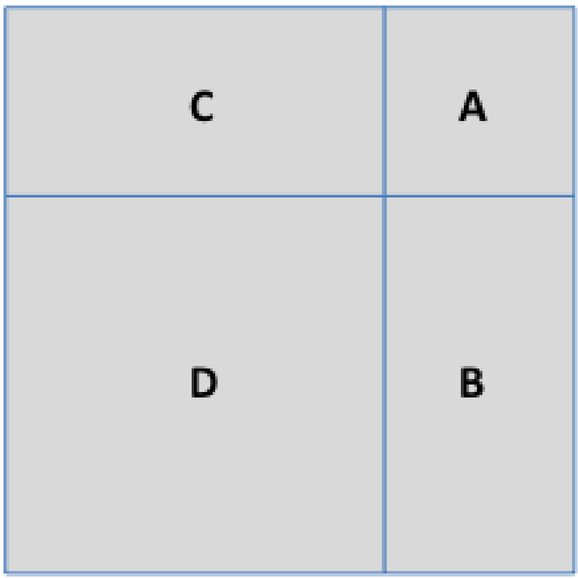


Figure 3.20: Example in Weighted Area Method

Table 3.1:Example of Weighted Area Method

Patch	C Factor	Area (m^2)
A	0.2	1
B	0.3	2
C	0.4	3
D	0.5	4

$$Area - Weighted\ C\ fator = \frac{Sum\ of\ Area - Weight\ C\ factor}{Sum\ of\ Area}$$

Equation 8

$$= \frac{0.2 \times 1 + 0.3 \times 2 + 0.4 \times 3 + 0.5 \times 4}{1 + 2 + 3 + 4}$$

$$= 0.4$$

3.5 Erosion Control Practices Factor, P

For this study, all oil palm and rubber plantations are assumed to have terracing as erosion control. While other areas where erosion control practices is not available are given P values of 1.

To compute P factor for oil palm and rubber plantation, the land use and land cover map is overlayed with the DEM file of the study area to extract the slope of the area. Then, the oil palm and rubber plantations were assigned a P value according to the slope steepness as shown in Table 2.6. Figure 3.20 and Figure 3.21show the oil palm and rubber plantation and land slope in percentage respectively.

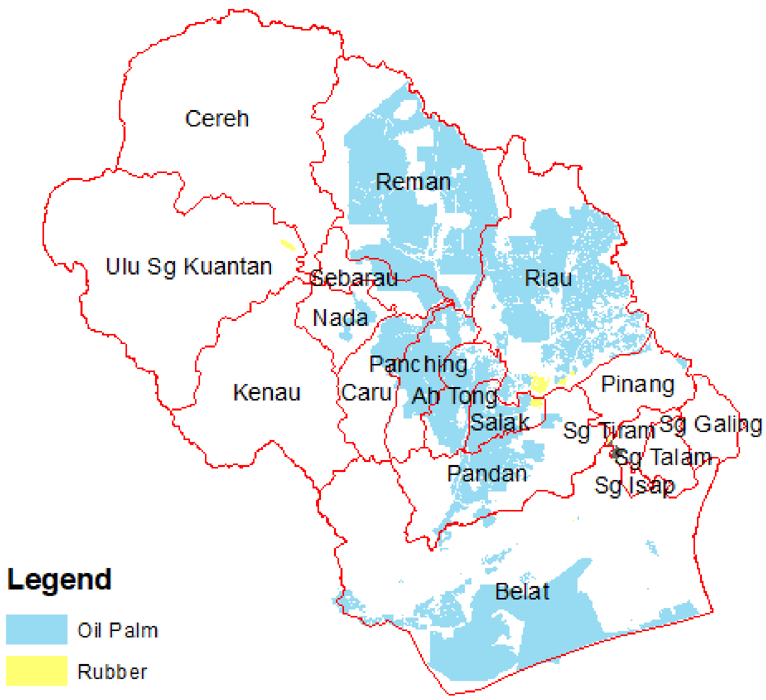


Figure 3.21: Oil Palm and Rubber Plantation in Kuantan River Basin

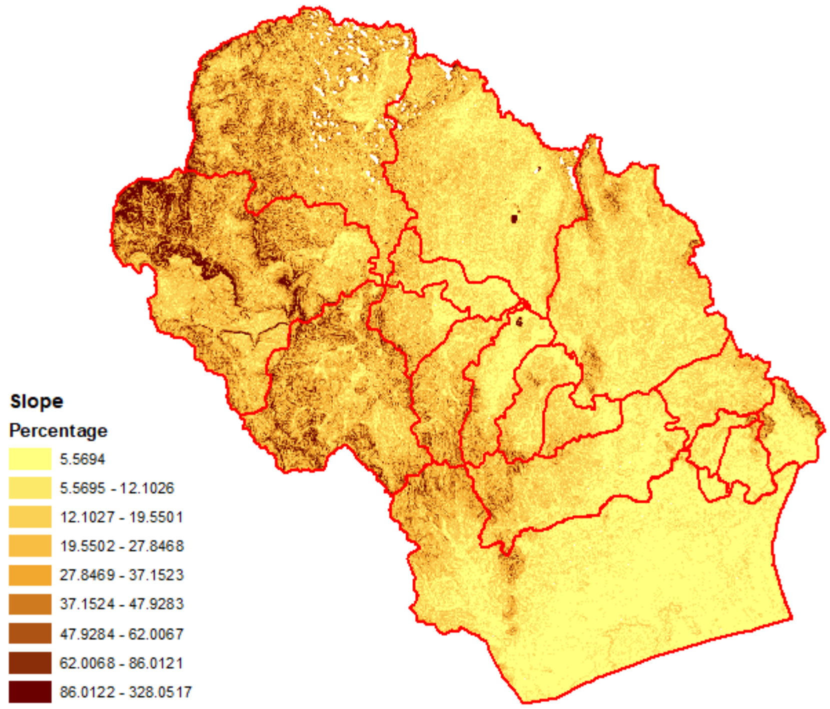


Figure 3.22: Slope in Percentage

The P values of the each sub basins are then calculated by applying the weighted area method. Figure 3.22 shows the Slope in oil palm and rubber plantation.

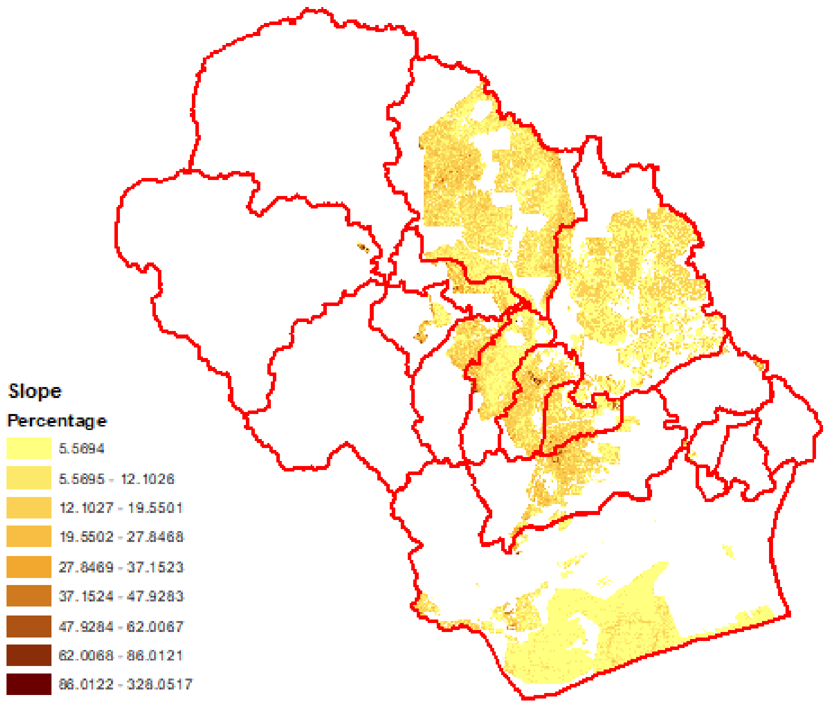


Figure 3.23: Slope of Oil Palm and Rubber Plantation

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Rainfall Erosivity Factor, R

Rainfall erosivity map of Malaysia can be found in MSMA. A clearer and more detailed version of rainfall erosivity map of each state can be found in Guideline of Erosion and Sedimentation Control in Malaysia. Weighted Area Method is applied to find out the rainfall erosivity factor for each sub basin in Kuantan River Basin. Overall R Factor values of each sub basins are listed in Table 4.1. Rainfall Erosivity Map of Kuantan River Basin (Figure 4.2) is extracted from rainfall erosivity map in Guideline of Erosion and Sediment Control (Figure 4.1).

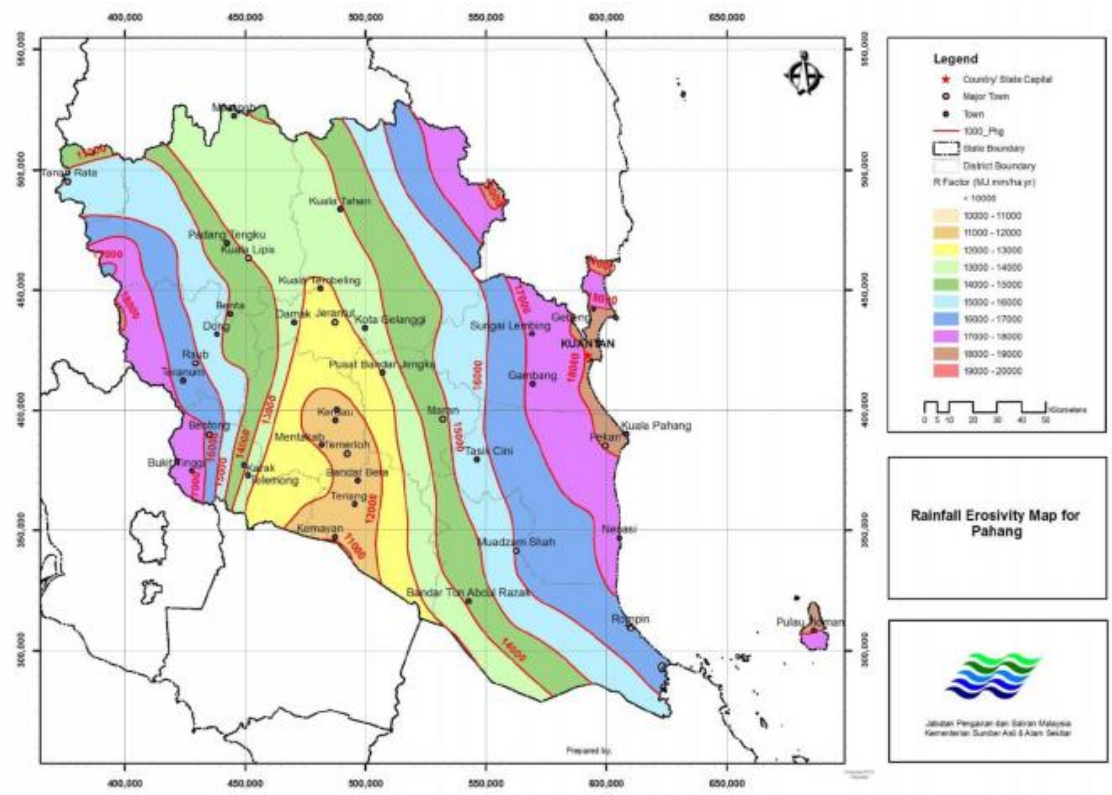


Figure 4.1: Rainfall Erosivity Map of Pahang

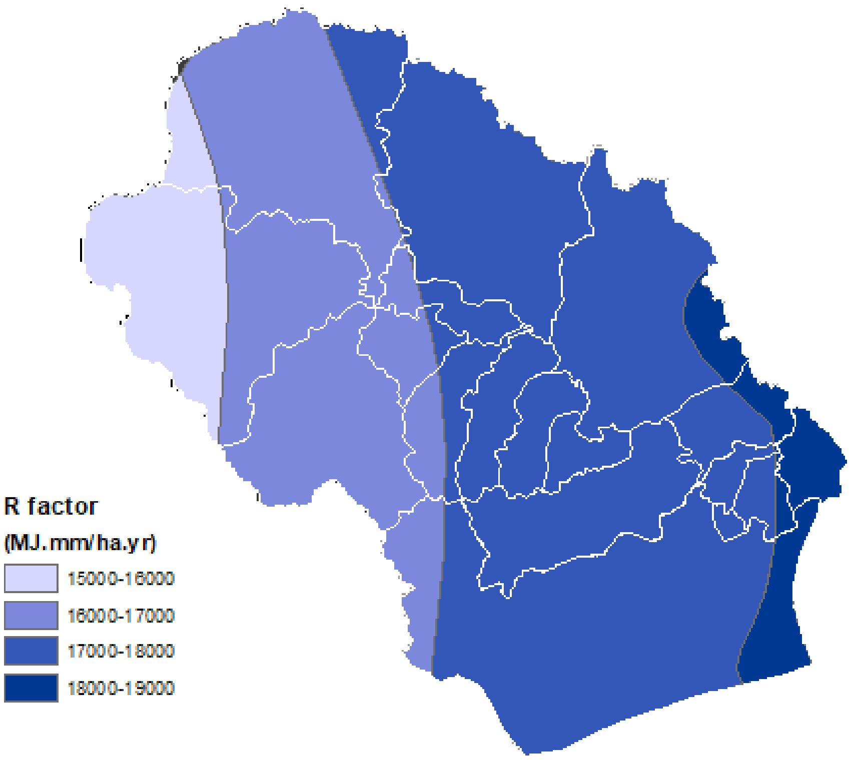


Figure 4.2: Rainfall Erosivity Map of Kuantan River Basin

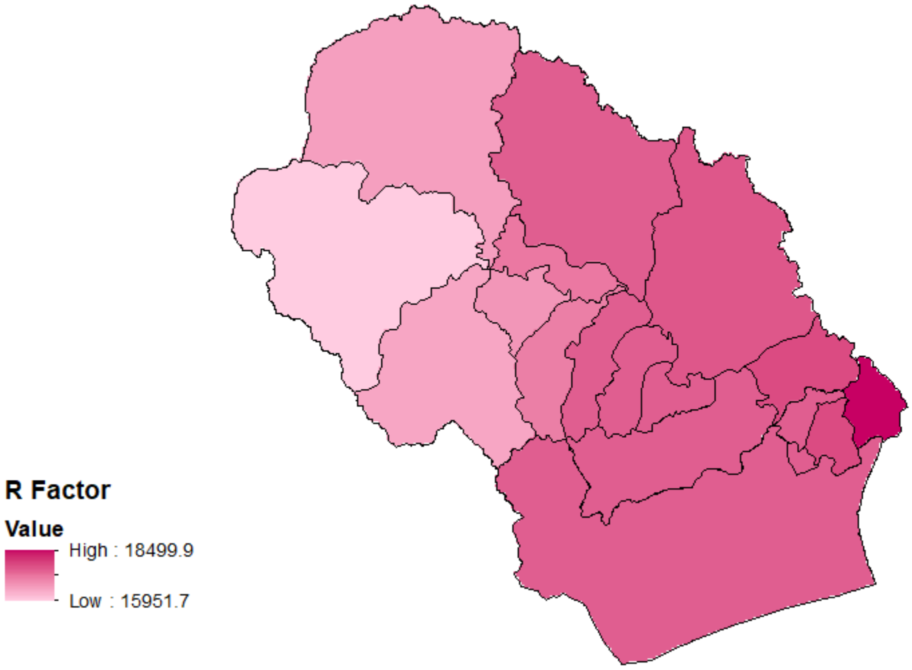


Figure 4.3: Rainfall Erosivity Factor of Each Sub Basin

From Figure 4.3, it is clear that R factor of the whole Kuantan River Basin ranges from 15952 MJ.mm/ha.year to 18500 MJ.mm/ha.year. From the Figure 4.3, it can be clearly seen that the Ulu Sungai Kuantan Sub Basin has the lowest R Factor whereas the sub basin with the highest R Factor is Sungai Galing. Therefore, we can conclude that the nearer is the location to inland, the lower is the overall sub basin R Factor values.

Table 4.1: Rainfall Erosivity Factor of Each Sub Basin

Sub Basins	R Factor (MJ.mm/ha.year)
Ah Tong	17500.0000
Belat	17503.0271
Caru	17029.3694
Cereh	16559.7563
Kenau	16500.0000
Nada	16681.5128
Panching	17500.0000
Pandan	17500.0000
Pinang	17791.0921
Reman	17490.6044
Riau	17606.2998
Salak	17500.0000
Sebarau	17139.9131
Sungai Galing	18499.9484
Sungai Isap	17500.0000
Sungai Talam	17786.1485
Sungai Tiram	17511.6723
Ulu Sungai Kuantan	15951.6897

4.2 Topographical Factor, LS

Slope length, L and Slope steepness, S were calculated as a single topographical factor, LS. After determining L and S respectively, LS can be determined in Table 2.1 by utilising the formula (Equation 1) by Wischmeier and Smith (1978).

Slope steepness can be computed from DEM data. Figure 4.4 shows that LS factors of Kuantan River Basin ranges from 2.769 to 554.767. Slope length is measured on the slope map from the highest point to the lowest point.

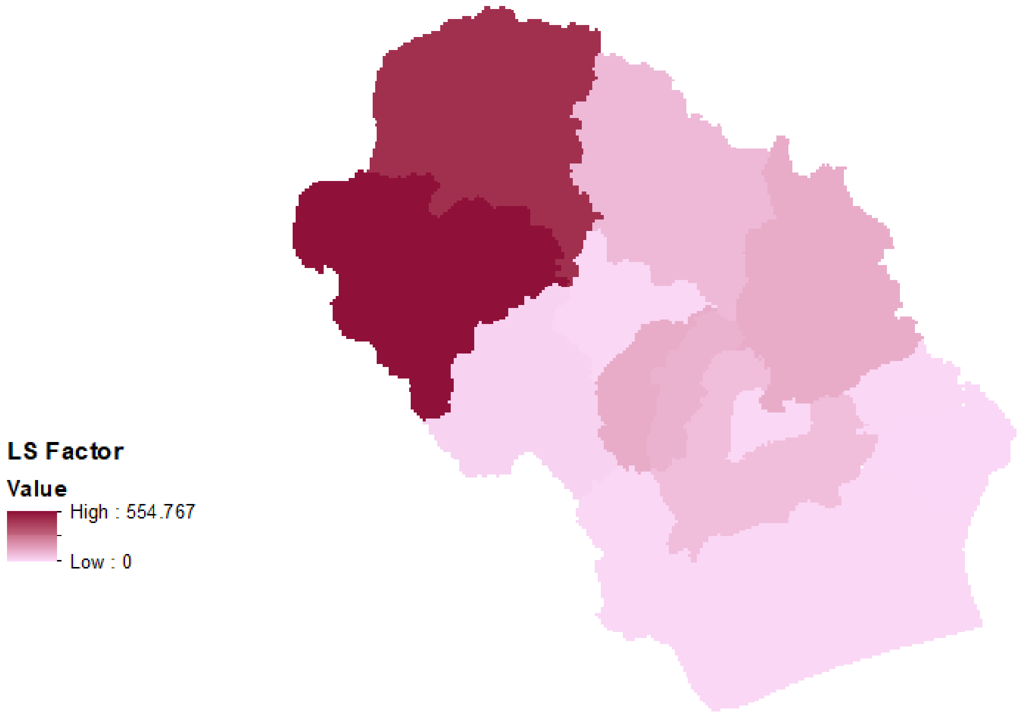


Figure 4.4: LS Factor Distribution of Kuantan River Basin

Table 4.2 shows the λ, s and LS for each sub basin. From the Table 4.2, it is clear that Ulu Sungai Kuantan Sub Basin has the highest LS factor, which is equal to 554.7672 whereas the lowest LS factor falls on Sungai Isap Sub Basin (2.7688). Ulu Sungai Kuantan also has the steepest slope at 55.91%, followed by Cereh at 36.32%. It can be seen from topography map that there are a lot of slopes present in the form of mountains and hills in the Ulu Sungai Kuantan sub basin as mountain ranges exist in that area. Other than that, it can be seen from the land use map that the Ulu Sungai Kuantan and Cereh sub basins are relatively less developed compared to the other sub basins.

The sub basin with the most gradual slope is Sungai Isap sub basin. It can be seen in the topography map that Belat and Sungai Isap are among the most developed areas in the 18 sub basins. Generally, areas like this will have more correlated slopes compared to undeveloped areas.

Table 4.2: λ, s and LS of Each Sub Basin in Kuantan River Basin

Sub Basins	λ (m)	S (%)	LS Factor
Ah Tong	3382.8320	18.93	66.7250
Belat	17308.1104	4.48	2.9593
Caru	4360.4099	18.83	77.0696
Cereh	12702.9280	36.32	466.2305
Kenau	6320.0358	6.52	10.8247
Nada	7,875.2600	4.50	4.2315
Panching	3521.2735	22.69	93.3309
Pandan	7495.2776	14.32	67.7418
Pinang	7,538.8000	4.50	4.1582
Reman	14282.5689	11.92	74.5482
Riau	13676.7509	15.31	108.3783
Salak	7,237.4700	4.50	4.0909
Sebarau	10,227.4900	4.50	4.6978
Sungai Galing	3898.0388	8.50	12.2836
Sungai Isap	2,727.5400	4.50	2.7688
Sungai Talam	4045.6780	5.80	7.4391
Sungai Tiram	4940.0952	11.52	21.7788
Ulu Sungai Kuantan	4470.3497	55.91	554.7672

4.3 Cover Management Factor, C

The Cover Management Factor, C Factor of Kuantan River Basin is generated from the Land Used Land Cover Map from DID. C values were extracted from Table 2.5 and were assigned to each polygon on the maps, according to their landuse (Figure 4.6). The C Factor map is shown in Figure 4.5, where the C factors range from 0 to 1.

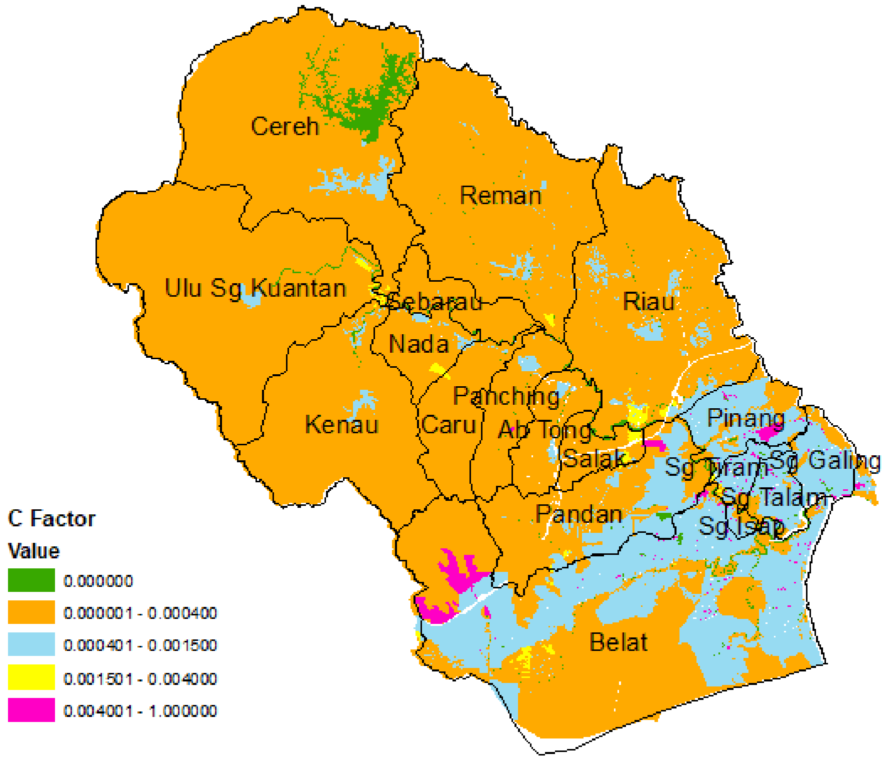


Figure 4.5: C Factor Distribution of Kuantan River Basin

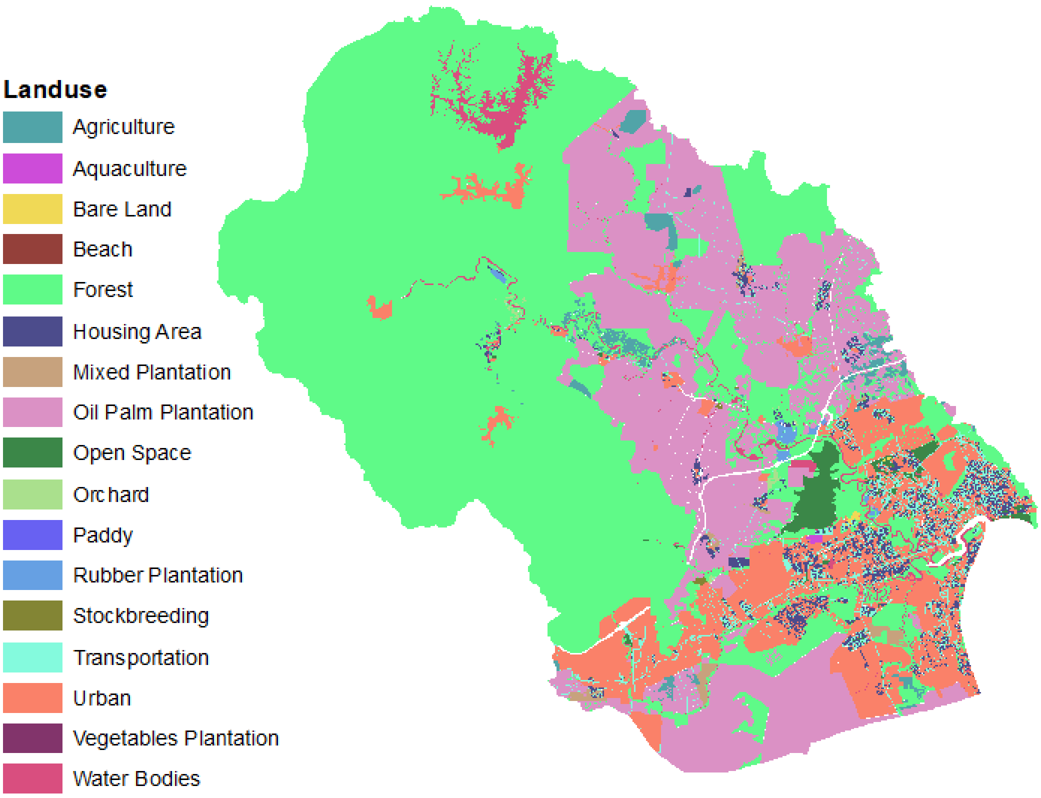


Figure 4.6: C Factor Distribution of Kuantan River Basin Based on LULC

Table 4.3: C Factor of Each Sub Basin in Kuantan River Basin

Sub Basins	**C Factor**
Ah Tong	0.000455
Belat	0.002624
Caru	0.007176
Cereh	0.000400
Kenau	0.000423
Nada	0.000447
Panching	0.002865
Pandan	0.001826
Pinang	0.015432
Reman	0.000455
Riau	0.013817
Salak	0.004280
Sebarau	0.107015
Sungai Galing	0.012958
Sungai Isap	0.001358
Sungai Talam	0.011628
Sungai Tiram	0.034870
Ulu Sungai Kuantan	0.000396

The north-west of Kuantan River Basin has the lower C factors as most of the lands are forested areas, whereas the southern and eastern parts of Kuantan River Basin have a greater value of C factor. This is because the southern part of Kuantan River Basin is the metropolis where most developments are at and therefore that area carries C factors of urbanized land. Sub basins located at the north and the west, like Ulu Sungai Kuantan, Cereh and Kenau, have lower C values, ranging from 0.01 to 0.05 as most of the land there are forests. On the other hand, the west of Kuantan River Basin are occupied by oil palm plantation, which C factors equal to 0.2. In Ulu Sungai Kuantan, 89.9% of the land is forest whereas in Cereh, forests occupied 88.2% of land.

4.4 Erosion Management Practices Factor, P

Conservation Factor, P represents the conservation practice applied on the land. The P factor value was assigned to each polygon according to their conservation practices. For areas without conservation practice, P factor is taken as 1.

Table 4.4: P factor of Each Sub Basin in Kuantan River Basin

Sub Basins	P Factor
Ah Tong	0.43
Belat	0.58
Caru	0.21
Cereh	0.10
Kenau	0.11
Nada	0.21
Panching	0.38
Pandan	0.40
Pinang	0.77
Reman	0.35
Riau	0.37
Salak	0.41
Sebarau	0.38
Sungai Galing	0.80
Sungai Isap	0.64
Sungai Talam	0.80
Sungai Tiram	0.85
Ulu Sungai Kuantan	0.10

From Figure 4.7, it can be seen that Belat Sub Basin has the higher P factor whereas the south-west of Kuantan River Basin has the lowest P factor value. Different values of P factor were distributed scatteredly in Kuantan River Basin. P factors assigned to each type of land use and land cover are listed down in Appendix A.

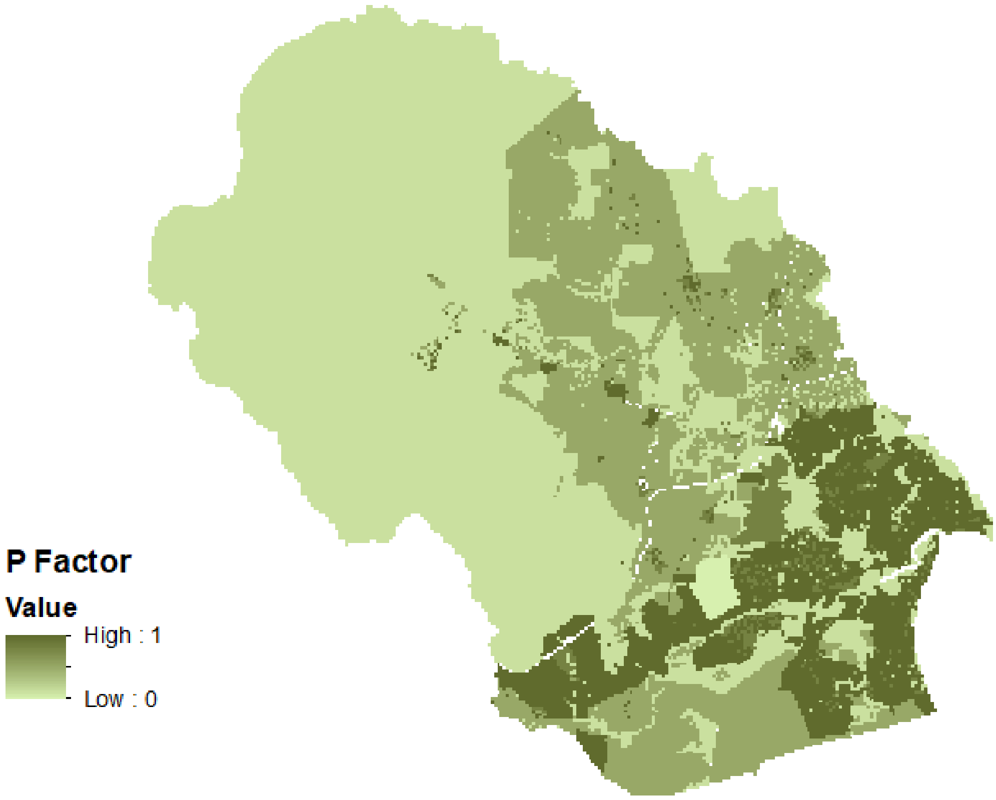


Figure 4.7: P factor of Each Sub Basins in Kuantan River Basin

4.5 Annual Soil Erosion Rate, A

Annual soil erosion rate of each sub basin is then calculated by using Equation 1. The results are displayed in Table 4.5. The erosion rate from the sub basin of Kuantan River Basin ranges from 0.24t/ha/year to 400.61t/ha/year with the sub basin which is most susceptible to soil erosion being Sungai Tiram and the least susceptible being Kenau. The soil erosion rate of KRB is considered to be very severe.

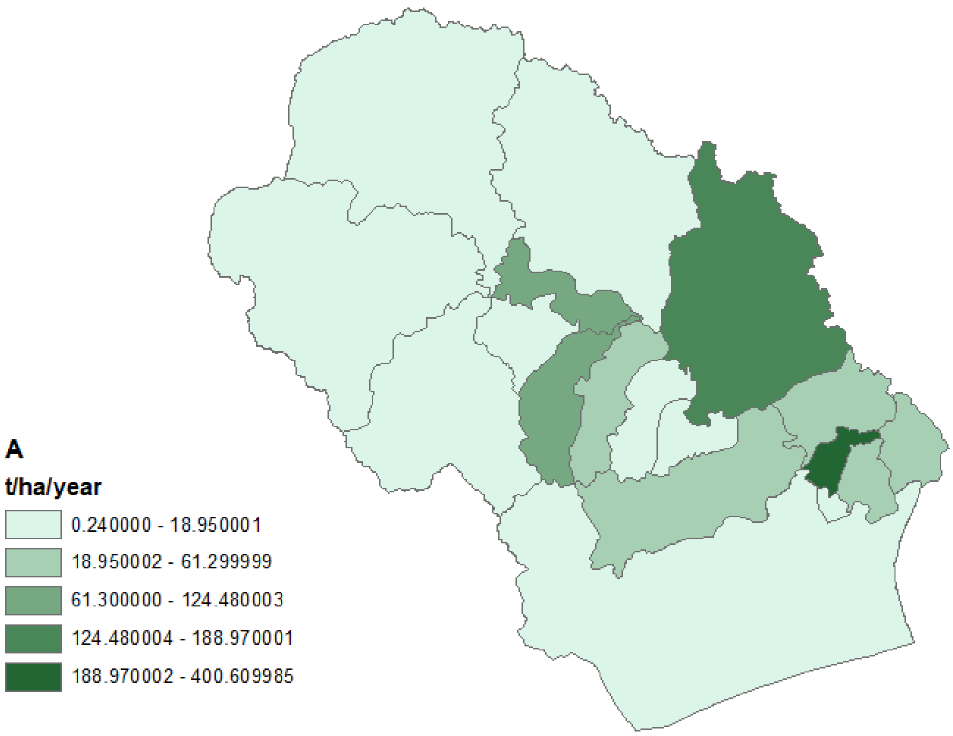


Figure 4.8: Soil Erosion Map of Kuantan River Basin

Table 4.5: Annual Soil Erosion Rate, A of Sub basin

Sub Basins	R Factor	K Factor	LS Factor	C Factor	P Factor	A (t/ha/year)
Ah Tong	17500	0.0593	66.73	0.000455	0.19	5.99
Belat	17503	0.0287	2.96	0.002624	0.39	15.22
Caru	17029	0.0723	108.38	0.007176	0.13	124.48
Cereh	16560	0.0285	466.23	0.000400	0.1	8.8
Kenau	16500	0.0289	10.82	0.000423	0.11	0.24
Nada	16682	0.0795	4.23	0.000447	0.55	1.38
Panching	17500	0.0703	93.33	0.002865	0.14	46.05
Pandan	17500	0.0345	67.74	0.001826	0.34	25.39
Pinang	17791	0.0378	4.15	0.015432	0.57	24.55
Reman	17491	0.0489	74.55	0.000455	0.14	4.06
Riau	17606	0.0422	108.28	0.013817	0.17	188.97
Salak	17500	0.0415	4.09	0.004280	0.16	2.03
Sebarau	17140	0.0629	4.7	0.107015	0.16	86.76
Sg. Galing	18500	0.0274	12.28	0.012958	0.76	61.3
Sg. Isap	17500	0.0505	2.77	0.001358	0.63	2.14
Sg. Talam	17786	0.0306	7.44	0.011628	0.70	32.96
Sg. Tiram	17512	0.0386	21.79	0.034870	0.78	400.61
Ulu Sungai Kuantan	15952	0.0505	554.77	0.000396	0.1	18.05

Among the 18 sub basins, there is only one sub basin that has a soil erosion rate exceeding 200 t/ha/year, that is Sungai Tiram, where this sub basin only takes up 1% of the total area of KRB. After putting the data into the map accordingly, it can be seen that the soil erosion rate varies spatially in the study area. This data is interpreted from a few perspectives. From Graph 1, it is apparent that Sungai Tiram Sub basin has the highest soil erosion rate.

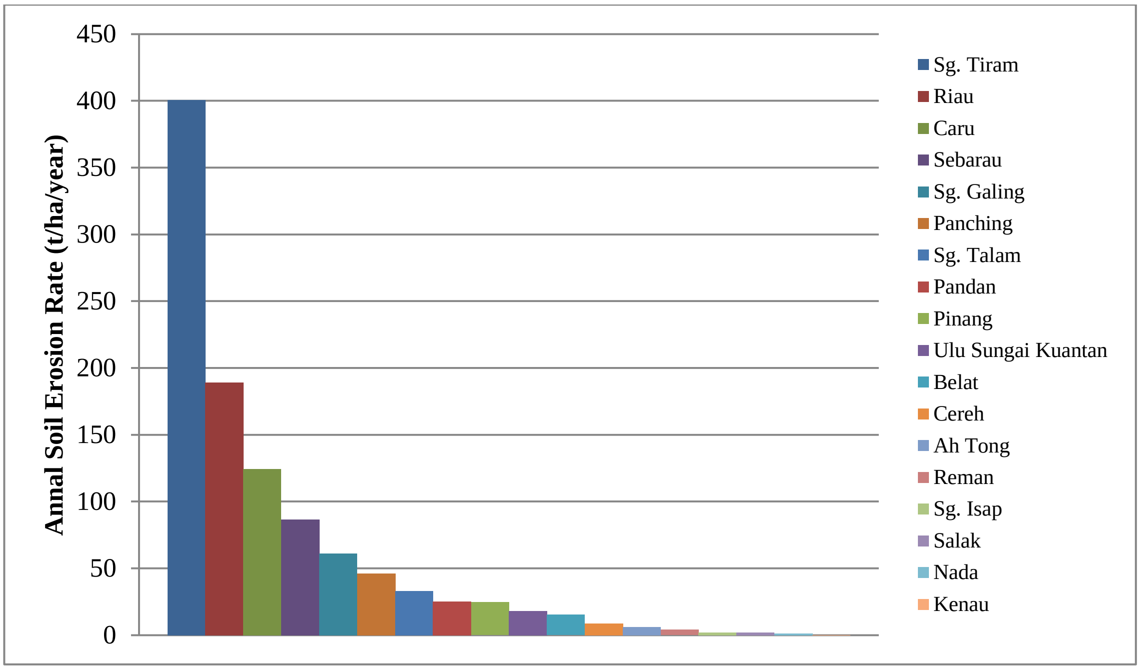


Figure 4.9: Annual Soil Erosion Rate of Kuantan River Basin

4.5.1 Relationship between soil erosion rate and LS Factor

Due to the mountain ranges located in the north, Ulu Sungai Kuantan and Cereh have the highest LS Factor. Therefore, these two sub basins have obtained soil erosion rate of 8.8t/ha/year and 18.05t/ha/year, respectively. Whereas on the south, Sungai Isap have the lowest LS Factor, followed by Belat. These two sub basins have obtained soil erosion rate of 2.14t/ha/year and 15.22t/ha/year respectively, which are lower than that of Cerah and Ulu Sungai Kuantan. This emphasizes the role of topography as a significant parameter in soil erosion.

4.5.2 Relationship between soil erosion rate and C Factor

From Figure 4.9, it is apparent that in Kuantan River Basin, 54% of the land is covered by forests and more than half of these areas, are located in the north-western part of the study area, where Ulu Sungai Kuantan, Cereh and Kenau are located. Therefore, it is clear that this part of the study areas have the lowest C Factor values among the 18 sub basins.

Forests as a type of landcover, can greatly reduce the kinetic energy from rainfall. Moreover, pervious ground of the forest land allows stormwater to be intercepted and seeped into the groundwater table. Consequently, runoff will be reduced and hence the soil erosion rate also be lessened.

Kenau Sub basin takes up 14.4% of the total forests area in Kuantan River Basin. Looking at the sub basin only, 96% of the land is forests .As a result, having a moderate LS factor at 10.82, the lowest soil erosion rate happened at the Kenau Sub Basin(0.24 t/ha/yr). Ulu Sungai Kuantan, however, despite having relatively low C factor, has a considerable higher soil erosion rate at 18.05 t/ha/yr because of the extreme steepness.

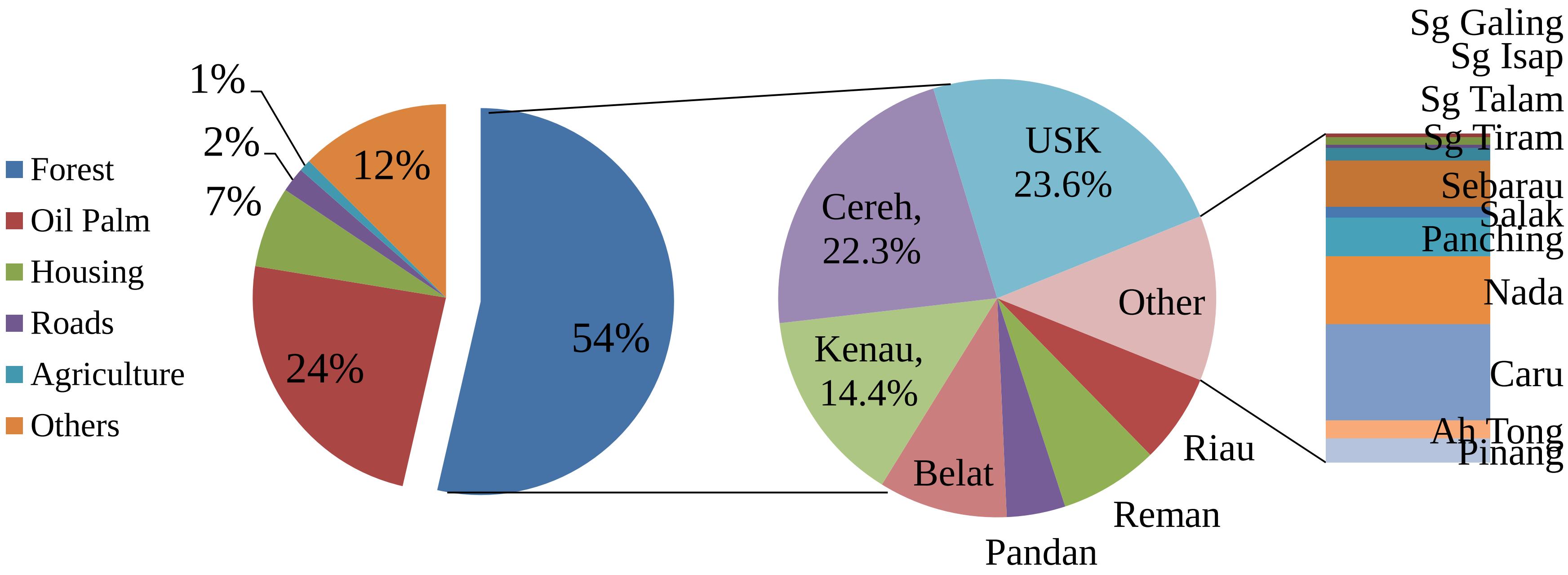


Figure 4.10: Distribution of Forests

CHAPTER 5

CONCLUSION

5.1 Introduction

This chapter summarizes and concludes the findings that were obtained and observed from this research. It will also include the limitations.

5.2 Conclusion

USLE is a popular approach to assess soil loss. Soil erosion rate are influence by a few factors, including rainfall, soil properties, topography of the area studied, land cover and erosion management applied. By using GIS software. USLE can be modeled much easier. A lot of information, like vegetation coverage, slope steepness, and sub basins areas can be obtained easily by utilizing GIS software.

The objectives of this research are to determine the R, LS, C and P Factors in USLE for the Kuantan River Basin, and to create a soil erosion risk map (Figure 4.8) based on the findings obtained. With the data obtained, it is apparent that the annual soil erosion rate varies spatially in Kuantan River Basin. The overall annual soil erosion rate of each sub basins varies from 0.24t/ha/year to 400.61t/ha/year. The potential soil loss in Kuantan River Basin is very severe, especially at the center and the north of the study area. The south of the area studied have a relatively lower soil erosion rate, ranging from 2.14 t/ha/year to 15.22t/ha/year.

5.3 Limitation

Calculation of soil erosion rate is based on findings, soil properties and rainfall data of each sub basin. Therefore the computation of soil erosion rate is based on each sub basin. In this case, the soil erosion risk map is less detailed as there is only one erosion rate for each sub basin.

Other than that, the landuse and landcover map obtained from JPS is not up to date. Some of the landuse data was stated to be still in development and has not been updated. Google Earth and Google Streetview are utilized to check the site condition.

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APPENDIX A
TABLE 5.1

Zoning 1	Zoning 2	Zoning 3	Area (m^2)	P Factor
Pertanian	Pertanian	Lain-lain	17847054	0.50
Pertanian	Pertanian	Kelapa Sawit	406579484	0.14
Hutan	Hutan Darat	Hutan Simpan Kekal	641036310	0.10
Hutan	Hutan Darat	Lain-lain	267080447	0.10
Pengangkutan	Jalan	Lain-lain	35205331	1.00
Perumahan	Kampung	Kampung Tanah Rancangan	4751389	0.80
Pertanian	Pertanian	Pertanian	1841	0.50
Institusi dan Kemudahan Masyarakat	Perkuburan	Perkuburan Islam	540077	0.50
Hutan	Hutan Darat	Hutan Perlindungan	411858	0.10
Institusi dan Kemudahan Masyarakat	Kesihatan	Klinik Desa	35377	0.80
Institusi dan Kemudahan Masyarakat	Pendidikan	Sekolah Rendah	2263051	1.00
Institusi dan Kemudahan Masyarakat	Keagamaan	Masjid	445297	1.00
Institusi dan Kemudahan Masyarakat	Keselamatan	Balai Polis	94171	1.00
Cadangan Perumahan	Perumahan Terancang		840070	0.50
Infrastruktur dan Utiliti	Bekalan Air	Tangki Air	277060	1.00
Pertanian	Pertanian	Dusun buah-buahan	1636715	0.50
Perumahan	Kampung	Tradisi	9926	0.80

Zoning 1	Zoning 2	Zoning 3	Area (m^2)	P Factor
Institusi dan Kemudahan Masyarakat	Kegunaan Kerajaan/Badan Berkanun	Badan Berkanun	315151	1.00
Pertanian	Pertanian	Getah	3449749	0.12
Institusi dan Kemudahan Masyarakat	Kesihatan	Klinik Kesihatan/Poliklinik	250724	1.00
Perumahan	Perumahan Bukan Strata	Rumah Kos Rendah	45911	1.00
Perumahan	Kampung	Kampung Tradisi	3530240	0.80
Institusi dan Kemudahan Masyarakat	Kemudahan Awam	Dewan Orang Ramai	179727	1.00
Institusi dan Kemudahan Masyarakat	Kemudahan Awam	Pejabat Pos	13585	1.00
Institusi dan Kemudahan Masyarakat	Pendidikan	Sekolah Menengah	2862701	1.00
Infrastruktur dan Utiliti	Bekalan Air	Loji Air	93594	0.10
Cadangan Institusi dan Kemudahan Masyarakat	Pendidikan	Tadika	2630	1.00
Institusi dan Kemudahan Masyarakat	Kegunaan Kerajaan/Badan Berkanun	Muzium	16905	1.00
Komersial	Pasar	Pasar Basah	51847	0.80
Perumahan	Kampung	Lain-lain	8199063	0.80
Pengangkutan	Pengangkutan Darat	Terminal/Stesen Bas	67570	1.00
Badan Air	Semulajadi	Sungai	13360072	0.10
Badan Air	Semulajadi	Tasik	16844490	0.10
Perumahan	Perumahan Bukan Strata	Sesebuah	4402940	1.00
Infrastruktur dan Utiliti	Bekalan Elektrik	Pencawang Elektrik (PE)	325752	1.00
Badan Air	Semulajadi	Lain-lain	20821	0.10
Cadangan Pertanian			2306284	0.50

Zoning 1	Zoning 2	Zoning 3	Area (m^2)	P Factor
Institusi dan Kemudahan Masyarakat	Perkuburan	Perkuburan Cina	638727	0.50
Institusi dan Kemudahan Masyarakat	Kemudahan Awam	Lain-lain	18628	1.00
Komersial	Runcit	Rumah Kedai	5201122	1.00
Institusi dan Kemudahan Masyarakat	Kegunaan Kerajaan/Badan Berkanun	Pejabat Kerajaan / Agensi Kerajaan	4621309	1.00
Komersial	Makanan dan Minuman	Medan Selera	277599	1.00
Tanah Lapang dan Rekreasi	Rekreasi Komersial	Lain-lain	137459	1.00
Komersial	Kemudahan Penginapan	Chalet	1423639	0.80
Infrastruktur dan Utiliti	Bekalan Elektrik	Laluan Rentis 132 kv	1164684	1.00
Komersial	Makanan dan Minuman	Gerai/Penjaja	113136	1.00
Pertanian	Pertanian	Pertanian Campuran	6875892	0.50
Institusi dan Kemudahan Masyarakat	Kemudahan Awam	Balai Raya/Pusat Komuniti	39780	1.00
Perumahan	Kampung	Perumahan Ladang / Estet	382342	0.80
Infrastruktur dan Utiliti	Bekalan Air	Empangan	119577	0.10
Institusi dan Kemudahan Masyarakat	Keagamaan	Tokong	119592	1.00
Cadangan Hutan	Hutan Darat	Hutan Perlindungan	14978627	0.10
Cadangan Komersial	Perniagaan Terancang		88074	1.00
Cadangan Institusi dan Kemudahan Masyarakat	Keselamatan	Balai Bomba dan Penyelamat	88680	1.00
Cadangan Industri	Industri Ringan	IKS	23034	1.00
Cadangan Tanah Lapang dan Rekreasi	Tanah Lapang	Taman Tempatan	96103	0.80

Zoning 1	Zoning 2	Zoning 3	Area (m^2)	P Factor
Cadangan Institusi dan Kemudahan Masyarakat	Kemudahan Awam		36693	1.00
Cadangan Institusi dan Kemudahan Masyarakat	Pendidikan	Sekolah Menengah	1225672	1.00
Infrastruktur dan Utiliti	Bekalan Air	Rumah Pam Bekalan Air	16646	0.80
Institusi dan Kemudahan Masyarakat	Pendidikan	Institut Pengajian Tinggi/Kolej/Politeknik/Maktab	6894407	1.00
Pembangunan Bercampur	Kegunaan Bercampur	Lain-lain	270729	1.00
Pengangkutan	Jalan	Jalan Negeri	3972	1.00
Pengangkutan	Jalan	Lebuhraya	36211	1.00
Pertanian	Penternakan	Burung	31445	0.10
Komersial	Runcit	Barangan Keperluan Harian	161066	1.00
Cadangan Perumahan			114970979	0.50
Perumahan	Perumahan Bukan Strata	Berkembar	4023413	1.00
Perumahan	Perumahan Bukan Strata	Teres	9739501	1.00
Institusi dan Kemudahan Masyarakat	Keagamaan	Surau	136035	1.00
Infrastruktur dan Utiliti	Pembetungan	Stesen Pump Rangkaian	153318	0.50
Institusi dan Kemudahan Masyarakat	Pendidikan	Tadika	82077	1.00
Infrastruktur dan Utiliti	Pengairan dan Perparitan	Rangkaian Sistem Perparitan/Monsun Drain	1480063	0.10
Cadangan Industri			11259562	1.00
Industri	Industri Sederhana	Lain-lain	1128812	1.00
Tanah Kosong	Tanah Pembangunan	Lain-lain	504144	0.80
Infrastruktur dan Utiliti	Pembetungan	Loji Rawatan Kumbahan	365487	0.50

Zoning 1	Zoning 2	Zoning 3	Area (m^2)	P Factor
Industri	Industri Sederhana	Bengkel membaiki kenderaan bermotor dan berjentera	326187	1.00
Komersial	Makanan dan Minuman	Restoran Makanan Segera	15641	1.00
Hutan	Hutan Yang Dibersihkan	Hutan Yang Dibersihkan	8084110	1.00
Industri	Industri Berat	Lain-lain	742714	1.00
Infrastruktur dan Utiliti	Bekalan Gas dan Petroleum	Laluan Paip Gas PGU I	1378418	1.00
Komersial	Stesyen Minyak	Stesen dan Servis Termasuk Perkhidmatan Berkaitan	109899	1.00
Institusi dan Kemudahan Masyarakat	Keselamatan	Pusat Pemulihan Dadah	1507331	1.00
Perumahan	Perumahan Strata	Rumah Berbilang Tingkat	133739	1.00
Infrastruktur dan Utiliti	Telekomunikasi	Stesen Bukit	10452	1.00
Tanah Kosong	Tanah Tidak Diusahakan	Berumput/Semak/Belukar/ Tanah Terbiar	29570	0.80
Infrastruktur dan Utiliti	Pembetungan	Kolam Oksidasi	106807	0.10
Komersial	Runcit	Lain-Lain	69596	1.00
Cadangan Tanah Lapang dan Rekreasi	Tanah Lapang	Taman Kejiranan	239509	0.80
Infrastruktur dan Utiliti	Bekalan Gas dan Petroleum	Stesen Pengagih Gas	206118	1.00
Industri	Industri Sederhana		139565	1.00
Komersial	Borong	Peralatan Kenderaan	612	1.00
Komersial	Perkhidmatan Peribadi dan Isirumah	Lain-lain	1878	1.00
Komersial	Runcit	Peralatan Kenderaan	10238	1.00

Zoning 1	Zoning 2	Zoning 3	Area (m^2)	P Factor
Cadangan Tanah Lapang dan Rekreasi	Kawasan Hijau	Zon Penampan	368865	0.80
Institusi dan Kemudahan Masyarakat	Keselamatan	Kem Tentera	9354500	1.00
Perumahan	Perumahan Strata	Sesebuah	24994	1.00
Industri	Industri Ringan	Lain-lain	110244	1.00
Komersial	Kompleks Perniagaan	Arked/Bazar	59801	1.00
Institusi dan Kemudahan Masyarakat	Pendidikan	Taska	3705	1.00
Komersial	Pasar	Lain-lain	8511	1.00
Institusi dan Kemudahan Masyarakat	Keselamatan	Lain-lain	1242613	1.00
Perumahan	Perumahan Bukan Strata	Kuarters Kerajaan	1299540	1.00
Tanah Lapang dan Rekreasi	Tanah Lapang	Laman Rekreasi	618016	0.80
Komersial	Perkhidmatan	Bengkel Kenderaan	87755	1.00
Komersial	Borong	Peralatan dan Bahan Binaan	61154	1.00
Industri	Industri Sederhana	Industri pembuatan barangan komputer dan barangan elektronik	28517	1.00
Tanah Lapang dan Rekreasi	Kawasan Hijau	Lain-lain	163331	0.80
Komersial	Runcit	Peralatan dan Bahan Binaan	25972	1.00
Komersial	Perkhidmatan	Perkhidmatan Profesional	152866	1.00
Komersial	Runcit	Produk Makanan dan Minuman	159	1.00
Komersial	Perkhidmatan	Klinik Swasta	1899	1.00

Zoning 1	Zoning 2	Zoning 3	Area (m^2)	P Factor
Komersial	Perkhidmatan	Hospital/Pusat Rawatan Swasta	78130	1.00
Komersial	Makanan dan Minuman	Restoran/Kafe/Bistro	107792	1.00
Komersial	Runcit	Peralatan Rumah/Pejabat	20042	1.00
Komersial	Runcit	Barangan Peribadi	1864	1.00
Pantai	Semulajadi	Pantai Berpasir	66542	0.10
Komersial	Hiburan dan Riadah	Lain-lain	9241	1.00
Institusi dan Kemudahan Masyarakat	Kemudahan Awam	Tandas Awam	274	1.00
Tanah Kosong	Tanah Tidak Diusahakan	Tapak Projek Terbengkalai	23	0.80
Komersial	Perkhidmatan	Lain-lain	193537	1.00
Komersial	Perkhidmatan Peribadi dan Isirumah	Dobi	144	1.00
Komersial	Runcit	Kedai Pejabat	649387	1.00
Tanah Lapang dan Rekreasi	Kemudahan Sukan dan Rekreasi	Lain-lain	92901	1.00
Institusi dan Kemudahan Masyarakat	Kegunaan Kerajaan/Badan Berkanun	Lain-lain	153170	1.00
Industri	Industri Sederhana	Kilang alat jentera dan kelengkapan jentera	185490	1.00
Institusi dan Kemudahan Masyarakat	Rumah Kebajikan	Pusat Pemulihan Akhlak	1036	1.00
Infrastruktur dan Utiliti	Telekomunikasi	Rangkaian Telekomunikasi	3211	1.00
Tanah Lapang dan Rekreasi	Rekreasi Komersial	Padang Golf	1409689	1.00
Tanah Lapang dan Rekreasi	Rekreasi Komersial	Rumah Kelab	50762	1.00
Infrastruktur dan Utiliti	Bekalan Elektrik	Laluan Rentis 32 kv	205384	1.00

Zoning 1	Zoning 2	Zoning 3	Area (m^2)	P Factor
Komersial	Makanan dan Minuman	Lain-lain	9114	1.00
Komersial	Pendidikan Swasta	Universiti/Institusi Pendidikan Tinggi	33175	1.00
Tanah Lapang dan Rekreasi	Kemudahan Sukan dan Rekreasi	Kompleks Sukan	336622	1.00
Tanah Lapang dan Rekreasi	Tanah Lapang	Tanah Lapang	308504	0.80
Komersial	Borong	Gudang/Stor	43398	1.00
Institusi dan Kemudahan Masyarakat	Kegunaan Kerajaan/Badan Berkanun	Istana	263395	1.00
Tanah Lapang dan Rekreasi	Tanah Lapang	Taman Tempatan	1401400	0.80
Infrastruktur dan Utiliti	Pelupusan Sisa Pepejal	Tapak Pusat Pengumpulan/Pemindahan	5298	0.50
Komersial	Borong	Produk Makanan dan Minuman	11480	1.00
Industri	Industri Ringan	Gudang (tempat simpan barang secara sementara, seperti gudang getah, plastik, kontena)	66935	1.00
Industri	Industri Sederhana	Industri pembuatan kayu dan produk kayu	318868	1.00
Komersial	Perkhidmatan Peribadi dan Isirumah	Bengkel Mencuci Kereta	19861	1.00
Pertanian	Penternakan	Lembu	119094	0.10
Infrastruktur dan Utiliti	Bekalan Air	Loji Rawatan Air	330621	0.10
Pengangkutan	Pengangkutan Darat	Tempat Letak Kenderaan	62583	1.00
Institusi dan Kemudahan Masyarakat	Pendidikan	Lain-lain	201061	1.00

Zoning 1	Zoning 2	Zoning 3	Area (m^2)	P Factor
Pengangkutan	Pengangkutan Darat	Depot Bas	32142	1.00
Pengangkutan	Pengangkutan Udara	Lapangan Terbang Kecil (Airstrip)	40107	1.00
Komersial	Borong	Barangan Keperluan Harian	20311	1.00
Komersial	Kemudahan Penginapan	Hotel	64510	0.80
Institusi dan Kemudahan Masyarakat	Rumah Kebajikan	Rumah Warga Emas	20228	1.00
Komersial	Runcit	Runcit	1371	1.00
Infrastruktur dan Utiliti	Telekomunikasi	Menara Pemancar Telekomunikasi	2934	1.00
Perumahan	Kampung		50399	0.80
Pengangkutan	Pengangkutan Darat	Lain-lain	3773	1.00
Komersial	Pasar	Pasar Borong	28823	0.80
Perumahan	Perumahan Strata	Lain-lain	8230	1.00
Perumahan	Perumahan Bukan Strata	Lain-lain	11402	1.00
Industri	Industri Berat	Industri primer besi dan keluli	55911	1.00
Industri	Industri Sederhana	Industri pembuatan barangan elektrik	9009	1.00
Infrastruktur dan Utiliti	Pembetungan	Lain-lain	859	0.10
Cadangan Tanah Lapang dan Rekreasi	Tanah Lapang	Lain-lain	39349	0.80
Industri	Industri Berat	Kilang papan/kertas	61402	1.00
Cadangan Institusi dan Kemudahan Masyarakat			84552	1.00
Cadangan Komersial	Runcit	Rumah Kedai	24759	1.00
Perumahan	Perumahan Strata	Kuarters Kerajaan	207422	1.00

Zoning 1	Zoning 2	Zoning 3	Area (m^2)	P Factor
Komersial	Kompleks Perniagaan	Hypermarket	60336	1.00
Infrastruktur dan Utiliti	Pengairan dan Perparitan	Lain-lain	1883	0.10
Infrastruktur dan Utiliti	Pengairan dan Perparitan	Stesen Pam	332346	1.00
Infrastruktur dan Utiliti	Bekalan Air	Lain-lain	112684	0.10
Industri	Lombong/Kuari	Perlombongan lain-lain	96110	1.00
Industri	Lombong/Kuari	Kuari	4102	1.00
Institusi dan Kemudahan Masyarakat	Keselamatan	Balai Polis Komuniti/Pondok Polis	7128	1.00
Cadangan Pengangkutan	Pengangkutan Darat		858	1.00
Pertanian	Penternakan	Ayam	13844	0.10
Pertanian	Pertanian	Padi	581	0.50
Pertanian	Pertanian	Sayur-sayuran	23221	0.50
Tanah Lapang dan Rekreasi	Tanah Lapang	Taman Kejiranan	446968	0.80
Pertanian	Akuakultur	Ikan	462392	1.00
Institusi dan Kemudahan Masyarakat	Rumah Kebajikan	Rumah Anak Yatim	55788	1.00
Komersial	Stesyen Minyak	Stesen	39396	1.00
Cadangan Tanah Lapang dan Rekreasi	Tanah Lapang	Lot Permainan	29840	0.80
Pengangkutan	Pengangkutan Udara	Lapangan Terbang	349085	1.00
Cadangan Tanah Lapang dan Rekreasi	Tanah Lapang	Padang Permainan	3927	0.80
Komersial	Runcit	Peralatan Komunikasi dan Matlumat	3851	1.00
Komersial			4050	1.00
Badan Air	Semulajadi	Paya/Tanah Bencah	398772	0.10
Infrastruktur dan Utiliti	Pengairan dan Perparitan	Kolam Tahanan	14387076	0.10

Zoning 1	Zoning 2	Zoning 3	Area (m^2)	P Factor
Pengangkutan	Pengangkutan Darat	Terminal/Stesen Teksi	2375	1.00
Komersial	Kompleks Perniagaan	Pusat beli-belah	39709	1.00
Infrastruktur dan Utiliti	Telekomunikasi	Menara Radar / Antena	5640	1.00
Tanah Lapang dan Rekreasi	Tanah Lapang	Lain-lain	214352	0.80
Tanah Lapang dan Rekreasi	Keagamaan	Surau	1828	0.80
Institusi dan Kemudahan Masyarakat	Keagamaan	Kuil	34687	1.00
Institusi dan Kemudahan Masyarakat	Kesihatan	Hospital	373381	1.00
Industri	Industri Sederhana	Kilang produk makanan	4079	1.00
Tanah Kosong	Tanah Pembangunan	Tapak Pembinaan	212195	0.80
Perumahan	Perumahan Bukan Strata	Rumah Pekerja	8846	1.00
Tanah Lapang dan Rekreasi	Rekreasi Komersial	Gelanggang Sukan/Permainan	9865	1.00
Institusi dan Kemudahan Masyarakat	Kemudahan Awam	Perpustakaan Awam	16874	1.00
Infrastruktur dan Utiliti	Bekalan Elektrik	Lain-lain	149	1.00
Pengangkutan	Jalan	Jalan	14105	1.00
Tanah Lapang dan Rekreasi	Tanah Lapang	Taman Bandaran	219173	0.80
Pertanian	Penternakan	Kambing/Biri-Biri	355212	0.10
Komersial	Perkhidmatan Peribadi dan Isirumah	Kedai Jahit	269	1.00
Badan Air	Buatan	Lombong/Bekas Lombong	984267	1.00
Cadangan Tanah Lapang dan Rekreasi	Tanah Lapang	Taman Wilayah/Negeri	12986377	0.80

Zoning 1	Zoning 2	Zoning 3	Area (m^2)	P Factor
Perumahan	Perumahan Bukan Strata		344949	1.00
Tanah Lapang dan Rekreasi	Tanah Lapang		37514	0.80
Pengangkutan	Jalan		114248	1.00
Pengangkutan	Pengangkutan Air	Jeti	583	1.00
Infrastruktur dan Utiliti	Pembentungan	Loji Rawatan Kumbahan	3186	0.50
Komersial	Runcit		6563	1.00
Cadangan Tanah Lapang dan Rekreasi			30035	0.80
Industri			7866	1.00
Perumahan	Kampung	Kampung Orang Asli	132817	0.80
Komersial	Kemudahan Penginapan	Lain-lain	148	0.80
Komersial	Kompleks Perniagaan	Lain-lain	51433	1.00
Pembangunan Bercampur	Kegunaan Bercampur	Perumahan-Komersial	40492	1.00
Komersial	Perkhidmatan	Syarikat Insurans/Kewangan	384	1.00
Institusi dan Kemudahan Masyarakat	Kegunaan Kerajaan/Badan Berkanun	Kegunaan Kerajaan/Badan Berkanun	5735	1.00
Infrastruktur dan Utiliti	Bekalan Elektrik	Bekalan Elektrik	691	1.00
Komersial	Tempat Letak Kenderaan Swasta	Tempat Letak Kenderaan Terbuka	35589	1.00
Komersial	Kompleks Perniagaan	Pejabat	24583	1.00
Institusi dan Kemudahan Masyarakat	Keagamaan	Gereja	33933	1.00
Komersial	Perkhidmatan	Bank	5327	1.00
Institusi dan Kemudahan Masyarakat	Keselamatan	Ibu Pejabat Polis Kotinjen (IPK)	33545	1.00
Komersial	Komersial	Lain-lain	164	1.00

Zoning 1	Zoning 2	Zoning 3	Area (m^2)	P Factor
Institusi dan Kemudahan Masyarakat	Rumah Kebajikan	Rumah Persatuan / Pertubuhan	14109	1.00
Komersial	Perkhidmatan Peribadi dan Isirumah	Pusat Penjagaan Kanak-Kanak	922	1.00
Komersial	Kemudahan Penginapan	Pangsapuri servis	26590	1.00
Tanah Lapang dan Rekreasi	Kawasan Hijau	Zon Penampan	806554	0.80
Perumahan	Perumahan Strata	Rumah Pekerja	3575	1.00
Institusi dan Kemudahan Masyarakat	Kesihatan	Lain-lain	24713	1.00
Perumahan	Perumahan	Kuarters Kerajaan	3328	1.00
Perumahan	Perumahan Strata	Teres	964	1.00
Infrastruktur dan Utiliti	Pembetungan	Pembetungan	1569	0.10
Cadangan Perniagaan			57206	1.00
Institusi dan Kemudahan Masyarakat	Kesihatan	Klinik 1Malaysia	254	1.00
Komersial	Pendidikan Swasta	Tadika	258	1.00
Tanah Lapang dan Rekreasi	Kawasan Hijau	Kawasan Hijau	2521	0.80
Komersial	Stesyen Minyak	Stesyen Minyak	1040	1.00
Tanah Lapang dan Rekreasi	Kemudahan Sukan dan Rekreasi	Stadium	66439	1.00
Komersial	Kemudahan Penginapan	Rumah Rehat/Rumah Tetamu	19041	1.00
Tanah Lapang dan Rekreasi	Tanah Lapang	Lot Permainan	441937	0.80
Tanah Lapang dan Rekreasi	Tanah Lapang	Padang Permainan	652455	0.80

Zoning 1	Zoning 2	Zoning 3	Area (m^2)	P Factor
Perumahan	Runcit	Kedai Pejabat	138	1.00
Komersial	Kemudahan Penginapan	Rumah Tumpangan	56104	1.00
Institusi dan Kemudahan Masyarakat	Kegunaan Kerajaan/Badan Berkanun	Mahkamah	3743	1.00
Institusi dan Kemudahan Masyarakat	Perkuburan	Perkuburan Hindu/Sikh/Bahai	26984	0.50
Institusi dan Kemudahan Masyarakat	Perkuburan	Krematorium/Dewan Pengurusan Mayat	4320	0.50
Institusi dan Kemudahan Masyarakat	Perkuburan	Perkuburan Kristian	4023	0.50
Institusi dan Kemudahan Masyarakat	Institusi dan Kemudahan Masyarakat	Pejabat Kerajaan / Agensi Kerajaan	60	1.00
Badan Air	Semulajadi	Laut	9703	0.10
Pantai	Semulajadi	Pantai Berlumpur	9106	0.10