UNIVERSITI PUTRA MALAYSIA

EVALUATION OF BIOENGINEERING SOIL EROSION CONTROL TECHNIQUES IN STANDARD USLE PLOTS

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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 pintoi*), 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 they 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

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Mei 2000

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

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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 tompok 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 rumpur 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 berlapik "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 satıva*) 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 berlapik "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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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
$\overline{R}$	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 life 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