



UNIVERSITI PUTRA MALAYSIA

**EVALUATION OF BIOENGINEERING SOIL EROSION
CONTROL TECHNIQUES IN STANDARD
USLE PLOTS**

YONG HONG LIANG

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CONTROL TECHNIQUES IN STANDARD
USLE PLOTS**

By

YONG HONG LIANG

**Thesis Submitted in Fulfilment of the Requirements for the
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YONG HONG LIANG

May 2000

Chairman: Associate Professor Ir. Mohd Amin bin Mohd Soom, Ph.D.

Faculty: Engineering

This erosion control study on Serdang series soil was conducted in standard Universal Soil Loss Equation (USLE) plots of 9% slope at the Department of Biological and Agricultural Engineering (DBAE) field station, Universiti Putra Malaysia (UPM). Rainfall was recorded with an automatic pluviometer. Runoff and soil losses were collected at the downslope in calibrated buckets.

The first set of experiments (1/1/98 - 31/12/98) was carried out on 5 plots. These plots were treated with vetiver (*Vetiveria zizanioides*), legume (*Arachis pintoii*), spot turfing and close turfing (*Axonopus compressus*), respectively. A plot was left bare without vegetation as a control. Results showed that there were no significant differences on soil loss among the treatments with values less than 60 t/ha/y. The bare plot had significantly greater soil loss and runoff of 170 t/ha/y and 670 mm, respectively. There were no significant differences in runoff between the plots with legume and vetiver, vetiver and spot turfing and finally spot turfing and



close turfing. The close turfing produced the lowest erosion losses with 99% and 90% less soil loss and runoff, respectively compared to the bare plot.

The second set of experiments (1/5/98 - 30/4/99) was carried out on another 5 plots. The plots consisted of "coco-fibromat" + hydroseeding, hydroseeding + "fibromat", "fibromat" + hydroseeding, hydroseeding alone and "geojute" + hydroseeding. Hydroseeding alone had significantly greater soil loss (4 t/ha/y) and runoff (170 mm) than other hydroseeding treatments (< 0.8 t/ha/y and < 90 mm). The runoff depths between hydroseeding alone and "geojute" + hydroseeding was not significantly different. Hydroseeding anchored with "fibromat" resulted in lower soil loss and runoff, with 98.2% and 58.2% reduction, respectively compared to hydroseeding alone.

The third set of experiments (1/11/98 - 31/11/99) was carried out on the 5 plots that were constructed later in September 1998. The plots were treated with bermudagrass (*Cynodon dactylon*), natural vegetation (*Pennisetum purpureum*), upland rice (*Oryza sativa*) and upland rice + "fibromat". A plot was left bare without vegetation as a control. The results revealed that there were no significant differences on soil loss among the treatments with values less than 55 t/ha/y. The bare plot had significantly greater soil loss and runoff of 125 t/ha/y and 597 mm, respectively. There was no significant difference in runoff between the bare plot and bermudagrass plot. The upland rice anchored with "fibromat" produced the lowest erosion losses with 99% and 98% reduction in soil loss and runoff, respectively compared to the bare plot.

Treatments with biomats and close turfing gave the best protection against soil erosion with cover management factor lower than 0.01. The highest correlation ($r = 0.87$) was obtained between the soil loss from the bare plots and $KE > 25$.

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**PENILAIAN TEKNIK-TEKNIK KAWALAN HAKISAN TANAH
KEJURUTERAAN BIOLOGI DALAM PETAK-PETAK PIAWAI USLE**

Oleh

YONG HONG LIANG

Mei 2000

Pengerusi: Profesor Madya Ir. Mohd Amin bin Mohd Soom, Ph.D.

Fakulti: Kejuruteraan

Satu kajian kawalan hakisan dijalankan di tapak penyelidikan Jabatan Kejuruteraan Biologi dan Pertanian (KBP), Universiti Putra Malaysia (UPM) Petak-petak Kajian Persamaan Kehilangan Tanah Universal (USLE) dengan kecerunan 9% digunakan dengan tanah jenis siri Serdang Hujan direkod dengan menggunakan sebuah tolok hujan automatik Air larian dan kehilangan tanah dikumpul dalam tangki-tangki yang terletak di hujung cerun

Eksperimen pertama (1/1/98 - 31/12/98) dijalankan dalam 5 petak Ia dirawat dengan vetiver (*Vetiveria zizanioides*), kekacang legume (*Arachis pintoi*), tanaman rumput turf tempok dan tanaman rumput turf rapat (*Axonopus compressus*) Satu petak tanah gondol disediakan untuk kawalan Keputusan menunjukkan tiada perbezaan jelas antara rawatan untuk kehilangan tanah dengan nilai kurang daripada 60 t/ha/y Petak tanah gondol jelas menghasilkan lebih kehilangan tanah dan air larian masing-masing sebanyak 170t/ha/y dan 670 mm Tiada perbezaan jelas pada air larian antara petak-petak kekacang dan vetiver,

vetiver dan tanaman rumput turf tompok, dan tanaman rumput turf tompok dan tanaman rumput turf rapat. Tanaman rumput turf rapat memberi kehilangan hakisan yang minimum dengan mengurangkan kehilangan tanah dan air larian masing-masing sebanyak 99% dan 90% dibandingkan dengan petak gondol.

Eksperimen kedua (1/5/98 - 30/4/99) dijalankan dalam 5 petak yang lain. Ia merangkumi "coco-fibromat" + hydroseeding, hydroseeding + "fibromat", "fibromat" + hydroseeding, hydroseeding sahaja dan "geojute + hydroseeding". Hydroseeding sahaja jelas menghasilkan lebih kehilangan tanah (4 t/ha/y) dan air larian (170 mm) daripada rawatan hydroseeding lain (< 0.8 t/ha/y dan < 90 mm). Tiada perbezaan jelas pada air larian antara hydroseeding sahaja dan "geojute" + hydroseeding. Hydroseeding berlapis "fibromat" mengurangkan kehilangan tanah dan air larian masing-masing sebanyak 98.2% dan 58.2% dibandingkan dengan hydroseeding sahaja.

Eksperimen ketiga (1/11/98 - 31/11/99) dijalankan dalam 5 petak yang dibina kemudian. Ia dirawat dengan rumput bermuda (*Cynodon dactylon*), tumbuhan asli (*Pennisetum purpureum*), padi bukit (*Oryza sativa*) dan padi bukit + "fibromat". Satu petak tanah gondol disediakan untuk kawalan. Kajian menunjukkan tiada perbezaan jelas antara rawatan untuk kehilangan tanah dengan nilai kurang daripada 55 t/ha/y. Petak tanah gondol jelas menghasilkan lebih kehilangan tanah dan air larian masing-masing sebanyak 125 t/ha/y dan 597 mm. Tiada perbezaan jelas pada air larian antara petak-petak tanah gondol dan rumput bermuda. Padi bukit berlapis "fibromat" memberi kehilangan hakisan yang

minimum dengan mengurangkan kehilangan tanah dan air larian masing-masing sebanyak 99% dan 98% dibandingkan dengan petak gondol.

Rawatan dengan biomat dan tanaman rumput turf rapat memberi perlindungan yang baik terhadap hakisan dengan faktor pengurusan pelindung kurang daripada 0.01. Perhubungan sekaitan yang paling tinggi ($r = 0.87$) diperolehi antara tanah terhakis dari petak tanah gondol dengan $KE > 25$.

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TABLE OF CONTENTS

ABSTRACT	ii	
ABSTRAK	v	
ACKNOWLEDGEMENTS	viii	
APPROVAL SHEETS	ix	
DECLARATION FORM	xi	
LIST OF TABLES	xiv	
LIST OF FIGURES	xvi	
LIST OF PLATES	xviii	
LIST OF ABBREVIATIONS	xx	
CHAPTER		
I	INTRODUCTION	1
	Statement of Problem	2
	Objectives	3
II	LITERATURE REVIEW	4
	Soil Erosion	4
	Natural Erosion	4
	Accelerated Erosion	5
	Types of Erosion	5
	Interrill Erosion	5
	Rill Erosion	6
	Gully Erosion	6
	Factors Influencing Soil Erosion	6
	Rainfall Erosivity	7
	Soil Erodibility	9
	Slope Steepness	10
	Vegetation Cover	11
	Universal Soil Loss Equation	14
	Cover Management Factor	15
	Physical Effects of Grass	16
	Rainfall Interception	17
	Surface Runoff	17
	Infiltration	18
	Root Reinforcement	18
	Grass Hedges	19
	Bioengineering	19
	Turfing	22
	Hydroseeding and Matting	23
	Cover Crops	24
	Vetiver	25
III	MATERIALS AND METHODS	28
	Study Site	27



	Experimental Design	29
	Runoff and Eroded Sediment	46
	Rainfall Erosivity Index	46
	Cover Management Factor	49
	Statistical Analysis	50
IV	RESULTS	52
	Rainfall Characteristics	52
	Runoff and Soil Loss	54
	Soil Loss Ratio	57
	Rainfall Erosivity and Soil Loss	70
	Cover Management Factor	76
	Costs	76
V	DISCUSSION	79
VI	SUMMARY AND CONCLUSIONS	92
	Summary	92
	Conclusions	95
	Recommendations	96
	REFERENCES	97
	APPENDIX	
	A Guelph Permeameter Test	104
	B Mechanical Analysis of Serdang Series	106
	C Mechanical Analysis of Alluvium Soil	108
	D Soil Parameters for Use in Nomograph	109
	E Sample Calculation of Rainfall Erosivity, Runoff and Soil Loss in October 1999	110
	F Sample Calculation of C-factor of Hydroseeding + “Fibromat”	114
	BIODATA OF AUTHOR	115



LIST OF TABLES

Table		Page
1	Classes and Erosion Potential for Different Slope Categories	11
2	Properties of the Surface Soil (0 - 30 cm)	28
3	Rainfall, Intensity and Erosivity Indices By Months and Years During the 1998 - 1999 Study Periods	53
4	Monthly Distribution of Runoff Depth and Soil Loss of Each Treatment During 1998	58
5	Monthly Distribution of Runoff Depth and Soil Loss of Each Treatment During 1998 - 1999	60
6	Monthly Distribution of Runoff Depth and Soil Loss of Each Treatment During 1998 - 1999	62
7	Observed Percent Cover For Hydroseeding Alone in 1998 - 1999	66
8	Observed Percent Cover of Each Treatment in 1998 - 1999	67
9	Correlation of Soil Loss from Bare Plots With Erosivity Indices, Raindepth And Runoff	70
10	C-Factor of Each Treatment	77
11	Direct Cost of Each Treatment	78
12	Advantages and Disadvantages of Various Bioengineering Techniques	88
13	First Set of Readings With Height of Water in Well Set at 5 cm	104
14	Second Set of Readings With Height of Water in Well Set at 10 cm	104
15	Calculation of Rainfall Erosivity Indices of October 10, 1999	110
16	Calculation of Collected Runoff of October 10, 1999	112



17	Calculation of Collected Soil Loss of October 10, 1999	112
18	Rainfall Characteristics, Runoff and Soil Loss in October 1999	113



LIST OF FIGURES

Figure		Page
1	The Factors Which Affect Rainfall Erosion	7
2	Nomograph for Computing the K Value of Soil Erodibility for Use in the Universal Soil Loss Equation	10
3	Formation of Platforms Between Hedgerows By Trapping of Topsoil Wash Over Time	26
4	Configuration of the USLE Plots	30
5	Layout of the Erosion Plot	31
6	Monthly Rainfall Distribution During 1998 - 1999 Compared To 10-Year Average Monthly Rainfall	55
7	Total Runoff and Soil Loss for Each Treatment (January 98 - December 98)	59
8	Total Runoff and Soil Loss for Each Treatment (May 98 - April 99)	61
9	Total Runoff and Soil Loss for Each Treatment (November 98 - November 99)	63
10	Monthly Distribution of Soil Loss Ratio of Close Turfing	64
11	Monthly Distribution of Soil Loss Ratio of Spot Turfing	64
12	Monthly Distribution of Soil Loss Ratio of Vetiver	65
13	Monthly Distribution of Soil Loss Ratio of Legume	65
14	Monthly Distribution of Soil Loss of Hydroseeding Alone	66
15	Monthly Distribution of Soil Loss Ratio of Upland Rice + "Fibromat"	68
16	Monthly Distribution of Soil Loss Ratio of Upland Rice	68
17	Monthly Distribution of Soil Loss Ratio of Natural Vegetation	69



18	Monthly Distribution of Soil Loss Ratio of Bermudagrass	69
19	Relationship Between $KE > 25$ and Soil Loss for Bare Plot in 1998	71
20	Relationship Between $KE > 25$ and Soil Loss for Bare Plot During November 1999 - October 1999	71
21	Relationship Between Raindepth and Soil Loss for Bare Plot in 1998	72
22	Relationship Between Raindepth and Soil Loss for Bare Plot During November 1998 - October 1999	72
23	Relationship Between EI_{30} and Soil Loss for Bare Plot in 1998	73
24	Relationship Between EI_{30} and Soil Loss for Bare Plot During November 1998 - October 1999	73
25	Relationship Between AI_m and Soil Loss for Bare Plot in 1998	74
26	Relationship Between AI_m and Soil Loss for Bare Plot During November 1998 - October 1999	74
27	Relationship Between Runoff and Soil Loss for Bare Plot in 1998	75
28	Relationship Between Runoff and Soil Loss for Bare Plot During November 1998 - October 1999	75
29	Determining the 30-minutes and 7 5-minutes Rainfall	111



LIST OF PLATES

Plate		Page
1	Vetiver Planted 15 cm c/c and 1 m Row Spacing	34
2	<i>Arachis pintoi</i> Planted 25 cm c/c and 1 m Row Spacing	35
3	Close Turfing	36
2	Spot Turfing in 23 cm Square Sod and Pegged Down 20 cm Apart Side By Side	37
3	Hydroseeding on Geojute Applied Using High-Pressure Sprayer	38
6	Geojute After Hydroseeding	38
7	Fibromat Anchored on the Plot	39
8	Upland Rice After 5 Months Planting	40
9	Upland Rice (Left) and Upland Rice + "Fibromat" (Right)	42
10	Natural Vegetation Mainly Occupied By Napier Grass	42
11	Bermudagrass Seeded in Holes At 15 cm Apart	43
12	Bare Plot After Weeding	44
13	Study Site After Planting Vetiver in Rows	45
14	Vetiver Died After 4 Months	45
15	Fixed Observation Point Classified As Covered	47
16	Fixed Observation Point Classified As Bare	47
17	Downloading Rainfall Data from Pluviometer By Using A Notebook Computer	48
18	Full Vetiver Hedge Formed in 8 Months	81
19	Creeping Stolons of <i>Arachis pintoi</i> Retard Movement of the Eroded Soil	81
20	Comparison of Hydroseeding Plots After 2 Months	82



21	Residue Mulch Produced By the Grass	84
22	Bermudagrass Did Not Cover the Whole Plot at the End of the Study	87
23	Crown of Vetiver Rotted	90
24	Transported Sediment Tends to Bury the Young Vetiver	90



LIST OF ABBREVIATIONS

A	Average Annual Soil Loss
A_R	Root Cross-sectional Area
C	Cover Management Factor
E	Energy
I	Rainfall Intensity
K	Soil Erodibility Factor
K_s	Saturated Hydraulic Conductivity
P	Support Practice Factor
\bar{R}	Steady State Rate of Flow
T_i	Tensile Strength of Roots of Size Class i
T_R	Average Tensile Strength of Root or Fibre (kN/m^2)
KE	Kinetic Energy
LS	Slope Length and Steepness Factor
MC	Moisture Content
OM	Organic Matter
pH	Soil Acidity or Alkalinity on Longarithmic Scale of 1 - 14
AI_m	Lal Index
EI_{30}	Wischmeier Index
NPK	Nitrophoska
UPM	Universiti Putra Malaysia
SLR	Soil Loss Ratio
DBAE	Department of Biological and Agricultural Engineering
USLE	Universal Soil Loss Equation



$KE > 25$	Hudson Index
ΔS_R	Shear Strength Increase From Root Reinforcement
a_i	Mean Cross-sectional Area of Roots in Size Class i
n_i	Number of Roots in Size Class i
t_R	Average Tensile Strength of Root pr Unit Area of Soil
ϕ	Friction Angle
θ	Angle of Shear Rotation

CHAPTER 1

INTRODUCTION

Looking briefly into the history of land use, it seems that human interference by clearing of natural vegetation covers result in serious soil erosion. Lake and Shady (1993) quoted nearly 2 billion hectares of land worldwide has been degraded between 1945 and 1990. This amount is greater than the size of China and India combined!

Tropical countries like Malaysia has a climate which is abetted by monsoon. Without taking proper mitigation, high intensity rainfall strikes on denuded slope causing a spate of landslides in the country. Examples include the July 1995 landslide at the Genting Highlands slip road which resulted in at least 21 deaths and the mud slide tragedy in September 1996, near Kampar, Perak, where 37 lives were lost. Sulaiman (1989) documented soil loss from isolated land use in Peninsular Malaysia and soil loss was much greater in urban development area. He also pointed out an alarming increase in the rate of soil loss following a greater intensity of the land use. Excessive runoff generated from logging activities, golf courses and highway constructions usually moves directly from drainage structures into waterways and cause considerable sedimentation in nearby streams and lakes.

Traditional methods of controlling streamflow and landslide induced erosion have relied on structural practices such as retaining wall, sheet piles and rip rap. However, such solutions may not be acceptable as they are expensive and cost implications. An alternative approach is bioengineering, a method using live plants alone or combined with dead or inorganic materials to arrest and prevent slope failures and erosion (Franti, 1996). Advantages of bioengineering solutions are

- (a) Less expensive and lower long-term maintenance than structural measures,
- (b) Environmental compatibility with landscape and limited access sites,
- (c) Strengthen the soil by binding action of vegetation roots,
- (d) Environment friendly of wildlife habitat, water quality improvement and aesthetics,
- (e) Use of natural by-products such as rice straw, jute, coconut fibres etc

Statement of Problem

Many of the bioengineering techniques used in Malaysia are not being fully examined. Ahmad (1990) highlighted the problems of the soil erosion on the North-South Expressway. Unprotected and improperly installed measures on cut slopes exposed the soil surface to rills and gullies erosion. Besides, most estimates of soil erosion emphasised on agricultural land. Soil loss equations have been developed using data from studies conducted on cropland. Little information on bioengineering characteristics and performances has been obtained.

Objectives

The objectives of this study are as follows

- 1 To quantify the effect of commonly used bioengineering slope erosion control techniques The effect of biodegradable mat on vegetation growth and development are examined The potential of local vegetation as erosion control measures also will be studied
- 2 To determine the cover management factor (C) in the Universal Soil Loss Equation (USLE) of each bioengineering technique
- 3 To obtain the correlation between soil loss with various rainfall erosivity indices