CHAPTER 1

Introduction

1.1 Disaster scenario of Thailand

Thailand has suffered various kinds of natural disasters each year (Chalermpong, 2002). Landslides are one of the major natural disasters in Thailand that cause tremendous loss of lives and property, especially landslides in hilly areas. Extremely intense rainfall in November 1988 in Southern Thailand triggered the worst landslide in the history of the country, leaving three hundred and seventy three people dead and property damage amounting to 280 million US dollar (Phien-wej et al., 1993). In August 2001, disastrous landslides and flooding event took place in Phetchabun Province in Central Thailand. The incident claimed 136 lives with over 5 million US dollars in property damage (Yumuang, 2006). Moreover, the landslide events which occurred in Tak and Mae Hong Son Provinces in May 2004, and those that occurred in Uttaradit, Phrae, and Sukothai Provinces on May 2006 (Tantiwanit , 2007) were among other landslide events that have been taking place almost annually and causing considerable damages, particularly, to the road network in the hilly and mountainous terrains in Northern Thailand.

1.2 Rationale

Landslide movements are considered very complex because they are generally controlled by various factors, including geology, topography, hydrology, meteorology and clay mineralogy (Dahal and Kafle 2003). Clay minerals in general and smectite in particular are quite resistant in dry conditions, but rapidly lose their cohesive strength in wet conditions. Smectite-rich clay layers with high water contents can have the properties of a lubricant, which, in turn, can be critical for slope stability. In addition to their high plasticity, these smectite-rich clays have a high swelling potential, which can induce significant vertical overpressure, reducing even more the strength properties. Therefore, the presence of smectite-rich soils seems to be the main factor controlling the tendency of landslide to occur during or after rainy periods (Azanon et al. 2010).

Landslides often occur in Thailand as a consequence of heavy rainfall. However, the landslide located on highway 1095 (Mae Ma Lai– Pai highway) at kilometer 53 in Mae Taeng district, occurred on 28th August 2011 after rainfall of only 30 mm/day on 26th-27th August 2011. The accumulated precipitation over that period was approximately 40 mm. from the rain gauge station 3 km northeast of the landslide area. Geology of the area is characterized by weathered granitic rocks. It is postulated that the failure of slopes may depend certain other factors, with rainfall as a main trigger. Therefore, factors controlling landslide in this area should be investigated.

1.3 Research objectives

The aim of the study is to investigate the type of clay minerals and the effect of clay in landslide located at kilometer 53 on highway 1095 (Mae Ma Lai– Pai highway) in Chiang Mai province.

1.4 Usefulness of the research

This research will provide a better understanding of clay mineralogy and related landslides in weathered granitic soils in Thailand.

1.5 Definition of landslide

According to Varnes (1978), the term "landslide" is used to describe a wide variety of processes that result in the perceptible downward and outward movement of soil, rock, and vegetation under gravitational influence. It is also one of the most effective and widespread mechanisms by which the landscape is developed. Natural slopes that have been stable for many years may suddenly fail due to various reasons like loss of strength, stress changes, ground water changes and climate conditions (Abramson et al, 2002). Failure of natural slopes is typically studied under the category of landslides. Landslide denotes a process of mass movement of rock, debris or earth down a slope. Forming materials include rock, soil, artificial fill, or a combination of these materials (Cruden, 1991). Landslides are the downhill and outward movement of slope-forming materials under the influence of gravity and also, in most cases, water (Cruden and Varnes, 1996). The materials may move by falling, toppling, sliding, spreading, or flowing (Montgomery, 2000).

1.6 Causes of landslide

Landslides are the results of two interacting sets of factors, the preconditioned and triggering factors. The preconditioned factors, which govern the stability conditions of slopes, are generally naturally induced while the triggering factors are induced either by natural factors or by human interventions (Komac, 2006). Landslides can be triggered by a variety of external stimuli, such as intense rainfall, earthquake shaking, water level change, storm waves or rapid stream erosion that cause a rapid increase in shear stress or a decrease in shear strength of slope-forming materials (Varnes, 1984). In addition increasing population and urbanization, human activities such as deforestation or excavation of slopes for road cuts and building sites, etc., have become important triggers for landslide occurrence (Montgomery, 2000). Landslide causes are geological factors, morphological factors, physical factors and factors associated with human activity.

Landslides have several causes, including geological, morphological, physical and human. Geological causes include weak materials, weathered materials, jointed materials, adversely oriented structures and contrasts in permeability. Morphological causes include a steep slope, wave erosion or fluvial erosion. Physical causes are rainfall, rapid snowmelt and thawing. Human can cause landslides by excavating, removing vegetation, irrigating and mining.

1.6.1 Geological causes

Geological Causes are factors that make the materials that form a slope susceptible to failure. Key causes include, for example, materials that are weak or that are weathered materials with strong joint sets, especially where they are orientated in such a way that they allow sliding to occur, and material combinations that cause water to be retained. One of the geologic factors that contribute to landslides is a type of material from which the slope is formed. The materials can be plastically weak, sensitive or collapsible materials. These materials, in presence of certain triggering factors, can easily lead to landsliding by breaking apart the structure and thus reducing the strength and creating a finer-grained equivalent of quick sand that is prone to landsliding (Montgomery, 2000).

The degree of weathering and the thickness of the weathered soil also influence the occurrence of landslide to a great extent. Weathering is the physical and chemical disintegration or decomposition of geologic deposits (Watkins et al., 1975). Highly weathered rock has low shear strength. Increase in thickness of a residual soil due to weathering increases the overburden pressure causing an increase in the shear stress in the soil mass. The occurrence of a landslide also depends strongly on the rock type, jointed, sheared, and fissured materials and their orientation.

The number of landslides in granitic rocks compared with other lithologies depends on factors that promote decomposition, such as climate and erosional history. The humid tropics is the site of the most intense chemical weathering, and as a result many of the granitoid problem areas, such as Hong Kong and Rio de Janeiro, are also within that zone. Rhodes (1968) compared the landslides in granitic rock to ten other lithologies in humid tropical New Guinea. He found that silicic igneous rocks had the most landslides per unit area. On the other hand, Radbruch and Crowther (1973) indicated that in California, granitoid has one of the lowest rates of slope failure of any rock type.

The engineering properties of granitic rocks change as weathering continues. Granitoids break down progressively from massive blocks to a deep layer of clay-size particles. Therefore, the disciplines of both rock mechanics and soil mechanics are useful for investigating the slope stability of such materials. The shear strength and critical slope angle decrease as a granitic rock mass weathers. Merritt (1972) described how knowledge of the characteristic critical slope angle at each weathering stage was helpful in a construction project on intrusive rock in Colombia.

1.6.2 Morphological causes

Landslides, and especially large catastrophic landslides, cause significant changes in the Earth's natural environment. Mountain and valley morphologies are most significantly affected by downslope movement of large landslide masses. Morphological changes to the land can change the landscape of the land and end up causing landslides as the land beneath the flat surface of cliffs is slowly worn away. Important morphologic processes which triggers landslide are tectonic uplift, volcanic uplift, glacial rebound, fluvial erosion of the slope toe, wave erosion of the slope toe, glacial erosion of the slope toe, erosion of the lateral margins, subterranean erosion (solution, piping), deposition loading of the slope or its crest, and vegetation removal by erosion, forest fire or drought (Montgomery, 2000). It is not a straight forward relationship in which steeper slopes are less stable. In Norway, for example, slopes formed from unweathered gneiss are able to form cliffs that can stand vertically to elevations of many hundreds of metres along the margins of fjords. A further key morphological factor can be the concavity or convexity of the slope, which can serve to concentrate water in key locations. Finally, in many high mountain areas, the loss of glacial ice leaves slopes unsupported and thus prone to failure, whilst in coastal environments the under-cutting of cliffs can lead to reductions in stability (Petley, 2005).

Shear stresses on a slope are a function of overburden weight, slope angle (in which non-cohesive materials is more important than slope height) and the geotechnical properties of slope sediments. The infinite slope approach to stability analysis for shallow slides can be used to predict the threshold angle for slope failure (Carson,1976) and hence conditions prior to debris flow development on lower slopes.

The surface of the Earth, both on the continents and beneath the oceans is continually modified by internal forces and the forces of gravity, both particularly the latter, produce landslides. The net morphologic effect of landslides is to reduce slopes to angles at which they possess long-term stability. The processes involved vary enormously from extremely large rapid movements to extremely slow micro-displacement. The result is denudation in the source area, frequent erosion along the transport path, and then deposition, the degree of whose permanence varies widely (Small and Clark, 1982).

1.6.3 Physical causes

Physical causes for landslide include intense rainfall, rapid snow melt, prolonged precipitation, freeze-and-thaw weathering cycles as well as shrink-and-swell weathering. The occurrence of landslide also depends on the water holding capacity and nature of materials the slope is made of. For instance, shrink and swell weathering of expansive soils in the presence of high moisture content could lead to slope failure. In the high altitude region rapid melting of deep snow, freeze and thaw weathering and thawing of permafrost are of important factors which enhance the possibility of occurrence of landslide. Other physical factors include natural phenomenon such as earthquake and volcanic eruption. Earthquake shocks and vibrations in granular soils, not only increase the external stress on slope material, but they can cause a reduction in the pore space which effectively increases pore pressures.

An increase in water content not only adds the weight of the unstable mass but it also causes a decrease in shear strength either by reducing the apparent soil cohesion or through the increase of pore water pressure at the potential slip surfaces. The presence of water also softens clay minerals that may be present and thus reduce strength and cohesion inducing slope failure. Significant volume change may occur in some materials, notably clays, on wetting and drying out (Bell, 1983). Seepage force within a granular soil can produce a reduction in strength by reducing the number of contacts between grains. Water can also weaken slope materials by causing materials to alter or to dissolve.

Major earthquakes also have triggered multiple historic landslides over large areas. These often consist of thousands of individual landslides that in total have significant effects on the Earth’s surface. In May 1960, one of the world’s strongest earthquakes (Mw=9.2) (Kanamori, 1977) struck the coast of south-central Chile causing numerous major landslides and hundreds of surficial slides (Davis and Karzulovic, 1963; Weischet, 1963). The largest individual mass movements were three contiguous landslides with a total volume of 40 million cubic meters.

The world’s largest historic landslide is the 1980 Mount St. Helens rock slide and debris avalanche in the Cascade Range of southwestern Washington State, U.S.A., which was triggered by a catastrophic volcanic eruption (Voight et al., 1983). This 24 km, 2.8 km^3 landslide buried about 60 km^2 of the valley of the North Fork Toutle River under a cover of hummocky-surfaced, poorly sorted debris, ranging in size from clay to blocks of volcanic rocks with individual volumes as large as several thousand cubic meters (Schuster, 1989).

1.6.4 Human causes

Human activities triggering landslides are mainly associated with construction and involve changes in slope caused by terracing for agriculture, cut-and-fill construction for highways, construction activity, mining operations, rapid draw down of dams, changes in land cover such as deforestation, and changes in irrigation or surface runoff.

The human-induced landslides are caused by changes of the strength or effective stresses, changes in geometry and boundary conditions, and modifications or changes of the material behavior (Terzaghi, 1950).

Mining activities in a South Wales coalfield created tailings coal debris. The stability of these human constructions was precarious on many occasions, and several unstable incidents, without grave consequences, occurred in this area. However, the Aberfan soil heap dramatically slid on the October 21, 1966, destroying buildings (e.g. a local junior school and 18 houses) and killing 144 people (Bishop and Penman, 1968; Siddle et al., 1996).

Excavation of steep slopes for house building, foot path construction, plot levelling, and agricultural terraces causes water stagnation, increased infiltration and reduces lateral support, leading to increased pore pressure and landslide risk. Excavation of steep slopes for house building, foot path construction, plot levelling, and agricultural terraces causes water stagnation, increased infiltration and reduces lateral support, leading to increased pore pressure and landslide risk (Bhudu, 2000; Knapen et al., 2006; NEMA, 2008).

Population pressure forces people to cultivate unsuitable steep slopes, thus contributing to slope instability (Yanda and Shishira, 2001; William, 2002; Soini, 2005; Knapen et al., 2006; Buyinza et al., 2008). The role of cultivation on steep concave slopes in inducing slope instability has been inferred by many a scholar whereby the soil hydrological conditions are greatly altered by way of enhancing saturation and also triggering debris flows under extreme rainfall events (Ian and Flores, 1999; Inganga et al., 2001; Glade 2002; Nyssen et al., 2002; NEMA, 2007).

Deforestation is considered one of the main preparatory factors for landslide occurrence on most East African highlands, because it decreases the factor of safety through root decay (Sidle and Terry, 1992; Inganga et al., 2001; Knapen, 2003; Vanacker et al., 2003; Knapen et al., 2006); thereby enhancing the risk of shallow slope movement (Sidle and Terry, 1992; Vanacker et al., 2003).

1.7 Landslide classification

Landslide classification is based on Varnes (1978) system (Table 1.1) which has two terms: the first term describes the type of movement (Figure 1.1) and the second term describes the material type.

1.8 Study area

Along the Highway 1095 (Mae Ma Lai - Pai), the areas are composed of weathered granite, which is known to be very sensitive to weathering and vulnerable to landslides. Thick weathered granitic soils and heavy rainfall make the highway susceptible to landslide. During the rainy season, a lot of landslides are reported along this highway. On August 28, 2011, landslides occured at kilometer 53 along the road cuts after rainfall and interrupted the flow of traffic after rainfall. Hence, clay mineralogy of weathered granitic soils was studied to evaluate the susceptibility of landsliding along the highway. This research focuses on clay mineralogy of weathered granitic soils in landslide (kilometer 53) and non-landslide areas (kilometer 50) on Highway 1095 (Figure 1.2).

Table 1.1 Major types of landslides. Abbreviated version of Varnes' classification of slope movements (Varnes, 1978).

TYPE OF MOVEMENT		TYPE OF MATERIAL		
		BEDROCK	ENGINEERING SOILS	
			Predominantly coarse	Predominantly fine
FALLS		Rock fall	Debris fall	Earth fall
TOPPLES		Rock topple	Debris topple	Earth topple
SLIDES	ROTATIONAL	Rock slide	Debris slide	Earth slide
	TRANSLATIONAL			
LATERAL SPREADS		Rock spread	Debris spread	Earth spread
FLOWS		Rock flow (deep creep)	Debris flow (soil creep)	Earth flow
COMPLEX		Combination of two or more principal types of movement		

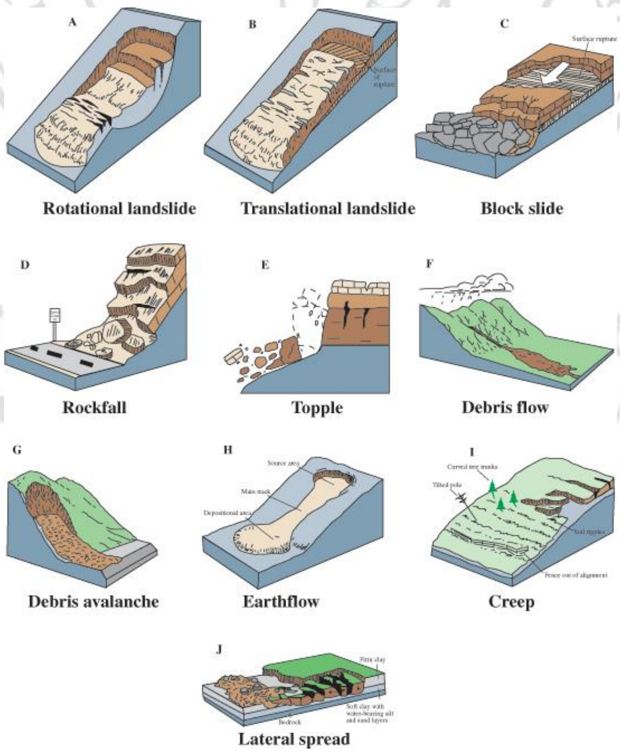

Figure 1.1 Diagram illustrating the major types of landslide movement. (From US Geological Survey Fact Sheet 2004-3072, July 2004).

1.9 Geology

The rocks of northern Thailand can be divided into four categories including Precambrian rocks, Paleozoic rocks, Mesozoic rocks, and Cenozoic rocks/sediments. Precambrian rocks, characterized by gneiss and associated high-grade metamorphic rocks, are normally exposed along high mountain ranges extending from north to south in the west from Chiang Mai, Lampang, to Tak via Doi Inthanon, Doi Pui, Doi Suthep, and Lan Sang and extend to Kanchanaburi (Uttamo, 2000; Silaratana, 2005). Figure 1.3 shows the geologic map of northern Thailand. Silaratana (2005) and Uttamo (2000) subdivided Paleozoic rocks in northern Thailand into three series, Lower Paleozoic, Middle Paleozoic, and Upper Paleozoic rocks.

Lower Paleozoic rocks include Cambrian and Ordovician rocks distributed in the western part of northern Thailand. The Cambrian rocks are quartzite, sandstone and shale. The Ordovician rocks are argillaceous limestone, limestone, dolomitic limestone, and shale.

Middle Paleozoic rocks include Silurian-Devonian rocks consisting of phyllite, carbonaceous phyllite, and quartzite are normally distributed from north to south in the central part of northern Thailand from Chiang Rai via Chiang Mai to Lampang.

Upper Paleozoic rocks of Carboniferous-Permian age include conglomerate, sandstone, shale, chert, and limestone.

Mesozoic rocks in northern Thailand are lithologically divided into two facies, marine and younger continental facies. The marine facies comprise the Triassic Lampang Group, the Upper Triassic to Jurassic Mae Moei Group, the Triassic Nam Pat Formation, and the Jurassic Huai Pong, Hua Fai, and upper Umphang Groups. The continental facies are characterized by red bed sandstone, siltstone, mudstone, with conglomerate, relatable to the red bed Khorat Group in the Khorat Plateau. Triassic igneous rocks including migmatite and granite are widely distributed throughout northern Thailand.

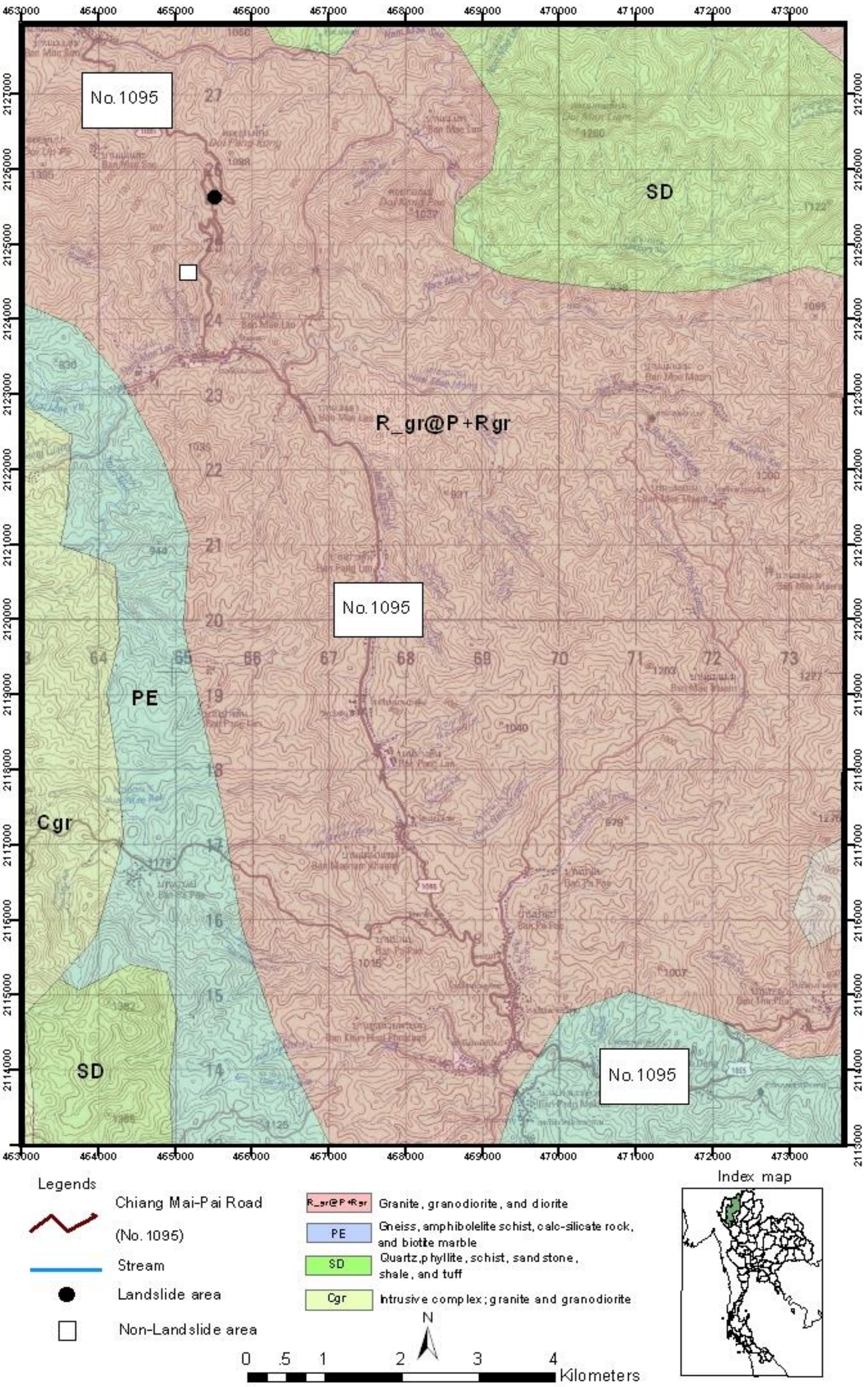

Figure 1.2 Location map of the study area (modified from DMR, 2002).

Cenozoic sediments occur mainly in the intermontane basins in the lowland. Several small basins are also found on the high mountains. The basins are characterized by graben and half-graben structures. The basin-fills are composed of Tertiary and Quaternary deposits. Tertiary strata are unconformably covered by younger Quaternary deposits. Some Tertiary rocks are exposed along the basin margins, as well as along streams. The Tertiary deposits are characterized by semi-consolidated sediments consisting of mudstone, siltstone, sandstone, conglomerate, oil shale, coal, and diatomite together with fossil fauna and flora. Quaternary sediments include unconsolidated clay, silt, sand, and gravel of mainly fluviatile in origin.

1.10 Climate of Chiang Mai area

The climate of Thailand is under the influence of the monsoon winds of seasonal character i.e. southwest monsoon and northeast monsoon. The southwest monsoon which starts in May brings a stream of warm moist air from the Indian Ocean towards Thailand causing abundant rain over the country, especially the windward side of the mountains. Rainfall during this period is not only caused by the southwest monsoon but also by the Inter Tropical Convergence Zone (ITCZ) and tropical cyclones which produce a large amount of rainfall. May is the period of first arrival of the ITCZ to the Southern Part. The ITCZ then moves southerly direction to lie over the Northern and Northeastern Parts of Thailand in August (Figure 1.4). Chiang Mai has a tropical climate and the weather is typically hot and humid throughout most of the time. The weather in Chiang Mai is divided into three distinct parts, hot season, rainy season, and cool season. There are 3 seasons in Chiang Mai, the cool season from November to February, the hot season from March to May and the rainy season from June to October.

The southwest monsoon usually arrives from the Indian ocean at the end of May and lasts until early October. The heaviest downpours in August and September and normally cause flooding some areas. The average monthly rainfall in Chiang Mai over the period in between 1988 to 2013 is shown in Figure 1.5 (Thai Meteorological Department, 2013).

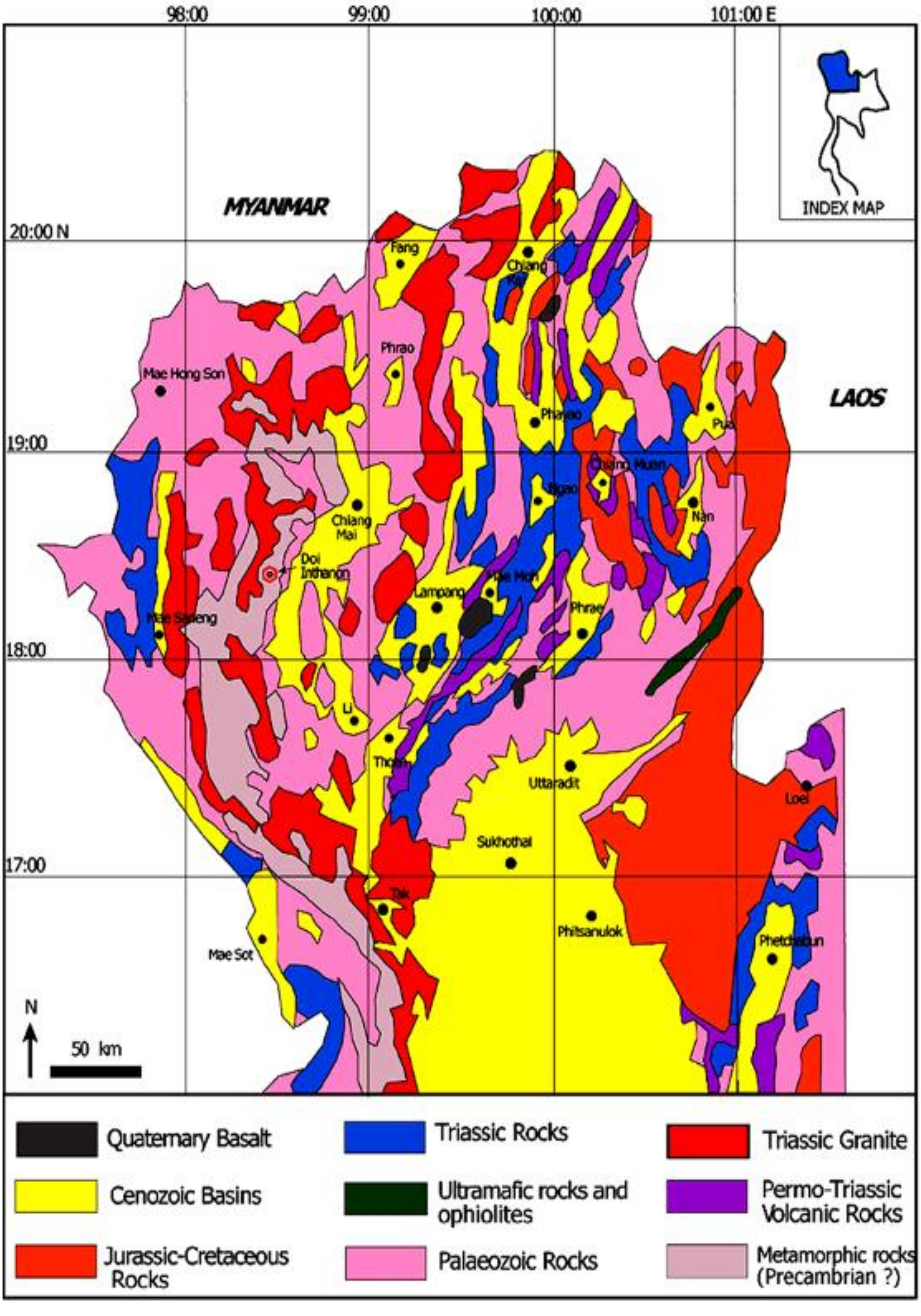

Figure 1.3 Geologic map of northern Thailand showing the age series of rocks (modified after Uttamo, 2000).

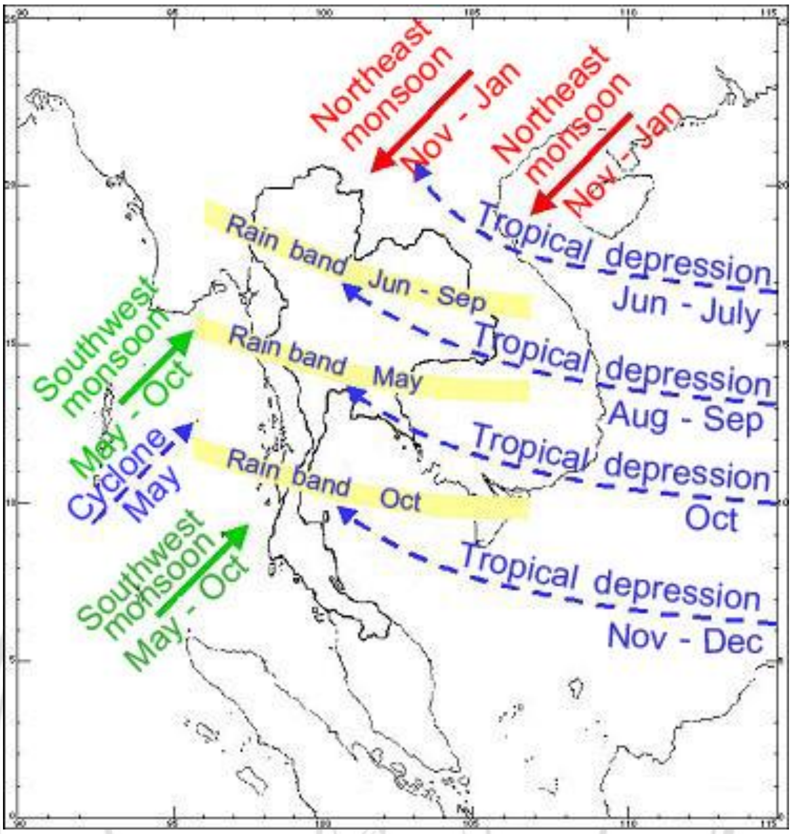

Figure 1.4 Map of the annual monsoon direction in Thailand (Samphutthanon,2014).

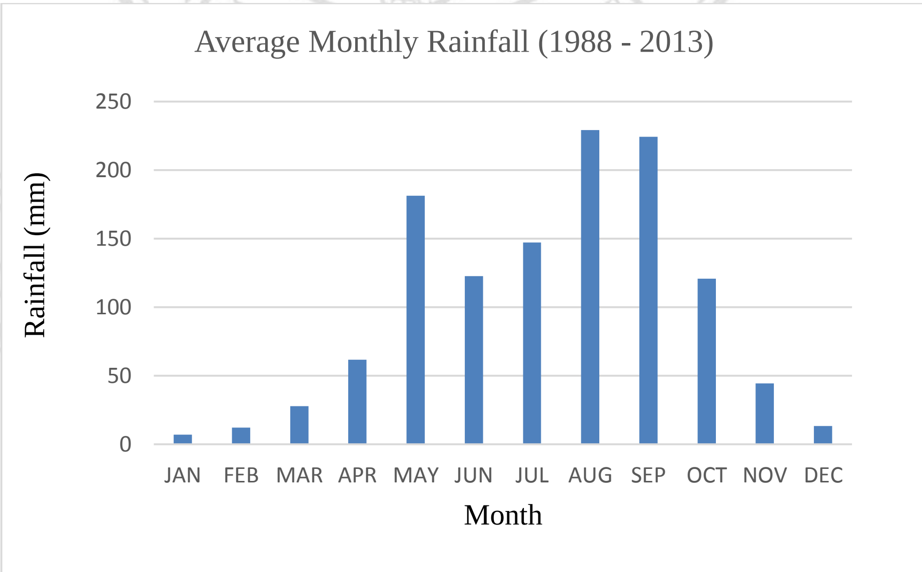

Figure 1.5 Average monthly rainfall in Chiang Mai (1988-2013).

(www.cmmet.tmd.go.th)