CHAPTER 3

STUDY AREA

3.1 General Description

The Nilgiri district is located in the southern state of Tamilnadu in India, bounded on the north by the state of Karnataka, on the east by Coimbatore and Erode districts, on the south by Coimbatore district and on the west by the state of Kerala. The topography of the Nilgiri district is hilly and steep, with an altitude varying between 900 and 2,636 m. The Nilgiris has found a place in the landslide hazard map of India when widespread rains caused over 350 landslides in the years 1978 and 1979. The frequency of landslides has increased in recent years with major slides with large number of deaths occurring in 1990, 1993, and 2009 (Ganapathy et al., 2010). The landslide which occurred on 11th November, 1993 in Marappalam on Mettupalaiyam – Uthagamandalam Highway washed away 18 homes situated in the village killing of 12 peoples. The slide also resulted in the death of 21 passengers in two busses which went rolling down on steep slopes (Ganapathy and Hada, 2012). The 1990 cloud burst resulted in a major landslide event which buried 35 families in Geddai village.

Due to heavy rains in the Coonoor and Ketti areas for three days from 8th to 10th November, 2009 over 150 landslides occurred and killing of 42 peoples and also damaging more than 2000 houses. In the past landslides 1978 and 1979, most of the landslides occurred in the tea estates and areas where vegetable crops are cultivated and few houses suffered damage. The only major fatality in 1979 is in Selas where two womens and two childrens were buried alive by a landslide on the slopes of a hill causing a run out of approximately 500 m (Seshagiri et al., 1982).

The landslides in Nilgiris have been investigated in the past and were generally on individual slides (Srinivasan, 1961). When the district was devastated by landslides in the years 1978 and 1979, the Department of Geology and Mining and Geological Survey of India made a detailed joint investigation and documented the landslide events.
and prepared a landslide hazard zonation following a geomorphic approach (Seshagiri et al., 1982). Ramakrishnan et al., (2002), Priyadharshini et al., (2003) have investigated the landslides in Nilgiris using satellite imagery data and GIS technique.

Nilgiris has been historically affected by major landslides, the most recent ones being Runnymede, Hospital, Glenmore, Coonoor and Karadipallam slides (Bhandari 2006; NDMG 2009). Similar phenomenon that occurred in November 1993 in the upper reach of Marappalam of Coonoor taluk has damaged Coonoor to Mettupalayam ghat road of about 1 km. Due to continuous rainfall during December 2001, two massive slides occurred near Pudukadu on the Coonoor to Mettupalayam highway (Nilgiris 2011). Intense rainfall triggered landslides at more than 300 locations which affected road and rail traffic, damaged buildings, caused the death of more than 40 people and left hundreds homeless (Chandrasekaran 2010; Chandrasekaran et al., 2011; GSI 2011). Mettupalayam to Coonoor to Ooty National Highway (NH67), the lifeline of the Nilgiris, was affected by landslides at many places and remained cutoff for a period of 3 months. Nilgiris Mountain Railway (NMR) suffered severe damages, and the railway track was left hanging at many places with the supporting subgrade washed away. In the 27 km length of Mettupalayam to Coonoor track section, about 18,000 m3 of debris had to be removed.

A huge landslide near the spot where the Sispara ghat road passes over Kundah hills, sliced part of Kudikadu hill in 1824, after heavy rains lashed the area for eight days. Harness, Baike and Benza have recorded this landslide, popularly known as Avalanche landslide. The Kotagiri to Mettupalayam road was damaged by a heavy rainstorm in 1881 in that same year landslips in Coonoor Ghat road and many places. A rainfall of 129 cm was recorded in a short period causing disastrous floods during year 1891. In December 1902, 53cm of rain in Kotagiri including 22cm on a single day, brought havoc. In October 1905, 17cm of rain brought in its wake ‘death and damage’ in Coonoor through landslips.
During November 2009, more than 100 major landslides occurred within three days due to extreme rainfall was received in Coonoor, Ooty and Kothagiri regions. The loss of life due to landslide events in Nilgiris was less than 10 during 1978 and 1979 but in the subsequent events the fatality has increased with 36 people killed in 1990, 40 deaths in 1993 and 42 in 2009. Further, landslides in 1978 and 1979 have occurred close to settlements rarely but in the latter events, more houses are being destroyed resulting in increased fatalities. The increase in fatality and damage of houses clearly indicates that people have established their homes in unsafe zones.

Since the fatality and frequency of landslides have increased during the recent years, it has become necessary to identify the areas which are prone to landslides and strengthen the existing structures and exclude such areas from future housing programmes. Landslide hazard zonation map was attempted in the joint investigation of landslide in Nilgiris by Department of Geology and Mining, Govt. of Tamil Nadu and GSI using geomorphic approach based on expert opinion. The study was mainly based on the layers extracted using aerial photographs taken after the landslide event and Survey of India Toposheets which was costly and time consuming. The developments in remote sensing GIS technology have not only made the work of assessing the landslide proneness less expensive and easy but also enables visualisation of areas with different degree of landslide susceptibility in the form of maps.

Presently landslide susceptibility maps are being prepared by several techniques which include geomorphic, probabilistic, Artificial Neural Network methods. The probabilistic methods are more popular (Rowbotham and Dudycha 1998; Rautelal and Lakheraza 2000; Lee and Min 2001; Zhou et al., 2002; Lee and Choi 2003) and the landslide mapping is carried out in large scale selecting macro-watersheds of about 100 km². Such quantitative studies were few in Nilgiris. In the present study it is proposed to select the Coonoor macro-watersheds in the central part of Nilgiris Mountains where several landslide have taken place to prepare a landslide susceptibility zonation map.
3.2 Topography

The entire Nilgiris district is hilly, the height range from 2000 to 2600 m above mean sea level (MSL). They comprise steep near vertical slopes in the southern flanks on the Bhavani valley side and moderately steep slopes in the north towards Moyar valley. Jaiswal (2011) has used a twofold classification of Nilgiri plateau into Doddabetta landform proposed earlier by Parthasaradhi and Vaidhyanathan (1974) and Ootacamund (now called as Uthagamandalam) landform. The Doddabetta landform according to him contains high peaks and rocky escarpments and radial drainage pattern and the Uthagamandalam landform is characterised by gentle landscape, deep soil development and meandering streams. According to GSI (1982) 3 erosional surfaces viz, Doddabetta, Uthagamandalam and Coonoor surfaces were delineated.

The Nilgiris is classified into five plantation surface based on topography (Fig. 3.1) namely, Doddabetta Planation Surface (DPS), Uthagamandalam Planation Surface (UPS), Kothagiri Planation Surface (KPS), Coonoor Planation Surface (CPS) and Gudalur Planation Surface (GPS).

The highest altitude region in Nilgiris is the Doddabetta Planation Surface with altitude is greater than 2300m above MSL. The Doddabetta Planation Surface major part is unoccupied and it consists of reserve forest and raingauge station exists in the area. The rainfall intensity is almost similar that of Uthagamandalam and it is located nearby. The Doddabetta Planation Surface occupies a small area in the central part of nilgiris. Landslides are moderate however the topography is distinguished by the presence of escarpments and the slope is steep, which chiefly due to the presence forest cover.

The elevation of Uthagamandalam Planation Surface is 2200 m above mean sea level (MSL) and it is characterized by gentle slope. The average annual rainfall range of the area is 1100 to 1200 mm. the landslides of the area is moderate to high, since the topography is characterized by rolling and absence of rugged peaks.
The Kothagiri Planation Surface is 2000 m MSL, the topography of the area is very steep and characterized by rugged peaks and it rises immediately from the plains. The average annual rainfall of the area is reported around 1400 mm. the landslide hazards trigger very high in the Kothagiri Planation Surface due the intense rainfall and topography nature.

The altitude of the Coonoor Planation Surface rises to 1700 m above MSL and characterized by the eastern margin is steep. The Coonoor Planation Surface is separated from the Kothagiri Planation Surface by Honnathalai and Jaguntha hill ranges of Doddabetta Planation Surface. The marked uplift along NW-SE direction is brought out in the three dimensional view of the Nilgiri plateau. The annual rainfall of the coonoor area range from 1400 to 1800 mm. The topography of the area is characterized by steep slopes; hence the landslide hazard is very predominant.

The Gudalur Planation Surface is 1000 m MSL and it is located in the western part of Nilgiris. The average annual rainfall of the area is very high and exceeding 2500 mm. The landslide hazards are less due to rugged topography is fewer in nature. The eastern and south-eastern parts of Nilgiris forming the Uthagamandalam Planation Surface, Coonoor Planation Surface and Kothagiri Planation Surface have high population density containing the urban centers of Uthagamandalam, Coonoor, Kothagiri and numerous settlements located all along the Nagapattinam – Gudalur National Highway and hence, landslide hazard severely affect the community.

3.3 Report of the Landslides in Nilgiris

1865: Major Storm was occurred in and around Ooty and Coonoor. Coonoor Railway station was submerged with water upto 5 feet from ground level. In Ooty Lake rose up to top of willow bound and threatened to breach.

1891: Rainstorm caused many landslips at Coonoor Ghat, and cause major damage to the Kotagiri and Metuppalayam road.
1902: 21 inches rainfall (three times the average amount) was received in Coonoor, and also, in Kothagiri 24 inches was received, of which 8.45 inches rainfall received in one night. The new and old Coonoor railway station was blocked for a month and all the traffic of the eastern side of the plateau was thrown upon the Kotagiri that, which was itself in a perilous condition slips having occurred throughout and being serious in six places out of its twenty one miles length.

1905: In Coonoor 6.8 inches of rainfall received within three hours and the Coonoor river and its effluents travel downward due to heavy and imidiate floods, the formers sweeping right over the bridge parapet located near railway station. The railway employee’s families from quarters have been rescued by breaking of backside window with owbars.

1978: In Ooty 323mm of rainfall was recorded of which 243 mm was received during the period 5.00 pm of 4th to 8.00 am of 5th November. Many people’s were die and losses their houses by landslides and drowning. Also, reports received from Kookalthurai, Madithorai, Kallati and Adashola areas of Coonoor taluk for causalities due to landslides.

1979: In 12th of November 1979 started heavy rainfall and maximum amount of rainfall received 114.5 mm at Kodanad. On 13th it was attain maximum of 149.4 mm at Coonoor and 169.9 mm at Kodanad. On the 15th night triggered landslide at Doddacombai and 16th night again there was heavy rain at Coonoor resulting in washing away of one woman and 2 Childrens. The rainfall recorded at 16th night at Coonoor and Kodanad was 145.2 mm and 142.2 mm respectively. On 19th there was major landslide of 100 yards and the width of about 1.00 km in length occurred at Selas of Ketti Village of Coonoor Taluk resulting in filling up of a Valley of 30’ to 50’ sediment. The rainfall was recorded on that day at Kotagiri, Kodanad and Kundah was 90.4 mm, 99.8 mm and 78.0 mm respectively. There was intense rainfall of
71.0 mm at Devala on 21st. On 28.11.79 also there was heavy rainfall recorded around 144.2 mm at Coonoor raingauge station.

1990: The NE Monsoon was heavy and there was a 'cloud burst' results more than 35 families was burried, living at Geddai.

1993: Cloud burst occurred in the upper part of Marappalam in Coonoor Taluk, more than 18 huts at below the road were wiped out in Coonoor MTP that Road for about 1.5 Km. The Road traffic was stopped for more than a fort night. 12 poples die and 15 persons were missing. It is laid that 21 passengers were washed away with two buses. An important highway, sheared stretched of rail road for about 300 m.

1998: Due to continuous rain fall, a big boulder weighing about 20m tonnes felt at Coonoor Mettupalayam main road result the road was closed for traffic, the boulder was removed by blasting and earth slips and traffic was resumed.

2001: Due to heavy rainfall received continously, results two major landslides occurred near pudukadu on the Coonoor and Mettupalayam highway and damaging of two bridges and traffic has been closed. In addition, a closer damage was also happened to the railway track between Coonoor to Mettupalayam.

2006: Continuous heavy rainfall in the Nilgiri Hills, numerous landslides were reported to have occurred at the early hours on 14.11.2006 killing one and three persons were injure. The traffic in NH 67 was closed and blocking of Mountain Rail track between Mettupalayam and Coonoor (nilgiris.nic.in).

2009: More than 100 major landslides were reported within 3 days from 8th to 10th of November, 2009. The event was restricted to Coonoor, Uthagamandalam and Kothagiri taluks results 48 peoples lost their lives and severe damage of houses,
roads and railway lines. The total estimated property losses are worth about Rs.300 crore by the Government report.

The landslides were more in the Barliyar- Coonoor - Kethi sector as the region received heavy rainfall of 378 mm in Barliyar, 899 mm in Coonoor and 1171 mm in Kethi in three days from 8th to 10th November, 2009 while the annual average rainfall is 1210 mm in Coonoor and 1856 mm in the district. These landslides were caused due to excavation of the slope or its toe, deforestation, improper discharging of sewage water from settlements, establishment of settlements in unstable slopes, creation of dumps of waste which facilitated infiltration of water.

3.4 Study Area

The Coonoor macro-watershed investigated in the present study (Fig.3.2) falls in the north-eastern part of Bhavani River Sub-Basin of Tamil Nadu. It lies between Latitudes 11°18'27.42" N - 11°24' 35.426" N and Longitudes 76°41'19" E – 76°53'20" E forming parts of Survey of India Toposheet Nos. 58 A/11/SE, 58 A/15/NW, 58 A/15/SE, & 58 A/15/SW. It covers an area of about 134.9 sq. kms with a maximum length of 22 kms in East – West direction and 12 kms in NE – SW direction. The minimum and maximum altitudes of the watersheds are 340 m and 2600 m respectively above MSL. The macro-watersheds can be divided into four sub-watersheds viz., Upper Coonoor, Upper Katteri, Lower Coonoor and Lower Katteri. The area is selected for study as it is severely affected by landslides. The study area receives rain mainly during southwest and northeast monsoons. Based on State Groundwater Division, PWD, data for Connor station, the watershed receives an average rainfall of 620 mm during the Southwest monsoon from June to August, and the northeast monsoon from October to December record an average rainfall of 280 mm.
Fig. 3.1 Three dimensional model showing the relief of Nilgiris. The western part is characterized by lower relief and on the other hand the eastern and southeastern part is endowed with steeper slopes and higher elevation. UPS – Uthagamandalam Planation Surface; CPS – Coonoor Planation Surface; KPS – Kothagiri Planation Surface; GPS – Gudalur Planation Surface.
3.5 Climate and Rainfall

In Nilgiris, it attains the temperature maximum of 25°C and a minimum of 10°C in summer season. During winter season the maximum temperature is 20°C and the minimum of 0°C. The district receives both south-west monsoon and north-east monsoon as well. In Coonoor located center part of the study area, the raingauge station receives average annual rainfall based on recent 30 years is evaluated as 1,773 mm and pre-monsoon, South-West monsoon and North-East Monsoon seasonal rainfall are obtained as 416, 369 and 988 mm respectively (Evangelin Ramani Sujatha et al., 2017 - conference).
Impounding of water by hydroelectric dams, large scale deforestation, rapid and indiscriminate industrial and agricultural developments bring in an imbalance in the environment, particularly in climate. The district receives both in south-west monsoon (June to August) and north-east monsoon (October to December). The south-west monsoon is more active and brings relatively a large amount of heavy rainfall. Rainfall play significant role for causes of landslide in the Nilgiris.

3.6 Geology

The large number of spurs and branches of the Nilgiris Mountains extending in all directions with narrow crests separating from each other by deep narrow gorges and valleys with high velocity streams carrying run off from adjoining hills and valleys is the characteristic geology of the terrain. The Nilgiri ranges comprise metamorphic rocks which include charnockite, mafic granulites, pyroxenites and magnetite quartzites of Archaean age and are intruded by dolerites during the early Proterozoic. The ghat road provides some opportunity to examine the rocks but well cutting seldom reach bed rock.

Geological mapping of the area is difficult since the thick soil cover preclude. The rock observation in the field only in limited area like Doddabetta, Barliyar, in and around Kambatti and Kaggucci outcrops is noticed. The Survey of India published the geological map of the area shows that major part of the area is occupied by charnockite and gneiss is found in the northern boundary. The dolerite intrusions are noticed in south-eastern part trend towards NE-SW direction and are sub parallel to Bhavani shear. The Supracrustal rocks are found as small enclaves and aluminous laterite and bauxites are found in some places. A brief description of the individual rock formations is given below:

3.6.1 Charnockite

Charnockite forms the country rocks in the Nilgiris ranges. They are hypersthenes-bearing bluish grey rocks formed by metamorphism under granulite facies. It is interbanded with or carries enclaves of supra crustal rocks of divergent composition including mafic granulites, pyroxenites, and banded magnetite quartzites of
metasedimentary origin. The texture of charnockite exhibit granoblastic and the mineral consist of quartz, feldspar, hypersthenes, garnet and hornblende. The essential minerals are Garnet, biotite, apatite and zircon are present as accessory minerals.

P-T conditions of metamorphism based on coexisting garnet and pyroxenes yield temperatures ranging from 730 to 750°C (Raith et al., 1990) at 6 to 10 kbar (Harris et al., 1982; Janardhan et al., 1982). Isotopic data on the charnockites suggest a late-Archaean age (2,600 Ma) for the emplacement of protoliths and the granulite event is dated as 2,500 Ma. Since, the mafic granulites, pyroxenites and magnetite quartzite are present as enclaves they predate the charnockite.

The charnockite with patches of gneiss and schistose rocks are the major geologic formations in this area. The free silica content varies from 50% to 60% and above in the charnockites. The acidic charnockites, which has more than 70% silica content, is found to be of wide spread occurrence in this area. Biotite gneiss is found at lower lands bordering the Nilgiris hills. Lenses of biotite gneiss are found in charnockite. Hornblende and garnet are also identified.

3.6.2 Older Supracrustal rocks

The mafic granulites are classified into two types viz, garnetiferous and non garnetiferous in which the garnetiferous rocks is characterized by separate banding and present as linear enclaves 100 to 200 m long. The garnetiferous has granoblastic texture and the grain size is medium, studded with porphyroblasts of garnet which are up to 1 cm in size and constitute more than 20 percent of the rock. The essential minerals are garnet, plagioclase, clino-pyroxene. These rocks occurring in the foot hills near Mettupalaiyam have been described as plagioclase eclogites. Hence they are formed by high pressure metamorphism. The non garnetiferous varieties are found as linear enclaves of less than 100 m and are also noticed as xenoliths in charnockite. The texture is granulitic in nature with polygonal equant shaped minerals. The essential minerals comprised of dark coloured plagioclase and ortho and clino- pyroxenes are present and
the accessory mineral is Garnet which differs from the garnetiferous type by their smaller grain size.

The pyroxenites occurring in the area are closely associated with the garnetiferous mafic granulites and are essentially composed of clino and orthopyroxene and hence are websterites. They exhibit cumulous texture with polygonal pyroxene grains and secondary development of hornblende is noticed. The magnetite quartzite exhibit banded structure with alternating magnetite rich and quartz rich layers. In addition to quartz and magnetite, they contain accessory amounts of grunerite and hypersthenes.

3.6.3. Dolerite

Dolerite an igneous rocks and no exact dates are available, the rock initially molten and injected as a fluid charnockite and are not affected by the 2.6 Ga metamorphic event, they are considered as Post-Archaean. The rocks are dark coloured compact and two essential minerals are plagioclase and augite with sub-ophitic texture. The chief accessory mineral is Magnetite.

The geological map of the study area (Fig. 3.3) shows that the total area is occupied by charnockite covered with laterite which forms an irregular soil horizon. The rocks are metamorphic origin.
3.7 Geomorphology

Geomorphology plays vital role to control the landslides due to landforms are the resultant products of paleo/recent geological processes. Deep valleys are carved by the stream action as the area receives heavy to very heavy rainfall and resultant to produce undulating landscape in the plateau. A tectonic activity also plays important terrain characteristic exhibit steep scarps and escarpments with occasional barren rock outcrops.

Coonoor Planation Surface rises from 1700 m to 1800 m above MSL and characterized by the eastern and southern part of the area. The land forms comprised with deflection slope, highly dissected plateau, moderately dissected plateau and valley fill. The rivers in the southeastern part have carved deep valleys and escarpments are noticed in the area around Coonoor, Adderley and north of Barliyar. The most important geomorphic feature in the area is the Katteri river valley which is greater than
1,000m deep in the eastern part. The geomorphology map of the study area (Fig.3.4) prepared based on IRS LISS – III satellite image shows that major part of the area forms dissected plateau and deflection slope in which the highly dissected plateau is most extensive landform in the watershed formed due to erosion action of the streams which cut the valley due to the steep gradient. The moderately dissected plateau landforms are located in the western and center part of the study area which are characterized by gentle slope and stream form erosional valleys which are moderately deep. The deflection slope located in the SE and Eastern part of the study area and Valley fills are distributed in western part followed by central part and north eastern part of boundary.

3.8 Drainage

The Nilgiri district is drained by a number of streams originating from the number of peaks available in the district. The major rivers in this district are Bhavani and Moyar. The Bhavani River originated from the south of the district and the moyar river starts from the north of the district. Among the Bhavani river starts in Bhavaniar Betta and flows towards southwest ward direction and move to southwards direcction. The Khuda river drains southern part of the district which, joins Bhavani river in the south. The Moyar river is one of tributaries of Bhavani river which flows in an eastern ward and is flanking the northern ward boundary of the district. The two streams such as Sigur and Pykara are the major streams of Moyar River. Also number of small streams joins this river from north – northwest and south directions. The Katteri is another minor river, which flows eastwards and joins the Bhavani River. The river Kethar halla is flowing in the northern direction. Most of the rivers in Nilgiri plateau have been harnessed by drawing them at several points under the Kunda, mukurthi, Pykara, Chalatti, Puzhe and Moyar Hydro- electric schemes (CGWB 2008). The drainage pattern is predominantly dendritic type and in few places radial and rectangular drainage pattern are observed.
Fig.3.4 Geomorphology map of the study area

Fig.3.5 Drainage map of the study area
Fig. 3.6 Coonoor watershed flow diagram of the study area

However, the study area, map shows (Fig 3.5) the type of drainage is dendritic in rest of the watershed. Radial drainage pattern is found in the southwest part of the area in upper Katteri and lower Katteri watersheds. Both the rivers are V order streams according to Strahler’s stream ordering. Coonoor macro-watershed sub divided into 4 sub watersheds namely, Upper Katteri, Lower Katteri, Upper Coonoor and Lower Coonoor shown in flow diagram (Fig. 3.6).
3.9 Soil Types

The major part of Nilgiris District is covered by lateritic soil. The soil derived from metamorphic rock under the influence of weathering. The cross section of soil may be observed in the road cuts in the uthagamandalam kotagiri road. Soil formation proceeds on stages and which may grade indistinctly from one into another. Sethumadhava Rao (1961) outlined that the depth of clay and silt zone extends from 30 to 48 m in the Hindustan photo Film Factory area. In the Glenmore area, geophysical sounding methods have recorded a depth to rock zone up to 25 m. (Aiyengar, 1964). GSI (1982) have reported that the soil rich in humus is underlain by clay rich soil which preserves the structures found in the source rocks and is hence, is formed in situ and rarely transported during landslides. This horizon has been named as lithomargic clay by GSI (1982). The lithomargic clay, and weathered rocks are resting over by massive rocks occur. The thickness of the humus rich soil and the lithomargic clay horizon determined by drilling is upto 28.40 m which is underlain generally by fractured rocks. Weathered rocks generally form a thin layer and hardly exceed 2.00 meters thickness as seen in some bore holes.

In study area the soil thickness is varied and rock outcrops occupy in western boundary near Tambatti, Nada, Kettipalada and in northern boundary near Indira Nagar, China Bandishola. The thin soil horizon observed in eastern part of the area. The thickness of the soil is moderate in center part of the area and maximum thickness observed around 22.00 m to 26.00 m in north, south and north eastern part of the study area.

The soil map of the study area (Fig. 3.7) has been classified in to clay, clay loam, loam, loamy sand, rock outcrop, sandy clay, sandy clay loam and sandy loam. The soils in study area dominated by sandyclay and loamysand. Further, the zone of weathering is deep in Nilgiri district, especially in areas of rolling topography and gentle slopes. Massive rocks are present in steep slopes and rocks found in gentle slopes in a few road cuttings can, therefore, be taken only as boulders.
3.10 Lineaments

Lineaments are linear feature observed in satellite data. The lineaments are formed due to geological conditions. Lineaments of geomorphic origin may represent a change in terrain elevation, such as valley ridgeline, slope break or influx line (Jordan et al., 2005). Lineaments are associated to geological control due to tectonics disturbances like faulting and shearing and occurrence of dykes. The river flowing course may change from its original direction also represent a tectonic displacement. Lineaments of tectonic origin play vital role in causes of landslides and the landslide hazard zonation as fractured rocks are highly vulnerable to erosion and as a result steep slopes may form. Therefore, lineaments are always considered as a important causative factor as
landslides are more frequent in its close proximity (O’Leary et al., 1976; Chauhan et al.,
2010).

The major fault systems that have resulted in the uplift of Nilgiri plateau are
Bhavani River lineament, along the southern extremity of the Nilgiri plateau which
trends NE-SW and the E-W trending Moyar lineament in the north. In study area the
map shows (Fig.3.8) a major lineament is noticed in E-W direction in the southern and
center part of katteri watershed which extend from Oranali to Buriliyar and Tambatti to
Coonoor respectively. While, Moyar and Bhavani lineaments are located outside the area
of study and major lineaments do not appear to influence the lineament pattern within the area
investigated. The area shows many lineaments which are mainly oriented in NNW-SSE
direction followed by E-W and NE-SW.

Fig .3.8 Lineament map of the study area
3.11 Land use and land cover

Hill range ecosystems are consistently experiencing land use and land cover changes due to natural and manmade activities (Agarwal et al., 2002). Land use and land cover dynamics of the Nilgiri district, characteristic of mountainous terrains. The elevation, typical weather and good rainfall supports evergreen forests called as shoals. Also, the grasslands cover predominantly during the past. In Nilgiris district five hill tribes live on the isolated plateau namely Irulas, Badagas, Todas, Kotas and Kurumbas were using the forest crop for their food. They were hunters, and domesticated buffalos for dairy products, gathered honey, swidden or slash-and-burn cultivation was adopted on a small scale as the land is vast and population was limited it did not affect nature (Venugopal, 2004). There is still dispute about the Badagas origin whether they are native tribes of nilgiris like Todas and Kothas or migrated from Karnataka. Beginning of 14th century the Badagas tribes started the standard agriculture on a small scale.

The land use started to change drastically, since the British peoples set their foot and they were occupied the forest and grassland and stimulate by natural process and are always ready to be occupied once again for cultivation. From the beginning of 19th century, the british colonizers started the developmental activities in Nilgiris results, forest and grassland are transformed drastically in to tea plantation and other historical products. Also, they launched numerous foreign trees, vegetables and fruits grow in suitable climatic conditions. Gradually the trend of decreasing the natural vegetation during post independence period on a accelerated phase. The settlement started to increase due to people’s migration from plains and establishment of small and large scale industries like Hindustan Photo Films, cordite factory, etc., and remarkable growth of tourism industry resulted in widespread urbanization of the province.

The forest cover in the total Nilgiris district is estimated as 60% and within the area investigated natural forests are only 14%. The forests in the fringe areas of these
Reserve forests were systematically converted into forest plantations (10%) and tea estates (6%). Silver oak trees are planted in tea estates to provide shade. The grasslands with rolling topography and gentle slopes were converted cultivable lands where vegetable crops are grown. The area under plantation is the most extensive land use in the area constituting 60% of the area. Settlements in the Nilgiri have expanded particularly in the latter half of 20th Century. However, within the area urbanization is limited and is essentially due to population growth and settlement of outsiders is limited.

The land use and land cover map of the study area (Fig.3.9) classified into 9 categories viz., Built-up land, cropland, forest, forest plantations, land with scrub, plantations, tank bed cultivation, tank bed vegetation and reservoir. Among these, Tea plantations occupied most of the area followed by forest and Built-up land.

Fig.3.9 Land use and Land cover map of the study area