CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

Landslide is the third type of natural disaster in terms of worldwide importance. Natural and man-made activities can produce landslides which can lead multiple human and economic losses (Fleming and Taylor 1980, Guzzetti 1999). Slope failures are more widespread, and over the years they may cause more damage to properties than any other geological hazards (Varnes 1984). Mantovani et al (1996) have defined the study of landslides into three stages namely (i) detection and classification of landslides, (ii) monitoring activity of existing landslides and (iii) analysis and prediction of the slope failures in space and time.

Steep terrain and high frequency of rainfall make landslide occurrence frequent on natural terrain (Dai & Lee 2002). Geotechnical and terrain features that influence landslides are cohesion, angle of internal friction, slope and relative height, orientation of slope (aspect), proximity to drainage, vegetation cover and proximity to major faults (Gokceoglu & Aksoy 1996). Intense rainfall coupled with the increase in human activities associated with urban development has contributed to increase instability of slopes (Bhasin et al 2002).

The earliest record of regional landslide mapping is the huge landslides that occurred in parts of Calabria in Italy during 1783. It had
affected many settlements and blocked rivers that created 215 lakes. This was as a result of co-seismic effect of a major earthquake (Cotecchia & Melidaro 1974). Many case studies are also illustrated to describe the catastrophic nature of landslides in the world (Brabb & Harrod 1989, Brabb 1993). Schuster & Fleming (1986) has estimated the annual losses due to the landslides in United States, Japan, India and Italy at one billion or more each. Subsequently, Schuster & Highland (2001) studied the socioeconomic impact of landslides in Western Hemisphere highlighting extreme events such as a debris avalanche in 1970 in Huascaran, Peru with a death toll of 20,000 people, a debris flow in 1985 in Nevado del Ruiz, Colombia killing 25,000 people and the 30,000 that were killed or are missing as result of the 1999 landslides and floods in northern Venezuela.

2.2 LANDSLIDES IN OOTY HILLS (NILGIRIS)

In the Indian sub-continent, landslides are common in three major regions namely, the Himalayas in north and northeast, Western Ghats in the southwest and the Nilgiris in the south. The major factors behind these landslides are active tectonics in the Himalayan landslides, slope erosion and rock fall in the Western Ghats and rainfall in the Nilgiris (Seshagiri et al 1982). The Nilgiris landslides are demonstrated to be the reflection of pore pressure increase during the rainy seasons (Ramasamy et al 1996). The major problem in Nilgiris district is the deforestation. Previous studies on deforestation and land use changes in Western Ghats showed a loss of 25.6% in forest cover between 1973 and 1995 in the southern part (Jha et al 2003). Due to the lack of a landslide inventory, the knowledge about geological, geomorphological, tectonic and hydrological conditions under which these events happen is limited or even unknown in Nilgiris. Similarly limited work has been done so far where landslides correlate with environmental variables like soils, slope, etc. to produce susceptibility and hazard maps. Limited
studies have been carried out in areas where the landslide hazards are correlated to elements at risk to generate risk maps.

Severe landslides occurred during 1978, when more than 100 landslides were recorded within an area of 250 km$^2$ in Nilgiris. In 1979, more than 200 landslides were reported in the same area. In 1992, a number of landslides occurred causing damage to the roads and private property in the Coonoor segment. During 1993, about 408 landslides have been reported, of which Marapalam area of the Coonoor region is the most severe one (Balachandran et al 1996). The important triggering factors of landslides in Nilgiris are inadequate drainage system, more soil thickness, deforestation, improper land use practices, disturbance of natural topography by anthropogenic activities heavy rainfall and construction activities.

A number of studies have been carried out in the Nilgiris by various agencies with different approaches (Seshagiri et al 1982). A case study of debris avalanche at Marappalam in Nilgiris district was reported by Balachandran et al (1996).

Landslides occur frequently on cut slopes along road and railroad (Jaiswal & Westen 1999), and occasionally on natural slopes. In recent past, major landslide events affecting natural slopes in Nilgiris were recorded in 1978, 1979, 1987, 1993, 1996, 2006, and 2009. These events resulted in numerous casualties and loss to properties in the Nilgiri hills (Seshagiri et al 1982, Balachandran et al 1996). In 1993, a debris slide at Marapallam killed more than 50 people, and destroyed 18 houses and one mosque (Balachandran et al 1996). In 2009, rainfall triggered more than 300 landslides in the Nilgiri area, which affected both cut and natural slopes and resulted in 80 casualties and an estimated loss of Rs. 208 million (Ganapathy et al 2010). To reduce the disastrous impact of landslides on society and to facilitate a rationale for land use planning, such as in the case of the Nilgiri hills, landslide risk
quantification forms a fundamental tool in risk management process (Fell et al 2005, 2008).

Landslides occur as a consequence of various triggering factors. Rainfall is one such important factor. But the human intervention like deforestation may cause the soil to lose its capacity and ultimately leads to landslides during heavy rainfall. The Nilgiris now entered an anxious era of landslides since the calamitous landslides of 1978. The frequency of landslides has been increased in recent years with major slides occurred very recently in November 2009.

2.3 REMOTE SENSING AND GIS IN LANDSLIDE STUDIES

GIS has become an important and compulsory tool in landslide hazard and risk assessment studies, and it is the challenge to keep on using it as a tool. When using GIS, the four components of a landslide risk assessment can be differentiated: (i) data collection, (ii) data entry, (iii) data management and (iv) data modeling.

Carrara et al (1992a), used GIS technology for the prediction and monitoring of landslide hazards and highlighted some of the negative aspects of the extensive use of GIS, such as: computer-generated outputs are considered to be more objective and accurate than products derived by experts in the conventional way through extensive field mapping; the use of GIS and the production of less accurate hazard maps by users that are not experts in earth sciences; the increased focus on the use of new computational techniques for landslide hazard assessment, less interest on the collection of reliable data and for the average earth scientist it is difficult to keep up with the rapid developments in the field of Geo-information Science. Also the change of GIS software from one version to the next, in which the methods that had been developed earlier on do no longer function, because of changes
in file structure or interface, can be frustrating to many earth scientists.


2.4 MORPHOMETRIC ANALYSIS


2.5 LAND USE/ LAND COVER STUDIES

The investigations on land use and land cover have been advanced since fifties in different parts of the world. Remote sensing methods
consisting of aerial photography play a significant role because of its application and effort in retrieval of different natural resources. In sixties there was development in an appraisal in the application of aerial photography in the study of land use / land cover in different parts of the world as in USA (Avery 1965, Colwell 1965), Spain (Bruijina & De 1974) and Hongkong (Lo 1979).

Investigations on land use / land cover have been carried out in various parts of India through aerial photographs and satellite remote sensing techniques. Srivasthava & Narayana (1974) have studied the technical developments and made an attempt towards mapping of land use in Dehradun city using aerial photo interpretation methods.


Brahbhat et al (2000) demarcated land use / land cover change mapping in Mahi canal command area, Gujarat, India using multi-temporal satellite data that have been used to investigate the land use / land cover and change detection mapping in Mahi canal command area, Gujarat. Yang & Lo (2002) prepared land use land cover changes in the area of Atlanta using high-resolution satellite imagery. Jayakumar & Arockiasamy (2003) studied land use / land cover mapping and their changes in part of Eastern Ghats with
special reference to remote sensing and GIS. Land use / land cover alterations and their impact assessment particularly with reference to pre-monsoon climatic conditions at Gangetic planes of West Bengal region were studied by Sadhukhan et al (2003).

Identification of the agricultural pattern and their impact over Hazira region, Gujarat through spatial, non-spatial and satellite techniques along with field verification were done by Shailesh Nayak (2005). A detailed mapping of vegetation and other land use / land cover identification in an Alpine arid region (Nubra Valley, Ladakh) was performed using satellite remote sensing data.

Land cover change has been described as the most significant regional anthropogenic disturbance to the environment (Roberts et al 1998). In essence both land use and land cover changes are products of prevailing interacting natural and anthropogenic processes by human activities. Studying land use dynamics is essential in order to examine various ecological and developmental consequences of land use change over a period of hiatus. Land use and land cover change with land degradation are as a result of motivated by the same set of proximate and underlying factor elements to environmental processes, change and management through their influence on biodiversity, heat and moisture budgets, trace gas emissions, carbon cycling, livelihoods, a wide range of socio-economic and ecological processes (Desanker et al 1997, Verbug et al 2000, Verburg et al 2002, Fasona & Omojola 2005).

Application of remotely sensed data as made possible to study the changes in land cover in less time, at low cost and with better accuracy (Kachhwaha 1985) in association with Geographical Information System (GIS) that as provided suitable platform for data analysis, update and retrieval (Star et al 1997, McCracker et al 1998, Chilar 2000). Space borne remotely
sensed data may be particularly useful in developing countries where recent and reliable spatial information is lacking (Dong et al 1997). Remote sensing technology and geographic information system (GIS) provide efficient methods for analysis of land use issues and tools for land use planning and modeling. By understanding the driving forces of land use development in the past, managing the current situation with modern GIS tools, and modeling the future, one is able to develop plans for multiple uses of natural resources and nature conservation. The change in any form of land use is largely related either with the external forces and the pressure built up land within the system (Bisht & Kothyari 2001).

2.6 LANDSLIDE VULNERABILITY MAPPING

The study of landslides has drawn worldwide attention mainly due to increasing awareness of the socio-economic impact of landslides, as well as the increasing pressure of urbanization on the mountain environment (Aleotti & Chowdhury 1999). Although it is yet difficult to predict a landslide event in space and time, an area may be divided into near-homogeneous domains and ranked according to degrees of potential hazard due to mass movements (Varnes 1984). Such maps are called Landslide Hazard Zonation (LHZ) or Landslide Susceptibility Zonation (LSZ) maps.

During the past three decades, attempts at landslide hazard zonation studies have been made in different parts of the country. Since then a large number of landslides were investigated, but Landslide Hazard Zonation Mapping as it is commonly understood today, is relatively a new concept. Different approaches to zonation have been followed by different investigators.

Krishnaswamy (1980) may be perhaps the first person to attempt landslide zonation mapping at the national level. He made the three fold
geomorphic division of India into the peninsular, the Indo-Gangetic plain and the Extra-Peninsular as the basis for evaluating the relative incidence of landslides. The first attempt on regional level landslide hazard zonation mapping studies in the North Eastern region (Majundar 1980) and in the North West Himalaya (Narula et al 1996) was made by Geological Survey of India. The next major attempt on regional zonation mapping was made in 1982 for the Nilgiris district of Tamil Nadu State, India. Maps were prepared by considering the lithology, general physiography, rainfall patterns, seismicity and domains of crustal adjustments. Krohn & Slossen (1976) demarcated landslide prone or resistant bed-rock and categorized the area into high, moderate and low zones.

The second generation landslide hazard zonation maps on 1:50000 scale was attempted by the GSI in the Nilgiris hills, India, in which more than the overlay, the numerical method with ratings were given for slope angles, thickness of soils, drainage and land use and five landslide susceptibility zones were identified (GSI 1982). It addresses soil and debris slides. Landslide Hazard Zonation maps on 1:50000 scales have been prepared of an area aggregating about 12,000 sq. km. in the Chenab, Sutlej, Beas and Ganga basins utilizing the overlay methods. In all these studies the remotely sensed database was also utilized for making the landslide incidence maps with representative field checking. The inputs for these included the detailed morphometric, characterization of slope forming materials, and the geomechanical behavior of the discontinuity surfaces which contain low strength sheared material, the critical angles of failure of different materials, identification of type of failure in a particular material and given natural conditions as derived from landslide incidences (Gupta et al 1988, Sharan 1992).

One of the early projects on zonation was carried out by Central
Road Research Institute in 1984, in which hazard zonation techniques were used to choose a most suitable alignment from the possible alternative alignments on landslide affected stretches in Sikkim area. During 1989, a hazard zonation map was prepared for a part of Kathgodam-Nainital highway. This map was prepared with the objective of enabling the department to evolve a suitable maintenance strategy to keep the hill slopes along the road free of landslide problem (Sharma & Kandpal 1995).

Landslide hazard zonation mapping in parts of Beas valley, Himachal Pradesh (Prakash Chandra 1996) and in parts of Bhagirathi valley, Garhwal in North Western Himalayas (Gupta 1996, Sharma & Kandpal 1995) are mostly confined to small area and limited number of slides. Studies along NH31A of Sikkim in Eastern Himalayas (Sengupta & Gohosh 1996) are mostly based on the Landslide Hazard Evaluation Factors (LHEF) rating scheme, which is mainly a quantitative way to ascertain relative importance to factors for slope instability.

Landslide Hazard Zonation along the pilgrim road routes in the Himalayan regions of Uttaranchal and Himachal Pradesh was done using remote sensing and GIS techniques based on the Analytical Hierarchical Process and Saaty’s principle of pair wise Comparison model by NRSA, Hyderabad (2001). They modeled landslide hazard zonation based on true topographic conditions without the effect of triggering factors.

Ramakrishnan et al (2002) made attempt to identify landslide prone areas using photogrammetry with 3D GIS techniques. The advantage of the high resolution data helps in deriving 2m contour, which is ideal to get the elevation and slope values of the terrain. Prabu et al (2009) developed a new model for landslide hazard mapping through the integration of GIS, remote sensing and neural networks. He compared conventional method of landslide mapping with the use of neural networks in landslide mapping.
Anbalagan (1992) evolved new quantitative approach based on major causative factors of slope instability. He adopted a landslide hazard evaluation factor rating scheme for Landslide Hazard Zonation. Sanjeevi Kumar et al (2004) developed the web based GIS for landslide inventory for the Nilgiris district. It includes spatio-temporal landslide database, different landslide inducing factors and landslide hazard zonation. This application was developed in ArcIMS to view the landslide information together with other data layers.

Bureau of Indian Standards has published a code (IS 14496 (Part 2):1998) on ‘preparation of Landslide Hazard macro Zonation Maps in mountainous terrains Guidelines’ based on LHEF rating scheme for different causative factors. The BMPTC (2003) has taken the effort to produce the Landslide Hazard Zonation Atlas of India on 1: 6 million scales. This small landslide hazard maps only provide a mega view of landslide hazard distribution across The country.

2.7 LANDSLIDE RISK ASSESSMENT

Although landslide risk was already defined by Varnes (1984), the quantitative estimation of risk remains a difficult task due to problems in quantifying the individual components of the risk equation (Fell et al 2005, Van Westen et al 2006). Van Westen et al (2006) highlighted some of the challenges in quantitative risk analysis related to the unavailability of a complete landslide inventory, the difficulty in incorporating landslide run-out for all landslide susceptible areas, and the difficulty in assessing vulnerability of elements at risk due to insufficient damage data. Even though numerous publications on the concepts of risk analysis are available (e.g., Guzzetti 2000, Dai et al 2002, Fell et al 2008), many limitations make the actual quantification of spatial landslide risk rather difficult.
For a quantitative risk analysis at least three types of information are required. These are related to the probability of occurrence of landslides at the location of elements at risk, the quantification of the number of elements at risk exposed, and the expected degree of loss to these elements at risk given the magnitude of the landslide. The probability of occurrence of landslides forms the key component in defining different landslide hazard scenarios for risk analysis. This probability can be assessed either by computing the probability of failure of a slope (or the reactivation of existing landslides) or through the frequency analysis of past landslide events (Corominas 2001). The latter requires making several specific assumptions on the occurrences of future events, which include the number and sizes of future landslides expected (Chung & Fabbri 2005). If a complete landslide inventory is available then the probability of occurrence of landslides in each mapping unit can be obtained directly using the frequency of past landslides (Guzzetti et al 2005, Jaiswal et al 2011). However, such inventories are mostly not available and therefore a direct assessment of landslide hazard becomes difficult. Difficulties also arise if landslides are first-time failures. If the return period of triggering events for reactivated landslides is known, the estimation of the probability of future landslide activity is more straightforward (Coe et al 2000, Catani et al 2005).

Recently, a number of attempts have been made to quantify landslide risk (Kong 2002, Catani et al 2005, Zezere et al 2007, Remondo et al 2008). Researchers have expressed risk in different ways such as loss over a specified time period or annual loss, depending on the quality of landslide information, the scale of the study, and the aim of the analysis. However, if the analysis is meant for defining risk reduction strategies then it is recommended to express risk as annual loss in order to be able to carry out a quantitative cost-benefit analysis, and also because quantitative risk acceptance criteria for loss of life are usually expressed in per annum terms.
(Fell et al 2008). In most case studies, risks are quantified for elements at risk located in the landslide initiation areas, whereas much less work has been done to assess risk by incorporating run-out distance of a landslide (Bell & Glade et al 2000). If an area has a potential for hazardous debris flows then the estimation of run-out distance is essential in order to evaluate the actual risk. Several empirical methods such as the mass-change method (Cannon 2000), the angle of reach method (Hungr et al 2005), and process based methods (Remaitre et al 2005) are suggested for run-out calculation. The question remains, however, how to incorporate these for the many possible landslide initiation areas in a quantitative susceptibility map with many mapping units having different spatial probabilities (Van Westen et al 2006).

Process-based methods have been used to demarcate landslide hazard areas but they experience serious problems with parameterization, which makes their application problematic over larger areas, especially in a heterogeneous terrain setting (Kuriakose et al 2009). One way to include run-out distance in risk analysis, over a large area, is to use empirical relationships such as the identification of all hazardous zones likely to affect the elements at risk that are located down slope of the landslide initiation areas, followed by a loss estimate for each element separately.