CHAPTER II

LITERATURE REVIEW

2.1 Erosion process

Soil erosion is the detachment and movement of the mineral particles and organic material of the soil through the action of water or wind. Soil erosion by water generally begins when rain drops and their splash strike soil on sloping land. Rain drop or splash detach soil particles when they are not protected by vegetation, surface mulch or some other type of cover. When rainfall exceeds the infiltration capacity of the soil, these detached particles move down slope with the runoff. When runoff concentrates in small, natural depressions or in marks left by farm implements, networks of small channels or rills begin to form. Once rilling begins, small erosion channels rapidly form. Continued rill erosion can result in large channels that cut through the top soil and into the subsoil.

As far as erosion under action of water is concerned, detachment and the transport of soil particles from the land by water, including runoff are two main phases (Schwab *et al*., 1993). Detachment is the dislodging of soil particles from the soil mass primarily by rain splash and from running water. Transport of soil particles can be described as the movement of detached soil particles from the original location by rain drop splash and runoff. It is a natural process which is facilitated by human activity. It can be categorized into two major types as (i) geological erosion and (ii) man-induced erosion (Schwab *et al.*, 1993). Geological erosion occurs independently from human activities. It has been a main process of landscape development. Man-induced erosion occurs because of the disturbance of the soil caused by human activities. Man-induced erosion is characteristic for high organic matter losses and soil-structure breakdown.

2.2 Concept of erosion risk

The main factor acting against the sustainability of agricultural production is land degradation. Among the different land degradation processes, soil erosion is the biggest threat to the conservation of soil and water resources. Soil erosion has accelerated in most of the world in recent decades due to population pressure and limited resources, which have also led to the increased and more continuous use of steeper lands for agriculture (Millward and Mersey, 1999). Increasing population, deforestation, land cultivation, uncontrolled grazing and higher demands for fire wood often cause soil erosion (Reusing *et al.*, 2000).

Risk is the probability that negative consequences may arise when hazards interact with vulnerable areas, people, property, and the environment. It is a concept, which describes a potential set of consequences that may arise from a given set of circumstances (ADPC, 2002). Hence erosion risk is the potential of erosion that arise when hazards interact with vulnerable areas.

Hazards are the sources of risk. Hazards create risk by exposing pre-existing vulnerabilities. It can be any substance, phenomenon or situation, which has the potential to cause disruption or damage to people, their property, their services and their environment (ADPC, 2002). In the case of soil erosion, biophysical conditions leading to erosion increase vulnerability. Human activities that trigger soil erosion are the hazards which create a risk by exposing these vulnerabilities (Figure 1).

Vulnerability is a concept, which describes factors or constraints of an economic, social, physical or geographic nature, which reduces the ability to prepare for and cope with the impact of hazards (ADPC, 2002). Steep slope, high detachability, high transportability is the factors which reduces the ability to protect soil from erosion by the impact of external energy. If there is a potential for an event to occur there is a risk. It is a combination of the interaction of hazards, exposure, and vulnerability. If we can eliminate one of the factors we can avoid risk.

2.3 Factors affecting soil erosion

Four main factors control soil erosion, i.e., climate, soil, vegetation and topography (Schwab *et al.,* 1993). Miller (1988) concluded that soil and land degradation are driven by a combination of forces, such as poverty, excessive population, low productivity, lack of knowledge, ability and desire – or disincentives- to adopt technology, and properly defined or inadequate land-tenure systems.

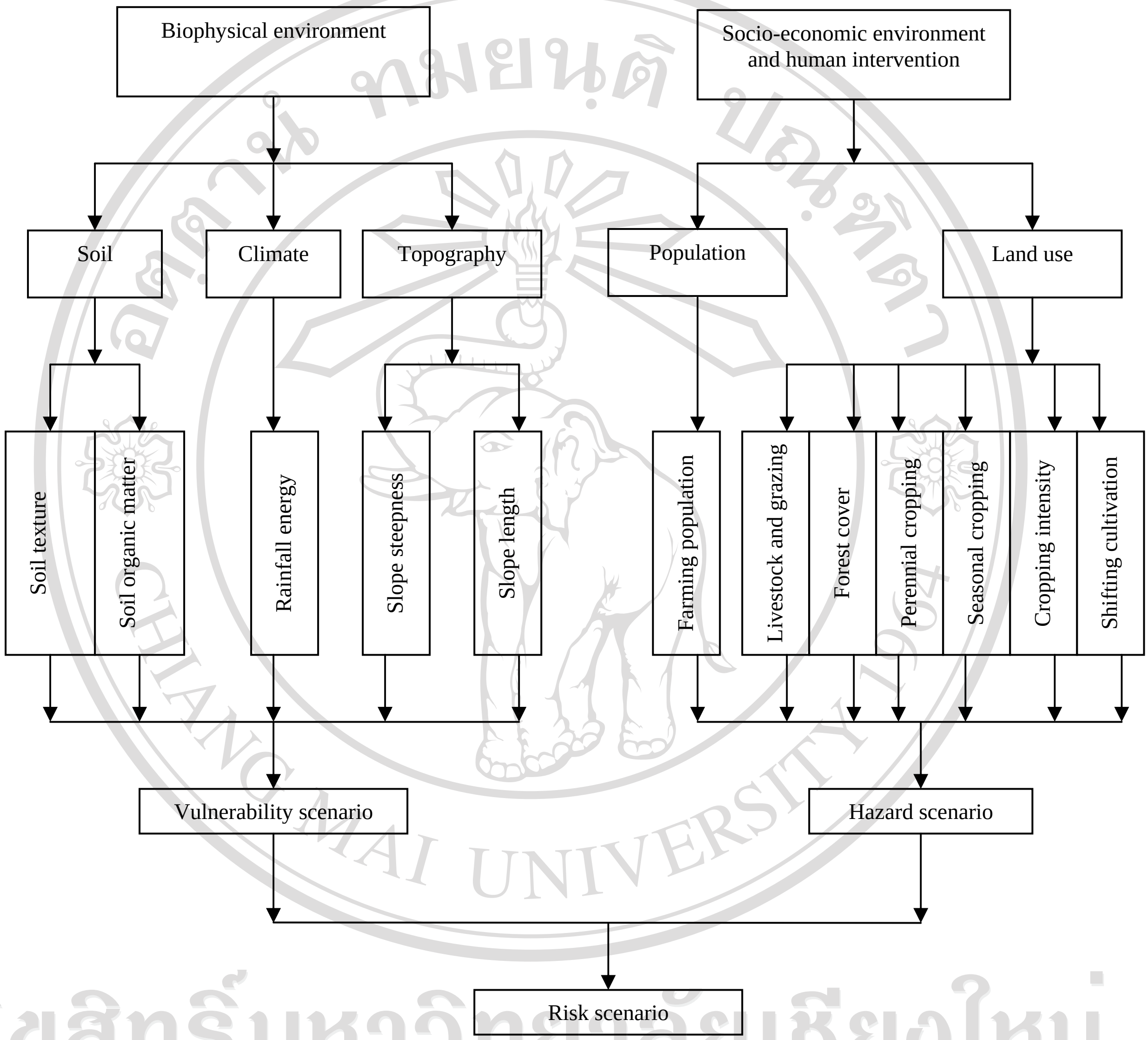

Figure 1. Vulnerability, hazard and risk scenario.

(Source: Hossain, 2003)

2.3.1 Biophysical factors

Climate

Hudson (1981) showed that precipitation is the most important climatic factor affecting erosion caused by water while temperature, humidity, wind and solar radiation have more indirect effects. There is a close relationship between rainfall and erosion, especially the intensity of rainfall. Schwab (1993) stated that runoff occurs only when the rate of precipitation exceeds the rate of infiltration into soil.

Soil

The stability of soil aggregates determines the detachability of the soil particles and hence the erodibility of the soil. Under otherwise similar conditions, there is more soil loss from erodible soils with less stable soil aggregates. Schwab *et al*., (1993) describes the influence of detachment and transportation of soil particles on soil erosion as "soil detachability increases as the size of soil particles or aggregates increases, and the soil transportability increases with a decrease in the particle or aggregate size". The physical feature of the soil such as soil texture, structure, organic matter, water content, chemical and biological characteristics influence the soil erosion (Hudson, 1981).

Vegetation

Vegetation, natural or planted, is the most efficient controlling factor of soil erosion. The above ground parts of the vegetation protect the soil from the energy of raindrops, runoff, and wind while the roots stabilize and improve the mechanical strength of the soil, resulting in reduced soil erosion. The effect of vegetation cover on soil erosion also depends on the type of the plants (e.g., crop), their height and stage of development, and the characteristics of the climate and soil.

Human activity

The human activities also indirectly effect soil erosion. Jansson (1982) depicts cultivation, grazing and burning, road construction, urbanization and mining as the main causes of a reduction in vegetation cover, thus contributing towards an increase in soil erosion.

2.3.2 Land-use practices

Land use practices have strong affects on soil erosion. Appropriate cropping patterns will minimize soil loss. For example, in China IBSRAM (International Board for Soil Research and Management, 1993) found that on 30-40 % slopes and with farmers' practices, soil loss was 70.9 $t.ha^{-1}$. In alley cropping systems the total soil loss was 28.6 $t.ha^{-1}$.

In a study of the relationship between different land use practice efficiencies and increasing soil fertility by using crop residues, Prasad and Power (1997) showed that the quantity of residue and how it is managed affects a number of factors important to soil fertility and productivity, including the processes of nitrogen immobilization and mineralization. The removal of 2.24 Mg ha^{-1} of high carbon standing residues may effect immobilization and reduce total soil carbon and nitrogen. Surface mulch may also influence soil temperature, soil moisture and herbicide efficiency. Differences in residue, affecting these processes even with similar C/N ratios.

2.3.3 Socio-economic factors

A complex of social, cultural and economic factors causes people to apply inappropriate agricultural technologies, which eventually lead to soil erosion. The socio-economic complex is composed of four key factors i.e., population pressure, poverty, inappropriate or non-functioning institutional frameworks and suitable agricultural technologies (De Graff, 1993). Shaxson (1999) showed that many of the general socio-economic problems such as, those related to poor cannot be adequately solved in the short term, whereas specific problems such as , a lack, weakness, the farmers' associations can often be solved relatively quickly, and with beneficial results.

Riksen *et al.*, 2001 showed that the response of human activities on soil properties is non-linear, and with most changes occurring during the initial low levels of soil use.

2.4 Cause-effect chains linked to soil erosion

The onset of accelerated erosion depends on the exposure of soil mass to the energy factor. Once it is exposed the degree and extent of erosion depends on the biophysical condition of the terrain. Therefore the terrestrial factors that facilitate erosion are related to the activities which expose the soil to the energy factor. Human activities are the main causes of erosion hazard. These again are largely driven by complex socio-economic factors. Consequently, erosion hazard is a compound and interdependent condition of both the natural and cultural environment. Miller (1988) concluded that soil and land degradation are driven by a combination of forces, such as poverty, excessive population, low productivity, lack of knowledge, ability and desire- or disincentives- to adopt technology, and poorly defined or inadequate land-tenure systems. These elements must be addressed in any interventions or policies initiated to retard land degradation. If sustainable agricultural systems are to be implemented, then systems components, such as resources, technology, and institutions, must be accommodated (Crosson, 1986).

Scherr and Yadav (1996) stated that the common factors of soil degradation are natural or climate factors that include climatic change and variation; and artificial or biological factors that include negative influences of human activities on the natural environment, such as over-cultivation, over-grazing, large scale irrigation of farmland, over cutting of fuel wood, inappropriate agricultural production technologies and industrial activities.

Some writers claim that erosion increases as a function of population density (Roose, 1996). Pieri (1989) stated that it is true in a given agrarian system, if the population passes a certain threshold, land starts to run short, and soil restoration mechanisms seize up. FAO (1998) reported that in the Sudano-Sahelian zone, when the population exceeds 20-40 inhibitants per sq km, the fallow period for shifting cultivation is shortened to the point of ineffectiveness, and one speaks of densely populated degraded area when the population reaches about 100 inhabitant per sq km. Adults then have to migrate during the dry season to find supplementary resources in order to ensure their families' survival.

The degree and scale of density varies from place to place depending on terrain, soil and climatic conditions. According to FAO (1998) the term high density is not used in Java, a region characterized by volcanic soils, until the population goes beyond 250-750 people per sq km.

The case of Rwanda and Burundi are particularly striking: despite very acid soils and slopes of over 30-80%, families manage better on a single hectare than in the Sahel, so long as they intensify their production systems, practice intercropping, plant trees, stall-feed livestock, quickly recycle all wastes, and stop the bleeding of nutrients through erosion and drainage.

It may then be concluded that the environment becomes degraded as population density grows, until it reaches a certain level after which farmers are obliged to change their production systems (Roose, 1996).

FAO (1983) reports that some 23 percent of the world's land is used for grazing livestock, and soil erosion caused by overgrazing is one of the most important environmental problems in the developing world. On an average, rangeland in developing countries is a third more crowded with livestock than rangeland in the developed world. Overgrazing by cattle reduces plant cover, eliminating the most desirable forage species first. This open up the land to undesirable weeds, bush, and trees and leads to increased soil erosion and lower soil fertility. The land becomes less and less productive.

With less nutritious forage available, some grazers respond by actually increasing the size of their cattle herds to compensate for losses in weight. In other instances, sheep replace cattle as forage deteriorates, eventually sheep are replaced by goats, which will eat just anything, including young trees. The end result is barren land, windstorms, erosion and floods.

2.5 Consequence of erosion

Soil erosion causes off-site problems as well as on-site soil degradation (Lal, 1988). On-site effects are particularly important on agricultural land. Typical off-site problems are the reduction of the transport capacity of rivers and drainage ditches, an enhancement of the risk of flooding, the blocking irrigation channels and the shortening of the life of reservoirs (Morgan, 1995).

Decades of research have shown that soil erosion and soil productivity are intricately related and that they cannot be separated easily. Usually erosion results in a net decrease of the long-term inherent productivity of the soil. It also affects long-term productivity by reducing tilth and the soil's water holding capacity. In particular, long-term productivity is decreased by the removal of plant nutrients and organic matter from the top soil. It removes the fine silt and clay particles that hold plant – available water and provide nutrients to plants. It also decreases the infiltration capacity of the soil, which leads to increases in surface runoff (H. Md., Moqbul, 2003).

2.6 Assessment of erosion risk

For land use planning and prioritization it is important to be aware of the potential erosion risk of land rather than a calculated estimate of soil loss. There are a wide range of expert-based and model-based erosion-risk assessment methods. Most of these have used the mathematical formula of Universal Soil Loss Equation (USLE) as a basis for calculation but the model has some important limitations and drawbacks. The USLE is applicable for sheet and rill erosion, on gentle and uniform slopes generally not exceeding 10% gradient. Another limitation is the fact that the model neglects the interactions between factors, for instance between slopes and vegetative cover, etc. Besides, this model is only valid to estimate average annual soil loss over a period of 20 years and is not applicable at the scale of a single rainfall event.

Simulation models are the most effective way to predict soil erosion processes and their effects by using a Geographic Information System (GIS) and Remote Sensing (RS). Therefore, models have the potential to make major contributions toward developing better conservation practices and improving the management of land resources (Meyer, 1980).

Pallaris (2000) stated that despite the knowledge acquired and the many technological advances, the threat of land degradation remains as pertinent as ever and one of the main reasons for this is that high risk areas are not being effectively and efficiently identified by the existing erosion risk models. Existing secondary data related to the environmental, socio-economic and land use conditions of an area can be used reliably to identify relative soil erosion risks of a particular area and their spatial distribution.

2.7 Soil erosion in Myanmar

2.7.1 Current status

The entire area of Myanmar dry zone is considered affected by various levels of soil erosion. In several townships (sub-districts), i.e., Kyaukpadaung, Magway, Chaung U, Thaung Thar, Nga Htoe Gyi and Ma Hlaing, land degradation and erosion rates are severe, leading to chronic food insecurity and various degrees of poverty (Carucci, 2001).

Ways are needed to address the increasing occurrence of drought as a consequence of this process, for the benefit of the inhabitants of the area as well as for the country at large. Rehabilitation and reclaiming land in the dry zone should be viewed as a priority by all stakeholders involved in rural development (Carucci, 2001).

According to the FAO's study, the dry zone townships are characterized by clay, sandy loam and sandy soils (including gravel). The soils clearly vary with topography. According to soil survey data collected by the project, all soil series have low fertility and declining organic matter levels. Potassium levels are similarly low. Nitrogen is required for all non-legume crops on all soil types. This suggests the low organic matter level in the soil. Available soil moisture holding capacity of the soils of the dry zone is low and with the high level of evapo-transpiration, constitutes a major constraint to crop growth during periods of inadequate rainfall (June and July). Management practices that conserve soil moisture or increase the water holding capacity of the soils are being practiced to help take advantage of the full growing season. Hard pan formation is common to all upland areas.

Soil erosion is a serious problem and in some places the soil has almost completely removed by water and wind erosion. Soil erosion is particularly severe in the upland areas of Kyaukpadaung and Chaung U largely as a result of the high intensity of rainfall and surface runoff. Moreover, since most of the soil in these areas is moderately textured with a slope ranging from 5-15% the erodibility of the soil is also high. In contrast, the incidence of soil erosion in the foot plain is lower. In Magway because of the sandy topsoil there is a high level of erodibility. The susceptibility of the soil to erosion is compounded by the high level of rainfall occurring over short periods. Table 1 shows that among three Divisions of Myanmar dry zone, Magway Division has greater area than other Divisions in all erosion levels. Wind erosion is a particularly severe problem while rill and gully erosion are largely confined to wasteland areas. Sheet and rill erosion and vertical dissection are widespread, resulting in an uneven topography. A rather identified rills and sheet erosion at any site. Gullies are; of course, obvious in the landscape of the region (Figure 2 and Figure 3). Soil erosion and land degradation are the two components responsible for declining production potential of the region.

Table 1. Erosion susceptibility in the central dry zone of Myanmar.

	Area of Erosion Susceptibility (Acre)			
Name of Division	**Slight**	**Moderate**	**Critical**	**Grand Total**
Sagaing	5,293,257	226,362	3,435	5,522,154
Magway	7,839,612	2,257,853	284,657	10,382,122
Mandalay	4,968,877	555,614	128,692	5,653,183
Dry Zone Total	**18,100,846**	**3,039,829**	**416,784**	**21,557,459**

(Source: Than, 2001)

Figure 2. Rill erosion in the field of study area.

(Source: Field survey, 2007)

Figure 3. Gully erosion in the filed of study area.

2.7.2 Research on soil erosion

There is no research on soil losses and erosion in the whole Dry Zone of Myanmar. Agriculture research stations do not include runoff and soil erosion measurement plots. No erosion and land classification studies and maps defining the capability of the land in terms of sustained production of major kinds of land uses are available. It is then almost impossible to estimate with accuracy peak runoff discharges, data on soil losses and erosion trends if not by using empirical models and approximate estimations (Carucci, 2001).

There has been less research on crops suitable for the Dry Zone conditions, soil management practices and soil conservation and water harvesting measures due to the emphasis given to the humid areas and their most cost-effective return. Agricultural University and schools do not emphasize much on soil conservation, particularly for the Dry Zone conditions, and practical experience is virtually non-existent.

2.8 Land degradation

2.8.1 Effect of land degradation

With increasing world population, pressure on land and soil has also increased. The intensification of land use and increasing yields has mainly been enabled through the use of higher external inputs, such as fertilizers and pesticides. This has led to increased soil and land degradation resulting in productivity losses of soils, and consequently declined food production, especially in areas where the high level of required external inputs cannot be maintained. This situation has created a great interest in sustainable land use that prevents or minimizes soil degradation. Currently it has become a central issue among researchers and policy makers.

Land degradation is a process which implies a reduction of potential productivity of the land (Hill *et al.*, 1995b). Barrow (1994) pointed out that land degradation is a reduction in rank or status of the land. Blaikie and Brookfield (1987) affirmed that land is degraded when it suffers from the loss of its intrinsic qualities and capabilities. Biswas and Biswas (1974) reported that about 10% of the world's arable land had been spoiled by human activities. The Global Assessment of Soil Degradation (GLASOD, 1988) figures indicate that almost 40% of the agricultural land had been affected by human-induced soil degradation, and that more than 6% is degraded to such a degree that restoration to its original productivity is only possible through major capital investments (Oldman, 1994). Rehabilitation of the highly degraded soils to their original productivity is not possible; it is only possible on the lightly and moderately affected soils. The soil and land resources are finite. Therefore, these negative changes need to be accurately monitored and their long-term effects and ecological risks should be estimated. Though degradation is a key issue in sustainable land management, increased agricultural productivity still remains a key issue in a world with increasing population (Zoebisch and De Pauw, 2002). Therefore, increasing productivity should go together with sustainability of the land resources.

Soil degradation is a result of one or more processes which lessens the current and or potential capacity of the soil to produce (qualitatively and/ or quantitatively) goods or services (FAO, 1977). It includes accelerated erosion, compaction, hard-setting, loss of organic matter and microbial diversity, drawdown or depletion of nutrient stocks, salinization, desertification and other manifestation of degradation.

Soil erosion is the most widely recognized and most common form of land degradation and, a major cause of falling productivity (Stocking and Murnaghan, 2001). It is the decline of the capacity of soils to produce goods of value to humans.

2.8.2 Problems of land degradation

Land degradation is the decline of the capacity of soils to produce goods of value to humans. Miller et al. (1988) reported that in Iowa, USA, it takes approximately 30 years or more to develop 1 inch of top soil under ideal conditions where erosion is very low. This would be equal to about 165 tons per acre. Accordingly, tolerable soil losses would range from 2 to 5 tons per acre per year for different soils (Miller *et al.*, 1988). Most agricultural practices, especially in sloping landscapes, increase the erosion potential, which is commonly called *accelerated* or *excessive* erosion. When a soil experiences accelerated erosion, removal of renewed soil properties occurs faster than renewal rates. If the soil is removed faster than soil formation, the quality of soil declines, production costs rises and at a certain stage economic crop production will no longer be feasible (Foster, 1977).

2.9 Roles of GIS technologies in soil erosion studies

Aronoff (1981) stated that a GIS is designed for the collection, storage and analysis of objects and phenomena, where geographic location is an important characteristic or essence of the analysis. Burrough (1986) explained GIS as a powerful set of tools for collecting, storing, retrieving as well as transforming and displaying spatial data from the real world. Computerized GIS has ability to keep current spatial data and multiple analyses of multiple data sets in a single integrated database. It allows planners to assess impacts before implementing a plan to reduce risks and make more appropriate decisions. GIS allows for vast amount of information on different themes and from different sources to be integrated and displayed in a user-friendly format (Mellerowicz *et al.*, 1994).

Application of GIS in various fields has been developed rapidly over the past few years. The range of applications for GIS has become more common and less expensive. Further development of GIS application procedures- to facilitate more diversified land planning objectives and decision-making- may be expected under the pressure of huge volumes of geo-referenced data from many different sources.

Simulation models are the most effective way to predict soil erosion processes and their effects by using a Geographic Information System (GIS) and Remote

Sensing (RS). Therefore, those models have the potential to make major contributions toward developing better conservation practices and improving the management of land resources (Meyer, 1980).

Landsat TM images and GIS analysis techniques were used for land degradation and erosion mapping (Szabo *et al.*, 1998). Bojie *et al.* (1995) integrated DEM, slope, aspect and land use to study soil erosion types and they suggested that GIS analysis could help organize erosion surveys and facilitate mapping. Many researchers have employed GIS and RS technologies to model soil erosion (Rode and Frede, 1997; Millward and Mersey, 1999). Jong *et al.* (1999) used multi-temporal Landsat TM images to account for vegetation properties, a digital terrain model within a GIS to account for topographical properties. One of the most important factors to determine soil erodibility is the vegetation cover. As a general rule, the erosion risk decreases as plant intensity rises. Morgan *et al.* (1978), Berney *et al.* (1997) and Ahlcrona (1988) successfully applied RS data to determine vegetation cover and land use related to soil erosion.