The Effect of Land cover Change on Run off and Erosion in Nam Chun, Lomsak, Petchabun, Thailand

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by

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Abstract

Land cover change dynamics and its impact on the environment and the reactions towards these changes calls for stakeholder intervention. Increasing conversion of natural cover is rendering the land cover vulnerable to destruction by the ever active functional processes such as runoff and erosion. Soil physical properties are destabilized and breaking its stability to resist the force of detachment, surface flow and erosion. With high rates of land cover change and effects on soil characteristics requires concerted efforts to identify and quantify critical areas where there is urgent need for attention. This study's main objective was to identify and quantify land cover change in Nam Chun sub catchment. It was conducted in Nam chun sub catchment to estimate the rate of runoff and erosion caused by water erosion due to land cover change. Land cover change analysis was done to compare two maps of 2002 and 2007 of the same area after 5 years. It was established that land cover has undergone change in the five years. The most affected were the natural forest cover whose area had reduced by 42% of its original area and 22% of the total area of the sub catchment. Orchards and agriculture have increased at the expense of natural cover. Among the soil physical properties the saturated hydraulic conductivity (Ksat) was found not significantly different in all land cover types in the area. While crusting, bulky densities, porosity, cohesion by shear strength were all significantly different at P values of < 0.01 and < 0.05. LISEM model was used to asses run off and erosion. Two factors instrumental in affecting infiltration and runoff were considered. Ksat as a factor of land cover and rainfall were varied in the model for sensitivity analysis. It was discovered that much as there is land cover change in the area there was less influence by Ksat, on runoff. Rainfall amount has a higher influence. There was much surface flow detached in the catchment but no significant deposition in the area. The stream channel also had more detachment without the deposition. Peak discharge simulation showed that the orchards have the highest discharge than any other type of land cover. Change from natural to agriculture was found to be more vulnerable to erosion and increase in discharge than to natural cover. The results showed that the soil loss rate using flow detachment was consistently higher than the. The rate of discharge was also simulated in a small sub-catchment with in the Namchun catchment area and compared with daily measured stream discharge. The discharge rate simulated on an event basis was used to derive the total discharge rate. Comparisons of the results of the simulated and measured discharge rates showed that the simulated discharge was by far higher than the measured ones. This was especially because the measured discharge rate was mainly based on base flows of the stream when there was no enough rainfall and runoff. In general, from the study it is concluded that the incorporation of base flow in a stream using LISEM as a means of measuring runoff from fields within the sub catchment can be useful in considering assessment of erosion

Key words: Land cover, Runoff, Erosion, Surface flow detachment, LISEM,Nam Chun sub catchment.

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1. Introduction

1.1. Background

Soil erosion is one of the major effects of land use and land cover change. Soil erosion is a serious global problem that has increased throughout the 20th century. About 85% of land degradation in the world is associated with soil erosion, most of which occurred since the end of World War II (Angima, Stott et al. 2003).

Natural resource conservation is faced with critical problems due to the effect of human induced land cover changes that demolish soil and land resources. This has increasingly spread in many parts of the world for the last 50 or so years. Changes in land cover are normally due to the need for socio-economic development and to meet the increasing food demands for billions of world population (FAO 2003). High rate of population growth associated with socio-economic development have led to increasing conversion of forests to other land uses such as agriculture, urban areas and infrastructure development (Agency 2005). In addition, commercial logging, decline in vegetation by overgrazing (Kosmas, Gerontidis et al. 2000), shifting cultivation, intensive agriculture and practices like conversion of forest land by fire are other prominent factors causing land cover change. These activities not only result into immediate land benefits and land cover changes but also affect topsoil physical properties. They have significant impact on erosion and agricultural soil properties, including soil degradation by acidification, nutrient leaching and organic matter depletion (Szilassi, Jordan et al. 2006)and negative offsite effects down stream((Patanakanog, Shrestha et al. 2004). Land cover change is also alleged to be caused by man-induced land-use changes, which are mainly associated with increasing urbanisation and change of the agricultural practices (Camorani, Castellarin et al. 2005). Abandonment of agricultural lands due to economic and social changes is followed by significant impacts on soil erosion. Land abandonment may have positive or negative impacts on soil protection from erosion because fundamental ecosystem processes are influenced by changes in agricultural practices and soil resources management (Koulouri and Giourga 2007). Traditional, extensive cultivation, which is abandoned, spread on marginal areas and located mainly on sloping terraced lands with low productivity soils affect water erosivity, runoff volume, and determine soil erodibility. In areas of steeper slope gradient, soil erosion is higher because of the decrease in protective cover of annual plants as compared to shrubs' cover that increases.

(Koulouri and Giourga 2007)

1.2. Thailand Situation

Nam Chun Catchment is one of the mountainous areas of Lom sak district of Thailand has had its land under go transformation over decades now. Land cover has mainly been affected by population pressure, changes in industry, urban growth and agricultural development. These have increased demand for more land for their expansion especially in lower areas of the district (Local development department, LDD 2001). As a result, agricultural areas have shrunk and deforestation has increased due to the need for more commercial land (Shrestha, Yazidhi et al. 2004). Forests have been continued to be converted to annual cropland and subsequently to perennial ones (Verburg, Veldkamp et al. 1999). Extensive deforestation for timber, firewood collection or cultivation by local farmers to produce subsistence food and income, have left many upland areas of Thailand deforested (GLASOD 2005, Local development department, LDD 2001)).

Nam Chun catchment found in the Northern Petchabun province of Thailand (figure 1.-1 below) is no exception to this problem. Almost all suitable land for cultivation has been used up or is under intensive cropping. The problem is critical on hill slopes where forest lands continue to be depleted for agriculture (Patanakanog, Shrestha et al. 2004). Increased human activities in the catchment is also characterised by improper land use and tillage practices, over cultivation on steep slopes, overgrazing, and deforestation. Slash and burn is a common practice for clearing uplands forests for crop land (Kuneepong, Patanakanok et al. 2005). These activities affect top soil conditions such as infiltration, soil water capacity, and soil strength. On mountain slopes, such conditions lead to intensified generation of runoff and erosion whenever there is high rainfall intensity. The down stream off-site effects such as the reduction in soil productive capacity in valley floors force people to move up the sloping areas for agricultural land. This results into further claim on forest land and destruction of land cover.

1.3. Modelling Erosion

Modelling erosion as is a scientific way of representing the real world situation that describes erosion process and its underlying factors. Models provide an assessment of erosion rates that are used in soil conservation (Jetten and Favis-Mortlock 2006). Numerous models have been developed over time to act as tools for obtaining information to predict future pressure by erosion on environment (Souchère, Cerdan et al. 2005) and new ones are being designed. However, a number of these models have been developed or calibrated for their own areas for which they apply and yet erosion is not region specific. There is therefore need for new models and or modification of old ones (Jetten, de Roo et al. 1999; Jetten, Govers et al. 2003) to sort out such a problem. In some instances erosion patterns appear to be, in part, chaotic in nature in that they can be very sensitive to tiny variations in initial conditions at some locations (Jetten and Favis-Mortlock 2006). Despite this, scientists are satisfied with model performance in predicting future events ((Jetten and Favis-Mortlock 2006). Therefore use of models depends on the user's objective and the need to be addressed which requires detailed understanding of the erosion process and its underlying factors in order to identify parameters needed for calibration of the model.

1.4. Statement of the Problem

The description of Thailand situation in section 1.2 above shows that a number of problems can be attributed to the cause of erosion and environmental degradation in Nam Chun catchment. Among them is the increase in population and its associated needs that range from social, economic and physical. The physical needs include land which is the main source of lively hood in rural areas of Thailand. However, Shortage of land for farming in lower Nam Chun for development and need commercial timber led to the encroachment on marginal lands including forests. Larger portions of forest land have been brought under cultivation (Patanakanog 2004). Nam Chun catchment has undergone a transformation to almost losing its original natural cover due to human interference. Deforestation has for long degraded much of the natural forest cover in the area and led to land degradation problems such as erosion. The 2001 August 11th heavy storm that led to landslides, flooding and destroyed life and property in Nam Chun and the surrounding areas down stream (Shretha 2004) worsened the situation. Government of Thailand put in place programmes to control excessive deforestation and discourage upland farming in the area (Local government development department (LDD 2001). Despite the programmes, deforestation has continued and led to unselective cutting down of trees. Forests have been and are still being replaced by crops, cultivation on steep slope and improper land use practices continue to cause more damage to the environment. Shifting cultivation of arable crops are moved from low land areas to steep slopes and crops are switched from other crops, during harvest, planting, and other areas left fallow before re occupation by farms or left as grasslands. Environmentalist seeking to design programmes for conserving land degradation fail to understand this complex phenomena. Land degradation in the area by land slides, decline in soil fertility and soil erosion will continue if the problem of deforestation and land cover destruction is not investigated and addressed for proper policy design and implementation.

Previous studies done in the area assessing erosion were constrained by lack of validation data. More so, many of the methods like soil erosion models used on similar studies were meant for specific regions and require a lot of data (Sapkota 2008). This suggests the need for up to date information and specific data requirements to be used to address problems of controlling land cover destruction in the area and its related problems of land degradation including soil erosion. Understanding the spatial distribution of land cover and actual change effects on soil properties and erosion is a key research question of this study. The Limburg soil erosion model, LISEM originally made for the Province of Limburg, the Netherlands, to test the effects of grass strips and other small scale soil conservation measures on the soil loss on scale basis between 2 to 20 square kilometres ((De Roo and Jetten 1999) was used to assess erosion in the catchment at the sub catchment scale. LISEM is an event based model which is used to analyse the effects of a severe rainfall event on erosion. For comparative analysis of the land cover change, extent and erosion during the time erosion for both years was assessed.

1.5. Main Objective

To assess the effect of land cover changes on surface runoff and erosion in a sub catchment of Nam Chun catchment

1.5.1. Specific Objectives

1. To identify major land cover changes in Nam Chun watershed between 2002 and 2007.
2. Analyse the effect of land cover changes on topsoil physical characteristics in the area.
3. Establish and map erosion hazard in Nam Chun watershed using crop calendar and land use trend information, identifying erosive periods in the year.
4. Assess the effect of land cover pattern on run off and erosion.

1.5.2. Hypothesis

1. Land cover changes are responsible for the variations in soil erodibility
   in a potentially erosive part of the year.
2. Land cover change in the watershed have led to increase in surface flow and erosion.
3. The type of land cover change influence the rate of erosion

1.5.3. Research questions

1. What is the major land cover change in the Nam Chun watershed since 2002?
2. What is the rate of the erosion in the sub catchment?
3. What is the impact of land cover changes on soil physical properties such as organic matter, saturated hydraulic conductivity, cohesion and crusting of soil in Nam Chun sub catchment?
4. Which kind of land cover change has had more effect on erosion in Nam Chun?
5. How far are runoff field effects noticeable in a stream, in view of the changes and connectivity?
   between erosive fields and drainage pattern?

1.6. The Conceptual Framework

The conceptual frame work presented in figure 1 below take the land use as a system where rain, man's ambitious needs and goals are external input to the system. Increase in population on the low land accompanied by urbanisation has forced people to exert pressure on the limited productive land. This has forced people to move to marginal lands like steep slope, river banks and clearing forests. Accompanied by high tropical rainfall and cleared vegetation will lead to low infiltration and hence high surface run off. The increase in the surface run off will increase erosive power. The poor farming methods and other land management practices compound the situation. They affect the soil texture, soil strength and result into erosion. In addition, slash and burn as a means of clearing land for farming has an influence on erosion by destroying organic matter and increase erodibility

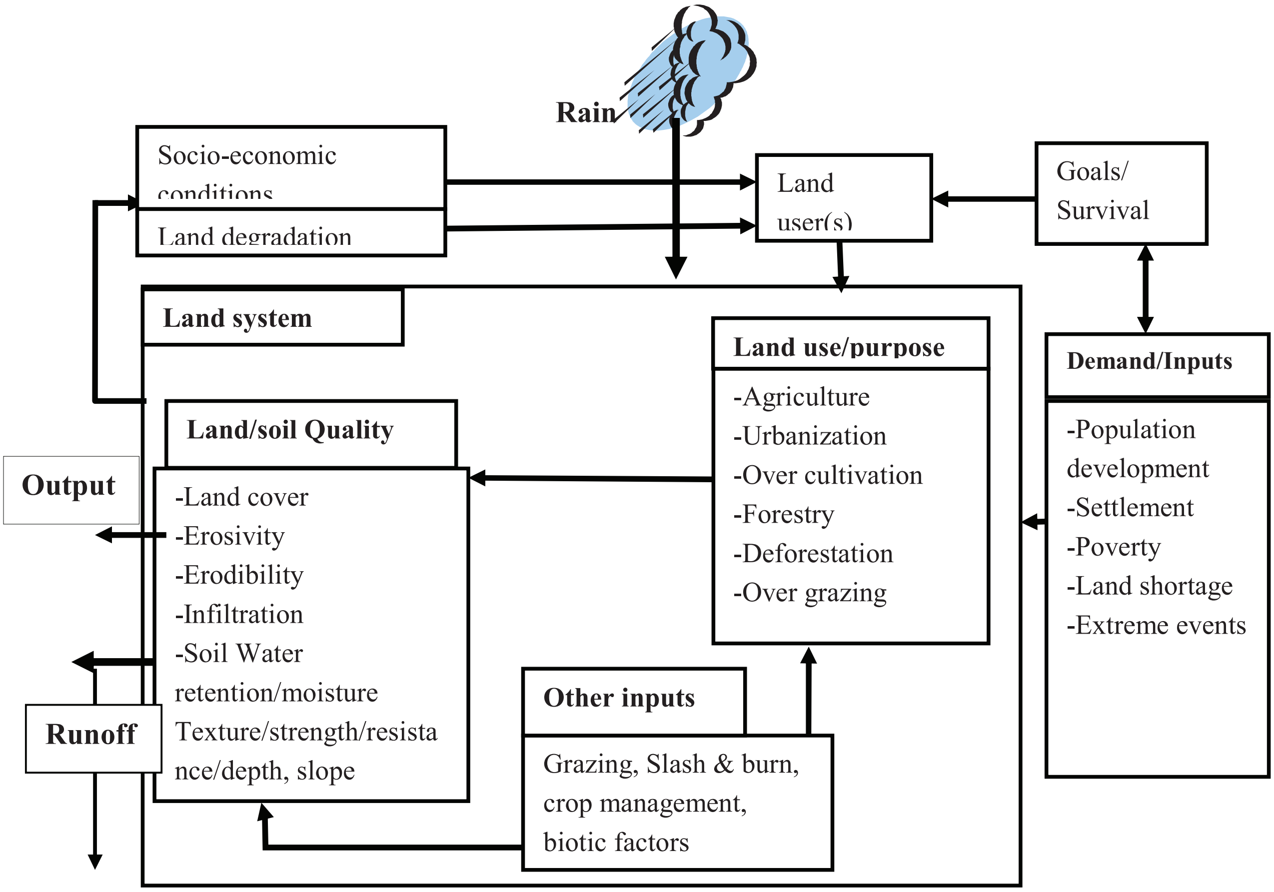

Figure 1-1: The conceptual framework

1.7. Structure of the Thesis

The thesis is organized in seven different chapters. The first chapter of the thesis consists of the introduction which includes the background to the problem of soil erosion by water, study objectives, research questions, Conceptual framework, hypothesis, and the description of the research approach and description of the study area. Chapter two is basically literature review regarding factors affecting soil erosion and soil erosion modelling. Chapter three is the description of methodology, field techniques, measurements, and data collection. Chapters four and five are about data analysis on land cover change, soil properties and land cover effects on soil properties. The results of the study are discussed alongside the analysis. Chapter six is about erosion modelling and assessment of run off and erosion from in respect to land cover types in the Nam Chun sub catchment. Chapter seven is the conclusion and recommendation of the study. Data and maps that could not fit in the thesis main part of the study are included in the appendix

1.8. Study Area

1.8.1. Location

The study area is Nam Chun Sub-watershed in upper PaSak watershed located mainly in LomSak and part of Kao Kor districts, Phetchabun Province, Thailand (see figure 1-2 below). It lies within Latitude 16º 44’ to 16º 48’ N and 101º02’ to 101º09’ E and covers an area of 66.5 km2. The watershed is about 500km north of the country’s capital city, Bangkok. The Elevation of the area varies from 186 to 1,490 m above sea level.

The topography of the area is made up of both high hills and wide valleys that separate them. The higher parts of the sub catchment is under forest cover and crop farms dominate the mid and lower slopes which are intensely cultivated. Orchards are mainly found in mid and valley bottoms although some double as farmlands. Consequently, larger areas of the sub catchment are seasonally ploughed bare and are thus more susceptible to erosion. There one main stream that drains the sub catchment is about 3 m wide, that seems rather stable but its discharge reduces during the dry season. The stream originates from the higher parts of the sub catchment, carries and accumulates sediments through the sub catchment to pour into the main Nam Chun river on the south eastern part of the catchment.

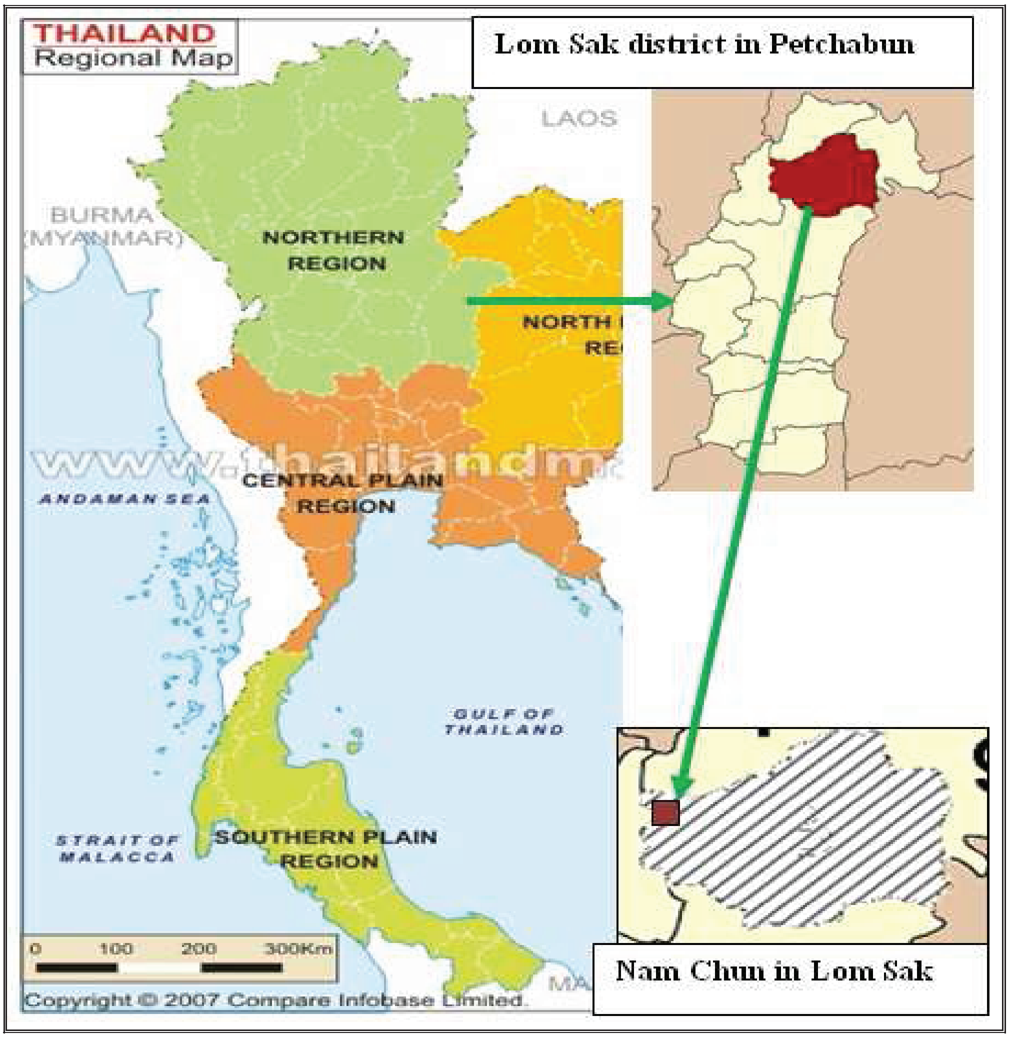

Figure 1-2: Map of Thailand shwing the location of Nam Chun in Lom sak district in Petchabun Privince

1.8.2. Geology and Geomorphology

The geology of Nam Chun area is mainly composed of uplifted sedimentary rocks of the Korat group found in the upper parts of the catchment. These consist of the oldest rocks of conglomerate, sandstone and shale of Huai Hin Lat formation. They are partly intercalated with andesitic tuff and agglomerate. The next formation is Nam Phong which contains red-brown cross-bedded sandstone and conglomerate. Both were formed during the upper Triassic period (Ekkanit 1998). The formation of the Korat group that occur in the study area is Pha Wihan which is the youngest and consist of white and pink, cross-bedded sandstone with pebbly layers in the upper beds. It also has some intercalations of the reddish-brown and grey shale. The lower plain consists of the Quaternary colluvial and alluvial terrace deposits

1.8.3. Soils

Soils in the Nam Chun catchment are classified under the great groups of the Haplustalfs, Palustalfs, Dystrustepts and Haplumbrepts. The general soil moisture regime in the area is characterized by complete dryness in the four months of summer. Soils in Nam Chun range from very shallow to moderately deep and well drained soils. The alluvial from Quaternary alluvial sediments occur in the lower and valley parts of the catchment. They are classified basing on the landscape in which they are formed using the letters of alphabet representing the landscape (Ekkanit 1998). P stands for plateau, HM for high mountain, LM for low Mountain and V for valley. Within each landscape soil are identified by the relief, followed by the litho logy, land form and soil type. All the last three, save for soil type have numbers, and altogether lead to a soil unit as presented on the geopedological map unit displayed in figure 1-3 and the legend 1-1 below. The sub catchment which is the study area is located within the main catchment and has similar soil unit classification as in figure1- 3 and legend there after.

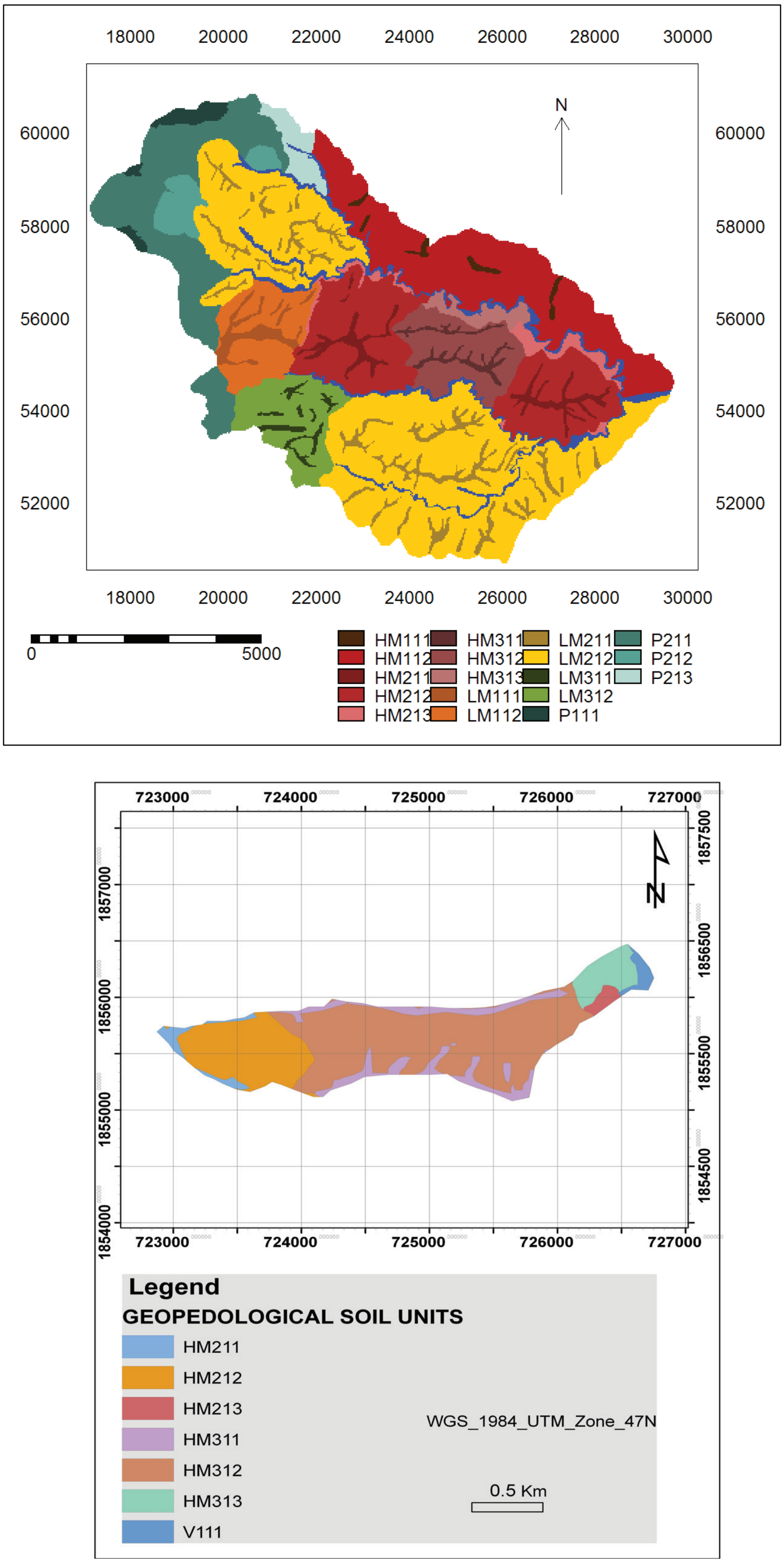

Figure 1-3: Map of Nam Chun catchment and sub catchment showing Geopedological soil units

Table 1-1: Legend to the Geopedological soil map unit in figure 1-4 above

Landscape	Relief	Lithology	Landform	Soils	Map unit
Plateau (P)	Cuesta (P1)	Sand Stone (P11)	Undifferentiated		(P111)
	Escarpment (P2)	Sand Stone (P21)	Scarp	Typic Haplustalts	(P211)
			Talus		(P212)
			Undulating Slope Complex		(P213)
High Mountain (HM)	Ridge (HM1)	Andesite (HM11)	Summit		(HM111)
			Slope Complex	Ultic Haplustalfs	(HM112)
	Ridge (HM2)	Andesitic Tuff (HM21)	Summit	Lithic Haplustolls	(HM211)
			Middlle Slope	Ultic Haplustalfs	(HM212)
			Foot Slope	Ultic Haplustalfs	(HM213)
	Erosional Glacis (HM3)	Andesitic and Rhiolitic Tuff (HM31)	Summit	Lithic Haplustalfs	(HM311)
			Middlie Slope	Typic Paleustalfs	(HM312)
			Foot Slope	Lithic Haplustalfs	(HM313)
Low Mountain (LM)	High Ridges (LM2)	Andesitic Tuff (LM21)	Summit	Ultic Haplustalts	(LM211)
			Middle Slope	Ultic Haplustalts	(LM212)
	Moderately High Ridges (LM1)	Andesitic and Rhiolitic Tuff (LM11)	Summit	Typic Haplustalts	(LM111)
			Middle Slope	Ultic Haplustalts	(LM112)
	Low Ridges (LM3)	Andesitic and Rhiolitic Tuff (LM31)	Summit	Typic Dystrustepts	(LM311)
			Middle Slope	Ultic Haplustalts	(LM312)
Valley (V)		Alluvial Colluvial	Side slope/bottom complex	Fluvents and Haplumbrepts	(V111)

1.8.4. Climate

The climate of the area is mainly the typical monsoon tropical climate that exhibits dry cool winter, wet hot summer and a hot rainy period with an annual average rainfall of about 1066 mm and a Mean annual temperature of 26º (Lom Sak weather station 2008). The rainy season starts from early May and ends in October with some traces of rain in November. Rainfall amount is usually more in the hilly and mountainous areas than in the lower areas. Sometime the monsoon rains are unpredictable and cause damage to the environment whenever an abrupt down fall comes. For instance the 2001 flood caused by unexpected heavy rainstorm killed many people, damaged crops and property. The rainfall seasonal variation and pattern show the typical Asian monsoon pattern with high rainfall during one part and only traces or no rainfall in the other part of the year. Such a pattern has an influence in the area especially regarding farming activities (Shrestha, Yazidhi et al. 2004). Below is table 1-2 and figure 1-4 show average monthly rainfall for the last 35 years for Lom sak station located at the lower lands of Nam Chun station

Table 1-2: Rainfall from Lomusak meteorological station (X:

Months	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Rainfall in mm	5	22	43	61	162	144	142	197	201	84	16	4

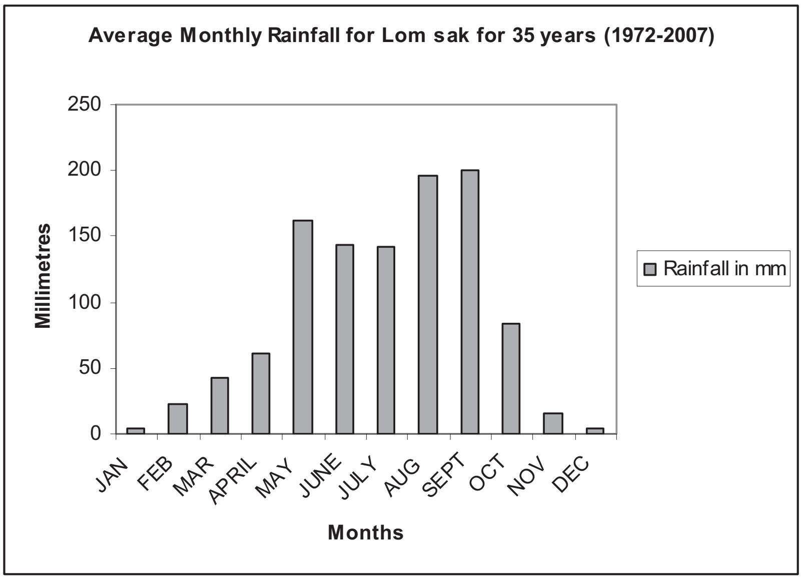

Figure 1-3: Average Monthly Rainfall for Lom sak for 35 years

1.8.5. Vegetation and Land cover

The Catchment is characterised by five major land use cover types which include forest, degraded forest, agriculture or crop land, orchard and grasslands. Much of the original forest that was 58% of the total land area in 1988 had been encroached upon and reduced to 41% (Patanakanog, Shrestha et al. 2004) and a larger portion is either grassland which increased by 25% after over use, agricultural land, degraded forest and orchard areas. The main annual crop in the area is maize and is predominantly grown in the mid slopes and valley bottoms of the sub catchment. Other crops grown in the area together or after maize harvest are annuals like mungbeans and soy beans sugarcane and cassava and also in some areas, a variety of vegetables are grown. The upper parts of the catchment are covered by grasslands whose area may have been previously used for cultivation purposes. (See Appendix 5)

2. Literature Review

2.1. Land cover

Changes in land cover disrupt the natural arrangement of soil physical properties and influence its response to run off, consequently increasing the amount of soil that is eroded and land degradation (Morgan 1995). Cover change exposes soil to rain which results in soil particle detachment. Freely flowing water over land causing fine particles to close up pore spaces within soil aggregates and hence increases run off**.**

Natural land cover help to regulate water flows both above and below ground. Vegetation canopies and leaf litter help to attenuate the impact of raindrops on the earth's surface, thereby reducing soil erosion. Plant roots hold the soil in place, especially on steeper slopes, and also absorb water. Openings in leaf litter and soil pores permit the infiltration of water, which is carried through the soil into the ground water. Forests land cover serve as important buffers, reducing sediment loads and keeping runoff from moving too quickly into streams Extensive deforestation contributes to flash flooding and sedimentation of water courses at lower elevations down stream. In built-up environments the impervious surfaces increase the speed of runoff, with rain water being channelled to streams much more rapidly than under conditions of natural vegetation cover. Secondly, infiltration is reduced, which reduces the groundwater levels and therefore the base flow of streams.

2.1.1. Land cover Change

Land use cover changes represent another anthropogenic 'system disturbance' which directly or indirectly influences many hydrologic processes including soil water(Lahmer, Pfützner et al. 2001) Different land use/ cover changes play an important role in determining the rate and amount of erosion by affecting infiltration during a given rainfall event. Detection of such changes has became an important factor in monitoring resource use, land degradation and erosion problems.

2.1.2. Land cover classification

In spite numerous methods of detecting and interpreting land cover change by use of satellite images and other sources, several uncertainties exist including estimates of rates and extend of change of land uses cover mapped by satellite imagery (Hurtt, Xiao et al. 2003). More so it is a little difficult to run a conventional classification algorithm to map land cover in areas with strong

topographical variations complicated by over lap of different nature land cover
(Alfred 2001
)) and where single date imagery is used to map land cover change, it is difficult to differentiate cover types exhibiting vegetation re-growth. Degraded forest, cultivation and young pastures, grass areas are conflicting and are further compounded by lack of optimal available medium resolution images to spatially represent vegetation cover during the high erosion risk period ((Vrieling, de Jong et al. 2008). For this study, the timing of field work and availability of cloud free images of the study area during the field work period complicates the matter as ground truth data is of a different date to that of the satellite image.

2.1.3. Impact of land cover Change.

The impact of reduced vegetation cover on the soil water dynamics and soil moisture on different land use leads to higher evapo-transpiration and water withdrawal and thus influence the soil water content and physical properties on agricultural fields (Giertz, Junge et al. 2005). Studies have revealed that reduced macro fauna leads to lower infiltration capacity significantly in cultivated soils than in grasslands and forest. This causes higher surface runoff, erosion, soil loss on fields and further effects soil physical properties and reduce field capacity.

2.1.4. Land use Trends and Seasonal Crop Calendar

The different land use trends have considerable influence on land cover change, and eventually soil physical properties and erosion processes. Different land use trends influence land cover differently and as such determine the rate of surface soil disturbance and the rate at which it is forced to runoff and consequently erosion and land degradation(Morgan 1995).Farming systems exert a dominant influence on field and farm scale variation in erosion. In a number of cases, it is ascribed by planting and harvesting (Auerswald. K 2006
)Planting takes place during rain season while harvesting conditions leaves gardens with less cover which may expose soil to the risk of being eroded if it coincides with heavy rain. In Nam Chun harvesting is accompanied by home made trucks that move to gardens and end up creating trails and trucks through which runoff increases erosion.

2.2. Soil erosion factors

2.2.1. Rainfall

The effect of rainwater reaching the surface of the earth depends on its state that determines the suction force pulling water into the soil which decreases with increasing water in the soil. As the soil fills up with water however, the suction head force decreases and the gravitational gradient becomes the driving force conducting water down the soil profile. With continued saturation of the soil, the rate at which water moves into the soil approaches the saturated hydraulic conductivity. Under such conditions, if the rainfall intensity is greater than the rate at which the soil accepts water, ponding occurs at the surface. Further input of rainwater causes the capacity of surface storage to be exceeded resulting in surface runoff (Hillel 1980; White 1997)

Rainfall erosivity depend on the rainfall intensity which may differ from those that measure volume or amount of rainfall (Salles, Poesen et al. 2002).High intensity events promote the soil aggregates to break down quickly, producing a reduction in the infiltration capacity since the soil surface is “sealed” and runoff can occur immediately (Morgan 1995). Higher sediment yield and runoff values are normally direct measurements of soil loss using runoff in watersheds, where low-intense but persistent rainfall events saturated the soil, especially in those soils with high infiltration capacity under low slope inclination, producing minimal runoff and soil loss. Highly erodible soil located on a steep slope subjected to heavy rainfall generates more runoff and soil loss. .

2.2.2. Terrain, Slope and Height

The slope steepness and slope length are the key characteristics of topography on erosion. To open up steeper slopes increases erosion potential due to acceleration of velocity and more run off occur than on gentler slopes and hence the rates of erosion is higher. When the slope is relatively steep, it adds energy to the runoff by increasing its velocity (Morgan 1995) Long slope also allows greater accumulation of runoff over upslope area (Wischmeier 1978). The shape of the slope also determines whether the process is erosion or sedimentation.

2.2.3. Soils

Erodibility is the inherent resistance to soil particle detachment and transportation by rainfall. It is determined by the cohesive force between the soil particles, and may vary depending on plant cover, the soil’s water content and the development of its structure at successively greater rainfall intensities for a given land use cover and surface condition treatment (Wischmeier 1978). Erodibility shows nature and stability of soil in the erosion process. Soils are vulnerable erosion due its erodibility (Hudson 1996) The erodibility of the soil depends on various soil properties which are a combined measure of which influence the soil’s infiltration capacity, detachability, and transportation ability. Various soil properties such as texture, cohesion and, structural stability, crusting and organic matter are some of the crucial factors in determining the erodability of soil(Fen-li Zheng and Mark A. Liebig 2004). Infiltration capacity is related to the spatial variability of soil properties such as soil structure, organic matter content, and soil moisture. These soil properties are also related to soil surface characteristics like vegetation cover, rock fragments cover, rock fragments position, and different types of crusts are usually distributed in patches upon the hill slopes (Rawls.W.J**.** 1994).

2.3. Erosion Features

Erosion features and indicators include; rills, Pre rills, Valleys and gullies. Occurrence of these features is a sign of erosion and requires observation of what really happens is situ (Takken, Jetten et al. 2001). Using indicators of erosion intensity, different types of land use can be compared in erosion hazard assessment. Information on the relative resistance soil in erosion areas vary within soil and water conservation with different practices. These features are indicators of erosion indication on what happens in the field and what contribution it has on sediment delivery down stream.

2.4. Erosion Modeling

Field studies for prediction and assessment of soil erosion are expensive, time consuming and need to be collected over many years. Though providing detailed understanding of the erosion process, field studies have their own limitations because of complexity of interactions and difficult in the generalization of results. Soil erosion prediction and assessment has been a challenge to researchers since the early 20th century and several models have been developed in response (Lal 2001) These models are categorised as, empirical, semi empirical and physical process based models. Empirical models are primarily based on observation and are statistical in nature. Semi empirical models are based on spatially lumped forms of water and sediment continuity equations while physical process based models are intended to represent the synthesis of individual components which affect erosion, including complex interactions between various factors and their spatial and temporal variability. Some of the widely used erosion models include; Empirical: USLE, RUSEL, MUSLE, Semi empirical are MMF, RMMF and Physical process based models: WEPP, EUROSEM, and LISEM.,(Lal 2001).

3. Methods, Materials and Measurements

3.1. Methodological Framework

The research methodological frameworks in figure 3-1 outlines the research activities for this study and are described in the section thereafter.

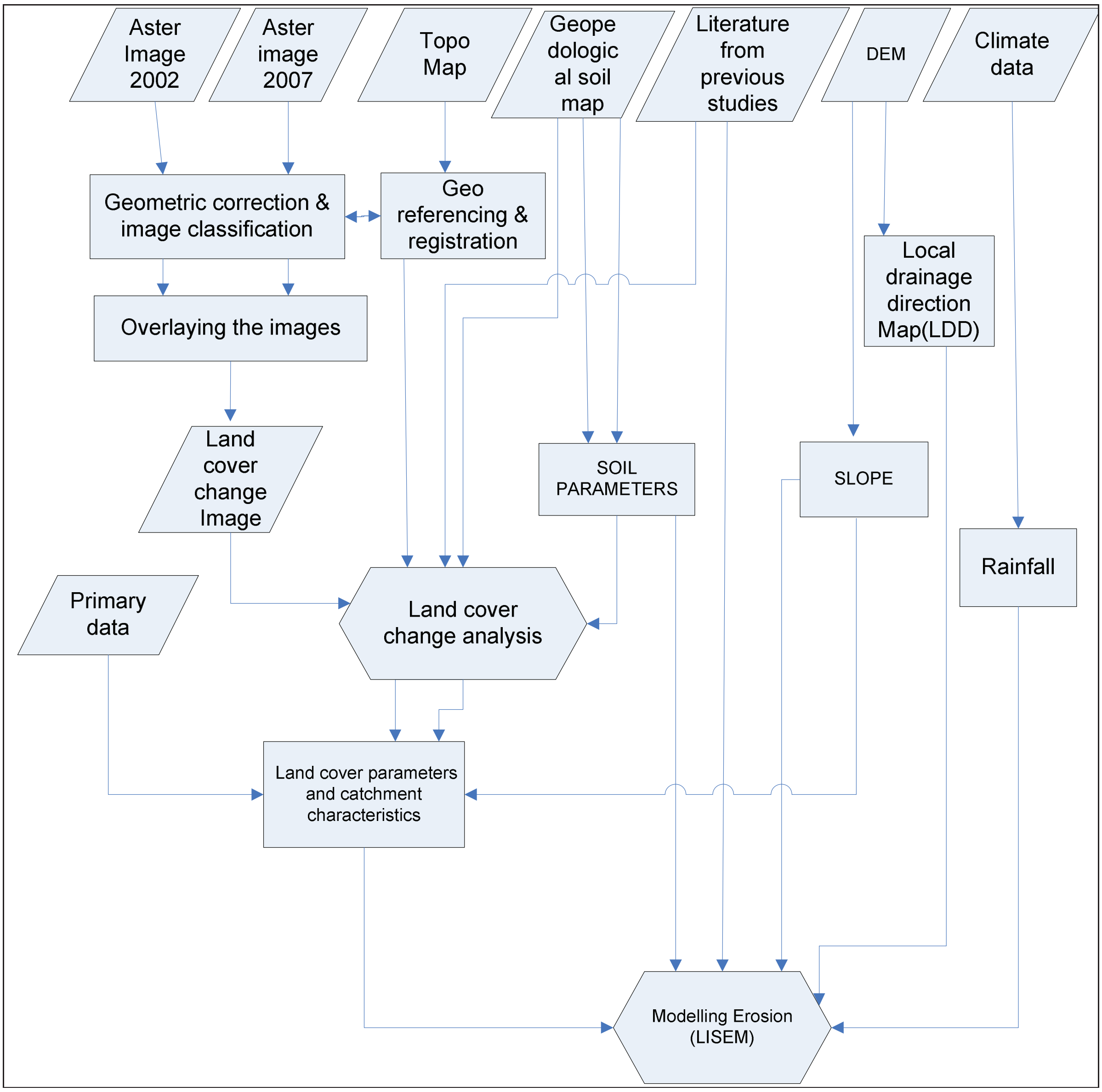

Figure 3-1: Methodological Frame work

The methodological frame work is a schematic overview of the research activities that took place during the study. First stage is of image processing and visual interpretation with the use of a topographic map. This exercise partly led to the knowledge base and collection of training samples needed to classify and produce base maps for detecting and quantifying land cover change in the area.

The second part of the frame work is to use the 2007 land cover map, soil map and land cover parameters identified together with primary data collected from the field and literature for modelling erosion in the area presented in the chapter 6

The third part of the framework includes the collection of data from literature and previous studies. Data was retrieved for analysing and modelling run off and erosion. Other in puts like rainfall data, an important component for analysing erosion was collected from previous records at local weather station in Lom Sak and also measured directly from the field.

The Fourth part of the methodological frame work has the DEM and Climate data. These are important components required by the LISEM that was used for modelling run off and erosion. A 30 metre DEM was acquired from the ITC data base and was used to derive the slope and local drainage map for by the model. Finally the modelling of run off and erosion is done by using the LISEM model and the out come of it is presented later chapter 6

3.2. Materials used

The following were materials that were used for this study:

1 A topographic map for the area of scale 1:50,000

2 The Aster 4 Feb 2002 and 22Jan2007 Images with 9 different bands were obtained from ITC data
From which land cover base maps were made.

3 Soil Map of Nam Chun catchment was obtained from the same ITC data set

4. A 30m digital Elevation Model (DEM) obtained from the ITC soil data base.

5. The software's used were; Arc GIS 9.2 version, Eridas, ILWIS for producing input maps for PCRaster for the model scripts and LISEM model version 2.56 for simulating runoff, Microsoft Excel for statistical analysis, Microsoft Visio for the production of flow charts and Microsoft Word for typing the thesis.

6. Sampling equipments used in the field included; Garmin XL12GPS 12 channel receiver, sample Collection bags, 30 meter measuring tape, compass, plastic floating bottle, rope, stop watch, Measuring cylinder, beaker, funnels, 4cm hand shear vane, hammer, soil sampling rings, core sampler, spade, auger, field knife, FAO Guidelines for soil description, and a field notebook.

3.3. Primary data Collection.

3.3.1. Soil data and sampling

Soil sampling and data collection was done a reconnaissance trip were made in the field to familiarise with the study area. After that soil sampling and samples collected was done randomly from land cover types that were suspected to have undergone change over the last five years. For investigation on selected soil properties in relation to the main land cover types of the sub catchment, a total of 44 soil samples plus 16 points from previous studies were collected and considered for this study. Figure 3-3 below Soil observations were made from mini pits and in some cases by auguring. Soil descriptions were based on the FAO (1990) guidelines for soil descriptions. The data collected was entered into the field data collection sheet and later in the computer for analysis. The soil samples collected were analysed at ITC laboratory for soil properties like soil initial moisture, saturated hydraulic conductivity, organic matter, bulky density, and crusting index were determined. Some data not directly collected from the field was retrieved from literature. All these data have been used in analysis and modelling erosion in the later chapters 4, 5 and 6 as shown in appendix.

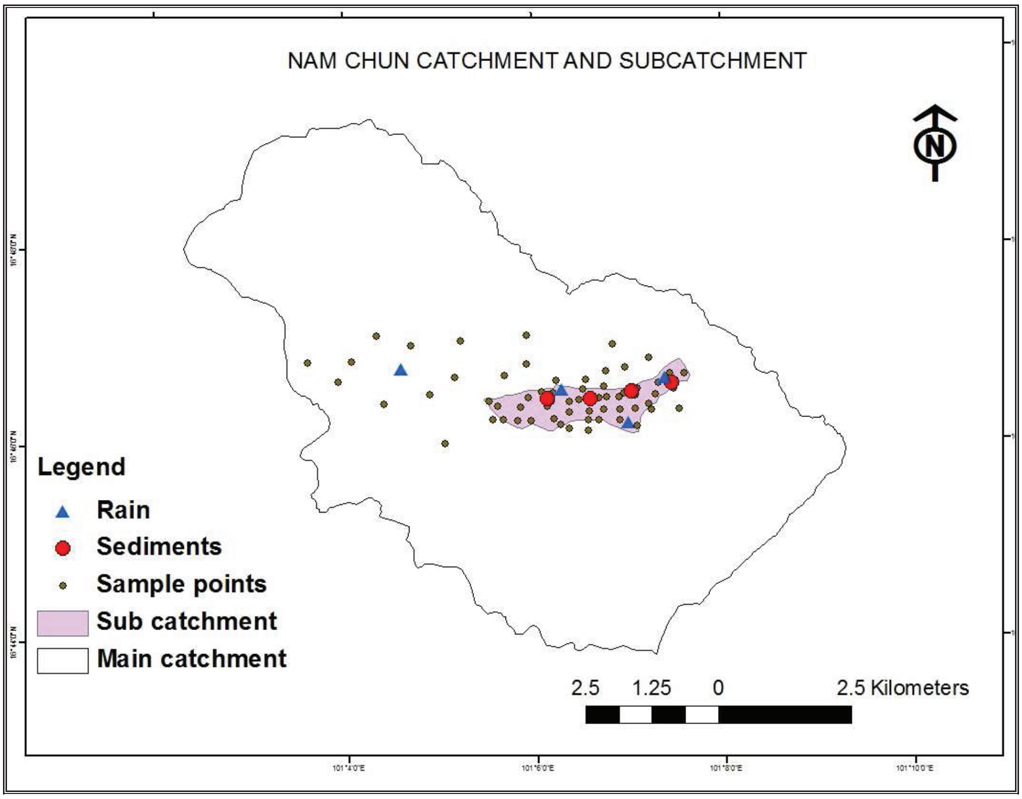

Figure 3-2:Map of Nam Chun showing sample points , rain gauge and sediment points

3.3.2. Rainfall Data.

Rainfall data was also collected from the field at four temporal rain gauges of known diameter set up by the researcher (figure 3-4). Three of them placed at different points within the sub catchment. One was placed outside the sub catchment and three inside the catchment figure 3-4. Measurements were done on 24 hour basis. The volume of the water collected over a period of 24 hours was measured in a graded jar and recorded for analysis.

Figure 3-3: Putting up a raingauge to measure rain at one of the points in the catchment (X: 721266,Y:1856276)

The funnel of known diameter and surface area was used to collect falling rain and collected volume of water was known and height of the rain converted into rainfall data for the month of September 2008. see table--- in chapter 4.

There were no event based measurements taken during the field work and. Much of the climate data was got from Lom sak weather station which is situated at the lower areas south east of the Namchun main Catchment.

3.3.3. Velocity Discharge.

Discharge measurements were taken after every suspected rainfall event from a sub-catchment. A simple float method was used and a stopwatch to make the measurements at the sub catchment level. This method was preferred because of the level of water which was not sufficient for the use of the current flow metre. A half submerged bottle was let into the stream and a stop watch used over a distance of 10 meters while taking the time taken through the distance. This was done several times at each selected section and an average of the time was recorded to compute velocity discharge at each point. The cross section of the stream was also measured every other time the river velocity was taken. The velocity of the flow and the cross section area of the stream are used to compute the discharge by the stream using the equation: $Q= VxA$; where Q is discharge in $m3/s$ and V is Velocity of flow in meters per second (m/s). Finally, the velocity of the stream was computed for each of the point section from which the discharge is calculated and presented in table 3-2 below. The current meter was used to measure velocity discharge at main river outlet over a time period during the field work time in September, 2008. Several measurements were made at each section point to calculate mean discharge. Total metre count at each marked point was recorded to finally compute total discharge for the main outlet as presented later in chapter 5

3.3.4. Sediment Delivery

Sediment delivery measured from the sub catchment outlet was done at the location of known stream width. Water depth and channel width were measured each time Sediments were collected for measurement. The Sediment delivery in the stream at the sub catchment level was measured using a bottle of known weight. Water with sediments from the stream, allowed to decant, dried and measured. The weight of the sediments per amount of water was obtained by subtracting the weight of the bottle in which the sediments were collected. The same was done at the main outlet of the catchment and both measurements were calculated and are presented in the table below.

3.4. Land cover Analysis.

3.4.1. Land cover Data and classification

Land cover change identification and mapping exercise was done for the whole Nam Chun catchment area using Aster 2002 and Jan 2007. The disturbed and undisturbed parts of land cover were the main target of this study. A total 340 training samples were collected for supervised classification of Aster image 2007 to create a land cover map and compare with a classified image of 2002 to determine change over time. The Feb 4 2002 Aster image was classified basing on the same data in addition to the basic knowledge of the area acquired during field work. The accuracy of this map was not checked because of the timing and no record of historical data for land use of 2002 apart from the spatial evolution knowledge and recent primary data of the same area. The two maps generated from the two images were compared at the stage of land cover analysis to detect and quantify land cover change within the five years.

Land cover map of Nam Chun catchment for 2007 was prepared by classifying an Aster image Jan 22 2007. Supervised classification with maximum likelihood algorithm was used. The image of 2007 was classified into 8 different land cover classes, agriculture, degraded forest, forest, grass land, orchard, urban or build up area and, water body by using training sample point data taken from the study area. The accuracy of the classification result was validated through accuracy assessment by using separate set of ground truth data and it was found to be 74% which was appropriate for this study. The sub catchment, land cover of 2007, was subset from the main sub catchment as seen in figure 4-1 below

3.4.2. Land cover Detection and Classification Techniques

Land cover change detection techniques and classification in a time series of imagery have been used to monitor changes in land use cover in many tropical environments where shifting cultivation, vegetation phonology, and pasture and grassland development and deforestation, crop stress cause damage (Cohen et al 1998). Change detection techniques such as the principle components analysis and image differencing integrate spectral transformations to enhance change analysis and interpretation. Normally the first and last component contains almost all data requirements for classification of land (Cohen and Fiorella 1998). The first component is stable contains almost 90% of the whole data. This component is therefore useful for image interpretation and classification.

Using spatial evolution concept to various land use cover trends are important in showing and indicating when a certain land cover existed and the magnitude of change of that land cover has gone through. (Alejandro et al 2007). The removal of forest covers to farm, shifting agriculture and abandonment of portion of cropland for many years to fallow or regenerate lead to cover change (Alejandro et al 2007). For this study, the principal component analysis, spatial evolution analysis and ground truth data were used in to detect and classify land cover as presented in chapter 4 below

3.5. Land use Trends and crop calendar

During the field study, a crop calendar detailing all land use trends/seasonal activities of Nam Chun catchment was obtained from the Ministry of agriculture and up dated in the field using information from farmers on the ground and local population. Details of the land use trend crop calendar are presented in the subsequent chapter 4 and appendix.

3.5.1. Soil Physical Properties.

To determine the physical properties, top soil samples were collected from the sub catchment and main catchment were brought to ITC soil laboratory for the particle size analysis and organic matter (OM) analysis. The Pipette method for the particle size analysis using FAO standard guidelines and soil organic matter (OM) was determined using the Loss by Ignition method (Denis Baize, 1993). The results of the laboratory analysis are provided in the appendix. Other soil property like cohesion by shear vane was measured in the field. Crusting index which depend on soil texture was calculated using the FAO (1983) formula given as;

$$\text{Crusting Index} = \frac{(1.5\times finesilt + 0.75\times coarsesilt}{\%clay + 10\times\%OM}$$ **Equation 3-1**

Where OM, is organic matter.

3.6. Erosion model and parametisation

Erosion modelling in a GIS environment using the LISEM requires four basic maps from which other 24 input maps are generated. The four include land use cover map, soil map, DEM and impermeable areas map which for this study was not considered. First the land use map of the whole catchment was prepared by using supervised classification of ASTER image of 22 Jan 2007. The accuracy of the land cover classification map was assessed by ground truth data collected during field work. The whole Namchun catchment land cover map was first prepared and the sub catchment map was subset from it. Land cover was classified into five major types of agricultural, degraded forest, forest, grass land and orchard, the road and stream which were added later by clipping. The soil map prepared by Solomon (2005), was obtained in digital form and the sub catchment was extracted from the main catchment map. The Geopedological soil units within this map were used as soil types in modelling erosion later in chapter 6 The of land cover and soil water variables such as the Ksat, initial soil moisture, random roughness, manning's n canopy cover fraction, canopy height, LAI, soil cohesion, crusting and wetting value were considered as inputs. Other soil inputs considered were from the soil unit map. Rainfall, one of the main inputs is entered in the model as a text file.

4. Land cover change

4.1. Land Cover Change Analysis

Nam Chun sub catchment land cover is generally categorised into five classes namely agriculture, forest area, degraded forest, grassland and orchards. These classes are different in terms of vegetation class and character and use. These land cover type have however been undergoing change for the last three decades or so (Shrestha 2001) due to the need for land for farming and exploitation of timber by the locals and economic merchants. Since the 1970s activities like deforestation for timber and firewood, farming and grazing have created land cover changes that have affected natural soil cover in the area. To analyse such cover changes in Nam Chun sub catchment two maps study area from 2002 and 2007 in figure 4-1 were compared to quantify the changes presented in table 4.1 below.

Computation for the area which has undergone change all started from a 15 by 15 metre rasterised map which was the pixel resolution of the image from which the maps were developed. Computations are presented in table 4-1 and figure 4-1 below.

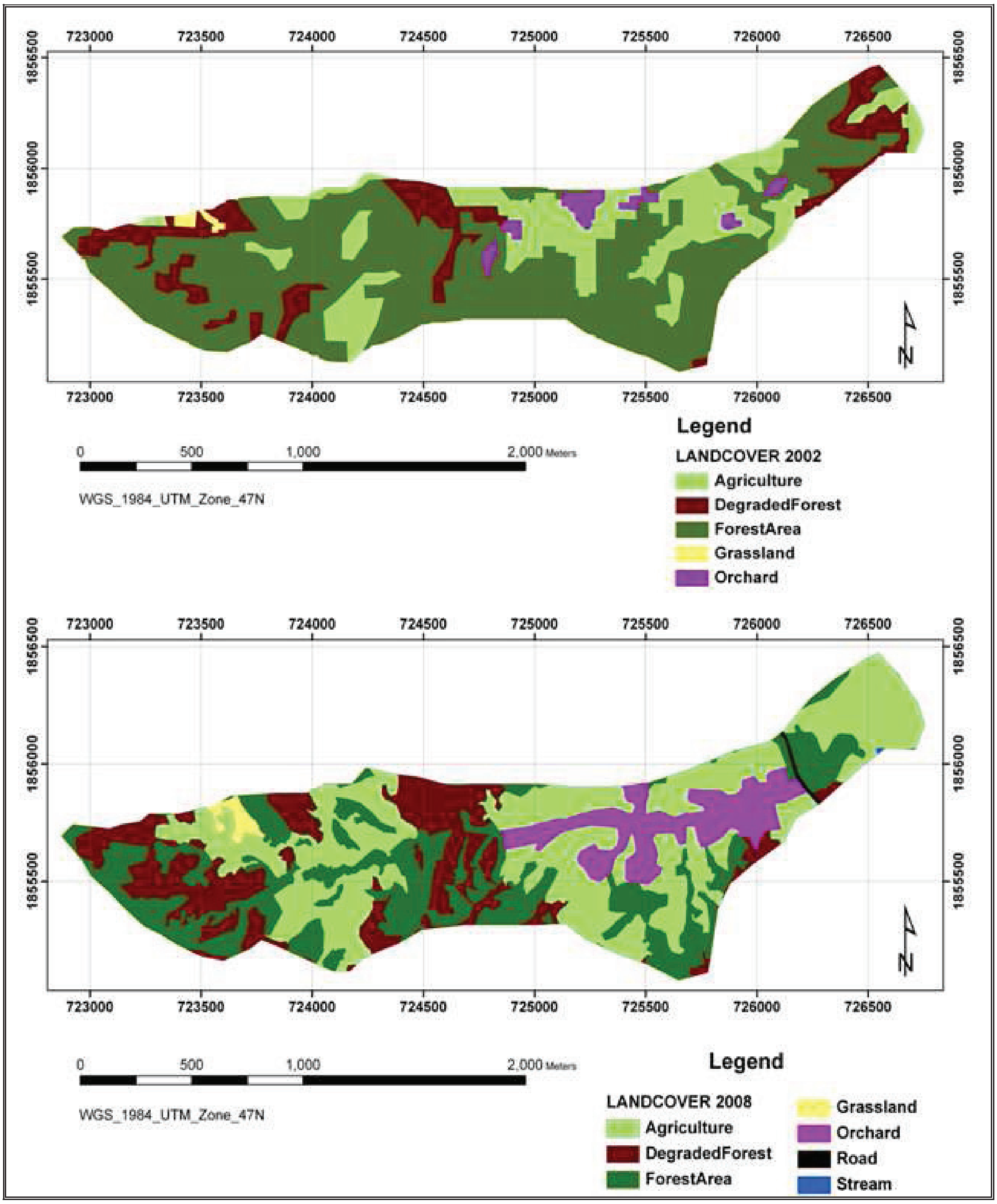

Figure 4-1: Land cover Maps 2002 and 2007

Table 4-1: Land cover change analysis

Land cover Change From 2002 to 2007						
	2002		2007			
Land cover	Land area in hectares	% of total Land area	Land area in hectares	% of total Land area	Land area change in hectares	Over all %change
Agriculture	52.7	23	92.7	41	40	18
Degraded Forest	48.9	22	42.5	19	6.4	3
Forest Area	114.9	51	66.1	29	48.8	22
Grassland	1.1	0	2	1	0.9	0.4
Orchard	8.3	4	22	10	13.7	6
Road	0	0	0.6	0.3	0.6	0.3
Stream	0	0	0.1	0.04	0.1	0
Total	225.9	100	225.9	100	110.5	49

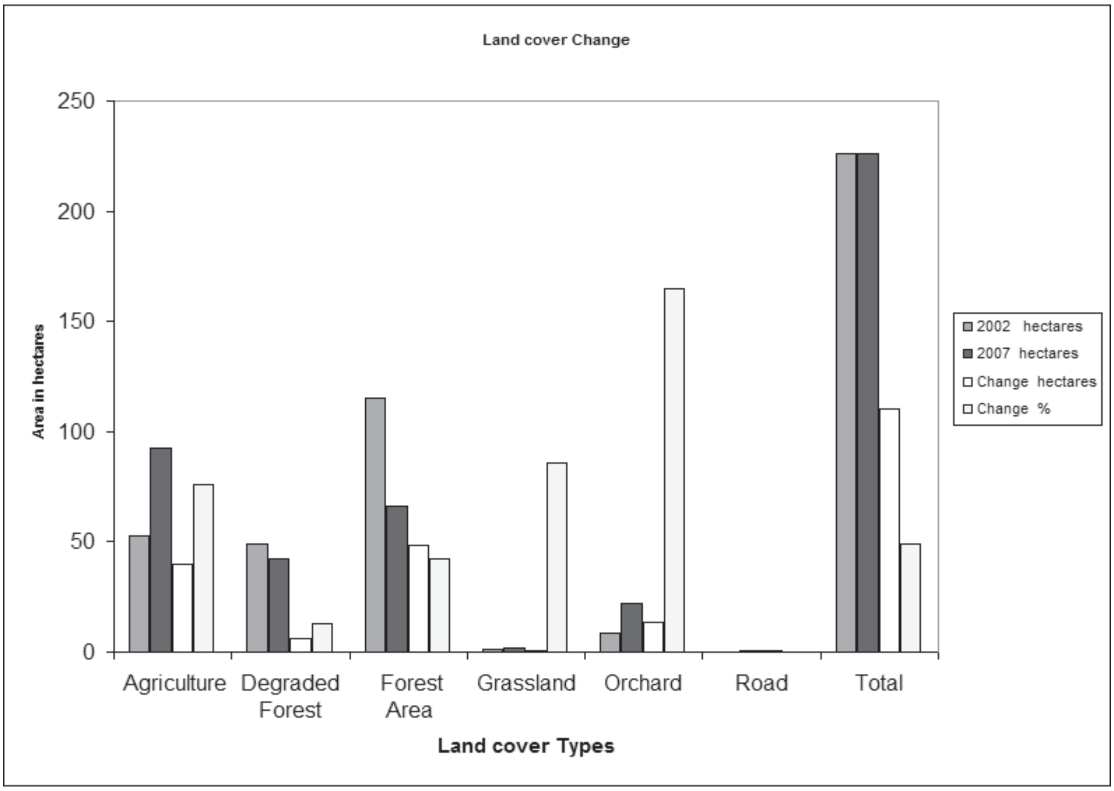

Figure 4-2: Land cover change graph

The results showed that land cover change in Nam Chun is a reality and has generally been occurring over the period 2002 to 2007. Basing on the two land cover maps in figure 4-1, out of about 225.9 hectares of land, 49% under went change irrespective of type of land cover. Area coverage of forest has significantly reduced from 1149 to 66.1 hectares representing 42% reduction of its original size and over all percentage change of about 22% change. Degraded forest has also reduced in size from 49 to 43 hectares representing 13% of its original area and about 3 % of the total sub catchment area. Orchards farms increased by more than 100% of its original area and overall change 6% of the area total while grasslands have also increased by 86% of its original area but minimal 0.4% of the total area. Aagriculture increased by 76% of its former land area and about 18% of the total sub catchment area as in table 4-1. While natural cover forests and degraded forest areas have been reducing, much of the human induced cover is increasing. The orchards which increased more than others occupy lower parts of the sub catchment and along the stream. The area is characterized by water logged conditions. Some are abandoned areas or former farms under fallow. Built up area is minimal and only about ten constructed household are found in the area. The road and stream that are seen to have increased by almost 100% were just digitised and added to the land cover map of 2007 and had not been considered in classification of 2002 image

4.2. Land use trends and Seasonal crop Calender

The land use trends and crop calendar are related to land cover change because they involve removing and replacing soil cover either temporary or permanently. Land use trends may act as pointers to what exactly happens in the field and when it occurs. To reconstruct the land-use trend of the study area a crop calendar prepared by Shrestha Babu Bharat with knowledge from the farmers in the district figure 4-3 was used to show how cover change may occur in a cropping system over time.

Trends and crop rotation as a land use activity in a year that may account for what change occurs where in an area at a time The cropping pattern and trend in Nam Chun sub catchment is associated with clearing land in preparation for planting, weeding and harvesting of the crop. Also there are fallow periods in between harvest and re- planting of crop or change to another crop figure 4-4 below. Sometimes in between maize harvest and replanting, mug beans are planted as cover crops to protect the soil from erosion agents while other areas are left to fallow covered by maize residues. The fallow or abandoned land may regenerate into bush and grassland or later turned into agricultural land.

Also planting, weeding, harvesting and fallow are all activities of land cover change that may have an influence on the underlying layer of soil. In situations where the land is exhausted, the recovery may take long and the soils remain exposed to damage by functional forces like erosion as in figure 4-10 below.

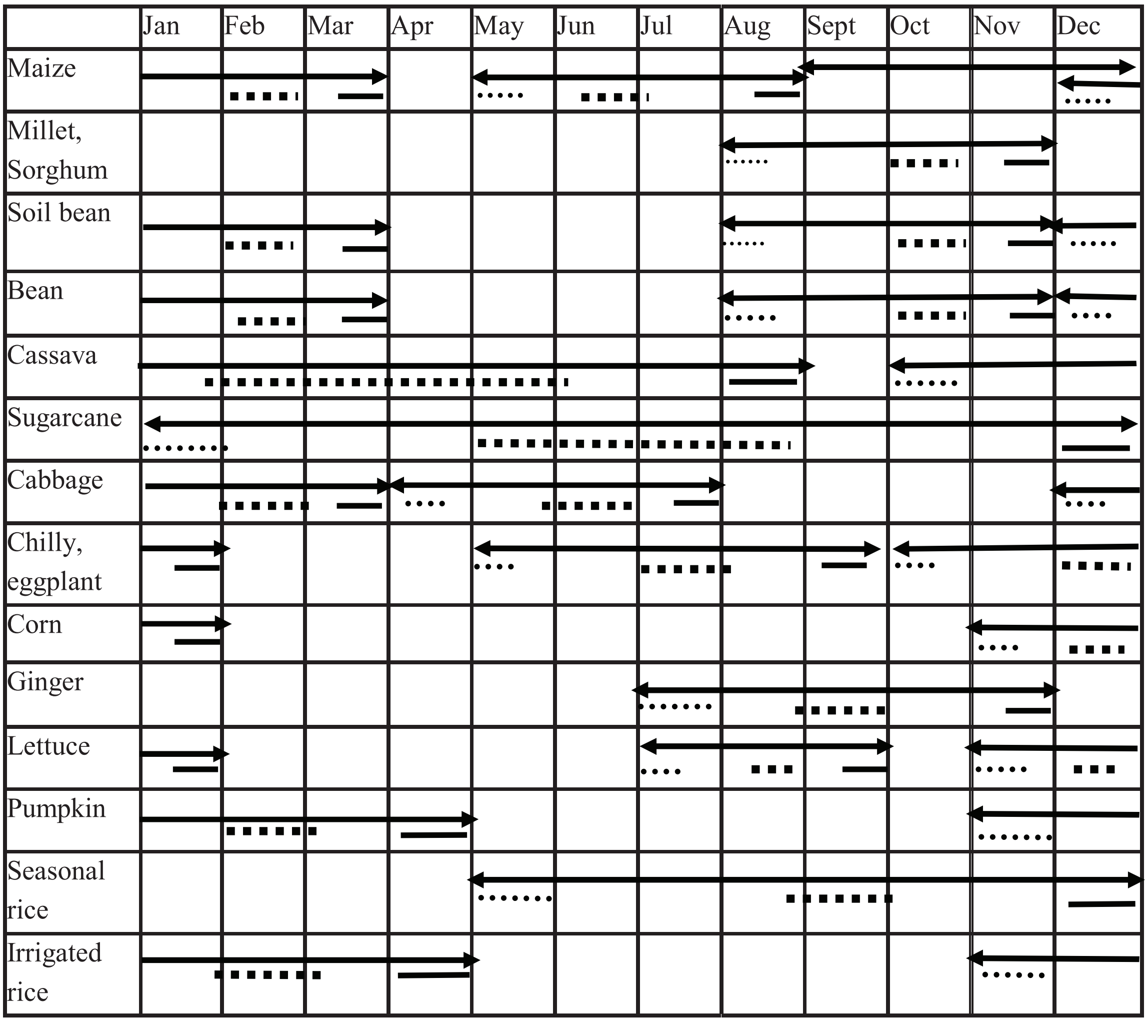

Figure 4-2: Crop calendar for Lom sak district and surrounding areas

Legend:

Whole cropping period	←——→
Planting period (young plant)	················
Main growing period	■■■■■■■■■■■
Harvesting period	▬▬▬▬

Figure 4-3: Legend to crop calendar

Source: Land development Department, Thailand and modified in the field with farmers' information (September .2008) Verification exercise for the crop calendar was done during field work and unlike in the whole district where a crop like maize is grown twice a year, ground information in the catchment indicated, its grown three times and covers the whole year save for the month of April. Irrigated rice, ginger and pumpkin are also not grown in the catchment.

4.3. Rainfall, Land use trends and erosion

The average monthly rainfall distribution in the Nam Chun sub catchment show that the amount of rain is highest between the months of May and October. The total rainfall and its seasonal variation within the year show the typical Asian monsoon pattern with over 50% of total rainfall from May to October and the other half year dry. More so 75% of the rain days occur at the time when more land in the sub catchment is under cultivation and some are bare due to clearing for planting season exposing it to more erosion process figure 4-1 below and the combined graph in figure 4-3.

Table 4-2: Avarage annual rainfall for Lomusak district for 35 years (1972-2007)

Month	Average annual rainfall per month in mm	% of yearly rainfall	Average Rain days	%of yearly rain days
JAN	3.1	0.9	1.1	0.9
FEB	13.1	4	2.3	1.9
MAR	21.4	6.5	4.7	3.9
APRIL	22.9	6.9	8.4	6.9
MAY	46.9	14.1	15.9	13.2
JUNE	40.9	12.3	17	14.1
JULY	33.7	10.2	18.3	15.2
AUG	51.7	15.6	20.7	17.2
SEPT	50.1	15.1	18.8	15.6
OCT	33.7	10.2	10.1	8.4
NOV	10.4	3.1	2.6	2.1
DEC	3.6	1.1	0.7	0.5
Total	331.6	100	120.6	100

Source: Lom sak Weather Station (X : 74000; Y :1857000)

The daily rain fall recorded in the field show a similar trend of low rain fall during the month of September which is almost the end of season. For the first two of the of September there was rain and almost nothing in the last two as presented in table 4-2 and figure 4-1 below. The three rain gauges within the sub catchment and one outside were to find out any variance in rainfall amount. Rainfall was however found to be homogeneous in the area. as seen in 4-3

Table 4-3: Daily rainfall pattern for the sub catchment for september 2008

Date	Rain gauge 1	Rain gauge 2	Rain gauge 3	Rain gauge 4
11-Sep	13	13	12	0
12-Sep	84	84	77	53
13-Sep	0	0	0	0
14-Sep	14	14	27	15
15-Sep	11	11	12	12
16-Sep	17	17	31	17
17-Sep	0	8	9	8
18-Sep	2	2	9	2
19-Sep	0	0	8	0
20-Sep	23	23	8	23
21-Sep	0	0	0	0
22-Sep	0	0	0	0
23-Sep	0	0	0	0
24-Sep	0	0	0	0
25-Sep	0	0	0	0

Source: Field raingauges 1: X: 726263 Y: 1856125; 2 X: 724333, Y: 1855292
3 : X :725582 Y: 1855292 4 :X :721266, Y : 1856276

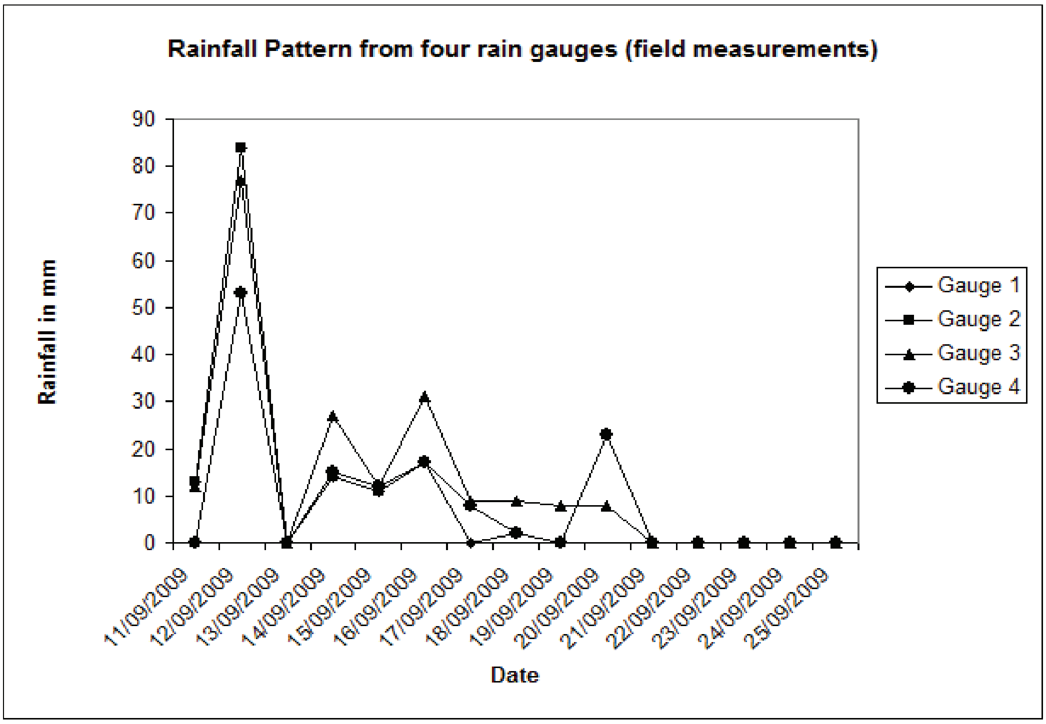

Figure 4-4: ielld Rainfall Pattern line Graph

Dependency on rain fed cropping system may determine the severity of erosion in agricultural areas. In Nam Chun sub catchment the effect and severity of monthly rainfall and the changes in the soil surface cover due to cropping system may influence run off and erosion. Crops such as maize, beans cassava, soy beans millet and upland rice are all rain fed crops grown in the area (figure 4-4). All these are grown during the rain season. Crops like Maize, cassava and sugar cane are grown throughout the year. This reduces the fallow period and keeps the soils under use all the time. As a result soils are constantly disturbed save for the dry season for some crops. This may lead to loss of soils aggregate stability due to constant tilling. Worse still more crop farms are located on the higher and mid slope areas of the sub catchment which may affect soil stability and accelerate run off during rainfall season.

Intensified cropping, seasonal, occasional or on temporal basis to utilise the short lived rain leads to reduction in the fallow period and affects soil cover. In the process, soils are left bare and may result into intensive runoff during heavy rains. The practice is common in Nam Chun sub catchment.

The cropping calendar for this area in figure 4-2 indicates a cropping system that run throughout the year. Majority of the crops are planted after the rain starts in the month of May and goes on till there is no rain any more figure 4-4. Apart from maize and rice which are planted immediately the rains begin, crops like millet, sorghum and soybean are planted at the beginning of august. The time lag between May and august when planting such crops begin the time when rainfall intensifies, gardens are under preparation and soil is bare. This may increase runoff and erosion as soils remain under rain and without cover for some time. Also the time lag between actual planting and when the crops grow to provide cover is long enough to cause havoc to bare soil which is already loosened during preparation. During such time runoff and erosion problem is likely to increase due intensive rain at the time. Similarly after harvest some gardens formerly under crops like beans remain bare before vegetation germinates. Between then and beginning of new planting season in May for maize and rice and august for others, the land in question remains bare. They are vulnerable to erosion agents before planting starts and runoff may intensify when the gardens are still bare or are under preparation for the new crop.

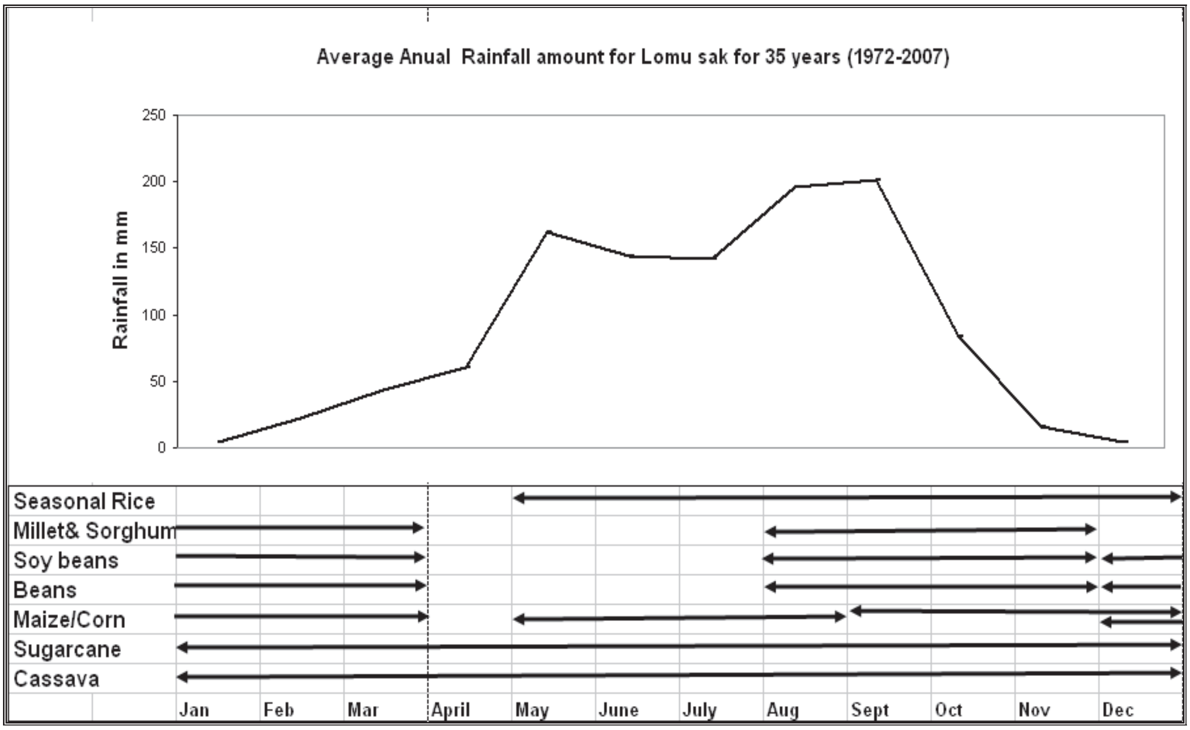

Figure 4-4: Crop calendar and average annual rainfall for Lom sak district

Studies have shown that seasonal changes of vegetation cover determine the steady state infiltration rates and play an important role in the soil hydrology. During dry season the infiltration rates are high, no runoff is observed on vegetation covered soils while infiltration is low during rain season and when soils are bare but for the vegetated surfaces, runoff is negligible (Cerdà 1996). With continued heavy rain much and excess water is available which leads to over land flow as run off. The amount of rain fall in Nam Chun sub catchment is so on average and may have an accumulated impact (Table 4-2 and Figure 4-6) over time. When it exceeds ground water capacity soil surface storage more will be available at the surface. If more rain is available together with a sloping gradient may lead to surface runoff and erosion.

Rainfall pattern (Table 4-2) in Nam Chun show that high intensity rainfall occurs in May to October of each year. This is when there are significant changes on land for planting. As a result soils are left bare and un protected from rain and other erosion agents. Where soils are bare and accumulate water to reach saturation up to zero infiltration capacity after previous rainstorms, more surface water is converted into overland flow and run off. More so for the study area uphill cultivation and planting of crops during the same season and the frequent tilling and weeding expose soil to intensive rainfall and become more vulnerable to erosion as seen in figure 4-3

Maize is a crop that is grown in the study area almost throughout the year requires vigilant attention and frequent tilling of land. Farmer seemingly aware of the erosion problem on the hillside tend to mulch their gardens with previous crop residue as in figure 4-10. However the practice does not prevent it from being eroded by excessive runoff. Beans which are planted as soil cover crops after maize harvest have had no effect in protecting soil from detachment. Water through such gardens creates runoff as gulleys and other erosion feature are formed as in figures 4-7 to 4-9. This may imply that the soils' aggregate stability is weak and can not hold leading to run off despite the presence of cover crop. This is worsened by the trucks that transport maize harvest form the fields when they mark gardens with wheel trucks that may act as water ways for runoff during rain.

Figure 4-5: a and b gulleys developing in well covered cropland

Figure 4-6: a and b: a isTracks made by transport tractors developing into linear erosion features and b are rill features in abandoned former cropland now orchard

5. Soil Properties

5.1. Introduction

The soils in the area are mainly of high silt and clay content categorized in silt clay loam, silt loam to silt clay and clay textural classes. The reason is that textural classes may be linked to their historical land formations of the quaternary era which is responsible for the formation of present day litho logy in the area (Ekkanit 1998). However soils in the area may have been affected by human induced changes and activities that remove soil cover. Activities such as farming and deforestation impact on soils surface characteristics. Intensive farming disrupts the soil composition and texture because of continuous tillage and shifting cultivation. More so deforestation which has been going on in the area for last 35 years or so (Patanakanog, Shrestha et al. 2004) has contributed to the removal of land cover leaving soils bare and without cover. This affects the soil physical character, texture and its water behaviour. In the long run it may affect the soil's capacity to infiltrate and reduced its water holding capacity which may lead to run off.

5.2. Soil Texture

Soil textural classes were obtained after laboratory analysis as per each land cover found in Nam Chun sub catchment. Table 5-1 and figure 5-1 below show average distribution of soil texture in each land cover type in the sub catchment. The distribution reveals a trend that characterises the soils in the area. The area soils are mainly of silt content categorized as silt clay loam, silt clay and clay texture classes. The general trend showed that silt content is highest in the forest with52% and lowest in the degraded forest with39%. Agriculture is second to forest cover with 46 % while orchard and grassland having 41% and 40% each respectively. Clay content is relatively high in the area. Grassland has more clay contend and also orchard with 44 % and forest is lowest with 32%. Sand content is more in degraded forest followed by agriculture 18% while forest and orchard have 15%. The relatively high clay and silt content in the sub catchment may be attributed to the disturbance by cultivation or any deforestation that expose soils to agents that remove the top cover part. Organic matter is found to be more in the forest and slightly higher than degraded forest and lowest in agriculture. Similarly this trend may be due to disturbance resulting from cultivation and farm related activities.

Table 5-1: Texture distribution in land cover types

Land cover	%CLAY	%_SILT	%_SAND	%OM
Agriculture	35.83	46.05	18.26	1.83
Degraded Forest	41.15	38.53	20.17	2.39
Forest	32.26	52.25	15.62	2.75
Grassland	43.78	40.07	16.15	2.25
Orchard	43.63	40.97	15.39	2.04

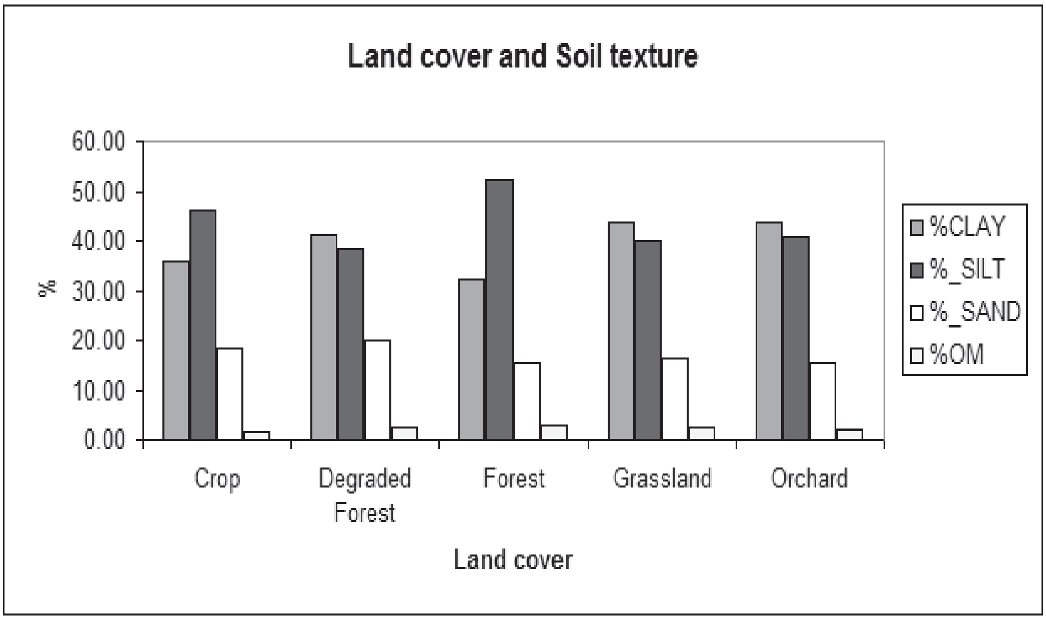

Figure 5-1: istribution of Texture in Landcover types

To show the relationship between soil texture distribution in different land use cover types. Table 5-1 and figure 5-2 above shows that the forest has the highest organic matter as compared to other land cover classes. Organic matter decreases in the degraded forest, orchards and grassland cover classes. The agricultural cover class has the lowest organic matter of 1.83%. There is however, not much difference between the organic matter of forest (highest) and agriculture (lowest) with 2.25% and 1.83% respectively. Grassland and orchards areas showed relatively lower values but higher than agriculture. This may be because, the grasslands and orchards are areas once used for cultivation. Conversion of forests into the other types of land uses may lead to a decrease in soil organic content. In agriculture, mechanical destruction of organisms, increase compaction that affects organic matter.

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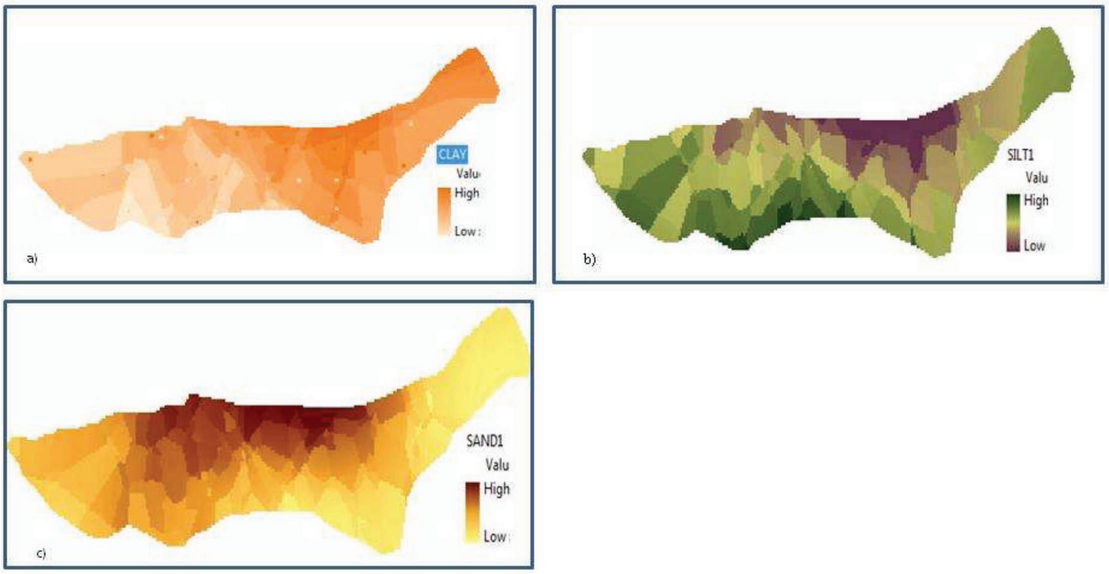

Figure 5-1: Texture Maps: of Namchun subcatchment

To understand the distribution of texture classes in relation to land cover, texture maps were developed from point data map for soil samples. Simple interpolation by simple kriging was used to develop tshown in figure 5-3 belowThese maps can be interpreted well together with land cover map in figure 4-1 in chapter 4 above. It showed how soil texture is distributed in the sub catchment. Figure 5-2 a) Far left corner shows the distribution of clay in the sub catchment. It is highest in the orchard areas and lowest in the forest areas. Figure 5-2 b) Far right corner is silt which is highest in forest areas and lowest in orchard and some agricultural area Figure 5-2 c showed that sand is more in the degraded and orchard areas than in the forest areas.

5.3. Land Cover Effects

To establish the land cover effect in Nam Chun sub catchment a statistical analysis using SPSS one way analysis of variance (ANOVA) was used to compare the differences between the means of key soil properties among major land cover in the study area. It was on the basis of the null hypothesis that there is no significant difference between soil physical properties among the land use types and the results are presented in table 5-5 below. These properties include saturated hydraulic capacity, bulky density, cohesion; crusting and porosity were considered because of the influence in soil water behaviour. The five land cover types identified and considered representative of the area include agriculture, degraded forest, forest, grassland and orchards. The analysis was comparing one physical property among the many in each land cover. The ANOVA results are illustrated in the box plots figure 5-4 below and table 5-6 below

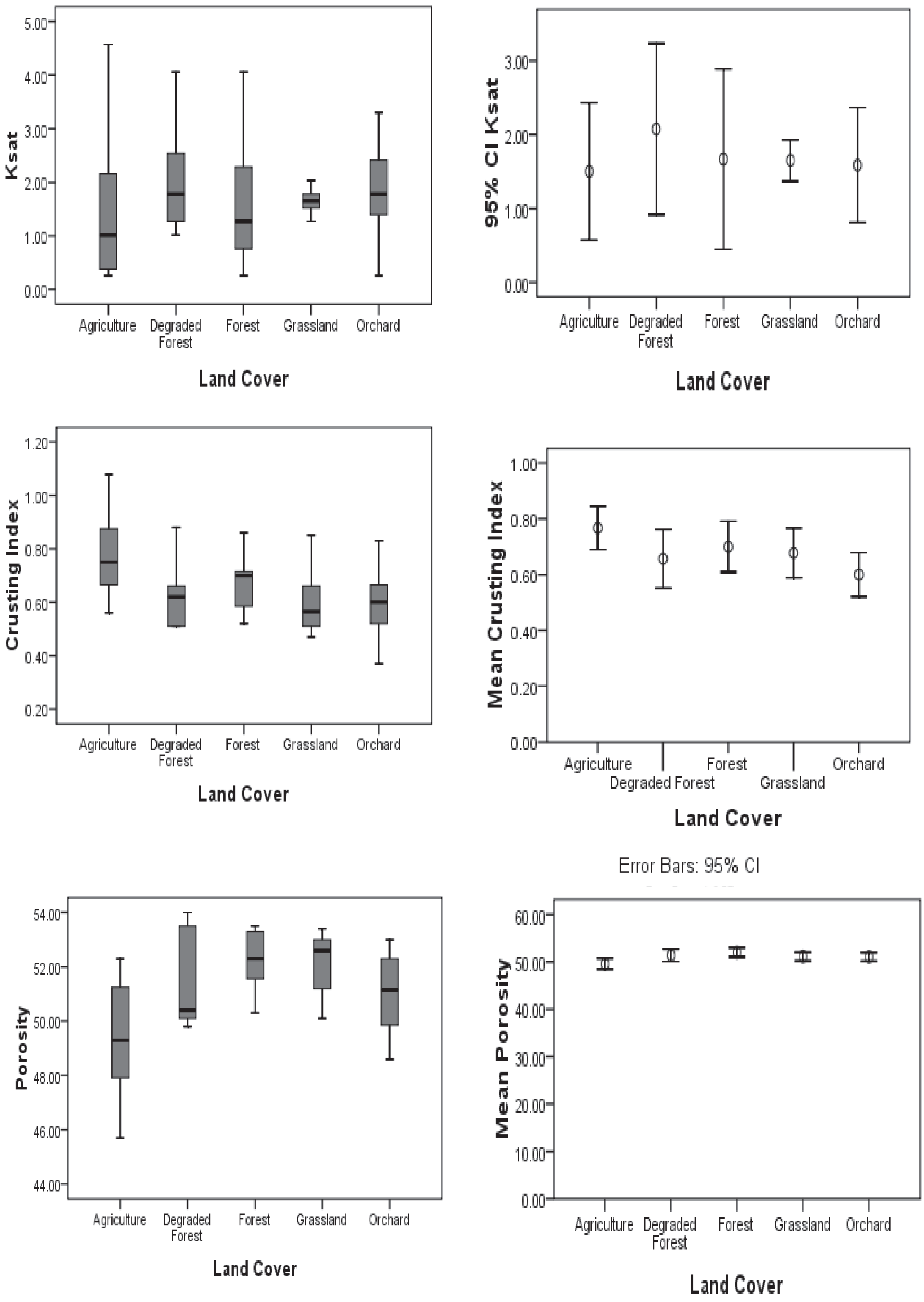

Figure 5-2: Panel of three pairs of Box plots showing soil properties with Land cover

Error Bars: 95% CI

Error Bars: +/- 2 SE

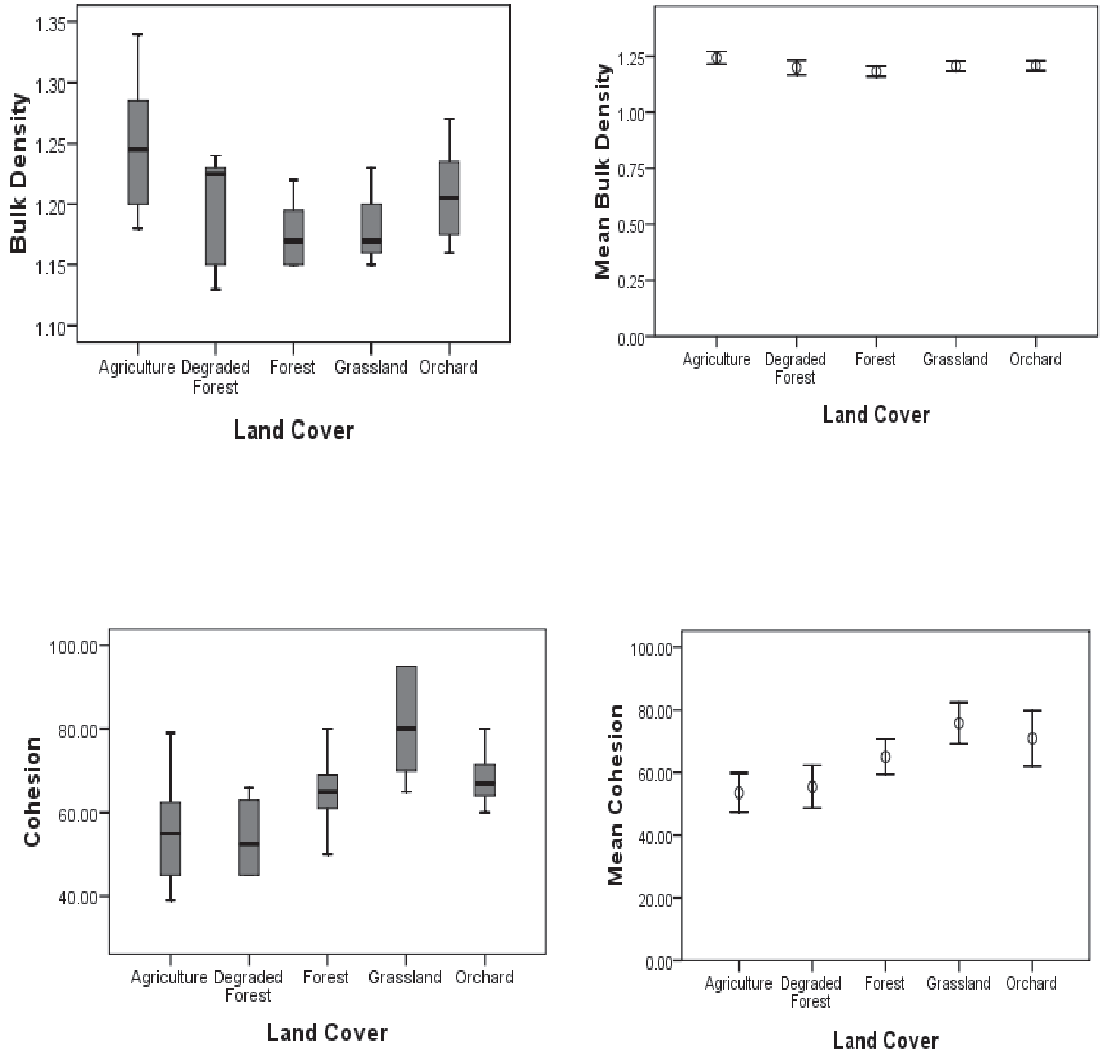

Figure 5-3: Two more pairs of box plots

The above five pairs of box plots figure 5-3 and 5-4 show how land cover affects the variations of soil physical properties. The relationship is summarised in table 5-2 below

Table 5-2 Soil properties and Land cover

Soil property between groups	F value	P-value (significant level)	Significance
Saturated hydraulic conductivity(Ksat)	0.302	0.875	n_s
Crusting Index	2.819	0.039	*
Porosity	4.147	0.007	**
Bulky density	4.188	0.007	**
Cohesion	6.296	0.001	**

*Significant difference at P< 0.01**; significant at P< 0.05 *; n.s: No significant difference*

The summary results in table 5-3 above, soil properties were compared within groups and results show that different soil properties such as Ksat, crusting index, porosity, bulky density and cohesion were significantly different among groups. Saturated hydraulic conductivity (KSat) ranges from maximum at 4.57 in degraded forest to minimum 0.25 in agriculture. It is not significantly different between groups with an F value of 0.30 and P value of 0.875. Its standard deviation is highly distributed as illustrated in the error bars. Crusting index ranges from maximum at 1.08 in agriculture to minimum 0.37 in grassland. It is significantly different among the groups with F value of 2.819 and P value of 0.039. Similarly Porosity is significantly different at F value of 4.147 and P value of 0.007 and it's between the maximum of 54 in grass and minimum in agriculture at 45.7. Cohesion is significantly different among the groups at F value of 6.3 and P Value of 0.001. It ranges between maximum of 95 in grassland and minimum of 39 in degraded forest. Bulky density is also significantly different with F value of 0.302 and P value of 0.875 with Maximum at 1.34 in agriculture and minimum at1.13 in grassland.

However the significant differences in the one way ANOVA results above do not show the magnitude of the significance, and in which land cover. To understand the magnitude of the significance a multiple comparison LSD post hoc analysis was done for each soil property among one or more land cover types. Comparing a particular soil property and different land cover types is meant to find out the multiple influences soil properties may have on each other within one or more land cover types and at what level of significance as presented below in table 5-6 below.

Table 5-3:Multiple comparison analysis for soil properties and landcover types

Soil Property	Land cover	Land cover	significance
Ksat	Agriculture	Degraded forest Forest Grassland Orchard	n.s
Crusting Index	Agriculture	Degraded forest Forest Grassland Orchard	* * * **
Porosity	Agriculture	Degraded forest Forest Grassland Orchard	* ** ** **
Bulky density	Agriculture	Degraded forest Forest Grassland Orchard	* ** ** **
Cohesion	Agriculture	Forest Grassland Orchard	* ** **
	Degraded forest	Orchard	**
	Forest	Grassland	*
	Grassland	Degraded forest	**

*Significant difference at P< 0.01**, Significant at P< 0.05 *,n.s: No significant difference*

Table 5-6 is a summary of multiple comparison LSD results from ANOVA analysis was comparing one soil physical property among many land cover types. It was revealed that the Ksat is not significantly different in all land cover types. These results are consistent with the one way results in table 5-4. Crusting index is significantly different among agriculture and degraded forest and grassland at $P < 0.05$. Porosity in agriculture verses degraded forest was significant at $P < 0.05$ while agriculture with forest, grassland and orchard were significant $P< 0.01$. Also the results in table 5-5 showed that bulky density in agriculture and degraded forest were significant at $P < 0.05$ while with forest, grassland and orchard were significant at $P < 0.01$. Cohesion in agriculture with forest is significant at 0.05 and with grassland and orchard is at $P < 0.01$. Further cohesion in degraded forest and orchard, grassland and degraded forest are significant at $P < 0.01$ while in forest and grassland was significant at $P < 0.05$. More details of results which were not significant were left out but included in the appendix---.

6. Modelling Erosion

6.1. The LISEM

The LISEM is a physical process based soil erosion model which was developed in Netherlands to simulate both the effects of the current land use and on-site effects of soil conservation measures. These include grass strips and spatial changes of tillage practices like mulch, crop cycle changes (Jetten and de Roo, 2001). The model is event based and designed for small scale areas of 50 m2 to 5 km2). Currently it is used by the Limburg Water board to design several hundred rainwater buffers to protect the villages. Outside the Netherlands it has been used mostly to simulate land use change in several countries in north-west and Mediterranean Europe, East Africa, and Asia (Hessel and Jetten 2007). It also simulates the hydrology and sediment transport during and after a single rainstorm event in agricultural landscape (De Roo and Jetten 1999)

Its link to a GIS model requires all input and output data and maps in raster format and rainfall in text format. The maps are of known grid cell resolution usually between 2 and 20 m. LISEM incorporates all the soil erosion processes at play in a catchment. Hydrological processes included are spatially distributed rainfall, interception and through fall, and infiltration using a two-layer Green and Ampt or a solution of the Richard's equation. Erosion includes splash erosion and flow erosion based on transport capacity using unit stream power. Water and sediment are routed with a kinematic wave over a raster grid.

The model takes into account the catchment as a system and drainage divide as a system boundary. Within the boundary of the system, the model simulates run off and erosion as a consequence of single rainstorm. When a model is run in a time step series, it represents an open boundary system. The model follows the principle of conservation of mass. In this case, it is the water balance in a catchment where rainfall is the major input of water and can be described mathematically as Rainfall-loss (interception, infiltration, surface-storage, percolation, evapo-transpiration) = Runoff. In this system there is no loss (destruction of mass or water). The model processes also take into account surface compactness and channel roughness all of which affect infiltration and are the interests of this study.

6.1.1. The Model Frame work

The LISEM framework (Figure 6-1) shows a flow chart of the LISEM model. The model is divided into two parts; the water part which is about run off and discharge and the erosion part. Rainfall is the main input of the water part which after interception the remaining reaches the earth surface where it can form surface storage or infiltrate (Hessel 2003). After certain thresholds are exceeded surface storage may occur which will, result into surface run off, overland flow into the channel discharge. Infiltration leads to deep percolation and underground water. The erosion processes include soil detachment by splash and run off sediment transportation by over land and stream water, and deposition is into the channel or on land down stream. The processes involved in regulating the erosion process and the controlling links shown in figure 6-1 below.

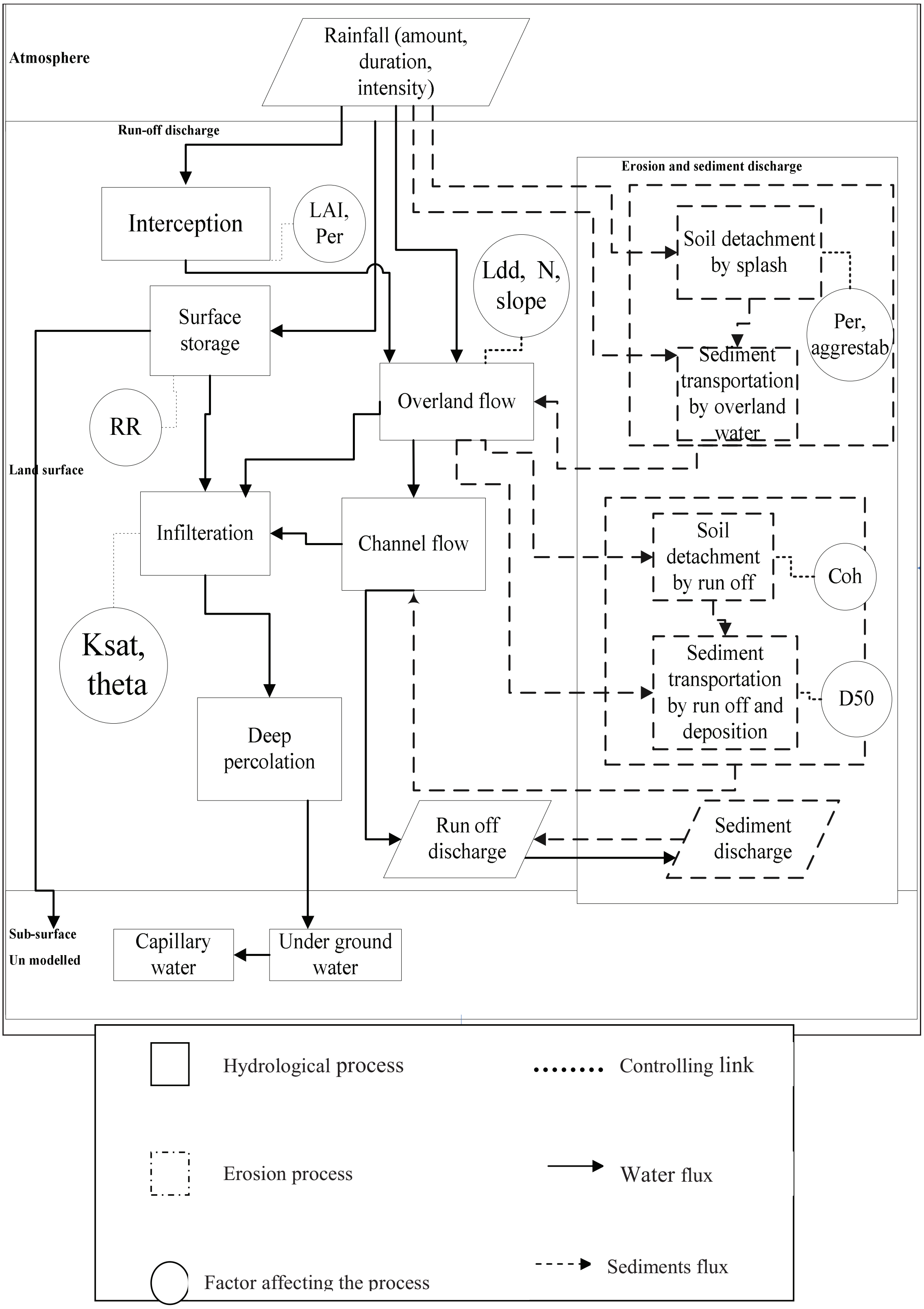

Figure 6-1: LISEM model frame work

Legend for model Frame work

LAI: Leaf area index,

Ksat: Hydrological conductivity index

Theta: Initial moisture content

RR: Random Roughness

Ldd: Land drainage direction;

N: Manning's from literature and observation of roughness

Per: Vegetation cover fraction

aggrestab: Aggregate stability with drop test.

Coh: Cohesion with shear vane

D50: Median of texture (texture analysis)

6.1.2. Model Parametisation

The study area is Nampong sub catchment found in the mid south eastern part of main Nam Chun catchment. It measures 2,259 square kms. It was selected because it was suitable for the LISEM model which models erosion on small catchments of between 2 to 20 square kilometre areas.

The LISEM uses a number of parameters to assess erosion. Some of them were derived from literature and others were measured in the field. It uses four basic input maps, the DEM, soil unit map, impermeable areas and digital land cover map from which other 24 maps are generated for modelling erosion. For this study all the maps were of the same grid size of 15 by 15 m because of the Aster image resolution which were used in making the land cover maps. Parameters for the model are as listed in table 6-2 below. The model also uses the Green and Ampt infiltration sub model.

6.1.3. In Put Data for LISEM

Table 6-1: LISEM input data

Parameter	Name	Method	Unit
Catchment characteristic			
Local drain direction	LDD.map	derived from DEM	-
Catchment boundaries	AREA.map	derived from DEM	-
Area covered by raingauges	ID.map	mapping	-
Slope gradient (sine of slope angle)	GRAD.map	derived from DEM	-
Location of outlet and suboutlets	OUTLET.map	derived from DEM	-
Rainfall data	ASCII	derived from fieldwork	mm/hr
Vegetation			
Leaf area index	LAI.map	derived from PER.map	-
Fraction of soil covered by vegetation	PER.map	field observation	-
Vegetation height	CH.map	field observation	m
Soil surface			
Manning's n scalar	N.map	derived from literature	-
Random Roughness	RR.map	derived from literature	cm
width of impermeable roads	ROADWIDT.map	mapping	m
Green and Ampt Layer 1			
Saturated hydraulic conductivity	KSAT1.map	meaure from fieldwork	mm/hr
Saturated volumetric soil moisture content	THETAS1.map	meaure from fieldwork	-
Initial volumetric soil moisture content	THETAI1.map	meaure from fieldwork	-
Soil water tension at the wetting front	PSI1.map	derived from literature	cm
Soil depth	SOILDEP1.map	field observation	mm
Channels			
Local drain direction of channel network	LDDCHAN.map	derived from ldd.map	-
Channel gradient	CHANGRAD.map	derived from grad.map	-
Manning's n for the channel	CHANMAN.map	derived from literature	-
Width of channel scalar	CHANWIDT.map	derived from ldd.map	m
Channel cross section shape	CHANSIDE.map	field observation	-

6.2. Catchment Characteristics

Catchment characteristics include the slope gradient, local drainage direction, sub catchment boundary and outlet location. These maps were derived from the digital elevation map (DEM). Rainfall data was obtained from the field and from the Royal Irrigation Department, whose records of data are obtained automatically on hourly basis by use a rain gauge installed in the catchment. However, some rain data records were not available especially for some part of the study year due to the break down of recording equipment. For this study we are using rainfall data for 2006 with the assumption that the image data used was for the same period.

6.2.1. Vegetation Parameters

Vegetation parameters for modeling include the percentage of canopy cover (PER.map), crop height (CH.map) and leaf area index (LAI.map). The values for fraction of canopy cover and vegetation height for each land cover were estimates for each land cover made in the field presented in the table 8 below. Leaf area index was calculated from the fraction of canopy cover and land cover map was the main input for these variables. The main land cover variables observed from the field and used in the model are presented in table 6-3 below.

Table 6-2 : Fraction of canopy cover and vegetatio height

Land cover	**Fraction of canopy cover**	**Vegetation height (m)**
Agriculture	0.60	1.80
Degraded Forest	0.70	15.00
Forest Area	0.80	20.00
Grassland	0.95	1.05
Orchard	0.20	12.00

6.3. Soil Surface Parameters

Soil surface Parameters such as infiltration, storage capacity and overland flow and run off are some of the inputs that are considered in erosion modelling. Values used for saturated hydraulic conductivity, initial volumetric soil moisture content and saturated volumetric soil moisture content are presented in table 6-3. The wetting front suction values are presented in table 6-4.

Table 6-3: Soil data used in the model

Land cover	**Geological Unit**	**Texture**	**Saturated hydraulic conductivity (mm/hr Ksat**	**Initial volumetric soil moisture content**	**Saturated volumetric soil moisture content**	**wetting head**	**Average Soil cohesion(Kpa)**
Agriculture	HM211,HM311,HM312,HM313	Clay	0.55	0.35	0.51	31.6	6.4
	HM312,12,V111,HM313	Clay Loam	4.20	0.42	0.49	20.8	6.1
	HM312	Silt Clay	4.57	0.31	0.50	29.2	6.3
Degraded Forest	HM212,HM311,HM312	Clay	1.35	0.31	0.53	31.6	6.6
	HM212	Clay Loam	8.38	0.35	0.54	20.8	6.0
	HM212	Salty Clay Loam	4.06	0.33	0.50	27.3	8.0
Forest Area	HM211,HM213,HM311,HM313	Clay	1.63	0.52	0.51	31.6	7.7
	HM313	Silt Loam	1.52	0.25	0.53	16.7	4.5
Grassland	HM311,HM312,HM313	Clay	1.21	0.43	0.51	31.6	6.5
Orchard	HM312,	Clay	1.84	0.42	0.52	31.6	7.1
	HM312	Silt Clay	2.54	0.33	0.50	29.2	7.0

Table 6-4: Wetting front used in the model

Texture	Wetting front suction in cm
Clay	31.6
Clay Loam	20.8
Salty Clay	29.2
Salty Clay Loam	27.3
Salty Loam	16.7

Source: Maidment 1993; Gerlach Metamedi et al 2003

The other model requirements include random roughness (RR), , Manning's coefficient (N.map) and coefficients of the width of impermeable areas the ROADWIDTH.map and channel width (CHANSIDE.map). These inputs are important in influencing erosion process through infiltration, surface storage and overland flow velocity. The basic maps are derived from the land use cover types from where values of random roughness (table 6-5) were derived. These values were from the RUSLE handbook (Renard et al., 2000). They are based on tillage practices common in agricultural areas and used for estimating surface water storage capacity. The Manning's coefficients selected were based on land cover types found in Nam Chun sub catchment basing from literature (Chow 1959) and are considered as surface flow resistance. The road is impermeable and has no infiltration thus a small value assigned to it as presented in table 6-6 below.

Table 6-5: Random surface roughness used in the model

Land cover	Random Roughness (std in cm)
Agricultural Cropland	1.80
Degraded Forest	0.50
Forest Area	0.50
Orchard	0.50
Grassland	0.50

Source: Renard et al., 2000

Table 6-6: Mannings' n coefficients used by the model

Land cover	Manning's 'n' values
Agricultural Cropland	0.06
Road	0.01
Degraded Forest	0.30
Forest	0.40
Orchard	0.06
Water body	0.01
Grassland	0.24
Stream	0.05

Source: Chow, 1959.

6.4. Calibration of LISEM

Calibration of physically based erosion models is necessary to obtain an acceptable predictive quality (Jetten et al, 1999). Calibration of peak discharge is required to set the performance of the model. (Hessel, Jetten et al. 2003). However, shortage of measured data, calibrations and validation of the model was not done for this study. To simulate runoff, LISEM was calibrated using base channel simulation and base flow. The start was tuned to 1000 minutes. The channel base flux map was then increased till 10300. The start time was again brought back to 1300 minutes. The channel cohesion was then increased up to 80 which were considered very high. The cohesion was increased to have a chunivin.map equal to 6. This is to take into account the influence of plant and vegetation roots. Since the soils in the area are dominated by fine clay, silt clay and silt clay loams table 5-1, the structural stability was decreased to 10μm which is for very fine silt and increasing the channel cohesion to be as high as 80. This was based on the fact that the area is dominated by fine silt clay and clay that are easily transported. The likely effect is that the channel acts a signal to what is happening in the catchment and as well a transport route for sediments to down stream which may also cause enormous damage is done due to deposition of sediments eroded from up stream.

6.5. Rainfall Characteristics.

No calibration was carried out for the event-based LISEM model, but only three storms from two different years of the same period were used in the modelling and calculation of runoff and peak discharge. The model simulated the rainfall effect on the rainfall-runoff in the sub catchment basing on land cover types. The three rain fall events are of a short duration, with a higher intensity and infiltration capacity, while the land surface conditions are important indicators of the capacity of runoff generation and are represented by the Ksat when modelling. The duration and intensity of rainfall events influence soil properties that have an impact on erosion process. The three rainfall events used in this study were used to test the sensitivity of the hydraulic capacity as an indicator of surface cover characteristics and rainfall as an input. The three rainfall events ‘event one’ collected from the field and events, ‘two’ and three’ selected from ITC soil data base of previous studies in the same area and their characteristics are summarised below in table 6-7

Table 6-7: Rainfall characteristics

Rain Events	Total (mm)
Event one 13/09/2006	84.3
Event two 15/09/2006	92.4
Event three 16/09/2006	236.3

The model was run using each rain event and adjusted saturated hydraulic conductivity. The hydraulic conductivity was adjusted by multiplying with the factor of 100%, 50%, and 10%. The changes in peak and total discharge are presented under sub chapter 6.7 and rest in appendix ---.

6.6. Sensitivity Analysis

The sensitivity analysis is to establish the behavioral change of a model in response to the changes in its parameter that represent the real situation. Changes in one or more parameters were made to determine to which variable or parameter the erosion process is more sensitive. In this study, the parameters considered are the saturated hydraulic conductivity (Ksat) and rainfall. Ksat was selected because it determines the rate of infiltration and run off in the erosion process. Rainfall event is the main input to the erosion process. The Peak discharge, flow detachment on land and channel erosion and deposition all are as a result of infiltration and run off. Three rainfall events were modeled with Ksat which was multiplied by the factor of 100, 50 and 10 The Three rainfall events were labeled in order of occurance. Event one was recorded on 13 September, 2007 event two was on 15 september and event three was on 16 september both of 2006.

Table 6-8: Peak discharge for all Ksat and rain events and for 2002&2007

	2002	2007	2002	2007	2002	2007
Ksat and Year	Ksat10	Ksat10	Ksat50	Ksat50	Ksat100	Ksat100
Event one	13.82	14.51	10.66	11.16	10.46	10.7
Event two	12.49	13.08	10.48	10.77	10.42	10.53
Event three	31.82	32.55	25.68	27.09	20.93	23

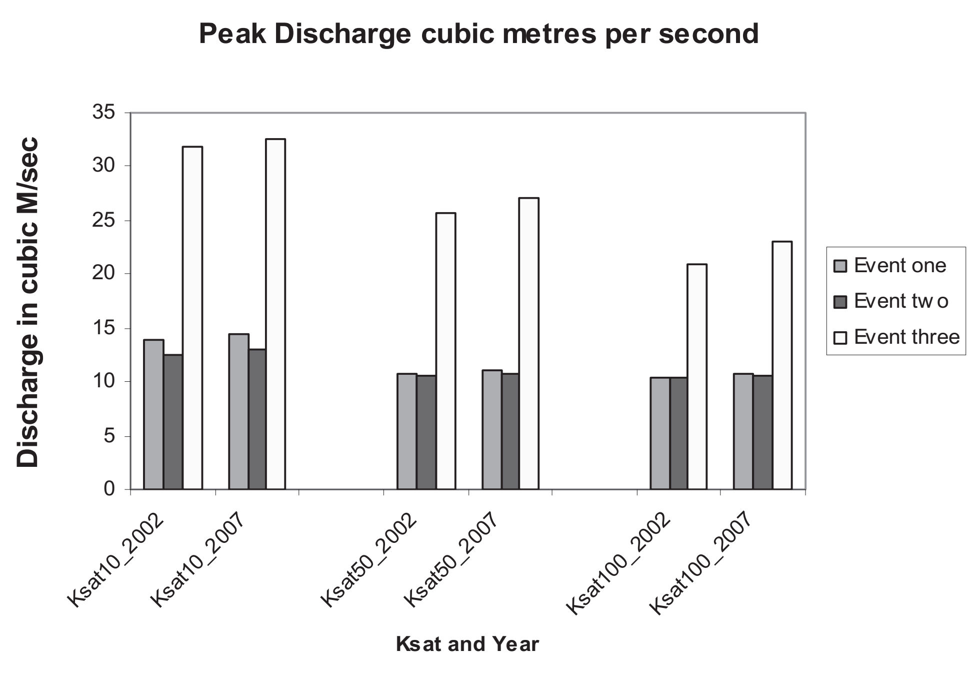

Figure 6-2: Peak discharge in cubic metres per second

Results in figure 6-2 show that Peak discharge decrease with the increase in Ksat for the three rain events. However, the difference between the three adjustments in ksat 10, 50 and 100 for both years showed a small difference in the discharge for every change on ksat. While increase in rainfall cause a slightly higher increase in discharge than the increase in Ksat factor. To further understand the most sensitive factor among rain and ksat two cases were developed when Ksat was first kept constant and rainfall was varied and same time step. Results are presented in figure 6-3 and 6-4 below.

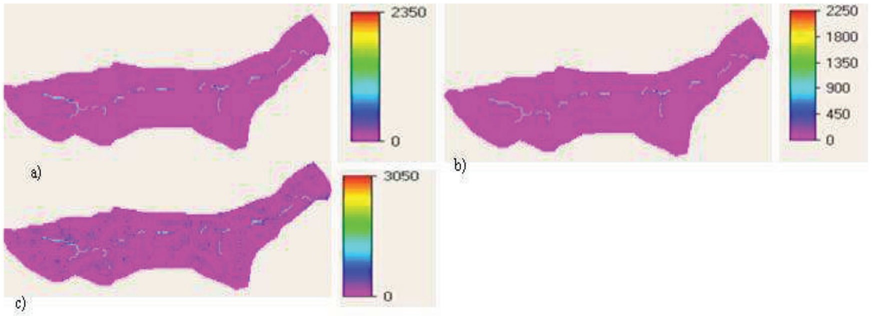

Figure 6-3: Varying rain and keeping Ksat constant for time step 250

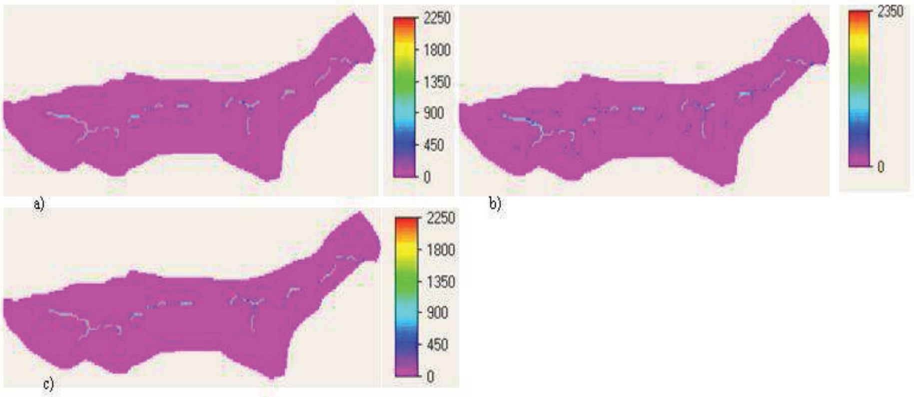

Figure 6-4: Varying ksat and keeping rain constant for time step 250

The figures 6-3 and 6-4 show that more rainfall led to more discharge (figure 6-3) while in higher ksat had no significant effect on discharge.. Other maps showing the variation of ksat and rainfall are included in the appendix 2.

6.7. Flow detachment

Flow detachment values in table 6-8 below have shows a high flow detachment for two rainfall events one, and two for Ksat10 Ksat 50. Ksat 100 had low detachment for rainfall event one and two and rain event has higher detachment for flow· However, the detachment on land is not succeeded by any deposition on land or even in the channel in Table 6-9 and figure 6-5 The river channel also experience higher erosion rates but with only very low or no deposition save for a few pixels. This may be due to the nature of soil textural classes of (silt, silt clay, sand clay loam) which are fine soil textural classes that are dominant in the area. This could be explained by the frequent flooding reported in the lowland areas of Lom sak

Table 6-9: Ksat and flow detachment for 2002 and 2007

	Flow detachment(tons)					
Ksat and Year	**K10_2002**	**K10_2007**	**K50_2002**	**K50_2007**	**K100_2002**	**K100_2007**
Event one	6153	7470	967	1782	135	251
Event two	4895	6228	341	683	63	109
Event three	25522	29057	18836	22080	14181	17340

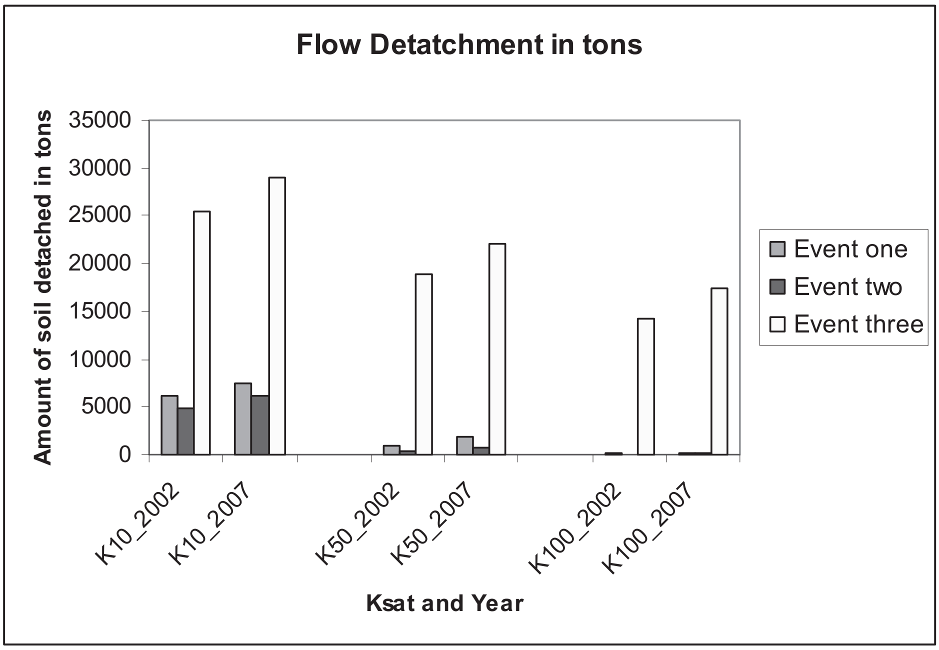

Figure 6-5: Ksat and amount of soil detarched in tons

To understand the dynamism of erosion and deposition of sediment discharge, the flow detachment was compared with total discharge. Total discharge at the outlet is higher which means that not only flow detachment contributed to sediment delivered in stream but many other area patterns under different cover are contributory to run off into the stream.

6.8. Average soil Loss in kgms per hectare

Average soil loss from the catchment is also much related to rainfall other than land cover. This is exhibited by changing the ksat during the three rain storms. Change in ksat had almost no effect on soil loss. Soil loss only changed when the third rainfall event was added (table 6-10 and figure 6-6)

Table 6-10: Amount of soil Loss in kgms per hactare

Ksat and Year	K10_2002	K10_2007	K50_2002	K50_2007	K100_2002	K100_2007
Event one	30347	32456	25316	25891	25066	25174
Event two	28596	30147	25110	25312	25011	25047
Event three	72195	82929	54984	64334	43884	52016

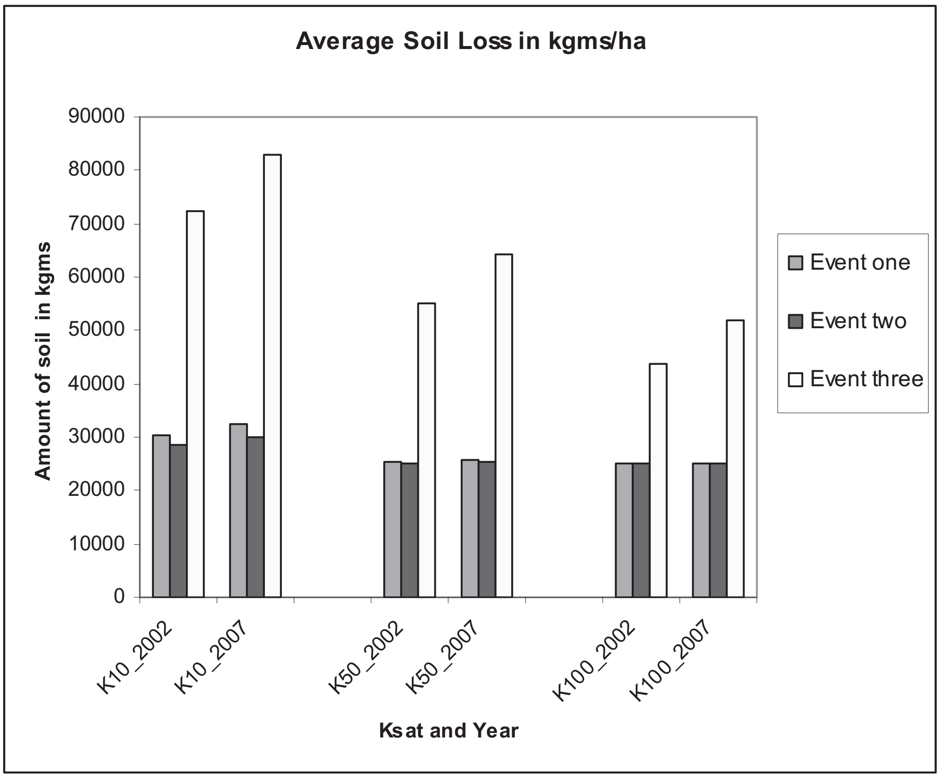

Figure 6-6: Average soil loss in kgm per ha.

6.9. Flow detarchment and deposition on Land

Throughout the simulation, flow detachment does not proceed to deposition anywhere in the sub catchment or the channel. Much of the detached materials as seen in table 6-11 and figure 6-14 are deposited at any point in the sub catchment and not even in the channel. This means than the sediments are buffered some where in the sub catchment and can not reach the channel.

Table 6-11: Comparison between detachment and deposition for all ksat one year only

	Detachment	**Deposition**	**Detachment**	**Deposition**	**Detachment**	**Deposition**
Ksat and Year	**K10_2007**	**K10_2007**	**K50_2007**	**K50_2007**	**K100_2007**	**K100_2007**
Event one	7470	-5475	1782	-1580	251	-235
Event two	6228	-4852	683	-636	109	-127
Event three	29057	-14281	22080	-12018	17340	-10418

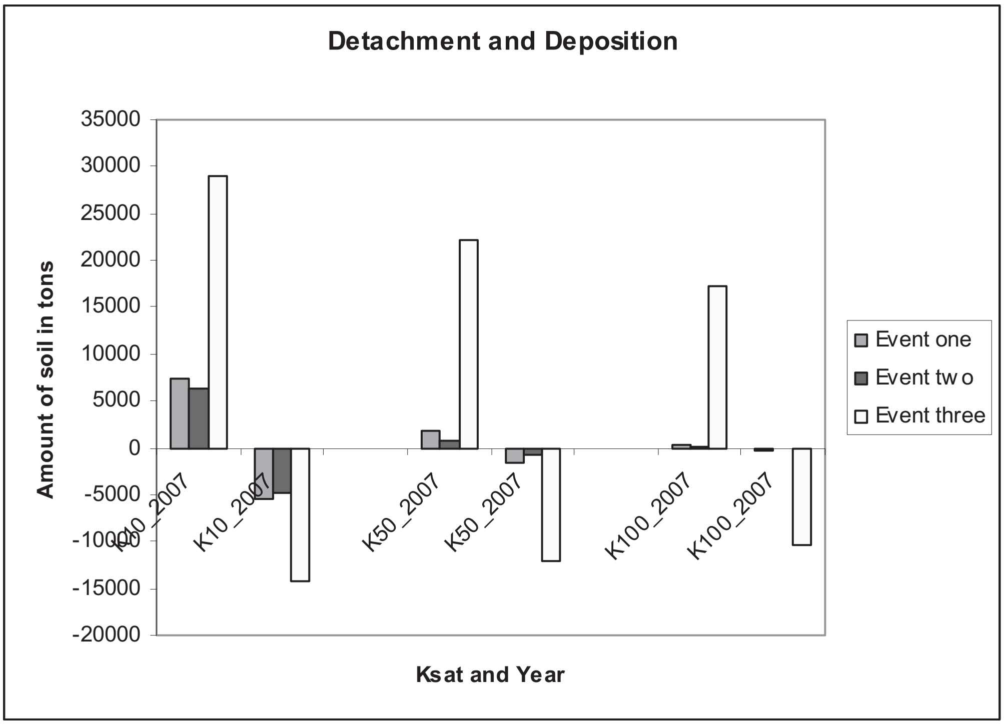

Figure 6-7: Ksat and amount detached and deposited for one year only

6.10. Flow Detatchment and Total Discharge

The table 6-1 and figures 6-15 and 6-16 below show the relationship between flow detachment and total discharge for Ksat 10 and 100 for both years respectively. The results show a similar trend with other results relating Ksat and rainfall. The difference between flow detachment and total discharge is high implying that what is discharged is not necessarily removed from the sub catchment. It may be a pointer to what happens in the sub catchment. The change in Ksat led to an insignificant difference either. The discharge remained higher than detachment which implies that erosion could be coming from the gardens and buffered by land use pattern only for the channel to reflect what is occurring in the catchment.

Table 6-12: Deatachment and total discharge for ksat 10 for both years.

	2002		2007	
Rain Events	**Detachment K10**	**Total Discharge K10**	**Detachment K10_**	**Total Discharge K10**
Event one	6152.8975	260561	7470.244	261891.5
Event two	4894.7525	257429.2	6228.057	258875.4
Event three	25521.724	314628.3	29056.6	316330.8
	K50_2002		**K50_2007**	
Event one	967.24994	248900.2	1781.569	250316.8
Event two	341.22181	248436.6	682.8733	249109.2
Event three	18835.944	293571	22080.47	297259.4
	K100_2002		**K100_2007**	
Event one	134.6027	248333.1	251.0148	248739.5
Event two	63.33177	248277.1	109.2526	248447.1
Event three	14180.512	279384.6	17340.19	284458.8

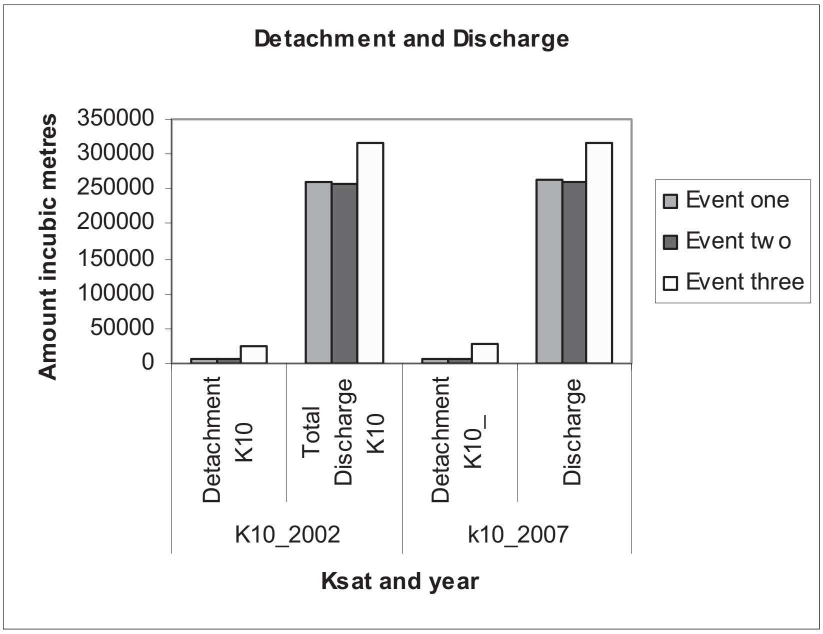

Figure 6-8: Detachment and total Discharge

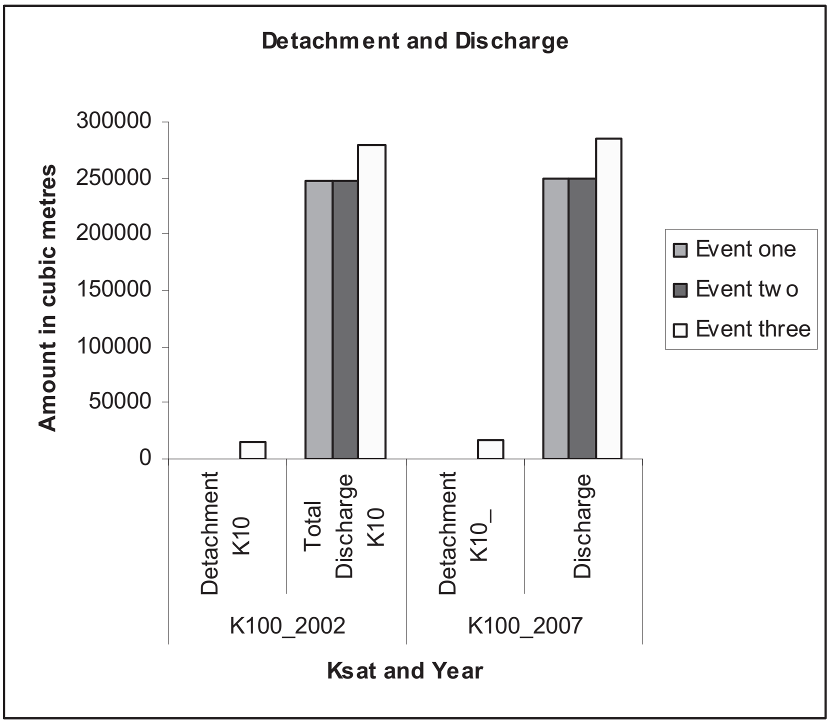

Figure 6-9: Detachment and total discharge

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6.11. Channel Erosion and deposition.

Channel erosion is a response to incoming run off from streams or overland flow from fields along with sediments loads. No or less infiltration will lead to excess water ponding on the soil surface and the result is run off as overland flow. Sediment transported by overland flow may move down slope to be deposited or buffered by a land use pattern in between the source and the stream. Where as there is massive erosion in the fields and the channel as predicted in the model, there is minimal deposition on land and in the channel too. It means that much of the eroded materials from fields are removed away from the area without necessarily entering the channel. Alternatively the channel may only be indicating what actually happens in the sub catchment and not really being transported as such (see in maps in the appendix 5 below). Similarly the eroded material may be heading for transportation to the lower lands which is the likely cause problems down stream

6.12. Run off rates for Land cover types

To examine the differences between runoff for different land use cover of the study area several land use scenarios were generated. This was with the assumption that differences resulted from the different land cover. 2007 land cover map was used as a basis and peak discharge per land cover was used for assessing runoff for each land use. Rain event three and the three factor ksat of were 10, 50 and 100 were used on each of the scenarios and peak discharge, flow detachment and total discharge were compared.

Table 6-13:Peak discharge per landcover in cubic metres per sec.

Peak Discharge			
Land cover	Peak discharge litres/sec		
	Ksat 10	Ksat 50	Ksat100
Agriculture	37858	32552	28331
Degraded Forest	32522	26388	21526
Forest	31903	25014	19597
Grassland	31903	19597	31903
Orchard	39675	36495	33849

From the above results in table at Ksat 10 the orchards and agriculture have the highest and second discharge followed by the degraded forest. The forest and grassland have the least discharge. Similarly the trend follows in the Ksat 50 and ksat 100. Comparing the three ksat the trend is that as ksat is increased the discharge. However the change in discharge is insignificant which may be accounted for by the model uncertainty. The scenarios were also checked on flow detachment as in table 6.15 below. This was intended to find out on what actually happens in the catchment. Results showed that orchards experience more flow detachment, followed by agriculture and the least include forest, degraded forest and grassland. The same trend follows in the three ksat factors although in Ksat 100, grass is the lowest detached as presented in tables 6-18 to 6-20.

Table 6-14: Flow detachmment for each landcover in tons

Flow detachment on land			
Land cover	Flow detachment in tons		
	Ksat 10	Ksat 50	Ksat100
Agriculture	34831	27249	22480
Degraded Forest	22644	16705	12510
Forest	22498	11040	22498
Grassland	22498	15796	11040
Orchard	38260	32955	29215

The same was the case in total discharge in table 6-19 below. Orchards have more discharge compared to other land use covers. The same applies when the Ksat changes or increased the total discharge decreases but at very minimal amount

Table 6-15: Total discharge for each land use in cubic metres

Total discharge			
Land cover	Total discharge mm/sec		
	Ksat 10	Ksat 50	Ksat100
Agriculture	131	124	119
Degraded Forest	130	122	116
Forest	129	113	129
Grassland	129	119	113
Orchard	134	130	126

In the above three scenarios, the ksat change had an insignificant change in the peak discharge, flow detachment and total discharge

To find out which land cover is more vulnerable to erosion, three land cover scenarios were used basing on the 2007 land cover map. All land cover types were of the sub catchment was from present day land cover. Three land cover were considered. Forest area was to represent natural cover, agriculture representing the disturbed land and soil cover and grassland to represent already wasted lands or fallow. It was assumed that the present day is normal scenario preceded by a change to forest. The second was from forest to Agriculture and thirdly was to grassland. Peak discharge was monitored on event three at the three factor ksat. See table and figure below.

Table 6-16: Land use cover change scenerio

	Normal	Forest	Agriculture	Grassland
Ksat 10	33	32	38	38
Ksat50	27	25	33	33
Ksat100	23	20	28	28

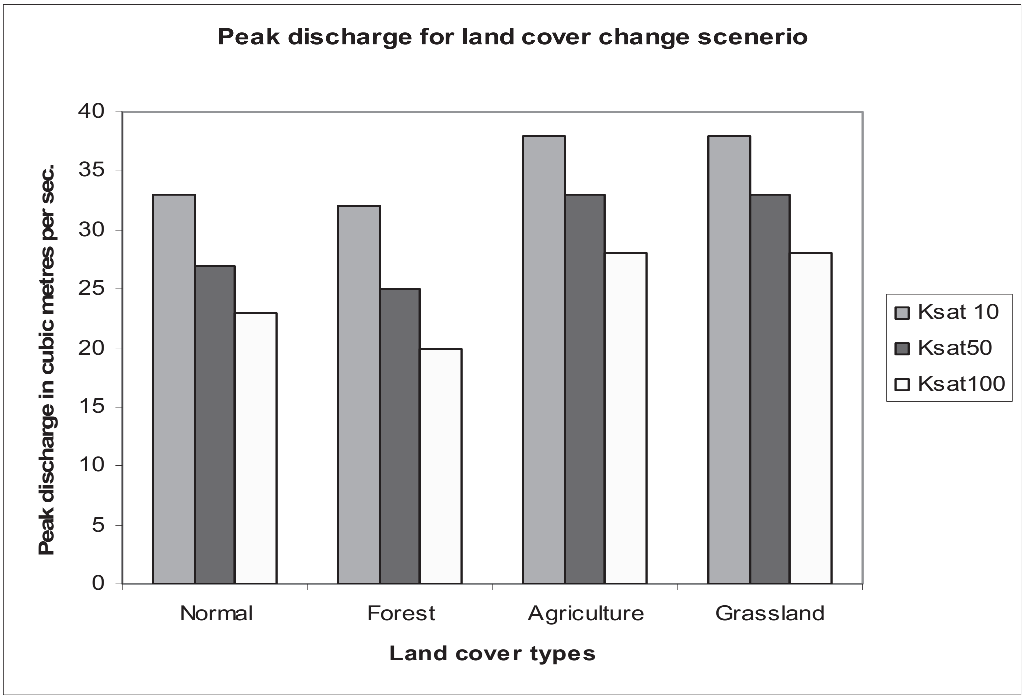

Figure 6-10:Peak discharge for Land cover change Scenerio

The results showed that the difference between each land use is small though it shows a change. Change from normal to forest saw discharge decrease while from forest to agriculture increased. The effect shows that change to agricultural land use led to the increase in peak discharge. Thus from normal to forest there was a decrease in peak discharge. When the forest was change to agriculture discharge increased and remained high in grassland. This could be explained by the fact that grasslands take over abandoned agricultural fields Similarly, the same was checked on the flow detachment as in table and figure below show that from normal to forest it decresed. When change was to agriculture flow detachment increased as illustrated in table 6-18 below.

Table 6-17: Flow detachment for Landcover change scenerio

	Normal	Forest	Agriculture	Grassland
Ksat 10	29052	22350	34905	34905
Ksat 50	22101	15742	27305	27305
Ksat100	17355	11023	22528	22528

7. Discussion, Conclusion and ecommendations

7.1. Discussion

Land cover has been undergoing different transformations in which many times lead to cover Loss or regeneration (Aledjandrio (2007). Deforestation is among the forces behind land cover land cover change in the world today (Masera et al 1997). Like in other regions of the world, deforestation in Nam Chun is triggered off by the need for agricultural land. The loss of forest cover and degraded forests in Nam Chun to other land use cover may lead to loss of soil cover. Also within the agricultural area, the cropping system and shifting of crops from one season to the other leaves a time lag where soils are left bare. In case it coincides with rainfall season run off is generated and hence erosion. Where crops are harvested or approaches maturity stage, soil cover is reduced. If this coincides with intensive rainfall as in between April and may (figure in chapter 4) for Nam Chun where soils are bare runoff may increase. Even when even when the gardens are covered well with crops, erosion occurs figure 4-6. This makes it difficult to conclude whether change due to removal of soil cover within the cropping calendar renders soil vulnerable to erosion.

Figure 6-13 showed the magnitude of ksat and the likely on peak discharge in a runoff event. Increasing saturated conductivity allows more of the available water to become overland flow. However the results from this study show that the reduction in discharge due to increase in ksat is small and not significant to warrant its impact on soil water relationship. The high value of saturated hydraulic conductivity at factor 100 also induces a smaller reduction in the peak discharge. When the conductivity decreases the peak discharge increases but also at very low rate figure 6-9 which is hardly above the model uncertainty. Flow detachment resulting from increased ksat with same rain fall event has a similar trend. Adjusting ksat from 10 to 50 and then to 100 factor is meant to increase infiltration and reduce runoff had no significant effect. It is true the rate reduces but the magnitude is too small to exceed the model uncertainty. The noticeable change is by the rain event. As rain event is changed the detachment changed too in both years as in figure meaning that rain is more significant in influencing erosion process in the area. The same is noticeable in total soil loss where change in ksat shows little change in soil loss in both years as compared to when rainfall event was changed. On the other hand flow detachment on land is not followed by the same rate of deposition on land. Deposition is reported lower and negative in all the Ksat factor of 10, 50 and 100. The same trend was evident in all the land use scenarios where change in was insignificant.

7.2. Conclusions

The research outlined here has attempted to study the relationship between land cover and soil physical properties and how they affect runoff. The main objective of this study was to assess the effect of land cover change on run off and erosion and more specifically, it focuses on land use cover change in Nam Chun sub catchment. Secondly it was to assess the effect of land cover the physical soil properties that are key players in erosion. It was meant to assess the rate at which land cover is affects different soil physical properties. In modelling erosion the lisem model was used to assess runoff and erosion as a consequence of land cover change in the sub catchment.

- Cover change analysis revealed that indeed land cover has changed in the last five years by 49% of the original area of the whole sub catchment. Agricultural land cover has increased at the expense of natural cover of forest which has reduced and also part of the degraded forest.

- The soil physical property analysis results have showed differences in each land cover. Land cover type has a significant effect on each soil property. The agriculture areas show lower hydraulic conductivity, higher bulk density and low porosity, higher crusting, than any other land cover type in the area. This could be an indication that the soil in agricultural areas is more compacted due to land use practices. However it is not clear whether these differences are responsible for different run off discharge from the catchment.

- The impact of land cover types on the runoff generation was revealed by hydraulic conductivity measurements that showed no significant differences between land cover types, especially between agricultural land use and natural vegetation. The consequence of this was shown in the results of runoff prediction. The results revealed that there is a trend in surface flow rate on different land cover types. Orchard and agriculture generate more surface flow than other land cover of forest, degraded forest and grassland which generate less surface flow and peak discharge.

- Rainfall amount other than saturated hydraulic conductivity is the most important factor in influencing run off and sediment discharge in the area, implying that land cover change may be occurring but without rainfall intensive erosion wouldn’t a problem.

- In LISEM the channel activity is explains what takes place actual happens in the catchment than channel activity. Channel erosion means a reaction of erosion in the landscape

- The scenario studies revealed that land cover change by which natural forest is changed into agricultural land results in increased runoff amounts and peak discharges of stream. However despite much flash and flow detachment in the catchment less deposition is predicted anywhere in the sub catchment

- Scenario analysis with change of saturated hydraulic conductivity can be useful in predicting what is likely to happen should and the policies to make in regard to removal of land and soil cover

7.3. Recommendations

The study revealed that land cover influences soil physical properties and may lead erosion. In this study however the removal of land cover does not necessarily mean erosion. Clearing of forest cover should however be accompanied by other conservation methods that strengthen the soil stability than cover preservation. No tillage practice would be a better alternative to avoid destruction of soil cohesion that could hold on to the incoming intensive rain to reduce run off. Avoiding future erosion problems would also call for introduction of incentives towards sustainable farm practices than the shifting or abandonment of land after which almost turn into wasteland. The Thailand government programme of having a soil doctor per village should be enhanced and become more practical to involve every stake holder in controlling erosion related causes such as frequent tilling.

7.4. Limitations of study

A number of limitations were encountered while carrying out this study. Major on the list is lack of rainfall data for use in physical process modeling. The main limitation of this study was that the available data for applying physically based models. Rainfall data used was a low resolution and from the 2006 records. In addition the area of study did not have a weather station and thus obtained data from outside the sub catchment which is not representative of the catchment in question. Even then, rain gauge records were hourly and not per minute as the model requires. Because of lack of data calibration of the model was based on discharge recorded in the field at the outlet and could not be validated as required and done in most studies where it has been applied. Also model uncertainty is a limitation that interferes with the model results. In some cases the uncertainty is due to insufficient knowledge of the user or insufficient data required for better manipulation. The amount of data required, especially precipitation which coincides with end of rain season in Thailand hinders limits the use of process model. Never the less the work has finally through them and the process is worth it.

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		Splash detachment(tons)				
	K10_2002	**K10_2007**	**K50_2002**	**K50_2007**	**K100_2002**	**K100_2007**
Event_one	62	55	56	49	45	40
Event_two	67	58	52	45	48	41
Event_three	172	163	172	161	170	158
		Flow detachment(tons)				
	K10_2002	**K10_2007**	**K50_2002**	**K50_2007**	**K100_2002**	**K100_2007**
Event_one	6153	7470	967	1782	135	251
Event_two	4895	6228	341	683	63	109
Event_three	25522	29057	18836	22080	14181	17340
		Deposition on land (ton)				
	K10_2002	**K10_2007**	**K50_2002**	**K50_2007**	**K100_2002**	**K100_2007**
Event_one	4749	5475	929	1580	151	235
Event_two	3965	4852	353	636	97	127
Event_three	13534	14281	11206	12018	9382	10418
		Total discharge				
	K10_2002	**K50_2002**	**K100_2002**	**K10_2007**	**K50_2007**	**K100_2007**
Event_one	260561	248900	248333	261892	250317	248740
Event_two	257429	248437	248277	258875	249109	248447
Event_three	314628	293571	279385	316331	297259	284459
		Channel erosion (ton)				
	K10_2002	**K10_2007**	**K50_2002**	**K50_2007**	**K100_2002**	**K100_2007**
rain	7282	7263	7318	7315	7319	7319
rain15	7291	7275	7319	7319	7319	7319
rain16	7161	7115	7204	7164	7237	7202
		Channel deposition (ton)				
	K10_2002	**K10_2007**	**K50_2002**	**K50_2007**	**K100_2002**	**K100_2007**
Event_one	953	1007	836	848	831	832
Event_two	917	962	831	835	830	830
Event_three	1393	1526	1244	1363	1132	1240
		Flow detachment and land deposition				
	detach	**deposition**	**Detach**	**deposition**	**detach**	**deposition**
	K10_2007	K10_2007	K50_2007	K50_2007	K100_2007	K100_2007
Event_one	7470	5475	1782	1580	251	235
Event_two	6228	4852	683	636	109	127
Event_three	29057	14281	22080	12018	17340	10418
		Flow detachment and land deposition				
	Detach	**Deposition**	**Detach**	**Deposition**	**Detach**	**Deposition**
	K10_2002	K10_2002	K50_2002	K50_2002	K100_2002	K100_2002
Event_one	6153	4749	967	929	135	151
Event_two	4895	3965	341	353	63	97
Event_three	25522	13534	18836	11206	14181	9382
			Average soil Loss in kg / Per ha			
	K10_2002	**K10_2007**	**K50_2002**	**K50_2007**	**K100_2002**	**K100_2007**
Event_one	30347	32456	25316	25891	25066	25174
Event_two	28596	30147	25110	25312	25011	25047
Event_three	72195	82929	54984	64334	43884	52016

Appendix 1: Model Results

Appendix 2 Location and altitude of two meteorological stations near Nam chun catchment

Station	X: cordinates	Y: coordinates	altitude (m)
Lomsak	740000	1857000	140
Lomkao	738000	1868000	160

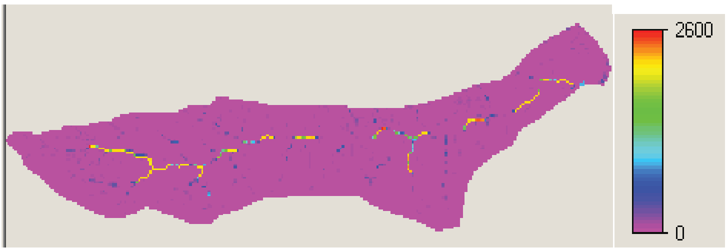
Appendix 3: Rain gauge station

Rain gauge Point	X	Y
Station I	726263	1856125
Station II	724333	1855898
Station III	725582	1855292
Station IV	721266	1856276

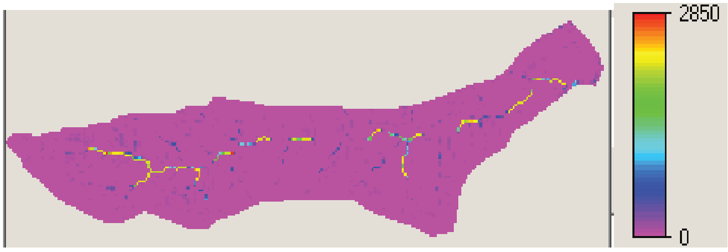
Appendix 4: Velocity discharge /sediment measuring point

Point	X	Y
I	724072	1855680
II	724839	1855693
III	725636	1855700
IV	726484	1856054

Appendix 5 LISEM model Output

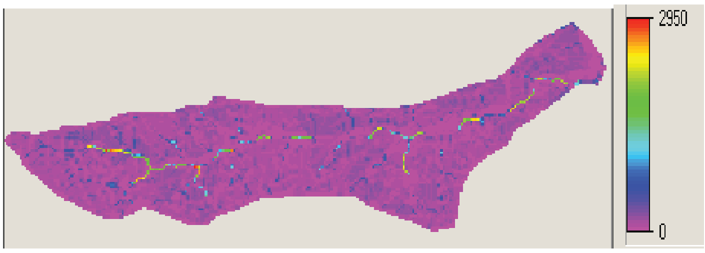


Ksat10 rain event two land cover 2002 erosion map

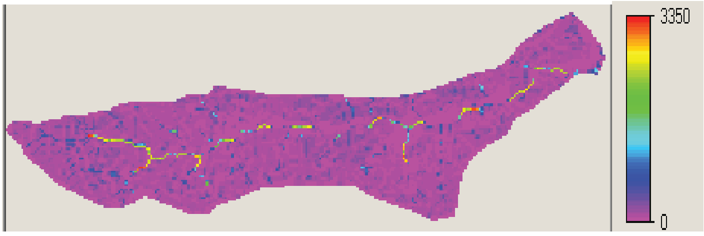


K 10 rain event two land cover 2007erosion Map

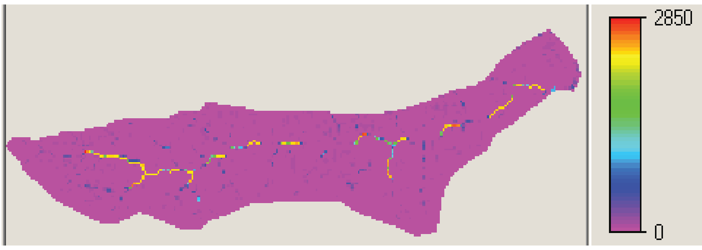
k10 rain event land cover 2007 deposition map



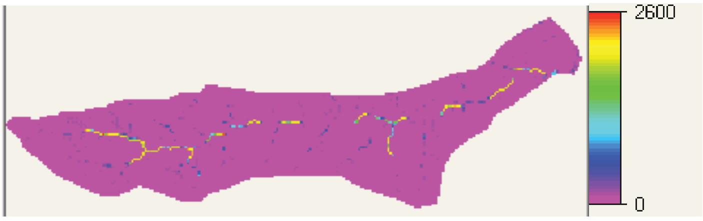
K10 rain event three land cover 2002erosion map



K10 rain event three land cover 2007 erosion map



K10 rain event one land cover 2002



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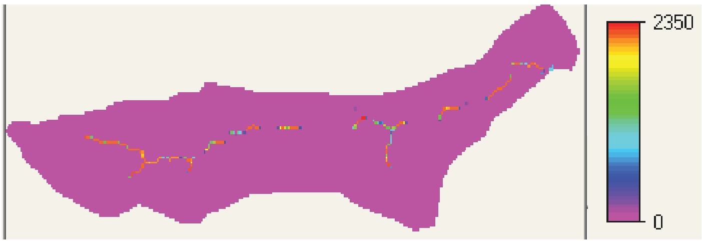
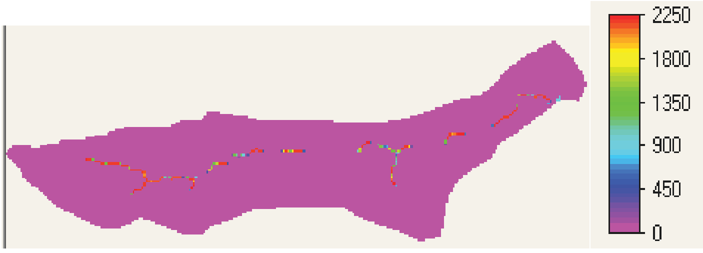
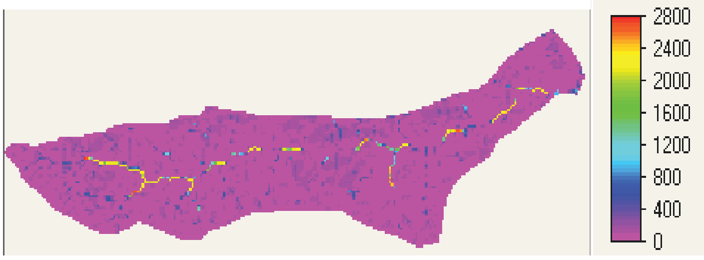


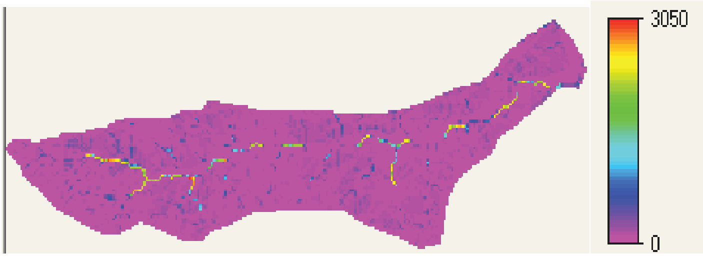
K50 rain event two land cover 2002



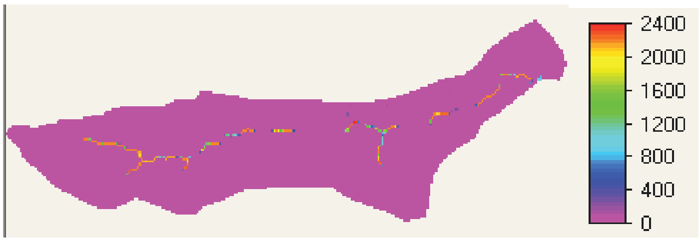
K50 rain event two land cover 2007



K50 rain event three land cover 2002

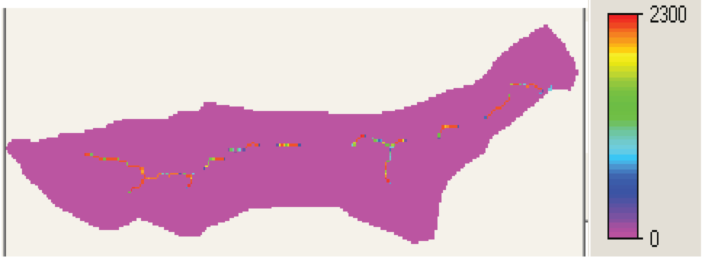


K50 rain event three land cover 2007

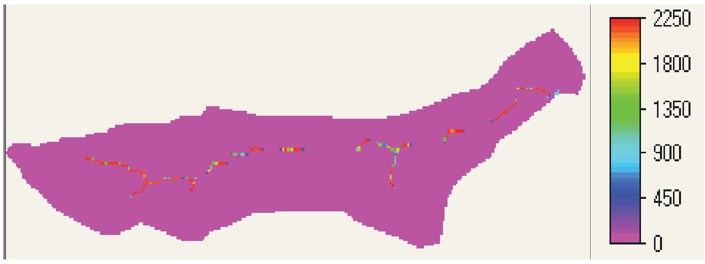


K50 rain event one land cover 2002

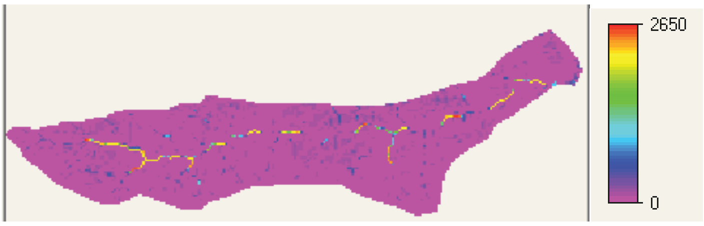
K50 rain event one land cover 2007



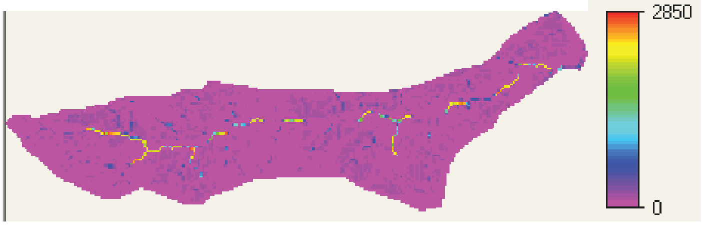
K100 rain event two land cover 2002



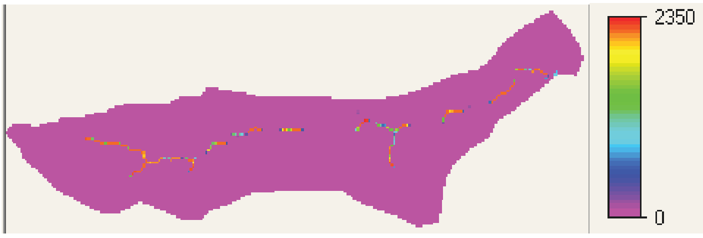
K100 event two lands cover 2007



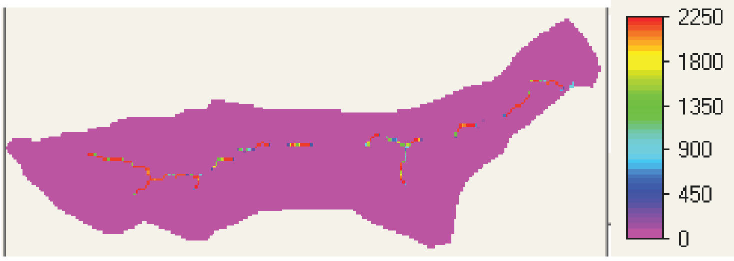
K100 rain event three land cover 2002



K100 rain event three land cover 2007

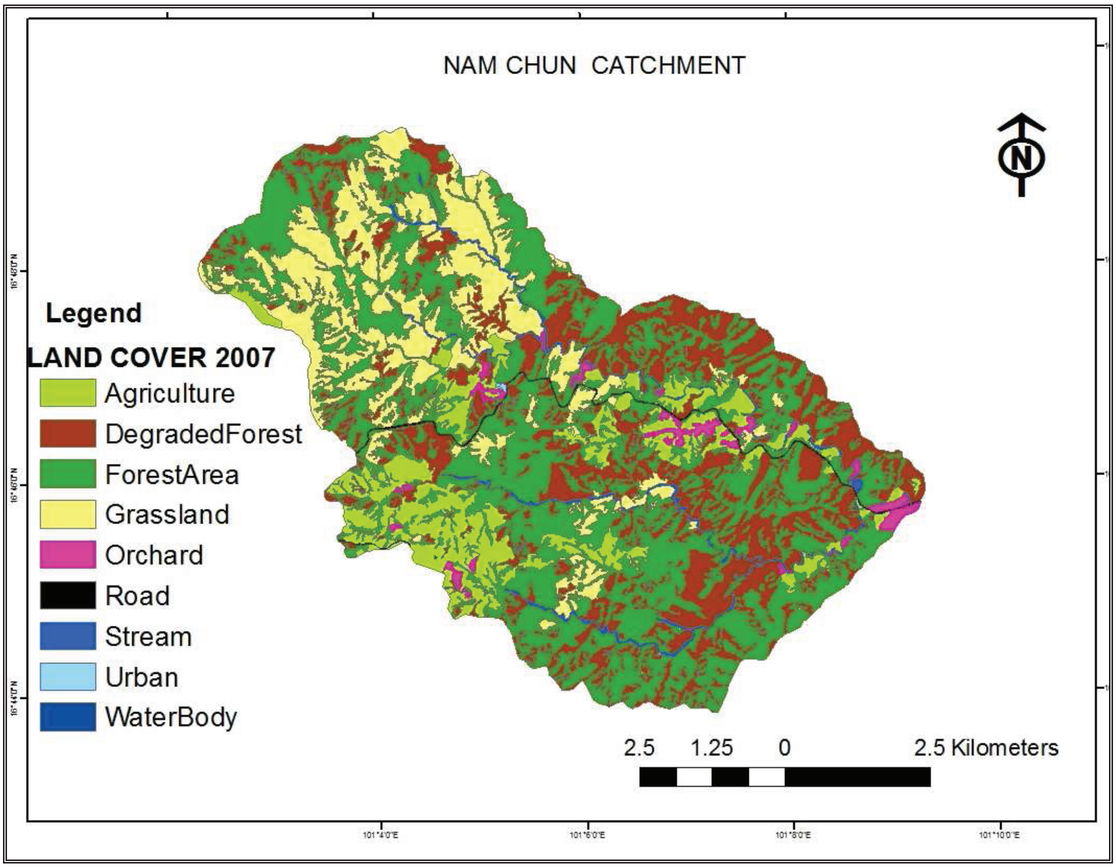


K100 rain event one land cover 2002



K100 rain event one land cover 2007

Appendix 6.



x	y	L.COVER	%_SAND	%CLAY	%_SILT	%OM
725059	1856821	Agriculture	27	42	31	0.9
725138	1855956	Agriculture	25	42	33	2.3
724238	1856054	Agriculture	23	35	42	3.3
724310	1855635	Agriculture	18	40	42	3.2
724166	1856517	Agriculture	23	42	35	1.1
726441	1855924	Agriculture	24	71	5	2.0
724321	1855228	degraded	23	47	30	2.2
723768	1855310	degraded	25	33	42	4.0
723564	1855562	degraded	16	39	45	2.5
725980	1855627	degraded	11	63	26	1.0
722125	1857050	degraded	20	47	32	2.0
725420	1856851	degraded	21	45	34	2.6
725141	1855524	degraded	14	60	25	1.9
725130	1855901	forest	21	47	32	2.4
725166	1856231	forest	17	43	40	3.3
722976	1855670	forest	12	55	33	3.4
720909	1856122	forest	15	41	43	1.9
723241	1855324	forest	23	69	9	2.4
723041	1855324	forest	16	61	23	1.0
723441	1855124	forest	19	72	9	2.2
724441	1855124	forest	14	68	18	2.9
725731	1855789	grass	22	47	32	2.4
720916	1855676	grass	14	56	30	2.6
720375	1856407	grass	32	32	36	2.5
721487	1856711	grass	10	61	29	2.5
720121	1856025	grass	13	49	37	1.3
721649	1856537	grass	15	41	43	2.0
721670	1856659	grass	10	55	35	1.9
723953	1855839	grass	13	56	31	2.0
723682	1856374	grass	23	32	45	3.6
726432	1856280	grass	13	54	32	0.9
723793	1856248	grass	21	38	41	2.9
724241	1855524	grass	22	67	11	3.9
724841	1855324	grass	25	70	5	2.5
725298	1856743	grass/shr	23	45	32	2.5
724741	1855902	Agriculture	28	37	35	1.6
725459	1855497	Agriculture	25	38	37	2.7
723674	1856900	Agriculture	22	44	34	0.8
725365	1855261	Agriculture	27	36	37	0.9
725041	1855324	Agriculture	25	72	4	2.4
725441	1855324	Agriculture	23	72	5	1.6
725441	1855524	Agriculture	21	69	11	1.1
724639	1855855	orchard	16	54	30	2.3
725669	1855724	orchard	9	50	41	1.9
725427	1856881	orchard	21	49	30	1.5
725182	1855757	orchard	20	44	36	2.1
725269	1855985	orchard	28	39	33	2.7
725141	1856463	orchard	20	51	29	2.3
725141	1856463	orchard	12	55	33	1.9
726041	1855924	orchard	24	66	10	1.9
726641	1855924	orchard	24	74	2	2.1
726041	1855524	orchard	20	66	14	2.2
725038	1855740	orchard	14	54	32	1.7
725420	1855749	orchard	19	59	22	2.0
726241	1856124	orchard	21.6	70.1	8.2	2.77
726441	1856124	denseforest	21.2	73.9	4.9	3.37
726641	1856124	Agriculture	23.1	74.9	2.0	1.62
726041	1855924	orchard	23.5	66.2	10.3	1.85
726241	1855924	orchard	24.4	71.3	4.4	3.16