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EROSION LOSSES FROM BANANA-PINEAPPLE INTERCROPPING AND SOIL LOSS PREDICTION USING RUSLE

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By

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Abstract of thesis submitted to the Senate of Universiti Putra Malaysia in fulfillment of the requirements for the degree of **Master of Agricultural Science**.

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Chairman: Dr Jamal Talib
Faculty: Agriculture

Soil erosion in agricultural upland conditions was investigated in Puchong Farm, UPM from an intercropping system of banana-pineapple. To study the effectiveness of this intercropping system four erosion plots of same length but different width were prepared on a 9 % slope. One plot was planted with banana crop, second with pineapple and third with intercrop of banana and pineapple, whereas one plot was kept as bare with regular cultivation every fortnight. All the plots were kept in weed-free condition. Each plot was equipped with sediment tanks, for the collection of soil loss and runoff from the plots. Measurement of soil loss and runoff was made after every erosive rainfall. The sediments and runoff water were analyzed for major nutrients after every growth period. The data indicate that the site soil is very susceptible to erosion. The highest soil loss during the nine months period was obtained from bare plot (105.5 mt/ha) followed by banana plot (40.6 mt/ha) whereas total soil loss from intercrop and pineapple plots were 26.5 and 25.0 mt/ha respectively. Total runoff from bare, banana, intercrop and pineapple were 11.1×10^6,

9.3×10^6, 6.3×10^6 and 7.2×10^6 L/ha respectively. These came as a result of total rainfall of 2020 mm which was about 25% higher than the average of 10 previous years.

Comparison of soil loss and runoff in different growth periods showed that, in the early growth period when the canopy cover was around 15%, soil loss and runoff were not significantly different among the plots. But after the establishment of crop canopy and root network, soil loss and run off were reduced significantly as compared to bare plot. The relationship of EI_{30} index with soil loss and runoff and the relationship of soil loss with runoff were significant at 1% probability level for all the plots. The analysis of fertility status showed that at the top of the slope there was decrease in the fertility except for K in intercrop and C, N, P and K for pineapple as compared to the center and bottom of the slope for every plot.

The order of nutrient loss from the plots during the study period was the same for all the plots with organic C being maximum and P being minimum. Total losses for N, P and K in sediments and runoff with respect to the added fertilizers were less from the cropped plots as compared to the bare plot. The high losses of nutrients from the bare plot were mainly due to high soil loss and runoff from the bare plot.

The results of soil erosion prediction with RUSLE showed that for pre-establishment period, RUSLE overestimated soil loss for the bare and intercrop plots and under estimated for the pineapple plot. Whereas there was no difference in measured and predicted soil loss for the banana plot. In the establishment period there was under estimation for bare and intercrop plots and over estimation for the pineapple plot. For the banana plot there was no difference in measured and predicted soil loss. In the early maturity period there was under estimation in soil loss for bare and banana plots and over estimation for intercrop and pineapple plots. In the overall experimental period there was under estimation in soil loss for bare, intercrop and pineapple, whereas for banana there was no difference in measured and predicted soil loss. The statistical analysis for overall experimental period showed that the measured and predicted soil losses were not significantly different. This result indicates that there is potential for RUSLE model to be used to estimate soil erosion and to plan conservation practices in agricultural lands in Malaysia.

From the study it can be suggested that intercropping of banana-pineapple is an effective system of intercrop for controlling long-term soil losses from sloping agricultural lands in Malaysia. Moreover, it involves less intensive crop and soil management practices and thus less soil disturbances. This practice may be more useful during replanting of plantation crop like rubber and oil palm in the uplands where banana and pineapple, favored economic crops of many smallholders, can be planted in between young rubber and oil palm.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi syarat keperluan untuk mendapatkan Ijazah **Master Sains Pertanian**.

KEHILANGAN OLEH HAKISAN DARI TANAMAN SELANG PISANG-NANAS DAN RAMALAN KEHILANGAM TANAH DENGAN MEMGGUNAKAN RUSLE

OLEH

MOHAMMAD ALMAS ABBASI
JANUARY 1998

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Hakisan tanah pertanian bercerun di bawah sistem tanaman selang pisang-nenas di Ladang Puchong, Universiti Putra Malaysia (UPM) telah dikaji. Untuk mengkaji keberkesanan sistem tanaman selang ini, empat petak hakisan yang sama panjang tetapi berlainan lebar telah disediakan di atas cerun 9%. Satu petak ditanam dengan pisang, kedua dengan nenas dan ketiga dengan tanaman selang pisang-nenas, sementara satu petak lagi dibiarkan terdedah dan sentiasa dibajak setiap dua minggu. Semua petak dijaga supaya berkeadaan bebas dari rumpai. Setiap petak dilengkapkan dengan tangki untuk mengumpul kehilangan tanah dan air larian dari petak tersebut. Penyukatan kehilangan tanah dan air larian di buat selepas hujan yang erosif. Sedimen dan air larian dianalisis untuk mendapatkan nutrien utama yang terkandung di dalamnya bagi setiap tahap pertumbuhan. Data menunjukkan bahawa tanah tempat kajian adalah jenis mudah terhakis. Kehilangan tanah yang tertinggi bagi keseluruhan masa kajian diperolehi dari petak terdedah (105.5 tan/ha), diikuti dengan petak pisang (40.6 tan/ha), sementara jumlah kehilangan tanah dari petak tanaman selang dan

nenas masing-masing ialah 26.5 dan 25.0 tan/ha. Jumlah air larian bagi petak-petak terdedah, pisang, tanaman selang dan nenas masing-masing ialah $11.1x10^6$, $9.3x10^6$, $6.3x10^6$ dan $7.2x10^6$ L/ha. Semua ini adalah hasil dari jumlah hujan 2020mm yang 25% lebih tinggi dari purata 10 tahun sebelum.

Perbandingan kehilangan tanah dan air larian antara tahap pertumbuhan menunjukkan pada tahap tumbesaran awal apabila tutupan kanopi kira-kira 15%, kehilangan tanah dan air larian tidak menunjukkan perbezaan yang bererti antara petak. Tetapi setelah pembentukan kanopi dan jaringan akar, kehilangan tanah dan air larian berkurangan dengan bererti berbanding dengan petak terdedah. Hubungan antara indeks EI_{30} dengan kehilangan tanah dan air larian dan antara kehilangan tanah dengan air larian adalah bererti pada paras kebarangkalian 1% bagi semua petak. Analisis status kesuburan menunjukkan pada bahagian atas cerun ada penurunan kesuburan berbanding dengan pada bahagian bawah dan atas cerun, melainkan K bagi petak tanaman selang dan C, N, P, K bagi petak nenas. Susunan kehilangan nutrien dalam semua petak rawatan sepanjang masa kajian adalah serupa di mana C organik yang paling tinggi dan P yang paling rendah. Jumlah kehilangan N, P dan K dalam sedimen dan air larian dengan penambahan baja adalah kurang dari petak bertanaman berbanding dengan petak terdedah. Kehilangan nutrien yang tinggi dari petak terdedah adalah disebabkan oleh kehilangan tanah dan air larian yang tinggi.

Keputusan ramalan hakisan tanah dengan menggunakan model RUSLE menunjukkan pada tahap permulaan tumbesaran, RUSLE memberikan anggaran yang berlebihan bagi petak-petak terdedah dan tanaman selang, dan anggaran yang berkurangan bagi petak nenas. Sementara bagi petak pisang, tiada perbezaan antara anggaran dan kehilangan tanah yang disukat. Pada tahap tumbesaran, anggaran berkurangan pada petak terdedah dan tanaman selang dan anggaran berlebihan pada petak nenas. Tiada perbezaan pada petak pisang. Pada tahap matang, anggaran berkurangan bagi petak terdedah dan pisang dan anggaran berlebihan bagi petak tanaman selang dan nenas. Perbandingan keseluruhan pula menunjukkan anggaran kehilangan tanah berkurangan bagi petak-petak terdedah, tanaman selang dan nenas, sementara tiada perbezaan bagi petak pisang. Analisis statistik menunjukkan tiada perbezaan yang bererti antara kehilangan tanah yang dianggarkan oleh RUSLE dan yang disukat dipetak-petak hakisan. Keputusan ini menunjukkan model RUSLE ada potensi untuk digunakan bagi meramal hakisan dan merancang pemuliharaan tanah dan air di kawasan-kawasan pertanian di Malaysia.

Dari kajian ini bolehlah dicadangkan bahawa tanaman selang pisang-nenas adalah satu sistem tanaman selang yang berkesan untuk mengawal kehilangan tanah bagi jangkamasa panjang daripada tanah-tanah pertanian bercerun di Malaysia. Apatah lagi, ia melibatkan tanaman yang memerlukan amalan pengurusan tanah dan tanaman yang kurang intensif, oleh itu kurang gangguan pada tanah. Amalan ini lebih berguna lagi semasa penanaman semula getah dan kelapa sawit di tanah bercuram di mana pisang dan nenas, tanaman ekonomik yang disukai oleh pekebun-pekebun kecil, boleh ditanam antara pokok getah dan kelapa sawit.

CHAPTER I

INTRODUCTION

The rapid erosion of soil by wind and water has been a problem since man began cultivating the land. Soil is a valuable natural resource that needs protection from excessive erosion if long-term crop productivity is to be maintained. Sediment produced by erosion can cause off-site damages by sedimentation, being a pollutant, and being a carrier of pollutants. Soil conservation is essential for continued productivity on agricultural croplands, particularly on hill slope. Without conservation practices, serious soil erosion can occur that will lead to land degradation, severely reduced productivity, increase runoff and off-site sedimentation problems. Therefore to cultivate sloping croplands safely, effective erosion control practices and techniques must be developed and used widely by the farmers.

Agriculture in Malaysia in the past was mainly associated with crop cultivation in the flat and fertile coastal areas. However, as economic activity and population increased, it spread rapidly to the uplands. Presently, agricultural expansion often involves land with steep slopes. Therefore the problem of soil erosion and degradation, sedimentation and river pollution have increased. There are strong indications that subsequent generations of crops are yielding less due to deterioration of soil properties (Ghulam et al., 1995). The soil erosion problem arising from these agricultural activities and growing environmental awareness merit a detailed study of soil erosion processes.

Soil and water are the two basic resources that have enabled Malaysia to achieve her present agricultural and national wealth. If the goal of a higher standard of living is to be achieved and thereafter sustained, it can only be done through development which is accompanied by adequate conservation which implies prevention and control of soil degradation. Soil and water are interrelated resources. Any degradation in one also produces ill effects on the other (Wan Sulaiman et al., 1983).

Malaysia is situated in the humid tropics with an annual rainfall ranging from 1500 to 3000 mm of which a large portion falls in storms of high intensity, causing severe and widespread erosion throughout the country. As pressure on land increases, more areas of rainforest are being cleared, more and more steep land are cultivated and high quality crop lands are being intensively used. These activities have aggravated the problem of soil erosion (Jamal et al., 1985). Nutrient loss is an important aspect of surface soil erosion since nutrients are mostly concentrated in the surface layer. The extent of nutrient loss is related to the size distribution of sediments. The surface geometry of tropical slope lands is often complex, therefore a mixture of erosion processes are expected to occur during most events (Ghulam, 1996).

Various measures have been taken to control erosion and conserve the fertile topsoil. These include various crop and soil management practices on sloping lands. Proper crop selection in itself is an important means of controlling soil erosion. Good soil management practices such as mulching and minimum tillage could further reduce soil erosion. Various intercropping systems have been practised on sloping lands, which include planting of annual crops with perennial crops, combination of annual crops with medium term crops and annual crops with legume crops.

Planting of many annual crops as intercrop between rubber and oil palm has increased the risk of severe soil erosion in the slopping agricultural lands of Peninsular Malaysia because these crops are clean tilled crops which require more cultural practices that enhances the removal of top soil (Soong et al., 1980). Creeping legumes on the other hand, are found to be more effective cover plants for controlling soil erosion when planted as an intercrop but their effect is not permanent. After some time these legumes die off due to the effect of shading (Soong et al., 1980). The combination of annual crops with medium term crops such as papaya was not suitable as the yield of the annuals decrease tremendously due to the shading effect of papaya tree (Mokhtaruddin et al., 1991).

The types of intercrop currently used are selected for their efficiency in controlling soil erosion and for their beneficial influence on the growth and yield of major crop. In Malaysia the farmers, especially the small holders are planting banana and pineapple as intercrop in between young rubber because these crops are short term and income generating. Pineapple, when planted as intercrop also acts as an erosion control measure due to its thick and dense canopy, which provides a protection cover to soil against heavy rain storms and also slow down its rate of runoff from the soil surface.

Prediction of the effect of different land use system on soil erosion is necessary to enable the best combination of the land use and management practices to be selected, in order to minimise soil erosion and maintain soil productivity. Equations that predict soil erosion are widely used tools for dealing with soil erosion problems. By far, the most extensively used equation for soil erosion by water is the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978). The USLE is typically used to help the farmers to select the conservation systems specifically tailored to the climate, soil and topography of the farmer's site and his preference. Beside croplands, the USLE is applied to forest lands, range lands, disturbed lands and construction sites (Foster and Lane, 1987). The revision and update of USLE is called Revised Universal Soil Loss Equation (RUSLE). It is the third version of USLE and is available in computer programme. It maintains the six basic equation structure of USLE and therefore can be easily use for soil erosion prediction from agriculture fields.

Therefore the purpose of this study is to measure and predict soil erosion in standard plots using Revised Universal Soil Loss Equation (RUSLE) and to estimate nutrient losses from the fields of banana-pineapple intercroping and monocroping systems on sloping agricultural lands.

CHAPTER II

LITERATURE REVIEW

Soil Erosion

Soil erosion is the removal of surface material by wind or water. " Erosion" means wearing away. It is a process consisting of detachment of individual particles from the soil mass and their transport by erosive agent such as wind or water. In this process when sufficient energy is no longer available to transport the particles, they are deposited (Morgan and Davidson, 1986). The quantity and size of material that can be transported are the functions of runoff characteristics such as flow velocity and turbulence, which generally increases as the slope steepens and as runoff increases (Donald et al., 1991).

During the erosion processes, raindrop impact and flowing water are the detaching agents, where as runoff is the main transporting agent (Foster, 1977). However the detachment ability of rainfall, at a given rainfall intensity, may vary between rain types and geographic locations (Kinnell, 1983). Soil erosion is of two major types namely geological and accelerated soil erosion.

Geological Soil Erosion

Geological soil erosion is the erosion of land in its natural environment without the influence of man. It is a universal phenomenon and through thousands of years, it has moulded the earth into its present shape. It is caused mainly by the action of water, wind, temperature variation, gravity and vegetation. Soil formation is caused by geological erosion combined with various soil forming factors. The virgin soils found in Malaysia today, are the direct results of soil formation processes and geological erosion in dynamic equilibrium. Unless this equilibrium is disturbed, the soil will preserve their individual identity, depth and characteristics for a long time (Soong et al., 1980).

Accelerated Soil Erosion

The equilibrium between geological erosion and soil formation is easily disturbed by the activities of man such as cultivating, deforestation, overgrazing, housing development, industrial plants and road construction which tend to accelerate the removal of soil material in excess of that is removed by geological erosion. This type of erosion is known as accelerated erosion (Soong et al., 1980).

According to Clarke (1983), man has destroyed an estimated 2000 million hectares of land, and currently the world potentially cultivable land amounts to only about 3000 million hectares (22 % of land surface). Soil erosion can be caused by inappropriate farming techniques such as deep ploughing of land (many times a year to produce annual crops), lack of crop rotation, the divorce of arable farming from livestock production, the planting of crops down the contour instead of along it, and the cutting down of the fallow period in shifting cultivation (Clarke, 1983). Soil loss and runoff study in countries like Jamaica, El Salvador and Taiwan have shown that traditional cultivation can result in soil losses of 100 to 200 metric tonnes of soil per ha/year. These rates of soil erosion are equivalent to a loss in soil depth of some 10 mm/year (FAO, 1990).

Soil Erosion in Malaysia

As in most other developing countries, vast area of rainforest in Malaysia is being rapidly transformed into agricultural land. Some of these lands particularly those near urban areas, are converted to industrial sites and housing requiring vast topographical modifications which often result in steep road cuttings, land fills, and land surfaces are being completely exposed to the forces of erosion. As pressure on the land increases, more and more steep land is being cultivated leading inevitably to soil erosion (Wan Sulaiman et al., 1983).

In Malaysia, it is estimated that 400,000 ha of agriculture land are subjected to soil erosion and required urgent soil conservation attention (Abdul Jamil, 1987). Removal of the forest vegetation has detrimental effects on the environment. With the absence of the leaf canopy the soil surface is exposed to the direct impact of the rain. Logging activities like use of heavy machinery in Malaysia has also contributed to soil erosion (Ghulam, 1978).

Erosion is a consequence of land use or changing land use. Malaysia is characterised by the dynamic nature of her land use. Vast areas of land forest are being cultivated into agricultural land. In turn agricultural land around urban centres are gradually being transformed into urban and industrial use. A total area of 86,000 ha were cleaned of forest cover for land (agricultural) development in the decade 1971-80, 0.5 million ha during the Fourth Malaysian Plan period, 1981-85 and 0.35 million ha during the Fifth Malaysian Plan period, 1986-90 (Wan Sulaiman et al., 1994).

Factor Affecting Soil Loss by Water

Soil erosion by water is influenced by diverse factors such as slope, soil, climate and vegetation . Each factor on its own, has profound effect on the amount of surface runoff and soil erosion (Soong et al., 1980). This was also confirmed by Wan Sulaiman et al. (1983) that soil erosion is influenced by four main factors, namely erosivity of the rain, erodibility of the soil, the slope of the land and the nature of the ground or plant cover.

Erosivity of the Rain

Hudson (1971) defined erosivity as the potential ability of rain to cause erosion. Erosion appears to be related to two types of rain events, short intense storms and prolong storms of low intensity. A number of erosivity indices have been introduced to characterise erosion by over land flow and rills, most of them based on the kinetic energy of the rain, such as Wishmeier's EI_{30} and Hudson's KE >25.

Wishmeier et al. (1958) found that soil loss is well related to compound index of kinetic energy and the maximum 30 minutes rainfall intensity. This index is known as EI_{30}. The equation to calculate EI_{30} {$e = 0.29[1-0.72 \exp(-0.25 I)]$, where e = rainfall energy MJ/ ha-mm and I = rainfall intensity mm/hr} has a finite positive value at zero intensity and becomes asymptotic at high intensities (Brown and Foster, 1987).

The use of the fixed critical intensity of 25 mm/hr is not appropriate for all soils (Kinnell, 1978). Kinnell proposed a more process oriented index (e > Is), which discounts rainfall energy during those periods of storm when there is no runoff, that is when rainfall intensity is less than or equal to the acceptance rate of the soil (Is). Kinnell (1983) further modified the concept that the critical intensity should vary with the acceptance rate of the soil to derive indices with separate variables to account for detachment (energy) and transport (runoff). The E >IsQ/TXS index of Kinnell (where QTXS is an estimate of the average runoff rate) attempts to consider the effect of runoff on the utilisation of effective rainfall energy.

Maene and Chong (1979) found the daily rainfall to be better correlated with surface wash along harvesting paths than EI_{30}, KE >25 or $\sum$ ai indices. This was also confirmed on bare plots in the same area and in Serdang on a *Petroferric Tropudult (* Mokhtaruddin and Maene, 1979, Wan Sulaiman et al., 1981 and Jamal et al., 1984). These results suggest that rainfall intensity could be expressed in terms of total rainfall instead of the recognised indices.

Erodibility of Soil

Hudson (1971) defined erodibility as the susceptibility of soil to erosion. It is a function of both physical characteristics and management of soil. According to Wan Sulaiman et al. (1983) it is the difference in resistance among soils to erosion (detachment and transport) and is determined by the properties of the soil such as texture, aggregate stability, shear strength, infiltrability, organic matter contents and chemical status.

Brayan (1968) favours aggregate stability to be the most efficient index for erodibility. A commonly used index is the K-value, which represents the soil loss per unit EI_{30}. Estimates of K-value may be made if the particle size distribution, organic matter content, structure and permeability are known (Wischmeier et al., 1971). Numerous indices of erodibility have been devised. They are either based on soil properties determined in the laboratory or in the field, or on the response of the soil to rainfall. Every soil property which can be quantitatively measured has at one time or another, been considered for this purpose.

Limited information are available on the erodibility of Malaysian soils but the influence of iron and other sesquioxides in the highly weathered Ultisols and Oxisols appear to be important (Maene and Wan Sulaiman, 1980 and Mokhtaruddin, 1983), whereby for the same soil, a large difference was observed between the field measured value (K= 0.25) and that estimated from the nomograph of Wischmeier (K= 0.37). On the basis of field observations Wong (1974) classified soil with clay content exceeding 27 % and sand content less than 45 % as less erodible and soils having more than 45 % sand and less than 27 % clay were classified as more erodible. Maene et al. (1975) used a rainfall simulator in the laboratory to compare erodibility of three soils. They found that Rengam series (*Oxic Tropudult*) was less susceptible to erosion than Durian (*Orthoxic Tropudult*) and Serdang series (*Typic Kandiudult*). Rengam soil series also had more water stable aggregates after simulated rainfall than the other soils.

Abdul Rashid (1975) compared five soil parameters with actual soil loosened by splash and runoff under simulated rainfall. The ratio of percentage silt and sand to percentage clay that is, the clay ratio was best correlated with splash erosion. The order of