ESTIMATION OF SEDIMENT YIELD FROM KUANTAN RIVER BASIN USING MODIFIED UNIVERSAL SOIL LOSS EQUATION (MUSLE)

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ESTIMATION OF SEDIMENT YIELD FROM KUANTAN RIVER BASIN USING MODIFIED UNIVERSAL SOIL LOSS EQUATION (MUSLE)

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ABSTRAK

Air dalam bentuk hujan adalah punca utama yang mempercepatkan kadar hakisan tanah di tanah yang menjadi hasil sedimen. Tujuan kajian ini adalah untuk menganggarkan hasil sedimen dari Lembangan Sungai Kuantan dengan menggunakan model matematik Modified Universal Soil Loss Equation (MUSLE). Satu siri data dikumpulkan untuk mendapatkan parameter kelantangan larian (V), pelepasan puncak (Qp), faktor kelimasan tanah (K). Perisian ArcGIS digunakan untuk mendapatkan faktor topografi (LS), faktor amalan kawalan hakisan (P) dan faktor pengurusan penutup (C). Dengan semua data yang berkaitan, hasil sedimen dari lembah sub-sungai Kuantan dikira menggunakan persamaan model MUSLE matematik. Oleh itu, hasil sedimen dari Lembangan Sungai Kuantan pada tahun 2015 dan 2035 boleh dibandingkan. Lebih-lebih lagi, sub-basin yang mengandungi jumlah sedimen tertinggi dan paling rendah dalam kedua-dua tahun boleh ditentukan. Sub-basin Riau mencapai tahap tertinggi dalam kadar sedimen dalam kedua-dua tahun 2015 dan 2035 iaitu 32750.52 tons/yr dan 2764.09 tons/yr manakala sub-basin Sungai Isap mempunyai bilangan sedimen yang paling rendah dalam kedua-dua tahun iaitu 1.5653 tons/yr dan 0.5177 tons/yr.

ABSTRACT

The water in the form of rain is the main cause which accelerates the soil erosion rate on the ground which become sediment yield. The purpose of this study is to estimate the sediment yield from Kuantan river basin using the Modified Universal Soil Loss Equation (MUSLE) mathematical model. A series of data were collected to get the parameters of runoff volume (V), peak discharge (Q_p), soil erodibility factor (K). ArcGIS software was utilized to obtain the topographic factor (LS), erosion control practice factor (P) and cover management factor (C). With all the relevant data, the sediment yield from Kuantan sub-river basin was computed using the MUSLE mathematical model equation. Sediment yield from Kuantan River Basin in year 2015 and 2035 was compared. And he sub-basins that contain highest and lowest amount of sediment yield in both years determined. Riau sub-basin has the highest amount of sediment yield in year 2015 and 2035 with the amount of 32750.24 tons/yr and 2764.09 tons/yr respectively. Conversely, Sungai Isap sub-basin has lowest amount of sediment yield in both years with the amount of 1.5653 tons/yr in year 2015 and 0.5177 tons/yr in year 2035.

TABLE OF CONTENT

DECLARATION	
TITLE PAGE	
ACKNOWLEDGEMENTS	**ii**
ABSTRAK	**iii**
ABSTRACT	**iv**
TABLE OF CONTENT	**v**
LIST OF TABLES	**viii**
LIST OF FIGURES	**ix**
LIST OF SYMBOLS	**x**
LIST OF ABBREVIATIONS	**xi**
CHAPTER 1 INTRODUCTION	**12**
1.1 Background	12
1.2 Problem Statement	13
1.3 Objectives of Study	14
1.4 Scope of Study	14
1.5 Significance of Study	15
CHAPTER 2 LITERATURE REVIEW	**16**
2.1 Background	16
2.1.1 Factors Affecting Sediment Yield and Soil Erosion	18

2.1.2 Type of Soil Degradation Affecting Sediment Yield 20

2.1.3 Soil Erodibility Factor 22

2.1.4 Topographic Factor 23

2.1.5 Cover Management Factor 24

2.1.6 Erosion Control Practice Factor 26

2.2 Predicting Sediment Yield 27

2.2.1 Sediment Yield from a Storm 27

2.2.2 Sediment Yield from Watershed 28

2.3 Research Gap 30

CHAPTER 3 METHODOLOGY 31

3.1 Introduction 31

3.2 Sample Collection 31

3.3 Soil Erodibility Factor, K 32

3.4 Cover Management Factor, C and Erosion Control Practices Factor, P 41

3.4.1 Insert Information in ArcGIS 41

3.4.2 Weighted Area Method 45

3.5 Slope Length and Steepness Factor, LS 48

CHAPTER 4 RESULTS AND DISCUSSION 50

4.1 Topographic Factor, LS 50

4.2 Cover Management, C and Erosion Control Practice Factor, P 51

4.3 Peak Flow, Q_p and Runoff Volume, V 53

4.4 Sediment Yield, Y 55

CHAPTER 5 CONCLUSION **62**

5.1 Introduction 62

5.2 Conclusion 62

REFERENCES **63**

LIST OF TABLES

Table 3.1 Distribution of Different Soil Associations in Peninsular Malaysia 33
Table 3.2 Erodibility of Five Common Peninsular Malaysia Soil 37
Table 3.3 Soil Series in Study Area 38
Table 3.4 Comparison Between Permeability Classes 40
Table 3.5 Temperature and Area of the Patch 46
Table 3.6 Practice and Erosion Control (P) factor for Contouring and Terracing 47
Table 3.7 C Factor Values 49
Table 4.1 Values for K, LS, C and P for Each Sub-basin 52
Table 4.2 Peak Flow for Various ARI in Year 2015 53
Table 4.3 Peak Flow for Various ARI in Year 2035 53
Table 4.4 Runoff Volume for Various ARI in Year 2015 54
Table 4.5 Runoff Volume for Various ARI in Year 2035 54
Table 4.6 Sediment Yield for Year 2015 55
Table 4.7 Sediment Yield for Year 2035 56

LIST OF FIGURES

Figure 2.1	Human-induced Soil Degradation Around the World	22
Figure 3.1	Post-Hole Auger of Iwan Type	32
Figure 3.2	Adding the Shapefiles	42
Figure 3.3	Shapefiles Inserted	43
Figure 3.4	Different Type of Soil Created	44
Figure 3.5	Map Exported and Opened in Google Earth Pro	45
Figure 3.6	Weighted Area Shape Patch	45
Figure 4.1	Slope map for Kuantan River Basin	50
Figure 4.2	Land Use and Land Cover Map in each sub-basin	51
Figure 4.3	Sediment Yield from Ah Tong, Cereh, Kenau, Pandan, Reman and Ulu Sungai Kuantan Sub-basins	57
Figure 4.4	Sediment Yield from Belat, Caru, Nada and Pancing Sub-basins	58
Figure 4.5	Sediment Yield from Riau, Sebarau, Sungai Galing and Sungai Isap Sub-basins	59
Figure 4.6	Sediment Yield from Sungai Talam, Sungai Tiram and Salak Sub-basins	60
Figure 4.7	Sediment Yield from Pinang Sub-basin	61

LIST OF SYMBOLS

λ	Sheet Flow Path Length (m or feet)
φ	72.6 foot for Imperial Units or 22.13m for SI
°C	Unit temperature in degree Celsius
Q_p	Peak Flow in metre cube per second
V	Runoff Volume in metre cube
Y	Sediment Yield in tons per year

LIST OF ABBREVATIONS

K	Soil Erodibility Factor
LS	Slope Length and Slope Steepness Factor
C	Cover Management Factor
P	Erosion Control Practices Factor
USLE	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

CHAPTER 1

INTRODUCTION

1.1 Background

Sediment yield of a sub-basin of a river is often caused by soil erosion which usually occurred naturally. Factors affecting the soil erosion can be categorized into human and natural prompted. Precipitation and steepness of slope comprise natural factors for the most part, while human causes consists of development or activities related to agriculture, mining and constructions. Such activities usually remove the protective vegetation concealment, resulting in accelerated erosion by both water and wind. Factors that occurred naturally affect the upper soil layer more often as compared to human prompted factors. Both contribute a significant amount of soil loss due to water erosion.

Soil erosion comes from water in the form of rain and runoff. Particles of the soil especially fine sand and silt are broken off and being dispersed when there is a rain. This damage of soil increases with heavy rain and thunderstorms. Runoff can carry these particles to rivers, oceans, streams or lakes. Runoff occurs when water drifts down a slope, or surface, and is not absorbed into the soil. Runoff increases when soil is over hydrated, as the soil is unable to absorb any more water. This runoff can carry more rich topsoil. Soil erosion removes valuable top soil which is the most productive part of the soil profile for agricultural purposes. The loss of this top soil results in lower yields and higher production costs.

While soil itself can resist erosion, this can be influenced by a variety of factors. Several things such as amounts of animal and plant matter which decomposed in the soil, the ability for water to pass through the soil, and good soil structure creates good resistance to erosion. For example, forest serves as a temporary water storage. Although fine sand, silty and loamy soil has good resistance, other soils have a poor resistance to erosion. Hence, a steep surface can increase the affects to erosion, obviously, because it increases speed, and destruction of the runoff and sediment. Therefore, root of the tree of the forest can help to anchor the soil and provide a support to prevent movement of soil. However, the erosion of soil apparently easier to occur due to urbanization of certain places. Trees are cleared away during deforestation in order to undergo development.

1.2 Problem Statement

Soil sedimentation from soil erosion is a serious problem that is currently affecting all the countries in the world. As a country having tropical climate, Malaysia always receives high amount of rainfall intensity especially during the monsoon season which normally happens from October to March. Furthermore, Kuantan which is the research area, is located at the east coast region of Malaysia, hence, sediment yield of the sub-basins of the river tend to be high during this period due to the reason that the area is highly affected by monsoon season where the amount of rainfall during October to March is very high.

Water in the form of rain will be the main cause which accelerates the soil erosion rate on the ground. When the human activities on forest land occurs, the removal of vegetative cover such as trees during deforestation will contribute to this event as the runoff will increased while the infiltration of water into the soil is lesser.

As is known, waterways comprise of drainage basin or watershed. This is the area of land where the precipitation of rain that falls within it will drain through the drainage basin before escaping into rivers, lakes, oceans and seas. When heavy rain occurs, the rain will wash away the topsoil and bring along the sediments and soil to the river basin due to the human activities near the river basin such as over cropping, overgrazing and deforestation. Therefore, there is a need to study the soil erosion near the Kuantan river basin which undoubtedly causes flooding as the sediments and soil that deposits in the river bed which in turn causes the river to be unable to cope with large volume of runoff during heavy rain.

1.3 Objectives of Study

The aim of this study is to estimate the sediment yield of Kuantan river basin. To achieve this, the main specific objectives are outlined as follows:

i) Assessment of sediment yield for each sub-basin of the Kuantan river basin using the MUSLE.

ii) Comparison of the sediment yield from each sub-basins between year 2015 and 2035.

1.4 Scope of Study

This study estimates the sediment yield using all the parameters of the MUSLE mathematical model equation on the Kuantan sub-river basin. A series of data will be collected with regards to the parameters of runoff volume (V), peak discharge (Q_p), soil erodibility factor (K), slope length and steepness factor (LS), support practice factor (P) and erosion management factor (C). Other than that, ArcGIS software is also used to determine the sampling location and to analyses area 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. Then, with all the relevant data, the sediment yield from Kuantan river basin will be computed using the MUSLE mathematical model equation.

1.5 Significance of Study

This study is very important to Kuantan area as Pahang is located at the east coast region of the peninsular of Malaysia which usually experience monsoon season starting from October to March. At the end of 2013, a catastrophic flooding happened as majority of the Kuantan area was inundated by water because at this time, heavy rain occurred and the Kuantan river basin did not manage to hold off the large volume of runoff from the rain. The daily maximum rainfall recorded for Kuantan rainfall station was 175 mm/day before the flood but during the catastrophic flood, the average amount of rainfall exceeded 800 mm from December 2013 to January 2014 (Wahid, Nasir, Hassan, Abu Bakar, & Tahir, 2015). Hence, it is very important that the sediment yield along with the annual soil loss at Kuantan river basin be investigated so that the results will be available to related parties that can plan the suitable Best Management Practice (BMP) tp be applied to mitigate the soil erosion problems as well as curb the flooding woes. Therefore, it is very vital to analyze the V, Q_p, C, LS, K and P factors of the MUSLE mathematical model equation in the Kuantan area since the Malaysian physical conditions such as the topography, weather, vegetation and soil types vary from state to state.

CHAPTER 2

LITERATURE REVIEW

2.1 Background

Sediment yield is defined as the total quantity of sediment expressed in unit of mass that can pass a point of interest from drainage basin in a given period of time. It is broadly understood in earth surface processes to mean the total volume or mass of sediment evacuated, transported, or deposited from a drainage basin. As the term yield implies, the amount of sediment removed is estimated or measured over a known period of time. Sediment yield is then reported as mass per year (typically tons/year) or volume per year. Sediment yield refers to the inorganic fraction of sediment, ignoring organic material frequently in transport in fluvial systems. Sediment yield is among the most difficult parameters to be accurately measured in the field, but accurate measurements are essential to provide the data required for better understanding of the delivery process. The quantity of sediment delivered to a reservoir depends on the rate of gross or absolute erosion in the watershed and the ability of the stream system to transport eroded material to the reservoir. The rate of gross erosion depends on climatic conditions, nature of the soils, slopes, topography and land use, while the ability of a stream to transport the eroded material to a reservoir depends on the hydro-physical conditions of the watershed. Sediment deposition in reservoirs is a complex and troublesome process. It piles up the debris behind a dam thereby reducing the capacity of the reservoir and its service function. The problem of essential concern is understand the rate at which the reservoir is filling and identifies the steps to be taken to minimise the loss of reservoir capacity so that the life of the reservoir may be prolonged.

Since sediment yield is highly related to soil erosion, it is necessary to study about the soil erosion priory to know more about its cause and effects. Soil erosion is a natural occurring process throughout all the land in the world. It can be classified as one form of soil degradation along with other types of soil degradation such as soil compaction, low organic matter, soil acidity problems, poor internal drainage, and loss of soil structure (Wall, Baldwin, & Shelton, 2007). Normally, these other types of soil degradation, if considered significant, will usually accelerate the soil erosion process. Soil erosion is a process that happens at a slow pace, but it can be very frightening when it causes massive loss of topsoil. In the majority of the farmland, this phenomenon has the potential to reduce the crop production, affect the surface water quality and damaged drainage networks. This loss of topsoil problem at farmland is discussed as the on-site effects from soil erosion. The soil fertility and cultivable soil depth are largely depend on the soil structure content, soil own organic matter and nutrient content, amount of soil loss from field, and soil distribution within a field. The erosion that happened lead to decrease in availability of soil moisture, resulting an arid conditions. As a result, soil fertility that lost through erosion ultimately leads to lands being deserted and there will be major concerns about the food production later on.

Furthermore, human disturbances including deforestation, agriculture, roads, mining, and urbanization alter the timing, composition, and amount of sediment loads to downstream ecosystems. Increased sediment yields can stress aquatic ecosystems downstream of impacted watersheds, including coral reefs, by decreasing light for photosynthesis and increasing sediment accumulation rates (Fabricius, 2005). Anthropogenic sediment disturbance can be particularly high on volcanic islands in the humid tropics, where erosion potential is high due to high rainfall and steep slopes. The steep topography and small floodplains on small volcanic islands limits sediment storage and the buffering capacity of the watershed against increased hillslope sediment supply. Such environments characterize many volcanic islands in the South Pacific and elsewhere where many coral reefs are sediment-stressed (Bégins et al. 2014).

Soil erosion remains the main mechanism of soil degradation, which threatens the global sustainability of the food production systems (Didoné et al.

2017). In tropical and subtropical regions, soil erosion has often been accelerated by improper agricultural practices, and particularly by the failure to implement appropriate soil conservation measures, such as crop rotation, runoff control and contour farming. Several studies showed that soil degradation generates the loss of basic soil properties relevant to the farming system and/or an increase of the production costs.

Hence, Modified Universal Soil Loss Equation (MUSLE) is derived from various factors to calculate the sediment yield. Sediment yield from MUSLE is presented by Equation 2.1:

$$Y = 89.6(VQ_P)^{0.56}(K.LS.C.P) \quad (2.1)$$

Where Y = Sediment yield in tons/year

V = Runoff volume in m^3

Q_p = Peak flow value m^3/sec

K = Soil erodibility factor

LS = Slope length and steepness factor

C = Cover management factor

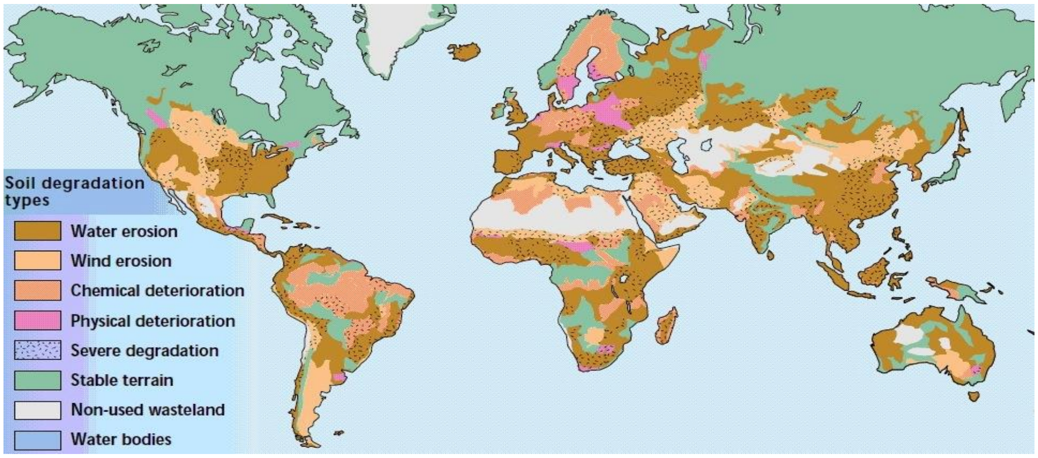
P = Erosion control and practice factor

2.1.1 Factors Affecting Sediment Yield and Soil Erosion

The main factors affecting the soil erosion can be divided into four categories which is the climate, vegetative cover, topography and lastly the structure and composition of the soil itself. Climate is a force to be reckoned with when soil erosion happened. With high amount and intensity of precipitation, the runoff and splash of rain will also quickly erode the soil's surface. Precipitation has been recognized as one of the main factors driving soil erosion and sediment yield for a long time, and soil erosion and sediment yield are the most important environmental problems worldwide (Nadal-Romero et al. 2015). The spatial and temporal distributions of soil erosion and sediment yield are difficult to assess because of high variability in precipitation on temporal and spatial scales, and this is particularly true in areas with a strongly contrasting seasonal rainfall regime and long history of human intervention. A large proportion of sediment yield can originate from disturbances that cover small fractions of the watershed area, suggesting management should focus on erosion hotspots. In the grazing-disturbed Kawela watershed on Molokai, Hawaii, most of the sediment originated from less than 5% of the watershed area, and 50% of the sediment originated from only 1% of the watershed (Risk, 2014). For vegetative cover, it acts as a medium between the soil and the atmosphere. The vegetative cover shelter the soil's surface from wind and rain by binding the soil together thus forming a mass of solid that is not susceptible to wind and rain soil erosion agents. In the meantime, a steep slope of topography will accelerate the soil erosion by means of increasing the velocity of the runoff along the slope. Soil structure and its composition also play a part in preventing soil erosion. In this context, the texture, organic matter content, macro porosity, and water infiltration capacity of the soil structure will mostly influence the soil erosion rate. The texture of a soil represents the sizes and proportions of the particles of the soil. Normally, soil can be divided into three categories which is sand, silt, and clay. Soil which has high proportions of sand will be considered coarse-textured and has high infiltration rate. Therefore, the potential of soil erosion on sandy soils is relatively low. In comparison, soils with a large amount of clays and slits are consider fine-textured. Clay has a capability to bind the soil particles together and reduce soil erosion. However, when fine particles encounter rapid flowing water, the fine particles will erode quickly before settling. In terms of organic matter content, the organic matter in a soil will help to build a more rigid soil structure by binding together soil colloids (Blanco & Lal, 2010). Thus, it made the soil more resistance to erosion. On the other hand, the soil macro pores is different in for every soil categories. Silty and clayey soils usually have smaller pores in comparison to sandy soils (Gardner, 1979). But the pores is generally larger to sandy soil. This is the reason why silty and clayey soils are able to store as much water compare to sandy soils due to the presence of larger and smaller macro pores. Lastly, the water infiltration capacity refers to the capability of the soil structure to allow water movement into the soil. It is also known as soil permeability. The soil texture and organic matter content are directly influencing the soil permeability. A gravel and sand mixture of soil that are affected by minor erosion from rainfall and shallow surface runoff will have high permeability.

2.1.2 Type of Soil Degradation That Will Affect Sediment Yield

Soil degradation will occurs eventually due to reaction with its agents. The agents can be classified into a few types, with the two major compartment of the agents that causes soil degradation being water erosion and wind erosion. Water erosion means that soil particles are detached either by splash erosion or more precisely raindrops, also by the effect of running water. Water erosion is influenced by four factors: rainfall, soil type, slope gradient, and soil use/vegetation cover. Through force, the raindrops will hit on the soil and break the aggregates. These fragments wash into soil pores and prevent water from infiltrating the soil. Water then accumulates on the surface and increases runoff which takes soil with it. The vulnerability of soils to water erosion depends on rainfall intensity where high intensity rainfall creates serious risk as heavy drops on bare soil causes the soil surface to seal, nature of the soil which the erodibility of clay soils vary in their ability to withstand raindrop impact. Next is the slope length, if a slope is long, water running down the slope becomes deeper and moves faster, taking more soil with it. Hence, the steeper the slope of a field, the greater the amount of soil loss from erosion by water. Soil erosion by water also increases as the slope length increases due to the greater accumulation of runoff. Furthermore, the speed of runoff increases on steep slopes, which increases the power of water to break off and carry soil particles. Water erosion also can be categorized to a few branches of different types which are sheet erosion, this means when a fairly uniform layer of soil is removed over an entire surface area; rill erosion occurs where water runs in very small channels over the soil surface, with the abrading effect of transported soil particles causing deeper incision of the channels into the surface; gully erosion occurs when rills flow together to make larger streams. They tend to become deeper with successive flows of water and can become major obstacles to cultivation; bank erosion is caused by water cutting into the banks of streams and rivers. It can be very serious at times of large floods and cause major destruction to property. The second major agent which is wind erosion occurs when strong winds blow over light-textured soils that have been heavily grazed during drought periods. It contributes to scalding, a process that forms smooth, bare areas on impermeable subsoils. The rate and magnitude of soil erosion by wind is influenced by the factors such as saltation, soil surface roughness, climate and vegetative cover. Saltation effect is where the wind suspends very fine particles and then transport it over great distances while the others are deposited or blown along the surface. Soil surfaces that are not rough or ridged offer little resistance to the wind. However, over time, ridges can be filled in and the roughness broken down by abrasion to produce a smoother surface susceptible to the wind. Climate and vegetative cover that affects the speed and duration of the wind has a direct connection to the extent of soil erosion. Soil moisture levels can be very low at the surface during periods of drought, thus releasing the particles for transport by wind, with lack of permanent vegetation cover in certain locations will speed up the movement of wind. Other minor agents such as chemical deterioration and physical deterioration also can be found in certain places as shown in Figure 2.1.



Source: (ISRIC et al. 1996)

Figure 2.1 Human-induced Soil Degradation Around the World

2.1.3 Soil Erodibility Factor

The soil erodibility factor K is affected by intrinsic soil properties. The main soil properties affecting K are soil texture, organic matter, structure and permeability of the soil profile. K shows to what extent soil can be detached by rainfall splash and surface flow (Zhang et al. 2008). It depends on the local soil properties including physical, chemical, biological and mineralogical and can be determined through sample analysis of the soil or from a soil map or pedological survey of the site or through a combination of these. K may have temporal as well as spatial variation for a particular type of soil. According to (Wischmeier and Smith, 1978), K factor (cover management factor) may be calculated for the unit plot (standard plot for which LS = 1 and CP = 1) by the following equation:

$$K=A/R \qquad (2.2)$$

(Renard et al. 1996) proposed a formula to determine the K factor on the basis of global data of measured K values, obtained from 225 soil classes.

$$K = 0.0034 + 0.0405 \times exp[-0.5(\frac{logdg+1.659}{0.7101})^2] \qquad (2.3)$$

Where

$$dg = exp(\sum f_i ln(\frac{d_i + d_{i-1}}{2})) \quad (2.4)$$

Where dg is the geometric mean particle size, di is the maximum diameter, di-1 is the minimum diameter and f_i is the corresponding mass fraction. K may be accurately estimated from soil loss data spread over the prolonged period, though it is very expensive, time consuming and impractical for many situations (Renard et al. 1997). Geostatistical methods like sequential Gaussian can be used to simulate K from the soil of the study area, which minimizes risk and takes proper land management practices with useful information (Wang et al. 2001). (Breshears et al. 2003) commented that there are several methods of estimating K such as measuring soil physiochemical properties, scouring, rainfall simulation, plot experiment etc. Some researchers (Zhang et al. 2008) pointed out that soil erodibility may be influenced by the presence of lime. Lime content increases aggregate stability, resulting in a decreased K (Zhang et al. 2008). (Vaezi et al. 2008) directly related the lime content to K. At present, long term monitoring of soil loss from natural runoff plots is the best method to estimate K for a given soil (Vaezi et al. 2008).

2.1.4 Topographic Factor

The effect of topography of land on soil erosion can be reflected by L and S factor in MUSLE. Due to the difficulty in the calculation of LS factor, an average LS value is assumed for entire region. This factor can be calculated in various ways depending on unit preferences and available data. According to (Risse et al. 1993), (Hann et al. 1994) and (Biesemans et al. 2000), the overall efficiency of USLE model depends mainly on the topographic factor (LS) and the cover management factor C.

Different empirical relations are used to determine this factor. Combining all the findings by the researchers (Zingg, 1940; Smith and Whitt, 1948), the following expression represents the relation of LS factor with soil erosion

$$LS = (\frac{\lambda}{22.13})m''(\frac{sin\theta}{sin5.143°})n'' \quad (2.5)$$

where m″ and n″ = fitted regression coefficients. According to (Wischmeier and Smith, 1978), the product of L and S is given by the following equation:

$$LS = (\frac{\lambda}{22.13})^{k'}[65.41 sin^2\theta + 0.065] \quad (2.6)$$

where λ = field slope length, k' = exponent factor ranging from 0.2 to 0.5 and θ = angle of slope.

It was concluded from the findings of that increase in slope length and slope steepness cause higher velocities in overland flow and correspondingly higher erosion. (Liu et al. 1994) stated that various functional forms (linear, power or polynomial forms) of soil loss predictive equations produce identical values of soil loss caused on hillsides by rainfall and runoff for slope up to 25 %. However, they provide different values of soil loss beyond this slope gradient. Some studies have concluded that slope steepness rather than slope length affects the value of the topography factor (McCool et al. 1987). Computing of length slope gradient factor (LS factor) of USLE/MUSLE equation is very difficult. According to (Mitasova et al. 1996), this drawback can be minimized by modifying LS factor where the influence of profile convexity/concavity using segmentation of irregular slopes is incorporated. (Oliveira et al. 2013) gave an idea to use Shuttle Radar Topography Mission (SRTM) data for computing MUSLE topographic factor in absence of topographic information. Though the effect of slope is considered in MUSLE, study can be conducted to examine the effect of slope on the determination of MUSLE-K factor.

2.1.5 Cover Management Factor

C factor (cover management factor) is the ratio of soil loss from cropped land under specified conditions (A_{crop}) to the corresponding clean-tilled continuous fallow (A_{allow}). It is influenced by various factors like specific vegetation cover, rotation sequence, overall functions of managing measures and the distribution of erosive precipitation in different vegetative period of crop. It is expressed as

$$C = \frac{A_{crop}}{A_{allow}} \times 100\% \quad (2.7)$$

In USLE, the cover management factor is derived based on empirical equations with measurements of ground cover, aerial cover and minimum drip height whereas in the MUSLE, the effect of crop and management is analyzed in more detail as the C factor is composed of subfactors such as impact of previous cropping and management, the protection of soil surface by vegetative canopy, reduction in erosion due to surface cover and surface roughness. For specific crop rotations, the approach to measure C value by field experiments is very time-consuming. (Takken et al. 1999) concluded that the relationships between vegetation and erosion could be further improved considering the distribution of vegetation. Important discussions on factor C are also available in different places (Gabriels et al. 2003). Constant values of the MUSLE C factor, produced in earlier studies, are usually used to evaluate soil erosion in watersheds. These values, however, do not accurately represent vegetation variation, particularly in large areas, which can result in mistaken estimates of soil loss. To avoid this problem many studies have been conducted to determine C factor by using satellite images for which various sub factors such as land cover classification map, image bands, ratios of image bands, vegetation index and vegetation coverage are needed to process using remote sensing techniques (Vrieling, 2006). Large effort has been made on calculating and mapping the C factors for use in soil erosion modelling by means of Geographic Information System, remote sensing data and spectral indices (de Asis and Omasa, 2007). The normalized differenced vegetation index (NDVI) derived from multispectral images is currently one of the most common environmental covariates of vegetation in order to monitor and analyze vegetation, its properties, and spatial and temporal changes (Wang et al. 2002). As a function of the NDVI, the fractional vegetation cover (FVC) provides information on the percentage of vegetation cover. The NDVI is an indicator of vegetation growth, for which Landsat-ETM (LTM) is given by the following equation:

$$NDVI = \frac{L_{TM4} - L_{TM3}}{L_{TM4} + L_{TM3}} \quad (2.8)$$

The value of NDVI ranges between −1.0 to +1.0. According to (Van Leeuwen and Sammons, 2004), the following formula is used to generate C factor

$$C = e^{(\alpha((NDVI)/(\beta - NDVI)))} \quad (2.9)$$

where α and β are two dimensionless parameters that determine the shape of the curve relating NDVI and the C factor. (Van der Knijff et al. 2000) found that the values of 2 and 1 selected for the parameters α and β produces good result for the value of cover management factor. These methods employ regression model to make correlation analysis between C factor values measured in field or obtained from guide tables and NDVI values derived from remotely sensed images. The goal of regression analysis is to estimate the unknown values of dependent variable based upon values of an independent variable using a mathematical model. However, under tropical climate conditions, the C factor tends to be higher than that calculated by these methods for the same vegetation cover. Therefore, a new method considering the variation of climatic conditions for calculating the MUSLE C factor, based on NDVI rescaling, was proposed by (Durigon et al. 2014). Very few research works were conducted on the crop rotational scheme. So investigations should be carried out considering the crop rotational scheme and positioning of crops in their rotation to assess the variation of the C-factor values.

2.1.6 Erosion Control Practice Factor

P-factor represents the effect of surface conditions like contouring, strip cropping and terraces on flow paths and hydraulics. This variable is set equal to 1 in military land management applications. However, different P factor scenarios may be considered to determine the various effects of different management techniques on soil-loss estimates. The documentations of softwares like FLUVIAL-12 (Chang, 2006) and SWAT (Neitsch et al. 2005) describe the modelling approaches for the prediction of USLE factors.

The evaluation of each subfactor of USLE or MUSLE is difficult because of many possible combinations, and the time spent with data acquisition and analysis. However, the advantage of predicting soil loss by using either of these methods is that over long period of time and large area, overestimations and underestimations can compensate each other, resulting in a good overall assessment of total soil loss. (Schönbrodt et al. 2010) and (Gabriels et al. 2003) discussed different issues and problems associated with USLE/MUSLE. Among the different techniques to predict USLE, confusions are there regarding the methodology to be used for the prediction of different factors. It depends on the site condition and availability of data. However, all the values cannot be validated due to the lack of field data.

2.2 Predicting Sediment Yield

2.2.1 Sediment Yield from a Storm

The determination of Sediment Delivery Ratio (SDR) is necessary to predict sediment yield at the outlet of catchment.(Kinnell, 2004) discussed the limitations of using SDR to determine sediment yield. Certain other empirical equations to predict SDR discussed in the succeeding sections, were reported (Schmidt and Morche, 2006). In most of the applications, where SDR has been used to determine sediment yield, it is assumed that the value of SDR is constant whereas in practices they have been shown to vary for different storm events. SDR also possesses high level of uncertainty since it is a complex function of space and time.

Pacific Southwest Inter-Agency Committee first developed the semi-quantitative model (PSIAC) in 1968 to predict the sediment yield. The methodology works well even with less amount of data and includes the effect of gully erosion and topography. However, this semi-quantitative approach is applied only in the planning purposes of dam construction and also for the analysis of the effect of the hydraulic structures on downstream sediment budgets.

(Williams, 1975) developed the MUSLE by replacing the rainfall energy with runoff which is expressed in the following form:

$$Y = 11.8(Q \times q_p)^{0.56} K(LS)CP \qquad (2.10)$$

where Y = sediment yield from an individual storm in a given day and q_p = peak rate of runoff volume. It was concluded that MUSLE eliminates the need of SDR and it may be used for individual storm event. Many researchers used MUSLE model to estimate sediment yield (R. Williams and D. Berndt, 1977) in different parts of the world along with different revisions.

2.2.2 Sediment Yield from Watershed

The most widely used common procedures to predict the sediment yield from a watershed are to use simultaneously flow duration curve as well as sediment rating curve (Crawford, 1991), reservoir sedimentation survey data (Verstraeten and Poesen, 2000) and estimation of soil erosion and sediment delivery ratio. Different empirical equations are there to calculate the sediment yield at the outlet of a reservoir. (Khosla, 1953) developed the equation to predict the volume of sediment yield in the following form:

$$Q_{SV} = 0.00323 A_{catch}^{0.72} \qquad (2.11)$$

where Q_{SV} = volume of sediment yield per year and A_{catch} = catchment area. But the drawback is that the equation underestimates the rate of sedimentation. (Flaxman, 1972) developed a more complicated empirical model that relates sediment yield to mean annual climate, watershed slope and soil characteristics. Later (Dhruvnarayana and Ram, 1983) developed the sediment yield equation in the following form:

$$Q_S = 5.5 + 11.1Q \qquad (2.12)$$

where Qs = annual sediment yield rate and Q = annual runoff volume. Garde and Kothyari (1987) estimated the mean annual sediment yield (Q′) from the large catchment and proposed the equation in the following form:

$$Q' = 1.182 \times 10^{-6} \times P^{1.29} \times A_{catch}^{1.03} \times D_d^{0.40} \times S^{0.08} \times C^{2.42} \qquad (2.13)$$

where D_d = drainage density and

$$C = \left(\frac{0.8FA + 0.6FG + 0.3FF + 0.1FW}{A_{catch}}\right) \quad (2.14)$$

FA denotes the arable land in the catchment and FG is the grass land, FF is the forest land and FW is the waste Land.

(FAO, 1997) performed traditional catchment experiments to measure the sediment yield at the outlet of a catchment and to assess the impact of changing land management practices on this yield. However, the traditional models are unable to predict the sediment yield accurately due to their inabilities to simulate accurately runoff rates and amounts, i.e. the hydrologic response at the basin scale. (Suresh, 2000) identified the factors which affect the sediment yield as land use, soil type, catchment size, climate and rainfall. Later (Krishnaswamy et al. 2001) and (Renschler and Harbor 2002) determined correlation between sediment yield and watershed area. Moreover, (Sun et al. 2002), (Paringit and Nadaoka 2003), (Jain et al. 2005) combined geographic information system with the rainfall-runoff model, the soil erosion model and the sediment transport model to compute the runoff and sediment yield in the watershed and made it easy to utilize the huge amount of geographic and hydrological parameters simultaneously in a watershed. (Dendy and Bolton, 1976) concluded from the empirical studies that sediment yield decreases substantially as watershed area increases whereas (Shen and Julien, 1993) confirmed the conclusions made from the above intuition that the SDR may reach 10 % as watershed area reaches 100 km2. However, this relation has some constraints as it encompasses huge amount of variables and has a limited theoretical basis. (Vente et al. 2007) reported that the sediment yield increases and decreases as a function of watershed area. The non linear relationship exists between them due to the spatial variation of topography, land use land cover or climate. The inverse relationship of SDR to watershed size has been assigned to longer travel distances (Parsons et al. 2006), longer travel times (Williams, 1975) and lower average land slopes (Boyce, 1975). (Verstraeten and Poesen, 2001) suggested that it might be more reliable to use sediment volume than sediment mass for sediment yield assessments. However, the use of reservoir sedimentation as a predicting tool of sediment yield accounts for some drawbacks such as the total deposition volume does not give information about temporal variation of sediment production and the calculated sediment yield is averaged over an extended time (Alatorre et al. 2012). Table 2 represents the empirical, physical and numerical models for predicting sediment yield. Numerical models do water routing on the basis of equal surfaces whereas physical based models do it on the basis of equal volumes for reservoirs with two outlet structures such as weir and orifice. In comparison to empirical and physical models, numerical models provide good prediction of shape and magnitude of the effluent sediment concentration graph. (Verstraeten and Poesen, 2002) carried out their studies to find the possibilities and limitations of the use of sedimentary deposits for determining the sediment yield in small water bodies. It was reported that the sediment depositions need to be converted to the sediment masses using the dry sediment bulk density. The measured sediment masses need to be corrected for assessing the trap efficiency of the small retention ponds to minimize the error to predict the sediment yield. The drawback of this method is that it is inadequate due to unavailability of data and it is incorporated with bedload transport which is very difficult to measure through sampling.

2.3 Research Gap

In the previous studies investigating sediment yield using MUSLE equation, there are many countries that are studied, including some states in Malaysia like Bukit Merah, Perak. However, there are no research that focus on studying sediment yield from Kuantan River Basin. Therefore, this is the first study that investigate annual soil erosion rate of Kuantan River Basin.

Also, every study has its purpose, some studies tend to determine the impact caused to water reservoir, while some are tend to determine the effect of sediment yield on the water surface. This study is to compare the difference of sediment yield between year 2015 and 2035.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter will be discussing on how the methods and data will be obtained in order to achieve the objectives of this study. In this study, the quantitative way of experimental approach methodology was utilized. It involved testing analysis and programming analysis with the analytical data presented in empirical results.

For this study, testing analysis will be more on laboratory works to obtain the K factor while the programming analysis will be utilizing the GIS software to obtain the C, P and LS factors. All these factors are very important in order to compute the annual soil loss of Kuantan river basin using the Modified Universal Soil Loss Equation (MUSLE).

3.2 Sample Collection

In sample collection, we travel to the selected soil type location which shown in the map from Google Earth Pro and collect them by using hand auger. The reference standard that used is American Society for Testing and Materials, ASTM D1425, Standard Practice for Soil Exploration and Sampling by Auger Borings. The model of hand auger that we used is Post-Hole Auger of Iwan Type as shown in Figure 3.1. It consists of two tubular steel segments. This segments is connected to the top of a handle or extension to form a nearly complete tube but with opposite openings. At the end, it has two radial blades pitched which function as cutters as well as blocking the contained soil from escaping. Due to its rotary drilling method, this boring is so suitable for soft to stiff cohesive soils but not suitable for saturated cohesion-less soil**.** By rotating the hand auger to a depth of 0.5 meters from the ground, the auger is then withdraw from the hole and the soil is removed. The empty auger is returned to the hole and the procedure is repeated until the required depth is fixed. The samples collected is sealed in reseal-able plastic. A total of 3 soil samples for each particular soil series will be collected.

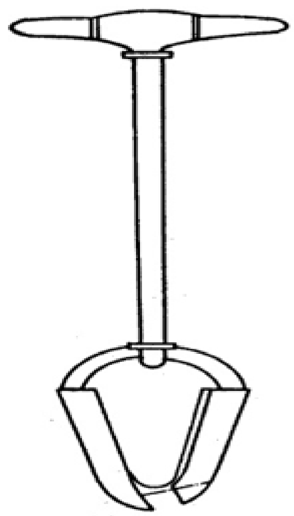


Figure 3.1 Post-Hole Auger of Iwan Type

3.3 Soil Erodibility Factor, K

Soil erodibility factor, K was derived based on the soil and geological aspect of the study area. Various information regarding soil series, permeability, bulk density, soil drainage and percentage of the soil porosity was obtained. According to (Soong *et al*. 1980), about 200 soil series have been identified and mapped in Malaysia. Each of the series differs in morphology, chemical and physical properties (Table 3.1).

Table 3.1 Distribution of Different Soil Associations in Peninsular Malaysia

Soil associations	Hectare	Percentage
CLASS I		
Kuantan	15 700	0.12
Segamat- Katong-Jempol	103 100	0.78
Rengam- Jerangau-Kg. Kolam-Tampoi	1 372 900	10.43
Prang	15 000	0.11
Munchong-Bungor- Serdang	223 600	1.70
Serdang-Munchong-Jeram	552 200	4.20
Selangor-Briah-Kangkong	233 400	1.77
Briah-Akob	131 800	1.00
	2 632 700	20.11
CLASS II		
Kala- Rengam	14 900	0.11
Serdang – Munchong – Seremban	89 500	0.68
Munchong – Malacca – Serdang	30 200	0.23
Bungor – Serdang – Malacca	20 000	0.15
Bungor – Durian – Tavy	70 7 00	0.54
Serdang- Kedah	74 100	0.56

Durian – Munchong – Serdang	2 50 600	1.90
Batang Merbau – Munchong	23 600	0.26
Batang Merbau – Durian	16 900	0.13
Chenain	21 100	0.16
Pohoi- Batang Merbau – Serdang	11 300	0.09
Harimau – Tampoi – Ulu Tiram	113 500	0.86
Telemong – Akob	498 800	3.79
Selangor- Organic Clay and Mucks	63 300	0.48
Selangor – Telok	16 500	0.13
	1 325 000	10.07
CLASS III		
Batu Anam – Bungor - Malacca	10 700	0.08
Batu Anam – Durian	119 100	0.91
Batu Anam – Durian – Malacca	24 800	0.95

Durian – Malacca – Tavy	250 900	1.91
Kulai – Yong Peng	27 300	0.21
Batu Anam – Malacca –Tavy	146 600	1.11
Kuala Brang – Serdang – Munchong	18 400	0.14
Marang – Batu Anam – Bungor	56 800	0.43
Durian – Kuala Brang	40 000	0.30
Pohoi- Durian – Tavy	59 400	0.45
Kawang – Kalu	19 500	0.15
Holyrood- Lunas – Rasau	233 600	1.78
Sogomana – Sitiawan	46 000	0.35
Organic Clay and Mucks	96 800	0.74
Batu Anam – Marang – Apek	3 200	0.02
Kuala Brang - Serdang – Marang – Apek	303 100	2.30
Gajah Mati – Malacca	156 900	1.19
Kamuning – Munchong	2 600	0.02
Malacca- Munchong – Tavy	107 900	0.82
Pokok Sena – Padang Besar	48 400	0.37
Manik – Sogomana	17 700	0.13
	1 889 700	14.36

CLASS IV		
Marang – Apek	30 700	0.23
Malacca – Tavy	69 900	0.53
Rudua- Rusila – Jambu	154 500	1.17
Kranji- Linau- Telok	291 400	2.21
Peat	768 500	5.84
	1 315 000	9.98
CLASS V		
Urban and Mined Lands	164 800	1.25
Steepland	5 474 900	41.59
	5 639 700	42.84
CLASS VI		
Padi Soil	360 900	2.74
TOTAL	**13 163 00**	**100**

Source: (Soong *et al*., 1980)

Since early of 1980, approximately 30 percent out of 13 million hectares of land in Peninsular Malaysia were classified as a suitable for agriculture activities. Other 25 percent were limited for agriculture and 45 percent the land are unsuitable for any form of agriculture. Among all soil series in Peninsular Malaysia; Serdang, Munchong, Rengam, Holyrood and Sg. Buloh were identified as the five most common series for erodible soil (Table 3.2).

Table 3.2 Erodibility of Five Common Peninsular Malaysia Soil

Soil series	Texture	Percent of organic carbon	Percent of aggregate >0.25 mm	Soil loss through (tones/ha)
Munchong	Clay	1.87	83.1	100
Rengam	Sandy clay loam	1.69	59.0	212
Serdang	Fine sandy loam	1.10	55.9	339
Holyrood	Loamy sand	1.35	73.5	252
Sg. Buloh	Loamy coarse sand	2.02	64.6	220

Source: (Soong *et al.*, 1980)

Serdang series on 30° slope under 100 cm of rainfall suffered soil loss equivalent to 339 ton per hectare (Department of Agriculture, 2000). On the other hand, Munchong series is less erodible because of its fine texture and well aggregated clay particles. Highly erodible soil like Serdang series is coarsely textured, poorly aggregated and low in organic matter. This shows that soil properties play an important role in determining the erodibility of soil type. Soil with strong structure and texture normally would tend to aggregate better. For this study, on screen digitizing method was applied on the soil map that covers 24 soil series in the study area (Table 3.3).

Table 3.3 Soil Series in Study Area

A. Alluvial Soil

	Series No.	Codes	Series Name	Percentage					Area (Ha)
				Clay	Silt	Fine sand	Sand	OM	
II	10	PET	Peat	60				30	10 110.96
III	11	TMG-AKB-LAA/LAC	Telemong Akob Local Alluvium	60	23	12	3	6.52	100 057.372
IV	18	HYD-LNS	Holyrood Lunas	17	6.5	52	24.5	4.98	2 000.664

B. Sedentary Soil

	Series No.	Codes	Series Name	Clay	Silt	Fine sand	Sand	OM	Area (Ha)
	25	MCA-TVY-GMI	Malacca Tavy Gajah Mati	50	24.5	20.5	5.5	0.5	1 092.418
	27	DRN-MCA-TVY	Durian Malacca Tavy	23	25	29	6	0.33	35 778.246

	32	RGM-JRA	Rengam Jerangau	22.5	15	21.5	36	3.3	55 055.956
	33	RGM-TPN	Rengam Tampin	23	16.5	26.5	29	2.5	16 893.914
	34	SGT-KTG	Segamat Katong	20	21	27.5	12	3.7	2 802.967
	39	DRN-MUN-BGR	Durian Munchong Bungor	36	16.7	32.7	11	2.98	23 208.897
VI	40	BGR-DRN	Bungor Durian	26.5	21	28.5	8.5	1.1	32 924.624
	46	SDG-KDH	Serdang Kedah	22	5	37.5	41	2.77	6 994.997
VII	49	STP	Steepland	25				0.5	269 602.545

a. On Coastal Palins and/or Riverine

b. On Riverine Flood Plains and/or Low Riverine Terraces

c. On Intermediate and Higher Terraces

d. On Undulating Plains to Rolling Land

e. On Rolling and Low Hilly land

f. On Hills and Mountains

Source: (Department of Agriculture, 2000)

Now days, most soil erodibility studies use USDA standards. Based on certain criteria, specifications, and due to the fact that each region on Earth may have its own particular soil series, Malaysia uses a different soil classifications. Soil permeability is one parameter used to derive *K* factor. It is a measure of the ability of air and water to move through the soil. Permeability is influenced by the size, shape and continuity of the pores depending on the soil bulk density, structure and soil texture. It has directly influenced by the amount of precipitation in the area. Soil permeability in Malaysia is divided into 6 classes ranging between 0 to 50 cm per hour (FRIM, 1999) and the USDA standard outlines that the United States of America contains 7 classes with permeability of 0 to 25.4 cm per hour. Table 3.4 below shows the different measurement classes and rates of soil permeability for Malaysia compared to USDA standards.

Table 3.4 Comparison Between Permeability Classes

Classes [a]	Rate (cm per hour)	Classes [b]	Rate (cm per hour)
Rapid	15-50	Very rapid	> 25.4
		Rapid	12.7 –25.4
Moderate to rapid	5.0-15	Moderately to rapid	6.35-12.7
Moderate	1.5 –5.0	Moderate	2.03-6.35
Slow to moderate	0.5-1.5	Moderately slow	0.51-2.03
Slow	0.2-0.5	Slow	0.13-0.51
Very slow	< 0.2	Very slow	<0.13

Class [a]: Source form Forest Research Institute Malaysia, 1999.

Class [b:] Source form United State Departments of Agriculture, 1992.

Malaysia has great annual rainfall compared to Europe countries, resulting in differences in determining permeability classes and values in the prior. Soil permeability impacts soil erosion since the more permeable, the faster the penetration of rainwater leading to lower soil moisture for arboreal sustainability. On the other hand, if soil is impermeable, rainwater may not be absorbed causing run off, used by which is primarily used by grass, shrubs and other ground surface vegetation. Therefore, this study will analyze the *K* factor with respect to Malaysia's environmental and climatic conditions. Soil erodibility values for several incomplete areas such as slopes and forests were determined using comparison techniques through geological aspects. This is possible because of the lack of information from the soil survey in forested and steep lands.

3.4 Cover Management Factor, C and Erosion Control Practices Factor, P

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, we make use of ArcGIS software. 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, looking the maps presented in soil type's categories cut the areas 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

GIS software is utilized to obtain the C and P factor as well as LS factor of the Modified Universal Soil Loss Equation (MUSLE). All the relevant map such as land use and land cover (LULC) map, soil map and topography map are obtained to overlay the information in the ArcGis. The land use and land cover map (LULC) was obtained from RTD, the soil map from DOA and the topography map was from JUPEM.

On ArcGIS, right click on the selected layer in the Table of Content. Click Add Data to add shapefiles into the activated map data frame as shown in Figure 3.2.

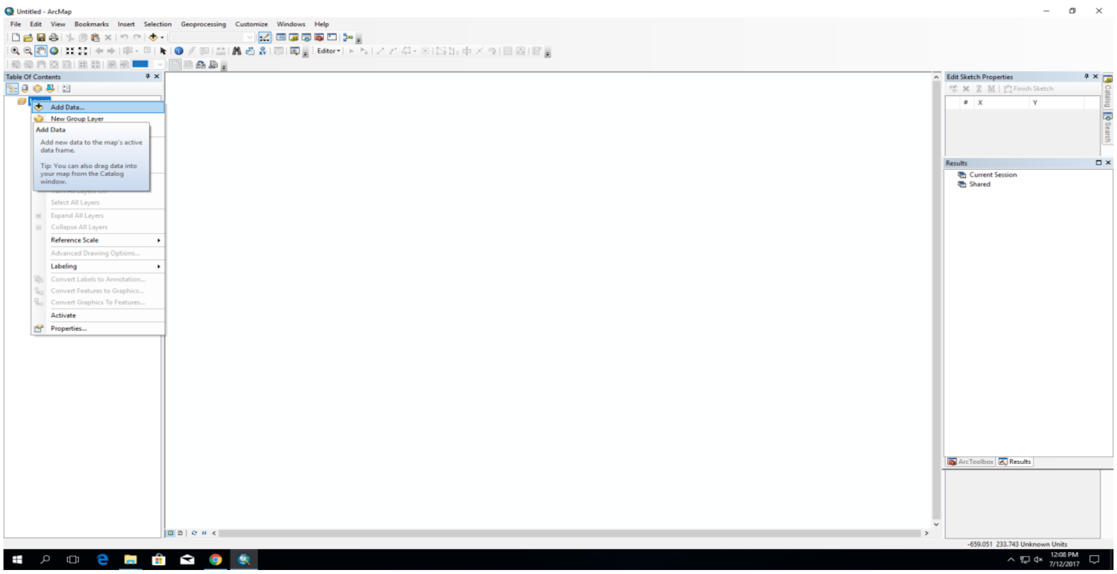


Figure 3.2 Adding the Shapefiles

After all shapefiles were inserted into the activated data frame as shown in Figure 3.3, information in different shapefiles of mainstream line of river, soil type, land used and land cover of Kuantan River Basin need to be obtained.

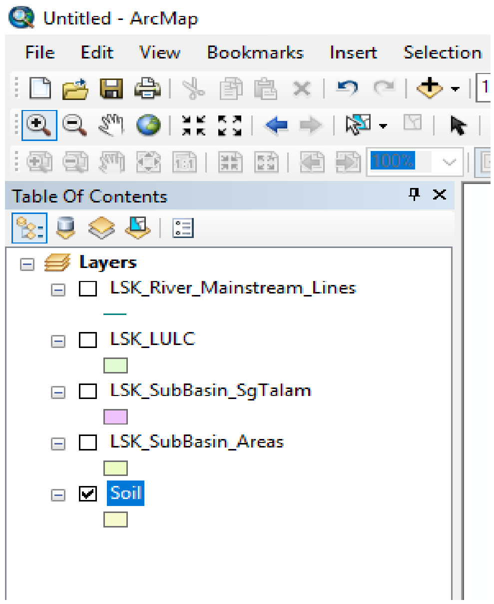


Figure 3.3 Shapefiles Inserted

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. Insert the shapefile required. In our case, since what we need to do is to determine the sampling location of each type of soil, the soil type shapefile is selected. Then, create a name for the centroid shapefile to be saved and exported (Figure 3.4).

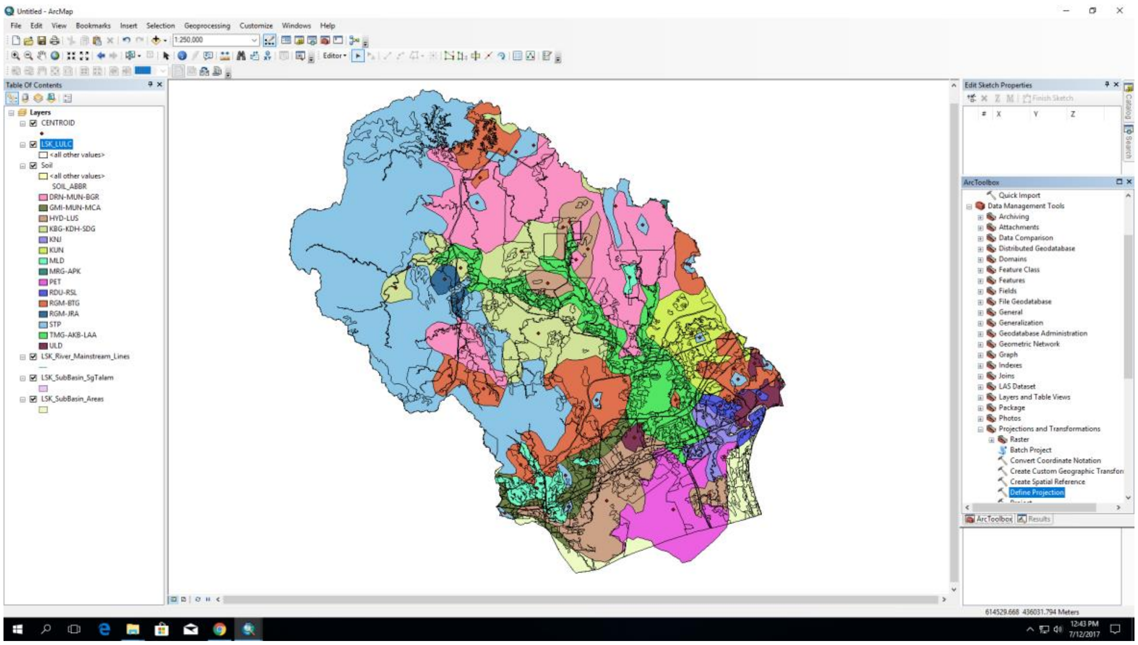


Figure 3.4 Different Type of Soil Created

Figure 3.5 shows the map generated by ArcGIS is then exported to Google Earth Pro so that the exact coordination of different soil type in the river basin can be seen and located with the help of the software.

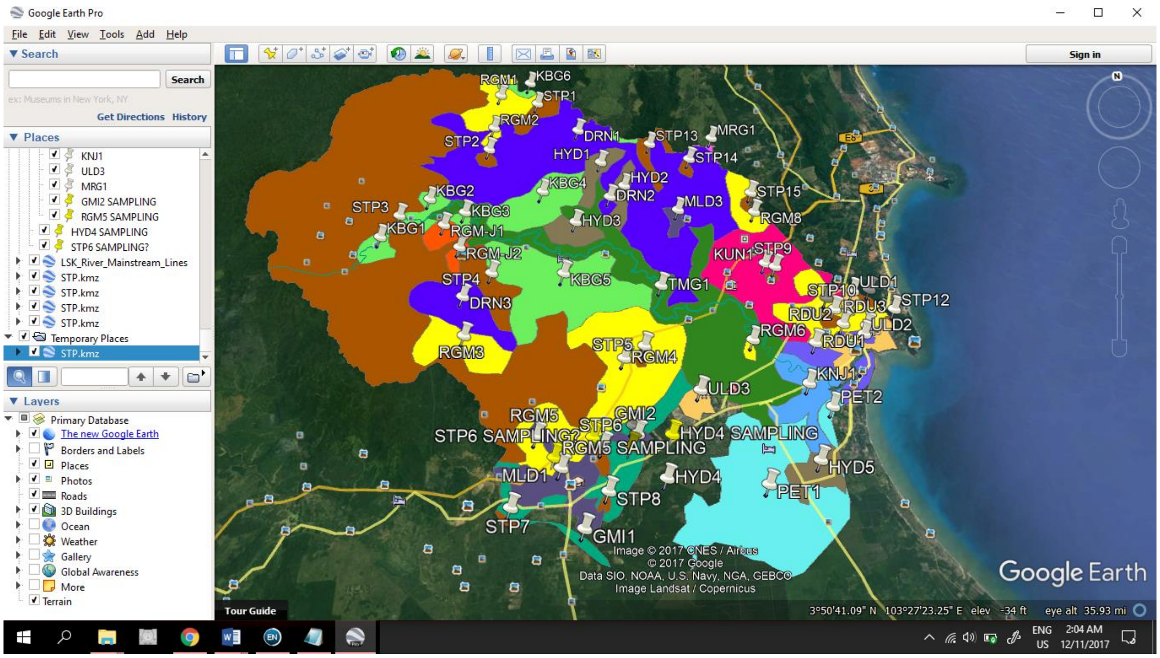


Figure 3.5 Map Exported and Opened in Google Earth Pro

3.4.2 Weighted Area Method

By using ArcGIS, the centroid of each area of the shape file is found. Next, the weighted area is calculated as shown in Figure 3.6 and Table 3.5 below.

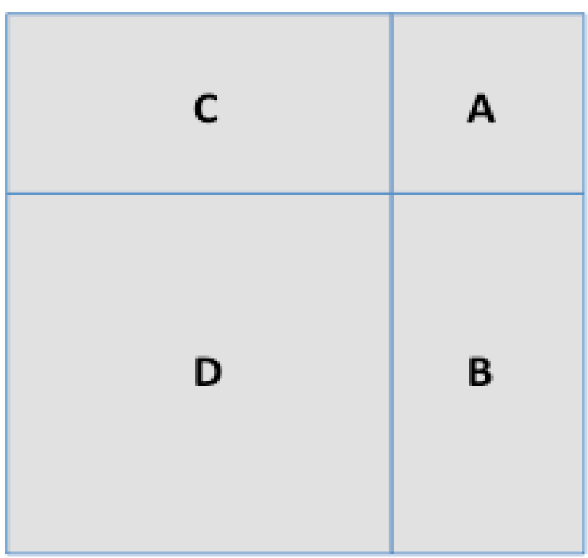


Figure 3.6 Weighted Area Shape Patch

Table 3.5 Temperature and Area of the Patch

Patch	Temperature (°C)	Area (m^2)
A	10	1
B	20	2
C	30	3
D	40	4

$$Area - Weighted\ Area\ Temperatur = \frac{Sum\ of\ Area{-}Weight\ Temperature}{Sum\ of\ Area} \quad (3.1)$$

$$= \frac{10 \times 1 + 20 \times 2 + 30 \times 3 + 40 \times 4}{1 + 2 + 3 + 4}$$

$$= 30°C$$

The *P* factor can be defined as the value of erosion control practice. Agricultural practices require the usage of large-scale machines to maintain largescale agricultural development that impacts the soil both directly and indirectly. Agricultural practice causes partial changes in the structure and natural horizon of soil layers. Besides, the use of large machines causes soil compaction, reduces infiltration and increases overland flow. In this study, strip contour cropping and up and down slope are considered to represent conservational and conventional agricultural practices respectively. Table 3.6 shows how the degree of slope affects the P factor consideration for contouring and terracing.

Table 3.6 Practice and Erosion Control (P) Factor for Contouring and Terracing

Erosion control practice	P factor value	
	Contouring	Terracing (Strip contour cropping)
0 to 2 ^{0} slope	0.60	0.30
2.01 to 7 ^{0} slope	0.50	0.25
7.01 to 12 ^{0} slope	0.60	0.30
12.01 to 18 ^{0} slope	0.80	0.40
18.01 to 24 ^{0} slope	0.90	0.45
Contour farming	0.50	
Cross slope	0.75	
Up and down slope	1.0	

Source: (Morgan, 1995)

Constant values of 0.25, 0.5 and 1.0 were used to present P factor for oil palm and rubber plantation, orchard and development areas (such as construction site, open area, urban, etc.). This process was conducted by using spatial analysis in ArcGIS environment that involved contour transformation in the study area.

3.5 Slope Length and Steepness Factor, LS

Computed by using Equation 3.2:

$$L = (\frac{\lambda}{\varphi})^m \tag{3.2}$$

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 3.3:

$$LS = (\frac{\lambda}{\psi})^m \times (0.065 + 0.046s + 0.065s^2) \tag{3.3}$$

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 3.3 is tabulated as shown in Table 3.7. With this table provided, we only have to determine the slope length in percentage and the direct distance from the origin of runoff to its point of interest. For our studies, the topography maps of state of Pahang from JUPEM which contain the contour lines and stream lines of the sub river basins of Kuantan River Basin are obtained.

Table 3.7 C Factor Values

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

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Topographic Factor, LS

Figure 4.1 shows the topographic slope map of Kuantan River Basin generated from the contour map purchased from JUPEM. From here, the slope and steepness value, LS factor is extracted using the ArcGIS software and calculated.

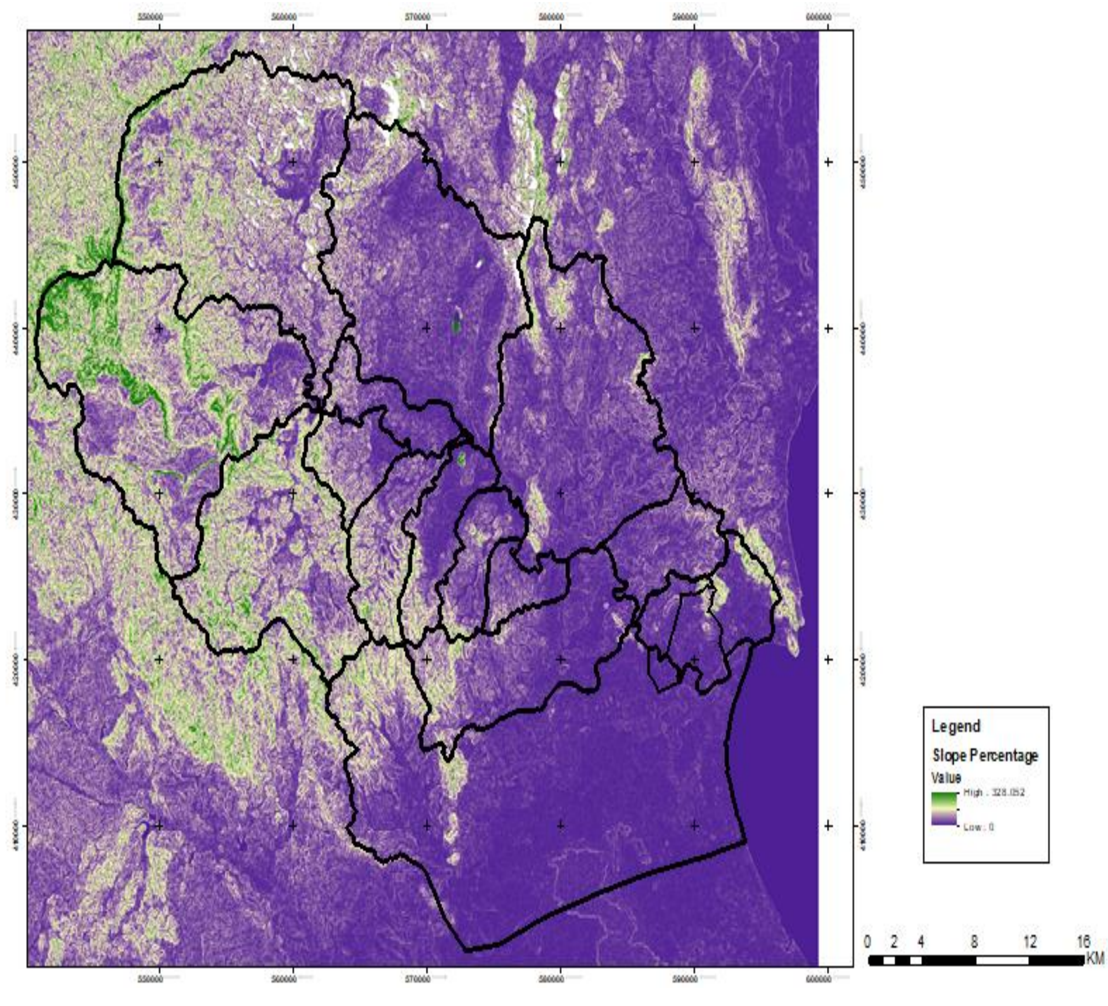


Figure 4.1 Slope Map for Kuantan River Basin

4.2 Cover Management, C and Erosion Control Practice Factor, P

From the Land Use and Land Cover (LULC) map as shown in Figure 4.2, the erosion management and support practice, C and P factor is computed by calculating the value for each of the unique polygon in map.

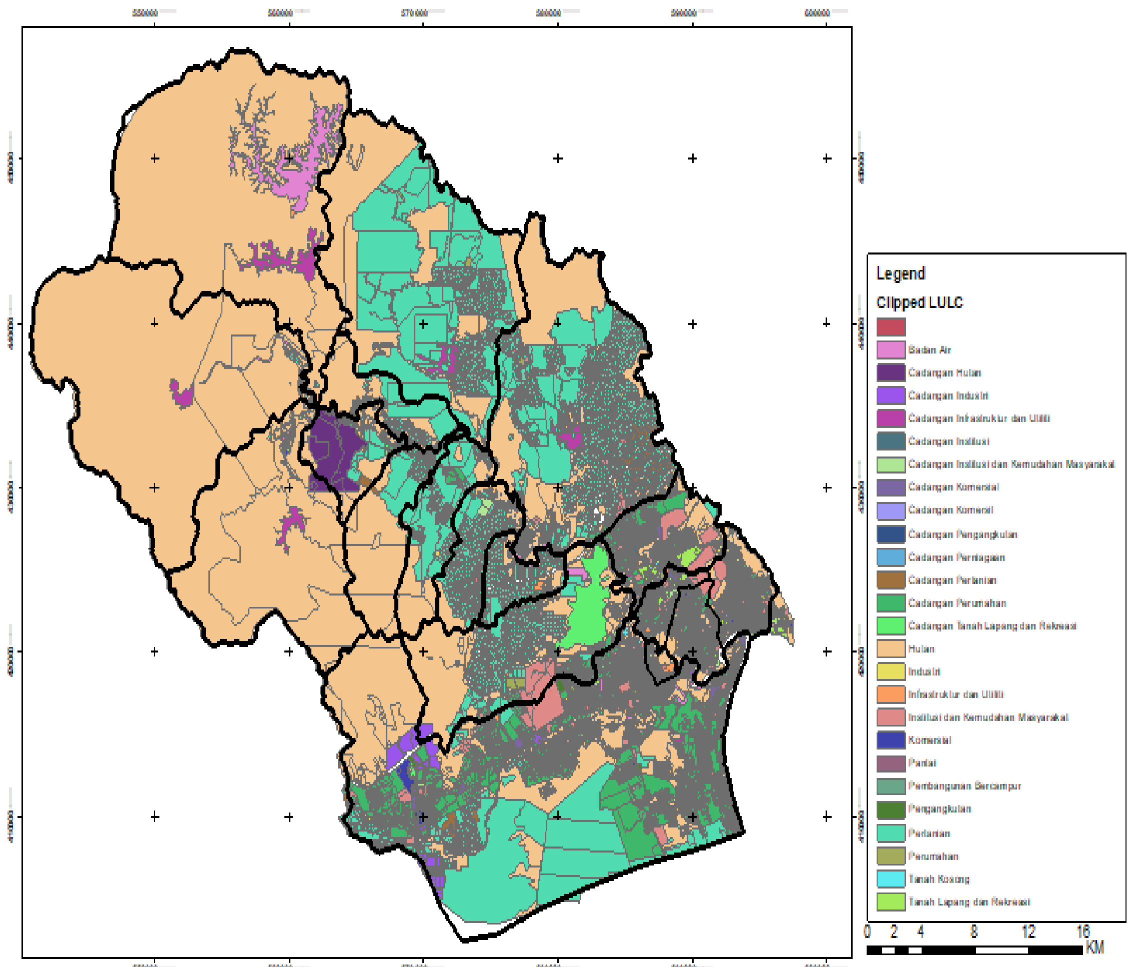


Figure 4.2 Land Use and Land Cover Map in Each Sub-basin

The values for K, LS, C and P for every sub-basins are computed as in Table 4.1. As for the erosion management and support practice, C and P factor are classified in two different years, 2015 and 2035 due to the future development and planning of the certain area within the sub-basins which will affect the condition of that area.

Table 4.1 Values for K, LS, C and P for Each Sub-basin

Sub-basin	K	LS	C_{2015}	P_{2015}	C_{2035}	P_{2035}
Ah Tong	0.0593	66.73	0.00046	0.19	0.00045	0.19
Belat	0.0287	2.96	0.02624	0.39	0.00239	0.50
Caru	0.0723	108.38	0.00718	0.13	0.00059	0.13
Cereh	0.0285	466.23	0.0004	0.1	0.0004	0.10
Kenau	0.0289	10.82	0.00042	0.11	0.0004	0.11
Pancing	0.0703	93.33	0.00287	0.14	0.00043	0.14
Pandan	0.0345	67.74	0.00183	0.34	0.00165	0.36
Pinang	0.0378	4.15	0.01543	0.57	0.01221	0.75
Nada	0.0795	4.23	0.00045	0.55	0.00048	0.17
Reman	0.0489	74.55	0.00046	0.14	0.00046	0.14
Riau	0.0422	108.28	0.01382	0.17	0.00076	0.26
Salak	0.0415	4.09	0.00428	0.16	0.00042	0.19
Sebarau	0.0629	4.7	0.10702	0.16	0.0004	0.16
Sungai Isap	0.0505	2.77	0.00139	0.63	0.00109	0.26
Sg Galing	0.0274	12.28	0.01296	0.76	0.00144	0.80
Sg Talam	0.0306	7.44	0.01163	0.7	0.00139	0.80
Sg Tiram	0.0386	21.79	0.03487	0.78	0.00346	0.85
Ulu Sg Kuantan	0.0505	554.77	0.0004	0.102	0.00041	0.10

4.3 Peak Flow, Q_p and Runoff Volume, V

Rational formula is used to obtain peak flow along with the runoff volume with average recurrence interval (ARI) of 2-ARI, 5-ARI, 10-ARI, 20-ARI, 50-ARI and 100-ARI. They are also classified for 2 different years, 2015 and 2035. Table 4.2 and 4.3 shows the peak flow while Table 4.4 and 4.5 shows the runoff volume values for every sub-basins in both years with respective ARIs.

Table 4.2 Peak Flow for Various ARI in Year 2015

Sub-Basin	Catchment Area (km^2)	tc (hr)	Impervious (%)	Qpeak (m^3/s) - Current Landuse, 2015					
				2-ARI	5-ARI	10-ARI	20-ARI	50-ARI	100-ARI
Ulu Sg. Kuantan	220.6	6.8	0.1	169.5	339.2	462.3	641.9	780.2	912.7
Sg. Chereh	69.5	7.5	0.2	64.9	120.8	160.0	220.2	260.6	302.4
Sg. Kenau	135.93	7.2	1.0	145.1	261.4	340.2	458.0	544.1	624.8
Sg. Sebarau	29.85	3.8	0.2	37.2	69.4	91.0	122.2	151.9	167.2
Sg. Nada	30.03	2.8	2.2	47.9	85.9	109.5	145.2	176.9	193.1
Sg. Caru	44.69	5.4	0.6	61.3	109.8	139.2	181.9	225.1	242.0
Sg. Reman	188.56	17.6	0.8	161.8	281.8	343.5	447.6	551.2	614.6
Sg. Panching	39.43	3.4	1.2	44.5	85.9	115.1	145.7	176.2	206.1
Sg. Ah Tong	30.98	3.1	2.7	39.1	73.1	96.9	121.0	145.5	169.5
Sg. Gading	20.56	1.3	2.4	40.1	84.8	108.5	127.9	155.8	179.5
Sg. Riau	180.05	8.3	4.4	259.8	525.4	663.6	781.9	966.6	1,127.5
Sg. Pinang	40.17	3.9	27.7	97.9	182.8	229.2	261.5	307.2	349.6
Sg. Pandan	98.17	9.1	8.8	143.9	290.6	367.1	429.2	505.5	596.0
Sg. Tiram	12.04	1.8	54.2	37.1	55.8	71.8	82.6	87.9	98.7
Sg. Talam	17.9	2.0	52.6	52.4	81.0	101.3	120.9	130.8	148.3
Sg. Isap	3.95	3.8	53.5	9.0	15.2	17.5	23.4	26.4	30.8
Sg. Belat	361.03	19.9	12.2	429.7	773.7	934.9	1,103.8	1,290.1	1,514.9
Sg. Galing	23.95	3.3	59.5	67.6	100.5	128.7	147.5	156.8	175.7
Tg. Lumpur (river mouth)	**1547.39**	**31.0**	**7.1**	**1,644.3**	**3,022.4**	**3,835.5**	**4,782.9**	**5,717.5**	**6,591.9**

Table 4.3 Peak Flow for Various ARI in Year 2035

Sub-Basin	Catchment Area (km^2)	tc (hr)	Impervious (%)	Qpeak (m^3/s) - Future Landuse, 2035					
				2-ARI	5-ARI	10-ARI	20-ARI	50-ARI	100-ARI
Ulu Sg. Kuantan	220.6	6.8	0.8	170.7	340.8	464.0	643.6	782.3	914.8
Sg. Chereh	69.5	7.5	8.2	69.7	125.9	165.1	225.3	266.7	308.8
Sg. Kenau	135.93	7.2	2.5	146.7	263.0	341.8	460.1	546.1	626.8
Sg. Sebarau	29.85	3.8	0.2	37.2	69.4	91.0	122.2	151.9	167.2
Sg. Nada	30.03	2.8	4.7	48.8	86.8	110.4	146.0	177.7	193.9
Sg. Caru	44.69	5.4	1.0	61.5	110.0	139.4	182.1	225.3	242.2
Sg. Reman	188.56	17.6	2.1	163.4	283.5	345.3	449.4	553.0	616.4
Sg. Panching	39.43	3.4	3.5	45.4	87.1	116.3	146.8	177.4	207.3
Sg. Ah Tong	30.98	3.1	5.4	40.0	74.1	97.9	121.9	146.4	170.4
Sg. Gading	20.56	1.3	2.4	40.1	84.8	108.5	127.9	155.8	179.5
Sg. Riau	180.05	8.3	6.2	262.6	528.3	666.5	784.7	969.4	1,130.2
Sg. Pinang	40.17	3.9	65.7	113.8	198.1	243.9	275.9	321.0	362.8
Sg. Pandan	98.17	9.1	12.6	147.0	294.4	370.9	433.0	509.3	599.7
Sg. Tiram	12.04	1.8	77.9	38.7	57.3	73.1	83.9	89.2	99.9
Sg. Talam	17.9	2.0	76.3	54.4	82.8	102.9	122.5	132.3	149.7
Sg. Isap	3.95	3.8	61.2	9.2	15.3	17.6	23.5	26.5	30.9
Sg. Belat	361.03	19.9	38.5	477.0	823.4	985.0	1,154.1	1,340.5	1,565.2
Sg. Galing	23.95	3.3	70.9	68.7	101.5	129.6	148.3	157.6	176.4
Tg. Lumpur (river mouth)	**1547.39**	**31.0**	**16.3**	**1,718.5**	**3,106.5**	**3,923.2**	**4,871.6**	**5,806.8**	**6,681.6**

Table 4.4 Runoff Volume for Various ARI in Year 2015

Sub-Basin	Runoff Volume (1000 m^3) - Current Landuse, 2015					
	2-ARI	5-ARI	10-ARI	20-ARI	50-ARI	100-ARI
Ulu Sg. Kuantan	19,597.6	33,768.5	44,294.4	59,941.7	71,664.9	82,896.0
Sg. Chereh	7,608.6	12,415.7	15,849.1	21,218.3	24,879.7	28,564.0
Sg. Kenau	16,178.4	26,372.9	33,442.4	44,105.3	51,719.2	58,893.3
Sg. Sebarau	3,646.9	5,927.4	7,411.7	9,584.6	11,676.3	12,760.6
Sg. Nada	4,135.2	6,574.8	8,128.7	10,522.0	12,689.3	13,804.5
Sg. Caru	6,355.5	10,200.6	12,569.8	16,048.1	19,611.6	21,015.5
Sg. Reman	25,719.6	41,667.7	49,964.1	64,045.0	78,151.4	86,830.1
Sg. Panching	4,439.3	7,225.3	9,210.1	11,313.6	13,440.9	15,542.3
Sg. Ah Tong	3,697.1	5,915.2	7,502.4	9,135.8	10,814.7	12,482.2
Sg. Gading	3,123.5	5,618.2	6,974.0	8,098.8	9,739.7	11,144.4
Sg. Riau	28,268.4	52,722.6	65,666.1	76,846.7	94,435.6	109,875.1
Sg. Pinang	8,561.0	14,760.7	18,200.5	20,619.8	24,051.4	27,252.5
Sg. Pandan	16,698.7	31,121.1	38,651.5	44,808.3	52,411.8	61,473.3
Sg. Tiram	2,939.8	4,172.1	5,226.8	5,945.6	6,302.3	7,020.6
Sg. Talam	4,215.3	6,143.7	7,511.8	8,849.2	9,522.8	10,717.2
Sg. Isap	780.7	1,361.2	1,540.4	2,000.4	2,231.7	2,578.1
Sg. Belat	70,455.5	120,943.4	144,756.4	169,771.2	197,447.8	230,908.8
Sg. Galing	5,889.5	8,352.4	10,471.1	11,886.4	12,592.3	14,024.0
Tg. Lumpur (river mouth)	**232,310.7**	**395,263.4**	**487,371.3**	**594,741.0**	**703,383.3**	**807,782.2**

Table 4.5 Runoff Volume for Various ARI in Year 2035

Sub-Basin	Runoff Volume (1000 m^3) - Future Landuse, 2035					
	2-ARI	5-ARI	10-ARI	20-ARI	50-ARI	100-ARI
Ulu Sg. Kuantan	19,760.7	33,963.2	44,503.5	60,165.7	71,897.1	83,134.5
Sg. Chereh	8,144.9	13,038.0	16,509.3	21,919.7	25,601.5	29,302.5
Sg. Kenau	16,362.4	26,582.8	33,663.3	44,337.8	51,957.7	59,136.4
Sg. Sebarau	3,646.9	5,927.4	7,411.7	9,584.6	11,676.3	12,760.6
Sg. Nada	4,216.1	6,667.2	8,225.7	10,624.2	12,794.9	13,911.5
Sg. Caru	6,375.7	10,223.6	12,593.9	16,073.3	19,637.7	21,041.8
Sg. Reman	25,967.7	41,947.9	50,255.2	64,349.6	78,465.9	87,149.5
Sg. Panching	4,533.8	7,335.8	9,327.6	11,436.6	13,568.2	15,673.1
Sg. Ah Tong	3,778.9	6,009.9	7,602.9	9,240.6	10,923.0	12,593.1
Sg. Gading	3,123.5	5,618.2	6,974.0	8,098.8	9,739.7	11,144.4
Sg. Riau	28,595.2	53,098.7	66,056.8	77,247.1	94,847.4	110,294.5
Sg. Pinang	10,080.9	16,479.9	19,981.6	22,434.1	25,903.1	29,131.9
Sg. Pandan	17,113.2	31,601.3	39,150.9	45,319.8	52,935.0	62,007.5
Sg. Tiram	3,094.0	4,338.0	5,398.7	6,120.5	6,478.4	7,198.8
Sg. Talam	4,415.2	6,357.9	7,732.0	9,073.6	9,748.9	10,945.7
Sg. Isap	793.9	1,376.1	1,555.6	2,016.0	2,247.5	2,594.1
Sg. Belat	78,291.6	129,592.4	153,627.2	178,819.6	206,648.7	240,252.2
Sg. Galing	6,019.7	8,491.2	10,614.1	12,031.5	12,738.2	14,171.4
Tg. Lumpur (river mouth)	**244,314.2**	**408,649.3**	**501,183.9**	**608,893.1**	**717,809.3**	**822,443.6**

4.4 Sediment Yield, Y

Hence, sediment yield for every sub-basin based on each ARI in both year 2015 and 2035 can be computed by using the MUSLE formula stated in Equation 2.1 earlier. The value of sediment yield in both year are compared. Table 4.6 and 4.7 shows the final results of the computation.

Table 4.6 Sediment Yield for Year 2015

Sub-basin	Sediment Yield in 2015 (tons/yr)					
	2-ARI	5-ARI	10-ARI	20-ARI	50-ARI	100-ARI
Ah Tong	24.033472	44.39069	59.3812	75.08845	91.50538312	108.007355
Belat	1204.80011	2266.505	2786.74	3343.894	3971.114715	4742.984956
Caru	885.53343	1599.672	2053.64	2735.311	3448.266495	3732.691539
Cereh	73.4853502	136.8972	183.706	258.6716	310.7649458	364.9198859
Kenau	4.78203509	8.742077	11.5732	15.96153	19.2176457	22.33196605
Pancing	218.208798	414.2762	559.094	715.8934	876.955821	1038.548468
Pandan	487.66169	1024.374	1318.24	1562.977	1870.106912	2242.356525
Pinang	256.531508	493.7365	630.167	727.5656	867.9269394	1000.728436
Nada	6.89948456	12.40627	16.0057	21.66043	26.86849791	29.58287399
Reman	107.084426	191.4278	236.765	315.559	396.3949635	446.9074391
Riau	6730.57677	14155.28	18243.3	21839.39	27601.95806	32750.24394
Salak	7.4542381	15.7514	20.4096	24.33359	30.13467172	35.17798885
Sebarau	339.486765	631.8394	833.41	1135.227	1432.203507	1588.333035
Sungai Isap	1.56531394	2.865914	3.32361	4.527108	5.149543856	6.086263807
Sungai Galing	406.15294	616.741	803.961	931.5952	995.699205	1127.187036
Sungai Talam	163.308805	257.3668	326.466	395.0982	430.2180966	493.1337412
Sungai Tiram	1357.70821	2075.931	2712.32	3153.243	3373.279642	3823.721639
Ulu Sungai Kuantan	459.558888	919.1669	1272.58	1811.684	2233.466733	2645.666079

Table 4.7 Sediment Yield for Year 2035

Sub-basin	Sediment Yield in 2035 (tons/yr)					
	2-ARI	5-ARI	10-ARI	20-ARI	50-ARI	100-ARI
Ah Tong	24.106167	44.14828085	58.86222112	74.23421385	90.32842305	106.4994092
Belat	158.234183	284.863066	346.4144156	412.1528586	486.0145157	576.7430393
Caru	73.0291913	131.74947	169.0704488	225.1040017	283.7055507	307.0822774
Cereh	79.454675	143.9944098	191.2843707	266.8251258	319.9002617	374.540665
Kenau	4.61148687	8.391457786	11.09189851	15.28539122	18.38747785	21.35584486
Pancing	33.4542494	63.0872866	84.85489174	108.36623	132.5890225	156.8423885
Pandan	477.663367	993.5704911	1274.905365	1509.083377	1802.851827	2158.592052
Pinang	318.437431	571.9719093	715.8407011	818.3792901	965.4829913	1104.294841
Nada	2.32365084	4.14653238	5.336606129	7.202265996	8.922186268	9.818353292
Reman	108.256576	192.7959137	238.2329513	317.1104683	398.013493	448.5612989
Riau	573.171846	1198.99057	1543.254498	1845.881072	2330.942592	2764.093802
Salak	0.86864515	1.835517005	2.378334015	2.835602746	3.511604561	4.099304192
Sebarau	1.26887223	2.361575108	3.114968454	4.243046569	5.353031235	5.936583946
Sungai Isap	0.51768912	0.936591476	1.084998006	1.474998916	1.676673593	1.980105413
Sungai Galing	48.5251745	73.20707947	95.1180191	110.0341612	117.5442565	132.9045249
Sungai Talam	23.3783984	36.27937657	45.71968212	55.13405833	59.92331301	68.51848471
Sungai Tiram	154.688163	232.8607565	301.663836	349.5867248	373.4855749	422.1530224
Ulu Sungai Kuantan	465.79657	929.0964444	1284.833985	1827.07602	2251.871717	2666.345241

Bar graph has been constructed to show a clear comparison of sediment yield between the two years studied. There are six sub-basins that will not experience any drastic changes between year 2015 and 2035, having a difference in yield percentage of less than 10%. These sub-basins are Ah Tong, Cereh, Kenau, Pandan, Reman and Ulu Sungai Kuantan.

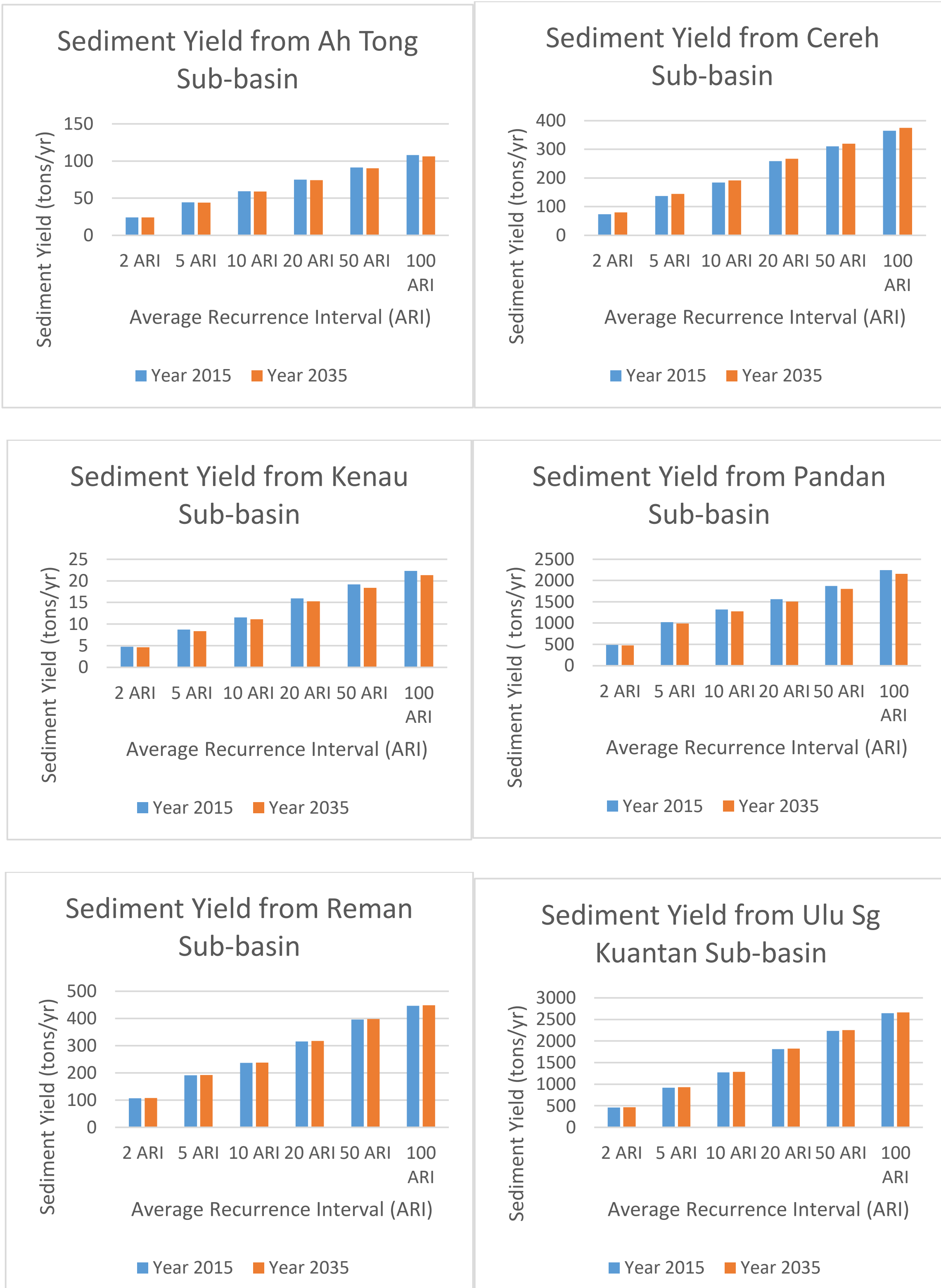


Figure 4.3 Sediment Yield from Ah Tong, Cereh, Kenau, Pandan, Reman and Ulu Sungai Kuantan Sub-basins

Whereas most of the sub-basins experienced drastic decrement in their sediment yield values with the range of 60% to 99.99%. These sub-basins are Belat, Caru, Nada, Pancing, Riau, Sebarau, Sungai Galing, Sungai Isap, Sungai Talam, Sungai Tiram, and Salak.

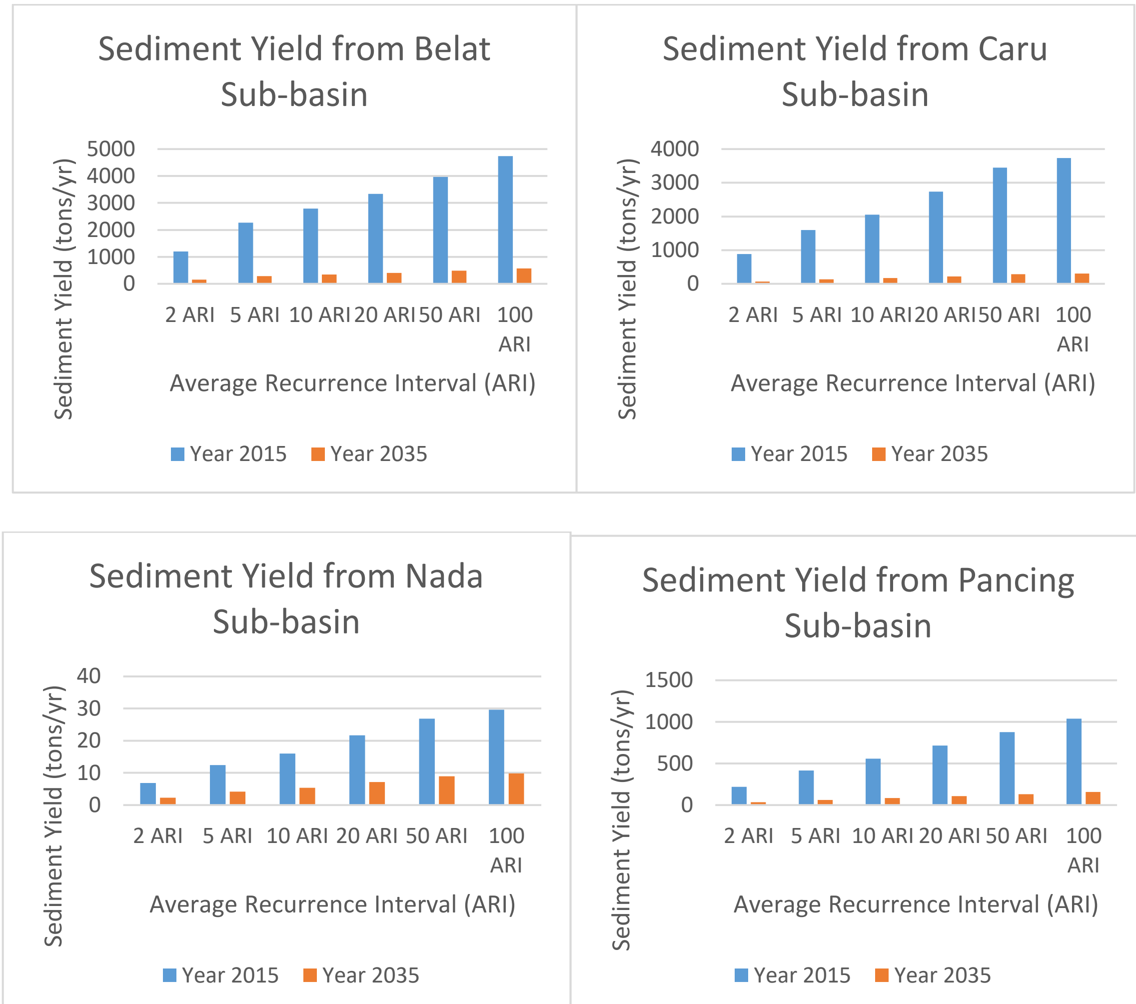


Figure 4.4 Sediment Yield from Belat, Caru, Nada and Pancing Sub-basins

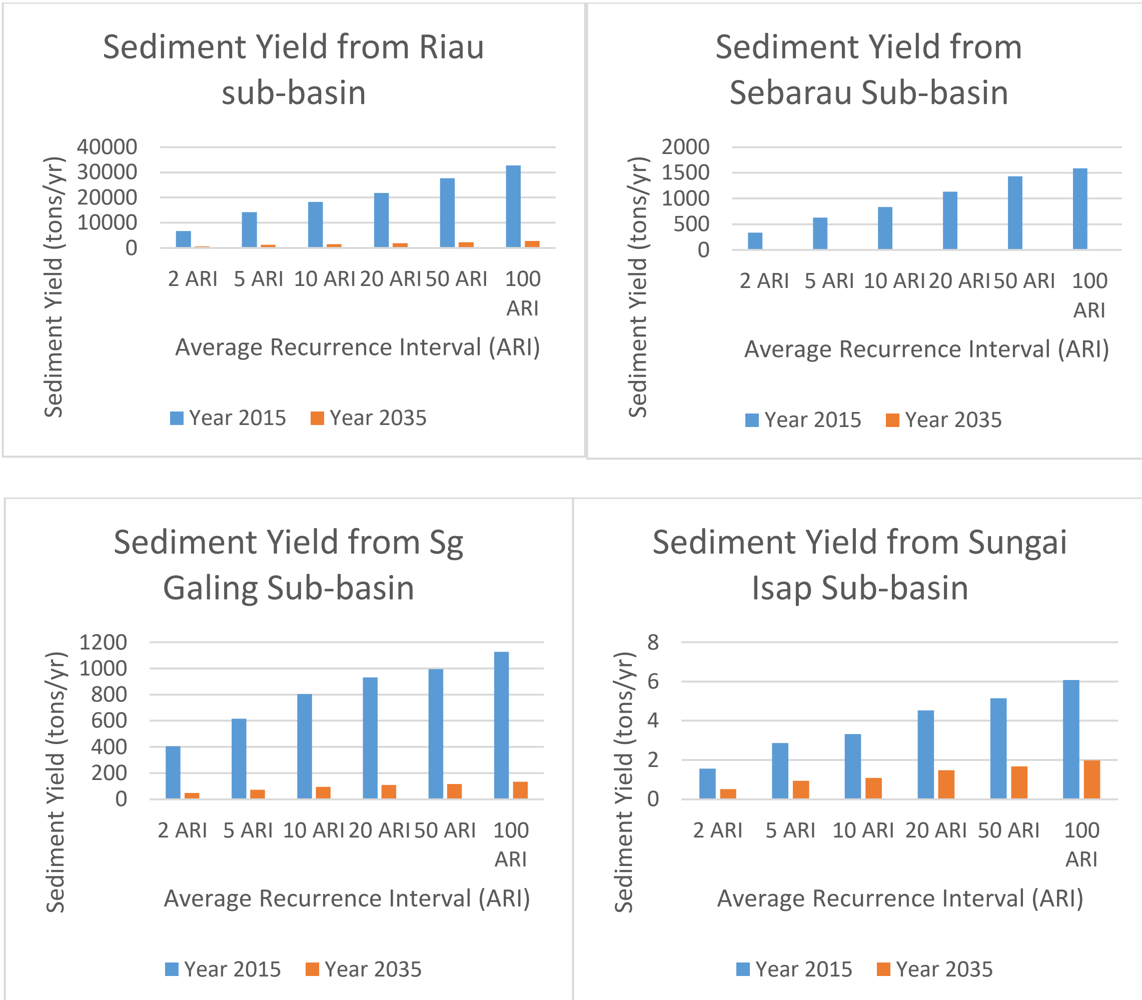


Figure 4.5 Sediment Yield from Riau, Sebarau, Sungai Galing and Sungai Isap Sub-basins

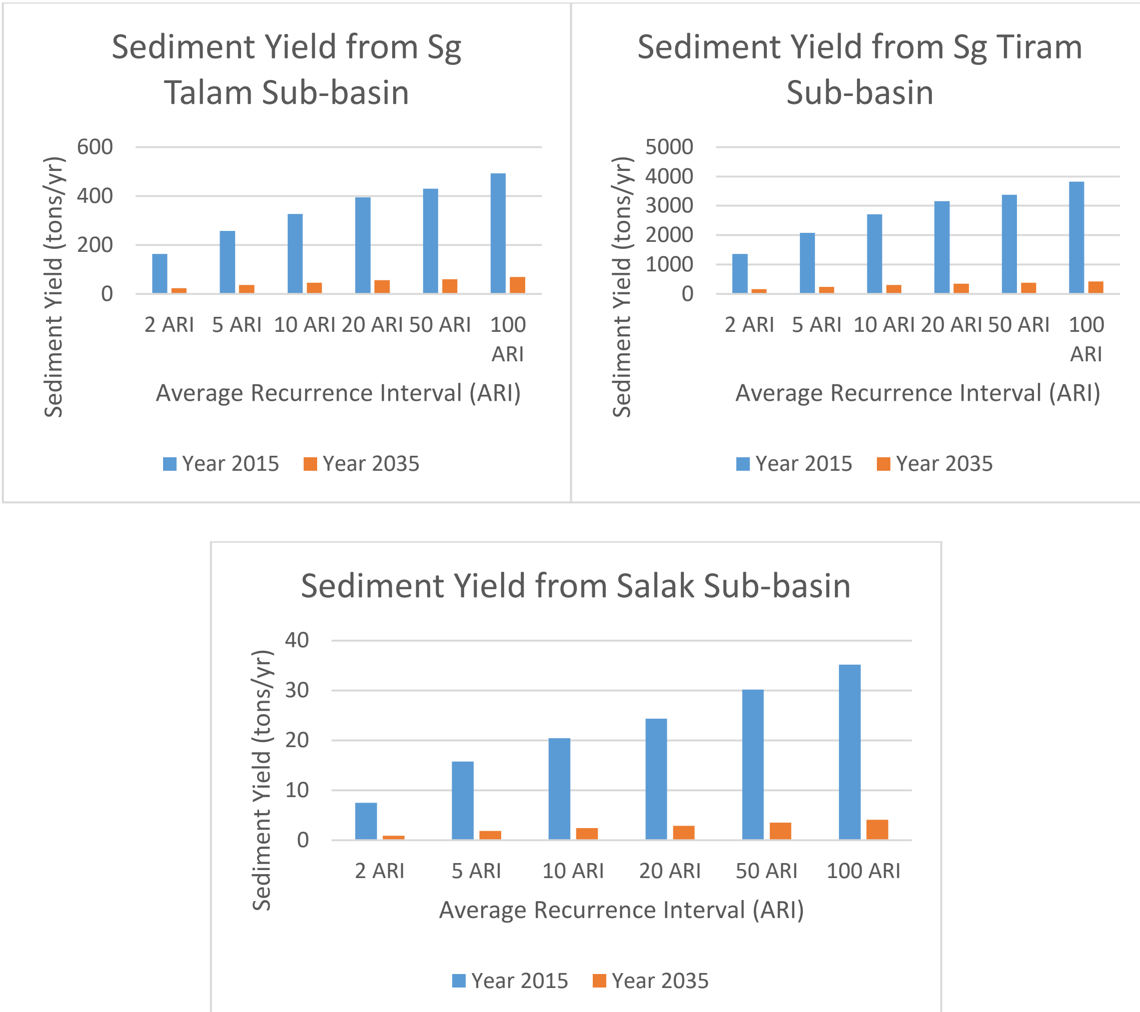


Figure 4.6 Sediment Yield from Sungai Talam, Sungai Tiram and Salak Sub-basins

On the other hand, there is only one sub-basin that will experience slight increment from year 2015 to 2035 which is Pinang with a percentage of 14.61% throughout the years.

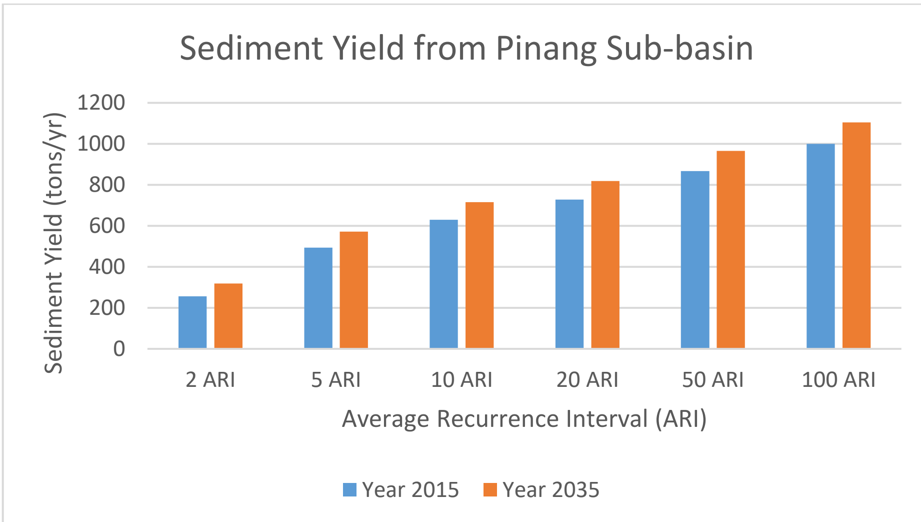


Figure 4.7 Sediment Yield from Pinang Sub-basin

CHAPTER 5

CONCLUSION

5.1 Introduction

Sediment yield can be assessed by using the Modified Universal Soil Loss Equation (MUSLE). Sediment yield is influenced by factors, including peak flow, rainfall volume, soil erodibility, topography of the area studied, land cover and erosion management applied. ArcGIS software is utilized to obtain vegetation coverage, slope steepness, and sub basins area. They are then computed with other factors to obtain the sediment yield.

5.2 Conclusion

The objectives of this research are to obtain the factors Q_p, V, K, LS, C and P for Kuantan River Basin and compare the current and future sediment yield. With the range of 0 to 10%, sediment yield from Ah Tong, Cereh, Kenau, Pandan, Reman and Ulu Sungai Kuantan sub-basins will not experience significant changes throughout the years. However, Belat, Caru, Nada, Pancing, Riau, Sebarau, Sungai Galing, Sungai Isap, Sungai Talam, Sungai Tiram, and Salak sub-basins has a drastic decrease of sediment yield with the range of 60% to 99.99% in year 2035 compared to 2015. As for Pinang sub-basin, it was predicted to experience slight increment of sediment yield with the percentage of 14.61% from year 2015 to 2035.

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