CHAPTER 1

INTRODUCTION
1.1 General

Every year, thousands of people all over the world lose their lives in natural disasters. These have large impact on the local and global economy. Natural disasters have major direct and indirect socio-economic effects, in addition to the physical destruction, that may occur. United Nations Disaster Relief Coordinator (UNDRO, 1991) estimates an annual increase of 60% in the number of people affected by natural disasters. It has been estimated that, natural hazards cost the global economy over 50,000 million dollar per year. Two-third of this sum is accounted by damage and the remainder represents the cost of predicting, preventing and mitigating disasters.

United Nations Educational Scientific and Cultural Organization (UNESCO), defined natural disaster as, probability of occurrence with in a specified period of time, with in a given area, of potentially damaging phenomenon (Varnes, 1978). These are natural phenomena or a combination of natural phenomena such as earthquake, mass movements, floods, volcanic eruption, tsunamis etc., and can cause many losses of lives and damage to the property. As world population increases, the risk attributed to natural disasters increases. No country is exempted from the complexities of nature’s forces and its far reaching implications, which are still not fully predictable. In developed countries, hazards can cause great damage to property with associated high costs. This is because, the developed countries are increasingly being aware of the importance of disaster management systems and efforts are being made to streamline preparedness, response and recovery mechanism at all levels. It is a well known fact that many developing countries, including India, are not always well prepared to deal with disasters. A lack of well developed disaster management plan results in severe loss of human life, animal life and property, which could be saved if the necessary mechanisms were in place.

Among the natural disasters, the study of landslides have drawn world wide attentions, mainly due to increasing awareness of socioeconomic impacts of landslides, as well as the increasing pressure of urbanization on the mountain environment (Hansen, 1984; Nagarajan, et al., 1998; Chung and Fabbri, 1999; Aleotti and Chowdhury, 1999; Dai and Lee, 2002; Saha, et al., 2005). Landslide causes property damage, injury and death and adversely affects a variety of resources. The economic impacts of landslides include the cost to repair structures, loss of property value, disruption of transportation routes, medical costs in the event of injury and indirect costs such as loss of timber and loss of fish stock. Water availability, quality and quantity can be affected by landslides. Large,
infrequent landslides contribute less to personal and property losses than the smaller, more frequent slides and debris torrents in populated areas.

1.2 Purpose and Scope

India has been traditionally vulnerable to natural disasters on account of its unique geo-climatic conditions. It is one of the four most disaster prone regions in the world. The country being a vast in area with tropical climate, experiences all types of natural disasters, except volcanic activity (Ganguly, et al., 1993). In the last decade (1990 – 2000), an average of about 4344 persons lost their lives and about 30 million people were affected by disasters every year. Floods, droughts, cyclones, earthquakes and landslides have been recurrent phenomena. About 60% of the land mass is prone to earthquake of varying intensities; 23% is susceptible to landslides; over 40 million hectors are prone to flooding; 8% of the total area is prone to cyclones and 68% is susceptible to drought (Kumar, 1998).

Landslides are among the major hydrogeological (natural) hazards that affect large parts of mountain terrain in India, especially the Himalayas, the northeastern hill ranges, the Western Ghats, the Nilgiris, the Eastern Ghats and the Vindhyas (NDMD, 2004). Among this, the regions most vulnerable to the landslides are the Himalayas and the Western Ghats. As a consequence of deforestation and anthropogenic activities, road construction and mountain development, the frequency of landslides and mass wasting have increased in the Himalayas and the Western Ghats regions in recent times (Thakur, 1996). The landslides that occur in the area are generally triggered by heavy rain, cloud burst and toe cutting of streams. The phenomena cause the loss of hundreds of human and animal lives across the Himalayas. The damage caused by landslides in the region was estimated to be more than US $ 1 billion, causing more than 200 deaths every year, which was about 30% of the total such loss of life world wide (Li, 1990).

The western flanks of Western Ghats, covering considerable part of Kerala, (especially the study area) are identified as one of the major landslide prone areas in the country. These regions are characterized by rugged hills with steep long side slopes on which rests the loose, unconsolidated soil and earth materials. The debris flows (here after referred as landslide), locally known as “Urul Pottal”, seasonally result in the development of new lower order streams on the slopes or widening of existing streams and subsurface seepages (Thampi, et al., 1995). The population pressure and urbanization have forced man to relocate and settle in the hilly tracts, leading to the conversion of natural forests to
agricultural lands. Heavy precipitation during the monsoon season in this region provides an important triggering mechanism causing landslides of various types. The characteristic pattern of this phenomenon is the swift and sudden down slope movement of highly water saturated overburden containing a varied assemblage of debris material ranging in size from soil particles to huge boulders destroying and carrying with it everything that is lying in its path (Sankar, 2005; Sekhar, 2006). The recognition of landslide prone topography is becoming increasingly important in environmental management and land use decisions. Information on terrain characteristics and potential geologic hazards are vital for regional as well as local planning.

Over the past few decades, many scientists have attempted to assess landslide hazards and produced hazard / susceptibility maps portraying their spatial distribution (Carrara, 1983; Bartarya and Valdiya, 1989; Gupta and Joshi, 1990; Anbalagan, 1992; Pachauri and Pant, 1992; Nagarajan, et al., 1998; Thampi, et al., 1997; Aleotti and Chowdhury, 1999; van Westen, 2000; Saha, et al., 2002; Ohlmacher and Davis, 2003; Suzen and Doyuran, 2004; Lee, 2005; Lee and Sambath, 2006; Lee and Pradhan, 2007). All the proposed methods are based upon a widely accepted principle of uniformitarianism (Varnes, 1984; Carrara, et al., 1991; Turner and Schuster, 1995). Landslide modelling and susceptibility mapping, for any given area, involves predicting the occurrence of future landslides based on observed preparatory factors. In order to predict the occurrence of landslides it is important to establish a statistical relationship between landslides and any possible factor. The approaches which have been used are qualitative and quantitative analysis (Aleotti and Chowdhury, 1999; Guzzetti, et al., 1999; van Westen, 2000; Brenning, 2005; Huabin, et al., 2005; van Westen, et al., 2006). Despite the methodological and operational differences amongst these methods, they are all founded upon one basic conceptual model. The basic conceptual model requires first the identification and mapping of a set of factors which are directly or indirectly correlated with slope instability. The model then estimates the relative contribution of these factors in slope failure and ends with the classification of the study area into different hazard zones or susceptibility degrees (Carrara, 1993; van Westen, 2000; Guzzetti, et al., 1999; Kanungo, et al., 2006).

Experience gained from hundreds of surveys carried out in different parts of the world has demonstrated that well trained investigators are able to detect and correctly map many or most of the landslides occurring in an area by applying aerial-photograph interpretation techniques and systematic field checks. However, old, dormant landslide
bodies are generally intensively modified by farming activity or covered by dense vegetation and thus, they cannot be readily identified and correctly classified (Thampi, et al., 1998). This introduces a factor of uncertainty that cannot be readily evaluated and explicitly incorporated in the subsequent phases of the analysis which is dependent on the skill of the surveyor, and the quality and the scale of aerial photographs, satellite images and base-maps used.

The conjoint analysis of all the terrain variables in relation to the spatial distribution of landslides has gained enormously from the geographic information systems (GIS), the ideal tool for the analysis of parameters with a high degree of spatial variability. The thematic maps for the various terrain variables with weights assigned according to their relative importance are subsequently overlaid with each other to generate an LHZ map using GIS operations (Gupta and Joshi, 1990; Nagarajan, et al., 1998; Gupta, et al., 1999; Saha, et al., 2002; Sarkar and Kanungo, 2004). This method is highly subjective and might therefore contain some implicit biases towards the assumptions made. For minimizing the subjectivity and bias in the weight assignment process, quantitative methods, namely, statistical analysis, deterministic analysis, probabilistic models, distribution-free approaches and landslide frequency analysis in GIS environment have emerged in recent years (Carrara, 1983; Yin and Yan, 1988; Carrara, et al., 1992; Guzzetti, et al., 1999; Jagathan and Chauniyal, 2000; van Westen, 2000; Lee and Min, 2001; Lee, et al., 2002; Arora, et al., 2004; Ayalew, et al., 2004; Melelli and Taramelli, 2004; Pathak and Nilsen, 2004; Lee, et al., 2004; Suzen and Doyuran, 2004; Zezere, et al., 2004; Saha, et al., 2005; Gorsevski, et al., 2006; Wang, et al., 2007).

1.3 Aim and Objectives

The aim of this work is to prepare a landslide susceptibility zonation map at a scale of 1:50,000 for the study area by recognizing and mapping the slide locations and the associated terrain attributes. Such a susceptibility zonation map will be useful in the planning of landslide hazard risk reduction measures in the region.

To fulfill the aim, this research work focused on the following five major objectives:

1. to provide a critical review of the literature related to landslide hazard/susceptibility zonation, evaluating both qualitative and quantitative methods.
2. to generate a landslide inventory of the study area, primarily utilizing global positioning system (GPS).

3. to identify and analyze the factors that are preparatory to the occurrence of landslides in the area.

4. to prepare a landslide susceptibility zonation (LSZ) map for the study area using satellite remote sensing data and geographical information systems (GIS).

5. to evaluate the accuracy of the landslide susceptibility map using a quantitative validation procedure.

1.4 Study Area – Geographical Settings

The area selected for the study is located in the southern part of India, Kerala state, Kottayam district, which forms the western slopes of the Western Ghats. The area is geographically defined as the upper catchments of River Meenachil namely, Kalathukadavu and Poonjar, and enclosed between $9^\circ 37' 00"$ N, $76^\circ 44' 00"$ E in the southwestern edge and $9^\circ 52' 00"$ N, $76^\circ 50' 00"$ E in the northeastern edge (Fig. 1.1) and covered in three topographical sheets: 58C/9, 58C/13 and 58C/14 (1:50,000), prepared by Survey of India (SoI). The catchments have an elongated form, extending north-south covering an area of 218.44 km$^2$.

1.5 Structure of the Thesis

The thesis is divided into seven chapters. Chapter 1 deals with the introduction, purpose and scope of the study. The definitions, classification and analysis of landslide hazard, vulnerability and risk constitute chapter 2. An extensive review of the previous work carried out on landslide hazard assessment is presented in chapter 3. The characteristics of the study area, types of input data and every single parameter maps are described in chapter 4. Analyses of the geospatial databases are given in detail in chapter 5. The chapter 6 of this thesis consists of the assessment of the analysis results and discussion regarding the produced landslide susceptibility zonation map. Finally the conclusions are drawn in chapter 7 based on the findings of the study.
Fig. 1.1 Study area location map