Soil Erosion

An interdisciplinary investigation of the relation between land use and soil erosion.

A report based on a fieldwork undertaken in the SLUSE - University Programme

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Introduction

XPDC and SLUSE

A 10 day expedition "Crocker XPDC ´99" was held in Tambunan district, Sabah, from 17th-20th of October 1999. This was the first one in the series of scientific expeditions planned for Crocker Range National Park and involved both local and foreign researchers. The Danish participants of the Crocker XPDC ´99 were a part of the SLUSE program. The SLUSE program is an interdisciplinary field course on Sustainable Land Use and Natural Resource Management. 4 lectures and 23 master students from the University of Aarhus, University of Copenhagen, Royal veterinary and Agricultural University and Roskilde University Centre attended the Crocker XPDC ´99. The Danish Group was divided into 6 groups dealing with different problems of land and resource use in relation to the CRNP. In the period Oct 18th to Oct 29th the investigations were carried out in the villages Patau, Tikolod and Kuyongon. This introduction contains information about Malaysia, Sabah, Tambunan district and the 3 villages that are relevant for the following reports.

Malaysia

Malaysia is situated in south-east Asia and has an area of 329,733 km^2, and is, according to an estimate from 1996, populated with 21.3 m inhabitants (Hunter 1998). The country is a confederation of 13 states stretching over two main parts; Peninsular Malaysia with 11 of the states and East Malaysia on the northern part of Borneo, with the states Sarawak and Sabah. The capital, Kuala Lumpur is situated on the Peninsular Malaysia. The official language is Bahasa Malaysia, even though English is widely spoken (The Europa World Yearbook 1999). The currency is Malaysian Ringgit and 1US$ = 3.799 MYR (Antweiler 1999)

Around 85% of the population live on the peninsular, and 15% in Eastern Malaysia. Sunni Islam is the official state religion, practiced by over half of the Malaysian population, mainly the Malays. About 19% follow the Buddhist belief – including most Chinese descendants. There is an Indian minority being mainly Hindu by belief, while there is a small Christian minority among all Malaysian ethnical groups. The major ethnic groups in Malaysia are shown in Table 1.1.

	Peninsular Malaysia	Sabah	Sarawak	Total
Malays and other indigenous groups	8,433,826	1,003,540	1,209,118	10,646,484
Chinese	4,250,969	218,233	475,752	4,944,954
Indians	1,380,048	9,310	4,608	1,393,966
Others	410,544	167,790	10,541	588,875
Non-Malaysians	322,299	464,786	18,361	805,376
Total	14,797,616	1,863,659	1,718,380	18,379,655

Table 1.1: The principal ethnical groups in Malaysia (Source: The Europa World Yearbook 1999).

The Federation of Malaya was established in February 1948, and Malaysia was established in 1963. Sarawak, Borneo and Singapore joined the federation, but in 1965 Singapore left it again. Being under separate colonial administrations before independence, Sarawak and Sabah still have a slightly greater level of administrative autonomy (The Europa World Yearbook 1999).

The federal parliament consists of the Yang di-Pertuan Agong and two Majils (Houses of Parliament) known as the Dewan Negara (senate) and the Dewan Rayat (House of Representatives). The former has 69 members where 26 are elected, 2 by each state legislature and 43 appointed by the yang di-Pertuan for a 3-year period. The Dewan Rakyat has 192 members and with a maximum life of 5 years (Hunter 1998).

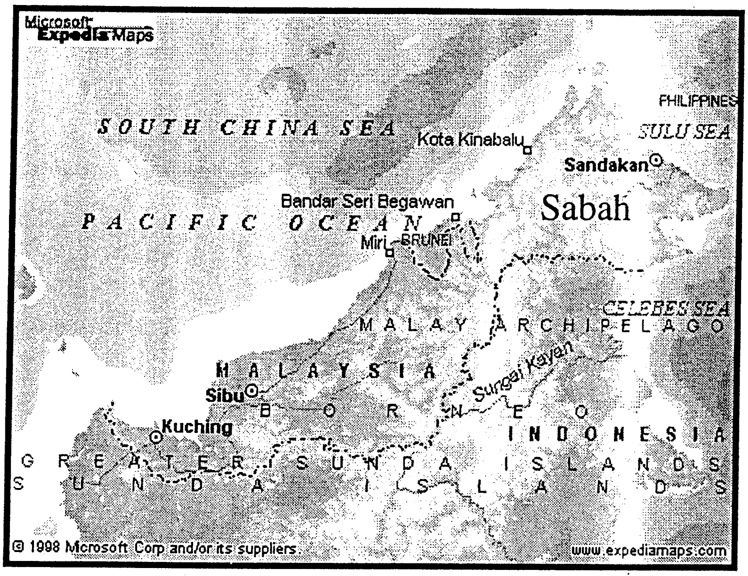
The industry of Malaysia, including mining, manufacturing, construction and power, made about 47.5% of GDP in 1997, with manufacturing as the largest export sector and engaging 38.2% of the employed labour. Agriculture, including forestry and fishing, accounted for approx. 11.7% of GDP, engaging 15.2% of the employed labor force in the same year. The country is the largest producer of palm oil in the world, but has lost its leading position when it comes to natural rubber. Cocoa, pepper, coconuts, bananas, tea and pineapples are also important cash crops, while rice is the most important subsistence crop. Extraction of energy comes mostly from the country's own oil, but the oil as energy resource has lost some importance to the favor of natural gas, which increased from 19% in 1985 to 33% in 1993. The oil went from 71% to 38% during the same years (The Europa World Yearbook 1999).

Sabah State

Formerly known as British North Borneo, the state occupies the northern most part of Borneo and borders to Indonesia in the South and Sarawak in the West. (Map 1.1.) The state is administratively divided into four main regions; the West Coast, Interior, Sandakan and Tawau. Its capital, Kota Kinabalu, also functions as the major port town of Sabah to the South China Sea. Sabah covers an area of 73,619 km^2 with an estimated population of 2,593,400, which gives a density of 35.2 persons per km^2 (The Europa World Yearbook 1999).

About 33% of the population of Sabah consists of people belonging to the Dusun ethnic group, who live in the interior and eastern part of the region, while Malay and Bajau´s dominate the west and northern coastal zones of the state. Chinese, however, mainly live in the urban areas. Immigration from the Philippines has further altered the ethnic complexity of Sabah. The majority of the population, the Dusun, are Christian while minority groups such as Malays and most Filipino immigrants are Muslims. Buddhism and traditional animist religions belong to minor groups (The Europa World Yearbook 1999; Cleary & Eaton 1992).

Sabah joined the Malaysian Federation in 1963 after the emancipation from the British North Borneo Company, which had run the state as a limited company since the 19th century (Hurst 1990). In the March 1999 election the Cabinet in Sabah has 48 seats. The party Barisan Nasional secured 31 seats and Parti Bersatu Sabah, 17 seats (The Europa World Yearbook 1999).



Map 1.1. Sabah State is situated at the northern point of Borneo (Source: Expedia maps)

The institutional set-up in the state of Sabah is divided in three levels; state, district and village. At the state level there is the Sabah government and different ministries as well as departments. The District Office is the main institution at the district level and beside it there are different departments of e.g. agriculture and forestry. The connection between the village level and district level is through the headman of each village and the Committee for Development and Security (Lasimbang 1996).

When Sabah joined the federation in 1963 the Sabah State got formally decision making power over resources such as land and minerals, as well as language, religion and education. Today however, many of these rights have either been abolished or almost eroded which has resulted in worsening relations between Sabah and the Federal Government (Lasimbang 1996).

Contrary to the highly industrialized states in the peninsular, Sabah is predominantly rural. During the late 1970s and early 1980s efforts were made to create a considerable number of industrial estates in Sabah. However, market forces have now determined that focus should be put on setting up facilities for small and medium industries (Brookfield et al. 1995). The industry in Sabah is mainly related to the processing of local raw materials like timber. However, offshore oil and gas sources have attracted manufacturing industries using oil and gas in their production (The Economist Intelligence Unit 1999).

The economy of Sabah is mainly based on forestry and agriculture. Log exports in Sabah now face a serious crisis, but they have, until recently continued without limitations. With imposed quotas in the late 1980s, log exports fell by over one-half between 1987 and 1990. However, in 1992 logs still composed half of Sabah's timber exports. A study from the Forestry Department predicted that timber production from natural forest would not be able to meet local demand from 1992 and onwards. Although oil and gas may sustain state revenues, serious problems are presented to Sabah in this new situation (Brookfield et al. 1995).

According to FAO (1981), about 30% of Sabah is suitable for agriculture but less than 10% of the state is under permanent cultivation. Due to this, FELDA (Federal Land Development Authority, Malaysia) has made efforts in innovating food-crop and cash-crop production systems. These production systems have extended into eastern Sabah since the 1980s when FELDA and Sabah Land Development Board cleared over 15.000 km^2 of forests in Sabah and converted it into various forms of agriculture. Farmers were settled down in the areas and the result has been a rapid growth in plantation, especially oil-palm and cocoa, and this shift has now replaced rubber as the main cash-crop (Brookfield et al. 1995).

The climate in Sabah is tropical-equatorial, temperature ranges from 24 – 28 °C, modified only by altitude and the humidity, which is very high, usually about 80-85%. There is no dry season in Sabah but generally heavier rains occur from about October to May. Average rainfall varies from 3000 mm in the west coast to 1900 mm in Tambunan in the interior Sabah. (Cleary & Eaton 1992; Phillips 1988).

Sabah is predominantly covered by Ultisoils. These soils are highly weathered, red-brown soils that develop in hot and humid climate. They contain a large amount of sesquioxides (aluminium and iron oxides) and the clay mineralogy is dominated by kaolinit. The cation exchange capacity is therefore low but varies with the soil reaction. Other soil types, with minor distribution in Sabah are Alfisoil, and a complex of Histosoils, Entisoil and Inceptisoils (Whitmore 1984).

Sabah is sometimes called "land of biodiversity" referring to the fact that the region has one of the highest species diversity in the world (Whitmore 1984). The natural vegetation of the area is tropical rain forest and mixed dipterocarp forest covers the largest area of Sabah (Hurst 1990; Whitmore 1984). The official forest policy includes objectives such as the maintenance of the sound climatic and physical condition of the state, and protection of flora and fauna. However, it also mentions the need to promote exports and wood-based industries. In 1984 the area of forest reserve in Sabah was 45% of the total state area. In two thirds of this area commercial logging is allowed (Cleary & Eaton 1992). Sabah, like other parts of Borneo has a rich and diverse wildlife, including different types of mammals, such as monkeys, deer, squirrels and bats as well as birds and fishes. Increased hunting and disturbance of natural habitats in the recent decades is now a serious threat to wildlife. Many species are becoming scarcer and in Sabah some 29 species of mammals and 106 species of birds have been listed as threatened species and are now protected (Cleary & Eaton 1992).

Crocker Range National Park (CRNP)

Crocker Range National Park covers an area of 139,919 ha and is the largest national park in Sabah. The park is situated on a long range of hills that rises from the western coastal plain of Sabah around 10 – 15 km inland from the coastline. (Map 1.2.) The main ridge raises between 900 and 1800 m above sea level. CRNP is a unique area in Sabah since it contains untouched dipterocarp forests, which are the major hardwood timbers of Sabah. The forests range from true lowland dipterocarp forest below 150 m to montane forest above 1200 m above sea level. Some tree species of the area are believed to be endemic to lowland and hill dipterocarp forests of north-western Borneo. The wildlife of the forest includes barking deer, bearded pig and hornbills. Larger mammals such as the clouded leopard and orangutan are extremely rare (Phillips 1988; Gaussett et al. 1999).

The park was enacted as a conservation area in 1984 for two main reasons; to preserve and protect the watersheds of the four main rivers in the west coast and the eight rivers from the interior plains. The other reason is to protect the wildlife and flora of the area, especially *Rafflesia spp.* the world largest flower (Gaussett et al. 1999).

"Take nothing but photographs, leave nothing but footprints" is the motto of Malaysian national parks, which indicates that any kind of utilization within the park borders is prohibited. According to Sabah Parks enactment from 1996 any person who hunts, or has the intention to hunt any animal or bird, collects or destroys any vegetation or minerals in the park shall be guilty of an offence and will be fined or imprisoned (State of Sabah 1996). According the park warden of CRNP, around 30 people are employed in the park but only 7 are employed as park rangers to protect the whole area, which means that people who violate the laws of the park are seldom discovered.

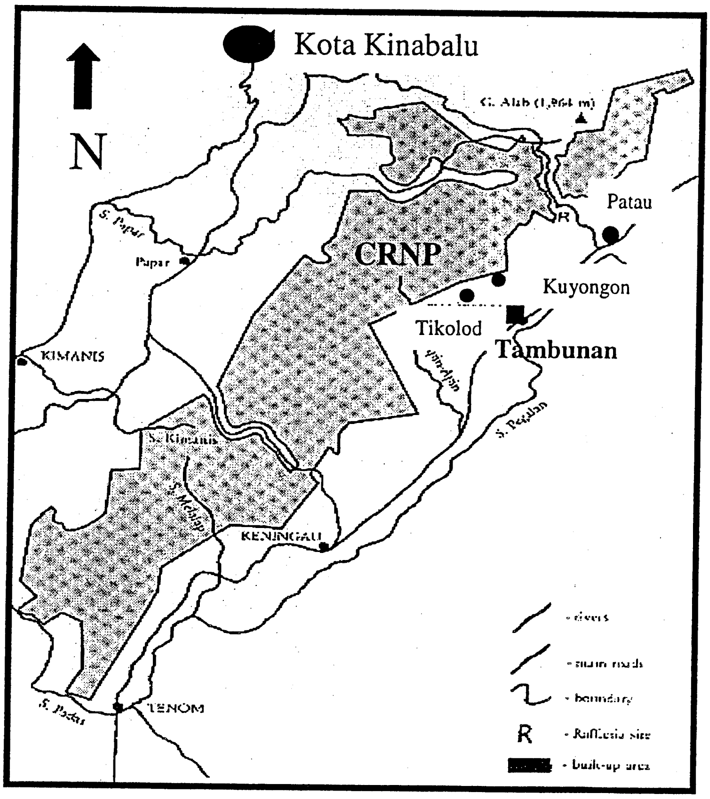
Tambunan district

Tambunan district is situated in the Interior Region of Sabah State (Map 1.2.). The district has about 28.000 inhabitants mostly living in small villages surrounding Tambunan town. The traditional form for agriculture is the shifting cultivation of upland rice. The system and the length of the fallow period varies between villages. Most farmers grow wet rice but cultivation of cash crops does not seem to play a major role in the villager's livelihood. Animal production is also limited to a small number of fowl and water buffalo. Non timber forest products are collected from the surrounding forest and CRNP and the products seem to be an important for the villager's livelihood. Temporary migration to towns and off-farm work seems to be an important income-generating factor although it has been stated that most people return to their villages (Gaussett et al. 1999).

Tambunan town shows obvious signs of being a farm town, with a market place where many of the farmers in the district sell their farm products, e.g. a large variation of vegetables, dried fish and a few handicrafts. There are also several shops with similar supplies of mixed everyday goods and tools, which might be used in the farms.

Patau, Tikolod and Kuyongon

Three villages in Tambunan district have been identified for the SLUSE study. These are: Patau, Tikolod and Kuyongon (Map 1.2.).



Map 1.2. The location of the research site. CRNP, Patau, Tikolod and Kuyongon (Source: Phillips,1988)

Patau

Patau village is located 20 km north of Tambunan by the main road to Ranau and lies approximately 1000 meters above sea level. The village has around 660 inhabitants living mainly of agriculture. There are two gravel roads leading to the CRNP 5-6 km away from the main road. Two research groups were doing their investigations in Patau. One group dealt with intensification of agriculture and another one with the possibilities of developing eco-tourism in Patau village.

Tikolod

Tikolod area consists of four harmlets situated in a river valley stretching from the main road between Tambunan and Keningau to the Crocker Range National Park. The largest hamlet has around 40 households and the three other hamlets have around 10 households each. There is approximately 70 households containing 470 people. Tikolod borders to either side of the valley it is situated in, with the surrounding hill peaks, so in fact the Tikolod village area is very much defined by the physical boundaries of the landscape (topography and infrastructure). In the late 1970´s there were only around 100 people in the village. This dramatic increase is caused by migration from Kionop village located within the boundaries of what is today the Crocker Range National Park. However, it is hard to make precise estimates, since the village underwent a transformation 18-20 years ago, from consisting of scattered households, to being centred around the four hamlets of today. Up stream the river valley consists of several smaller rivers where the two closest is the Tikolod river and the Bolotikon river. These smaller valleys both have ridges on each side. The sub catchment areas are bordering up to each other. The geological features were mainly sedimentary rocks of Tertiary age consisting of thick layers of sand-, silt-, mudstone and shale. There were many topographic features in the area that could be divided into many micro sub catchment areas. The slope gradients in the area differed from zero to almost vertical, and there were farming taking place on slopes with gradients differing from zero to around 50 degrees.

There was hardly any primary forest left but huge areas had secondary forest or were left fallow. The most common crops in both sub catchment areas were hill rice and ginger. The former was the main subsistence crop, the latter the main cash crop. The main land use is shifting cultivation using slash and burn techniques and the consequently planting of annual crops (ginger, hill rice), but also perennial crops are grown such as fruit trees, oil palm and even some coffee. The fallow period for the perennial crops will typically not be of the same duration as that of the annual crops, albeit less. The above-mentioned crops are all grown on the slopes of the valley. In the valley bottom, where the soil is levelled out, wet rice will often be planted permanently

The water and erosion group together with the land tenure group conducted their fieldwork in Tikolod area. The aim of the water and erosion group was to look at the potential risk for soil erosion and the land tenure group did research on land tenure issues such as the access to land and land use.

Kuyongon

Kuyongon village is located about 5 km from Tambunan, and lies in 950 meters above sea level. The village has about 260 inhabitants that live mostly from agriculture. Kuyongon lies only 4 km away from CRNP. Two groups stayed in Kuyongon. One investigated the gathering and use of forest products and the other one income-generating activities.

List of references

Antweiler, W. (1999): http://pacific.commerce.ubc.ca/xr/today.html. (Date: 7-12´99)

Brookfield, H., Potter, L., Byron,Y. (1995): In Place of the Forest. Environmental and Socio-econoomic Transformation in Borneo and the Eastern Malay Peninsula. United Nations University Press. Tokyo.

Cleary, M. & Eaton, P. (1992): Borneo Change and Development. Oxford University Press. Singapore.

Expedia maps (1999): www.maps.expedia.com (Date: 7-12´99)

FAO (1981): Forest resources of Tropical Asia. FAO. Rome. Italy

Gaussett, Q., Mertz, O., van der Keur, P., Mohamed, M. (1999): The Crocker Range Parks. www.cyberct.com.my/arbec/intro1.htm (Date: 5.12´99).

Hunter, B (1998): The Statesman's Year-Book, 1997-1998. Macmillan Press. Hampshire. England

Hurst, P. (1990): Rainforest politics. Ecological destruction in South-East Asia. Zed books. London.

Lasimbang, J. (1996): Wines that won't bind. Igwia document no.80. Igwia.

Phillips, A. (1988): A guide to the Parks of Sabah. Sabah Parks Publications no. 9. Kota Kinabalu.

State of Sabah (1996): An Enactment to amend the Parks Enactment 1984. No 7 of 1996. State of Sabah.

The Economist Intelligence Unit (1999): Country Profile Malaysia 1999/2000. The Economist Intelligence Unit Limited.

The Europa World Yearbook (1999): The Europa World Yearbook. Europa Publications. London

Whitmore, T.C. (1984): Tropical rain forests of the Far East. Clarendon press. Oxford.

Abstract

Soil erosion is a problem in Malaysia, which leads to increasing concern. The consequences of erosion are in many aspects devastating. Locally there are problems like soil fatigue, declining yield and pollution of water resources. Additionally there are many externalities, which causes problems downstream, like sedimentation of rivers and channels, destruction of animal habitats etc.

Soil erosion is typically associated with agriculture and its practises. However the interactions between social, institutional and physical parameters are highly complex. In order to get a better insight in these interactions we have applied an interdisciplinary approach trying to investigate the relation between land use and soil erosion.

With increasing population the need for more land under cultivation often increase. In Kampung Tikolod, the case-village of this research, the population has increased from approximately 100 villagers in the 1970's to approximately 470 today. Due to the location in a mountainous region, the opening of marginal lands means that farmers have to cultivate the hill slopes. Traditionally, agriculture in Tikolod has been a shifting cultivation culture.

The choice of crop is very important in terms of soil erosion. Rice and ginger are the two dominating crops in the shifting cultivation system in Tikolod. Applying the USLE-method we found that soil erosion can be a problem when these crops are farmed on very steep slopes (up to 50 degrees). The local perception of soil erosion is discussed and it is contested to what extent the local perception establish a connection between soil erosion and land use.

Trying to understand the process of soil erosion in order to make any recommendations or statements, it is essential to look at the whole context. Exploring farmers' motivations for choosing a crop give indications of how social and institutional factors influence land use and thereby put natural scientific data into context. Natural science serve to describe the physical processes - and quantify the problem - of soil erosion. In this way the relation between the land use and soil erosion is investigated in the following.

Preface

This report aims at fulfilling the criteria for the SLUSE Interdisciplinary Joint Basic Course 1999-00. SLUSE is a 1-year master level education conducted by the Danish University Consortium on Sustainable Landuse and Natural Resource Management. SLUSE is funded by DANCED (Danish Corporation for Environment and Development) which can be regarded as the development-oriented organisation acting on behalf of the Danish Ministry of Environment and Energy.

The work has been carried out partly in Sabah, Malaysia and partly in Copenhagen, Denmark. During the 3 week stay in Malaysia we spend a week and a half doing fieldwork in the village of Tikolod, Tambunan District, Sabah. The rest of the work was done in Kuching, Sarawak as guests at Universiti Malaysia Sarawak, UNIMAS. In Sabah we had the pleasure of joining the Crocker Range National Park (CRNP) XPDC. In this highly stimulating environment of international scientist and interesting scientific issues, we tried to contribute with the work carried out in Tikolod.

A central part of the idea behind SLUSE is to educate candidates in thinking and working in interdisciplinary ways. The research team met these demands by consisting of student of 5 different backgrounds: Hans Ulrich Lopdrup (forestry), Marie Kaas (agronomy), Bo Gregersen and Jørgen Aalbæk (geography), Lim See Moi (economy) and Poul Erik Lauridsen (anthropology). Mrs. Lim from UNIMAS joined the rest of the team when it arrived in Malaysia.

We all have an interest in environmental issues concerning erosion. When working with erosion we considered land use to be central. Therefore the study has focussed on relations between land use and soil erosion. Besides the task of describing causes and effects of erosion at present, it has been a goal to discuss potential erosion. We have used our interdisciplinary backgrounds in establishing a broad spectre research design combining a range of tools and methods from both natural and social science. This was followed up by an iterative process of evaluating methodology and adjusting research design.

Acknowledgements

We are grateful to:
Assistant Professor Peter van der Keur, Roskilde University Centre
Assistant Professor Anita Veihe, Roskilde University Centre
Assistant Professor Ole Mertz, University of Copenhagen
Assistant Professor Quentin Gausset, Univerity of Copenhagen
Assistant Professor Uffe Nielsen, Royal Danish Veterinary and Agricultural University
Assistant Professor Calvin, UNIMAS

Special Thanks to:
Professor, Dr. Murtedza Mohamed, UNIMAS
Assistant Professor Chew Chang Guan, UNIMAS
The villagers of Tikolod for their hospitality and tolerance.

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1. Introduction

Kampung Tikolod is located on the border of Crocker Range National Park in the Tambunan District, Sabah. This is a mountainous region with abundant rainfall, steep slopes and high intensity rainfall events (SLUSE, 1999). Typically for tropical uplands, farmers in this area cultivate the hill slopes using the farming system of shifting cultivation. Increasing population densities can lead to increase in the proportion of land under cultivation. This is done either by shortening fallow periods or by opening marginal land. Increasing human activity, and especially the widespread expanding activities of agriculture, can have a serious impact on the amount of soil erosion (Ismal, 1997). Accelerating soil erosion in the uplands adversely affects not only people and the ecosystems locally - but also downstream communities and facilities. These externalities are for instance sedimentation in channels and reservoirs, pollution of water supplies and altered streamflow patterns (Brooks, 1993). The effect of soil erosion on the environment has long been a subject of concern in Malaysia (Department of Environment, 1996.)

1.1 Soil erosion as a problem

The term soil erosion describes the detachment and transport of soil particles from their place of origin by wind and water (Kirkby, 1980). When topsoil is washed away, a high proportion of the organic matter and nutrients are lost along with it. Once this nutrient-rich layer of soil is gone, fertility and thereby yield will decline. Plants function as a protective cover directly and indirectly towards erosion. The roots hold the soil in position. The canopy reduces the impact of raindrops before they hit the ground (rain splash erosion) and the plants themselves, slow down velocity of surface runoff (Department of Environment, 1996). Leaving the soil bare for a short period can have a great influence concerning erosion (Norman et al., 1995). The prevention or reduction of soil erosion relies on selecting appropriate strategies for soil conservation and this, in turn requires a thorough understanding of the processes of erosion. These processes are typically measured and analysed by employing natural scientific methods. These methods often try to assess the actual and/or potential soil loss from an area, to get an estimate of the erosion taking place. At present there is a lack of standard methods for assessing soil erosion in tropical soils.

Wischmeier et al. (1978) made an empirically based equation for predicting average annual soil loss, called the Universal Soil Loss Equation (USLE). The USLE was made for predicting soil loss in the USA, but it has also been used by a number of people in the tropics (Roose, 1977; Dr. Tie, 1999; Cooley et al., 1983). Different authors have argued, that most of the problems associated with soil displacement is not only a matter of detecting "natural" causes of soil erosion. This is due to the fact that soil erosion often is highly influenced by human activity (Napier et al., 1991). Farmers make decisions about agricultural practices that will be used on the land in the context of socio-cultural, economic and institutional factors, which might constrain their behaviour (Napier, et al., 1991). By undertaking an investigation of soil erosion related to land use, we therefore find it relevant to investigate from a social scientific approach, how the socio-cultural, economic and institutional factors influence on the land use - in this case in the village of Tikolod. The importance of recognising local knowledge about environmental sustainability has been emphasised within the social sciences over the last two decades (Croll et al., 1992; van Beek et al., 1992; Ellen, 1986). The interest in local knowledge was derived from criticism of the top-down approach within development work, where western scientific knowledge was dominating. Ignoring local knowledge can be problematic in two ways: 1.) Local knowledge has been developed within the local environment and is therefore based on experience with the local environment, whereas western scientific knowledge often work with universality which might not fit the particular location of the project site. 2.) Project designs, which do not take local knowledge into account, may not be locally understood or accepted, since the project follow another rationale than the local (Brooks, 1993). Therefore it has been an important part of the fieldwork to investigate the local knowledge in order to detect how soil erosion is perceived and to see if any soil conservation practises could be detected and related to the local knowledge.

Soil erosion is one type of problem that contains elements, which are understood as typically natural scientific and therefore measurable. It also contains elements with a social dimension closely interrelated with human activity. By employing both natural scientific and social scientific methods in the investigation of soil erosion, we aim to approach the issue in a more comprehensive way than if only one type of method was used. Therefore our approach is interdisciplinary in the way that we have chosen to have both a social and a natural scientific part, but also to the extent that data gathered by means of one method has fed back and contributed to the research-design in the other parts and vice versa.

1.2. Objectives

1.2.1. The overall objective:

To investigate relations between land use practises and actual as well as potential soil erosion along the two rivers of Tikolod and Bolotikon.

1.2.2. Specific objectives:

To investigate the local knowledge of soil erosion.

- How the land is utilised.
- What are the local perceptions of soil erosion.
- Is there any local soil conservation practices.

To investigate how social and institutional factors influence on lands use.

To investigate the potential erosion in relation to the cultivation dry rice *Oryza sativa* and ginger *Zingiber officinale.*

To search for the hydrological findings indicating differences in soil loss between the two sub-catchments.

1.3. Outline of report

Chapter two contains a description of the study area. In chapter three a description of the methods and concepts of an interdisciplinary approach is made. Chapter four deals with the elaboration of social scientific methods and findings. All specific information on the USLE and findings from this are presented in chapter five. Chapter six presents the principles and findings from the hydrological work. All findings and methods from the preceding chapters are discussed thoroughly in relation to the central issue of land erosion and soil erosion in chapter seven. The conclusions are presented in chapter 8.

2. Methods

Erosion risk assessment should, as mentioned earlier, be approached from both a social- and natural scientific point. This we explain from the concept that erosion problems are caused by physical parameters like slope and rainfall as well as human activities. The importance of human activities makes social science crucial in order to make a qualified discussion on possible outcomes within the issue of erosion and to recommend any facilitations.

The USLE is meant to provide a qualified prognosis on potential annual soil loss based on present land use. Such an "all things being equal"-approach is nevertheless of limited use, contemplating an area under rapid transition, if not modified and contextualised in the light of the trends in this transition. With these aspects taken into considerations, a range of outcomes can be imagined, depending on socio-cultural and economic changes.

Since the USLE is an empirical model, it implies that the development up to present is extrapolated to give an idea of future development. In a relatively short time span, this can be regarded as a reasonable approach considering physical parameters as for instance precipitation patterns, slope gradients or soil characteristics. However, parameters in the USLE determined by crop management- and conservation practices are very likely to change radically even in a short time period. In an attempt to compensate for this we will use different techniques of Rapid Rural Appraisal (RRA) to get useful information - e.g. on the future choices of crops and trends in management.

It has already been stressed that natural scientific findings will only be of limited value, if they are not discussed in relation to the socio-cultural context. In addition to this observation, it should be noted that the social scientific work benefits from the natural science. For instance the task of asking probing questions is facilitated by having a team of interviewers with a diverse interdisciplinary background knowledge.

The social scientific part investigates by means of RRA tools erosion and the potential for erosion. Focus areas are how the land is utilised, and which parameters influence on the farmers' choice of certain types of land use. Another crucial part of the social scientific work is to the investigate the of the locals' perceptions of soil erosion and to see how the phenomenon is understood and interpreted.

Many researchers have stressed the challenge of choosing the right methods to extract only the data that is necessary in order to obtain the complete and accurate information that is required for a particular research (see for instance Mikkelsen (1995). RRA can be seen as a methodology alternative to conventional science methods for international development research, planning, monitoring, and evaluation. It is used to gather, analyze, and deliver information from rural villagers in a time- and cost effective, accurate, contextual and insightful manner (Chambers, 1992; Messerschmidt, 1995; Mikkelsen, 1995). Therefore, the RRA can be useful in situations where the sources available for a survey are limited (Aalbæk, 1994). This is also the argument why we found that the tools of RRA would be appropriate for our nine day research, where the task was to collect sufficient quantitative and qualitative data to fulfil the objectives of the study.
The RRA-tools and the social scientific research design will be presented in detail in chapter three.

Natural scientific data can be grouped in two different sections. One is the soil erosion risk assessment part and the other has gathered data on hydrology. The risk assessment part will try to estimate the potential for erosion related to different types of land use, slope characteristics, soil properties etc. For this purpose the empirically based USLE (Universal Soil Loss Equation) is being used. The knowledge gained from this part has been used as a preliminary suggestion on the estimate of the potential for erosion in the area. The methodology of USLE is presented in detail in chapter four.

The dynamic part of the natural scientific research has been searching for hydrological indications of land use related soil erosion. In this sense, the use of hydrology can be seen as a possibility for seeking support and confirmation of findings from other parts of the research. The hydrological methods used is elaborated in chapter five.

3. Research approach of the social scientific part

The social scientific part has by means of social scientific methods investigated the actual soil erosion as it appears interviewing farmers in Tikolod. In the social scientific part it was investigated how the land is utilised, and which parameters influence on the farmers choice of a certain types of land use. Another crucial part of the social scientific work has been the investigation of local perceptions and knowledge of soil erosion to see how the phenomena was understood and interpreted by the people. Finally another objective is to investigate how social and institutional factors influence on the land use strategy among the farmers. To gather these data it was necessary to employ several different methods as we were both looking for very specific information about the land use system and more interpretative descriptions of the phenomena of soil erosion.
The social scientific data were collected using the following methods:

- 15 Semi Structured Interviews (SSI's)
- 1 Group Interview
- 2 Land use mapping sessions
- 1 Cropping Calendar session
- 1 Matrix scoring and ranking for crops grown

These methods are all part of what has been termed the Rapid Rural Appraisal (RRA) or Participatory Rural Appraisal (PRA)- methodology (Mikkelsen 1995)

3.1 Rapid Rural Appraisal (RRA) or Participatory Rural Appraisal (PRA)

RRA can be seen as an alternative methodology to conventional science methods for international development research, planning, monitoring, and evaluation. It is used to gather, analyse, and deliver information from rural villagers in a time- and cost effective, accurate, contextual and insightful manner (Chambers, 1992; Messerschmidt, 1995; Mikkelsen, 1995). Furthermore, the RRA can be useful in situations where the sources available for a survey are limited (Aalbæk, 1994). The RRA methods therefore seemed able to provide the qualities we were looking fore given the limited time available for the research.
The RRA and PRA-methodology are closely related and share many principles. The RRA and PRA are so to speak toolboxes containing various methods and techniques which can be used separately or in combination, by a research team or by an individual field worker, to help address broad researchable topics or specific technical tasks (Messerschmidt, 1995).

It can be rather difficult to establish a clear distinction between the PRA and RRA as many methods are categorised as both PRA and RRA. However, the PRA is more complex and comprehensive. Where RRA is a time- and cost effective way to extract information from an area on a certain topic the PRA is involving and encouraging locals to work themselves with their problems on their own basis (Mikkelsen, 1995). The data gathered are indeed based on local peoples participation and contributions in the interviews and exercises we undertook during the fieldwork. But our fieldwork did not aim to engage local people in a process of changing their practices nor to create an awareness about certain issues and it is therefore problematic to term it PRA. Therefore the term RRA will be used in the following even if many of the methods and issues discussed could also be termed PRA.

3.1.1. Semi-Structured Interviews (SSI's)

The purpose of this tool is to obtain specific quantitative and qualitative information from a sample of the population and gain a range of insights on specific issues (Case, 1990; Mikkelsen, 1995). A major benefit from using SSIs are - according to Case (1990), Casley & Kumar (1988), Mikkelsen (1995) - that they do not just provide the answers, but also the reasons for the answers. Individuals may more easily discuss sensitive issues as SSI helps the interviewer to become acquainted with community members and the villagers might perceive the outsiders as more objective.

SSIs are conducted with a fairly open ended topic-focussed framework which allows for a smooth flow of conversational, two-way communication (Casley & Kumar, 1988). Not all questions have to be designed and phrased ahead of time. When planning the SSI's we prepared a number of questions which focused on some specific topics we found to be relevant. All members of the group contributed to the list of questions which were organised in an interview guide and in this way the different scientific approaches were reflected in the interview guide. The interview guide contained all together 7 different topics: Everyday life, Institutional relationships, Income, Land Use, Erosion, Hydrology, Demography and Future. Doing the first interviews we soon realised that it was not possible to cover all topics in one interview and one interview would therefore only focus on 3-4 of these topics. Most of the questions asked in this survey were phrased as open-ended questions during the interviews which were in line with the topics in the interview guide rather than the questions stated there. This allowed both ourselves and the person being interviewed the flexibility to probe for details and discuss individual issues. This was found beneficial because of the possibilities of getting unexpected information that would not have been revealed by structured interviews. All members of the group did at least two interviews, but one member of the group - the anthropologist - was due to the force of his background involved actively in all interviews and sessions to create continuity and comparability in the investigation. During all interviews a researcher with natural scientific background was all ways present and made it possible to ask questions on specific soil erosion issues. One would lead the interview, and the other would take notes while the interpreter would translate. The interviews which took from 2-4 hours were conducted during the daytime or in the evening - in the fields or at the villagers' houses. Conducting the interviews in the field was beneficial since the possibility of observations of the farmers practices improved the probing questions considerably. At the end of each day the information gained was analysed.

3.1.2. Locating informants

Locating informants was bit more complex than planned and expected before we arrived in the village of Tikolod. The planned village meeting on our first day in the village was cancelled because of a funeral and when it was finally held the second day only few of the male farmers showed up. We were able to arrange informants for the mapping session the following day. At the mapping session we established a contact with a by-passer, a twenty year old young man from the village who helped us set up interview appointments with people who fulfilled certain criteria. The criteria set up for the informants were the following:

- They should be farmers in the watersheds of either the Bolotikon or Tikolod river
- Both young and elder farmers should be represented
- Both farmers with a lot of land and farmers with only a little land should be represented
- They should have fields with a variety in land use and steepness of the slopes

Most informants we identified together with the young man from the village, but we were also able to identify a few informants while doing natural scientific measurements in the field.
Other informants who should be mentioned is the officer at the regional Department of Agriculture and a ranger from the Crocker Range National Park.

3.1.3. Group Interview

By the end of the fieldwork 5 key informants, chosen to represent the variety in land use and age among the informants, participated in a group interview. The focus of the group interview was to discuss in a group what problems the farmers face in land use and to what extent soil erosion figure among these problems. These issues had been covered in the SSI's but making the farmers discuss it among themselves gave us an indication of the representativity of the information farmers had provided when interviewed alone.

3.1.4. Land use mapping

A general mapping session was the first social scientific RRA activity during the fieldwork. Three informants participated and were asked to draw a map of the area of Tikolod. Trying to be open-ended in our approach we encouraged the participants to include the information they themselves found important. Later we asked for more specific information such as boundaries of the Tikolod area and who owned specific fields. The map produced was brought along to all the SSI's and informants were asked to fill in their own fields as well as discussions concerning geographical issues could be anchored in the map.
By the end of the fieldwork 5 informants chosen because of their comprehensive knowledge of the Bolotikon and Tikolod watersheds produced a specific land use map. They were asked to include

information about: rivers, roads, fields, ridges marking the boundaries of the watersheds, owner of the field, size of the field (if possible), crop at the field, whether there was a grant on the field and locations of recent landslides (within the last year). The data in Appendix 1 is based on the information provided with this map.

3.1.5. Cropping Calendar

The relative short duration of the fieldwork gave us the opportunity to see for ourselves how the farmers farm their fields at that particular time of the year (mid October). To get an overview of what the land use looks like all year around we chose to ask 5 informants to establish a cropping calendar (see appendix 2). The cropping calendar provides information about work and crops not identifiable at the time of the fieldwork and gives a generalised picture of the land use cycle. Working with assessment of the risk of soil erosion it is important to know whether the soil is sometimes exposed totally to the falling rain. This is an important information when trying to estimate the Crop Management Factor for the USLE-equation and the cropping calendar served to provide this information also.

3.1.6. Matrix scoring and ranking for crops grown

The matrix scoring exercise identify needs and priorities and compare preferences/ priorities between groups (Case, 1990; Pretty et al., 1995). In our approach it served to investigate farmers motivation for growing various crops on their fields. They were asked to give each crop a score from 0-5 where five signifies "the most" or "the best" regarding certain qualities. The qualities of the crop they were asked to give a score was 1. to what extent the crops was used for food in the household, 2. to what extent the crop served as a source of income, 3. labour requirement cultivating the crop and 4. palatability, if the crop has a good taste. The scores are listed in Appendix 3.

3.2 Offsetting Biases

3.2.1 Cross-cultural communication

The SSI's seem to demand more concentration and co-operation by the interviewers/interpreter compared to more structured interviews. This is because new questions are made in relation to answers just given, making the accuracy of inter language communication very important. Posing questions during the interviews much emphasis was put into excluding western concepts and categories of the issues raised. One example is that instead of only using the term soil erosion questions would also concern soil fertility. Soil fertility was identified as to be a well known concept in Dusun as the Dusun until recently actually practised a fertility rite every year (Willams 1965; Appell 1966). Asking for fertility as well as the concept of erosion was therefore one way of trying to overcome the possible bias of cross-cultural communication.

3.2.1 Offsetting biases

The possibility of strategic answers is also a possible bias. By this is meant that the villagers might answer according to what influence they think our survey will have to their situation, e.g. if the villagers view a possibility of getting some kind of improvements then they might answer according to this. Another possible source of error, to our survey, by using the RRA tools for collecting data is that most of the knowledge is obtained through a translator, and we cannot exclude that some data might have been coloured or misunderstood by this. Talking with local people who spoke English and discussing findings with the Land Tenure group were some ways of cross checking the information provided by the translator. The Malaysian member of the group was also a source of cross checking the information from some of the interviews, but only when the communication was in Malay (most interviews were in Dusun).

3.2.1 Triangulation

Triangulation, or multiple strategies, is a method to overcome the problems and biases that stem from studies relying upon a single method or source of information. You gather the same information in another way (Aalbæk, 1994; Mikkelsen, 1995). In our investigation the different SSIs were used to cross check each other. The Group interviews and the scoring and ranking was used to cross check the SSIs, though grouping informants and let them discuss might have been dominated by some participants. These triangulations were very useful and encouraged further investigation. It also revealed misunderstandings and made us capable of making more precise questions at the interviews.

Though we have tried to eliminate biases during the fieldwork, the results presented in the following should be read having certain limitations in mind. A sample of 15 SSI's and a few RRA-workshops was sufficient to gain an overview of the issues of soil erosion during the fieldwork but to explore and understand the problem in detail further investigation must be undertaken. More interviews, broader sampling and the possibility to practise participant observation could positively contribute to bring about a more details and minimise biases.

3.3 Erosion from a social scientific perspective

3.3.1. Land Use

To investigate the actual soil erosion in the village of Tikolod related to the land use in the area it is crucial to understand the land use systems in Tikolod. At present, the land use pattern in the chosen sub-catchments along the rivers of Tikolod and Bolotikon is dominated by ginger and dry rice (appendix 1). Where it is possible the valley bottoms are often made into terraces with wet rice, but it does not dominate the land use in the watersheds as it only make up about 10 % of the fields in the watersheds (appendix 1). Rice whether wet rice or dry rice is mainly used for own consumption in the household. Other less important constituents of the local diet are banana, fish (farmed in ponds or in wet rice fields) and various fruits (especially durian is very popular). Fruits are both gathered in the forest and on fallow land but are also grown on the fields often inter-cropped with either ginger or dry rice. Fruits are used both for own consumption within the household and as a means of income. Ginger is at the moment unquestionable the most important cash crop farmed, and it covers app. 40% of all fields in the Tikolod watershed and app. 50% of the fields in the Bolotikon watershed. Dry rice makes up about 20 % of the land use in the watersheds. Ginger and dry rice are the major crops (covering approximately 60% in the watershed of Tikolod and 70% in the watershed of Bolotikon) which are farmed in a shifting cultivation system on slopes up to 50 degrees of steepness. The rest of the fields under cultivation are mainly covered by wet rice, fruit trees, rubber and oil palm.

Compared to nearby villages the growth of ginger dominates to a higher extent the land use in Tikolod. This is probably due to the fact that in the mid 1980's one of the farmers in Tikolod discovered that if a piece of primary forest is cleared for the first time ginger produces a higher yield compared to plots cleared after secondary forest. Other farmers adopted his innovation in land use and thereby created a shift towards dominance of ginger in the local land use. High market prices and a growing interest in income generating crops might have given farmers an incentive to favour ginger on the best fields. Ginger can be left stored in the ground for up to two years and harvested when prices are favourable. As it is now only few people grow a second crop after ginger because the land need to regain fertility. They leave the land fallow for a period after harvesting the crop, before it is then cleared and farmed again.

Previously dry rice covered most of the land. Dry rice is now usually used as the second crop after the first fallow period (the 2-4 year fallow period following ginger). Sometimes the dry rice is inter-cropped with tapiok (tapiok is actually the name of processed part of the cassave, but as this was the name used during the interviews this has been adopted in the following) which can stay in the ground for up to 2 years. Inter-cropping is the exception and is mainly practised with tapioca, coffee, durian and other fruit trees in the fields.

3.3.2. The fallow

The length of the fallow period might play a central role in relation to soil erosion. If a steep slope field is farmed several times in a row without being left fallow, the fertile top soil is gradually washed away and the yields can decrease dramatically if no fertilizer is added. To detect whether a piece of land has regained its fertility, some of the farmers employ the use of plant indicators. For instance the appearance of Tungoe, Tagahas and Pintap (all Dusun names) trees and a certain type of wild banana indicate that a piece of fallow land has regained fertility sufficient to be farmed again. One farmer said he was able to distinguish whether the piece of fallow land would be suitable for ginger or dry rice using plant indicators. The most fertile land would typically be allocated for the growth of ginger. Therefore ginger has typically been chosen as the first crop after clearing primary forest (burning primary forest generally leave more nutrient rich ashes than secondary forest).

According to several of the informants, the length of the fallow period has not changed noteworthy over the last 20 years. They claimed that the fallow period is now as then approximately 2-4 years for most farmers. Farmers with plenty of land seem to have a fallow period that is a bit longer, i.e. 4-7 years.
This is the case even if the population of Tikolod has increased from about 100 inhabitants in the late 70'ies to approximately 470 inhabitants in 1999 (population increased partly due to immigration from the village of Kionop in the National Park). If it is true that it hasn't lead to a serious decline in the length of fallows it is probably due to the possibility for the farmers to open up new land for agricultural purposes in the past. A possible explanation will be elaborated in the following y looking at the institutional relationships.

3.3.3. Institutional relationships

So far it has been possible for the farmers in the area to open up new land without having an approval (a grant) from the authorities. Farmers have started farming new land once they have applied for the land at the Land and Survey Department and informed the local chief about the application. From the time of the application until the land is surveyed the land has a status of "L.A". (Land Application). It is rather costly to get land surveyed which is a prerequisite for a final approval from the Land and Survey Department. It is not uncommon that it takes more than a decade from the application is submitted to the final approval is issued from the authorities. Many farmers have therefore proceeded and started farming the land without final approval i.e. without a grant for the land. In this sense lack of ownership has not prevented farmers from clearing new land and it has to some extent been possible for farmers and immigrants to obtain new land. Both the watersheds along the Bolotikon and Tikolod rivers are some of the areas that has been developed for agricultural purposes over the past twenty years. So far, lack of available land has not lead to a heavy intensification of the land use in the area with a shortening of the fallow period as a consequence. As such land tenure doesn't seem to have played a crucial role in terms of erosion up till now.
Land tenure might, however, play a key role in the selection of crops for land use. This is due to the fact that the Department of Agriculture provides subsidies to promote certain crops. The subsidies are only approved for land that already has obtained a grant and it is therefore likely that the government can promote certain crops on land with a grant.
In each of the two watersheds there were 7 plots where the farmers had obtained a grant for the land (appendix 1). Of these 14 plots (approximately 14% of all fields), 13 plots had a crop for which it is possible to obtain subsidies from the Department of Agriculture. The crops grown with subsidies are mainly wet rice, fruit trees and rubber. The only field with a grant that did not have any of these crops was planted with ginger. This strongly indicates that providing subsidies for certain crops can work as an incentive for the farmers in selecting what crop to grow.
In this way the Department of Agriculture can actually contribute to a shift in land use in the

future and promote certain crops and farming systems. Interviews with the farmers indicated that an intensification will take place in the near future. Several farmers would instead of leaving the land fallow after harvesting, plant long term crops such as fruit trees, rubber or oil palm.

If the tendency continues it can lead to the termination of shifting cultivation in the area in the future and transform the present shifting cultivation land use system towards long term crops such as fruit trees, rubber, oil palm etc. How this will affect the level of soil erosion in the watershed depend heavily on the way the long term crops are grown. An example with oil palm, which is one of the long term crops expected to be cultivated in the future, can exemplify this. Oil palm can according to one informant be planted on the steep slopes in the watersheds. Before planting the oil palm plant a platform is created where fertiliser can be added. The oil palm will be planted in the middle and weeds or a cover crop will cover the ground during the first years. After a few years the canopies of the oil palm trees will join and cover for the sun light. If no sun light reaches the cover plants they will eventually disappear and leave the soil exposed. If the soil is exposed during heavy rains soil erosion is likely to happen. Though the Department of Agriculture can facilitate trends in land use among the farmers soil erosion and means to conserve the soil has not been part of information provided by the agricultural extension officer. Only when farmers apply for subsidies they will receive a visit from an agricultural extension officer. The only purpose of the visit is to inspect whether the cultivated crop qualifies for a subsidy. Asking several farmers who they would consult if they were looking for a piece of good advice about land use, no one mentioned the agricultural extension officer or the Department of Agriculture. They would rather ask one of the successful and respected farmers in the village. This indicates that even if soil erosion is on the agenda in government or educational authorities the information and awareness is not provided in more remote villages.

3.3.4. Soil Erosion in ginger and dry rice fields

Interviews with farmers revealed that soil erosion caused the soil surrounding the root of ginger could be washed away. The exposure of the root leads to a decreasing yield when soil erosion is moderate and can cause a total removal in worse incidents. Rice can also be washed away during heavy rain, especially when the plants are young leading to a loss in yield and soil fertility. Plants being washed away will typically occur when small streams form during heavy rains as well as in the gullies on the fields. The local farmers' used plants being washed away as an indication of soil erosion. Land slides on the fields was also recorded as a problem that would occur on steep slopes during longer periods (2-3 weeks) of heavy rain.

3.3.5. Soil conservation

Practices with soil conserving effects were actually identified in the way the land is farmed but the rationale behind these practises was very rarely to conserve the soil. For example a few farmers put the felled stems of smaller trees across the field lying horizontally as contour lines on a 40 degree slope which to some extent can prevent the soil from being washed away. But when asked why he did this one farmer replied "because it makes it easier to walk".

In the gullies on some of fields he had also left some stems lying there - not to prevent soil erosion - but because it would be a lot more work to move them further away.

From these examples it can be seen that soil conservation practices can be identified in the land use practices in Tikolod but these practices are not linked with soil conservation by the locals themselves.

Other practices such as weeding the ginger fields are to some extent connected with preventing soil erosion. The weeds are only cleaned for the first 3 months after the ginger has been planted because the weeds otherwise would dominate and overgrow the ginger. After 3 months the ginger plant has gained sufficient height and the weeds are left to grow between the ginger, and the roots of the weeds fixate the soil to some extent. From a traditional yield optimising perspective the field should be kept clean of weeds at any time but in the very hilly area the weeds can prevent soil erosion to some extent. This practice is however not followed in the dry rice fields on the hills, maybe because the dry rice is more sensitive to competition from the weeds.

How the weeding is practised can also have an effect on soil erosion. If the weeds are pulled up of the ground by the roots the soil surface is disturbed, thereby making the soil surface more loose and easily removable by the rain. By means of herbicides as a chemical substitute for weeding it is possible to control the weeds without disturbing the soil surface. Therefore the use of herbicides can actually reduce the level of soil erosion caused by weeding (Tie, 1999). In Tikolod there seemed to be a tendency that young farmers (20-40 years of age) practised spraying their fields whereas elder (40 years -) and more conservative farmers were reluctant adopt this new practice. The considerable amount of time saved in weeding when using herbicides (chemical weeding) motivated farmers to adopt use herbicides. In the future it is likely that more and more farmers will adopt the practise of spraying which can reduce soil erosion caused by mechanical weeding. However the farmers do it to save time and increase yield and not to conserve the soil.

3.3.6. Local perceptions of soil erosion

Soil erosion does take place on the farmers fields in the chosen sub-catchments though it does not figure as a consequence of land use in the local perception of erosion whereby soil erosion is linked to the action of the rain.

When asked about the three most important problems farmers face in land use during a group interview, soil erosion didn't figure as a problem, whereas weather figured as a serious problem. When digging deeper into this answer it turned out that the problem with the weather was the rain that caused landslides, gully erosion and general movement of soil. They didn't see soil erosion as the problem but rather that the weather (that is the rain) was the problem.
This should not be taken as an indication that soil erosion is not a concept in Dusun. During the fieldwork at least three different concepts of soil erosion were identified:

1.)Norulun (Dusun) meaning "wash away"- general movement of soil
2.)Notuhan (Dusun) the dusun word for landslides
3.)Noung Kudan (Dusun) that is erosion of river banks and gully erosion on the fields.

Other local conceptions of soil erosion considered that "soil fertility was washed down" and that is why the soil fertility is better at the bottom of a slope than at the top.
From the interviews and workshops it appeared that soil erosion actually is a problem for farmers in Tikolod but they do not see it as consequence of their land use and they are not sure whether it can be prevented. The various soil conservation practices we were able to identify among the farmers in Tikolod (as elaborated in the previous section) were very rarely informed by an explicit local knowledge about soil conservation. Practices that actually conserve the soil were driven by other motivations/rationales such as saving time, easing the work and improving the yield. If we asked them "do you have any means to conserve the soil" the answer would be "no". This indicates that if soil conservation is actually imbedded in the local way of farming it can not be detected as an articulated local knowledge. Following a traditional northern scientific tradition many scientists have a tendency to see indigenous cultivation as grounded in local knowledge (Richards, 1993). In this way there is a tendency to credit local knowledge of agriculture with a spurious epistemic independence as if were the regular outcome of a process of 'peasant intellectualism' parallel in some way to the processes of intellectualism in northern academic life (Richards, 1993). Richards states that this assumption runs the risk of ethnocentrism, since it conveys the northern way of categorising the world to traditional knowledge systems. This assumption can also be traced in some anthropologists ways of conceptualising sustainable resource management as an inherent aspect of local culture and knowledge (Richards, 1993).
According to Richards the practise of non-industrialised rural (African) farmers is not an outcome of an isolated agronomic knowledge, but rather strategies improvised by the farmer (Richards, 1985). When identifying the local soil conservation practises among the farmers in Tikolod it is tempting to conclude that the practices are the outcome of a local knowledge about how to prevent soil erosion thereby ascribing the farmers with an explicit knowledge of a sustainable soil erosion management system. But as described above the soil conservation practices only rarely followed a rationale to conserve the soil and as Milton has argued sustainability is a coincidental consequence of human activity and other factors. Therefore sustainability can be an aspect of the local practise

but should not be regarded as a natural outcome of local farmers striving for harmony with the environment (Milton, 1996), based on an articulated local knowledge. This finding is important to keep in mind when discussing soil conservation practices in the discussion in chapter 7.

4. Soil erosion risk assessment

In this chapter the soil data collected from the case area will be analysed. The findings will be based on the laboratory results and on data from literature. An estimation of the parameters in USLE will be carried out. The estimations will then be used to determine the average annual soil loss in relation to dry rice and ginger. The exact figures of soil loss are not the main interest, but the ratios and relations between the two types of crops. To look for indicators supporting that erosion actually has taken place Cation Exchange Capacity (CEC taken as a measure for fertility) data, from respectively the top and bottom of each plot will be compared.

4.1 USLE

Models have been used for decades in the field of erosion risk assessments. Working within the topic of predicting future erosion risks we have chosen to use the Universal Soil Loss Equation (USLE) to estimate the annual soil loss related to land use. The USLE, originally developed in the United States in the 50´s was a model designed to predict average annual soil loss caused by sheet and rill erosion. In contrast to newer computer animation models which typically are physically based models, USLE was created on an empirically basis consisting of 10.000 plot years in the USA (Wischmeier et al., 1978).

USLE has been applied many places outside USA because of its relative simplicity and ease of parameterisation. However the USLE has many constrains to it - especially when applied in the tropics. First of all it was developed on the basis of the *conditions in the USA* and secondly it does not consider the impact of runoff on erosion in a direct way. Thirdly it can not be applied directly to a specific year or a specific storm/rain event. Fourthly, it does, when working on catchments scale, not deal with the deposition of sediments like some of the computer models do. Therefore there has been made several modified models of USLE like: MUSLE (Modified USLE), RUSLE (Revised USLE), MUSLET (Modified USLE for Tropics) (Renard et al., 1994; Cooley 1983).

USLE: $A = R * K * LS * P * C$ (Wischmeier et al., 1978).

In the following we will define each factor and explain how it is determined in our case:

4.1.1 R: Rainfall erosivity index

Erosivity is the ability of the precipitation to cause erosion and it is partly the impact of raindrops and partly the consequences of the runoff that the precipitation generates. The ability of the rain to generate erosion depends on its intensity and drop size distribution. The erosivity of a rainstorm depends very much on the amount of kinetic energy or momentum contained in the rainstorm. According to Lal and Elliot (1994) the relationship of kinetic energy intensity is described by Kinnel (1981) in two ways: (a) the rate of expenditure of the kinetic energy in the rainfall. The units in this one are *energy per unit area per unit time.* (b) Says something about how much kinetic energy there is per unit quantity of rain. This is measured in *"units of energy per unit area per unit depth."* (Lal and Elliot, 1994), where the term "depth" refers to amount of rainfall. The unit could for instance be [MJ/ha/mm]. The momentum is related to mass and velocity and says something about the impact caused by mechanical stress that leads to detachment of soil aggregates (Ibid.). For given vegetation and soil conditions, one storm can be compared with others, and in this way it is possible to create a numerical scale of erosivity values (Selby, 1993).

The raindrop ability to cause erosion or the R factor is responsible for four effects that are:
1). The impact causes desegregation of the soil particles.
2). The soil particles can be laterally displaced (creeping).
3). The splash-effect can splash soil particles into the air (saltation).
4). The soil particles can be selected or sorted by the impact caused by raindrops.

When estimating the Erosivity Index (R) of the USLE Equation, Wischmeier et al., (1978) made, according to Lal and Elliot (1994) and Selby (1993), a relation between the rainfall parameters and the soil loss. This was done by using the total kinetic energy (E) of a rainstorm in its maximum 30-minute intensity (I30) (Lal and Elliot, 1994; Landon, 1991; Selby, 1993). This reflects both the potentials of raindrop impact and the turbulence made in overland flow. The energy in a storm can be calculated by using an energy-intensity equation:

$$E = 0.119 + 0.0873 \log 10 \times I \quad [MJ/ha/mm]$$

(Lal and Elliot, 1994).

An event with a large amount of rainfall may not cause much erosion if the intensity is low. Impact of raindrops larger than 5 mm is very rare because raindrops usually break into smaller drops when bigger than 4.6 mm. The speed will also be limited because the acceleration will only continue until the friction equal to the gravitational force of the drop. (Selby, 1993). Studies from around the world have shown that this causes problems using the I30 to describe erosivity. This I30 often leads to overestimation of the erosivity when working with tropical rainfall data. Because of this Wischmeier and Smith (1978) suggest that no I30-values over 75 mm / hr should be used. In Malaysian Borneo, Dr. Tie uses the I30-value of 75 mm/hr (Ibid.), he recommends the use of Foster et al's (1981) equation to estimate the R factor since it has proven to give good estimations:

<u>R = 0,276P x I30/173,6 = 214,6 (US units)</u>

R = 0,276P x I30 = 0,276 x 1800 x 75 = 37260 (metric units)

(Where P = annual rainfall in (mm) and I30 = max. Annual 30 min. rainfall intensity (mm/hr).

Morgan (1986) also recommends this method as acceptable in estimating the R factor. On the other hand he makes clear that when values estimated from Foster et. al. equation is very low two other methods can be used.

The first method takes the mean annual precipitation (P)	= 1800 mm
and multiplying with mean value of R.	= 1800 x 0,5
Erosivity index R in US units	= <u>900</u>
Erosivity in non US units	= 900 x 173,6
	= 155700
The second method only uses kinetic energy KE >25 J / m2 / mm.	= 9,28P – 8838
	= 9,28 x 1800) – 8838
	= 7866 J / m^2
Convert to Nm	= 7866 Nm / m^2
Convert to kgf m	= 7866 x 0,102
	= 802,3 kgf m m^2
Multiply by I30 (75 mm / hr)	= 802,3 x 75
	= 60172,
Erosivity in metric units	= 60172,5 kgf m m^2 x mm /h
Convert to erosivity index R in US units	= 60172,5 / 173,6
	= <u>346,6</u>

The best result will, according to Morgan, be achieved when taking the average value of the results from methods 1 and 2. In this case the erosivity will be in US units:

	= (900 + 346,6)/2
	= <u>623,3</u>
In metric units	= (155700 + 60172,6) / 2
	= 107936,1

The values estimated from the Foster equation is not considered low compared to other values, therefore this value (214,6) will be used in the further calculations.

4.1.2 K: Soil erodibilty factor

This factor is a measure of the soil susceptibility to be eroded. It depends on soil texture, structure, organic matter content and permeability and it quantifies the cohesive, or bonding character of the soil type and its resistance to dislodging and transport due to raindrop impact and overland flow. The K-factor is usually determined from the soil-erodibility nomograph in the USLE handbook, which was derived from data collections in the United States. However, this practise is questionable when working in the often organic-rich soils of the tropics differ a lot from e.g. the Great Plains in the US. Therefore to derive the K-factor directly from plot experiments is better. When doing a "hit´n´run" project like ours this is a major task and we will have to rely on the nomograph and try to support it with literature. Due to Morgan (1986) close correlations between measured and predicted values from the nomograph have been found in west Java Indonesia. He states that it seems reasonable to use the nomograph when organic content is between 1 and 4 percent which means that there is no need for extrapolating the values of the nomograph. Furthermore, Stephen (1995) found from a study on 10 different Malaysian soil types that the USLE nomograph correlated well with the simulated laboratory plots and he recommends the use of USLE nomograph in Malaysia for determining the relative erodibilty of soils as a cost effective, rapid and simple tool. Since none of our soil samples had an organic content above 4 percent the use of the nomograph is further acceptable. Our soil samples were analysed at Pusat Penyelidikan Pertanian (Agriculture Research Centre) in Kuching for the following parameters: Soil-texture (USDA), organic C, Cation Exchange Capacity (CEC). From these results and the nomograph the k-factors have been estimated for each plot. In the results from the laboratory the particle size are specified, so we assume that silt are contains silt plus fine sand according to the USDA.

E.g. Field 1 (dry rice):

Average sand %	= 44,15
Average (silt + fine sand) %	= 23,22
Organic-C %	= 2,62
First estimate K	= 0,08

When estimating the final K-factor we have made the assumption from our observations that the structure is a fine granular - which equals about 2 in the nomograph. The obersvation of a relative high clay content has been compared with the data of Stephen (1995) on acrisol (FAO) soil types that the permeability is about 4-5 in the nomograph (see appendix 1 for the results):

Final K-factor = 0,14

The final K-factors vary from 0,12 - 0,19. Comparing the final K-factor values with other K-factors found by Stephen (1995), Hatch (1979) in Malaysia they are all < 0,2. Due to Morgan (1986) K-values between 0,1-0,2 correspond with a soil of medium erodibilty.

4.1.3 LS: Topographic factor

The two factors length and slope highly influence the erosion process. Steeper slopes induce higher velocity of overland flow. Long slopes also results in increased velocity since water accelerates and accumulates from a larger area. Thus both can result in higher erosion potential, but not in a linear way (e.g. in the tropics soil loss is proportional to the square of the slope). It is convenient to join the factors into a single term: - LS-factor. We have used the equation given by Morgan (1986) to calculated the LS-factors for slopes steeper than 5 °:

$$LS = (\sqrt{L/22}) \times (0{,}065+0{,}045 \times S+0{,}0065 \times S^2) \text{ (Morgan, 1986)}$$

The data on LS-factors are presented in appendix 4.

4.1.4 P: The protection - or support practice factor

The P-factor in the USLE is defined as the ratio of soil loss with a specific practice to the corresponding soil loss with up-and-down-slope tilling. The factor is supposed to take into account practices that reduce erosion. More specifically it involves practices that modify the effective length of the slope. This is typically ploughing or tilling along the contour, strip cropping, interception drains or terracing. It is important to notice that conservation cropping (e.g. sod-based rotation) and management (e.g. crops residues left on the field) are included in the C-factor.
In our case none of the mentioned practices are being applied to the fields of dry rice and ginger. Therefore we will set the parameter to equal one, i.e. the maximum value (Wischmeier, 1978).

4.1.5 C: The crop-management factor

The crop-management factor C is the ratio between the amount of soil loss under specific crop-cover management conditions and the soil loss from bare soil (Morgan 1986). According to Morgan (1986) the estimated C factor is the C value for each plant stage period weighted accordingly to the percentage of the mean annual erosivity within that period and summed to give the annual C-factor. Due to Wischmeier et al. (1978) the effects of crop canopy, residue mulch, incorporated residues, tillage and land use residual are all incorporated in the calculation of the C factor. The estimated C factor for ginger will in this project be an average of the ratios for soil loss at the different crop stages, found in table 5 row 159 in the USLE handbook, multiplied with the R-factor for the different growth periods. A lot of research has been done on dry rice in relation to soil erosion, so the C factor for this will be obtained from literature.

In Tikolod they mainly grow dry rice and ginger. Ginger can - according to our informants - be planted from February to March. The following three months they weed the ginger mechanically (and spray with herbicides) After three months they leave the ginger fields. Weeding will reduce the ground cover and this might lead to increased erosion. If the ginger roots are exposed be this they will be damaged and yield declines. The ginger can be harvested 7-8 months after planting, but they usually leave it in the ground for up to a year after planting (see appendix 2).

The dry rice is seeded in August. Through August and September the farmers protect the small rice plants by spraying with herbicides and mechanically weeding. In late September the rice plants are 80 cm. When the rice plants are almost mature they are inter-croped with tapioca (Appendix 2). Therefore in the estimation of the C-factor for the dry rice values for tapioca are incorporated. During the whole growing period the fields are weeded. The rice plants are harvested in January. In August they can harvest the tapioca.

From studying literature on the C factor for different crops it seems that there has not been done any research on ginger before. We find that potato is the most appropriate plant to be compared with ginger since they are both root crops with rather small roots. The values for potato in table 5 row 159 in the USLE handbook is used in this report as much as possible. In the US six crop growth stages are identified (Wischmeier, 1978), but they generally do not fit the shorter growing periods in the tropics. When Singh et al. (1983) did C-factor estimations in India, they only used 3 crop stages, this is the general practise in India (Rao, 1981). Therefore only 3 crop stages are used for our estimations. The C-value for the third growing period will be a bit lower that the value listed in table 5 row 159, this is due to the fact that the weed at that time takes much space in the field. The values in table 5 are from a potato field it is where it is assumed that the space between the plants are weeded. Due to the morphology of both ginger and rice they never reaches a complete cover of the soil only partial cover. The needed vegetation cover percentages for estimating the C-factor for ginger were gathered on the 6 plots, which were in different growth stages.

Ginger:
Stage 1. Planting, germination and seeding establishment stage to 1 months of crop stage growth (canopy cover 5-10 %). From the 1st of February to the 30th of April.
Stage 2. One months to 3 months of growth (canopy 18-20 %). The 1 of May to the 31st of July.
Stage 3. Final growth stage, from 3 months to crop harvest (canopy cover 37 % and ground cover 12 %). The 1st of August to the 1st of February. The C-factor for ginger is estimated in table 5.1.

Table 5.1: An estimate of the C-factor for ginger

Crop stage	C-value	Adjustment factor (% R-Value)	Estimated C-factor
1	0.64	0.25	0.16
2	0.56	0.28	0.16
3	0.25	0.47	0,12
C factor for the year			0,44

Source: C-values are taken from Wischmeier, 1978 table 5 row 159.

Comparing the C-value for ginger with other root crops the high value is not out of proportion. The root crops generally have higher values than other crops.

The rice field is from August to October only covered with rice, in the end of October beginning of November the tapioca is inter cropped. In January when the rice is harvested the field is left with cassava. Roose (1975) and Singh et al. (1983) have estimated the C-factor for rice. Roose was working in West Africa and Singh in India. The annual values found by Roose and Singh is respectively 0.1-0.2 and 0.28, by calculating the average of these values, the estimated C-factor for rice is 0.215. Since the field is covered with tapioca for the rest of the year a C value for tapioca is used here (Morgan, 1986). Roose (1975) estimated it to be 0.5. The estimated C-factor for rice will then be: (0.215 + 0.5)/ 2 = 0.36.

4.1.6 Results

After having estimated all the factors of the USLE model it is possible to calculate the predicted average annual soil loss, A for both rice and ginger. We will use the span of different slopes for each crop to make an interval as suggestion for the average soil loss connected to respectively dry rice an ginger. We will at the end try to estimate the soil loss for the two sub-catchments.

Table 5.3: Average annual soil loss for ginger. Fields market with R are located in the Tikolod river sub-catchment, and fields without are located in the Bolotikon river sub-catchment:

Ginger	Slope	R	K	LS	P	C	A t/ha/year
Field 1	30°	214,6	0,19	7,06	1	0,44	283,9
2	40°	214,6	0,14	22,60	1	0,44	669,5
6	20°	214,6	0,16	5,03	1	0,44	170,3
R3	40°	214,6	0,14	19,57	1	0,44	579,8
R4	30°	214,6	0,15	7,48	1	0,44	237,4
R5	20°	214,6	0,12	3,15	1	0,44	79,9
Average A							**336,8**

Table 5.2: Average annual soil loss for dry rice. Fields market with R are located in the Tikolod river sub-catchment, and fields without are located in the Bolotikon river sub-catchment:

Dry rice	Slope	R	K	LS	P	C	A t/ha/year
Field 3	40°	214,6	0,14	20,21	1	0,36	489,9
4	30°	214,6	0,18	7,89	1	0,36	245,9
5	20°	214,6	0,19	2,39	1	0,36	78,6
R1	30°	214,6	0,15	9,98	1	0,36	259,2
R2	20°	214,6	0,13	3,05	1	0,36	68,6
R6	40°	214,6	0,14	19,57	1	0,36	474,4
Average A							**269,4**

4.2 CEC and soil erosion:

As part of the procedure of estimating the K-factor in the USLE we had 24 soil samples analysed. Beside from the data on texture and organic-C content we had the samples analysed for CEC values. Since each plot had samples taken from both the top and the bottom of the slope we were looking for evidence of soil erosion where organic-C and to some extend clay had been washed down the slope. If erosion has happened it is reasonable to believe that the CEC and thereby the fertility is highest at the bottom of the slope, which was claimed by some of the farmers. From a t-test analysis of the values under the hypothesis that the mean of differences (μ) = 0 there was no significant. Which means that there are no differences between top and bottom. However, when grouping the data in terms of crop and slope, and thereby getting the chance of eliminating non-significant figures we found:

- There are no significant difference between the rice and ginger in terms of CEC differences from top to bottom.
- When using the CEC value of the top as a covariant there **were significant** CEC differences for the 40° slopes, but still not for 20° and 30° (appendix 6).

This means, that from the recorded soil data we can not tell whether there is a difference between rice and ginger concerning the erosion. Likewise there were no significant on 20° and 30° slopes, but we can justify that the steep slopes (40°) have a significant higher CEC_{bottom} compared to the CEC_{top} .

4.3. Summary

From the USLE calculations we find that ginger has a greater C-factor than dry rice. This corresponds with the predicted average annual soil loss, which is considerably greater than that for dry rice. From our calculations on CEC we found a significant difference between CEC_{top} and CEC_{bottom} on the steepest slopes, but not for the other slopes gradients. This figure of CEC can indicate that erosion has taken place on the 40° slope. We did not find any significant differences between dry rice and ginger, which mean that the CEC findings cannot support the USLE findings that ginger is connected to more soil loss than dry rice. It should be mentioned that all the A- values are surprisingly high, but it is the relative ratio between rice and ginger which is most interesting.

5. Drainage and suspended matter.

5.1. Methods, description in details.

When working with hydrology, the precipitation is of central importance. The term precipitation covers rain, snow, hail, sleet and small drops from fog (Gunston,1998). In tropical areas it will mainly be rainfall that is important. Working in the field in the tropics it can be necessary to collect primary rainfall data to supplement secondary data if any is available. Primary data can be collected with a number of rain gauges depending on the size of the study area and how precise the data need to be. It is also important to take into consideration how often the rain gauge should or can be checked. Some rain gauges have to be checked every day, but when using a "tipping-bucket" rain gauge connected to a data logger, time and intensity of rainfall will be registered automatically. Both intensity and total amount of rainfall are important factors with respect to soil erosion. Working, e.g. in a catchment, it would be an advantage to have several rain gauges to get a good estimate of rainfall in the area. When this is not possible the selection of the gauging site should be done carefully, even though it can be very difficult to find that one spot to represent a relatively large, topographically varied area.

When doing hydrological fieldwork in a river, it will often be essential to get measurements of stream flow, water level, discharge and maybe suspended material. When trying to estimate the stream flow it is important to take into consideration Gunston (1998):

1) The shape or physical parameters of the channel cross section are not the same at the different measurement sites.
2) The cross section area changes as the water surface level moves up and down.

3) The shape of the channel will change and the speed of this process depends very much on the river bed materials.
4) The speed/velocity differs across the cross section of the river.
5) The deepness of the river.
When gauging a river it is important to be aware of why, where and when the measurements are carried out, and how precise the measurements have to be. The gauging can in principle be done in two different ways: Usually measurements are supposed to be carried out so often that the instrumentation should be installed permanently. Less often, portable equipment can be used on an infrequent basis. When the gauging method should be selected, several factors should be taken into account, and some of these being:
1) Is the streamflow in the river continuous or irregular/seasonal?
2) The shape and straightness of the river in the area where the measurements are carried out. A straight non turbulent area with linear flow is preferred.
3) The depth and width at the gauging site.
4) Variations between flood flows and low floods.
5) A station can be damaged when the river is being overtopped.
6) The required accuracy and frequency of the measurements can vary with the purpose of the research and the stream flow pattern for the specific river.
(Gunston, 1998)
The area of the cross section can be found using measurements of the river's width as well as the depth in a number of intervals across the river. When estimating velocity it is common practice to use a current meter and combine this to data on the cross section area. If a current meter is not available or the stream is too weak or too strong a floating object over a known distance can be used to measure velocity (Gunston, 1998). When discharge is calculated, a very simple equation can be used:

Discharge = cross section area of river x velocity of flow x the time period (Gunston, 1998).

5.2. Application of methods

We found a river of significant size (the Bolotikon River) and decided to do measurements in the related subcatchment. On the second day a station was set up over the river, which the next eight days should be used in the measurements in the river. Having set up the station, it was decided to set up another station over the Tikolod River. By doing this, it becomes possible to compare the drainage of the catchments related to the two rivers. This was done on the amount of water (the discharge), the amount of suspended material and the turbidity values. Linked with data gathered on rainfall, a crude picture of the response in drainage to specific rainfall events can be established.

The two stations were established about 20 metres upstream from the merging point of the rivers. The possibility to do measurements and take samples in both rivers at practically the same time, made these locations very favourable.
It was considered a problem though, that the Tikolod River had a sharp turn about 40 metres upstream from the station. This had a shade effect for the flow on the inside bend of the turn, and there were small fluvial deposits as point bars. To avoid influence from this, velocity measurements in Tikolod River were made on a stretch only 15 metres long compared to the 20-metre stretch at the Bolotikon Station. This secured that stream flow was relatively regular, non turbulent and linear on the stretch where the measurement was done. The stations were anchored at the banks and a string was placed over each stream perpendicular to the brinks. The string was marked for every half meter. The water depths were measured below where the strings were marked so the cross section areas of the rivers could be calculated as the sum of the areas of 1/2 meter wide rectangles. This method is described by Gunston (1998). At stage=0, the cross section area was calculated to 1,975 m2 for the Bolotikon River and 3,200 m2 for the Tikolod River.

The first day the stream flow was measured in River Bolotikon using a current meter. After this session it was realised that the current meter was not functioning correctly. There were not any direct solutions to this since it could not be repaired nearby. This forced us to use the less precise, yet still hydrologically accepted, method of using travelling speed of floats. Water bottles partly filled with water were used. The floats travelled a distance of 20 meters in River Bolotikon and 15 metres in River Tikolod. Instead of 14 and 17 measurements appropriate when using the current meter, we only measured velocity using eight floats pr. session. This is considered appropriate since it was not possible to do the measurements in equal intervals across the river. Under a flooding (see below) we were only able to measure over a distance of 10 metres in the Tikolod River due to security concerns.

When stream flow velocity was measured, the corresponding water turbidity was measured using a back scanner turbidity meter which gives a rather precise measurement of the visibility in the analysed water sample. The values for turbidity were established as an average of at least three samples taken at different places across each river.

It was only possible to get a few water samples analysed in laboratories. Turbidity samples on the other hand are cheap, easy and fast to make which makes it possible to do a lot of measurements. It was decided to take turbidity samples and then later correlate turbidity to the amount of suspended matter mg/l. Unfortunately, the last four days of the research period did not have any noteworthy rainfall events. Because of this water samples supposed to calibrate the conversion from turbidity to the amount of suspended matter, were only taken at very low values of turbidity, and hence they were of no use. To compensate for this, the experience of Bartholdy (1999) is used to establish a correlation: Bartholdy has used the back scanner method in Danish tidal areas and has found that turbidity-values [NTU] can be converted to a measure of suspended matter [mg/l] simply multiplying with a factor 2. (E.g. 10 NTU» 20 mg/l). It is quite problematic to convert experience from a marine tidal area to a specific river where totally different circumstances might rule. The obvious shortcomings and limitations to this method must cause a healthy dose of caution when concluding on the derived data. Even if this is far from "best practice"- solutions, it was still the best method available. Furthermore, findings showing differences between the rivers, if imprecise in absolute values, still show ratios that must be expected to be quite correct.

There were only two rain gauges available so primary data on rainfall is not considered very reliable or representative of the area. At first, the rain gauges were placed following a principle of covering the Bolotikon catchment as good as possible. This implied that one gauge (Bolotikon) was placed on a hill around one kilometre upstream from the rivers merging, whereas the other gauge (Tikolod) was placed only 40 metres upstream. The problem was then that these locations made the comparisons between the two catchments difficult. Therefore, after a few days the rain gauge near the merging, was moved further up the Tikolod catchment. This was considered more appropriate because this could give a better picture of the direct response in discharge and the amount of suspended material to specific rainfall events in any of the catchments.
The highest I30-value measured during the research period was around 25-27 mm/hr

5.3. Findings

Most of the time the rivers were flowing calmly. A flooding occured at one point but during normal conditions the Bolotikon River had an average discharge of about 1,3 m3/s and the Tikolod River had about 2,3 m3/s. The corresponding amounts of suspended matter in the rivers were on average around 10,52 mg/ l and 28,72 mg / l. When considering that the Bolotikon and the Tikolod catchments had the sizes of 18,4 and 32,4 km2 respectively, this means that, with caution, we can estimate the average load of suspended material passing the two stations per second per square kilometer catchment to 0,58 [g / s /km2] and 1,64 [g / s /km2] for the Bolotikon and the Tikolod respectively. (See tables). Taken sample for sample, the amount of suspended matter leaving the Tikolod cachment was between 1,6 and 4,9 times higher than the similar Bolotikon values. -This strongly indicates that the catchment connected to the Tikolod River is somehow more exposed to erosion compared to the catchment of Bolotikon River. A variety of reasons for this can be mentioned. As land use related vegetation cover- and soil management differences offer possible reasons, topography, different rainfall patterns or differences in geology cannot be ruled out as possibly important parameters.

A flooding happened on the 21. of October around 17,30 p.m. Fortunately, the hydrology special team was situated at the hydrology station, when this happened. Measurements were taken place in both rivers when a "tidal wave" came rushing down the rivers. In a matter of only 2-3 minutes the water level had risen 40 cm in the Bolotikon River and possibly also around 40 cm in River Tikolod. It was not safe to enter River Tikolod, so we had to make a qualified estimate standing on the brink. The flooding lasted at least an hour. 44 minutes after the initial "tidal" wave was observed discharge were still increasing in both rivers. The huge amounts of water made it impossible to make methodologically correct measurements of stream flows since besides the violently flowing water, stems with diameters with up to 50 cm, were washed down the rivers. Measurements had to be carried out in a way that would not endanger the research team, so we threw fruits in the rivers and measured velocity this way. The travel time for the 20-m distance in Bolotikon River was 7,7 seconds and for 10 m in Tikolod River it was around 2 seconds. Due to the higher water surface level, the cross section area expanded from 1,975m2 to around 4,975m^2 in the Bolotikon River and from 3,2 m^2 to around 6,8 m^2 in the Tikolod River.

The discharges during the flooding can be calculated as:
Bolotikon River: (1,975 + (7,5 x 0,4)) [m^2] x (20 m / 7,7 s) = 4,975 [m^2] x 2,597 [m/s])=12,9[m^3/s]).
Tikolod River: (3,2 + (9,0 x 0,4) [m^2] x (10 m / 2,0 s)) = (6,8 [m^2] x 5,0 m/s » 34,0 [m^3/s]

Turbidity was tried measured at this point but the range of the turbidity meter was exceeded in both rivers. Unfortunately, we did not at that time know, if water samples could get analysed at a laboratory. Because of this we did not have any containers for water sampling during the incident. It could have been very interesting to see how much suspended material there was in the water, and it could have helped us correlate the turbidity [NTU] with the amount of suspended material [mg/l]: Simply adding controlled amounts of demineralised water could have given an infinite amount of matching NTU-mg/l values (Bartholdy, 1999) If we assume that the turbidity values were in the range of 1000, which were the maximum limit the samples went over, we get values of 2098,8 and 1408,7 [g/sec/km^2]for the Tikolod and Bolotikon. This illustrates the importance of extreme events in geomorphology.

Not counting the values estimated during the flood, the amount of suspended material in the Bolotikon and Tikolod respectively, was on average 10,52 [mg / l] and 28,72 [mg / l]. When related to the size of the catchments, the average measured througflow of suspended matter has been around in the 1,64 [g / s /km^2] Tikolod catchment and 0,58 [g / s /km^2] in the Bolotikon catchment.

5.4. Summary

The rainfalls in the two sub catchments were, except for one incident, not that diverse in intensity. It could have been interesting to collect diverse rainfall data, and see these compared with the measurements in the river and investigate if any correlation could be made. The flooding can be correlated with the high intense rainfall incidents in the two sub catchments, starting about an hour before the flooding started.

In the rivers, more measurement-sessions were undertaken in the morning, compared to other times of the day. In getting an insight in the hydrological conditions, it would have been an advantage to have data covering whole days. In the period the measurements were carried out, the rain was falling very arbitrary. The rainfall data from the two catchments shows that the rain is minimal at night.

During the eight-day stay in the village of Tikolod, many measuring sessions in the two rivers took place. Lack of possibility to get a sufficient amount of water samples analysed in local laboratories, turbidity was measured in stead, for later correlation. These measurements were related to discharge in the rivers which again was seen in relation with the local rainfall data in the two sub catchments. The discharge in the two rivers was corresponding very well with the size of the two catchments; both had a factor 1,8 in difference.

6. Discussion

The findings presented in the previous three chapters have outlined a range of aspects regarding how land use influence on soil erosion in the farming system in Tikolod. In this chapter the various findings are correlated and discussed across the different disciplines, which have been employed to accomplish the findings. Approaching the discussion interdisciplinary we aim to address the issues of soil erosion from different perspectives and thereby create a more complete assessment and evaluation of how land use influence soil erosion in the village of Tikolod.

6.1 Choice of crop

The cultivated type of crop is highly important concerning soil erosion. This is due to two things: The management that the crop implies - in terms of weeding requirements and the time of year that planting or seeding is optimal. Secondly, the crop itself has a direct influence on soil loss in terms of morphological and physical characteristics. As an example different shapes and sizes of leaves influence on the drop impact and the different type of root systems influence on how well the soil is kept in place. Furthermore different types of harvesting disturb the soil in different ways (e.g. harvesting root plants in comparison with crops where only parts above ground are used). When estimating the C-factor for the USLE all these properties for the specific type of crop are taken into account.

Due to these differences of crop properties, crop choice and decisions on crop choice are highly important. According to observations and information from the land use mapping (appendix 1) the land use in the chosen sub-catchments is dominated by ginger and dry rice making up approximately 2/3 of cultivated fields. But what are the motivations for the farmers to choose these crops to that extent? From the Matrix Scoring and Ranking workshop we tried to investigate the farmers motivations for growing the different crops (appendix 3). In the matrix dry rice figures mainly as used for consumption within the household and that it is valued for its good taste. On the other hand, ginger is mainly a cash crop and it receives a very high score in terms of income, but a very low score in terms of consumption within the household. It seems therefore reasonable to conclude that the motivation for growing ginger is to get an income and the motivation for growing rice is to provide a nutritious and well tasting food for the household.

Another factor that motivates the farmers to grow a certain crop is low labour requirement. Looking at the scores of ginger and dry rice it shows that dry rice (and wet rice) has a relatively lower labour requirement than ginger. Comparing this information with a similar investigation undertaken by a research team on agriculture in Patau (appendix 6) revealed a difference between the two villages in the score given ginger and wet rice for labour requirement. Wet rice figure as having a higher labour requirement than ginger in Patau which is the opposite picture of Tikolod. In Patau wet rice dominates the land use more than in Tikolod and is sold as a cash crop besides the use for consumption within the household. A possible explanation of the difference in the villagers' evaluation of the higher labour requirement for growing ginger in Tikolod as compared to Patau could be that they simply grow more ginger in Tikolod and put more labour into the cultivation of ginger. This indicate that the scores given express the actual labour put into growing a crop (total amount of time spend on the crop) rather than the relative labour requirement of a crop (time spend pr. yield unit) in at least one of the two Matrix scores compared. Other cash crops grown in Tikolod figure relatively low on the income score - durian, rubber and langsat being the highest with a medium score. The importance of ginger as a cash crop is therefore significant and alternative cash crops and income opportunities must be found if the growth of ginger is reduced. Changing the land use in the direction of more long term land use such as fruit trees, oil palm and rubber is an option some of the locals consider as future possibility. The effect of these trees on erosion have a decreasing effect (table 5.2).

Developing the land use into more long-term use do represent several difficulties. First of all we find that land tenure would be a key element in this development, since it seems unlikely that any long term investments will be made by the villagers as long as the land rights are not secure. At present only 15% of the fields have a grant according to the land use map (see chapter 4 and appendix 1) this seem to have an effect on the land use. Of the 14 fields with a grant in the chosen sub-catchments 13 had a crop which qualifies for a subsidy from the government. Secondly, it is an investment, which many villagers probably can not afford. This calls for the opportunity of either favourable loans or that government subsidies are sufficient and the arrangement of these functional.

As mentioned above the crop choice is influenced by many different factors such as taste, income and institutional relationships like land tenure and subsidies. Dry rice and ginger, which make up 2/3 of the land use, are almost entirely cultivated on land without grants. When farmers have a grant fruit trees and other subsidised land uses are profound.

6.2. The cultivation of rice and ginger related to soil erosion

The crop management of dry rice and ginger are important in relation to erosion. Data on the crop management properties of ginger and dry rice was determined through the interviews and the cropping calendar (appendix 2).

We found that weeding in ginger fields is less intensive and weeding stops completely after 3 months. In contrast the rice fields are weeded mechanically and sprayed with herbicides throughout the whole growing period, generally leaving the soil more exposed. This supports that ginger should have a smaller C-value than dry rice. However, as mentioned earlier most root crops do have a high C-value due to the disturbance of the soil surface when harvested. This is an important difference between ginger and dry rice. Dry rice is cut leaving the roots in the soil where ginger when harvested are pulled out of the soil leaving the soil more disturbed and with no roots left. From our calculations we found that ginger has a slightly higher C-factor than rice. However, the statistical calculations on CEC did not indicate any significant difference on ginger and dry rice (appendix 5). This mean that we can not support that a higher C value for ginger leads to more erosion for ginger than for dry rice. But to relate the C-value of ginger and rice to other crops is still valid.

Another concern when investigating the relation between crops and erosion is the coincidence of heavy rainfall when the planting and harvesting take place. The farmers in Tikolod seeded the rice in July-august and harvest in January-march. Ginger was also planted from February to end of March making that particular period the time of the year with most soil disturbance. The farmers themselves claimed this period to be the rainy season and the time of the year with the most severe soil erosion. This is contradicted by rainfall data from the area over the last 30 years. These data show that January to March usually have the same or less rainfall than the rest of the year. The fact, that the months of the year with the least rainfall is perceived by the farmers to be the rainy season, indicates that it is not the rain which causes the increased soil erosion, but rather the agricultural practise. A possible explanation why the farmers consider the rain to be a larger problem in the months of January to march could very well be that the soil is more prone to erosion during these months due to disturbance of the soil surface. Even if this is the case the farmers still consider soil erosion to be caused by the rain only and not by the their land use activities.

When discussing soil erosion caused by farmers' land use activities, it is important to note that dry rice and ginger is cultivated in a shifting cultivation system. The most important characteristic about the shifting cultivation is the fallow period which is discussed in the following.

6.3. The importance of the fallow

Shifting cultivation is an agricultural practice, which by some is considered primitive and unproductive (Berg, 1993). This could be part of the agenda when the Department of Agriculture is encouraging the farmers in Tikolod to turn their shifting cultivation practises into more permanent systems by offering subsidies to wet rice, fruit trees and oil palms.

Looking at the field plots in the two sub catchments investigated, the agricultural systems seems to involve considerable problems with soil erosion. One of the calculations states that there is an annual soil loss of approximately 669,5 kg / ha /year. This seems as a lot and it would be impossible to practice agriculture in the long term if it was not for the fallow. If the fallow period, where the soil regains fertility, is taken into account the average annual soil loss could be reduced. Comparing the results of A found in the USLE with other results of A found by Stephen (1995) in Thailand. The values calculated for Tikolod looks very high. This can be due to a number of factors e.g. that the P-factor equals 1 at all the fields. The fact that P is one makes a huge difference conserning A on the slopes with 40°.

Tikolod has experienced an expansion in population from about 100 to around 470 over the past 20 years, which has caused an increased need for agricultural land. The migration was partly caused by the establishment of the Crocker Range National Park in 1984, where people moved from the village of Kionop which is situated within the boundaries of the park. According to the interviews of farmers this has not, as one would expect, led to a decrease in length of fallow periods. A reason for this could be that farmers have been able to open up new land without having an approved grant for the land. The use of marginal land in the chosen sub-catchments has increased to meet the growing demand. This means that the cultivation of steep slopes with a high erosion risk has become more frequent.

6.4 Soil conservation – a local practise

Soil conservation concerning erosion was not a big issue among the farmers according to our investigation. The local perception was that soil erosion was caused by the rain and farmers were very reluctant to believe that they could reduce it. When interviewing the farmers the issue of soil erosion was approached from different angles and with different concepts trying to identify a local knowledge about processes of soil erosion. Since the farmers did not link soil erosion with their land use, we tried to detect soil conserving effects in their agricultural practices. This was done to see if local knowledge maybe was imbedded in agricultural practices rather than explicitly articulated knowledge. Interviewing in the fields, a few practices with soil conserving effects were identified such as: stems lying horizontally across the slope of a rice field, stems left in streams, roots left in the ground after burning the fallow land and the use of herbicides instead of weeding manually (see chapter 4). However, none of the farmers did accredit these practices for their soil conserving effects. The outspoken motivation was to save labour. The only agricultural practice they confirmed would have a soil loss reducing effect, was letting the weeds grow in ginger fields when the crop is three months old.

From the work with the USLE the LS-factor is considered highly important for the amount of soil loss. The influence of this factor can through conservation practises be reduced. By shortening the length of the fields the velocity of surface runoff decreases and thereby soil loss decreases. This can be done in several ways, e.g. by doing strip cropping. The slope is the single parameter in the USLE with the highest impact on erosion. Therefore levelling and redesigning of the fields by building terraces have a great effect. This could also be part of the government's intensive for offering subsidies for wet rice.

Compared to other farming systems in South East Asia it is very limited to what extent soil conservation is practised on the steep slopes in the Tikolod area. Terraces in order to conserve the soil and fertility of the soil is common other places (Sharma, 1999). To establish terraces demand a lot of labour and it has been questioned whether or not the benefits are larger than the costs (Kiome et al., 1995). Another less labour requiring soil conservation practices could be building contour bunds along the contours of the slopes. The contour bunds are built from soil and crop residues (Sharma, 1999). Compared to terraces, contour bunds are fairly cheap, easy to establish and provides a good protection against soil loss (Kiome et al., 1995). Contour bunds and similar contour line techniques, which are supposed to decrease the velocity of the running water, have been practised successfully in indigenous farming systems around the south pacific region. In the Tikolod area only one farmer practised similar techniques (placing stems along the contour lines), and apparently he did so because it made it easier to walk on the very steep slopes of the field.

When the issue of local knowledge of soil erosion was addressed earlier (in chapter 4) it was contested that local knowledge always lead the rural farmers in direction of the most sustainable agricultural practices striving for living in harmony with the nature. Looking at Tikolod the land use includes growing crops on fields with a steep slope - gradients more than 40°. Through the work with USLE we found that this practise highly influence erosion. Furthermore we found significant differences of top- and bottom CEC on the 40° slopes - also indicating erosion. This fact makes it interesting to discuss what could be done to prevent soil erosion from happening. Through qualitative interviews with the farmers we were not able to identify that local farmers are aware that their land use practices actually influence on soil erosion. If conservation practises are introduced in order to minimise erosion in the future, it is important that the farmers become aware of the positive and adverse effects of their own practices.

At the moment the agricultural extension officer from the Department of Agriculture or any other agency does not provide this kind of training/education. The only implicit indication that soil erosion is an issue in the policy of the Department of Agriculture is that they provide subsidies for long-term crops (but only for land with a grant). The rationale behind these subsidies might as well be that shifting cultivation by many is regarded as a dyeing practise, which is unsuitable and old-fashioned.

Whether shifting cultivation is abandoned or not it is still relevant to have means to control soil loss. As elaborated (in chapter 4) the shift towards long term crops does not prevent soil erosion in itself. It is highly important that long-term crops are supplemented with cover crops to prevent soil erosion. If farmers are trained in these issues in the future, their own practices can be used as a starting point. By enforcing and maybe supplement (eg. contour bunds) the allready existing practices the training will more likely follow their own rationale and not be rejected.

6.5. Differences found between the Bolotikon and the Tikolod catchment

The hydrological work found a difference between the two sub-catchments in the amount of suspended matter in the rivers. It was concluded that even if the validity of the results in terms of the absolute numbers can be questioned, there still seems to be evidence of a significant difference in the ratios of suspended matter pr. square km catchment. Most likely this difference is due to a greater extend of soil erosion in the Tikolod sub-catchment.

One possible parameter causing a difference, can be differences in the types of crops cultivated. An early direct observation suggested that there seemed to be a difference between the sub-catchments in terms of the ratio of areas cultivated with dry rice- and ginger respectively. This is not possible to support with any other findings. At the time the official land use maps became available, we realised that they did not cover the sub-catchments under study. This was one of the reasons why we conducted another land use mapping session for the two specific sub-catchments. Even though the map was made by insightful villagers and contains lots of useful information, unfortunately it is not suitable for extraction of data on sizes of fields. The information we got from the RRA-derived land use map shows that, at least when measured in number of fields, there is no significant difference in the crop distribution considering the two sub-catchments. The hypothesis of the differences being caused by differences in the ratio of crops under cultivation cannot be rejected, but it cannot be proven either.

Another possible explanation might simply be differences in the ratio of land cultivated compared to the total area of the sub-catchments: The fact that the Tikolod catchment is about 80% bigger than the Bolotikon, implies that Tikolod should have more than 1,8 times as much land under cultivation. This can not be supported by the land use map or any other source of information. But it should be mentioned that according to the land use map, there is a tendency in Tikolod to cultivate plots close to the river. In Bolotikon the trend is apparently to cultivate plots quite a distance from the river compared to the Tikolod practice. Therefore runoff from the fields in Bolotikon will more often pass through vegetation belts on the way to the river. A most important vegetation belt in these terms will be wet rice cultivated on terraces. Terraced wet rice will lead large amounts of water through large basins thus slowing the velocity of the runoff considerably and will lead to sedimentation of solids detached further uphill. This seems to offer at least part of a likely explanation for the differences in sub-catchment releases of solids. Especially the cultivation of wet rice makes a difference here, but other plant belts might be adding to the importance of the process. Pre-river sedimentation can not be regarded as a solution to soil loss and declining yield in the uphill fields. However on a sub-catchment- or farm level the process can be described as a recapturing of fertility that elsewhere would have been lost. Several wet rice farmers stated during interviews as well as informal conversation, that it is not necessary to use fertilisers. This further supports the hypothesis of terraces fixing nutrients and organic matter washed down from upstream.

Finally, differences in rainfall, geology, soil properties, topography and the expansion of newly cleared land could cause differences in suspended matter between the sub-catchments. But we do not have any relevant data confirming these explanations.

6.6 Discussion of methodology

Broad ranges of methods have been used to investigate the relation between land use and soil erosion in Tikolod. Soil samples, measurements of slope characteristics, gathering rainfall data, measuring stream flow and suspended matter in the river water and finally social scientific data gathered by the use of semi-structured interviews and various RRA-workshops as already described in the previous chapters. A large amount of data has been gathered using the various methods to describe the research questions set up in the objectives. Gathering data using one or a few of these methods it might be possible to describe some aspects of land use and soil erosion. Working together in an interdisciplinary way has expanded the possibilities of approaching the problem and combining the USLE, RRA and hydrology and in a way created a synergistic effect both during the research and when analysing the data afterwards.

When interviewing the informants in the SSI's a member of the group with natural science background was always present. Especially when asking for soil conservation practices the nat. science background contributed positively to detect any soil conserving effects of the local practices (e.g. stems lying along the contours on the slope) even when the locals did not recognise it themselves. When planning the interview sessions it was prioritised that the interpreter and the one member of the group with anthropological background should participate in all interviews to secure continuity in the process and comparativity of the data gathered during the interviews. As we interviewed some informants several times the second interview could easily be repeating and overlapping with the first if the interviewer was not the same. The four participants with natural scientific background participated in at least two interviews each. Shifting the interviewers changed the interview situation relatively often which off course gave a broader range of contributions but it also had the back draw that a new person was introduced to the interview situation four times during the fieldwork. The research design in the social scientific part was adjusted to meet need for some specific data in the natural scientific investigation. Choosing to work with the sub-catchments of the Bolotikon and Tikolod rivers and focus the land use investigation dry rice and ginger made it interesting to sample the informants following certain criteria. These criteria were set up in order to meet both social scientific and natural scientific interests. Social scientific methods and findings have indeed also contributed to the natural scientific investigation. The first land use mapping created and overview of the area. The first mapping did not only provide an overview of the area but also an estimate of which crops were cultivated must frequently, rice and ginger. This was in line with the observations done in the fields. Estimating the factors in the USLE specific information on the soil preparation and crop management was important. Due to the short time of our stay it was only possible to collect data on the soil preparation and plant management factors for that particular time of the year. Working with the parameters in USLE there is not a lot of data available for the tropics. The cropping calendar provided information about these practises and made it possible to make an estimation for the rest for the year. The RRA-workshops provided a lot of information useful in both the natural and social scientific approach. The information gathered in these groups sessions (Land use mapping, Cropping Calendar and Matrix scoring and ranking for crops grown) is rather structured and easy to digest compared to the data gathered through SSI's. But without having the SSI data as a reference it would have been impossible to assess the validity of the data collected in the RRA workshops. The SSI's are time consuming but the qualitative interview method is the only way to explore the local perception of soil erosion and to assess whether the data from the RRA-workshops are representative. Due to their more descriptive nature this information could of course not be covered in natural science measurements but natural science findings has also helped to discuss some of the social scientific findings. This was the case when farmers considered January to march to be the rainy season in the SSI's but rainfall data from the hydrological survey shows that these three months receives less rain than the rest of they year. In this case natural scientific measurements added new meaning to a social scientific observation.

Perhaps the most important contribution from the interdisciplinary approach was the mutual exchange of information and the final correlation of the findings from the various disciplines. The social scientific data has contextualised the natural scientific findings. The measurements undertaken in the USLE serve to estimate the actual soil loss pr. year, but only taking present factors into account. By implying social scientific research it has been possible to get information about the rest of the year, the past but also to investigate if any future changes in land use are expected to happen. Furthermore the social scientific research has provided information about farmers motivation for choosing certain crops and served to assess to what extent the farmers consider soil erosion to be a problem related to their land use. Taking social and institutional factors into account it has therefore been possible to give recommendations for how the issue soil erosion can be addressed in the future in the area.

The natural scientific method has enabled us to describe both the physical process of soil erosion and to evaluate the qualities of rice and ginger. In addition to this it has also served to quantify and make it possible to assess the size of a possible problem with soil erosion. The social science methods used provided information whether soil erosion is a problem from the perspective of local individuals, but it is hard to quantify how big a problem it is in terms of environmental impact. For this purpose the natural science methods contributed significantly.

7. Conclusion

The overall objective of the research was to investigate relations between land use practises and actual erosion as well as potential erosion. This has been done using an interdisciplinary approach. The overall benefit has been a synergism in the interdisciplinary working process. Natural science has provided background knowledge, which has supported the interview situation but also served to describe physical processes as well as quantifying the soil erosion. Social science findings have contextualised the natural scientific findings and investigated local perceptions of soil erosion. Information about farmers' motivations for growing certain crops and the history of land use are issues not always taken into account applying the USLE-method. However, the interdisciplinary approach also has disadvantages. The working process has given good results but a lot of hours have passed clarifying interdisciplinary misunderstandings, often discussing in terminology not familiar to all group members. This task has provided a positive experience and revealed new strengths and back draws of the various disciplines and the interdisciplinary approach.

When looking at the two sub-catchments of Tikolod and Bolotikon we found that the amount of suspended matter per square kilometer differs between the rivers. Many possible explanations have been brought up, but we find that the most likely is the location of hill rice- or ginger fields in relation to the rivers. In Bolotikon the fields are located further away from the river as compared to Tikolod. This can be expected to cause a decrease in the amount of suspended matter leaving the sub- atchment, because runoff is being lead through basins in the form of wet rice terraces, reducing the velocity of the water. This will make eroded material sediment locally. Even if this does not solve the field-specific problem, this can be viewed as beneficial due to two reasons: 1) Fertility is regained for the benefit of local cultivation, 2) The problems with sedimentation and siltation further downstream can be reduced.

Farmers in Tikolod do have a knowledge of soil erosion and they were able to identify and describe several different processes of soil erosion on their fields. By asking farmers about variations in fertility and problems with weather or water quality, plenty of evidence was found that villagers do experience problems with erosion. In Dusun at least three different concepts of soil erosion exist describing the processes of gully erosion (Noung Kudan), land slides (Notuhan) and the general movement of soil (Norulun). Local plant indicators of fertility was also observed. But soil erosion is according to local perception caused by the rain and is not seen as a consequence of land use. Most informants considered January-March to be the rainy season even if the rainfall is higher the rest of the year. The local perception might consider this period to be the rainy season, because agricultural practices cause soil erosion at this time of year.

Shifting cultivation is still the dominating land use system in Tikolod with ginger and dry rice covering approximately ½ and 1/5 respectively, of all fields in the chosen sub-catchments. Rice is valued for its good taste and is mainly for own consumption whereas ginger is the single most important source of income in the village. These qualities of the crops are the main motivating factors for farmers to grow them. Land tenure seem to play an important role in terms of farmers choice of crop. There is a tendency that fields with an approval from the authorities (fields with a grant) are cultivated with crops for which it is possible to obtain a subsidy (wet rice and long term crops such as fruit trees and oil palm.). In the future it is likely that the land use system will change towards more long term crops.

By applying the USLE, we intended to find estimates for potential erosion with respect to the most common crops for the two sub-catchments, namely ginger and dry rice. From the results, ginger is supposed to have the highest erosive effect. However, the absolute figures seem unreasonable high, and to look at the difference between ginger and rice is more interesting. The high values of assessed potential erosion may arise from the conservation practice factor "P." It should be stressed however, that the figures might be quite precise. The recent opening up of marginal steep-gradient land can be expected to have a serious impact on soil erosion: The USLE showed that the S in the LS-factor is very important: The LS-value is at least doubled by increasing the gradient from 30*C to 40*C. This means that an attempt in reducing soil erosion should be put into avoiding the use of marginal lands of very steep slopes or soil conservation practices such as to build terraces or contour bunds should be employed.

From USLE we found a difference in C-value between ginger and dry rice with respect to soil loss. However, the findings on the CEC calculations could not support this. Therefore we cannot recommend one crop for the other in terms of soil conservation practises. But from the findings from USLE and CEC we feel quite confident in stating, that the steep slopes are the most important factor-, and crucial to soil erosion.

Soil conservation practices were identified in the farming system but the farmers did not link this effect with these practices. The motivation behind the various soil conservation practices identified, was typically to save time or make the work easier. The farmers did not ascribe erosion reducing effects to their soil conservation practices. Only leaving weeds in ginger was known to "prevent the rain from washing the root of the ginger away". Taking into account that farmers in the area farm very steep slopes (up to 50 degrees gradients) thereby causing soil erosion, it seems important that soil conservation is employed in the agricultural practices. The agricultural extension officers from the local Department of Agriculture do not provide any training in soil conservation practices and are not paying the farmers frequent visits. If action needs to be taken to reduce the problem of soil erosion training and improvement of local farmers' awareness of how land use influence soil erosion seems like a good place to start. The training can follow the rationale of the locals by enforcing and supplementing the already existing practices and thereby reduce the risk of being rejected. In this way changes in agricultural practice can reduce soil erosion.

The overall objective of the research was to investigate relations between Land Use practises and actual erosion as well as potential erosion. This has been done using methodologies that usually are not combined. The overall benefit has been a synergism in the interdisciplinary working process. Natural science has provided background knowledge, which has supported the interview situation. It has served to describe physical processes as well as quantifying the soil erosion. Social science findings have contextualised the natural scientific findings. Information about farmers' motivations for growing certain crops and the history of land use are issues not always taken into account applying the USLE-method. However, the interdisciplinary approach also has disadvantages. The working process has given good results but a lot of hours have passed clarifying interdisciplinary misunderstandings, often discussing in terminology not familiar to all group members. This task has provided a positive experience and revealed new strengths and back draws of the various disciplines and the interdisciplinary approach.

When looking at the two sub-catchments of Tikolod and Bolotikon we found that the amount of suspended matter differs between them. Many possible causes have been brought up, but we believe the most likely is the placement of the fields in relation to the rivers. In Bolotikon the fields are located further away from the river and this will decrease the amount of drainage to it.

Farmers in Tikolod do have a knowledge of soil erosion and they were able to identify and describe several different processes of soil erosion on their fields. By asking farmers about variations in fertility, problems with weather or water quality, plenty of evidence was found that villagers do experience problems with erosion. In Dusun at least three different concepts of soil erosion exist describing the processes of gully erosion (Noung Kudan), land slides (Notuhan) and the general movement of soil (Norulun). But soil erosion is according to local perception caused by the rain and is not seen as a consequence of land use. Most informants considered January-March to be the rainy season even if the rainfall is higher the rest of the year. The local perception might consider this period to be the rainy season because agricultural practices cause soil erosion at that time when it rains.
Shifting cultivation is still the dominating land use system in Tikolod with ginger and dry rice covering respectively app. ½ and 1/5 of all fields in the chosen sub-catchments. Rice is valued for its good taste and is mainly for own consumption whereas ginger is the single most important source of income in the village. These qualities of the crops are the main motivating factors for farmers to grow them. Land tenure seem to play an important role in terms of farmers choice of crop. There is a tendency that fields with an approval from the authorities (a grant) are cultivated with crops which it is possible to obtain a subsidy for (wet rice and long term crops such as fruit trees and oil palm). In the future it is likely that the land use system will change towards more long term crops.

By applying the USLE, we intended to find estimates for the potential erosion with respect to the most popular crops for the two sub-catchments, namely ginger and dry rice. From the results ginger is supposed to have the highest erosive effect. However, the absolute figures seem unreasonable high, and to look at the difference between ginger and rice is more interesting. From USLE we found a difference, but the findings on the CEC top –bottom could not support this. Therefore we can not recommend one for the other in terms of soil conservation practises. However from the findings we feel quite confident in stating, that the steep slopes are the most important factor-, and crucial to soil erosion. This means that an attempt in reducing soil erosion should be put into avoiding the use of marginal lands of very steep slopes or to build terraces on the steep slopes or contour bunds.

Soil conservation practices were identified in the farming system but the farmers did not link this effect with these practices. The motivation behind the various soil conservation practices identified was typically to save time or make the work easier. The farmers did not ascribe erosion reducing effects to their soil conservation practices. Only leaving weeds in ginger was known to "prevent the rain from washing the root of the ginger away". Taking into account that farmers in the area farm very steep slopes (up to 50 degrees of steepnes) thereby causing soil erosion it seems important that soil conservation is employed in the agricultural practices. The agricultural extension officers from the local Department of Agriculture do not provide any training in soil conservation practices and are not paying the farmers frequent visits. If action needs to be taken to reduce the problem of soil erosion training and improvement of local farmers awareness of how land use influence on soil erosion seems like a good place to start. The training can follow the rationale of the locals by enforcing and supplementing already existing practices.

8 References

Appell G. N. 1966: The Ethnography of the Dusun-speaking Peoples of Sabha. Sarawak Museum Journal, vol 14, 28-29

Aalbæk, A. 1994: Preparing Investigation of Methods for Surveying Tree Seed Denmands Among Farmers in Tanzania, Royal Vet. And Agri. Uni; Copenhagen, Denmark

Bartholdy, J., 1999: Personal communication, Copenhagen

Beek, W. E.A. van, 1993: Processes and Limitations of Dogon Agricultural Knowledge. I 1993 Hobart, Mark: An Anthropological Critique of Development. The Growth of Ignorance. London. Routledge.

Brooks, K. N., 1993: Challenges in upland conseravtion: Asia and the Pacific, Regional Office for Asia and the Pacific (RAPA), Food and Agricultural Organization of the United Nations (FAO), Bangkok, 1993. RAPA publication: 1993/5.

Case, D. D 1990: The Community's Toolbox- the idea, methods and tools for participatory Assessment, Monitoring and Evaluatiio in Community Forestry, Community Forestry Field Manual, Forest, Trees and People, FAO, Vol 2

Casley, D. J and Kumar, K. 1988: The Colletion, Analysis, and Use of Monitoring and Evaluation Data, 4 ed. The World Bank, Washington, D. C, USA

Chambers, R. Saxena, N. C. Shan, T. 1989: To the Hands of the Poor, Intermediate Techonology Publications, London, UK

Cooley, K. R., and Williams, J. R., 1983: 'Applicability of the universal soil loss equatuin (USLE) and modified USLE to Hawaii', in El-Swaify, S. A., Moldenhauer, W. C., and Lo, A. (eds), soil erosion and conservation, Soil Conservation Society of America, 509-522.

Croll, E & Parkin, D, 1992: BUSH BASE: FORST FARM. Culture, Environment and development. London. Routledge.

Ellen, R. 1986: What Black Elk left unsaid: on the illusory images of Green primitivism. 1986 Anthropology Today 2, 6: pp.8-12.

Department of Environment, Malaysia, 1996: Guidelines for the Prevention and Control of Soil Erosion and Sedimentation in Malaysia. Department of Environment, Ministry of Science, Technology and the Environment, Malaysia.

Gunston, H., 1998: Field Hydrology in Tropical Countries. A practical Introduction. Intermediate Technology Publications, London.

Ismal, W. A., 1997: 'The Impact of Hill Land Clearance and Urbanisation on Runoff and

Sediment Yield of Small Catchments in Pulau Pinang, Malaysia' in Human Impact on Erosion and Sedimentation (Proceedings of Rabat Symposium 56, April 1997). IAHS publ. No. 245, 1997, 91-100.

Kinnel,P.I.A. and L.M. Risse 1998: USLE-M: Empirical modelling rainfall erosion through unoff and sediment concentration. Soil Sci. Soc. Am. J. 62, 1667-1672

Kirkby, M. J., 1980: 'The problem' in Kirkby, M. J., and Morgan, R. P. C. (eds), Soil erosion, Wiley, 1-12.

Lal, R., 1975: 'A Brief Review of Erosion Research in the Humid Tropics of South East Asia' in Greenland, D. J. and Lal, R. (eds) , Soil conservation and management in the humid tropics, Wiley, 203-213.

Lal R. and Elliot, W., 1994: Erodibility and Erosivity (chapter 8 from unknown book)

Landon., 1991: Booker Tropical Soil Manual, Annex G, Longman.

Messerschmidt, D.A. 1995: Rapid appraisal for Community Forestry: The RA Process and Rapid Diagnostic Tools, IED Participatory Methodology Series, Internation Institute for environment and development

Milton, K.1996:Environmentalism and cultural theory: exploring the role of anthropology in 1996 environmental discourse. London. Routledge.

Mikkelsen, B., 1995: 'Methods for Development Work and Research. A Guide for 1995 Practitioners' London. Sage

Morgan, R. P. C., and Davidson, D. A., 1986: Soil erosion and Conservation, Longman.

Napier, T. L., Napier A. S., and Tucker, M. A., 1991: Soil and Tillage, Elseveir, 20(1991) 365-382

Norman, M. J. T., Pearson, C. J. and Searle, P. G. E., 1995: The Ecology of tropical food Crops, Cambridge, second edition.

Prety, J. N, Guijt, I. Thompson, J. Scoones, I 1995: A Trainers Guide for Partitioners, Sage Pub. New Dehli, India.

Rao, Y. P., 1981: 'Evaluation of cropping management factor in the Universal Soil Loss Equation under natural rainfall conditions of Kharagpur, India' in Proc., Southeast Asian Regional Symposium on Problems of Soil Erosion and Sedimentation. Asian Inst. Tech., Bankok, Thailand. 241-254.

Renard, K.G. and Freimund, J.R., 1994: Using monthly precipitation data to estimate the R-factor in revised USLE, in Journal of Hydrology 157 (1994) 287-306.

Richards, P.1985: 'Indegeneous agricultural revolution'. Unwin Hyman. London.

Richards, P. 1993: 'Cultivation: knowdledge or performance?' In Mark Hobart (ed.) An anthropological critique of development. London. Routledge.

Roose, J. E., 1977: 'Application of the Universal Soil Loss Equation of Wischmeier and Smith in West Afica' in Greenland, D. J. and Lal, R (eds), Soil censervation and management in the humid tropics, Wiley, 177-87.

Selby, M. J., 1993: Hillslope Materials and Processes, Oxford University Press.

Singh, G., Babu, R., and Chandr, S., 1983: 'Research on the universal soil loss equation in India' in El-Swaify, S. A., Moldenhauer, W. C., and Lo, A. (eds), soil erosion and conservation, Soil Conservation Society of America, 496-508.

SLUSE -Malaysia 1999: Online information on the fields course, http://www.geogr.ku.dk/sluse/index.htm

Stephen, E.A.O.,1995: A comparative study of the erodibility of some Malaysian soils. Msc. Thesis, University of Sains Malaysia.

Tie, L., 1999: Personal communication, Kuching, Malaysia

Williams, T. R. 1965: The Dusun, a north borneo society, Holt.

Wischmeier, W. H. and Smith, D. D. 1978: Predicting rainfall erosion losses - a guide to conservation planning. Agriculture Handbook No. 537 (U.S. Department of Agriculture, Washington, DC).

Appendix 1

Land use data

The data listed in this appendix are based on information provided by 5 local farmers from the watersheds of the Bolotikon and Tikolod rivers, during a land use mapping – workshop. The farmers were asked to include specific information about: land use (crop, intercropping etc.), contour lines, who is farming the field, land with a grant on, fields with recent landslides. The result was a rather detailed map of the land use in the watersheds.

Land use in S. Bolotikon watershed.

Crop	Number of plots	Percentage of plots
Hill rice	11	18,33%
Ginger	30	50
Fruit trees* (mainly Durian)	11	18,33
Wet rice	5	8,33
Maniok	1	1,66
Coffee (intercropped)	1	1,66
Oil Palm (intercropped)	1	1,66
Total	60	100%

Land use in S. Tikolod watershed.

Crop	Number of plots	Percentage of plots
Hill rice	7	17,07%
Ginger	17	41,46
Fruittrees* (mainly Durian)	7	17,07
Wet rice	3	7,32
Rubber	2	4,88
Maniok	2	4,88
Coffee (intercropped)	2	4,88
Oil Palm	1	2,44
Total	41	100%

* On approximately half of the plots with fruit trees, the trees are intercropped with only a few trees in a Ginger or Hill rice field. It is therefore important to note that hill rice covers a larger percentage of the land than fruit trees even if the figures in the matrixes above are equal.

Land use on land with a grant

In each watershed there were 7 plots where the farmers had obtained a grant for the land. Of these 14 plots (approximately 14%), 13 plots had a crop for which it is possible to obtain subsidies from the Department of Agriculture. The crops grown with subsidies are mainly Wet rice, fruit trees and Rubber. The only field with a grant which did not have any of these crops was planted with Ginger.

Appendix 2 **Cropping Calendar** for one rice-field and one ginger-field, from fallow to fallow.

May -cutting/clearing for dry-rice (no big trees) -clearing the bushes -teams of 12 persons 2 acre per day	June -cutting big trees -2 acre per day with chainsaw (2-3 persons) -drying at least 25 days between June-July -they do not sell the logs (use for gullies)	July -burning in July (everybody burns the fields at the same time) -1 acre takes ½ hour -they work together if there is fields nearby which can't be influenced by the fire -after rain they clean the field plots -letting weed grow until August	August -the dry-rice is seeded and after two days the weed is removed/killed by spraying -they help each other with the rice-seeding (30-40 persons) -40 people can do more than 6 acre/day	September -protecting the small rice-plants through all September -herbicides, weeding, rat-poison -if the wild plants grow randomly they prefer weeding -no fertiliser -in late September the rice plants are about 80 cm.	October -go to fields and maintain their rice-fields -inter-cropping with Tapioca (when the rice is all most mature)
November -checking the rice field (small houses in the fields) -cleaning a new fallow area for ginger (like May) -clearing, cutting, burning same procedure as dry-rice (one-two weeks between clearing bushes and logging) -tapioca is inter cropped	December -checking the rice-fields -ginger = rice (June) -burning the becoming ginger-fields	January -rice is harvested (4 people one acre in one week) -all most everybody finish harvesting -ginger = rice (July) -corn is inter-cropped where they do not overshadow the ginger	February -no more rice left -Tabioca is taking the time on the fields. Do not take much time -planting ginger	March -no work on Tabioca fields -planting ginger	April -no work on the Tabioca fields -maintaining ginger (spraying, weeding)
May -no work with Tabioca -maintaining ginger (spraying, weeding)	June -no work with Tabioca -ginger from previous year and last January is sold	July -no work with Tapioca -leave ginger, weeding will expose soil to rain which will destroy the roots	August -harvest Tabioca (still young), mostly for own consumption -leave ginger	September -leave rice-field for fallow -leave ginger -ginger from February can be harvested	October -leave ginger -ginger from March can be harvested
November -leave ginger, ginger can be left in the ground for about 8 months, before it starts to rot	December -leave ginger	January -leave ginger	February	March	April

Appendix 3

Matrix Scoring and Ranking for Crops

(Number in boxes refer to overall rank pr. Criteria; min. score is 0, max. score is 5)

Crop / Criteria	Hill rice (Tidong)	Wet rice (Runan)	Ginger (Layo)	Fish (Kolan)	Coffee (Kopi)	Oil Palm (Kelapa Sawit)	Maniok (Tabioka)	Banana (Pundi)	Durian	Rubber	Langsat
Food	5	5	1	3	3	3	3	4	3	0	3
Income	1	1	5	2	2	2	2	2	3	3	3
Labour Requirement	4	3	5	2	5	4	2	2	3	5	3
Palatability	5	5	2	3	3	2	4	3	5	0	4

Appendix 4: Soil & plot data for the two sub- catchments of Tikolod and Bolotikon

Soil data Catchment A (Bolotikon)

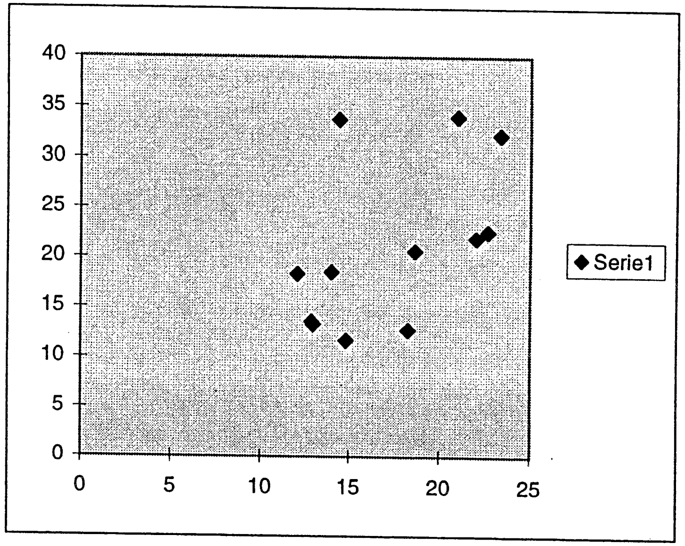
Field	Soilsampl	CEC	Sand %	Silt %	Clay %	org. C %	K-factor	LS-factor	Slope %
#1	1	18,64	44,89	21,93	33,18	2,42	0,14	7,05	58
	1A	20,66	43,41	24,5	32,09	2,83			
#2	2	21	38,57	37,47	23,95	2,62	0,18	22,6	84
	2A	34,08	44,7	33,19	22,11	5,97			
#3	3	22,04	46,41	37,13	16,45	3,9	0,19	20,21	84
	3A	21,97	43,82	34,57	21,6	3,74			
#4	4	12,96	56,89	23,28	19,82	1,95	0,15	7,88	58
	4A	13,31	56,6	23,75	19,64	1,74			
#5	5	14,82	64,12	17,65	18,23	2,06	0,13	2,38	36
	5A	11,72	70,87	15,13	13,99	2,13			
#6	6	12,07	58,4	19,46	22,14	1,76	0,14	5,03	36
	6A	18,34	49	25,44	25,55	2,47			

Soil data Catchment B (Tikolod)

Field	Soilsampl	CEC	Sand %	Silt %	Clay %	org. C %	K-factor	LS-factor	Slope %
#1	R1	18,27	28,43	35,1	34,46	2,52	0,19	9,97	58
	R1A	12,77	45,23	34,88	19,88	1,9			
#2	R2	22,67	65,81	22,19	12	2,5	0,14	3,04	36
	R2A	22,61	62,79	23,58	13,62	3,35			
#3	R3	23,36	44,98	37,62	17,4	3,29	0,16	19,57	84
	R3A	32,29	48,84	26,48	24,7	3,4			
#4	R4	13,99	56,23	21,26	22,5	2,23	0,14	7,48	58
	R4A	18,53	54,8	23,6	21,59	2,75			
#5	R5	12,86	57,53	22,49	19,98	2,07	0,15	3,15	36
	R5A	13,59	60,73	21,8	17,46	2,19			
#6	R6	14,4	56,29	19,72	23,98	2,02	0,12	26,73	84
	R6A	33,79	56,67	20,43	22,89	6,24			

Appendix 5: t-test on the CEC values

	CEC top	CEC Bot	Differens
	18,64	20,66	-2,02
	21	34,08	-13,08
	22,04	21,97	0,07
	12,96	13,31	-0,35
	14,82	11,72	3,1
	12,07	18,34	-6,27
	18,27	12,77	5,5
	22,67	22,61	0,06
	23,36	32,29	-8,93
	13,99	18,53	-4,54
	12,86	13,59	-0,73
	14,4	33,79	-19,39
Sum			-46,58
Mean			-3,88
Varians			7,07
t-test			-1,901
P			5< x < 10



```
data cec;
input afgr $ h cectop cecbund;
diff = cectop - cecbund;
cards;
g 30 18.64 20.66
g 40 21 34.08
r 40 22.04 21.97
r 30 12.96 13.31
r 20 14.82 11.72
g 20 12.07 18.34
r 30 18.27 12.77
r 20 22.67 22.61
g 40 23.36 32.29
g 30 13.99 18.53
g 20 12.86 13.59
r 40 14.4 33.79
;
run;

proc gplot data=cec;
plot cectop*cecbund=1;
run;

proc glm data=cec;
class h afgr;
model diff= h afgr cectop;
lsmeans h / pdiff;
run;

proc glm data=cec;
class h afgr;
model diff= h cectop;
lsmeans h / pdiff;
run;

proc sort data=cec;
by h;
run;

proc means data=cec;
```

KLASSEVARIABEL

KOVARIAT

$$diff = H_i + CECTOP + \varepsilon_{ij}$$

$i = 1, 2, 3$

TILFÆLDIG VARIAT

```
var diff;
by h;
output out=udcec mean=m_diff var=v_diff n=n lclm=lclm uclm=uclm;
run;

data udcec;
set udcec;
y=uclm; output;
y=lclm; output;
run;

symbol3 i=hilot v=none;

proc gplot data=udcec;
plot y*h=3;
run;


proc reg data=cec;
model diff= h;
output out=udceec student=sres predicted=p;
run;
```

General Linear Models Procedure

Dependent Variable: DIFF

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	339.89644608	113.29881536	4.30	0.0439
Error	8	210.62772059	26.32846507		
Corrected Total	11	550.52416667			

R-Square	C.V.	Root MSE	DIFF Mean
0.617405	-132.1888	5.13112708	-3.88166667

Source	DF	Type I SS	Mean Square	F Value	Pr > F
H	2	250.41761667	125.20880833	4.76	0.0436
CECTOP	1	89.47882941	89.47882941	3.40	0.1025

Source	DF	Type III SS	Mean Square	F Value	Pr > F
H	2	339.89636583	169.94818291	6.45	0.0214
CECTOP	1	89.47882941	89.47882941	3.40	0.1025

General Linear Models Procedure
Least Squares Means

H	DIFF LSMEAN	Pr > |T| H0: LSMEAN(i)=LSMEAN(j) i/j	1	2	3
20	0.3437277	1	.	0.9312	0.0136
30	0.6670650	2	0.9312	.	0.0111
40	-12.6557927	3	0.0136	0.0111	.

)TE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

Appendix 6

Problems with increased production related to Crops.

Matrix scoring made in Balaraya - Kampung Narayat (Patau)- date: 28-10 - duration 2.5 hours
Participants: Mrs Hasnah Kunsalam - Mrs Queen, Mr. Tajin Kodiong, Isa Adon, Mary Kassim, Esther "Okum" and Alice Nanga, and the student crew: Pernille Dyg, Mahamad Dirir, Lim Su San, Abdelaziz Taoutaou and Michael Sehested.
Interpreters: Yuri & Johnny

	Weeds	Cater-pillar	Rodents	Drough t	Rain	Birds	Insects	Soil fertility	Distan-ce	Machi-nery	Labour require-ments	Lack of land	Wild boar	Deer	Fire
Wet rice	2	5	5	5	3	5	5	3	2	5	5	3	-	4	-
Dry rice	4	2	5	5	2	5	5	3	5	4	4	2	-	4	1
Coffee	5	5	-	5	-	-	2	3	5	4	4	3	-	-	5
Durian	2	4	3	5	-	-	-	3	5	4	4	3	-	-	5
Cassava	2	1	5	3	-	1	-	-	2	2	3	-	5	5	3
"Tankran"	5	1	5	5	3	-	3	3	3	2	3	-	-	-	-
Long bean	1	2	3	4	3	-	-	3	2	1	2	-	-	-	-
Mushroom	-	2	-	4	-	-	-	-	-	3	5	-	-	-	-
Pineapple	1	-	5	2	-	-	-	-	2	2	3	-	-	-	2
Sw.potato	2	5	5	3	-	-	-	3	4	1	3	-	5	4	1
Jackfruit	1	5	3	1	-	-	-	-	1	1	1	-	-	-	-
Cucumber	2	4	2	5	-	-	4	4	5	1	3	-	-	-	-
Chili	4	-	-	4	-	4	-	2	1	1	2	-	-	-	-
Tobaco	5	5	-	3	3	-	-	5	5	1	5	-	-	-	-
"Brinjal"	1	1	-	2	1	-	-	2	1	1	2	-	-	-	-
Ginger	1	-	-	2	1	-	-	4	5	1	4	2	-	-	-
Banana	1	-	2	1	-	3	-	1	1	2	2	5	-	-	1

Minimal problems gives score 1 - Maximum problems gives score 5
(That there isn't any problem related to increased production with crop at al, gives score: -, which equals a zero)

Appendix 7 -sediment discharge

Tikolod Sediment load:		
Time[hrs]	Q [m^3/sec]	[g/sec*km^2]
36.3	2.17	1.07
79.23	2.94	3.37
89.35	2.94	2.32
129.3	1.79	0.89
132.15	1.87	1.28
158.3	1.95	0.92
41.45	34	2098.8

Bolotikon Sediment load:		
Time[hrs]	Q [m^3/sec]	[g/sec*km^2]
36.3	0.87	0.22
41.1	1.35	11.50
79.23	1.47	0.90
89.35	1.35	0.75
129.3	1.39	0.56
132.15	1.25	0.60
158.3	1.37	0.47
41.45	12.96	1408.6957

Appendix 8. Rainfall, Tikolod, own data

Bolotikon:

Date Time	mm of rain	
10/20/99 14:36:47.0	0	Start
10/21/99 14:37:10.0	1	
10/21/99 16:11:01.5	2	
10/21/99 16:13:14.5	3	
10/21/99 16:15:05.5	4	
10/21/99 16:16:44.0	5	
10/21/99 16:18:11.0	6	
10/21/99 16:19:08.5	7	
10/21/99 16:20:08.5	8	
10/21/99 16:21:15.0	9	
10/21/99 16:22:50.0	10	
10/21/99 16:26:34.0	11	
10/21/99 16:33:59.5	12	
10/21/99 16:43:55.5	13	
10/21/99 17:01:22.5	14	
10/21/99 17:15:07.0	15	
10/21/99 17:36:01.5	16	
10/22/99 09:08:07.5	17	
10/22/99 09:10:24.0	18	
10/22/99 09:17:03.5	1	
10/22/99 19:53:00.5	2	
10/22/99 19:59:40.0	3	
10/23/99 22:20:35.5	4	
10/24/99 15:26:11.0	5	
10/24/99 15:32:40.5	6	
10/24/99 15:39:03.5	7	
10/24/99 15:44:48.0	8	
10/24/99 15:48:32.5	9	
10/24/99 15:53:06.5	10	
10/24/99 16:14:48.0	11	
10/25/99 18:07:15.0	12	
10/26/99 16:50:32.5	13	
10/26/99 18:25:56.0	14	
10/26/99 19:19:44.5	15	
10/26/99 20:04:51.5	16	
10/28/99 10:04:01.0	17	
10/28/99 12:17:37.0	17	End

Tikolod:

Date Time	t_0510_2	
10/20/99 10:28:48.0	0	Start
10/20/99 12:16:46.5	1	
10/20/99 12:28:49.5	2	
10/20/99 12:31:40.0	3	
10/20/99 12:33:43.5	4	
10/20/99 12:37:53.0	5	
10/20/99 13:39:06.5	6	
10/21/99 14:10:06.5	7	
10/21/99 15:14:15.5	8	
10/21/99 16:07:32.0	9	
10/21/99 16:10:35.0	10	
10/21/99 16:12:53.5	11	
10/21/99 16:16:48.0	12	
10/21/99 16:22:12.5	13	
10/21/99 16:29:06.0	14	
10/21/99 16:38:49.0	15	
10/21/99 17:01:56.5	16	
10/21/99 17:12:47.5	17	
10/21/99 18:05:02.0	18	
10/22/99 19:44:53.5	19	
10/22/99 22:09:39.0	20	
10/24/99 15:19:02.0	21	
10/24/99 15:32:50.0	22	
10/24/99 15:44:43.0	23	
10/24/99 16:02:20.5	24	
10/25/99 10:18:06.5	25	
10/25/99 13:44:30.0	26	
10/25/99 13:44:31.5	27	
10/25/99 13:44:36.5	28	
10/25/99 18:11:14.5	29	
10/26/99 16:54:19.5	30	
10/26/99 17:38:50.0	31	
10/26/99 18:41:34.5	32	
10/26/99 19:29:24.0	33	
10/26/99 20:24:02.5	34	
10/27/99 13:12:47.5	35	
10/28/99 10:32:07.0	36	
10/28/99 11:51:04.0	36	End