UNIVERSITI PUTRA MALAYSIA

THE EFFECT OF INTERCROPPING ON SOIL STRUCTURE ATTRIBUTES AND SOIL EROSION ON SLOPING LAND

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By

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Thesis Submitted to The School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Doctor of Philosophy

May 2002

بسم الله الرحمن الرحيم

In the Name of Allah, Most Gracious, Most Merciful

Dedication

This thesis is dedicated to:

My beloved parents

Asbir Sutan Saidi (Papa)
late Darlis (Mama)
Hj. Nurlis (Etek)

My parents in law

H.Yuzar Akmam and Hj. Djawanis

My Dearest Wife

Media Sandra Kasih

Our nice children

- *Nadya Intan Kemala Adrinal*
- *Berlian Naufal Adrinal*

For their everlasting love.

Abstract of the thesis submitted to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

THE EFFECT OF INTERCROPPING ON SOIL STRUCTURE ATTRIBUTES AND SOIL EROSION ON SLOPING LAND

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May 2002

Chairman : Assoc. Prof. Dr. Jamal bin Talib

Faculty : Agriculture

Soil erosion problems in Malaysia have been recognized for a long time. However, management of upland area that is more exposed to soil erosion and soil degradation risk through introduction of different cropping systems is still largely unknown. Consequently, the current knowledge of rates of soil loss on upland slopes is very limited. Therefore, the objectives of this study were to evaluate the effect of intercropping on soil structure attributes and soil erosion, and to evaluate effect of slope position on structural attributes and soil erosion.

Two experiments of intercropping of banana and pineapple and intercropping of immature rubber with banana and pineapple consisting of standard erosion plot and on farm research respectively were carried out for 40 months. In the first experiment, four standard erosion plots of slopes 9% and length 22.1 m were prepared. Plot sizes were 22.1 x 2.5 m, 22.1 x 5.0 m, 22.1 x 5.0 m, and 22.1 x 2.5 m for bare plot, banana plot, banana-pineapple intercropped plot, and pineapple

plot, respectively. In the second experiment a farmer's field of an area 11,250 m^2 of intercropping was selected. The slope varied from 9 –15 %. Both experiments focused on evaluating some soil properties that were closely related to soil structure such as bulk density, soil aggregate stability, soil organic matter, runoff, and soil loss. The effect of root biomass on the above properties was also evaluated.

Results from both experiments indicated that banana when intercropped with pineapple showed optimum performance in improving soil structure attributes particularly in increasing soil organic matter and aggregate stability. Due to better and thicker canopy coverage and as well as the role of their root network in building good soil structure, the combination of banana and pineapple is more effective in reducing runoff since this system provided a better protection for soil surface against impact of raindrops and improved soil infiltrability. It was found that the least soil erosion occurred under pineapple, and banana-pineapple intercropped whilst the most soil erosion occurred under rubber. Stepwise multiple linear regressions demonstrated that soil loss was closely related to root biomass, soil organic matter, and aggregate stability of the soil. In terms of slope position, results showed that at depth of 0-15cm, middle slope had lowest bulk density and highest soil organic matter content and percent soil aggregation indicating the convex nature of the landscape. Due to higher deterioration of soil properties on the upper slope compared to other slope positions the most soil erosion observed to be on the upper slope position. Several future studies is needed especially on crop suitability in relation to its physiological, morphological and economic values in an intercropping system on the sloping lands.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi syarat keperluan untuk mendapatkan Ijazah Doktor Falsafah

KESAN TANAMAN SELANG KE ATAS STRUKTUR TANAH DAN HAKISAN TANAH DI TANAH BERCERUN

Oleh

ADRINAL

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Masalah hakisan tanah di Malaysia telah dikenalpasti sejak dulu lagi. Walaubagaimanapun, pengurusan kawasan tanah tinggi yang lebih terdedah kepada hakisan tanah dan pencuraian tanah melalui kombinasi sistem penanaman belum lagi dikenali secara luas. Oleh itu pengetahuan terkini mengenai kadar kehilangan tanah pada tanah tinggi bercerun masih terhad. Oleh itu, objektif kajian ini adalah untuk menilai kesan daripada sistem penanaman ke atas struktur tanah dan hakisan tanah, dan juga untuk menilai kesan daripada kedudukan cerun ke atas struktur tanah dan hakisan tanah.

Dua kajian tentang sistem tanaman selang antara pisang dan nenas di atas plot hakisan piawai, dan tanaman selang antara getah muda dengan pisang dan nenas di lapangan telah dijalankan selama 40 bulan. Pada kajian pertama, empat petak hakisan piawai yang mempunyai kecerunan 9% dan panjang 22.1 m telah disiapkan. Saiz bagi setiap petak adalah 22.1 x 2.5 m, 22.1 x 5.0 m, 22.1 x 5.0 m

dan 22.1 x 2.5 m masing-masing untuk petak terdedah, petak pisang, petak tanaman selang pisang dengan nenas dan petak nenas. Sedangkan kajian kedua dijalankan di ladang tanaman selang petani yang mencakupi jumlah luas 11,250 m^2. Kecerunan berjulat dari 9 hingga 15%. Kedua-dua kajian tertumpu untuk menilai beberapa sifat tanah yang berkait erat dengan perubahan kestabilan struktur tanah seperti: ketumpatan pukal, kestabilan agregat tanah, kandungan bahan organik, biomas akar, dan juga terhadap larian permukaan dan kehilangan tanah yang disebabkan oleh sistem tanaman selang yang diamalkan.

Hasil dari kedua-dua kajian yang telah dijalankan menunjukkan bahawa tanaman selang pisang dengan nenas meningkatkan kestabilan struktur tanah terutama sekali di dalam kandungan bahan organik dan kestabilan aggregat tanah. Disebabkan oleh penutupan kanopi yang lebih baik, disamping juga peranan jaringan akar dalam menciptakan struktur yang baik, kombinasi di antara pisang dan nenas adalah lebih efektif di dalam mengurangi larian permukaan kerana sistem ini menyediakan perlindungan yang lebih baik terhadap permukaan tanah dalam mengurangi kesan titisan hujan dan meningkatkan keupayaan resapan air tanah. Didapati bahawa hakisan tanah yang terendah adalah di bawah kawasan nenas, diikuti kemudian di bawah tanaman selang pisang-nenas, sedangkan tanah yang paling banyak terhakis adalah di bawah kawasan pokok getah. Regresi linear berganda mengikut kaidah berperingkat menunjukkan bahawa kehilangan tanah berkait erat dengan biomas akar, kandungan bahan organik, dan kestabilan agregat tanah. Dalam hal kedudukan cerun, hasil menunjukkan bahwa pada kedalaman 0-15 cm, cerun tengah mempunyai ketumpatan pukal yang paling rendah dan kandungan bahan organik serta peratusan pengaggregatan tanah yang paling tinggi

yang menunjukkan keadaan lansekap yang cembung. Kerana kerusakan sifat tanah yang lebih tinggi di bahagian atas cerun dibandingkan dengan bahagian cerun lain, maka hakisan tanah yang paling tinggi telah dijumpai di bahagian atas cerun. Beberapa kajian lanjut adalah diperlukan mengenai kesesuaian tanaman dan kaitannya dengan fisiologi, morfologi, dan nilai ekonomik di dalam sesebuah sistem tanaman selang di tanah bercerun.

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Adrinal

This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirements for the degree of Doctor of Philosophy. The members of the Supervisory Committee are as follows:

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Agg	Aggregate
au	auxiliary root
AWHC	Available Water Holding Capacity
B	Banana
B-P	Banana–Pineapple
cm	centimeter
cm^{-3}	cubic centimeter
c.v	cultivars
DMRT	Duncan Multiple Range Test
FAO	Food and Agriculture Organization
g	gram
ha	hectare
II	Instability Index
kg	kilo gram
km	kilo meter
kPa	kilo Pascal
L	liter
m	meter
MAP	Months After Planting
mL	mili liter
mm	mili meter
MPa	Mega Pascal

MWD	Mean Weight Diameter
MWD_d	Mean Weight Diameter dry
MWD_w	Mean Weight Diameter wet
N	Normal
OM	Organic Matter
P	Pineapple
R	Rubber
R-P	Rubber – Pineapple
rpm	rotation per minute
RRIM	Rubber Research Institute of Malaysia
SI	Stability Index
SL	Soil Loss
SOM	Soil Organic Matter
Sr	Soil root
USA	United Stated of America
USDA	United States Department of Agriculture
Var.	Variety
WSA	Water Stable Aggregate
Wt.	Weight

CHAPTER I

INTRODUCTION

Malaysia is located in the humid tropics where a large proportion of rain falls in storms of high intensity (Wan Sulaiman *et al.* 1990). The annual rainfall ranges from 1500 to 3000 mm and causes severe and widespread erosion (Jamal *et al.* 2000). The high rain intensity and erosivity increases the severity of the soil loss problem. As pressure on land increases, more areas of rainforest are being cleared, in particular, more steep land are being cultivated with high quality croplands that need intensive management. Most of the development and land clearings for agriculture and other purposes in Malaysia take place not only in lowland but also increasingly on the foothills up to an elevation of 920 m. These foothills are between 155 m to 465 m high and are in a belt of maximum rainfall; therefore their potential for erosion is greater on this elevation (Goh, 1982). As a consequence of intensive farming on sloping land the high incidence of soil loss is due to erosion, thereby resulting in decline of soil fertility. It is estimated that 400,000 hectares of agricultural land are subjected to erosion and require urgent soil conservation attention (Jamil, 1987). Another factor that could trigger soil degradation in Malaysia is the unchecked loss of topsoil. This could happen on hilly and steep terrain where proper conservation practices are not effectively carried out (Jamil, 2000).

Soil erosion on sloping land areas is a complex phenomenon involving detachment and transport of soil particles, infiltration, storage and runoff of rainwater (Romkens *et al.*, 1998). Excessive soil loss can lead to soil structure deterioration, organic matter depletion, decrease of soil fertility and hence reduced crop yield (Lal, 1984, 1988 b). In this situation, erosion control is indispensable in the development of sloping land for agriculture purpose.

Resistance of soil to erosion (detachment and transport) is determined by the properties of soil such as texture, aggregate stability, infiltrability, shear strength, organic matter content and chemical status (Wan Sulaiman *et al.* 1983). The structure of surface soil is usually given most attention in relation to soil erosion, because it is most easily subjected to deterioration under raindrop impact, and easily altered due to agricultural practices. Good soil structural stability resist detachment, maintains high infiltration rate, reduces runoff and consequently leads to low soil erosion. Various measures have been taken to control erosion and conserve the fertile topsoil. They include various crop and soil management practices on sloping land. Proper crop selection and good soil management practices are important factors in controlling and reducing soil erosion. However limited studies on the effect of management of fragile upland through combination of cropping systems in Malaysia.

Malaysian Agriculture has two major and distinct sectors namely, the estate or plantation and the small holding sector (Rahim, 1986). About 1,267,094 hectares (50.87%) of industrial crops are cultivated under smallholdings (Department of

Agriculture Malaysia, 1998). Most of the rubber small holders prefer planting banana and pineapple as intercrops, instead of annual crops with young rubber for economic sustainability, because these crops could generate better income (Almas, 1998).

Besides the role of the canopy cover of the plant, which provides a protection, cover to soil against heavy rainstorms and run off on the soil surface, the plant's root systems contribute a significant factor in the formation of good soil structure. The effectiveness of plant for stabilizing soil structure depend on the extent to which movement of particles or aggregates under the erosive influence of water can be restricted (Goss, 1991), the growth stages of crop, the extent of their foliage development, the density of ground cover, the root density and plant height (Morgan, 1979; Benwale, 1986; Hashim and Wong, 1987).

Even though, soil erosion studies in Malaysia have been reported for a some time (Jamal *et al.*, 1985), the current knowledge on erosion processes in upland steep slopes is very limited. Aside from slope steepness, slope position and slope shape also influence the extent of erosion because these parameters determine transportation and depositional processes of soil sediment where eventually affecting *in situ* soil properties and soil erosion as well. Based on the above reason, the study is focused on the effect of intercropping and slope positions on soil structure attributes and soil erosion on sloping land.