QUANTIFICATION AND MODELLING OF SEDIMENT LOADING IN OIL PALM CATCHMENT

KHAIRATUNNISA BINTI MOKHTAR

Faculty of Civil Engineering
Universiti Teknologi Malaysia

UNIVERSITI TEKNOLOGI MALAYSIA

DECLARATION OF THESIS / UNDERGRADUATE PROJECT PAPER AND COPYRIGHT

Author's full name : **KHAIRATUNNISA BINTI MOKHTAR**

Date of birth : **22 JUNE 1985**

Title : **QUANTIFICATION AND MODELLING OF SEDIMENT LOADING IN OIL PALM CATCHMENT**

Academic Session : **2010/2011**

I declare that this thesis is classified as :

☐	**CONFIDENTIAL**	(Contains confidential information under the Official Secret Act 1972)*
☐	**RESTRICTED**	(Contains restricted information as specified by the organization where research was done)*
☑	**OPEN ACCESS**	I agree that my thesis to be published as online open access (full text)

I acknowledged that Universiti Teknologi Malaysia reserves the right as follows:

1. The thesis is the property of Universiti Teknologi Malaysia.
2. The Library of Universiti Teknologi Malaysia has the right to make copies for the purpose of research only.
3. The Library has the right to make copies of the thesis for academic exchange.

SIGNATURE

850622-04-5336

(NEW IC NO. /PASSPORT NO.)

Date : **28 FEBRUARY 2011**

Certified by:

SIGNATURE OF SUPERVISOR

PROF. DR. ZULKIFLI BIN YUSOP

NAME OF SUPERVISOR

Date : **28 FEBRUARY 2011**

NOTES : * If the thesis is CONFIDENTAL or RESTRICTED, please attach with the letter from the organization with period and reasons for confidentiality or restriction.

"~~I~~/We* hereby declare that ~~I~~/we* have read this thesis and in ~~my~~/our* opinion this thesis is sufficient in terms of scope and quality for the award of the degree of Master of Engineering (Hydrology and Water Resources)"

Signature : .....

Name of Supervisor I : PROF. DR. ZULKIFLI BIN YUSOP

Date : 28 FEBRUARY 2011

Signature : .....

Name of Supervisor II: PM. DR. SUPIAH BINTI SHAMSUDIN

Date : 28 FEBRUARY 2011

BAHAGIAN A – PENGESAHAN KERJASAMA*

Adalah disahkan bahawa projek penyelidikan tesis ini telah dilaksanakan melalui kerjasama antara _____ dengan _____

Disahkan oleh:

Tandatangan : ..... Tarikh : .....

Nama : .....

Jawatan : .....
(Cop rasmi)

* *Jika penyediaan tesis/projek melibatkan kerjasama.*

BAHAGIAN B – UNTUK KEGUNAAN PEJABAT SEKOLAH PENGAJIAN SISWAZAH

Tesis ini telah diperiksa dan diakui oleh:

Nama dan Alamat Pemeriksa Luar : PROF. DR. WAN RUSLAN BIN ISMAIL
PUSAT PENGAJIAN ILMU KEMANUSIAAN
UNIVERSITI SAINS MALAYSIA
11800 MINDEN, PULAU PINANG

Nama dan Alamat Pemeriksa Dalam : PM. IR. DR. AYOB BIN KATIMON
FAKULTI KEJURUTERAAN AWAM
UNIVERSITI TEKNOLOGI MALAYSIA
81310 SKUDAI, JOHOR

Nama Penyelia lain (jika ada) : PM. DR. SUPIAH BINTI SHAMSUDIN
SEKOLAH RAZAK UTM
UNIVERSITI TEKNOLOGI MALAYSIA
JLN SEMARAK, 54100 KUALA LUMPUR

Disahkan oleh Timbalan Pendaftar di Sekolah Pengajian Siswazah:

Tandatangan : ---------- Tarikh : ----------

Nama : ----------

QUANTIFICATION AND MODELLING OF SEDIMENT LOADING IN OIL PALM CATCHMENT

KHAIRATUNNISA BINTI MOKHTAR

A thesis submitted in fulfillment of the
requirements for the award of the degree of
Master of Engineering (Hydrology and Water Resources)

Faculty of Civil Engineering
Universiti Teknologi Malaysia

MAY 2011

I declare that this thesis entitled “Quantification and Modelling of Sediment Loading in Oil Palm Catchment” is the result of my own research except as citied in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : KHAIRATUNNISA BINTI MOKHTAR

Date : 28 FEBRUARY 2011

Dedicated to individuals
I love with all my heart

Thanks for everything in every second of my life
World is nothing to me compared to both of you
(Ayah and Mak)
Mokhtar Bin Abdullah
Khalijah Binti Ali

Thanks for the support and motivation
Backbone and colours of my life
(Brothers and Sister)
Muhamad Muzaffar
Ahmad Fakhrurrazi
Salman Rukaini
Aimran Ariffin
Muhammad Rusyduddin
Rukniatilhusna

Thanks for the patience and encouragement
Future and hope
Khairil Hidayat Bin Mohd Fadzilah

ACKNOWLEDGEMENTS

I wish to express my sincere appreciation to my project supervisor, Professor Dr. Zulkifli Bin Yusop for his guidance, encouragement, critics and cooperation. Without his continued support and interest, this project would not have been the same as presented here. I am also thankful to my co-supervisor Associate Professor Dr. Supiah Binti Shamsudin, for her cooperation and experience shared.

Special thanks to Mahamurni Plantation Sdn Bhd for their cooperation in conducting this field work study at Sedenak Estate. My sincere appreciation also extends to all my friends and others who provide assistance and support at various occasions especially Institute of Environmental and Water Resource Management (IPASA) staffs. Their views and tips are useful indeed. Last but not least, appreciation to my parents and siblings for their ideas, assistance and motivation. Unfortunately, it is not possible to list all of them in this limited space.

This study is part of the research activities under UTM's Vot 78254 granted by the Fundamental Research Grant Scheme (FRGS).

ABSTRACT

A small and matured oil palm catchment of 15.62 ha in Ladang Sedenak, Johor was monitored to study the Suspended Solids (SS) loading and factors influencing the sedimentation rate. This study is designed to establish comprehensive understanding on hillslope erosion processes in oil palm plantation catchment. Ten storm events with a total of 133 samples were analyzed for SS concentration and turbidity. Rainfall and streamflow were recorded continuously. Baseflow samples were also analysed. SS concentration ranged between 2 and 2710 mg/L during storms but only from 3 to 6 mg/L during baseflow. Turbidity values range between 20.5 NTU and 2875 NTU. The relationships between SS concentration and turbidity for individual storm events are not consistent with coefficient of determination, r^2 ranging from 0.37 to 0.96. The intercepts of the regression line range from -57.2 to 391.9 whereas the slopes from 0.44 to 1.66. Therefore, all event data are combined to minimise the variation. The new SS-turbidity relationship for the combined events is SS=0.813Tur+3.69 (r^2=0.86, p<0.0001). Sedimentation process was examined in terms of hysteresis loops which demonstrate five clockwise loops, three figure eight patterns and two single-valued lines. In general, there was a depletion of sediment supply before the discharge has peaked. The depletion of sediment delivery, relatively early in the storm event could be associated with a limited supply of sediment during long-lasting and intense storms. The EMC for SS concentration ranges between 36 and 2046 mg/L, with a mean of 940 mg/L. Based on the EMC values of individual storm, the resulted SS load range from negligible to 2.51 ton. SS loading was also predicted using MUSLE. The runoff factor in MUSLE was estimated using two different techniques; 1) by the established curve number technique (SCS TR-55) and 2) by rainfall-runoff relationship at the study site. A better prediction of SS loading was obtained when the peakflow in MUSLE was estimated from rainfall-runoff relationship. Analysis of soil erosion model showed that the annual SS loading predicted by MUSLE is 10.03 ton/ha/yr whereas the USLE is 12.31 ton/ha/yr. SS loading at the catchment outlet was corrected by multiplying value of soil loss on the hillslope with Sediment Delivery Ratio (SDR). By applying a SDR value of 0.87, the resulted SS loading is 10.71 ton/ha/yr which is close to the value derived by MUSLE (10.03 ton/ha/yr).

ABSTRAK

Kajian beban pepejal terampai (SS) dan faktor yang mempengaruhi kadar pengenapan di tadahan kecil (15.62 hektar) kelapa sawit yang matang telah dijalankan di Ladang Sedenak, Johor. Kajian ini di reka untuk mendapatkan lebih kefahaman mengenai proses hakisan cerun bukit di kawasan tadahan ladang kelapa sawit. Sepuluh peristiwa hujan dengan jumlah 133 sampel telah dianalisis untuk kepekatan SS dan kekeruhan. Curahan hujan dan aliran sungai direkod berterusan. Sampel aliran dasar juga dianalisis. Sampel air sungai ketika aliran ribut mempunyai julat kepekatan SS antara 2 hingga 2710 mg/L dan 3 hingga 6 mg/L ketika aliran dasar. Nilai kekeruhan pula adalah antara 20.5 NTU dan 2875 NTU. Hubungan antara kepekatan SS dan kekeruhan bagi hujan ribut yang berlainan adalah tidak seragam dengan r^2 antara 0.37 dan 0.96. Nilai pintasan garisan regresi yang berjulat antara -57.2 hingga 391.9 dengan kecerunan di antara 0.44 hingga 1.66. Oleh itu, kesemua data telah digabungkan untuk mengurangkan variasi. Hubungan baru antara kepekatan SS dan kekeruhan bagi semua hujan ribut adalah SS=0.813Tur+3.69 (r^2=0.86, p<0.0001). Kepekatan SS juga dianalisis dalam bentuk gelung histerisis. Gelung histerisis menunjukkan 5 pola melawan pusingan jam, 3 bentuk angka lapan dan 2 bentuk garisan. Secara umum bekalan atau punca SS telah berkurang sebelum berlakunya aliran puncak. Penurunan kepekatan SS yang lebih cepat berbanding luahan menunjukkan bekalan SS yang agak terbatas semasa hujan yang lama dan lebat. Nilai EMC bagi kepekatan SS adalah antara 36 dan 2046 mg/L, dengan purata 940 mg/L. Berdasarkan nilai EMC, julat beban SS bagi ribut yang berasingan adalah dari terlalu kecil (diabaikan) hingga 2.51 tan. Beban SS turut dianggar menggunakan MUSLE. Faktor air larian dalam MUSLE ditentukan menggunakan dua kaedah berbeza, 1) teknik CN (SCS TR-55) dan 2) hubungan curahan hujan-air larian di kawasan kajian. Ramalan beban SS yang lebih baik diperolehi apabila aliran puncak dalam MUSLE dianggar menggunakan hubungan curahan hujan-air larian. Jumlah beban SS tahunan yang diramal menggunakan MUSLE adalah 10.03 tan/ha/yr manakala USLE 12.31 tan/ha/yr. Beban SS yang diramal di titik limpah tadahan telah diselaraskan dengan mendarab nilai hakisan cerun dengan Nisbah Penghantaran Enapan (SDR). Dengan nilai SDR sebanyak 0.87, jumlah beban SS yang diperolehi ialah 10.71 ton/ha/yr iaitu hampir menyamai nilai yang diramalkan menggunakan MUSLE (10.03 ton/ha/yr).

TABLE OF CONTENTS

CHAPTER	TITLE		PAGE
	DECLARATION		**ii**
	DEDICATION		**iii**
	ACKNOWLEDGEMENTS		**iv**
	ABSTRACT		**v**
	ABSTRAK		**vi**
	TABLE OF CONTENTS		**vii**
	LIST OF TABLES		**xi**
	LIST OF FIGURES		**xiii**
	LIST OF ABBREVIATIONS		**xvi**
	LIST OF SYMBOLS		**xvii**
	METRIC EQUIVALENTS		**xviii**
	LIST OF APPENDICES		**xix**
1	**INTRODUCTION**		**1**
	1.1	Research Background	1
	1.2	Problem Statement	2
	1.3	Objectives	4
	1.4	Significance of The Study	5
	1.5	Scope of Study	5
	1.6	Research Methodology	6

2	**LITERATURE REVIEW**		**8**
2.1	Introduction		8
2.2	Catchment Research		9
2.3	Soil Erosion		13
	2.3.1	Soil Erosion Process and Sedimentation	14
	2.3.2	Types of Soil Erosion	16
	2.3.3	Factors Affecting Soil Erosion	17
2.4	Sediment Loading		20
	2.4.1	Suspended Sediment	21
	2.4.2	Impact on Suspended Sediment	23
2.5	Suspended Sediment and Turbidity Relationship		24
2.6	Suspended Sediment and Discharge Relationship		27
2.7	Sediment Yield		30
2.8	Sediment Yield Computation		31
2.9	Sediment Delivery Ratio (SDR)		32
2.10	Event Mean Concentration (EMC)		33
2.11	Conclusion		34
3	**METHODOLOGY**		**35**
3.1	Introduction		35
3.2	Site Description		36
3.3	Soil Characteristic		39
3.4	Instrumentation and Data Collection		40
	3.4.1	Manual Grab Sampling	40
	3.4.2	Sediment and Turbidity Measurement	41
		3.4.2.1 Turbidity	42
		3.4.2.2 Suspended Sediment Analysis	43
	3.4.3	Streamflow Measurement	43
	3.4.4	Rainfall Measurement	46
3.5	Data Analysis		46
	3.5.1	Hydrograph Analysis	46
	3.5.2	Statistical Analysis	47

	3.5.3	Box Plot Analysis	48
	3.5.4	Universal Soil Loss Equation (USLE)	49
	3.5.5	Modified Universal Soil Loss Equation (MUSLE)	54
	3.5.6	Event Mean Concentration (EMC)	61
	3.5.7	Long Term Sediment Yield Prediction	62
3.6	Conclusion		64
4	**RESULTS AND DISCUSSION**		**65**
4.1	Introduction		65
4.2	Suspended Solids (SS) Concentration		67
4.3	Storm Event Analysis		67
4.4	Hysterisis Loop		73
4.5	Turbidity		79
4.6	Turbidity and SS Concentration Relationship		81
4.7	Regression Analysis		85
4.8	Modified Universal Soil Loss Equation (MUSLE) Analysis		88
	4.8.1	Volume of Runoff, V_R	88
	4.8.2	Peak Discharge, Q_P	90
	4.8.3	Soil Erodibility Factor, K	91
	4.8.4	Slope Length Factor and Slope Steepness Factor, LS	92
	4.8.5	Crop and Management Factor, C	92
	4.8.6	Conservation Practice Factor, P	92
	4.8.7	Suspended Sediment Loading	93
4.9	Suspended Solids Prediction		96
	4.9.1	Results of Modified Universal Soil Loss Equation (MUSLE)	197
	4.9.2	Comparison with Universal Soil Loss Equation (USLE) Analysis	103
4.10	Conclusion		106

5 CONCLUSION AND RECOMMENDATION 107

4.11 Introduction 107
4.12 Conclusions 108
4.13 Recommendations 109

REFERENCES 110

Appendices 122-159

LIST OF TABLES

TABLE NO.	TITLE	PAGE
2.1	Sediment yield from various land uses	10
2.2	Global sediment loads	14
2.3	Sources of suspended sediment in small streams	23
2.4	Classes of C-Q relations and their criteria	28
3.1	Physiographical conditions of study catchment	38
3.2	Soil classification in Ladang Sedenak	40
3.3	Crop cover and crop management factor, *C*	53
3.4	Erosion control practice factors, *P*	53
3.5	Runoff curve numbers for agricultural lands	57
3.6	Ponding adjustment factor	61
4.1	Mean concentrations of SS for 10 storm events	66
4.2	Characteristics of sampling storm and the corresponding suspended solids concentration	68
4.3	Patterns of SS concentration hysteresis loop for various storm event	75
4.4	Mean concentrations of turbidity for 10 storm events	80
4.5	Summary of regression analysis between SS concentration against turbidity	87
4.6	Observed and predicted volume of runoff, V_R	89
4.7	Observed and estimated peak discharge, Q_P for predicting SS yield	91
4.8	Suspended solids loading for 10 storm events	94
4.9	Predicted montly suspended solids loadings	98

4.10 Measured and predicted soil loss and SS loading for vegetated catchments in Malaysia 105

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
1.1	Occurrence of Horton overland flow during heavy storm causing high suspended solid concentration in stream	4
1.2	The research design and procedure	7
2.1	Soil dislodgement, detachment, displacement, transport, and deposition	15
2.2	Principle factors affecting soil erosion and movement	18
2.3	Cohesive aggregates eroded from the bed may disaggregate downstream	20
2.4	A schematic diagram illustrating the various components of turbidity (top) reading and suspended solids (bottom)	25
3.1	Location of the experimental catchment in Ladang Sedenak, Kulai, Johor	37
3.2	V-notch weir installed at the study site	38
3.3	Results of hydrometer test suggesting sandy clay soil with organic	39
3.4	Turbidity probe inside a perforated plastic submerged behind the V-notch weir	43
3.5	Installation of water level logger	45
3.6	Onset RG3-M rain gauge installed at the study site	45
3.7	Hydrograph components	47
3.8	Description of box plot	48
3.9	Malaysian soil erodibility nomograph for computing soil erodibility factor, K	51

3.10	SCS Type II method for determining unit peak discharge, q_u from time concentration	60
3.11	Flow chart for predicting Suspended solids loading using Original MUSLE and Combined Equation between MUSLE and Chong's equation (Equation 3.8 and Equation 3.9)	63
4.1	Boxplot of suspended solids concentration of 10 storm events and during baseflow conditions	67
4.2	Sedigraphs for events on 05/06/08, 18/06/08 and 10/07/08	69
4.3	Sedigraphs for events on 16/10/08, 04/12/08 and 09/08/09	70
4.4	Sedigraphs for the events on 13/08/09, 16/08/09 and 17/08/09	71
4.5	Sedigraphs for event on 27/08/09	72
4.6	Hysteresis loops of SS concentration versus discharge for events on 05/06/08, 18/06/08, 10/07/08 and 16/10/08	76
4.7	Hysteresis loops of SS concentration versus discharge for events on 04/12/08, 09/08/09, 13/08/09 and 16/08/09	77
4.8	Hysteresis loops of SS concentration versus discharge for events on 17/08/09 and 27/08/09	78
4.9	Frequency of storm for different hysteresis classes	79
4.10	Boxplot of turbidity data during 10 storm events and during baseflow conditions	80
4.11	Temporal variation of SS concentration and turbidity for events on 05/06/08, 18/06/08, 10/07/08 and 16/10/08	82
4.12	Temporal variation of SS concentration and turbidity for events on 04/12/08, 09/08/09, 13/08/09 and 16/08/09	83
4.13	Temporal variation of SS concentration and turbidity for events on 17/08/09 and 27/08/09	84
4.14	Relationship between SS concentration and turbidity for different storm events	86
4.15	Relationship between SS concentration and turbidity for all events	87
4.16	Relationship between predicted SS loading using the original MUSLE and observed suspended solids loading	95

4.17	Relationship between predicted against observed suspended solids and the predicted loading using a combination of MUSLE, Equation 3.13 and Equation 3.14	95
4.18	Relationship between suspended solids and peak discharge	96
4.19	Daily rainfall and daily suspended solids load in August, September and October 2005	99
4.20	Daily rainfall and daily suspended solids in November, December 2005 and January 2006	100
4.21	Daily rainfall and daily suspended solids in February, March, and April 2006	101
4.22	Daily rainfall and daily suspended solids in May, June, and July 2006	102

LIST OF ABBREVIATIONS

AnnAGNPS	-	Annualized Agriculutral Non-Poin Source
EMC	-	Event Mean Concentration
MASMA	-	Urban Drainage Design Standards and Procedures for
MPOB	-	Malaysian Palm Oil Board
MSLE	-	Modified Soil Loss Equation
MUSLE	-	Modified Universal Soil Loss Equation
NTU	-	Nephelometric Turbidity Units
RUSLE	-	Revised Universal Soil Loss Equation
SCS TR-55	-	U.S. Soil Conservation Service Technical Release 55
SDR	-	Sediment delivery ratio
SS	-	Suspended sediment
USLE	-	Universal Soil Loss Equation

LIST OF SYMBOLS

C	-	Cropping and management factor
CN	-	Curve Number
I_a	-	Initial abstraction
K	-	Soil erodibility factor
LS	-	Slope length and slope factor
P	-	Conservation practice factor
Q_P	-	Peak discharge
q_u	-	Unit peak discharge
R	-	Rainfall erosivity factor
S	-	Slope steepness factor
V_R	-	Runoff volume
Y	-	Sediment yield

METRIC EQUIVALENTS

1 hectare (ha) = 10 000 square meter (m^2)

1 hectare (ha) = 2.47 acres (ac)

1 cubic meter (m^3) = 1000 litre

1 tonne per hectare (ton/ha) = 0.45 ton per acre (ton/ac)

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	Gavimetric Method	122
	Input properties	124
B	Storm events data	125
C	Rainfall events data	133
D	Monthly estimated loading details	143
E	Example of calculations	155

CHAPTER 1

INTRODUCTION

1.1 Research Background

Oil palm was introduced to Malaysia in 1870 as an ornamental plant, and in 1917, the first commercial planting was undertaken. Owing to the government encouragement to diversify the crops from rubber to oil palm, the planting was expanded rapidly. Since then oil palm plantations continue to expand throughout the country. Within relatively a short period, Malaysia became one of the world largest commercial producers and exporters of palm oil. In 2008, the total palm oil export earnings are RM 65.2 billion from RM 45.1 billon in 2007. Therefore, the palm oil industry contributes significantly towards the country's foreign exchange earnings and the increased standard of living among Malaysians (Wu *et al*., 2008).

Malaysia's plantation companies must produce crude palm oil using the best management and agriculture practices to guarantee the industry's sustainability and exports. The growth of palm oil industry has been phenomenal with the increasing demand for vegetable oil such as biodiesel, oleo-chemical products and biomass by-products. Oil palm plantation development initially involved opening up of land areas and associated activities such as land clearing, biomass management and

disposal, earthworks, planting and replanting activities. The impact of palm oil plantation is significant and therefore good management and agriculture practices are necessary.

Non-point source pollution has been recognized as a significant source of surface water quality problems (Ignazi, 1993; Ongley 1996). Fine and coarse sediment transported by surface water can result in different types of problem. Fine sediment is a major pollutant of aquatic systems. For example, deposition of fines has been repeatedly shown to degrade the benthic habitat of fish and other organisms (Lowe and Bolger, 2000) and impair water quality (Reiser, 1998). A major concern on stream and catchment management is the ecological impact of increased fine sediment load following land use practices (Brown and Krygier, 1971; Beschta, 1978). In agricultural areas, streams draining cultivated areas can undergo significant bank erosion and instability (Wilkin and Hebel, 1982) as well as increased sediment yields and runoff volumes (Allan *et al*., 1997; Vache *et al*., 2002), resulting in both sedimentation and significant soil and nutrient losses. As such excess fine sediment in streams often leads to ecological problems (Salant *et al*., 2008).

1.2 Problem Statement

Malaysia alone accounted for more than 40% of the total world palm oil production. In fact, for the past five decades, Malaysia's oil palm plantation area and crude palm oil production have been increasing gradually. From a mere 0.054 million hectares in the early 1960s, it increased steadily to 4.48 million hectares in 2008 (MPOB, 2009). Being a tropical palm, oil palm can be cultivated easily in Malaysia. An improved management of oil palm plantation needs to be implemented in order to achieve sustainable growth. Soil erosion and river sedimentation are important issues in water and catchment management. High erosion rate often leads to river

constriction, increases water treatment costs, threaten aquatic habitats, and increases in flood frequency.

Knowledge of rates of soil erosion and sedimentation losses is crucial for sustaining the health of plantation ecosystems. Malaysia is a developing country where agriculture plantation is an important component of land use. Beside forest, plantation ecosystems can play crucial role for the conservation of water and soil resources. According to Wurbs and James (2002), soil is protected from erosion by its vegetative cover. Human activities that disturb or remove vegetation, such as logging, mining, agriculture, and construction, may greatly increase soil erosion. Therefore, it is important to make sure that a large part of palm oil plantation is covered by vegetation to maximize and sustain the production.

Oil palm cultivation can accelerate erosion and sedimentation processes especially during clearing of land. This results in more sediment being washed away into water courses. Large amount of money is spent every year to clean up sediment and repairing eroded stream bank, washed out roads and other erosion damages. Moreover, high sediment load is also responsible for pollution of many lakes, stream and rivers. The only practical solution is to reduce the surface runoff thereby lowering erosion intensity. Accelerated erosion and sedimentation rates are best controlled by minimising ground disturbances and applying effective soil conservation measures.

Adequate soil erosion control requires a quantitative understanding of the mechanisms governing soil erosion, identifying those major factors that cause soil erosion, predicting the amount and distribution of soil loss in relation to possible causal factors, and making an erosion assessment for alternative best management practices that can be used to facilitate conservation policies (Gao *et al*., 2002; Wang *et al*., 2006). Hence, it is timely to carry out detailed studies on erosion and sediment yield from oil palm catchments which aimed at minimising erosion problems. Erosion and sedimentation measurement can be conducted using a small catchment

approach to enable linkages between slope and stream processes to be established. Thus far very little work has been carried out on rate of erosion from oil palm plantation on a catchment basis. Such information is crucial for planning and management of catchment resources in particular the soil and water. The effect from overland flow during heavy storm in the study site which caused high sediment concentration in stream is shown in Figure 1.1.

Figure 1.1: Occurrence of Horton overland flow during heavy storms causing high suspended sediment concentration in stream

1.3 Objectives

The main aim of this study is to quantify and predict sediment loss from oil palm plantation. The specific objectives are:

i) To determine sediment load into the stream during storm events.
ii) To investigate the hydro-meteorological factors that influence erosion and sediment loading in an oil palm plantation.
iii) To calibrate and validate soil erosion models for application to local environment.

1.4 Significance of The Study

Upon completion this study is designed to establish comprehensive understanding on hillslope erosion processes in tropical plantation catchment. Specifically the following outcomes are expected:

i) Validated erosion model for local application.
ii) A method for a reliable estimation of sediment loading.
iii) Major parameters that influence erosion and sedimentation are identified.

1.5 Scope of Study

Based on the above objectives, this study covers the following scopes of work:

i) Setting up experimental catchment in Ladang Sedenak.
ii) Installation of equipment which include rain gauge, water level recorder, water sampler and automatic turbidity meter.
iii) Sampling of streamflow during baseflow and stormflow conditions.
iv) Carry out laboratory analysis for suspended solids concentration and turbidity.
v) Estimate event sediment loading using Modified Universal Soil Loss Equation (MUSLE).
vi) Estimate sediment loading based on observed data in the field.
vii) Predict sediment yield based on rainfall and peak discharge data.
viii) Compare the observed sediment loading estimates from MUSLE and USLE models.

1.6 Research Methodology

The general methodology used in this study is summarized in Figure 1.2 which basically involves setting up of equipment, field data collection, laboratory analysis, data analysis, prediction of soil loss and suspended solids loading, and validation of selected erosion models.

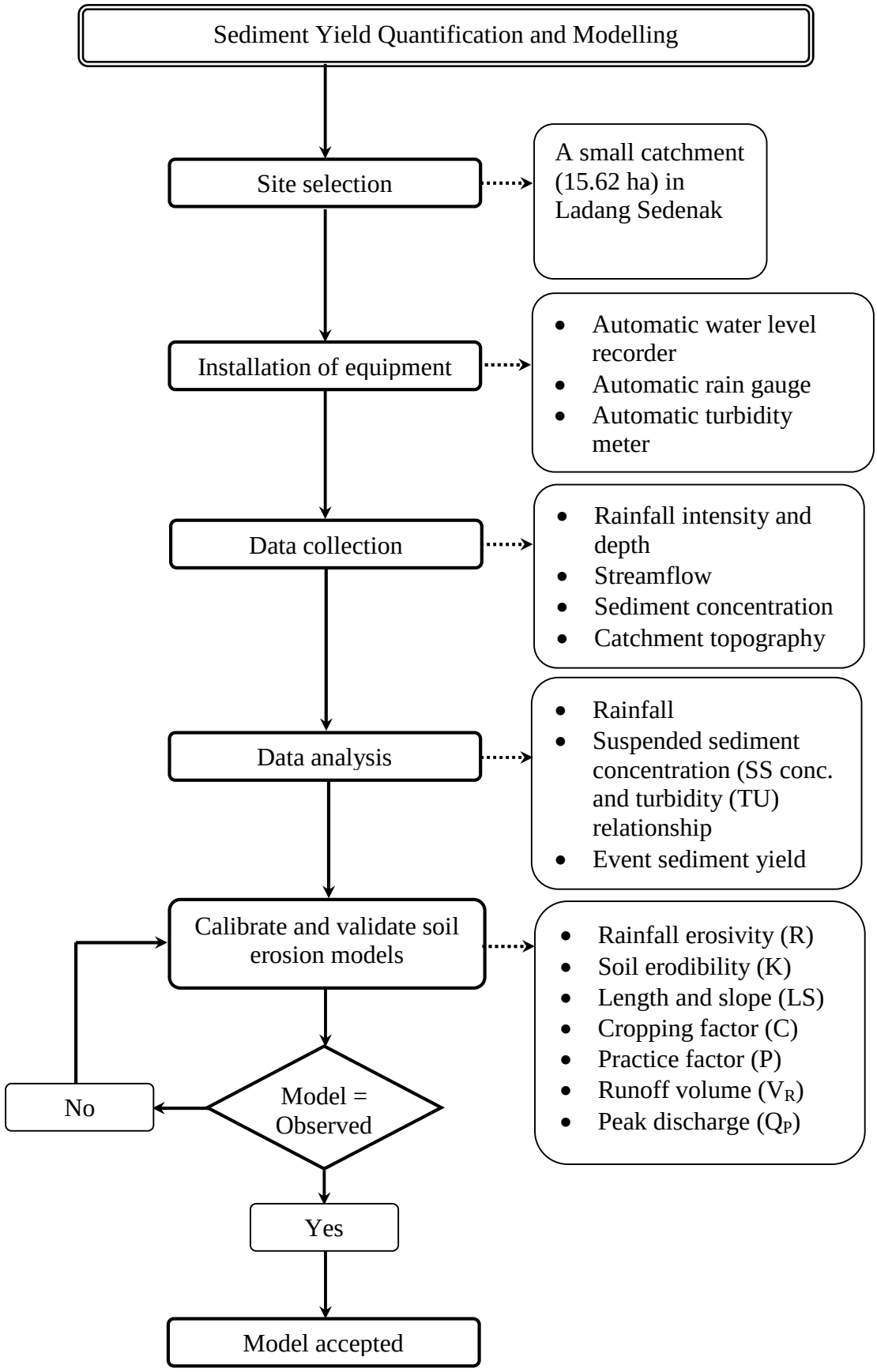

Figure 1.2: The research design and procedure

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Agricultural activities especially when involve land clearing and forest conversion could pose significant effects on water pathways and soil erosion, thus gradually deplete site productivity (e.g., Ross and Dykes, 1996; Harwood, 1996; Sidle *et al*., 2006). While the intensity of disturbance can exacerbate those impacts, all agriculture practices, including subsistence farming have environmental and social impacts both on-site and off-site. The planting of oil palm is no exception (Lord and Clay, 2006). Rainfall intensity is a major factor influencing soil erosion, especially sheet and inter-rill erosions (Meyer and Harmon, 1989; Truman and Bradford, 1993; Truman *et al*., 2007). Soil is detached by raindrop impact and the detached particles are transported to streams and water bodies by overland flow. The detachment of fine particles by overland flow can decrease the soil productivity (Sharpley and Smith, 1983; Blaschke et al., 2000; McDowell and Sharpley, 2003). Therefore, estimation of runoff and sediment yield is necessary for developing watershed management plans that involve soil and water conservation measures.

2.2 Catchment Research

Oil palm is generally planted on flat to undulating terrains. As a result, soil losses from erosion due to planting of oil palm can be maintained low especially when it can sustains a vigorous legume cover. Therefore, high quality and vigorous grass and legume species must be in place, fertilised and well managed in order to form a protective cover over the soil surface and withstand surface disturbances without degeneration (RRIM, 1990). Though soil cover is effective in preventing erosion and loss of organic matter from the top soil, the vegetative cover gradually die off and diminish as the oil palm grow bigger and taller due to lesser sunlight reaching the ground.

Consequently, oil palm plantations may create a variety of impacts on the surrounding environment which among other include loss of native vegetation, soil erosion, sedimentation in streams, rivers and estuaries, water pollution due to pesticides and fertilisers and other chemicals (Keu, 2000). Measurement of sediment yield in oil palm plantation in Malaysia were reported by Ling *et al.*(1979) and Nur Syahiza (2007) while others used USLE for estimating soil loss for various land use (Gregersen *et al*., 2003; Zulkifli and Okuda, 2005). The application of MUSLE for predicting soil loss from agriculture and forest areas that flow into reservoirs were reported in Malaysia by Supiah (2003) and elsewhere by Mahmoudzadeh *et al*. (2002) and Pandey *et al*.(2008). The variation in soil loss and sediment yield estimates is in part due to the difference methods used. Table 2.1 summarises the observed and predicted soil loss and sediment yield from catchments of different land-use type.

Table 2.1: Sediment yieldfrom various land uses

No.	Location	Area (ha)	Land use	Annual rainfall (mm)	Method	Soil loss/ Sediment yield (ton/ha/yr)	Sources
1	River Kuala Tasik, (Pulau Pinang, Kedah), Malaysia	6309.25	Rubber estate Rangeland Forest	1735	RUSLE	123	Shamshad *et al*.(2008)
2	SB2, Gua Musang, Kelantan, Malaysia	31.5	Oil palm	2743.8	USLE MSLE	8.05 14.54	Nur Syahiza (2007)
3	Triang Catchment, Malaysia	198700	Forest (62%) Rubber (22.4%) Oil palm (10.7%) Sundry crops (3.1%)	1811	USLE/GIS	35.9	Zulkifli and Okuda (2005)
4	Tikolod, Sabah, Malaysia	3240	Ginger Hill rice	n/a	USLE	336.8 269.4	Gregersen *et al*. (2003)
5	Layang Reservoir, Johor, Malaysia	400	Forest Oil palm Rubber	2385.4	MUSLE	37.15	Supiah(2003)
6	Sungai Lui, Selangor, Malaysia	6810	Forest	2265.8	Measured	0.90*	Lai(1993)
7	Matured oil palm plantation, Malaysia	n/a	Bare Legume covers Natural covers	n/a	n/a	79 11 10	Ling *et al*.(1979)