UNIVERSITI PUTRA MALAYSIA

# EFFECTS OF LOGGING OPERATIONS ON SOIL PHYSICAL PROPERTIES AND SOIL EROSION IN A HILL DIPTEROCARP FOREST OF PENINSULAR MALAYSIA

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By

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## LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| FAO | - | Food and Agriculture Organization |
| IAHS | - | International Association of Hydrological Science |
| IUFRO | - | International Union of Forestry Research Organization |
| m.a.s.l. | - | Meter above sea level |
| UNESCO | - | United Nations Educational, Scientific and Cultural Organization |
| USDA | - | United States Department of Agriculture |

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Chairman: Associate Prof. Dr. Mohd Mokhtaruddin Abdul Manan

Faculty : Agriculture

The effects of logging operations on soil physical properties and soil erosion in logged-over forest occurred mainly on severely disturbed soil, particularly on the skid trail and logging road. Erosion plots were established in these areas to quantify the amount of surface runoff and soil loss. Soil samples from the upper layer of the skid trail, logging road and undisturbed area were analyzed for soil physical properties.

Significant changes in soil physical properties were observed as a result of logging operations. The bulk density increased by 32 percent on the skid trail and 42 percent on the logging road, and the total porosity reduced by 62 and 69

percent, respectively. Logging operations not only reduced the total porosity but also changed the shape and size of pores. About 82 percent of the total porosity on undisturbed area consisted of elongated pores, 18.2 percent transmission pores and 11.4 percent fissures pores. On the skid trail, the total porosity consisted of 62 percent elongated pores, 6.2 percent transmission and 4.9 percent fissures pores and on the logging road, the figures are 35, 6.4 and 2.6 percent, respectively. Thus the infiltration rate is more rapid in undisturbed forest soil than in the skid trail and logging road because it is the elongated pores that play an important role in water transmission. The higher the infiltration rate the lower is the surface runoff.

The annual surface runoff from the logging road, skid trail and undisturbed forest were 20.3, 14.5 and 2.3 percent of the total rainfall, respectively. The corresponding soil losses are 13,341, 10,070 and 450 kg/ha/y, respectively. Therefore a major proportion of the sediment yield in logged-over forest originated from the logging roads and skid trails. Severe erosion occurred during the first year after logging and was less severe during the second year. On the other hand the sediment yield from the undisturbed areas was insignificant.

Slope is one of the factors influencing soil erosion from the skid trails and logging roads during the first year after

logging operations. The amount of soil loss in the logged-over forest can be reduced if the gradient of the skid trails and logging roads does not exceed 20 percent.

Erosion control measures should focused on controlling erosion from the logging roads and skid trails. Control measures such as construction of cross drains on logging roads and skid trails must be done immediately upon completion of logging operations. Another option for erosion control on logging roads and skid trails is to improve the surface condition of soil such as by sub-soiling. Such practice will improve the infiltration characteristics of the soils and enhancing regeneration of vegetation.

Abstrak tesis dikemukakan kepada Senat Universiti Pertanian Malaysia bagi memenuhi keperluan untuk memperolehi Ijazah Master Sains.

**KESAN-KESAN OPERASI PEMBALAKAN KE ATAS SIFAT-SIFAT FIZIKAL DAN HAKISAN TANAH DI HUTAN DIPTEROKAP BUKIT DI SEMENANJUNG MALAYSIA**

Oleh

**BAHARUDDIN KASRAN**

Desember 1992

Pengerusi : Prof. Madya Dr. Mokhtaruddin Abdul Manan

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Kesan-kesan operasi pembalakan ke atas sifat-sifat fizikal tanah dan hakisan di hutan yang telah dibalak sering berlaku di tanah yang mengalami kerosakan yang teruk, terutama di jalan tarik dan jalan balak. Petak-petak hakisan dibina di kawasan ini bagi menentukan jumlah air larian permukaan dan tanah terhakis. Contoh tanah di lapisan atas jalan tarik, jalan balak dan kawasan tidak diganggu telah dianalisa untuk menentukan sifat-sifat fizikal tanah.

Operasi pembalakan menyebabkan berlakunya perubahan ke atas sifat-sifat fizikal tanah. Ketumpatan pukal bertambah 32 peratus di jalan tarik dan 42 peratus di jalan balak. Sebaliknya jumlah keliangan masing-masing berkurangan kepada 62

dan 69 peratus di jalan tarik dan jalan balak. Operasi pembalakan bukan sahaja mengurangkan jumlah keliangan bahkan juga mengubah bentuk dan saiz keliangan. Kira-kira 82 peratus dari jumlah keliangan di kawasan tidak diganggu terdiri daripada liang memanjang, 18.2 peratus liang penghantaran dan 11.4 peratus liang rekahan. Di jalan tarik pula, 62 peratus jumlah keliangan terdiri daripada liang memanjang, 6.2 peratus liang penghantaran dan 4.9 peratus liang rekahan. Di jalan balak angka-angka tersebut ialah 35, 6.4 dan 2.6 peratus. Oleh itu proses penyusupan mudah berlaku di hutan tidak diganggu berbanding di jalan tarik dan jalan balak. Ini disebabkan oleh liang memanjang memainkan peranan penting bagi pergerakan air dalam tanah. Semakin tinggi kadar penyusupan semakin rendah air larian permukaan.

Air larian permukaan tahunan di jalan balak, jalan tarik dan hutan tidak diganggu masing-masing 20.3, 14.5 dan 2.3 peratus dari jumlah hujan. Ini bersamaan dengan kehilangan tanah masing-masing sebanyak 13,341, 10,070 dan 450 kg/ha/tahun. Oleh itu sebahagian besar hasil kelodak dari hutan telah dibalak berasal dari jalan balak dan jalan tarik. Hakisan yang teruk terjadi pada tahun pertama selepas pembalakan dan berkurangan pada tahun berikutnya. Sementara kawasan tidak diganggu menyumbangkan sedikit sahaja hasil kelodak.

Kecerunan merupakan satu daripada faktor-faktor yang mempengaruhi hakisan tanah dari jalan terutama pada tahun pertama selepas pembalakan. Jumlah tanah terhakis dari kawasan ini boleh dikurangkan jika kecerunan jalan tarik dan jalan balak tidak melebihi 20 peratus.

Langkah-langkah mencegah hakisan harus diutamakan untuk mengawal hakisan di jalan balak dan jalan tarik. Langkah-langkah tersebut seperti pembinaan parit melintang di jalan balak dan jalan tarik harus dilaksanakan serta-merta setelah operasi pembalakan tamat. Satu lagi cara bagi mengawal hakisan di kawasan ini ialah memperbaiki keadaan tanah seperti mengemburkan permukaan tanah di kawasan-kawasan tersebut. Amalan ini akan meningkatkan kadar penyusupan dan mempercepatkan pertumbuhan tumbuh-tumbuhan.

# CHAPTER I

## INTRODUCTION

During the past two decades more than 1.5 million hectares of lowland tropical forests in Peninsular Malaysia have been converted to agricultural land mainly for the planting of rubber, oil palm and cocoa. This has resulted in a massive reduction of forested land in the country. In 1955 forest constituted about 75 percent of the total land area in Peninsular Malaysia. This was further reduced to 55 percent in 1970, 50 percent in 1980 (Chong, 1985) and 47.7 percent in 1990 (Malaysia, Ministry of Primary Industries, 1991). Most of the forested land in Malaysia today are confined to hilly areas and steep terrains and the lowland dipterocarp forests have almost been totally replaced by agricultural crops.

Logging activities in the steepland areas have created a number of serious environmental and ecological problems. The most obvious are those pertaining to the hydrology of downstream areas, such as deterioration in water quality, increased soil erosion, river sedimentation and silting of reservoirs. In Malaysia, the effects of timber harvesting on soil erosion and sedimentation have been reported by a number of investigators including Burgess (1971), Baillie (1972), Liew (1974), Jones (1976), Salleh et al., (1981a, 1981b), Lai and

Shamsuddin (1985), Lai and Rentap (1986) and Baharuddin (1988a).

Most of these studies were based on experimental watersheds. The common approach is to estimate erosion by determining sediment content of stream water from the watershed. It provides the general idea of the treatment effect on sediment production, which is attributed mainly to surface erosion (sheet, rill and gully), stream bank and streambed erosion. The general conclusion of these studies is that logging activities contributed a significant amount of sediments in the stream water. Nevertheless, the exact source of sediments still remains unknown. It is imperative to indicate the exact location and sediment regime in the area so that systematic erosion control measures could be implemented to minimize sediment content in the streams.

In addition to sedimentation, forest harvesting operations are definitely one of the factors that changed the soil physical properties and aesthetic values of the landscape. Logging road construction, usage of heavy machinery and transportation during logging operations tend to modify the physical properties of the upper layer of forest soil which may significantly affect regeneration growth. The impact of logging operations on soil physical properties in temperate region is well documented (Froehlich 1972). However, in Malaysia, such study has not been reported, except by Kamaruzaman (1987). The

alteration of soil physical properties due to timber harvesting is closely associated with soil loss of the area. This relationship characteristics and the soil loss variation should be studied in order to gain a better understanding of the soil erosion problem.

This thesis reports a study of the relationship between timber harvesting, soil erosion and soil physical properties in a logged-over forest in Peninsular Malaysia. The general objective is to determine the amount of surface runoff and soil loss and to assess the changes in soil physical properties resulting from construction of logging road and skid trails in logged-over forest of Peninsular Malaysia. The specific objectives are to:

1. quantify the amount of surface runoff and soil loss from logging roads, skid trails and undisturbed forest, and
2. describe some selected soil properties such as bulk density, porosity, soil organic matter, soil water characteristics and infiltration rate on the logging road, skid trail and undisturbed forest.

The study was conducted in a logged-over forest at Tekam Forest Reserve, Pahang, Peninsular Malaysia. Nine erosion plots were established on three different sites, namely undisturbed forest, skid trails and logging roads. At each site, plots were

established on three different slope categories (10, 20 and 30 percent). The study commenced six months after logging operation was completed and continued for a period of two years, that is, from March 1987 to February 1989.

# CHAPTER II

# REVIEW OF LITERATURE

## Logging System in Malaysia

Selective logging method was introduced in Malaysia as a forest management system since 1948. It was then known as the Malayan Uniform System (MUS) (Wyatt-Smith, 1963). A new system known as the Selective Management System (SMS) was implemented in 1970 to replace MUS because the MUS system was found to be unsuitable to be practiced in the hill forest areas (Thang, 1986). This new system was designed to optimize the management objectives of an economic and efficient harvesting, forest sustainability and minimum forest development cost. In this system, minimum cutting limits are 45 and 50 cm diameter breast height for the non-dipterocarp and dipterocarp species, respectively.

The logging system which has been developed in the forests of Malaysia are completely mechanized and requires low capital (FAO, 1970, 1973; Ellis, 1976; Jones, 1976). The basic logging operations include tree felling, construction of forest road and log transportation. During road construction, the topsoil and forest debris are pushed aside to ensure firm and level footing for the skidding operation. The activities during this operation and the usage of heavy earth-moving equipment such

as tractors and skidders cause severe soil degradation. In log transportation, the crawler tractor is used for skidding or hauling the logs from the felling site to temporary landing (Plate 1). The logs that are skidded are usually large; 50 to 100 cm in diameter at breast height, cut into logs of about 5 to 7 m long or sometimes at tree length. Under such practice, only heavy equipment are used. The main vehicle tranporting logs to the logyard is a winch lorry locally known as "San-Tai-Wong" (Plate 2). These skidding and transportation activities can cause serious degradation of soil physical properties both during the dry and wet seasons. Soil degradation and compaction resulting from logging will certainly induce surface runoff and erosion.

## Soil Erosion and Surface Runoff in a Tropical Forest

In the temperate zone, surface erosion in undisturbed forest is minimal (Megahan and King, 1975). This is not true for the tropical forest because soil erosion can be detected even under natural forest (Leigh, 1978; Fearnside, 1979; Putjaroon and Pongboon, 1987). Putjaroon and Pongboon (1987) found that the amount of runoff and soil loss in a dry dipterocarp forest in Saholnakron Province of Thailand were 1,529 $m^3$/ha/y and 664 kg/ha/y, respectively. The values are however much lower when compared to that of abandoned fields

Plate 1. Extraction of Log Using Crawler Tractor on the Skid Trail.

Plate 2. Winched Lorry or "San-Tai-Wong".