UNIVERSITI PUTRA MALAYSIA

ECONOMIC VALUATION OF SOIL EROSION AND SEDIMENTATION IN CAMERON HIGHLANDS

CHEW CHANG GUAN

FEP 1999 3

ECONOMIC VALUATION OF SOIL EROSION AND SEDIMENTATION IN CAMERON HIGHLANDS

By

CHEW CHANG GUAN

Thesis Submitted in Fulfilment of the Requirements for the Degree of Master of Science in the Faculty of Economics and Management Universiti Putra Malaysia

April 1999

ACKNOWLEDGEMENTS

I would like to extend my gratitude to my project supervisor, Prof. Madya Dr. Mohd Shahwahid Haji Othman, of the Department of Hospitality and Recreation, Faculty of Economics and Management, Universiti Putra Malaysia (UPM), for his patience, guidance, ideas and comments throughout the preparation and completion of this project paper. Thanks are due also for his research financial support under the IRPA project fund (No. 05-02-04-0008). I would also like to thank him for allowing me to use the project data for my research analysis.

I would like to thank my parents, Mr. Chew Fai Min and Madam Song Phek Eng, for their patience and support to keep me going at times when I felt like giving up. Furthermore, I am very thankful to many people who have helped me in my work especially Y.M. Raja Harris B. Raja Hasbullah, Encik Ahmad Nazri Puteh, Encik Usof Yong, Encik Nazaril and Mr. Chew Wye Kuan from Tenaga Nasional Berhad; Dr. Abdul Rahim Nik, Encik Baharuddin Kasran and Dr. Zulkifli Yusop from FRIM; Dr. Awang Noor from the Faculty of Forestry, UPM; Dr. Eddie Chiew and Prof. Madya Dr. Ahmad Shuib from the Faculty of Economics and Management, UPM and my friends Miss Tee Tuan Poy, Dr. Phang Yuen Fun, Dr. Wong Kiong Kheng and Mr. Mustain Billah.

Finally, a very special appreciation to all the people in Kampung Raja, Cameron Highlands, the staff of the Department of Agriculture both in Kuala Lumpur and Cameron Highlands, and the librarians at UPM for their assistance.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

FIGURE **Page**

LIST OF PLATES

LIST OF ABBREVIATIONS

HEP	:	Hydroelectric Power
mt	:	Metric Tonne
meq	:	Milli equivalent
O.M.	:	Organic Matter
Pers. Com.	:	Personal Communication
ppm	:	Part per million
TNB	:	Tenaga Nasional Berhad
TNBG	:	Tenaga Nasional Berhad Generation

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in partial fulfilment of the requirements for the degree of Master of Science.

ECONOMIC VALUATION OF SOIL EROSION AND SEDIMENTATION IN CAMERON HIGHLANDS

By

CHEW CHANG GUAN

April 1999

Chairman : Associate Professor Mohd Shahwahid Haji Othman, Ph.D.

Faculty : Economics and Management

This study was conducted primarily to determine and quantify the costs associated with soil erosion (on-site costs) and sedimentation (off-site costs) in Sungai Ikan Catchment, Cameron Highlands. Data used on rate of sediment yield in the area was obtained from a study of Baharuddin et al., 1996. The average sediment yield in the Sungai Ikan Catchment was estimated to be 19.7 mt/ha/year. The on-site cost estimation revealed that a hectare of soil loss in a year is worth RM8178.62, which is the forgone net revenue of the farmer. The on-site cost is about 9.16% of the production cost of vegetable production. The total on-site cost due to erosion in Sungai Ikan Catchment is more than RM18.3 million for 18 years. For calculating the off-site costs, the incremental cost to TNB due to sedimentation is used. It shows that every metric tonne of sediment from Sungai Ikan Catchment incurred RM171.69 extra cost to TNB. The incremental cost due to sedimentation is about 10.09% of the total net revenue to TNB. The incremental off-site cost to Society, which taking into account the benefit of selling sand and the differential cost of electric to TNBG, the total incremental off-site cost to society is RM72.5 million for 18 years. The finding of this study could hopefully serve as a useful guide to the local authority in the preparation of land development and other parties who needed it. Implications of this finding for soil erosion and suggestions are discussed.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi sebahagian keperluan untuk ijazah Master Sains.

PENILAIAN EKONOMI BAGI HAKISAN TANAH DAN ENDAPAN DI CAMERON HIGHLANDS

Oleh

CHEW CHANG GUAN

April 1999

Pengerusi : Profesor Madya Mohd Shahwahid Haji Othman, Ph.D.

Fakulti : Ekonomi dan Pengurusan

Kajian ini adalah bertujuan untuk menentu dan menilai kos-kos yang berkaitan dengan hakisan (kos "on-site") dan endapan (kos "off-site") di Tadahan Sungai Ikan, Cameron Highlands. Data hasil endapan yang digunakan di kawasan ini adalah dapat dari kajian Baharuddin et al., 1996. Purata hasil endapan di Tadahan Sungai Ikan didapati ialah 19.7 mt/ha/tahun. Hasil kajian kos "on-site" ini mendapati hakisan tanah di setiap hektar dalam setiap tahun adalah bernilai RM8178.62, dimana ini adalah hasil bersih yang dilepaskan. Kos "on-site" ini adalah lebih kurang 9.16% dari kos pengeluaran sayur. Jumlah kos "on-site" yang disebabkan oleh hakisan tanah di Tadahan Sungai Ikan adalah lebih daripada RM18.3 juta untuk 18 tahun. Untuk mengira kos "off-site", kos tambahan kepada TNB yang disebabkan oleh endapan digunakan. Kajian ini menunjukkan setiap metrik ton endapan dari Tadahan Sungai Ikan telah mengakibatkan sebanyak RM171.69 kos tambahan kepada TNB. Kos tambahan yang disebabkan oleh endapan ini adalah 10.09% daripada jumlah hasil bersih TNB. Kos tambahan "off-site" kepada masyarakat, dimana mengambil kira keuntungan dari jualan pasir dan juga perbezaan kos electrik kepada TNBG, jumlah tambahan kos "off-site" kepada masyarakat

ialah RM72.5 juta untuk 18 tahun. Hasil kajian ini diharapkan boleh menjadi satu panduan kepada kerajaan tempatan untuk persediaan pembangunan tanah serta pihak-pihak lain yang memerlukannya. Implikasi hasil kajian ini tentang hakisan tanah serta cadangan-cadangan juga dibincangkan.

CHAPTER I

INTRODUCTION

Background of the Study

In the past three decades, land degradation caused by erosion was considered of minor importance for many countries, including Asian and European communities. Today, land degradation is a major concern in land use management throughout the world. Recent estimate by Food and Agriculture Organization (FAO) shows that global loss of productive cropland due to soil erosion and degradation is estimated to be nearly seven million hectares annually (FAO, 1991). In relation to this, world organizations such as the World Bank and Economy and Environment Program for South East Asia (EEPSEA) are focusing their research and projects on soil degradation and conservation to master this environmental problem. For instance, on October 28, 1997, the World Bank approved a US$55 million loan to finance the Land Management III Project in Brazil, which was designed to increase and sustain agricultural production, productivity, and income of thousands of farm families facing serious soil and water degradation problems in the State of São Paulo (World Bank, 1997).

With a growing demand for forested land (for agriculture & housing) and natural resources such as water (for fresh water and hydro-electric power generation), forested catchment[1] areas are getting scarce. Forest catchment provides different types of goods and services including commodities such as water, food, timber and environmental services such as bio-diversity, carbon storage and flood control. However, these benefits are not known and largely ignored because they are not traded in the market. In fact, most of the fresh water used in Malaysia for household, industry, agriculture uses are drawn from forested catchment. Moreover, hydroelectric power (HEP) generation, which constitutes 10% of the total energy production, requires water flows from catchment areas to run the turbines (Pers. Com. Mohd Ismail, 1998).

A forest catchment area may also be suitable for agricultural and tourism purposes, especially in the highlands. The highland weather is suitable for certain temperate crops, such as cabbage, tomato and flower. With an increasing demand for agricultural land, changes would take place to the ecosystem. For example, by opening the forestland, man exposes the soil surface to erosion from water and wind. The lack of proper care of the forest catchment will result in accelerated soil erosion and sedimentation. This damages the forest cover or vegetation, thus affecting its ability to hold large capacity of water and to regulate the flow of water. In addition to that, soil erosion diminishes crop productivity by removing nutrients, reducing organic matter, and restricting rooting depth as the soil thins (OTA, 1982).

Soil erosion is the process by which soil particles are detached from a place of origin and transported and deposited elsewhere. According to Troeh *et al.*(1980), there

---

[1] Forested Catchment is defined as naturally occurring units of the landscape, which contains a complex array of inter-linked and inter-dependent resource and activities bonded by topographic features.

are three main types of water erosion classified in terms of nature and extent of soil removel, namely sheet erosion, rill erosion and gully erosion. Sheet erosion pertains to the removal of thin layers of soil by raindrop splash and surface flow acting over the whole soil surface. Rill erosion, on the other hand, refers to the situation where erosions channels are small enough to be removed by normal tillage operation. In gully erosion type, erosion channels are already so large to be erased by ordinary tillage (Francisco, 1986).

Beside soil erosion, the eroded soil deposits on waterways and reservoir. This process is known as sedimentation. The degree of damage is determined, to a great extent, by the nature of the soil and its position in the landscape (Harlin and Berardi, 1987). Example of damages of sedimentation include the reduction of fish catch for downstream users, increase in sediment of dead storage in reservoirs, and water pollution for the usage of downstream users.

Economic Impacts

The impacts of soil erosion and sedimentation have profound economic implications for many countries, including Malaysia. For instance, degradation of land resources threatens prospects for economic growth and human welfare. The erosion and sedimentation impacts that result from human activities on the forest catchment areas can be classified into on-site and off-site impacts.

The on-site impacts of soil degradation measures the decline in quality of the land resource itself, such as degradation of natural soil fertility, loss of organic matter, market prices of agricultural inputs and outputs, and are therefore easily neglected in public and private decision-making. Thus, to incorporate these degradations in a cost benefit analysis would require measuring these impacts over an appropriate period of time and incorporating the economic costs of these degradations.

Problem Statement

The conversion of forestland to agricultural activities (legally or illegally) attests to the seriousness of soil erosion problems in the Cameron Highlands. The water resources are highly turbid and sediment laden and also exposed to organic and chemical pollution from heavy use of fertilizer (organic and inorganic) and pesticide. The loss in productivity due to erosion has an impact at all levels of society. If this problem is still ignored by society, the economic loss to society will be much higher in the future due to higher abatement cost. Seeing the weight of the on-site and off-site problem, a study on economic valuation of environmental impacts from erosion and sedimentation in Cameron Highlands can perhaps ensure environmentally sound development of the area. The main stakeholders[2] involved or affected are the farmers, local district council, Tenaga Nasional Berhad (TNB), Forestry Department and general public, where the soil erosion problem will increase their cost of maintenance and management.

Objectives of the Study

The objective of this paper was to quantify the net revenue of farmland when the external cost of erosion and sedimentation are taken into account. In order to do that, on-

[2] Stakeholders are groups of people, organized or unorganized, who share a common interest or stake in the system (Mohd Shahwahid *et al.*, 1998).

site and off-site costs associated with soil erosion and sedimentation in Cameron Highlands have to be computed. For the on-site cost, this would first require quantifying the physical quantities of topsoil and nutrient loss. Evaluating their value would require estimating the physical inputs (fertilizers) as replacement for the nutrient loss. The effect on production of certain crops owing to the amount of nutrient loss was estimated. For off-site cost of the sediment problem, the main downstream party affected is TNB. The extra production cost and the benefits forgone by TNB are computed. Having quantified the economic cost of the impact of soil erosion from farmland to the economy of Cameron Highlands, recommendation to address the soil erosion problem is given.

Limitations of the Study

This study undoubtedly represents an important step in quantification of soil erosion impact. The analysis, however, is partial in nature and based on a number of assumptions and generalizations which need refinement. The estimated value is a little underestimated. There are many other impacts of soil erosion and sedimentation, which have not been incorporated due to lack of time and budget. These impacts of soil degradation are shown in Table 1.

Table 1 : The General Impacts of Soil Erosion and Sedimentation in Cameron Highlands

Problem	Impacts
On-Site (Soil Erosion)	**Farmer** • Loss of soil moisture-holding capacity • Restriction of rooting depth • Loss of nutrients and organic matter **Society** • Land slide • Real property destruction • Threats to human life **Natural Resources** • Loss of Bio-diversity • Loss of timber • Loss of carbon storage • Loss of flood control • Loss of habitat for fauna
Off-Site (Sedimentation)	**Resident downstream (Orang Asli)** • Declining quality of domestic water supply • Increment in medical fee and expenses • Real property and crop destruction **Tourism** • Sedimentation of recreation park • Decline in tourist arrival • Decreasing income for hotels and other tourist oriented businesses **Tenaga Nasional Berhad (TNB)** • Increase in investment cost • Increase in maintenance cost • Decline in HEP production

CHAPTER II

LITERATURE REVIEW

Introduction

This chapter reviews and discusses different ways which have been used by researchers to study soil erosion. This includes the methods for evaluation of on-site and off-site costs, requirement of data, advantages and disadvantages of the approaches.

Effects of Soil Erosion

Evidence of the exhaustion of arable land under agriculture is found throughout history and in all parts of the world. Several authors (Tolley and Riggs, 1961; Pasig, 1981) have pointed out the need to treat the watershed as a unit in economic analysis and planning. This is due to the fact that the activities being performed in the uplands or forest zones, which generally result in soil erosion, will certainly affect the stability of the lowlands through sedimentation.

Khoshoo and Tejwani (1993), as quoted by Alladeen (1997) suggested that the consequences of erosion are all pervasive and pernicious. Soil erosion adversely affects the functioning of natural ecosystem (ecological impact), the production base (economic impact) and life of the people (social impact). Bishop (1992) for instance, pointed out that the consequences of erosion can be a cost or benefit which is not reflected in the market prices. Sedimentation of downstream reservoirs, hydroelectric facilities or irrigation channels is a typical negative externality. In comparison, the protection of watersheds provided by tree plantations, orchards and other perennial crops is an example of a positive externality. Such environmental externalities are often difficult to measure.

Measurement of Soil Loss

One of the methods in estimating the soil erosion loss is using the "Universal Soil Loss Equation". The "Universal Soil Loss Equation" (USLE) was developed in the United States through statistical analyses of erosion measurements by using an empirical equation. It was developed based on agricultural plots with certain ranges of variations in soil, climatological and slope conditions. The development of USLE was pioneered by W. H. Wischmeier and D. D. Smith from the US Agriculture (USDA), Agriculture Research Service and Purdue University in the late 1950s (Renard *et al.*, 1991). The amount of soil loss in mt/ha/year (A) was estimated by multiplying the rainfall / runoff (R), the erodibility factor of the soil (K), the length of the slope (L), the steepness of slope factor (S), the cropping and management factor (C) and the supporting conservation practice factor (P). It reflects the influence of all the major factors known to affect rainfall erosion. The equation is given as:

$$A = R*K*L*S*C*P$$

where,

A = Amount of soil loss (mt/ha/year)
R = Rainfall erosivity factor
K = Erodibility factor of the soil
L = Length of slope factor
S = Steepness of slope factor
C = Cropping and management factor
P = Supporting conservation practice factor (terracing, contouring an so forth)

According to Roslan (1996), to estimate the average annual soil loss, numerical values have to be established for all the factors. However, such data are lacking in Malaysia, for instance as in the case of Cameron Highlands. Thus, more research work on this field is needed. The importance of the soil-loss equation is to serve as a guide to the soil conservation programs for assisting in land use planning and management decision. From his study the soil erosion loss at three locations in Cameron Highlands using the USLE are computed as 95.092 mt/ha/3 months for Gunung Brinchang, 46.814 mt/ha/3 months for Sungai Ikan and 2.468 mt/ha/3 months for Tanah Rata area. The values of R, K, L, S, C and P used in the computation are shown in Appendix A.

Arnoldus (1977) warned users of USLE to take precaution in applying the equation to countries outside the United States for which it was originally designed. Modifications have to be made to make the equation applicable to outside environments like the tropical watersheds. For instance, in the modified model, vegetation-management (VM) factor will be replaced soil cover-management factor (C) and the soil conservation practice factor (P) in USLE (Baharuddin *et al.*, 1999). The new model is called modified soil loss equation, (MSLE) (Warrington *et al.*, 1980). The modified equation is given as:

$$A = R*K*L*S*VM$$

where,

R = Rainfall erosivity factor
K = Erodibility factor of the soil
L = Length of slope factor
S = Steepness of slope factor
VM = vegetation-management factor

Valuing the Costs of Soil Erosion

A range of analytical techniques is used to evaluate the impacts of soil degradation in terms of economic costs and benefits.

On-site impacts are most frequently studied, generally by an analysis of the effect of soil loss on crop production (Bishop, 1992). Assessments of off-site effects have been hampered by a lack of physical data. Barbier (1995) added that the off-site impacts of land degradation are often much harder to evaluate because the off-site benefits provided by land resources are not traded at all.

Economic Models for On-site Costs of Soil Erosion

Various methods are available to estimate the value of on-site costs for erosion. Each approach has its disadvantages and advantages:

Hedonic Pricing

Hedonic pricing compares the sale or rental price of plots of land which differ only in the extent of physical degradation (Bishop, 1992). This method is applicable only where land markets are well developed, and price data are available. The technique presumes that physical degradation is in fact reflected in land price. However, if property rights are ill defined or when speculation or policy distorts land markets, problems can arise. In view of this, Hedonic pricing may be more applicable in a developed country context in which rural real estate markets are well-established (Norse and Saigal, 1993). This approach may also understate the full cost of soil degradation to society, as it captures