EROSION POTENTIAL OF RAINFALL IN SEBERANG PERAI AREA

By

Norhisham Mustakim

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ABSTRACT

Soil erosion is highly dependent on rainfall energy which in turn is related to rainfall intensity, rainfall amount, drop size and its distribution. The kinetic energy of rainfall is a major factor initiating soil detachment. The kinetic energy of rainfall and amount of rainfall are highly correlated and the relationship allows a reliable and convenient estimate of the energy load of rainfall from the amount of rainfall. This study attempts to evaluate kinetic energy loads of rainfall and their distribution over the Seberang Perai area in Malaysia. An erosivity map was developed for Seberang Perai area from the daily rainfall of at 8 rainfall stations. This study provided an understanding of the erosive potential of rainfall over Seberang Perai area. The results of the study will contribute in designing conservation works and minimizing erosion risks.

ABSTRAK

Proses kejadian hakisan tanah adalah sangat bergantung kepada tenaga kinetik hujan. Tenaga kinetik ini ada amat berkait rapat dengan keamatan hujan, amaun hujan dan saiz titisan hujan yang terbentuk. Tenaga kinetik hujan adalah merupakan salah satu factor utama yang yang berpotensi menyebabkan pemisahan tanah daripada permukaannya. Korelasi antara antara tenaga kinetik hujan dengan amaun hujan adalah tinggi. Oleh itu, satu anggaran yang boleh dipercayai dan mudah boleh dilakukan ke atas tenaga kinetik hujan daripada amaun hujan. Kajian yang dijalankan ini adalah merupakan satu percubaan untuk menilai tenaga kinetik hujan serta agihannya ke atas seluruh kawasan Seberang Perai. Sebuah peta risiko hakisan tanah akibat daripada tenaga kinetik hujan telah dihasilkan untuk kawasan Seberang Perai. Data yang diperlukan dalam kajian ialah rekod hujan di kawasan Seberang Perai yang berlokasi di 8 stesen hujan. Kajian ini merupakan suatu pemahaman tentang potensi hujan yang mengakibatkan hakisan hujan. Oleh itu, keputusan yang diperoleh daripada kajian ini bukan sahaja dapat digunakan sebagai maklumat untuk merekabentuk kerja pemulihan malahan juga dapat meminimumkan risiko hakisan.

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I beg those who are not named owning to lack of knowledge or to error to pardon me in advance.

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CHAPTER 1

INTRODUCTION

1.1 Soil Erosion

Soil erosion is one of the three main processes of desertification. Soil erosion is natural process, but its rate has been greatly accelerated by human activity like agricultural tillage. In some areas, the soil has been already removed and in others areas the remaining soil has only limited lifetime at present rates of removal.

Soil erosion occurs when intense rainfall exceeds the capacity of soil to absorb water and it will generates overland flow of runoff. When the runoff is sufficiently powerful, it will picks up soil and carries it downslope, cutting small channel or rills in the fields. In extreme cases, this phenomena of erosion can causes a destruction of farmland which can only improve at very high cost by importing new topsoil or complete re-landscaping of the terrain. Where the soil is shallow, severe erosion leads to complete removal of the soil and exposure of bedrock and when the soil is deep, the rills will grow into gullies which too deep to plough over and will break fields into inconvenient fragements. Soil also eroded from areas between rills and gullies by removing the topsoil which has the best structure and the most of the organic matter and nutrients.

Erosion rates are directly controlled by the physical factors of rainfall, vegetation cover, soil type and also conservation practice.

On-site impacts of soil erosion are directly in loss material and indirectly in loss nutrient of nutrients. Where soils are already thin, erosion may lead to an irreversible removal of medium for plant growth. Erosion also will removes the most fertile topsoil which holds most of the organic matter and nutrients and it will increase the costs for remedial cultivation and additional fertilizer for the farmer especially.

Figure 1.1: The on-site impact of erosion: severe rilling on a hillslope at Rottingdean on the UK South Downs in 1987. Photo: John Boardman

Off-site impacts **,**eroded material may be re-deposited in buildings, roads, reservoirs and watercourses and nutrients in runoff and sediment increase europhication and may leads to alga development.

1.2 Soil Erosion In Malaysia

More than 60 % of Malaysia's land is classified as hilly (Ngai, 2000). Significantly, these hilly areas also coincide with forests and water catchments, making them very sensitive ecosystems (Chan, 1998). In Malaysia, soil erosion has brought forth losses of productivity of the land, contributed to sedimentation of river; nevertheless heavy soil erosion would no doubt lead to instability of the area which will lead to occurrences of landslides. In recent decade, intensification of industrialization, housing and construction, the development of tourism and agriculture and greater urbanization have lead to greater pressures on land. The demand for land is still high although land reclamation has been carried out on the developed land. Hills and forests are being destroyed for construction of dams and highways. Development of these areas has lead to many environmental problems and one of the most frequent problems is soil erosion (Chan and Ismail, 1998). Some of these problems have been exacerbated and turned into disaster due to the extremely fragile and sensitive nature of hill ecosystems. Therefore, the understanding and prevention of soil erosion is important to reduce the rate of soil loss to an approximately low level. An even greater danger arises in way of the less populated parts of Peninsular Malaysia, when well-intentioned "developed scheme" are prepared to introduce "modern" agriculture into the forest. In many parts of the Malaysia large machinery has been used to scrape away the forest and litter, and with it the few inches of fertile top soil, crop production schemes have been introduced without adequate erosion control measures, and poor management or poor labour quality or any factor other than adequate erosion attention to the need to conserve the soil fertility (Greenland and Lal, 1977). The collapsed of Highland Towers in late 1993, landslide at Genting Highlands private road, Puchong, Sepang, Karak highway, Gua Tempurung, the Keningau tragedy in our country has claimed lots of lives and properties (source: http://www.aguide.net).

1.3 The need of research

Nowadays, soil erosion has become a serious problem and this problem could only be solved if appropriate soil conservation measures are taken into account simultaneously with development. The conservation of natural resources implies utilization without waste so as to make a possible continuous high level of crop production while improving environment quality. During the past 30 years, many studies have documented the magnitude of soil erosion problems, expressed as billions of tons of eroded soil or billions of dollars of erosion and sedimentation damage each year (Toy *et al*., 2002). To design appropriate soil management systems and appropriate methods for erosion control, it is essential to have a clear understanding of the cause of erosion, and quantitative information on the factor involved. Research has been carried out for the kinetic energy load of rainfall over Seberang Perai area to obtain much more data on erosivity, so that appropriate iso-erodent maps can be prepared to guide agricultural practice throughout the area. The present scattered records are far from sufficient to produce useful maps. An increase in erosivity with increasing total rainfall, and with decreasing elevation, seems to occurs, but more data are required to establish this, and the quantitative magnitude of erosivity. Again, there is need for critical evaluation of much new information to ensure that the most appropriate erosivity index is selected to guide erosion control practices (Greenland and Lal, 1977). It is most gratifying to note how actively these studies are being pursued in the developing world at present time, and it is appropriate and important that summaries of the present state of knowledge be provided from time to time. This is to allow both the scientist and the agronomist to survey the field and identify those areas in Seberang Perai which are in need of further study on soil erosion. However, this must involve continued studies on the factors causing erosion and run-off, and various practices that can reduce the liability of erosion and increase the rate of infiltration of water through the soil surface to below the dept of rooting of the crop. This work must involve a very wide range of agricultural and scientific expertise.

1.4 Objectives project

The objectives of this study are:

i. To establish the erosive potential of rainfall in Seberang Perai area and

ii. To prepare rainfall erosivity map over the study area and

The secondary objective of this study is

i. To feed/provide basic data on rainfall erosivity characteristics at Seberang Perai area to an IRPA project called “GIS based Watershed Management System for Non Point Source (NPS) Pollution Modeling”.

1.5 Scope Of Project

This project involves collecting rainfall records at different rainfall stations distributed throughout Seberang Perai area. Erosive power of the annual rainfall will then be estimated with the data collected in order to prepare an erosivity map for Seberang Perai area.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Much of the erosion that occurs on land results from construction, maintenance or operations activities that disturb the soil and a lack of appropriate management practices that effectively protect soil from the forces of water and wind. Insufficient erosion control measures can result in damage due to loss of soil and increases in sedimentation, waterborne suspended solids, and airborne particulate matter. Because impacts from soil erosion can be long term and far reaching, a number of federal and local regulations control runoff to adjacent properties and discharge into waterways and bodies. Often, the damage resulting from erosion is more costly in term of remedial actions needed and impacts to operational activities and environment resources than is the implementation of appropriate control measures.

2.2 Types of erosion

The major classification of erosion types are by erosive agent, wind, water or gravity that causes the erosion.

i. Wind erosion

The flow of wind over the soil surface causes erosion when the erosivity of the wind exceeds the resistance of the soil to erosion. Water is denser than air so the wind velocity must be greater than runoff velocity in order to have a same amount of erosion due to water.

ii. Gravity erosion

Gravity force tends to transport the soil from the higher ground to the lower ground by its self weight.

iii. Water erosion

Kinetic energy of rainfall and the mechanical force of runoff are the reasons for the water erosion to occur. The general types of water erosion can be categorized as following:

a. Erosion due to rain
b. Erosion due to surface flow
c. Erosion due to subsurface flow
d. Coastal erosion
e. Glacial erosion

Soil erosion by water is the dominant geomorphic process for much of earth's land surface. Coastal and glacial erosions are not discussed in this study. Most attention is given only to water erosion in Malaysia.

2.3 Water erosion

Water erosion is closely related with rainfall intensity because impact from rain can detach more particles when falling at higher intensities (Van Dijk et al.,2002) and higher rainfall intensities lead to higher infiltration excess runoff rates, keeping more sediment in transports as well as actively entraining soil particles given the right condition (Rose, 1993). Soil erosion by water is the result of rain detaching and transporting vulnerable soil, either directly by rainsplash or indirectly by rill and gully erosion.

i. Rainsplash

Whether or not most soil erosion takes places as a result of rainsplash or surface runoff derived in directly from the rainfall, the connection between soil loss and the force of falling raindrops, expressed either by kinetic energy or by momentum, well established (Ellison, 1944; Mihara, 1951; Rose, 1960; Hudson, 1965). Rain will occur the soil move directly, this is known as 'rainsplash erosion' (or just 'splash erosion'). Splash is only effective if the rain falls with sufficient intensity. If it happened, then the raindrops will hit bare soil and their kinetic energy is able to detach and move soil particles a short distance. Because soil particles can only be moved a short distance (a few centimetres at most) by this process, its effects are solely on-site. Because rainsplash requires high rainfall intensities, it is most effective under convective rainstorms in the world's which is located at equatorial regions. Rainsplash is relatively ineffective where rain falls with a low intensity (e.g. because the rainfall is of frontal origin), such as in the north-western USA or in northern Europe.

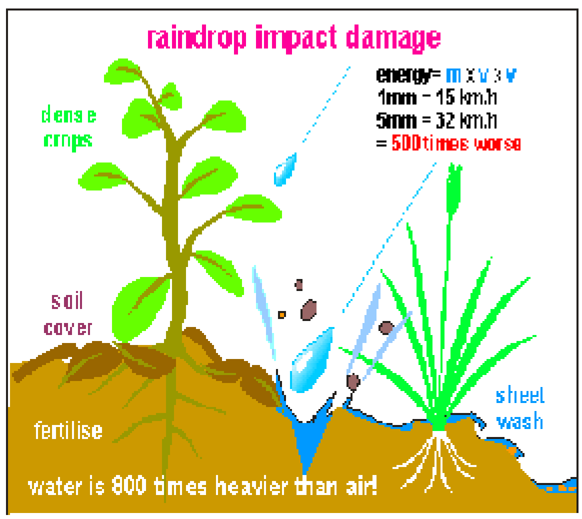
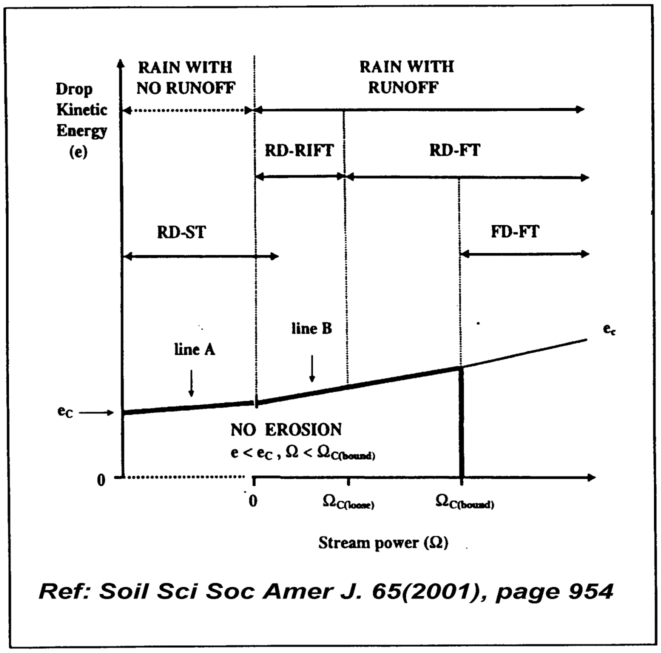


Figure 2.1: Water and soil splashed following single raindrop impact.



Detachment and transport processes associated with variations in raindrop and flow energies. e_c = critical raindrop energy to cause erosion. Line A = e_c prior to flow (increasing through crust development). Line B= e_c when flow occurs (increasing drop energy used to penetrate flow). $\Omega_{c(loose)}$ = critical stream power for transporting loose material. $\Omega_{c(bound)}$ = critical stream power for detaching soil from surface of soil matrix. RD - ST = raindrop detachment, splash transport. RD – RIFT = raindrop detachment, raindrop induced flow transport. RD – FT = raindrop detachment, flow transport. FD – FT = flow detachment, flow transport

Figure 2.2: A diagram illustrating the complex interactions between rainsplash, and detachment and transport by overland flow. Peter Kinnell (University of Canberra, Australia)

ii. Rill and gully erosion

Rainfall may also move soil indirectly, by means of runoff in rills (small channels) or gullies (larger channels, too big to be removed by tillage). This runoff may take the form of overland flow or it may become concentrated into rills and gullies. Few studies have been made of affects of either on soil in Malaysia. Morgan (1972) showed that overland flow occurred over 20 per cent of the area of small drainage basin on the University of Malaya campus where its return period was about 60 days. In many parts of the world, rill and gully erosion is the dominant form of water erosion. It is the fraction of rainfall which does not infiltrate (soak into) the soil and it will flow downhill under the action of gravity and then it is known as runoff or overland flow. Runoff might occur for two reasons. The first is that rain is arriving too quickly (i.e. with too high an intensity) to infiltrate. The runoff which results is then known as infiltration excess runoff, or Hortonian runoff. The second is that runoff might occur because the soil has absorbed all the water it can hold (i.e. it is saturated, or the soil is frozen). Runoff which results from this situation is known as saturation excess runoff.

When the flow of runoff is sufficiently intense to entrain soil particle directly, small channel or rill are formed on the surface, and material is eroded by rillflow which is concentrated along these drainage lines.

Under extreme storm and where the gradients are at least locally steep, erosion may lead to greater incision and it will form gullies which are too large to be obliterated by normal tillage. The development of gullies can fragemant farmland

and by steepening gradients to adjacent fields, it will lead a rapid extension of gully network and it will causes cultivation impracticable.

Figure 2.3: Large rills on an eroding hillslope.

2.4 Causes of erosion

Erosion is natural process caused by the forces of water and wind. It is influenced by a number of factor, such as soil type, vegetation and topography. It also can be accelerated by various activities that occur on land.

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2.5 Soil erosion process

The soil erosion process involves the dislodging, transport and deposition of soil particles. These forces are at work whether erosion occurs on large flat surface, slope, or in drainageway or other waterway. The control or modification of these forces is the primary aim of erosion control planning and design.

- Soil particles are dislodge by the impact of falling rain (which lifts and shifts particles), by the overland flow of water (from precipitation, snowmelt or manmade sources such as irrigation or construction activities), by wave action along shorelines or by action of wind.

- Dislodge soil particles are then transported by flowing water or the wind. As the flow of water increase in speed and volume, it transports particles either in rather uniform thin layers over a broad area (sheet erosion) or in concentrated channels (rill and gully erosion). Wave action and currents can transport soil and sand away from or along shoreline. Wind can transport heavy particles in a low trajectory above the surface in which individual particles may continually strike the ground and dislodge other particles, thereby increasing erosion. Wind can also lift and transport lighter soil particles several thousand of feet into air and many miles in distance.

- As the flow of water decrease, soil particles are deposited as sediment. In standing water, particles will settle to the bottom. The rate of settling is related to the movement of the water and the size of suspended soil particles as the water slows, particles begin to settle out, but fine particles may remain in suspension for long period.

2.6 Factors that influence soil erosion

There are numerous factors that influence soil erosion, including soil characteristics, vegetative cover, slope, water and wind.

i. Soil characteristics

The vulnerability of soil to erode is determined by soil characteristics such as particle size, organic content, soil structure, and soil permeability :

a. ***Particle Size*** - Soils that contain high proportions of silt and very fine sand are generally the most erodible and are easily detached and carried away. The erodibility of soil decreases as the percentage of clay or organic matter increases which clay are acts as a binder and tends to limit erodibility. Most soils with high clay content are relatively resistant to detachment by rainfall and runoff. Once eroded, the clays are easily suspended and settle out very slowly.

b. ***Organic Content*** - Organic matter creates a favorable soil structure, improving its stability and permeability. This increases infiltration capacity, delays the start of erosion and reduces the amount of runoff. The addition of organic matter increases infiltration rates (and, therefore, reduces surface flows and erodibility), water retention, pollution control, and pore space for oxygen.

c. ***Soil Structure*** - Organic matter, particle size, and gradation affect soil structure, which is the arrangement, orientation, and organization of particles. When the soil system is protected from compaction, the natural decomposition of plant debris on the surface maintains a healthy soil food web. The soil food web in turn maintains the porosity both on and below the surface.

d. ***Soil Permeability*** - Soil permeability refers to the ease water that can passes through a soil. Well-drained and well-graded gravel and gravel mixtures with little or no silt are the least erodible soils. Their high permeability and infiltration capacity helps prevent or delay runoff.

ii. Vegetative cover

Vegetative cover plays an extremely important role in controlling erosion by:

a. Shielding the soil surface from the impact of falling rain.
b. Slowing the velocity of runoff, thereby permitting greater infiltration.
c. Maintaining the soil's capacity to absorb water through root zone.
d. Holding soil particles in place.

Erosion can be significantly reduced by limiting the removal of existing vegetation and by decreasing duration of soil exposure to rainfall events. Give special consideration to the preservation of existing vegetative cover on areas with a high potential for erosion such as erodible soils, steep slopes, drainage ways, and the banks of streams. When it is necessary to remove vegetation, such as for noxious weed eradication, revegetate these areas immediately.

iii. Slope

Slope gradient and length affect the volume and velocity of runoff. As both gradient and length increase, the amount and rate of runoff become greater and erosion potential increases.

iv. Water

As the frequency, intensity, and duration of rainfall or flowing across the surface increase, amount of runoff produced and therefore the erosion potential increase.

v. Wind

As the frequency, intensity, and duration of wind increase, the potential volume of soil lifted into the air and distance that soil is transported increase.

2.7 Activities that contribute to soil erosion

Various activities that occur on land contribute to erosion by exposing soils to the forces of water and wind. Impacts from erosion can often extend beyond the immediate location of these activities to surrounding areas.

Construction projects can contribute to soil erosion both during and after the actual construction activity. Grading, clearing, and other activities that disturb the surface of the soil, alter existing topography and remove existing vegetation can increase erosion potential during construction.

Increase in the area covered by pavements and structures and failure to incorporate into the construction design control measures that adequately stabilize slope, re-established cover on exposed soils, or convey runoff can increase erosion long after is completed.

Ground maintenance activities can contribute to erosion when appropriate consideration is not given to the protection of soil. These activities include irrigation practices that increase runoff by over-saturating the soil or allowing sprinklers to spray onto hard surfaces or the clearing of brush or other vegetation without replanting or otherwise protecting exposed soils and snow removal activity that disturbs surface soils.

Infrequent or inappropriate maintenance of drainage system, plant material and potential erodible areas can also contribute to erosion. The failure to repair damaged drainage structures or regularly remove growth, debris and sediment from channels, trap and basin can increase flooding and runoff. Failing to control disease and pests can damaged plant material, thereby increasing erosion potential. Neglecting preventive measures that stabilize slopes and protect barren areas can increase the exposure of soil to the forces of water and wind.

Operational activities on land, such as those requiring expansive areas of airfield pavement or range training areas, can contribute to erosion by significantly increasing runoff and disturbing vegetation and soil.

The use of natural resources on the installation for activities such as off- road vehicle recreation, grazing and forestry can expose and stabilize soils, increasing the potential for erosion.

2.8 Erosion control planning process

In order to achieve effective control, a logical and comprehensive planning process should be followed that includes an existing conditions survey, an erosion potential analysis and the development of an erosion control planning. While this process is commonly followed when developing grading and drainage plans for proposed potential throughout the installation to determine corrective actions for existing problems and preventive measures for potentially erosive conditions.

i. Existing condition survey

Existing conditions surveys include written and mapped information on existing conditions on installation that may affect erosion. Such conditions include topography, drainage pattern, soil types the extent and kind of vegetative cover, impermeable surfaces and above and below grade drainage structures. This information should also document climatic information, including norms and extremes in temperature, precipitation and wind, which it will help to define expected and unusual weather conditions that may affect erosion.

The existing conditions survey should be conducted and maintained for the entire installation but a similar and more detailed survey should be prepared for proposed construction projects, identifying site-specific factors that may affect erosion and influence project design. The existing conditions survey provides the physical data upon which an erosion potential analysis will be based.

ii. Erosion potential analysis

An erosion potential analysis should identify drainage, potential runoff, prevailing wind and critically erodible soil areas. These critically erodible areas are determined based on combination of factors including the types and exposure of soils and steepness of slopes. Activities that might contribute to erosion should be noted to better define appropriate management strategies and maintenance practices. Drainage structure that require repair, renovation or clean out should be identified. Areas currently subject to significant erosion should also be identified.

As is the case with the existing conditions survey, the erosion potential analysis should be conducted for the entire installation, but more detailed analysis should be prepared on site-specific level for proposed construction projects. The erosion potential analysis forms the foundation upon which the erosion control plan will be developed.

iii. Erosion control plan

Based on the erosion potential analysis, an erosion control plam should be prepared to develop a program to correct existing erosion problems and prevent potential problems. The plan should identify erosion control construction projects and maintenance actions as well as establish a program to manage installation activities to help reduce or eliminate their creation or intensification of erosive conditions. Construction and maintenance projects should be prioritized based on the severity of existing or potential problems in terms of their impact to installation operations and maintenance or the environment.

A separate erosion control plan should be developed for proposed construction projects that indicates new development and all existing and proposed grading, on-site drainage and proposed temporary and permanent erosion control measures. Much of this information is commonly contained in the project grading and drainage plan, which is an appropriate vehicle to develop and communicate an approach to project-level erosion control.