सुलभ प्रतिवेदन
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भारत सरकार

भारतीय भूवैज्ञानिक सर्वेक्षण

GOVERNMENT OF INDIA
GEOLOGICAL SURVEY OF INDIA

कर्नाटक राज्य के कोडागु जिले में भूआकृति संख्या 48P/07, 11 और 12 के कुछ हिस्सों में वृहद पैमाने पर (1: 50,000) भूस्खलन संवेदनशीलता का मानचित्रण ।

(कार्य सत्र कोड संख्या:एल एस एम/एस आर/के और जी/2016/109)

(कार्य सत्र २०१६ - १७)

MACRO-SCALE (1:50,000) LANDSLIDE SUSCEPTIBILITY MAPPING IN PARTS OF TOPOSHEET NO. 48P/07, 11 & 12, KODAGU DISTRICT, KARNATAKA

(FSP CODE NO : LSM/SR/K&G/2016/109)

FIELD SEASON: 2016-17

By

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STATE UNIT: KARNATAKA & GOA/ राज्य इकाई: कर्नाटक एवं गोवा

2017

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अंकुर कुमार श्रीवास्तव, वरिष्ठ भूविज्ञानी

नेहा कुमारी, भूविज्ञानी

सारांश

भूआकृति संख्या 48P / 07, 11 और 12 के कुछ हिस्सों में भूस्खलन संवेदनशीलता का मानचित्रण पर्याप्त सुदूर संवेदन और क्षेत्र आदानों का उपयोग करके 1: 50000 पैमाने पर एक सहज भूस्खलन संवेदनशीलता मानचित्र और स्थानिक (जीआईएस-आधारित) भूस्खलन डेटाबेस तैयार करने के लिए किया गया था। आईआरएस लिश ।।। और बहुआयामी गूगल छवि के दृश्य व्याख्या के माध्यम से आर्क जीआईएस में भूमि उपयोग व भूमि आवरण नक्शा , सड़क, भू-आकृति विज्ञान, ढलान के गठन की सामग्री, जलनिकास, ढाल उतराई, ढाल वक्रता और ढलान पहलू मानचित्र प्री-फील्ड कार्य कलापों के अंतर्गत तैयार किए गए थे।

इस सन्दर्भ में किए गए क्षेत्र अध्ययनों को दो भागों में विभाजित किया जा सकता है - i) क्षेत्र के ढलान बनाने की सामग्री, भू-आकृति, आवरण प्रस्तर की मोटाई, भूमि उपयोग व भूमि आवरण और पूर्व में घटी भूस्खलन की घटनाओं की वस्तुसूची मानचित्रणों का मान्यकरण करना, व उन भूस्खलनों की वस्तुसूची बनाना जिन्हें इस उद्देश्य से सुदूर संवेदन स्रोत तथ्य में नहीं चुना गया क्योंकि उनके छोटे आयाम थे या जो उपग्रह डेटा अधिग्रहण के बाद ही विकसित हुए हैं ।

क्षेत्रीय अध्ययनों के दौरान, 72 भूस्खलनों को देखा और सूचीबद्ध किया गया था जिसमें कुछ नए भूस्खलन और साथ ही कुछ पूर्व में सूचीबद्ध किये गए भूस्खलन शामिल हैं। भूमि उपयोग व भूमि आवरण के संदर्भ में, अध्ययन क्षेत्र में मुख्य रूप से कम ऊंचाई वृक्षारोपण, उच्च ऊंचाई वृक्षारोपण, खेती द्वारा आच्छादित कुछ भाग के साथ काफी घने वनस्पति व मिश्रित घने वनस्पति क्षेत्र हैं। क्षेत्र के कुछ छोटे भाग बंजर और परती भूमि द्वारा आच्छादित हैं । क्षेत्र में, सभी विषयगत मानचित्रों की मान्यता, हाल के व ऐतिहासिक का संग्रह और भू प्रचालिक तथ्य पत्र के अनुसार क्षति की जानकारी एकत्र की गयी थी । क्षेत्र कार्य के तदोपरांत, आँकड़ा प्रतिरूपण और भूस्खलन संवेदनशीलता मानचित्र की तैयारी के अतिरिक्त सभी विषयगत मानचित्रों को अद्यतित किया गया था।

अधिकांशतः भूस्खलन सड़क के किनारे स्थित हैं जहां ढलान को संशोधित किया गया है। इन भूस्खलन के लिए हेतुक कारक मुख्य रूप से मानवजनित हैं, अर्थात ढलानों के आगे का सिरा हटाने से ढलानों की अस्थिरता व ढलानों पर उचित जल निकासी की कमी के कारण शैल संधियों में पानी का रिसाव। अध्ययन क्षेत्र में भूस्खलन के लिए झट प्रतिक्रिया कारक मुख्य रूप से बारिश है, जिसने चट्टानों के रोमकूप के दबाव की वृद्धि में योगदान दिया है जिसके परिणामस्वरूप शैल सामर्थ्य में

कमी और अनुवर्ती विफलता होती है। क्षेत्र के अधिकांश भूस्खलन स्वस्थानी मिट्टी / मखराला मिट्टी / अपक्षयित शैल अधिभार, विशेषकर मडिकेरी - सुल्ल्या, मडिकेरी-कलूर, मडिकेरी -ओंचला, पानाथुर-भागमंदला, तलकावेरी -कोरांगला, विराजपेट - माकुट्टा मार्ग खंडों में मुख्य रूप से सड़कों के किनारे ढलानों की व्यापक कटाई के कारण हुआ है । अध्धयन क्षेत्र में पर्याप्त भूस्खलन / ढलान विफलताओं की कमी के कारण, क्षेत्र की संवेदनशीलता का मूल्यांकन विश्लेषणात्मक पदानुक्रम प्रक्रिया (एएचपी) विधि का उपयोग करके किया गया है जिसमें विशेषज्ञ और ज्ञान-आधारित तकनीकों का उपयोग करते हुए वैयक्तिक कारकों को अलग अलग मूल्यांकन और अंतर-अनुमानक वजन दिया जाता है। विभिन्न भौगोलिक कारक वर्गों व भौगोलिक कारकों के गुणात्मक जोड़ों के महत्व मैट्रिक्स को तैयार करने / निर्णय लेने के लिए स्थानीय विशेषज्ञों और क्षेत्र में भूस्खलन के अध्ययन में लगे भूस्खलन के वैज्ञानिकों से चर्चा और टिप्पणियों के माध्यम से मूल्यांकन प्राप्त करने के पश्चात मात्रात्मक आव्यूह में ज्ञान-आधारित मूल्यांकन / वज़न, एएचपी का उपयोग करके गणितीय तरीके से आसानी से निर्धारित किया जा सकता है ।

अंतिम संवेदनशीलता के नक्शे के अनुसार, 44.5% क्षेत्र कम भूस्खलन संवेदनशीलता क्षेत्र के अंतर्गत आ रहा है जबकि 37.4% क्षेत्र मध्यम संवेदनशीलता क्षेत्र में वर्गीकृत है। लगभग 18.1% क्षेत्र उच्च भूस्खलन संवेदनशीलता क्षेत्र के अंतर्गत आ रहा है। मडिकेरी और उसके आस-पास का क्षेत्र मध्यम से उच्च संवेदनशीलता क्षेत्र के अंतर्गत आता है, यह इस बात की पुष्टि करता है कि अनियंत्रित ढलान संशोधन और अन्य मानवजनित गतिविधियां भूस्खलन की घटनाओं में योगदान करती हैं। अधिकांश उच्च संवेदनशीलता क्षेत्र ढलान ढाल वर्ग 25° से 35° के बीच देखे गए हैं। यह देखा गया है कि ज्यादातर भूस्खलन ढाल ढाल वर्ग 15°- 25° डिग्री (29 स्लाइड) और 25° से 35° (20 स्लाइड्स) में होते हैं। भूमि उपयोग व भूमि आवरण के सन्दर्भ में संशोधित ढलानों पर आबादी वाले क्षेत्र और व्यापक कटौती वाली ढलानों में भूस्खलन के लिए अधिकतम संवेदनशीलता है। भू-आकृति विज्ञान के संदर्भ में अधिकांश भूस्खलन मध्यम विच्छेदित ढलानों (34 भूस्खलन), उसके बाद कम विच्छेदित ढलानों (28 स्लाइड) में पाए जाते हैं । कम विच्छेदित ढलानों में देखे गए भूस्खलनों में से अधिकांश मडिकेरी के आसपास स्थित हैं जहां बड़े पैमाने पर ढलान संशोधन देखा गया था ।

MACRO-SCALE (1:50,000) LANDSLIDE SUSCEPTIBILITY MAPPING IN PARTS OF TOPOSHEET NO. 48P/07, 11 & 12, COORG DISTRICT, KARNATAKA
(FSP CODE NO: LSM/SR/K&G/2016/109)
Field Season: 2016-17

By
Ankur Kumar Srivastava, Senior Geologist
Neha Kumari, Geologist

ABSTRACT

Landslide Susceptibility Mapping in parts of Toposheets no. 48P/07, 48P/11 & 48P/12 was carried out to prepare a seamless landslide susceptibility map and spatial (GIS-based) landslide database on 1:50000 scale using adequate remote sensing and field inputs. Pre-field maps for Landuse/ Landcover (LU/LC), Geomorphology, Slope Forming Material, Regolith thickness, Drainage, Slope gradient, Slope morphometry (Slope, Aspect & Curvature) maps were prepared in Arc GIS through visual interpretation of IRS LISS III data, Carto DEM and multi-temporal Google Imageries.

Field studies undertaken in the present study area can be divided into two parts – i) field validation/updating of pre-field maps landuse/landcover, Geomorphology, Slope Forming Material, Regolith thickness, and landslide inventory map including collection of landslide inventory data for the new/ fresh landslides which were not picked in the RS source data used for this purpose because of their small dimensions or they have only developed after the acquisition of that particular satellite data.

During the field studies, 72 slides were observed and recorded which include some new slides as well as some previously reported slides. In terms of landuse/landcover, the study area predominantly comprises Low height plantations, High height plantations, mixed dense to fairly dense vegetation with some part covered by cultivation. Small patches of the area are also covered by barren and fallow land. In field, all pre-field thematic maps, collection of recent/historic landslides and damage data as per geo-parametric data sheet was recorded and validated. During post field work, data updation of all thematic maps and modelling was carried out for generating Landslide Susceptibility Map of the study area on 1:50,000 scale.

Most of the slides are recorded on modified slope along road sections. The causative factors for these landslide incidences are mainly anthropogenic i.e. destabilisation of slopes by removal of toe, lack of proper drainage at toe part and on the slopes causing seepage of water into the weaker plane like joints and fracture. The triggering factor for slides in the

study area is mainly rainfall which has contributed to increase in the pore pressure of the weathered rock mass resulting in reduction of shear strength and subsequent failure. Most of the slides of the area are occurring in in-situ soil/lateritie/weathered rock as overburden, on slope especially along Madikeri – Sullya, Madikeri – Kalur, Madikeri – Onchala, Panathur – Bhagamandala, Talakaveri – Korangla, Virajpet – Makutta road sections primarily caused due to extensive slope cuttings along roads. As the area lacks adequate no. of landslides/ slope failures, the susceptibility rating of the area was done using Analytical Hierarchy Process (AHP) method wherein ratings and inter-predictor weights are given to individual factors using expert or knowledge driven techniques. This knowledge-driven ratings/ weights in quantitative matrices can easily be determined mathematically using AHP, after preparing/ deciding on the qualitative pairwise importance matrix for different geo factor classes and amongst different geo factors for inter-predictor weights, obtained through discussion and comments received from local experts and landslide scientists engaged in landslide studies in the area. According to the final susceptibility map, about 44.5% area falls under low landslide susceptibility zone while 37.4% area is categorized in moderate susceptibility zone. About 18.1 % area falls under high landslide susceptibility zone. The area in and around Madikeri falls under moderate to high susceptibility zones, this corroborates the fact that uncontrolled slope modification and other anthropogenic activities contribute in landslide occurrence. Most of the high susceptibility zones correspond to slope gradient class between 25°- 35°. It has been observed that most of the slides occur in this slope gradient class 15°-25° (29 slides) and 25°-35° (20 slides). In terms of landuse/landcover the area having settlement on modified slopes and Extensive cut slopes has the maximum susceptibility to landslides. In terms of geomorphology most of the slides have been observed to occur in moderately dissected slopes (34 slides), followed by lowly dissected slopes (28 slides). Most of the slides noted in low dissected slopes are located around Madikeri where large scale slope modification was observed. Total 27 nos. of slides are recorded along Sullya-Medikeri road section (SH-88), 8 nos. of debris slides recorded along Madikeri-Murnad road section, 3 nos. of multiple debris slides are recorded along Madikeri-Onchalla road section, 14 nos. of debris slides recorded along Panatur-Bhagmandala road section, and 8 nos. debris slides are recorded along Madikeri- Abbi- Niduvattu road section of the study area. The slides observed are shallow translational debris slide; majority of slides are old reactivated slides of widening and enlarging in nature. The slides get activated in monsoon season due to water saturation and increased pore water pressure leading to slope failure causing damage to life and property.

MACRO-SCALE (1:50,000) LANDSLIDE SUSCEPTIBILITY MAPPING IN PARTS OF TOPOSHEET NO. 48P/07, 11 & 12, KODAGU DISTRICT, KARNATAKA (FSP CODE NO : LSM/SR/K&G/2016/109)

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I. INTRODUCTION

1.1 Background

With its ever increasing population and large scale encroachment of hilly and forested areas, landslides have become an area for concern in our country. Recent Kedarnath tragedy in 2013 is a prime example of the devastation that landslides can cause. In India, nearly 15% (0.49 million sq. km.) area is landslide-prone which is spread over 1112 Survey of India Topographic map sheets (NDMA 2009). Thus a systematic approach is required to map these areas for landslide susceptibility. A thrust in this activity is imminent to match the pace of infrastructural development in these areas. Accordingly, Geological Survey of India, being the nodal agency in the country for landslide studies launched National Landslide Susceptibility Mapping (NLSM) programme with an aim to produce a seamless landslide susceptibility mapping database across the country. To foster better progress rate and to improve the quality of landslide susceptibility mapping, along with requisite amount of field inputs, NLSM programme proposes to use very high-resolution Remote Sensing data for preparation of its landslide and geofactor database and GIS based landslide-dependent empirical techniques as well as knowledge based techniques (AHP) for data integration and landslide susceptibility modelling. The main purpose of this national programme is to prepare a nation-wide landslide inventory and susceptibility database for easy retrieval, use and updation in future whenever new events and large-scale changes in geo-environmental parameters are encountered.

Coorg (now Kodagu) district in Karnataka state lies in the southern part of Western Ghats with high hills. The district with its distinctive geomorphological, geological, hydrological and meteorological characteristics has long been known for landslides in selected areas during certain months of a year. The topography of the region is sensitive and any changes in the landuse/landcover pattern causes landslides or slope failures affecting the population. Thus, the district along with its scenic beauty and pleasant climatic conditions is also becoming known for natural hazards. Infrastructural development in the form of laying new roads and widening of the existing roads that involve the modification of slopes disturb the equilibrium attained by the nature. Majority of slopes along the high ways pose significant risk dominantly from rainfall-induced slope failures (Janardhana et al., 2016). Heavy rain during monsoon season leads to slope saturation by water that decreases the effective cohesion and generates hydrostatic pressures in the soil profile ultimately resulting in slope failures. Infrastructure development in terms of widening of existing road & construction must progress taking into account the scientific methods of slope treatment to restore and minimise the risk to slope instability.

Under the National Landslide Susceptibility mapping (NLSM) programme of Geological Survey of India (GSI), the following objectives have been prioritised -

(i) To prepare landslide inventory database using high resolution remote sensing data and field inputs,

(ii) To prepare Toposheet-wise (1:50,000 scale) spatial database for geo factors of landslides using as input maps, and

(iii) To prepare landslide susceptibility map using multi-class index overlay method in a GIS platform.

Landslide susceptibility mapping on scale 1:50,000, covering 1317 sq. km area in parts of Kodagu district was carried out under the Annual Programme of Geological Survey of India, Southern Region, vide FSP code no: LSM/SR/KG/2016/109 of Annual programme of GSI for field season 2016-17.

1.2 Study area

The study area lies in SOI toposheets nos. 48P/07, 48P/11 and 48P/12 in parts of Kodagu district, Karnataka and is bounded between latitudes 12°00’00”N and 12°30’00”N and longitudes 75°15’00E” and 75°45’00”E **(PLATE 1)**. The study area is a part of the Kodagu district which was earlier known as Coorg and located in the high precipitation zone with picturesque topography occupying the eastern and western slopes of the Western Ghats. It is bordered by Dakshin Kannad district in the north, Mysore district in the east and Kasargod district of Kerala state on the west and south. The study area is well connected by highways and other main roads. The Bangalore – Mangalore Highway (SH-88) and Mysore-Cannanore Highway (SH-88A) passes through the area. Fairly good network of roads exists connecting taluk headquarters with district headquarters. Madikeri town is well connected with all the important places of the state. It is about 262 km from Bangalore (State Capital), 128 km from Mysore and 130 km from Mangalore. The nearest Railway stations are Hassan and Mysore. Nearest Airport is located at a distance of about 130 km at Mangalore.

1.3 Present work

The present work includes preparation of various thematic layers on 1:50000 scale using Arc GIS 10.2 software and Google Earth imageries. Open Series Maps of the study area were also taken into account while preparing Landuse/Landcover, Road and Location maps. Landslide inventory prepared at headquarters was validated and updated in field. The pre field maps were validated in field and were updated on Arc GIS software at headquarters. The final landslide susceptibility map of the study area was prepared using Analytical Hierarchy Process and then classified into low, moderate and high susceptibility zones. The nature and target of work envisaged for FS: 2016-17 and the achievements are given in **Table 1**.

Table1. Nature, quantum of work and achievements

Nature of Work	Target F.S 2016-17 (sq. km)	Achievements in sq. km
1.Pre field map preparation		
a) Slope forming material map	1317	1317
b)Geomorphology and lineament map	1317	1317
c)Slope morphometry (slope, aspect & curvature) map	1317	1317
d)Landuse/Landcover map	1317	1317
e) Drainage map	1317	1317
f)Regolith depth map	1317	1317
ii)Preparation of landslide inventory map	1317	1317
2.Field based studies		
i)Field checking of all thematic maps	1317	1317
ii)Field validation of landslide inventory and collection of recent and historic landslides	1317	1317
iii) collection of landslide inventory and damage data as per 41 point geo -parametric sheet	1317	1317 (72 Nos. of slides)
3. Post Field studies		
i)Updation of thematic and inventory maps in GIS	1317	1317
ii)Preparation of Landslide susceptibility map in GIS	1317	1317

iii) Validation of landslide susceptibility map at important locations	1317	1317
4.Collection of rainfall data	1317 (Collected for 10 years for seven rain gauge stations)	

1.4 Physiography

The Western Ghats represent an orogenic mountain range with steep escarpments to the West, parallel to the west coast of India. The topography of the area ranges from gently sloping plains in the south eastern part to rugged hilly lands, with elevations ranging from about 600 m to 1682m above msl in the North. The western part of the study area, mostly forms the reserve forest, the prominent being Alletti East, Aletti West, Panathadi, Pattighat and Padinalknad Ghat reserve forests. The terrain in this part is very rugged with steeply sloping conical hills and deep valleys. The hills have a general NW- SE trend. The central, northeastern and eastern parts are undulating plane with isolated hillocks. The study area is marked by ridges with steep slopes, denuded surfaces and sinuous valleys suggesting that considerable period has elapsed during the development of the landforms. The central, southeastern and eastern parts are undulating plane with isolated hillocks. Major drainage is towards west and the area shows dendritic to parallel type of drainage pattern **(PLATE 3)**. The highest elevation point is 1682 m above msl is at Karthakadu Betta (12^{o}18'00"N: 75^{o}33'30"E) in southwestern part. Talakaveri (Brahmagiri), the place from where Kaveri River originates is an important pilgrim and tourist centre. The area receives moderate to heavy rainfall. The Kaveri river flows towards southeast and drains the southern part. Several third order streams drain the rest of the area. The area appears to be more or less stable as far as landslides are concerned barring the anthropogenic activities. The study area is traversed by antecedent river namely Cauvery. The average annual rainfall of Kodagu district is about 4000 mm and the area enjoys tropical climate. The climate is dominated by SW monsoon, starting in June ending in October providing a larger portion of annual precipitation. Rainfall data has been collected for seven rain gauge stations for the past ten years. The details of rainfall and its correlation with the occurrence of slides have been mentioned in **Annexure - III**.

1.5 General geology

The area exposes the rocks belonging to Sargur Group, Peninsular Gneiss-I of PGC and Charnockite Group, which are intruded by granites, pegmatites and dolerite dykes **(PLATE 2)**. (B. R. C. Iyengar, 1952-53; A Damodaran, 1951-52, 1952-53).

Litho-units of Sargur Group include garnet-sillimanite schist, kyanite bearing gneiss and amphibolites. The highly metamorphosed sediments, forming the garnet-sillimanite schist and kyanite gneiss are seen as narrow and discontinuous bands in the biotite gneiss. They are exposed at number of places in the northern part, northwest of Madikeri, southwest of Madikeri, north and east of Bhagamandala. A few small outcrops of kyanite gneiss are seen north of Appangala and east of Tattamane in eastern part. Enclaves of narrow amphibolite bands are seen exposed in the peninsular gneiss. They are seen exposed in the southeastern part and a few amphibolite enclaves are also seen exposed in northeastern part. These narrow bands of amphibolite are trending NW-SE.

PG-I of PGC consists of biotite gneiss and migmatites characterised by compositional banding and are well exposed over a large area. Biotite gneiss is well exposed in the north and eastern part. It is coarse grained, light coloured and comprises quartz, plagioclase and biotite.

Pyroxene granulites and charnockites constitute another major rock suite in the area. The two rock types are not separated in the map of this scale. Accordingly, they are shown together, though by themselves they differ in textural features as well as mineralogical composition. The pyroxene granulite shows invariably a granulitic texture and banding consisting of hornblende, diopside, augite and plagioclase feldspar. The charnockites which are closely interbanded with the granulites are generally light coloured, with medium grained texture.

Around Bettageri and northwest of Kodamburu in the eastern part a granite body is found intrusive into the biotite gneiss. The granite body is about 15 km in length and 2 km in width trending NW-SE. This rock occurs as massive boulders and consists of quartz, feldspar and biotite. A few thin pegmatite veins are noticed at 1.5 km south and 2 km northwest of Napoklu in southeastern part. These pegmatite veins are about 200-500m in length and intrude biotite gneiss. Dykes of dolerite cutting across the general foliation of the gneiss are noticed on the Madikeri-Mangalore road section. They are about 0.5-1 km in length and consist of plagioclase feldspar, augite and few flakes of biotite. Few laterite outcrops are noticed in the eastern and southeastern part. They are mostly confined to the slopes of the Ghats and more so, at the lower levels.

The Charnockite Group of rocks is the most dominant lithounit in the southern and western part of the study area. The Charnockite Group, comprises of charnockite gneiss/pyroxene granulite/hornblende diopside granulite, calc granulite and charnockite. Charnockite gneiss/pyroxene granulite with gneissic structure/granulitic texture is widespread in aerial extent.It is medium to coarse grained and mesocratic to melanocratic consisting pyroxenes, feldspar and biotite. Garnet bearing varieties are also common towards east. Pyroxene granulites occur as concordant or discordant bands within charnockite/charnockite bands either with sharp or gradational contacts. The regional trend of the foliation in biotite gneiss is NW-SE with dip of 50°-60° towards south. All the rock types in the area have been traversed by basic intrusive like dolerite dykes and acid intrusive like pegmatite of palaeoproterozoic age. Laterite outcrop of Cenozoic age have composition varying from aluminous to ferruginous. The ferruginous laterite is rich in iron content occurring in the study area at many places in eastern and southeastern part.They are mainly confined to the slopes of the Ghats at the lower level.

1.6 Methodology

The method to be followed is primarily landslide dependent following a raster-based GIS modelling approach for integration of all selected and weighted thematic maps to prepare 1:50,000 scale landslide susceptibility map but for areas where a-prior knowledge of landslide is missing or scarce and/or insufficient, any one of the following approaches may be adopted as per priority or terrain conditions and/or after due discussion with the local experts/workers.

a) Individual ratings for geofactor classes and weights of geofactors will first be determined based on a pilot study in the adjacent smaller area/ road corridor (preferably within the study area) where well-distributed landslide data are available by using various spatial association techniques. Later such ratings and weights will be used for the entire study area for model integration using the same multiclass index overlay method. In case of availability of similar or research work in adjacent and similar terrain nearby, the ratings and weights developed are used in such work and may also be used after due discussion with the local experts.

b) Individual ratings for geofactor classes and weights of geofactors will be determined using Analytical Hierarchy Process (AHP) after preparing the pair wise qualitative comparison matrix of all factors (Saaty, 1977) after due discussion with local experts and workers.

Methodology adopted can be broadly classified as follows: -

I. Pre-Field Studies

During pre-field period, landslide inventory and different thematic maps are prepared using different source data. The pre-field maps are as follows:

- **Landslide inventory**: Landslide inventory is prepared using old reports, multi temporal google imagery and LISS III/LISS IV data as source data in Arc GIS software **(PLATE - 11).**
- **Slope Morphometry (Slope, Curvature and Aspect) map:** Slope Morphometry (Slope, Curvature and Aspect) pre-field maps are prepared using Carto DEM data (freely available on BHUVAN portal www.portal.bhuvan.nrsc.gov.in) having 30m * 30m resolution as source data in Arc GIS 10.2 software **(PLATE-4, PLATE-5, PLATE 6).**
- **Drainage map:** Drainage pre-field maps are prepared using CARTO DEM data (freely available on BHUVAN portal www.portal.bhuvan.nrsc.gov.in) having 30m * 30m resolution as source data in Arc GIS software **(PLATE-3**).
- **Land Use Land Cover map (LULC):** Land Use Land Cover (LULC) pre-field map is prepared using multi temporal google imagery and Arc GIS base map as source data in Arc GIS 10.2 software **(PLATE -7**).
- **Geomorphology map:** Geomorphology pre-field map is prepared using multi temporal google imagery, Arc GIS base map and 1:50,000 scale NGLM legacy map as source data in Arc GIS 10.2 software **(PLATE -8**).
- **Slope Forming Material map (SFM):** Slope Forming Material (SFM) pre-field map is prepared using multi temporal google imagery, Arc – GIS base map, 1:50000 scale geological legacy map and proxies from LULC and geomorphology maps as source data in Arc – GIS 10.2 software **(PLATE -9**).
- **Regolith Thickness map:** Regolith Thickness pre-field map is prepared using multi temporal google imagery, proxies from geomorphology map and slope map as source data in Arc GIS 10.2 software **(PLATE -10**).

II. Field Based Studies

During the field validation period, all the pre-field maps are validated in the field by visiting all the assessable locations and noting the modifications. The landslide points from pre-field landslide inventory are also checked and if any new slides are encountered in the field the existing landslide inventory is updated.

III. Post-Field Studies

After the field validations are done, all the thematic maps are updated as per field inputs and finalised. The landslide inventory is also updated as per field inputs. Once all the thematic maps are finalised and landslide inventory is updated, heuristic (knowledge driven) techniques are adopted for modelling and generation of final landslide susceptibility map of the area. For modelling using heuristic (knowledge driven) techniques, individual ratings for geofactor classes and weights of geofactors will be determined using Analytical Hierarchy Process (AHP) after preparing the pair wise qualitative comparison matrix of all factors (Saaty, 1977) after due discussion with local experts and workers.

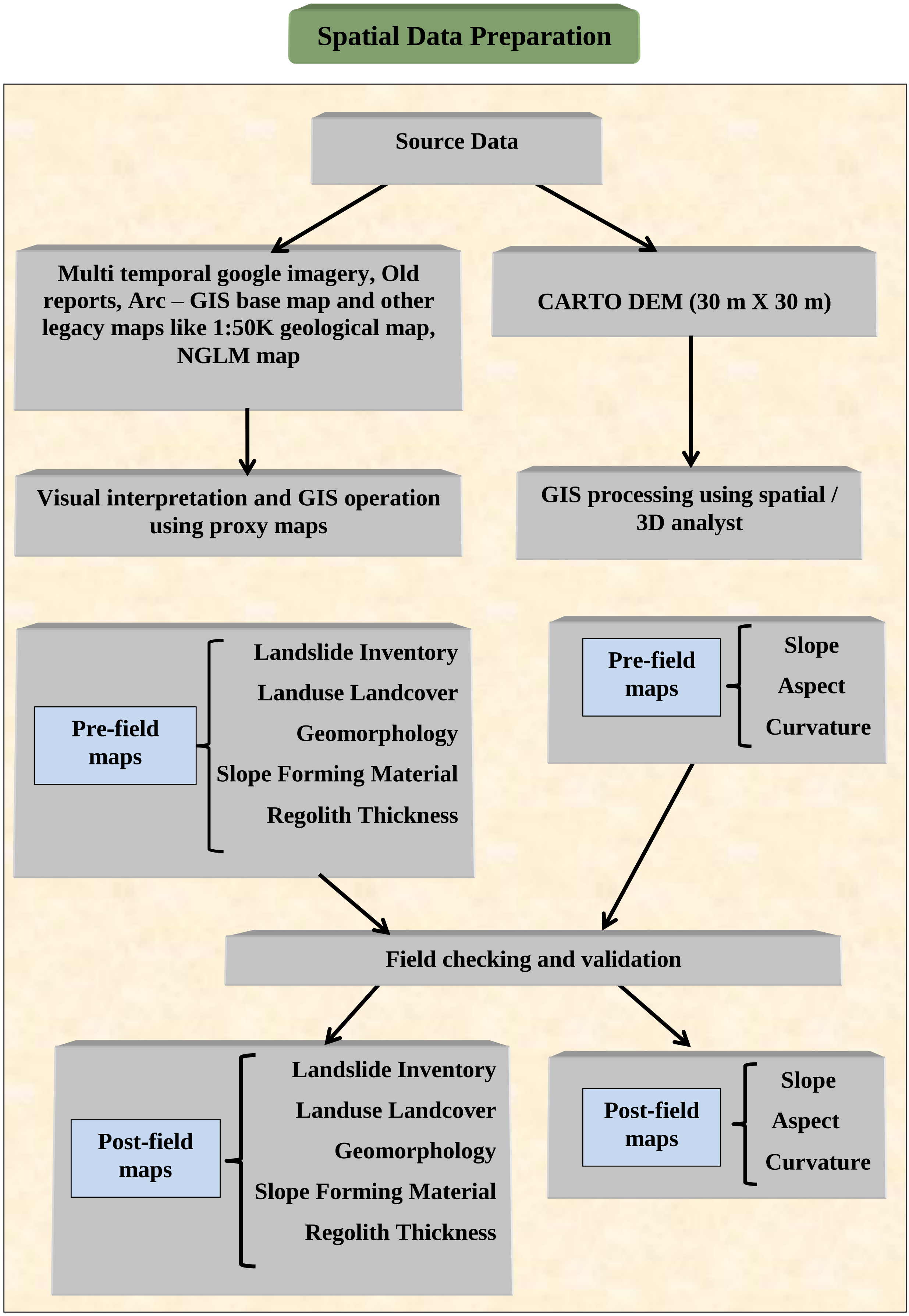
- Heuristic (knowledge driven) technique modelling requires fixation of individual ratings for geofactor classes and weights of geofactors for the entire area. So, these initial ratings are fixed with the knowledge of terrain and with discussion with local experts for Analytical Hierarchy Process (AHP).

- A total of eight factor maps, viz., Slope, Aspect, Curvature and Drainage (derived from 30 m resolution CARTO DEM). Geomorphology and Landuse/Landcover (prepared using multi-temporal Google Earth imageries and SPOT images as base maps in ESRI ArcGIS 10.2), Slope Forming Material and Regolith Thickness (through field-based studies and GSI Geological map) were prepared for susceptibility analysis. Besides these maps, Landslide Inventory maps were prepared using old inventory data from reports/ notes/ archives of GSI and new landslides augmented in the field.

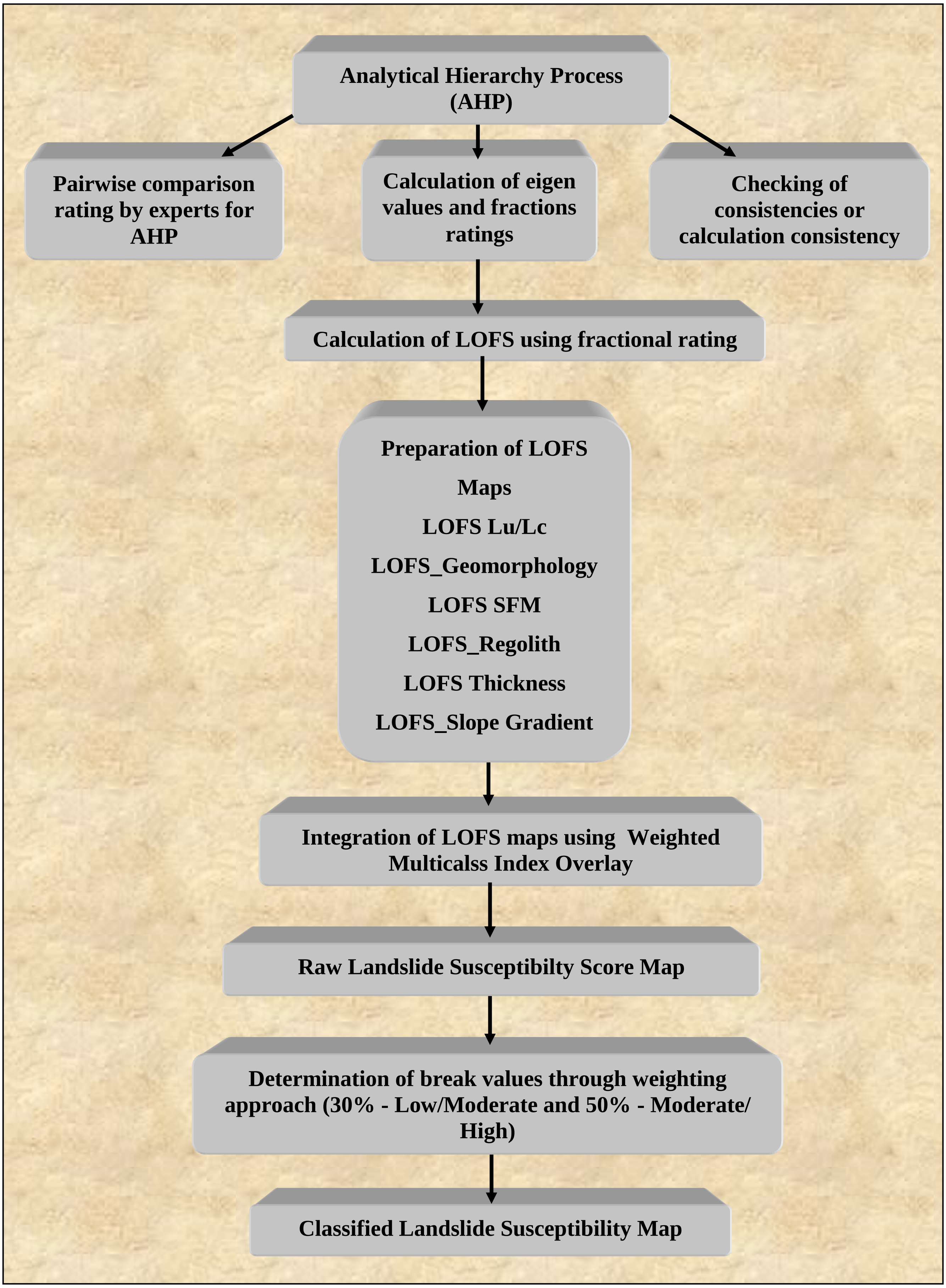
- All the above eight maps were used for assessment of factor class ratings. However, only six thematic maps (except aspect and drainage) were considered for validation of Landslide Susceptibility Map (LSM) of the study area, due to the absence of identified factor classes in a particular map.

- Once all the ratings for geofactor classes and weights of geofactors are fixed, Landslide Occurrence Favourability Score (LOFS) is calculated using pair wise comparison matrix and fraction rating in microsoft excel software.
- After calculation of LOFS for all the geofactor classes LOFS maps of the geofactors are prepared using Arc GIS software.
- Once all the LOFS maps are prepared, raw landslide susceptibility score map is prepared using weighted multi class index overlay method in Arc GIS software.
- After raw landslide susceptibility score map is prepared classified landslide susceptibility map is prepared and determination of break values are done through weighing approach (30% is the boundary between low to moderate susceptibility and 50% is the boundary between moderate to high susceptibility).

Figure –1: Flow diagram showing process of Landslide Susceptibility Mapping



Data Modelling



1.8 Acknowledgements

The authors express their deep sense of gratitude to Shri B. D. Thappa, ADG and HOD, SRO for providing technical and logistic support. It is a genuine pleasure to thank Shri R. K. Agarwal, RMH - IV for his constant monitoring of the projects and for all the technical help. The authors express their sincere gratitude to Shri C. G. Hemantha Kumar, and Shri M. A. Kareem, Dy. Director Generals, State Unit: Karnataka and Goa for their able support and guidance.

The authors are also thankful to Smt. Neeharika Jha Director (TC) for her support. The authors are grateful to Shri J. Srihari, Director and supervisory officer for Project: NLSM, State Unit: Karnataka & Goa, GSI, Bangalore for his supervision and help in tackling our infrastructural problems as well as his guidance in field.

The authors express their deep gratitude to Dr. Saibal Ghosh and Dr. Pankaj Jaiswal, Directors, GHRM Cell, and all other geologists in GHRM cell, CHQ, Kolkata for their efficient guidance, technical help and persistent motivation during pre-field, field and post field work without which the work would not have been completed successfully. Sincere gratitude is due to everyone involved in this project, directly or indirectly, without whom the project would not have been completed so smoothly.

I. PREVIOUS WORK ON LANDSLIDE STUDIES

Landslides and slope instabilities are major hazards to humans often causing economic losses, property damages and high maintenance costs, as well as injuries or fatalities. They can occur in natural slopes or man-modified slopes, and are triggered by various agents like rainfall, earthquakes, stream undercuts or excavations. Under natural slope conditions, the occurrence of landslides is mainly due to the favourable geo-environmental factors aided by rainfall or earthquakes. On the other hand, in man modified slopes, the aging of slopes constructed for major transportation systems and excavations are the added triggering factors along with the factors responsible for landslides in the natural slopes. Thus, it brings more challenge to deal with man modified slopes for landslide susceptibility mapping.

In Karnataka, the landslide studies are mainly focused in the Western Ghats region. The Western Ghats extend from Coorg (now Kodagu) District in the South to Uttar Kannada district in the north in Karnataka state covering an area of about 27855.45 sq. km Out of the approximately 34511 sq. km area of Karnataka and Goa, occupied by the Western Ghats the hill area having slopes higher than 10 degrees and vulnerable to mass movements constitutes about 8439 sq. km. Several Macro scale landslide susceptibility studies and preparation of landslide inventories have been carried out along NH and SH road corridors in Karnataka and Goa states in the past decade. In Karnataka, landslides are mainly cut slope failures primarily consisting of debris and sometimes rock and are mostly located along National Highways (NH-13, 17, 48 and 206) and State Highways (SH-1, 27, 48, 50, 64, 66, 69, 88, 89, 90, 93 and 95). In Goa region, landslides are mainly cut slope failures consisting of rock as well as earth/ debris, and are mostly located along National Highways (NH-4A and 17A), State Highways (SH-1, 3 and 4) and Konkan Railroad.

Landslide studies in the area have been carried out only along transportation corridors (NH & SH) in the Western Ghats. Temporal data for these slides is not available as far as the study area is concerned. Only some newspaper reports about landslides in the year 2006 and 2013 could be obtained. Landslides in the study area generally occur frequently from untreated cut slopes. These are usually small in size but pose considerable risk to life and property. Several landslides are reported along roads (Highways) every year during the monsoons indicating that the triggering factor for these slides may be rainfall besides anthropogenic activities

Previous works on landslides in the area include:

Microscale landslide studies were carried out on Biligeri Landslide, Coorg district, Karnataka by Mishra and Dharuman, 2010. On 27 July 2005, due incessant rain for 11 days in Somwarpet taluk, Coorg district, 200 m long ground crack was developed along the S10°W facing slope of hill trending ENE-WSW near Basaveswara temple, Biligeri village. The landslide complex was mapped between 2006 and 2007 on scale 1:1000, covering 0.10 sq. km area (Fig. 5.9), with aim to assess the nature, causes and triggering mechanism of the slide on the slope facing S10ºW in the ENE-WSW trending hill near Basaveshwara temple. The recommendations include providing proper drainage to the water accumulated at the slope, construction of retaining wall, providing inclined pile at the toe and vacating the slide zone during monsoon.

"Landslide susceptibility mapping of Madikere Town and its surrounding, Coorg district, Karnataka" by Mishra et al, 2010 in which mapping was done along road corridors with 1 km buffer on both sides of the road. The landslide susceptibility mapping of Madikere Town and its surrounding in Coorg district was carried out covering 85 sq. km area on a macro-scale (1:25,000), in parts of Toposheet: 48P/11/NE and 48P/15/NW. The majority of slides were found to be debris slumps and earth slumps mainly due to toe cutting of the slope for making road. The area was classified as low, moderate and highly susceptible. The recommendations include construction of drainage system on the slope to reduce the pore pressure, construction of retaining wall, stone pitching and gabions, biotechnical measure of slope protection and geometrical modification of slope by grading and benching.

"Landslide susceptibility mapping along Virajpet – Madikere – Sulya road corridor, Coorg district, Karnataka" was carried out by K.V. Maruthi and K.V.Chandran, 2013. Landslide susceptibility mapping of the road corridors has been carried out in GIS according to the methodology prescribed by Bureau of India Standards IS 14496 (Part 2): 1998, modified by Geological Survey of India. The recommendations suggested include geometrical modification of the slope by grading by bench, bio-technical measures of slope protection and proper drainage.

As per the landslide inventory along National Highway & State Highway of Ghat Roads in Coorg, Dakshina Kannada, Udupi, Shimoga And Chikmagalur Districts, Karnataka" by K. V. Maruthi and K. V. Chandran., 2013, majority of the slides seem to have occurred due to anthropogenic causes and triggered by heavy rainfall. The recommendations include proper drainage as the drainage is seen blocked or absent in around 60% of the affected areas. The water from uphill slope needs to be diverted in order to minimize sliding by providing contour drainage at the crown part & insertion of horizontal perforated pipes into the slopes which will act as weep-holes in the vertical slopes, thereby reducing the pore water pressure by draining out the excess water. This has to be given at appropriate intervals and lined drainage at the toe part are suggested. Retaining structures like retaining wall, stone pitching are recommended as per the site condition. Bio geotechnical measures of slope protection like plantation of Vetiver grass along the slope will reinforce most of the slides.

Besides these, post hazard studies have been carried out in the area whenever there have been reports of any landslide event. These includes July 2013 Landslide Event around Madikeri, Coorg district, Karnataka, when several landslides, ground subsidence and cracks were reported around Madikeri, Coorg district. Ground cracks, about 10-15 cm wide and extending for about 600-700 m. were observed on 21 July 2013 at the houses in Mannageri village located in Toposheet: 48P/11. The cracks are mainly caused due to increase in pore water pressure due to heavy infiltration of rainwater. A landslide was reported along SH-88 between Madikeri-Sampaje on 21 July 2013 (Lat.12º25′58.7″N: Long.75º40′17.8″E; Toposheet no. 48P/11). Unplanned expansion of habitation along with modified land use pattern have disturbed the natural equilibrium of the area have also contributed in the occurrence of such events. Removal of loose and hanging boulders, slope gradation and proper drainage at the toe as well as at the top were recommended as corrective measures.

Some historical landslide data pertaining to the study area is given in table 3.

Table -3 Details of historical landslides in the study area.

Field Season	Location	Toposheet no	Type of slide	Width (m)	Length(m)	Depth(m)	History	Slope condition	Trigger
2007-08	SH-88	48P11	Debris slide	30	20	2	New	Slope cut	High rain fall
2007-08	SH-88	48P11	Debris slide	60	9	2	New	Slope cut	High rain fall
2007-08	SH-88	48P11	Debris slump	23	8	2	New	Slope cut	High rain fall
2007-08	SH-88	48P11	Debris slump	29	10	1	New	Slope cut	High rain fall
2007-08	SH-88	48P11	Debris slide	10	12	2	New	Slope cut	High rain fall
2007-08	SH-88	48P11	Debris slump	15	21	1	New	Slope cut	High rain fall
2007-08	SH-88	48P11	Debris slide	12	7	2	New	Slope cut	High rain fall
2007-08	SH-88	48P11	Debris slump	10	5	0.5	New	Slope cut	High rain fall
2007-08	SH-88	48P11	Debris slump	12	30	1	New	Slope cut	High rain fall

2007-08	SH-88	48P11	Debris slump	10	12	1	Old and reactivated	Slope cut	High rain fall
2007-08	SH-88	48P11	Debris slide	10	38	1	New	Slope cut	High rain fall
2007-08	SH-88	48P11	Debris slide	10	9		New	Slope cut	High rain fall
2007-08	SH-88	48P11	Debris slide	10			New	Slope cut	High rain fall
2007-08	SH-88	48P11	Debris slide	6		1	New	Slope cut	High rain fall
2007-08	SH-88	48P11	Debris slide	20	7.5	1	New	Slope cut	High rain fall
2007-08	SH-88	48P11	Debris slump	20	7	1	New	Slope cut	High rain fall
2007-08	SH-88	48P11	Debris slide	20	7	1	New	Slope cut	High rain fall
2007-08	SH-88	48P11	Debris slide	20	50	2	New	Slope cut	High rain fall
2007-08	SH-88	48P11	Debris slump	14	10	0.5	New	Slope cut	High rain fall
2007-08	SH-88	48P11	Earth slump	10	5		New	Slope cut	High rain fall
2007-08	SH-88	48P11	Debris slide	25	20	5	New	Slope cut	High rain fall
2007-08	SH-88	48P11	Debris slide	15	10	2	New	Slope cut	High rain fall
2007-08	SH-88	48P11	Debris slide	23	10	1	New	Slope cut	High rain fall
2007-08	SH-88	48P11	Debris slide	25	20	3	Old	Slope cut	High rain fall
2007-08	SH-88	48P11	Rock fall	21.5	12	1	Old	Slope cut	High rain fall
2007-08	SH-88	48P11	Debris slump	25	15	2	Old	Slope cut	High rain fall
2007-08	SH-88	48P11	Debris slump	25	7		Old	Slope cut	High rain fall
2007-08	SH-88	48P11	Debris slide	10	12	1	Old	Slope cut	High rain fall
2007-08	SH-88	48P/12	Debris slide	10	7		Old and reactivated	Slope cut	High rain fall
2007-08	SH-88	48P11	Debris slide	17	10	2	Old	Natural but unstable	High rain fall
2008-09	2-3 km from Jodpal towards suliya, on SH-88	48P11	Debris slump	10	8	0.5	New	Slope cut	High rain fall
2008-09	Madikere-suliya road,SH-88	48P11	Debris slump	8	14	0.5	New	Slope cut	High rain fall
2008-09	Near Glencoorg estate, Madikere-suliya road,SH-88	48P11	Complex slide(half debris half rock)	18	26	1.5	New	Slope cut	High rain fall
2008-09	Near Glencoorg estate, Madikere-suliya road,SH-88	48P11	Debris slump	12	12	1	New	Slope cut	High rain fall

2008-09	Near big curve of Glencoorg estate, Madikere-suliya road,SH-88	48P11	Debris slump	18	60	1	New	Slope cut	High rain fall
2008-09	50 mts from slide no KA-179,Madikere-suliya road,SH-88	48P11	Debris slump	12	25	1	Old and reactivated	Slope cut	High rain fall
2008-09	200 mts from slide no KA-180 Madikere-suliya road,SH-88	48P11	Debris slump	12	18	1	Old	Slope cut	High rain fall
2008-09	50 mts from slide no KA-181,Madikere-suliya road,SH-88	48P11	Debris slide	11	15	1	Old	Slope cut	High rain fall
2008-09	180mts from slide no KA-182,Madikere-suliya road,SH-88	48P11	Debris slide	11	11	1	Old	Slope cut	High rain fall
2008-09	Madikere-suliya road,SH-88	48P11	Debris slide	12	28	1	Old and reactivated	Slope cut	High rain fall
2008-09	7 km from sampaje towards madikere,Madikere-suliya road,SH-88	48P11	Debris slide	10	18	1	Old	Slope cut	High rain fall
2008-09	6 km from sampaje towards madikere,Madikere-suliya road,SH-88	48P11	Debris slide	10	17	0.5	Old	Slope cut	High rain fall
2008-09	5.5 km from sampaje towards madikere,Madikere-suliya road,SH-88	48P11	Debris slump	7	15	1	Old	Slope cut	High rain fall
2008-09	4.5 km from sampaje towards madikere,Madikere-suliya road,SH-88	48P11	Debris slump	13	20	1	Old	Slope cut	High rain fall
2008-09	4.0 km from sampaje towards madikere,Madikere-suliya road,SH-88	48P11	Debris slump	13	30	1	New	Slope cut	High rain fall
2008-09	250 mts from Madikere towards virajpet, on Madikere-Virajpeth, SH-27	48P11	Debris slump	5.7	25	0.5	New	Slope cut	High rain fall
2008-09	100 mts from Madikere towards virajpet, on Madikere-Virajpeth, SH-27	48P11	Debris slump	15	20	1.5	New	Slope cut	High rain fall
2008-09	550 mts from Madikere towards virajpet, on Madikere-Virajpeth, SH-27	48P11	Debris slide	142	15	2	New	Natural but unstable	High rain fall

2008-09	600 mts from Madikere towards virajpet, on Madikere-Virajpeth, SH-27	48P11	Debris slump	12	7	1	New	Slope cut	High rain fall
2008-09	600 mts from Madikere towards virajpet, on Madikere-Virajpeth, SH-27	48P11	Debris slump	16	15	1	New	Slope cut	High rain fall
2008-09	600 mts from Madikere towards virajpet, on Madikere-Virajpeth, SH-27	48P11	Debris slump	25	25	3	New	Slope cut	High rain fall
2008-09	2 km from Madikere, 24 km towarrds Virajpet,on Madikere-Virajpeth, SH-27	48P11	Debris slide	17	26	2	New	Slope cut	High rain fall
2008-09	2.2 km from Madikere, 23.8 km towarrds Virajpet,on Madikere-Virajpeth, SH-27	48P11	Debris slide	15	30	2	Old and reactivate d	Slope cut	High rain fall
2008-09	On Madikere-Virajpeth, SH-27	48P11	Debris slide	10	48	1	New	Slope cut	High rain fall
2008-09	Madikere-Virajpeth, SH-27	48P11	Debris slide	15	5	1	New	Slope cut	High rain fall
2008-09	Madikere-Virajpeth, SH-27	48P11	Debris slide	8	20	1	Old	Slope cut	High rain fall
2009-10	Mangalevi Nagar in Maikere town	48P11	Debris slide	10	8	1	Old	Natural but unstable	High rain fall
2009-10	Mangalevi Nagar in Maikere town	48P11	Debris slide	30	8	2	Old	Natural but unstable	High rain fall
2009-10	Mangalevi Nagar in Maikere town	48P11	Debris slide	30	8	2	Old	Natural but unstable	High rain fall
2009-10	Mangalevi Nagar in Maikere town	48P11	Debris slide	30	8	2	Old	Natural but unstable	High rain fall
2009-10	Mangalevi Nagar in Maikere town	48P11	Debris slide	32	9	2	Old	Natural but unstable	High rain fall
2009-10	Mangalevi Nagar in Maikere town	48P11	Debris slide	30	9	2	Old	Natural but unstable	High rain fall
2009-10	sloping depression(nala section) at Jyothinagar.	48P11	Debris slide	12	8	2	Old	Natural but unstable	High rain fall
2009-10	Madikere Town	48P11	Debris slide	8	16	0	New	Slope cut	High rain fall
2009-10	Madikere Town	48P11	Debris slide	7	8	1	New	Slope cut	High rain fall
2009-10	Madikere Town	48P11	Debris slide	7	10	1	New	Slope cut	High rain fall
2009-10	Indiranagar Madikere town	48P11	Debris slump	6	6.4	0.5	New	Natural but unstable	High rain fall
2009-10	Indiranagar Madikere town	48P11	Debris slump	10	8	0.5	Old	Natural but unstable	High rain fall
2009-10	Indiranagar Madikere town	48P11	Debris slump	5	9	0.5	Old	Natural but unstable	High rain fall

2009-10	Indiranagar Madikere town	48P11	Debris slide	20	18	2	New	Natural but unstable	High rain fall
2009-10	500 m from Madikeri town	48P11	Debris slump	10	11	0.5	New	Slope cut	High rain fall
2009-10	On Madiker-Abbe falls road	48P11	Debris slump	12	25	0.5	New	Slope cut	High rain fall
2009-10	On Madiker-Abbe falls road	48P11	Debris slump	15	14	1	Old and reactivate d	Slope cut	High rain fall
2009-10	On madiker-Galibeedu road	48P11	Debris slump	18	15	1	New	Slope cut	High rain fall
2009-10	50 m before abbefalls cross road	48P11	Debris slump	10	8	0.5	New	Slope cut	High rain fall
2009-10	200 m from slide no KA-328	48P11	Debris slump	25	14	3	New	Slope cut	High rain fall
2009-10	500 m from slide no KA-329	48P11	Debris slide	10	25	0.5	New	Slope cut	High rain fall
2009-10	near slide no KA-330	48P11	Debris slide	8	11	0.5	New	Slope cut	High rain fall
2009-10	Madikere-Baghmandala road	48P11	Debris slide	22	15	1	New	Slope cut	High rain fall
2009-10	Madikere-Baghmandala road	48P11	Debris slide	8.5	31	0.5	Old and reactivate d	Slope cut	High rain fall
2009-10	Baghmandala-Karike road, 2km from Baghmandala towards Karike	48P11	Debris slide	11	18	0.5	Old	Slope cut	High rain fall
2009-10	Baghmandala-Karike road, 500 m from slide no KA-336 towards Karike	48P11	Debris slide	14	22	0.5	Old	Slope cut	High rain fall
2009-10	Baghmandala-Karike road, 300 m from slide no KA-337 towards Karike	48P11	Debris slide	26	30	1	New	Slope cut	High rain fall
2009-10	Baghmandala-Karike road, 50 m from slide no KA-338 towards Karike	48P11	Debris slump	12	17	0.5	Old	Slope cut	High rain fall
2009-10	Baghmandala-Karike road, 500 m from slide no KA-339 towards Karike	48P11	Debris slide	11	30	0.5	Old	Slope cut	High rain fall
2009-10	Baghmandala-Karike road	48P11	Debris slump	11	34	0.5	New	Slope cut	High rain fall
2009-10	Baghmandala-Karike road	48P11	Earth slump	10	15	1	New	Slope cut	High rain fall
2009-10	Baghmandala-Karike road	48P11	Debris slump	10	28	0.5	Old	Slope cut	High rain fall
2009-10	Baghmandala-Karike road	48P07	Earth slump	11	13	1	Old and reactivate d	Slope cut	High rain fall
2009-10	Baghmandala-Karike road	48P07	Debris slump	13.5	12	0.5	New	Slope cut	High rain fall
2009-10	Baghmandala-Karike road	48P07	Earth slump	9	13	0.5	New	Slope cut	High rain fall

2009-10	Baghmandala-Karike road	48P07	Earth slump	12	30	1	New	Slope cut	High rain fall
2009-10	Baghmandala-Karike road	48P07	Debris slump	8.5	15	0.5	New	Slope cut	High rain fall
2009-10	Baghmandala-Karike road, 800 m from slide no KA-348 towards Karike	48P07	Debris slide	15	75	1	New	Slope cut	High rain fall
2009-10	Baghmandala-Karike road, 500 m from slide no KA-349 towards Karike	48P07	Debris slump	15	30	1	New	Slope cut	High rain fall
2009-10	Baghmandala-Karike road, 20 m from slide no KA-350 towards Karike	48P07	Earth slump	8	13	0.5	New	Slope cut	High rain fall
2009-10	Baghmandala-Karike road, 500 m from slide no KA-351towards Karike	48P07	Earth slump	9	18	0.5	Old	Slope cut	High rain fall
2009-10	Baghmandala-Karike road, 20 m from slide no KA-352 towards Karike	48P07	Debris slump	9	19	0.5	New	Slope cut	High rain fall
2009-10	Baghmandala-Karike road	48P07	Debris slide	35	12	1.5	Old	Slope cut	High rain fall
2009-10	Baghmandala-Karike road	48P07	Composite (Half debris half Rock)	7	12	1	New	Slope cut	High rain fall
2009-10	Baghmandala-Karike road, 100 m from slide no KA-355 towards Karike	48P07	Debris slide	14	22	1	Old	Slope cut	High rain fall
2009-10	Baghmandala-Karike road near 10 KM mile stone towards Karike	48P07	Debris slump	12	21	1	Old	Slope cut	High rain fall
2009-10	Baghmandala-Karike road, 600 m from slide no KA-357 towards Karike	48P07	Debris slump	12	18	0.5	New	Slope cut	High rain fall
2009-10	Baghmandala-Karike road, 30 m from slide no KA-358 towards Karike	48P07	Debris slide	30	15	1	New	Slope cut	High rain fall
2009-10	Baghmandala-Karike road,1 km from slide no KA-359 towards Karike	48P07	Debris slide	22	24	1	New	Slope cut	High rain fall
2009-10	Baghmandala-Karike road, 500 m from slide no KA-360 towards Karike.	48P07	Debris slide	12	17	1	New	Slope cut	High rain fall
2009-10	Baghmandala-Karike road near 11 KM mile stone towards Karike.	48P07	Debris slide	22	31	1.5	New	Slope cut	High rain fall

2009-10	On Baghmandala-Karike road, 50 m from slide no KA-362 towards Karike.	48P07	Debris slide	13	18	1	New	Slope cut	High rain fall
2009-10	Baghmandala-Karike road, 20 m from slide no KA-363 towards Karike.	48P07	Debris slide	45	30	1.5	New	Slope cut	High rain fall
2009-10	Baghmandala-Karike road, 250 m from slide no KA-364 towards Karike.	48P07	Debris slump	19	32	1	New	Slope cut	High rain fall
2009-10	Baghmandala-Karike road, 800 m from slide no KA-365 towards Karike.	48P07	Debris slide	29	35	1	New	Slope cut	High rain fall
2009-10	Baghmandala-Karike road, 1 km from slide no KA-366 towards Karike.	48P07	Composite (Half debris half Rock)	28	32	1	New	Slope cut	High rain fall
2009-10	Baghmandala-Karike road, 2 km from slide no KA-367towards Karike.	48P07	Debris slide	16	40	1	New	Slope cut	High rain fall
2009-10	Baghmandala-Karike road, 800 m from slide no KA-366 towards Karike.	48P07	Debris slide	30	29	1	New	Slope cut	High rain fall
2009-10	Baghmandala Talcauvery road	48P11	Debris slump	12	18	0.5	New	Slope cut	High rain fall
2009-10	Baghmandala Talcauvery road	48P07	Debris slide	30	42	1.5	New	Slope cut	High rain fall
2009-10	Baghmandala Talcauvery road	48P11	Debris slide	9	26	0.5	New	Slope cut	High rain fall
2009-10	Baghmandala Talcauvery road	48P11	Debris slide	7	20	0.5	New	Slope cut	High rain fall
2009-10	Baghmandala Talcauvery road	48P11	Debris slide	38	14	2	New	Slope cut	High rain fall
2009-10	Baghmandala-Talcauvery road	48P11	New	26	2	35	soil	Slope cut	High rain fall

II. LANDSLIDE INVENTORY

Landslide inventories form an essential basis for landslide susceptibility, hazard and risk analysis. Landslide inventories that span a substantial period of time are one of the key requirements for landslide studies (Van Westen et al. 2008). The generation of a landslide inventory is a tedious work as landslides occur individually and have to be identified, mapped and inventoried. Landslide inventories contain basic information about landslides such as location, classification, morphology, volume, run-out distance, activity and date of occurrence/activity etc. and can be prepared through various methods such as detailed geomorphologic study, mapping from remote sensing data and topographic maps, historical archive studies and interviews. Each data source used to construct the new landslide inventory has its own uncertainties and limitations and therefore the details captured for each landslide entry vary in completeness and scientific content. In this study, satellite images and historical records are used as the main source for obtaining a multi-temporal landslide inventory.

3.1 Data Source: Landslides leave discernible signs on slopes, most of which can be recognized, classified and mapped in the field or from photo-interpretation (Varnes, 1978). These signatures are mostly visible as morphological changes such as changes in slope type, breaks in slopes, hummocky surfaces, etc. These morphological signs are interpreted here to determine important landslide information such as type of failure, the surface area, cause and the run-out distance. Detailed and systematic field work was carried out to generate the 41-point attribute data for landslides.

Preparation of the landslide inventory commenced with the search of archival data sources, particularly published and unpublished reports of GSI. The SPOT images available as a base map in ESRI Arc GIS 10.2 (up to the resolution of 30m) and high resolution Google Earth data of different time periods (from 2002 to 2015) were used as the main data product for generating the multi-temporal landslide inventory for this area.

3.2 Inventory Mapping: The following steps were used for mapping a landslide polygon in Arc GIS 10.2 and building its inventory attribute.

1. In Google Earth, every segment of the study area was viewed for all available time frames. Once the landslide is identified the same is marked as a polygon. The source or the zone of depletion and the run out is marked separately.

2. The mapped polygon is then saved as. kml file and later imported to Arc GIS using „conversion" function. In Arc GIS the kml to layer conversion is first done and then the layer data is exported as a polygon shape file or directly to the geodatabase. In this study the WGS 84 UTM projection (43N) is taken for analysis.

3. The landslide polygon is then corrected with the help of the ESRI base map. Any shift in the spatial location of the polygon, due to shift in the multi-temporal images of Google Earth data, is adjusted manually. Few landslides were also mapped directly from SPOT data and toposheets in Arc GIS.

4. For each landslide polygon, the attributes such as name, state, district, taluk, toposheet number, initiation and reactivation year based on dates of Google Earth images), slide type, slide material, length, width, surface area, cause, land use and element at risk is attached. Archival data were used for naming and defining the cause of the landslides.

5. A systematic and detailed field check was then carried out to validate the pre-field map at all the accessible locations. The morphological signatures left by landslides on slopes were used to identify the shape of landslides.

6. After identifying the landslides in the field, the morphological parameters (landslide scar length, width and depth) were noted carefully after measuring them in the field using a meter tape. Additional data such as landslide type, run-out distance, present land use/Landcover class, regolith thickness, structure, probable cause, and damage details were also added to the inventory. Any new landslides identified were plotted in the topographic maps and were digitized as polygons or points and entered in a geo-database of Arc GIS.Though in the present study area slides reported earlier which are marked on GIS using their locational attributes could not be identified and digitised due to thick vegetation cover. No slope failure could be identified using satellite imageries and Google Earth due to their small dimension and thick vegetation cover.

All the slope failures observed in the field are located in the North, North-Eastern and Western part of the study area. A total of 72 slope failures were observed and recorded in the field **(Annexure-II).** Most of the slides of the area are occurring in in-situ soil/lateritic/weathered rock overburden, especially along Madikeri – Sullya, Madikeri – Kalur, Madikeri – Onchala, Panathur – Bhagamandala, Bhagamandala – Talakaveri, Talakaveri – Korangla, Virajpet – Makutta road sections primarily due to extensive slope cutting along road sections. The slides range from as high as 8 m to 50m in length and width from 10m to 60m. They are mostly debris slides having a mixture of weathered rock and in situ soil at places. All the slope failures noticed so far in the area are debris slides and shallow translational failures barring a few slumps in the in-situ soil overburden **(Photo-2, 3, 4).** One rock slide was noticed on Talakaveri – Baghamandala road **(Photo-1).** Most of the slope failures appear to be reactivated old slides **(Photo-6)**. The overburden material observed in the field consist mostly of in-situ soil ranging in depth from 0.5 to 5m but at places, regolith depth is observed to be falling in the range of 5 to 10m. The central part of T.S. No.48P/11, which abounds in coffee plantations and has low lying hillocks is observed to have in-situ soil ranging in thickness from 5m to 10m. The slide observed on the outskirts of Madikeri town (Indiranagar) **(Photo-5)** was an old slide scar having a recent slope failure. Though this was a relatively small slope failure but there is a fair chance of it further retrograding and widening. It was a debris slide having highly weathered rock and a mix of in situ soil. The rock was highly jointed, sheared with formation of quartz boudins and stretching was also observed. The whole section for about 100 metres looked fragile. Due to high degree of weathering and a slope cut to go with that, the area poses high risk of slope failure during monsoons.

Another previously reported landslide in Madikeri (Mangaladevi Nagar, 2006) was also studied and found that retaining walls have been made to prevent under cutting action by nala, the numerous settlements on modified slopes were in grave risk due to unstable slopes, the slopes had weathered rock and in situ soil and also had steep slopes of 60° to 70°.

III. LANDSLIDE SUSCEPTIBILTY ANALYSIS

This chapter comprises of the materials and methods used in landslide susceptibility analysis using Analytical Hierarchy Process (AHP) for areas deficient in landslides.

4.1 Background

Landslide susceptibility deals with the likelihood of landslide occurrence in an area on the basis of interplay of various local terrain conditions. Landslide susceptibility is the relative probability for the occurrence of landslide in an area. This does not necessarily mean that slides will essentially occur in high susceptible zones and that the low susceptible zones will not have any slides. It is only a qualitative and quantitative estimation that how a particular mapping unit, under the effect of several factors may behave in the landslide perspective. Since the study area lacks natural and sufficient number of landslides AHP method of analysis is used.

The analytical hierarchy process (AHP) is a semi-quantitative method in which decisions are taken using weights through pair wise relative comparisons without inconsistencies in the decision process (Saaty, 1980). The AHP consists of the following five steps:

(i) Breakdown a decision problem into component factors

(ii) Arrangement of these factors in a hierarchic order

(iii) Assignment of numerical values (Saaty, 1977) to determine the relative importance of each factor according to their subjective relevance

(iv) Setup of a comparison matrix and

(v) Computation of the normalized principal Eigen vector, which gives the weight of each factor (Saaty and Vargas, 2001).

The advantages of using AHP as an expert based method in landslide susceptibility analysis (Long and DeSmedt, 2012) are : (i) all types of information related to landslides can be included in the discussion process; (ii) judgment is structured so that all information is taken into account; (iii) discussion rules are based on expert’s knowledge and experience; (iv) when a consensus is reached, weights for each relevant factor are obtained automatically by eigenvector calculation of the comparison matrix; and (v) inconsistencies in the decision process were verified using consistency index values.

4.2 Selection of Preparatory Factors: For susceptibility mapping, the selection of preparatory factors for landslides depends on the scale of analysis, the characteristics of the study area, the landslide type, the failure mechanisms and the priori knowledge of the main causes of landslides (Guzzetti et al., 1999).

A systematic overview of the important preparatory factors required for susceptibility mapping in different scales is given by Van Westen et al. (2008). A priori knowledge of the main causes of landslides in the area of interest is essential in selecting the most relevant factors out of the many known preparatory factors that can "theoretically" cause landslides (Ghosh and Carranza, 2010).

For areas where a-priori knowledge of landslide is missing or scarce and/or insufficient, any one of the following approaches may be adopted as per priority or terrain conditions and/or after due discussion with the local experts/workers.

a) Individual ratings for geofactor classes and weights of geofactors will first be determined based on a pilot study in the adjacent smaller area/ road corridor (preferably within the study area) where well-distributed landslide data are available by using various spatial association techniques. Later such ratings and weights will be used for the entire study area for model integration using the same multiclass index overlay method. In case of availability of similar or research work in adjacent and similar terrain nearby, the ratings and weights developed and used in such work may also be used after due discussion with the local experts.

b) Individual ratings for geofactor classes and weights of geofactors will be determined using Analytical Hierarchy Process (AHP) after preparing the pair wise qualitative comparison matrix of all factors (Saaty,1977) after due discussion with local experts and workers.

For susceptibility analysis six factor maps were prepared that are considered to be the main spatial causal factors for landslides in the area, out of the six maps, two are related to terrain morphometry derived from DEM and four are field based maps prepared from remote sensing data. A brief description of the significance and mapping techniques for each factor is given below.

4.3 Geo-factor Themes:

In general, the factors which influence where a landslide will occur, typically include slope angle, climate, weathering, water content, vegetation, overloading, geology, and slope stability. How these factors interrelate is important in understanding what causes landslides along with an understanding of the impact humans have on these factors by altering natural processes. Mentioned below are the factors that have been taken into account for estimating landslide susceptibility in an area using GIS. As far as data model is concerned, some of the geo-factor themes are categorical (e.g., geomorphology, aspect etc.) and others represent continuous data (e.g., slope, elevation etc.). These spatial factor maps are prepared using various source data and employing different mapping techniques which are detailed below.

4.3.1 Slope Morphometry: Slope morphometry is defined by slope gradient and curvature. The data for these factors was derived from CARTO DEM downloaded from BHUVAN portal having 30m resolution. Slope gradient and slope curvature (**PLATES 5 and PLATE 6**) for the study area was generated on Arc GIS 10.2 software using spatial analyst tool. A positive curvature represents upwardly convex surface, while a negative curvature indicates that the surface is upwardly concave at a given pixel. The concave hill slopes are areas having high soil moisture content and receive more surface run-off. Failures can be expected to occur more frequently in those areas than the slopes that are convex along the contour.

For the slope gradient map as a derivative of DEM, the area was classified in to five classes ranging from <15° up to >45°. About 35% area falls in low slope range i.e <15° class. 15°-25° slope gradient class occupies about 11% of the study area. A large part of the study area is occupied by 25° to 35° class (about 46%), which is having maximum weightage according to the ratings given in AHP. The area coverage in pixels along with LOFS and rank is given in **Table 4.**

Curvature map is classified into three classes i.e. convex, flat and concave slopes. Most of the area (about 46%) falls in flat slope. Curvature ranges from -0.1 to +0.1. The Convex slope (>0.1) class which is given the maximum weightage in the area covers about 25.4% of the study area while 28% of the area falls under Concave slope (<0.1). The area coverage in pixels along with LOFS and Rank is given in **Table 5**. More weightage and ranking is given to convex slope class (>0.1) and slope gradient (25°-35°). The convex slope is more fragile to loss of mass and 25°-35° slope are mostly influenced by anthropogenic activities and habitat in the study area.

Table 4- LOFS map and area coverage in pixels for Slope gradient of T.S Nos. 48P/07, 11 & 12

CLASS	Rank	LOFS	Area coverage (Pixels)	Area covered (%)
<15	2	0.1631	414124	35.1
15-25	4	0.4597	134361	11.39
25-35	8	1.0000	542738	46.01
35-45	6	0.2817	80631	6.83
>45	2	0.1631	7567	0.64

Table 5 -LOFS map and area coverage in pixels for Slope curvature map of T.S Nos 48P/07, 11 & 12.

CLASS	Rank	LOFS	Area coverage (Pixels)	Area covered (%)
Concave	4	0.4113	294839	28.01
Flat	2	0.1676	489836	46.54
Convex	6	1.0000	267757	25.44

4.3.2 Geomorphology: Geomorphology, along with information on soil, water and vegetation has become one of the essential inputs in planning for various developmental activities. The scope of geomorphology has further expanded with the landform maps widely used in various fields of resource surveys, environmental analysis, hydrological studies, engineering applications and geo-technical studies.

Geomorphology map **(PLATE 8)** of the study area was prepared in Arc GIS 10.2 software through visual interpretation of multi-temporal Google Imageries of the area. NGLM data acquired from SRO, Hyderabad was also taken into account while preparing the geomorphology map of the study area. The obtained pre field map was checked and validated in field. The post field changes in Geomorphology map have been shown in Fig. 3. In terms of geomorphology the area was grouped into 10 classes namely ridge top, highly dissected slopes, moderately dissected slopes, low dissected slopes, mounds, hill top, valley fill, pediment-pediplain complex, rolling plains, piedmont slope and river. The dissected slopes (high, moderate or low) were mapped based on visual interpretation by taking topographic ruggedness and presence of drainages as criteria. Most of the area (about 40.53%) falls in Highly dissected slopes followed by Lowly dissected slopes (22.81%), Pediment-Pediplain Complex (6.89%) and Moderately dissected slopes (22.25%). Highly dissected slope is given

maximum weightage using AHP method and has coverage of about 40.53% area. The area coverage for each class in pixels, LOFS and rank is given in **Table 5**. Highly dissected slope is ranked less than the moderately dissected slope based on the ground scenario. It is observed in the study area that the anthropogenic activities i.e. toe cutting, road cut section and extensive cut are predominantly triggering factor apart from natural causes occurring on the moderately dissected slope with 25°-35° slope causing instability on the slopes.
The details of geomorphic features are given as follows:

Ridge: This is the topmost part of the hills/mountains which is formed by the intersection of two escarpments from the opposite directions (NGLM Manual, 2010). It also acts as the water divide **(Photo-18)**.

Dissected Structural Hills: Hills, which are originated due to tectonic process and are highly dissected by the drainage lines. This can be further classified as highly, moderately and low dissection depending on the density of joints and drainage. Mostly this will be interpreted from a planimetric satellite data and the classification is highly subjective. (NGLM Manual, 2010) (Photo -15,16)

Pediment: A broad, flat or gently sloping, rock floored erosion surface or plain of low relief, typically developed by sub aerial agents (including running water) in an arid or semiarid region at the base of an abrupt and receding mountain front or plateau escarpment, and underlain by bedrock (occasionally by older alluvial deposits) that may be bare but more often partly mantled with a discontinuous veneer of alluvium derived from the upland masses and in transit across the surface. (NGLM Manual, 2010)

Pediplain: Pediplain is a broad, relatively flat rock surface formed by the joining of several pediments. Pediplain is usually formed in arid or semi-arid climates and may have a thin veneer of sediments. (NGLM Manual, 2010)

Pediment – Pediplain complex: A complex landform where both pediplain and pediments occur and it is difficult to separate them. These are observed near Talakaveri **(Photo -17)**.

Valley fill: The unconsolidated sediment deposited by any agent so as to fill or partly fill a valley(NGLM Manual, 2010).

Piedmont slope: A small, low cliff occurring in alluvium on a piedmont slope at the foot of, and essentially parallel, to, a steep mountain range, resulting from dislocation of the surface, esp. by faulting (NGLM Manual, 2010).

Rolling plain: An undulating plain with rugged topography. (NGLM Manual, 2010)

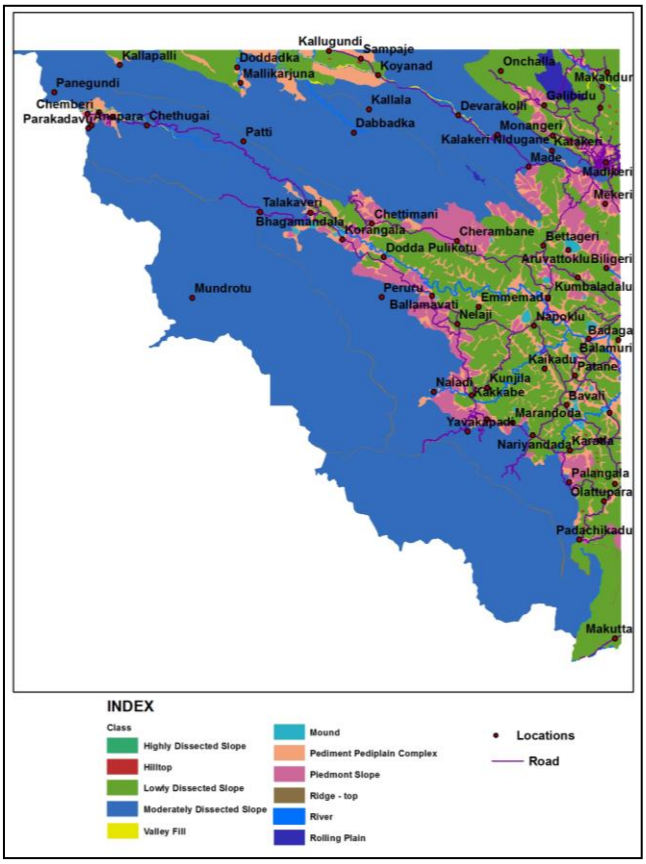
Mounds: Isolated hills having low relief and lowly dissected slopes and almost flattish, rounded tops.

Table 6 –LOFS, rank and area coverage in pixels for Geomorphology of TS nos. 48P/07, 11 & 12.

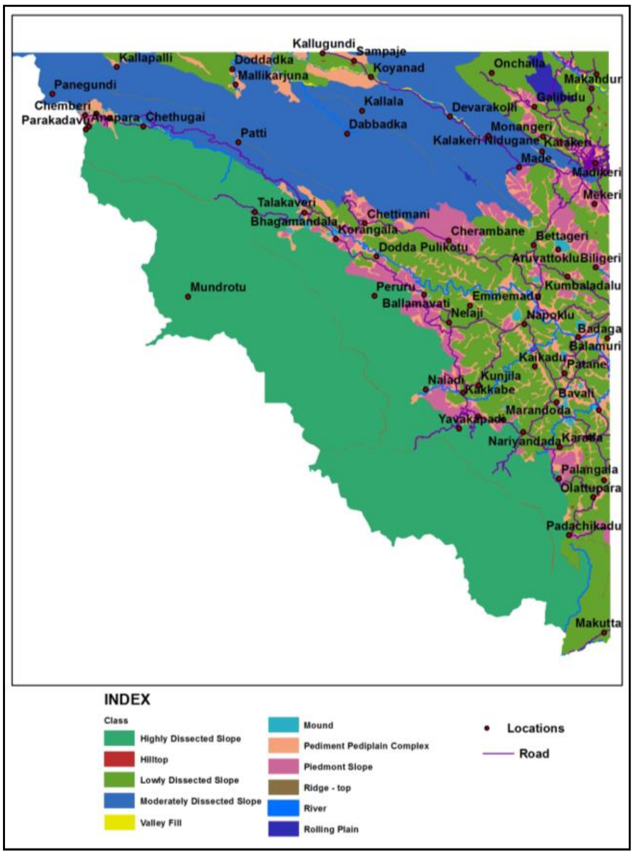
Class	Rank	LOFS	Area coverage (pixels)	Area covered (%)
Mound	2	0.0819	2361	0.437
Lowly Dissected Slope	4	0.1947	123029	22.81
Highly Dissected Slope	6	0.4020	218574	40.53
Moderately Dissected Slope	8	0.7279	120005	22.25
Piedmont Slope	4	0.1947	30274	5.61
River	0	0	1081	0.2
Rolling plain	0	0	3008	0.7
Valley Fill	0	0	1144	0.2
Pediment Pediplain Complex	0	0	37161	6.89
Ridge top	0	0	2175	0.40
Hilltop	0	0	447	0.08

Fig. 3 Post field changes in Geomorphology Map

Pre – Field Map



Post – Field Map



4.3.3 Land Use & Land Cover

The landuse/landcover of an area directly reflects the human interaction with nature. At places this interaction has exceeded the boundaries and led to man's conflict with nature resulting in the balance of nature being disturbed. This has resulted in many natural calamities – landslides being the foremost result of this over exploitation.Despite the Western Ghats being a UNESCO world heritage site and one of the eight hottest biodiversity hotspots in the world, it is still being exploited thoroughly, damaging natural slopes, flora and fauna. There have been drastic changes in the landuse/landcover patterns and scarcity of water, low rainfall in recent years in this area, may be a direct result of this anthropogenic activity.

The study area consists of lush green forests, low height and high height plantations consisting of coffee, cardamom, black pepper, teak, silver oak, rubber, etc. The commercial plantations form a major part of the landuse in this area causing large scale exploitation and disturbances in slope stability. Besides these, paddy cultivation also forms major part of the low lying area. Settlements are observed in almost all parts of the study area, a classic example of man encroaching into the nature's territory. This often results in slope cut failures, mostly along road cuts. This is augmented by heavy rainfall in the area. The major part of the area is occupied by plantations, which is the main source of income for the people in the study area, followed by forests and cultivated land. Human habitation has seen an increase in the past decade, since the area is a popular tourist destination; creation of holiday homes and resorts in the interior parts of the forests has led to deforestation.

Construction of roads, railways and dams has opened channels for exploitation and caused rapid changes in LULC of the area. The land use and land cover (LULC) map **(PLATE 7)** was prepared from the Google Earth data of the year 2012-time frame. Following the normal mapping procedure in Google Earth, first the polylines of different land use/cover were drawn and the same were imported in Arc GIS through kml to feature conversion. In Arc GIS the features were converted into polygons and then again exported to Google Earth through layer to kml conversion. Each polygon was named as per its LULC class and reconverted into a shape file through kml to layer conversion. The obtained pre-field landuse/landcover map was checked in the field at all accessible locations. The post field changes in landuse/landcover map have been shown in **Fig. 4**. The area in terms of landuse/landcover can be classified in to ten classes: Barren, cultivation, settlement, settlement on modified slope, sparse vegetated areas, moderate vegetated areas **(Photo-11),** thick vegetated areas, river, low height plantation, high height plantation, extensive cut slope, quarry **(Photo-12),** and fallow land. The areas along river banks is covered with alluvial material and along low lying valleys is covered with overburden material and are being used for cultivation **(Photo-8).** Major part of the area (about 49.99%) is covered with thick vegetation that lies in the western and northern part of the study area. The next highest area is occupied by low height plantations (LHP) that constitute about 25.85% of the area. High height plantations (HHP) occupy about 9.08% of the area followed by cultivation (6.43%) and settlement (1.81%). The central and south central part of the study area is occupied by LHP and western and northern part is covered by HHP **(Photo-10).** About 5.18% of the study area consists of barren land (Photo-14). Settlements in the area are widely distributed and are a vital cause in disturbing the natural equilibrium of slopes. Slope modification for settlement and commercial plantation is quite rampant in the area. LU/LC factor class 'Extensive slope cut' is observed to be most vulnerable sites for slope failures and occupies about .001% of the study area. The maximum weightage is given to extensive slope cut **(Photo-9)** followed by sparse vegetation and settlement on modified slopes **(Photo-13)** which occupy about 0.058% and 0.362 % of the area respectively. The area coverage of each factor class in pixels, LOFS and rank is given in **Table 7**.

Thick vegetation: The North – Western and Southern part of the study area predominates in thick vegetation which has been fragmented at many places by human activities. Most of the forests are exploited for timber and for cooking purposes. There are several varieties of spices also available in these forests.

High height plantations: These include commercial plantations like rubber, coconut, arica nut,teak, silver oak etc. They mostly cover the northern and north – western part of the area. Coconut plantations are found all over the study area.

Low height plantations: Kodagu district is famous for cashew, cocoa, coffee, tea and spices. These constitute the low height plantations of the area and occupy central, southern and north eastern part of study area.

Settlements: Due to high degree of commercialization and improvement in communication routes more and more area of the Western Ghats is being encroached upon by human settlements. Labourers from other states are also being brought in to work in plantations and live there. The study area is also a well-known tourist spot, hence to cater to the needs of the tourists, several holiday homes resorts and hotels have come up, thus increasing the urbanization index of the area.

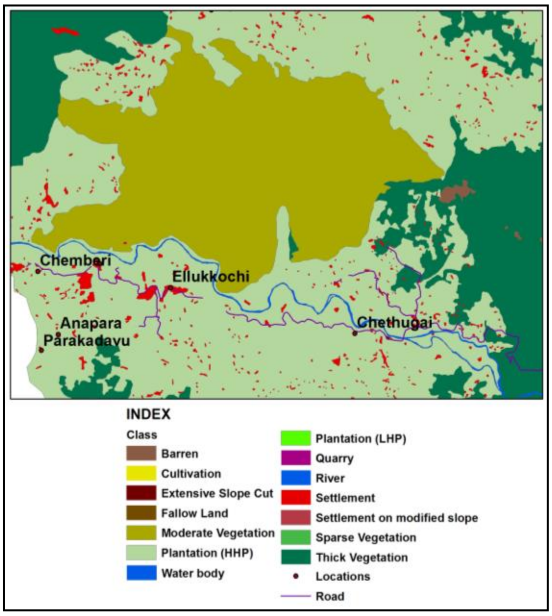
Settlements on Modified slope: Many slopes in and around Madikeri and other important localities such as Baghamandala, Talakaveri, Sampaje, Made etc. have been modified for human use thus increasing the landslide susceptibility index of the area.

Extensive slope cut: Roads and railways are required for improving connectivity and communication in any area. The study area also has good connectivity by road though at the cost of extensive damage to slopes. Slopes need to be cut in order to construct roads in the hilly terrains of the Western ghats. This weakens the slopes a great deal. This class has been given high rating for the same.

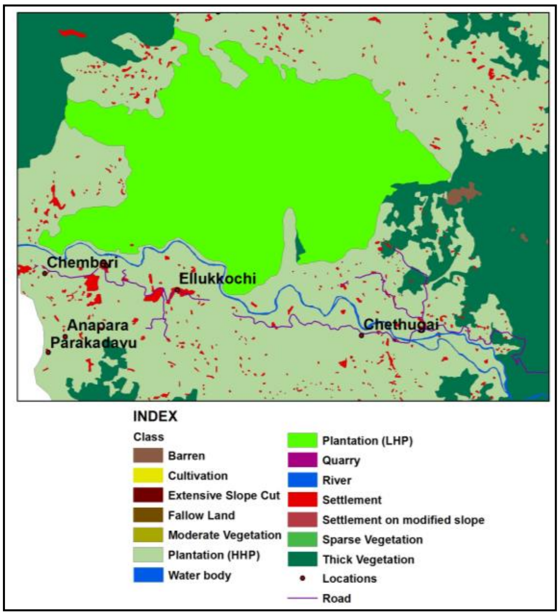
Table 7 – LOFS, rank and area coverage in pixels for Landuse/Landcover of TS nos. 48P/07, 11 & 12.

Class	Rank	LOFS	Area coverage (Pixels)	Area covered (%)
Cultivation	2	0.0937	34687	6.43
Extensive Slope Cut	9	1.0000	8	0.001
Fallow Land	1	0.0626	1554	0.288
Plantation (HHP)	4	0.1988	48996	9.08
Plantation (LHP)	3	0.1366	139441	25.85
Thick Vegetation	4	0.1988	269598	49.99
Sparse Vegetation	7	0.5631	318	0.058
Water body	0	0.0000	152	0.028
Settlement	1	0.0683	9772	1.813
Barren	1	0.0626	27958	5.18
Settlement on modified slope	7	0.5631	1954	0.362
River	0	0	1081	0.20
Quarry	5	0.2912	8	0.001
Moderate Vegetation	5	0.2912	3727	0.691

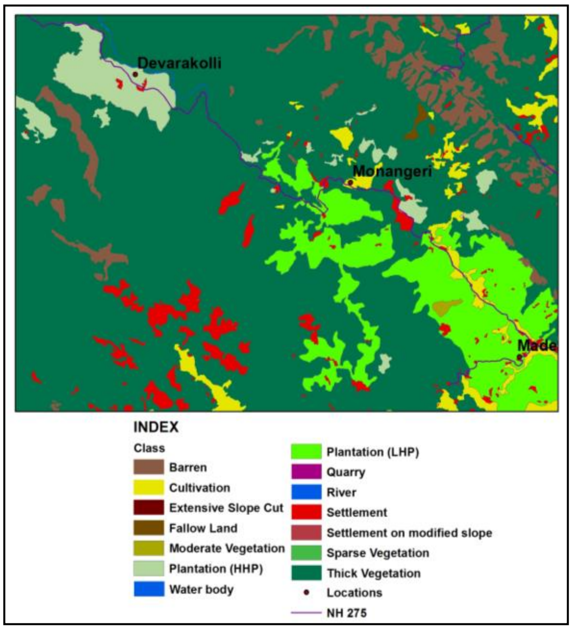
Fig. 4 – Post Field changes in landuse/landcover map of the study area



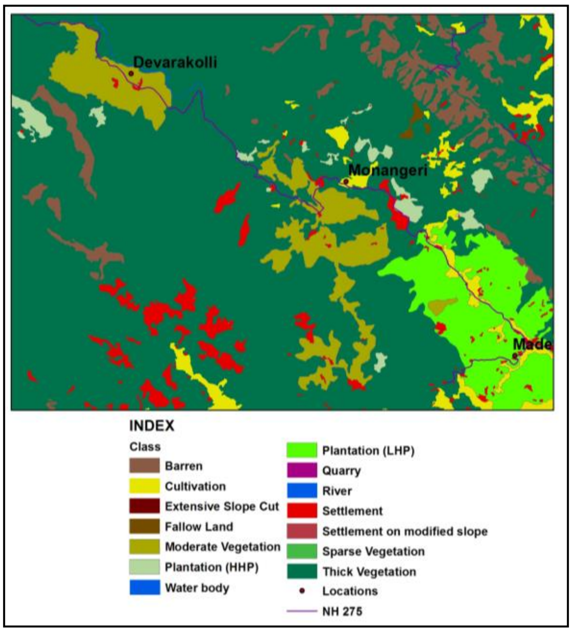
Pre-field map



Post- field map



Pre Field Map



Post Field Map

4.3.4 Slope 4.3.4 Slope Forming Material (SFM):

The area under study is observed to have shallow debris slides. These slides occur in the overburden part of slopes where the upper shallow layer slides on the more competent material either bedrock or denser overburden material. These slides are often triggered by high rainfall and anthropogenic activities. Thus careful study of slope forming material is a must for this study area. Slope Forming Material (SFM) (PLATE 9) map was prepared in Arc GIS 10.2 through visual interpretation of multi-temporal Google Imageries of the area and collection of data for material present on slopes. The study area in terms of Slope Forming Material (SFM) is classified in to three classes: Rock, weathered rock and In-situ soil. Though the area comprises of high hill ranges and valleys, transported soil could not be identified due to thick vegetation cover.

On slopes as well as ridge tops, barren rock is present at places where the slope gradient in general is more than 35°, most of the study area (about 44.57%) is covered by in-situ, granitic soil **(Photo-19)**, rock (24.7%) and weathered rock (**0.097%).** The factor class rock includes overburden material of 0.5m thickness. For this class different rock names are taken from the geological map of the study area by GSI. Laterite (Photo-20) is observed in patches near Sampaje. Weathered rock (Photo-22) is also observed along road cuts near Baghamandala, Chettimani and NW of Ballamwati. The weathered rock factor class is assigned maximum weightage as weathered rocks on slope are highly vulnerable, similarly equal weightage/rank is assigned to in-situ soil and amphibolites because minerals present in amphibolites are highly susceptibility to weathering and the loose in-situ soil has poor shear strength due to water saturation in Western Ghats climatic conditions. The area covered in pixels, LOFS and rank is given in **Table 8**.

Table 8 –LOFS, rank and area coverage in pixels for Slope forming material of 48P/07, 11 & 12.

CLASS	Rank	LOFS	Area Coverage (in pixels)	Area Coverage (%)
In-situ soil	**4**	**0.2409**	**240354**	**44.57**
Dolerite	**1**	**0.0682**	**34**	**0.006**
Granite gneiss	**1**	**0.0682**	**47675**	**8.840**
Pyroxenite	**1**	**0.0682**	**14**	**0.003**
Granite	**1**	**0.0682**	**944**	**0.175**
Garnet-sillimanite-gneiss + graphite + cordierite	**1**	**0.0682**	**21372**	**3.963**
Hornblende-diopside gneiss	**1**	**0.0682**	**88159**	**16.34**
Quartz vein	**1**	**0.0682**	**21**	**0.003**
Charnockite	**1**	**0.0682**	**198038**	**36.72**
Amphibolite	**4**	**0.2409**	**40**	**0.006**
Weathered Rock	**6**	**0.5437**	**527**	**0.097**
River	**0**	**0**	**1081**	**0.20**

4.3.5 Regolith Thickness: Thickness of overburden is directly controlled by slope forming material (SFM), geomorphology, land use/land cover and slope gradient. Overloading of slopes with sediments, debris, quarry dump may result in slope failures often triggered by heavy rainfall. During field work, regolith/overburden thickness is estimated by observing road cuts, forest trenches and nala sections wherever available. An attempt is made to get the approximate overburden depth and it is observed that in low dissected hill slope with low slope gradient, the overburden depth is relatively more (approx. 2-5 m or >5m) where as in low dissected slopes having steeper slope gradient, the overburden depth varies from 1-2m to occasionally upto 5m range. In the study area it can be classified in to three classes viz. <0.5 m, 0.5m to 5 m and 5m to 10m **(PLATE-10).** Along the moderate and steep slopes depth of overburden, in general, is less while along major weathered profiles, regolith thickness is more, these areas are more prone to landslides. Regolith depth of <0.5m depth is observed on rocky, steep slopes. This is then included into rock itself. Major part of the study area (about 26.92%) has a regolith depth of 0.5m to 5m. Some places (about 18.14%) have regolith depths of more than 5-10 m **(Photo 21)** like west of Kedamalluru and west of Chinniyapanda, east of Bhagamandala and Korangala and areas around Napoklu, Balamuri and Emmemadu. The factor class 0.5m to 5m is given the maximum weightage for landslide occurrence using AHP. Areas around Madikeri, Galibedu, Bettegeri, Sampaje, Dabbadka and Kottamudi are occupied by soil thickness of 0.5m to 5m. The area covered by each factor class in terms of pixels, LOFS and rank is given in **Table 9**.

Table – 9 LOFS, rank and area coverage in pixels for Regolith Thickness of T.S No. 48P/07, 11 & 12.

CLASS	Rank	LOFS	Area coverage (Pixels)	Area covered (%)
< 0.5 m	0	0	295130	54.72
0.5 - 5 m	7	1	145191	26.92
5 - 10 m	4	0.32296	97857	18.146
River	0	0	1081	0.20

4.4 Landslide Susceptibility Analysis (AHP)

Landslides or rather slope failures in the study area are concentrated mainly along roads and other transportation corridors. Recording these slope failures which are a result of anthropogenic activities and considering them for susceptibility zonation of the study area would be highly biased. Since very few, almost negligible amount of slides is observed elsewhere in the area, the normal method of modeling cannot be used here. In this situation, ratings and inter-predictor weights can only be determined using expert or knowledge driven techniques by implementing one of the following alternatives or by combining knowledge derived from attempting all the alternatives.

Alternative 1: Finalisation of ratings and weights in a smaller neighbouring area-

If landslide inventory data is available in a smaller catchment or road-corridor within or adjacent to the proposed study area (or Toposheet), attempts should be made to determine terrain-specific ratings and weights of geofactors through a pilot study in that particular pilot study area. This can be executed by employing different spatial association analysis such as determination of Yule’s Co-efficient, Distance Distribution Analysis etc. The ratings and weights determined so far through that pilot study can then be utilised for the entire study area where landslide data is not available. Since NLSM aims to develop and utilise terrain-specific ratings and weights, this seems to be the best approximation of terrain-specific importance of geofactors.

Alternative 2: Finalisation of ratings and weights using expert opinion and Analytical Hierarchy Process (AHP)-

In a situation of complete non-availability of landslide inventory data, there is absolutely no remedy other than utilising complete expert or knowledge driven ratings and weights into susceptibility modeling despite its subjectivity. However, this knowledge-driven ratings/ weights in quantitative matrices can easily be determined mathematically using AHP (Saaty, 1977; Ghosh et al., 2010), after preparing/ deciding on the qualitative pairwise importance matrix for different geofactor classes and amongst different geofactors for inter-predictor weights, obtained so far through discussion and comments received from local experts and landslide scientists engaged in landslide investigation of the area. The procedures of application of AHP through some examples are demonstrated through some illustration below.

In line of the above proposition, for determining the terrain-specific knowledge-driven ratings and weights through application of AHP, a mandate form/ questionnaire is prepared, where all the concerned landslide scientists, other geologists working in similar terrain and all experts of the concerned Region may submit their mandate/ answer in a semi-quantitative term by rating each geofactor theme separately. While giving the semi-quantitative rating in a scale of 1-9 for each geofactor theme, the mutual relative importance for influencing/ causing a single proposition that is landsliding in this case should be taken into account. A particular geofactor class having higher rating would be considered as more instrumental in influencing land sliding. For example, if we classify our slopes into 5 classes say 0-15, 15-25, 25-35, 35-45 and >45 and give semi-quantitative rating as 2, 4, 8, 6, 1 then it will be presumed that for land sliding, slope class 25-35 is the most important among all other classes.

4.4.1 Methodology: The Analytic Hierarchy Process (AHP), developed by Saaty (1980) is a method of structuring decision problems. The AHP consists of three levels of hierarchy. The first hierarchy level is the goal of the decision making, the second level involves how each of the existing criteria contributes to achievement of goal, and the third level is to find out how each of the alternatives contributes to each of the criteria.

The AHP method is appropriate and to be used where decisions are to be assessed quantitatively. It is assumed that human beings' natural reaction when facing a complex decision making process, is by grouping the decision elements according to common characteristics. This involves ranking the decision elements, and then comparing between each pair in each group in a form of matrix. Then inconsistency ratio and weight for each element can be measured. This provides ease in testing the data consistency. The higher consistency ratio, the assessment result becomes more inconsistent. The acceptable consistency ratio is less than or equal to 10%.

According to Taylor, Consistency Index (CI) can be calculated by using the following formula:

CI= maks eigen value-n/n-1 Eq-1

$maks.eigenvalue = \sum_{\iota} wi.\mathrm{ci}$ Eq-2

The consistency ratio is then calculated as,

$CR = CI/RI$ Eq-3

Where, n is the amount of items compared, w*i* is the weight, ci is the sum of column, CR is the

Consistency Ratio, CI is the Consistency Index and RI is the Random Consistency Index.

If CR ≥ 10%, the data acquired is inconsistent and If CR < 10%, the data acquired is consistent. The ratio-scale form is used as an input. The values in the ratio are organized in a matrix, which is called the pairwise comparison matrix. In the AHP method, the scale range 1–9 is assumed. It is limited to a ratio-scale 1–9 because according to the research conducted by Miller, human beings cannot simultaneously compare more than seven objects. The Standard Preference Scale used is given in table:

Preference Level	Numerical Value
Equally Preferred	1
Equally to Moderately Preferred	2
Moderately Preferred	3
Moderately to Strong Preferred	4

Strongly Preferred	5
Strongly to Very Strongly Preferred	6
Very Strongly Preferred	7
Very Strongly to Extremely Preferred	8
Extremely Preferred	9

Using the above Standard Preference Scale, a group of geoscientists from GSI engaged in landslide studies in India and in Western Ghats, in particular, were asked to rank the factor classes and the factor maps. The obtained score for individual factor class was used for determining the ratings for each factor class. The average score for the factor maps were ranked between 0 and 9. Matrix of pairwise ratings; estimated eigenvectors of pairwise rating matrix; and estimation of consistency vector (CV), consistency index (CI) and consistency ratio (CR) for judgment of consistency of pairwise ratings of factors, respectively for all maps was calculated. Example of LULC for calculation of LOFS is given in table:

Table-10: Generic Table showing mutual comparison rank of LULC factor classes.

CLASS	Rank	LOFS
Barren	1	0.0626
Cultivation	2	0.0937
Extensive Slope Cut	9	1.0000
Fallow Land	1	0.0626
Moderate Vegetation	5	0.2912
Plantation (HHP)	4	0.1988
Plantation (LHP)	3	0.1366
Quarry	5	0.2912
Settlement	1	0.0683
Settlement on modified slope	7	0.5631
Swamp	0	0.0000
Thick Vegetation	4	0.1988
Sparse Vegetation	7	0.5631
Water body	0	0.0000
River	0	0.0000

Table-11: Table showing matrix of mutual comparison ranks of LULC classes given rank >0.

LULC	B	CL	ESC	FL	MV	HHP	LHP	QR	S	SM	TV	SV
B	1.00	0.50	0.11	1.00	0.20	0.25	0.33	0.20	1.00	0.14	0.25	0.14
CL	2.00	1.00	0.13	2.00	0.25	0.33	0.50	0.25	2.00	0.17	0.33	0.17
ESC	9.00	8.00	1.00	9.00	5.00	6.00	7.00	5.00	9.00	3.00	6.00	3.00
FL	1.00	0.50	0.11	1.00	0.20	0.25	0.33	0.20	1.00	0.14	0.25	0.14
MV	5.00	4.00	0.20	5.00	1.00	2.00	3.00	1.00	5.00	0.33	2.00	0.33
HHP	4.00	3.00	0.17	4.00	0.50	1.00	2.00	0.50	4.00	0.25	1.00	0.25
LHP	3.00	2.00	0.14	3.00	0.33	0.50	1.00	0.33	3.00	0.20	0.50	0.20
QR	5.00	4.00	0.20	5.00	1.00	2.00	3.00	1.00	5.00	0.33	2.00	0.33
S	1.00	0.50	0.11	1.00	0.20	0.25	0.33	0.50	1.00	0.14	0.25	0.14
SM	7.00	6.00	0.33	7.00	3.00	4.00	5.00	3.00	7.00	1.00	4.00	1.00
TV	4.00	3.00	0.17	4.00	0.50	1.00	2.00	0.50	4.00	0.25	1.00	0.25
SV	7.00	6.00	0.33	7.00	3.00	4.00	5.00	3.00	7.00	1.00	4.00	1.00
Sum Clm	49.00	38.50	3.00	49.00	15.18	21.58	29.50	15.48	49.00	6.96	21.58	6.96

Table-12: Table Showing Fraction rate and LOFS values.

LULC	B	CL	ESC	FL	MV	HHP	LHP	QR	S	SM	TV	SV	Sum rows	Frac rate	LOFS
B	0.02041	0.01299	0.03702	0.02041	0.01317	0.01158	0.0113	0.01292	0.02041	0.02052	0.01158	0.02052	0.21283	0.01774	0.0626
CL	0.04082	0.02597	0.04165	0.04082	0.01647	0.01544	0.01695	0.01615	0.04082	0.02394	0.01544	0.02394	0.3184	0.02653	0.0937
ESC	0.18367	0.20779	0.3332	0.18367	0.32931	0.27799	0.23729	0.32293	0.18367	0.43092	0.27799	0.43092	3.39936	0.28328	1.0000
FL	0.02041	0.01299	0.03702	0.02041	0.01317	0.01158	0.0113	0.01292	0.02041	0.02052	0.01158	0.02052	0.21283	0.01774	0.0626
MV	0.10204	0.1039	0.06664	0.10204	0.06586	0.09266	0.10169	0.06459	0.10204	0.04788	0.09266	0.04788	0.98989	0.08249	0.2912
HHP	0.08163	0.07792	0.05553	0.08163	0.03293	0.04633	0.0678	0.03229	0.08163	0.03591	0.04633	0.03591	0.67586	0.05632	0.1988
LHP	0.06122	0.05195	0.0476	0.06122	0.02195	0.02317	0.0339	0.02153	0.06122	0.02873	0.02317	0.02873	0.46439	0.0387	0.1366
QR	0.10204	0.1039	0.06664	0.10204	0.06586	0.09266	0.10169	0.06459	0.10204	0.04788	0.09266	0.04788	0.98989	0.08249	0.2912
S	0.02041	0.01299	0.03702	0.02041	0.01317	0.01158	0.0113	0.03229	0.02041	0.02052	0.01158	0.02052	0.2322	0.01935	0.0683
SM	0.14286	0.15584	0.11107	0.14286	0.19759	0.18533	0.16949	0.19376	0.14286	0.14364	0.18533	0.14364	1.91425	0.15952	0.5631
TV	0.08163	0.07792	0.05553	0.08163	0.03293	0.04633	0.0678	0.03229	0.08163	0.03591	0.04633	0.03591	0.67586	0.05632	0.1988
SV	0.14286	0.15584	0.11107	0.14286	0.19759	0.18533	0.16949	0.19376	0.14286	0.14364	0.18533	0.14364	1.91425	0.15952	0.5631

Table-13: Table showing estimation of consistency vector (CV).

LULC	B	CL	ESC	FL	MV	HHP	LHP	QR	S	SM	TV	SV	Sum rows	CV
B	0.01774	0.01327	0.03148	0.01774	0.0165	0.01408	0.0129	0.0165	0.01935	0.02279	0.01408	0.02279	0.2192	12.3591
CL	0.03547	0.02653	0.03541	0.03547	0.02062	0.01877	0.01935	0.02062	0.0387	0.02659	0.01877	0.02659	0.3229	12.1696
ESC	0.15962	0.21227	0.28328	0.15962	0.41245	0.33793	0.27089	0.41245	0.17415	0.47856	0.33793	0.47856	3.71773	13.1239
FL	0.01774	0.01327	0.03148	0.01774	0.0165	0.01408	0.0129	0.0165	0.01935	0.02279	0.01408	0.02279	0.2192	12.3591
MV	0.08868	0.10613	0.05666	0.08868	0.08249	0.11264	0.1161	0.08249	0.09675	0.05317	0.11264	0.05317	1.04961	12.724
HHP	0.07094	0.0796	0.04721	0.07094	0.04125	0.05632	0.0774	0.04125	0.0774	0.03988	0.05632	0.03988	0.69839	12.4001
LHP	0.05321	0.05307	0.04047	0.05321	0.0275	0.02816	0.0387	0.0275	0.05805	0.0319	0.02816	0.0319	0.47182	12.1921
QR	0.08868	0.10613	0.05666	0.08868	0.08249	0.11264	0.1161	0.08249	0.09675	0.05317	0.11264	0.05317	1.04961	12.724
S	0.01774	0.01327	0.03148	0.01774	0.0165	0.01408	0.0129	0.04125	0.01935	0.02279	0.01408	0.02279	0.24395	12.6068
SM	0.12415	0.1592	0.09443	0.12415	0.24747	0.22529	0.1935	0.24747	0.13545	0.15952	0.22529	0.15952	2.09543	13.1358
TV	0.07094	0.0796	0.04721	0.07094	0.04125	0.05632	0.0774	0.04125	0.0774	0.03988	0.05632	0.03988	0.69839	12.4001
SV	0.12415	0.1592	0.09443	0.12415	0.24747	0.22529	0.1935	0.24747	0.13545	0.15952	0.22529	0.15952	2.09543	13.1358
													Sum CV	151.33

Table-14: Table showing calculation of consistency index (CI) and consistency ratio (CR).

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Mean CV		**12.6109**	
Consistency Index (CI) =			**(Mean CV-number of themes)/(No of themes -1)**
CI	**0.05553**		
Consistency Ratio (CR) =			**CI/RI**
CR	0.00463		
CR should never be more than 0.1			

In the same manner LOFS and consistency ratio (CR) were calculated for all the six factor maps. All the tables of the six factor maps for LOFS and consistency ratio calculations have been attached in Annexure – I.

Table-15: Table showing mutual comparison of individual factor maps and weights.

Factor Classes	
Factor	**Rank**
Slope	9
Curvature	2
SFM	6
LULC	8
Geomorphology	6
Regolith Thickness	4

Factor	Slope	Curvat	SFM	LUL	Geo	RT
Slope	1.00	8.00	4.00	2.00	4.00	6.00
Curva	0.13	1.00	0.20	0.14	0.20	0.33
SFM	0.25	5.00	1.00	0.33	1.00	3.00
LULC	0.50	7.00	3.00	1.00	3.00	5.00
Geom	0.25	5.00	1.00	0.33	1.00	3.00
RT	0.17	3.00	0.33	0.20	0.33	1.00
Sum Clmn	2.29	29.00	9.53	4.01	9.53	18.33

Factor	Slope	Curvature	SFM	LULC	Geom	RT	Sum rows	Frac rate	Weight	Weight W N
Slope	**0.43636**	**0.27586**	**0.41958**	**0.49881**	**0.41958**	**0.32727**	**2.37747**	**0.39625**	**12.8653**	**13**
Curvature	**0.05455**	**0.03448**	**0.02098**	**0.03563**	**0.02098**	**0.01818**	**0.18480**	**0.0308**	**1**	**1**
SFM	**0.10909**	**0.17241**	**0.10490**	**0.08314**	**0.10490**	**0.16364**	**0.73807**	**0.12301**	**3.99392**	**4**
LULC	**0.21818**	**0.24138**	**0.31469**	**0.24941**	**0.31469**	**0.27273**	**1.61107**	**0.26851**	**8.718**	**9**
Geom	**0.10909**	**0.17241**	**0.10490**	**0.08314**	**0.10490**	**0.16364**	**0.73807**	**0.12301**	**3.99392**	**4**
RT	**0.07273**	**0.10345**	**0.03497**	**0.04988**	**0.03497**	**0.05455**	**0.35053**	**0.05842**	**1.89685**	**2**

Once the LOFS values for geofactor sub classes are determined, all the LOFS values against the sub classes are compiled in an excel sheet. Then the LOFS attributes are joined in the raster map attribute table using "join and relates" option. Finally, LOFS map of the geofactor is prepared with the help of "Lookup" command in Arc GIS, using raster map of the geofactor as "input raster" and "geofactor_LOFS$LOFS" as lookup field.

For determination of Predictor Weight for the geofactor, one comparison matrix is calculated in microsoft excel software for the pair wise qualitative comparison of all the geofactors. In the comparison matrix, fraction weight is calculated for all the geofactors.

Once all the fraction weights are determined, minimum value within the fraction ratings is identified using the “MIN” command in excel software. Then all the fraction weight values are divided with the minimum fraction weight value to determine the Predictor Weight or weight of geofactors. In this way, as the fraction weights are divided with the minimum fraction weight value, the Predictor Weight or weight values will be one or more than one. For each geofactor, consider the nearest whole number as its Predictor Weight or weight.

For generation of “Raw Landslide Susceptibility Score Map” in Arc – GIS, “raster calculation” command under map algebra is used. For “Raw Landslide Susceptibility Score Map” the following formula is used.

Susc Score = *(LOFS_Factor1*weight of Factor1 + LOFS_Factor2*weight of Factor2 + LOFS_Factor3*weight of Factor3 + ………. + LOFS_Factor$_n$*weight of Factor$_n$) / Sum of inter – predictor weight*

In this type of knowledge-driven models, classification break values can be determined on the basis of the logic applied while giving mutual comparison expert driven ranking. It is always thought by any expert that rank value for any factor class is ≥ 5, and it is considered that the particular factor class has higher likelihood in influencing the landslides. This rank value of “5” in a scale of “0” to “9” comes after 50% of the absolute difference values (9-0 = 9; 50% of 9 is 4.5). That is why this 50% cut-off margin or weightage can be used to determine the break raster value between “*Moderate*” and “*High*” susceptibility classes (*BrMH*). Similarly, when rank value for any factor class is ≤ 3 (lower than 30% of the absolute difference value of 9), and it is considered that the particular geofactor class has lesser likelihood in influencing any landslides. Accordingly, 30% cut-off margin or weightage can be used to determine the break values between **“***Low***”** and **“***Moderate***”** susceptibility classes (*BrLM*).

Using the above logic the required break values can be det Using the above logic the required break values can be determined by solving the following formula:

BrMH = *[(Abs Diff LOFS Factor1*50)*weight of Fcator1 + (Abs Diff LOFS Factor2*50)*weight of Fcator2 + (Abs Diff LOFS Factor3*50)*weight of Fcator3 + …… + (Abs Diff LOFS Factor$_n$*50)*weight of Fcator$_n$] / Sum of inter – predictor weight*

BrLM *= [(Abs Diff LOFS Factor1*30)*weight of Fcator1 + (Abs Diff LOFS Factor2*30)*weight of Fcator2 + (Abs Diff LOFS Factor3*30)*weight of Fcator3 + …… + (Abs Diff LOFS* $Factor_n$**30)*weight of* $Fcator_n$*] / Sum of inter – predictor weight*

Once break values (BrMH and BrLM) are calculated, Classified Landslide Susceptibility Map is prepared by reclassifying the Raw Landslide Susceptibility Score Map using reclassify command in Arc – GIS. In reclassification window, three classes is chosen and in break values, 2nd topmost value given as the first value (Class 1), 1st topmost value is given as the second value (Class 2) and third value (Class 3) is given as one. Now the Raw Landslide Susceptibility Score Map is classified into the following categories: Class 1 stands for "*Low Susceptibility*", Class 2 stands for "*Moderate Susceptibility*" and Class 3 stands for "*High Susceptibility*" (Plate- 9).

V. LANDSLIDE SUSCEPTIBILITY MAP

Landslide susceptibility maps are key tools for landuse planning, management and risk mitigation. Landslide susceptibility mapping aims to differentiate a land surface into homogeneous areas according to their probability of failure caused by mass-movement at specific locations (Varnes, 1978). It relies on understanding complex mass movement processes and their controlling factors. An accurate and reliable landslide susceptibility map requires high quality data to arrive at useful decisions, and an appropriate methodology for analysis and modelling.

A Landslide susceptibility score map is thus obtained after generating LOFS maps for all the factor classes and using Weighted Multiclass Index Overlay method to generate raw susceptibility score map which is classified into low, moderate and high susceptible areas so that it can be understood easily by the common man. The susceptibility is expressed in terms of the relative likelihood of an area for initiation of landslide or slope failure in a pixel (the mapping unit) under the given geo-environmental conditions. According to the final susceptibility map (PLATE 12) obtained after AHP modelling, about 44.5% area falls under low landslide susceptibility zone while 37.4% area is categorized in moderate susceptibility. About 18.1 % area falls under high landslide susceptibility zone. The area in and around Madikeri falls under moderate to high susceptibility zones, this corroborates the fact that uncontrolled slope modification and other anthropogenic activities contribute in landslide occurrence. Most of the high susceptibility zones correspond to slope gradient class between 25° - 35° **(PLATE - 5).** It has been observed that most of the slides occur in this slope gradient class 15° – 25° (29 slides) and 25° - 35° (20 slides). In terms of landuse/landcover **(PLATE - 7)** the area having settlement on modified slopes and Extensive cut slopes has the maximum susceptibility to landslides. In terms of geomorphology **(PLATE - 8)**, most of the slides have been observed to occur in moderately dissected slopes (34 slides), followed by lowly dissected slopes (28 slides). It has to be noted here that most of the slides occurring in low dissected slopes are located around Madikeri where slope modification and slope disturbances are maximum.

Most of the area around NH-275 between Madikeri and Sampaje areas falls under moderate to high susceptibility which can be attributed to the fact that natural slopes have been excavated and modified for construction of highways, settlements and commercial plantations rendering the slopes unstable and prone to failures. There have been numerous occurrences of slope failures and road subsidence in the past along this highway. Still uncontrolled slope modification, removal of vegetation and overloading of slopes has been observed in the area.

Some areas around Patti ghat road (Baghamandala- Ellukochi road) are categorised under moderate to high susceptible areas. This ghat road has many previous instances of slope failures. The SFM along this road is mostly rock having steep slope gradient. Extensive slope cuts, removal of vegetation and slope modification has rendered the area unstable as far as slope strength is concerned. The area also has many small streams that cut across the slopes thereby reducing the cohesion of slope material. In terms of geomorphology this area falls under moderately dissected slopes. Slope gradient in this area ranges between 15° to 35° and more which is having maximum weightage as far as landslide susceptibility is concerned. Since slope gradient has been attributed with the maximum weightage these areas have been classified into moderate to high susceptible zones.

Areas North of Madikeri, NNE of Galibidu and NNW of Hebbatageri fall into high to moderate susceptibility zones. This may be attributed to high degree of slope disturbance for construction of roads and overburden thickness of about 0.5 to 5m and more. Extensive slope cuts and deforestation may also be the primary reasons for slope failure in this area **(Photo-9)**.

In the western part of the study area there are highly dissected slopes having slope gradient of 25° to 45° which has been given the maximum weightage for landslide susceptibility. Deforestation and slope disturbance have been observed in this part of study due to human interference, the place being a significant tourist destination. Due to these factors the western part of the area having steep hills and thick forest has been classified in moderate to high susceptible zone.

Most of the central and east – central part of study area is categorised into low to moderate susceptibility zone. This may be attributed to presence of low lying areas which abound in cultivation and low height plantations. In addition to this most of the area has slope gradients less than 15° which renders the area stable. Since the area has abundant vegetation the slope forming material, at most places is bounded by penetrating roots of these plants. This also provides stability to area as far as slope failure is concerned.

VI. CONCLUSIONS AND RECOMMENDATIONS

The hazards that landslides pose to society tend to be less appreciated as compared to other hazards. This is because landslides seldom occur at the same places. As compared to other hazards (viz. floods) where some sort of early warning systems has been developed, landslide warning in terms of time and location of occurrence can rarely be predicted with accuracy. Nevertheless, until some reliable system is developed for prediction of landslide occurrence, mitigation of damage caused by slope failures and creating better awareness among common man are only tools against this natural hazard. The area under study mostly has slides of small dimension. Small landslides make up the vast majority of landslide incidents that effect communities and individuals globally. These costs are mostly associated with human habitation and transport linkages. The decision whether to actively manage small landslides either by slope stabilisation methods or mitigation of their impacts is function of the cost – benefit analyses that are undertaken explicitly or implicitly **(Elisabeth T Bowman, 2015).** About 18% (237 Sq. Km.) area is grouped under High susceptibility zone in toposheet no.'s 48P/07, 11 & 12. Most of this area lies around transportation corridors and extensive slope cut areas. Besides hills with steep slopes are also grouped under moderate to high susceptible zones.

The susceptibility map thus obtained using Analytical hierarchy process (AHP) gives a qualitative indication in the study area about particular mapping units (pixel in this case having 50m * 50m resolution) being susceptible to landslide occurrence under the cumulative effect of geo factors under consideration. This does not have any time connotation and it is assumed that the same geo-environmental conditions will prevail in the future that augmented the present slope failures. These conditions may change with time and so will the susceptibility index of the area. The areas categorised under high and moderate zones are enlisted below in brief:

The picturesque town of Madikeri is densely inhabited with slope modifications for construction of houses and civil structures. This hill falls under moderate to high susceptible zone. Though the surrounding areas are covered under low susceptibility zones but still due to anthropogenic activities this hill has a possibility of slope failure occurrence in future under the influence of factors like rainfall, weathering etc. There have been previous instances of slope failures (in 2006 and 2013) causing sufficient damage to life and property. Since the area is densely populated slope failures may cause great damage to life and property. This has to be conveyed to the concerned authorities and preventive measures like slope terracing, retaining walls etc. should be taken up. Moreover, the local authorities should also consider shifting of residential areas to other stable areas to minimise damage from such calamities. A detailed study of the town may also be taken up.

Similarly, road sections on the Madikeri – Sullya, NH 275 have been observed to have weathered rock and also steep slope gradients. Several instances of slope failure and land subsidence have been reported in this area. This area also has high possibility of slope failures as indicated by susceptibility map. Heavy rainfall and deforestation may lead to loosening of the overburden which may slide. Preventive measures like slope stabilisation and conservation of forests need to be taken up so that the highway is kept safe from any damage.

Similarly, the ghat road between Baghamandal and Ellukochi has several historic instances of small slope failures which can be attribute to deforestation and slope modification.

Limitations

Every methodology tends to have its own limitations and constraints. Similarly, during the study, a few constraints in terms of the methodology adopted for this study were also identified which are enumerated below:

The mapping of the nature and extent of the slope forming material based on observations at accessible stretches may not depict the true picture on all studied hillslopes. Subsequently, the regolith thickness map is very subjective since the regolith thickness along a slope is visually estimated, few vulnerable sites may be explored or investigated through sub-surface exploration.on the basis of its exposure in a section and extrapolated to adjacent areas considering the terrain morphology.

The assumption of the methodology that the relation/s between spatial factors and past/present landslides are relevant to the occurrence of future landslides may not always hold true in nature.

The preparatory factors (e.g., slope, aspect, curvature, geomorphology and drainage) are not expected to change significantly in a short time period, local morphological changes may occur due to land sliding, but this will not substantially affect the susceptibility model. However, some local changes in the land use pattern can take place, such as terracing of slope for cultivation or excavation for construction of new buildings. Such changes can induce instability "locally‟ and may increase or decrease the susceptibility of that slope.

The susceptibility map is only valid under the given set of geo-environmental conditions taken as input in the susceptibility modelling. Any changes in the spatial distribution of the geo-environmental factors can affect the susceptibility of the area.

Spatio-temporal prediction of a landslide is still difficult on macro-scale; hence questions can be raised about the predictive capability of a susceptibility map given the uncertainty in the occurrence of a landslide.

Limitations in understanding the terrain and its landslide characteristics thereby affecting the selection of preparatory factors are also probable.

Despite the above, the generated landslide susceptibility map of the area is the first level spatial database on regional scale which can form the basis of landslide hazard and risk evaluation indicating the vulnerability and the elements at risk.

Recommendations

Based on the evaluation of the geofactors and understanding their relative importance that are specific to the terrain, as well as considering the scale of the study and the observations made in the field, the following generic recommendations are suggested:

The susceptibility map is generally meant for regional application because the information is shown on scale 1:50,000; however, they are still of considerable significance from the point of specific land use and urban planning. Nevertheless, it is recommended that a detailed site-specific study may be duly conducted before planning and execution of the civil construction works. Areas with high susceptibility falling under high hazard should be given due attention while executing civil constructions.

Landslide susceptibility mapping is useful in identifying potential landslide hazard zones but remedial measures to protect/treat the slide is of prime concern. In order to make these studies user friendly, the town planner/district administration should consult the report and landslide protection work should be undertaken in consultation with civil engineers.

In the event if a disaster strikes, the loss would be immense if buildings are not safely and properly located. Awareness among people is of utmost importance to reduce the loss of lives and property.

The awareness should include information about the potential danger, its identification and its communication; the physical significance of hazard and inherent uncertainties; ways to reduce landslide risk and the available local mitigation options.

LOCALITY INDEX

S. No.	Name	Toposheet No.	Latitude	Longitude
1	Anapara	48P/07	12° 26' 50.126" N	75° 22' 21.753" E
2	Arapattu	48P/11	12° 13' 30.768" N	75° 44' 8.569" E
3	Aruvattoklu	48P/12	12° 21' 32.923" N	75° 42' 46.948" E
4	Badaga	48P/11	12° 17' 44.917" N	75° 44' 54.480" E
5	Balamuri	48P/11	12° 17' 47.581" N	75° 43' 39.415" E
6	Ballamavati	48P/11	12° 19' 37.907" N	75° 36' 56.491" E
7	Bavali	48P/11	12° 15' 0.327" N	75° 42' 41.338" E
8	Bellumadu	48P/11	12° 14' 41.117" N	75° 44' 31.888" E
9	Bettageri	48P/11	12° 21' 44.016" N	75° 41' 42.609" E
10	Bhagamandala	48P/11	12° 23' 8.623" N	75° 31' 44.484" E
11	Biligeri	48P/11	12° 20' 46.493" N	75° 44' 24.438" E
12	Chemberi	48P/07	12° 27' 19.771" N	75° 22' 11.992" E
13	Cherambane	48P/11	12° 21' 56.227" N	75° 38' 0.486" E
14	Chethugai	48P/07	12° 26' 50.299" N	75° 24' 43.791" E
15	Chettimani	48P/11	12° 22' 40.764" N	75° 34' 22.464" E
16	Dabbadka	48P/11	12° 26' 30.866" N	75° 33' 36.067" E
17	Devarakolli	48P/11	12° 27' 14.374" N	75° 38' 5.086" E
18	Dodda Pulikotu	48P/11	12° 21' 15.859" N	75° 34' 52.896" E
19	Doddadka	48P/07	12° 29' 16.779" N	75° 28' 37.217" E
20	Ellukkochi	48P/07	12° 27' 12.041" N	75° 23' 15.539" E
21	Emmemadu	48P/11	12° 19' 9.441" N	75° 38' 55.827" E
22	Galibidu	48P/11	12° 27' 39.050" N	75° 41' 46.215" E
23	Hachchinadu	48P/11	12° 29' 2.528" N	75° 44' 27.756" E
24	Hebbettageri	48P/11	12° 27' 32.565" N	75° 44' 10.374" E
25	Kabbinakadu	48P/12	12° 14' 25.289" N	75° 39' 17.022" E
26	Kaikadu	48P/11	12° 16' 32.619" N	75° 41' 45.085" E
27	Kakkabe	48P/11	12° 15' 25.860" N	75° 38' 37.474" E
28	Kalakeri Nidugane	48P/11	12° 26' 21.968" N	75° 42' 7.707" E
29	Kallala	48P/11	12° 27' 29.859" N	75° 34' 15.669" E
30	Kallapalli	48P/07	12° 29' 22.989" N	75° 23' 35.263" E
31	Kallugundi	48P/11	12° 29' 57.913" N	75° 32' 32.989" E
32	Karada	48P/12	12° 13' 6.222" N	75° 42' 49.658" E
33	Katakeri	48P/11	12° 25' 43.650" N	75° 42' 5.049" E
34	Kedamalluru	48P/12	12° 11' 41.101" N	75° 44' 45.599" E
35	Korangala	48P/11	12° 22' 0.778" N	75° 33' 6.733" E
36	Kottamudi	48P/11	12° 19' 31.765" N	75° 41' 53.816" E

37	Koyanad	48P/11	12° 28' 55.882" N	75° 34' 38.473" E
38	Kumbaladadalu	48P/11	12° 20' 22.787" N	75° 43' 10.940" E
39	Kunjila	48P/11	12° 15' 45.038" N	75° 39' 18.064" E
40	Made	48P/11	12° 25' 3.563" N	75° 41' 5.240" E
41	Madikeri	48P/11	12° 25' 13.441" N	75° 44' 24.112" E
42	Makandur	48P/11	12° 28' 25.383" N	75° 44' 14.986" E
43	Makutta	48P/12	12° 5' 10.224" N	75° 44' 44.011" E
44	Mallikarjuna	48P/07	12° 28' 37.161" N	75° 28' 45.568" E
45	Marandoda	48P/12	12° 14' 17.043" N	75° 40' 22.866" E
46	Mekeri	48P/11	12° 23' 29.052" N	75° 44' 22.192" E
47	Monangeri	48P/11	12° 26' 24.263" N	75° 39' 46.080" E
48	Mundrotu	48P/07	12° 19' 33.618" N	75° 26' 39.714" E
49	Naladi	48P/11	12° 15' 35.080" N	75° 37' 0.258" E
50	Napoklu	48P/11	12° 18' 21.145" N	75° 41' 18.463" E
51	Nariyandada	48P/12	12° 13' 44.060" N	75° 41' 14.300" E
52	Nelaji	48P/11	12° 18' 26.091" N	75° 38' 1.118" E
53	Olattupara	48P/12	12° 10' 57.010" N	75° 44' 17.081" E
54	Onchalla	48P/11	12° 29' 6.071" N	75° 39' 55.006" E
55	Padachikadu	48P/12	12° 9' 20.216" N	75° 43' 13.164" E
56	Palangala	48P/12	12° 11' 44.815" N	75° 42' 47.764" E
57	Panegundi	48P/07	12° 28' 13.851" N	75° 20' 46.183" E
58	Parakadavu	48P/07	12° 26' 42.706" N	75° 22' 13.680" E
59	Patane	48P/11	12° 16' 14.792" N	75° 43' 2.881" E
60	Patti	48P/07	12° 26' 9.067" N	75° 28' 52.661" E
61	Peruru	48P/11	12° 19' 34.677" N	75° 34' 46.584" E
62	Sampaje	48P/11	12° 29' 38.120" N	75° 33' 54.977" E
63	Talakaveri	48P/07	12° 23' 10.491" N	75° 29' 34.777" E
64	Thottathil	48P/07	12° 27' 23.384" N	75° 22' 41.599" E
65	Yavakapadi	48P/12	12° 13' 54.330" N	75° 38' 27.607" E

REFERENCES

Iyengar, B. R. C Geology of parts of Northern Coorg. Unpub. GSI Report of FS 1952-53

Damodaran, A. Geology of parts of Southern Coorg, Southern India. Unpub. GSI Report of FS 1951-52.

Damodaran, A. Geology of parts of Southern Coorg, Southern India. Unpub. GSI Report of FS 1952-53.

Bowman, Elisabeth T. Small Landslides – Frequent, Costly, and Manageable. In : Shroder, John F., Davies, Tim (Eds.) Landslide Hazards, Risks, and Disasters. Hazard and Disaster series. 2015.

Ghosh, S., Carranza, E.J.M., van Westen, C.J., Jetten, V.G. and Bhattacharya, D.N., 2010: Selecting and weighting spatial predictors for empirical modeling of landslide susceptibility in the Darjeeling Himalayas (India). Geomorphology, 131 (1–2): 35-56.

Guzzetti, F., Reichenbach, P., Cardinali, M., Galli, M. and Ardizzone, F., 1999: Probabilistic landslide hazard assessment at the basin scale. Geomorphology, 72 (1-4): 272-299.

Iyengar, B R C. Geology of parts of North Coorg, Southern India. Unpub. GSI Report of FS 1952-53.

Janardhana M. R., Vinutha D. N , Abdul-Aleam Ahamed Ahamed D.AL-Qadhi,: Landslides in Coorg District of Karnataka State. International Journal of Innovative Research in Science, Engineering and Technology. Vol. 5, Issue 6, June 2016.

Long and De Smedt, 2012 Application of an analytical hierarchical process approach for landslide susceptibility mapping in A Luoi district, Thua Thien Hue Province, Vietnam. Environmental Earth Sciences. v66 i7. 1739-1752.

Mishra A.K., Pradhan U.K. and Singh L.P. 2010. A report on the Landslide Hazard Zonation of Madikere town on macroscale, Coorg district, Karnataka. Unpub. GSI Report of FS 2007-2009.

Mishra A.K., Dharuman R.A., 2010. A report on the detailed site specific study of Biligeri slide, Somwarpet taluk, Coorg district, Karnataka. Unpub. GSI report of FS 2006-2007.

Maruthi, K.V., Chandran K.V., 2013. Landslide Hazard Zonation of Virajpet-Madikere-Sulya Road Section, Coorg District, Karnataka. Unpub. GSI Report of FS 2012- 2013.

Maruthi K.V, Kumar V., 2013. A note on the preliminary post disaster investigation of landslides occurred around Madikeri, Coorg District, Karnataka. Unpub. GSI reports of FS 2012-13.

NGLM Manual NRSC, Hyderabad, 2010: Manual for National Geomorphological and Lineament Mapping on 1:50,000 scale, First Edition, 2010.

Saaty, T.L., 1977: A scaling method for priorities in hierarchical structures. Journal of the Mathematical Psychology, 15 (3): 234-281.

Saaty, T.L. (1980). The Analytic Hierarchy Process. New York: McGraw-Hill.

Saaty TL, Vargas LG (2001) Models, Methods, Concepts and Applications of the Analytic Hierarchy Process. Kluwer, Dordrecht

Van Asch, Th.W.J, Malet, J.-P., Van Beek, L.P.H 2006 Influence of landslide geometry and kinematic deformation to describe the liquefaction of landslides: Some theoretical considerations. . In: Engineering geology, 88 (2006)3-4 pp. 59-69

Van Westen, C.J., Castellanos Abella, E.A. and Sekhar, L.K. (2008) Spatial data for landslide susceptibility, hazards and vulnerability assessment : an overview. In: Engineering geology, 102 (2008)3-4 pp. 112-131

Varnes, D.J., 1978. Slope movement types and processes. In: Schuster, R.L., Krizek, R.L. (Eds.), Landslides: Analysis and Control. Special Report, vol. 176. Transportation Research Board, National Academy of Sciences, Washington, DC, pp. 11–33.

Varnes, D.J., 1984. Landslide Hazard Zonation: A Review of Principles and Practice. UNESCO, Daramtiere, Paris, p. 61.

SYNOPSIS OF WORK DONE

1	**Title of the report**	Macro-Scale (1:50,000) Landslide Susceptibility Mapping In Parts Of Toposheet No. 48P/07, 11 & 12, Kodagu District, Karnataka.
2	**FSP Code No**	LSM/SR/KG/2016/109
3	**Field Season**	2016 – 17
4	**Date of Commencement**	21st October 2016
5	**Date of Completion**	17th March 2017
6	**Officers associated with the investigation and no. of days spent in the field**	Ankur Kumar Srivastava, Senior Geologist (76days) Neha Kumari., Geologist (83 days)
7	**Quantum of work done**	

1. Pre-field preparation	
(i) Slope Forming Material map	1317 sq. Km
(ii) Geomorphology & Lineament map	1317 sq. Km
(iii) Slope Morphometry (slope, aspect & curvature) map	1317 sq. Km
(iv) Landuse / Landcover map	1317 sq. Km
(v) Drainage map	1317 sq. Km
(vi) Regolith thickness map	1317 sq. Km
(vii) Preparation of Landslide Inventory Map	1317 sq. Km
2. Field-based studies	
(i) Field-checking of all thematic maps	1317 sq. Km
(ii) Field validation of landslide inventory and collection of recent and historic landslides (using archives, old reports, road register etc.)	1317 sq. Km
(iii) Collection of landslide inventory and damage data as per 41 point geo parametric data sheet	1317 sq. Km (72 nos. of landslides)
3. Post-field studies & modelling	
(i) Updation of thematic and inventory maps in GIS	1317 sq. Km
(ii) Preparation of Landslide Susceptibility Map in GIS	1317 sq. Km
(iii) Validation of landslide susceptibility map at important locations	1317 sq. Km
4. Collection of rainfall data from available rain stations	1317 sq. Km (Collected for 10 years for seven rain gauge stations)

8 **Expenditure**

Wages (Rs.)	Rs. 67,609.00
OC (Rs.)	Rs. 41,361.00
POL (Rs.)	Rs. 33,233.00
Total (Rs.)	Rs. 1,42203.00

FIVE POINT PROFORMA

Title of the report: Macro-Scale (1:50,000) Landslide Susceptibility Mapping In Parts Of Toposheet No. 48P/07, 11 & 12, Kodagu District, Karnataka.	
1. Background of the investigation at whose instance or with what particular objective in view the investigation was undertaken	The item was taken up as per the annual programme of GSI vide FSP Code No: LSM/SR/KG/2016/109 with an objective to prepare seamless Landslide Susceptibility Map of India.
2. Whether the item of investigation was included in the approved programme for the year concerned. If so, particulars, such as item No. page reference etc. may be given.	Yes FSP Code No: LSM/SR/KG/2015/099 Item No: 159
3. Date of commencement of the investigation with month and year, and exact number of days spent by the officer(s) in the field in connection with the investigation.	21st October 2016 1. Ankur Kumar Srivastava 76 days 2. Neha Kumari 83 days Total 159 days
4. Brief comments by Director / Supervisory officer on the conclusion and recommendation by the author(s) with suggestion for implementing the same.	I fully agree with the conclusions drawn and recommendations made by the authors.
5. Please state specifically how the results of the investigation were achieved compared with the objective for which it was undertaken	The objective of the investigation is fully achieved.
Date: Place: Bengaluru	Shri J. Srihari Director

PLATE - 01

LOCATION MAP OF STUDY AREA

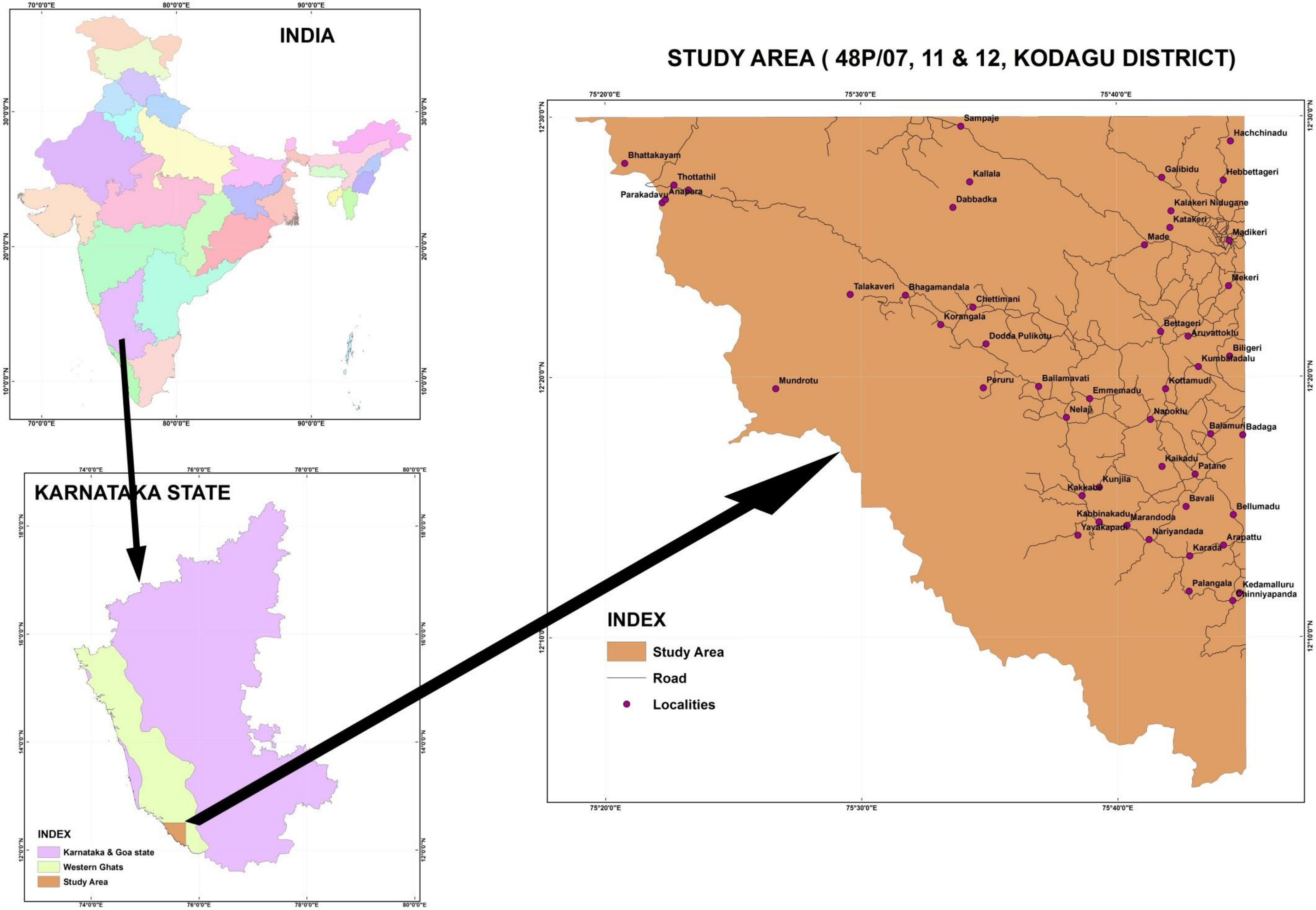
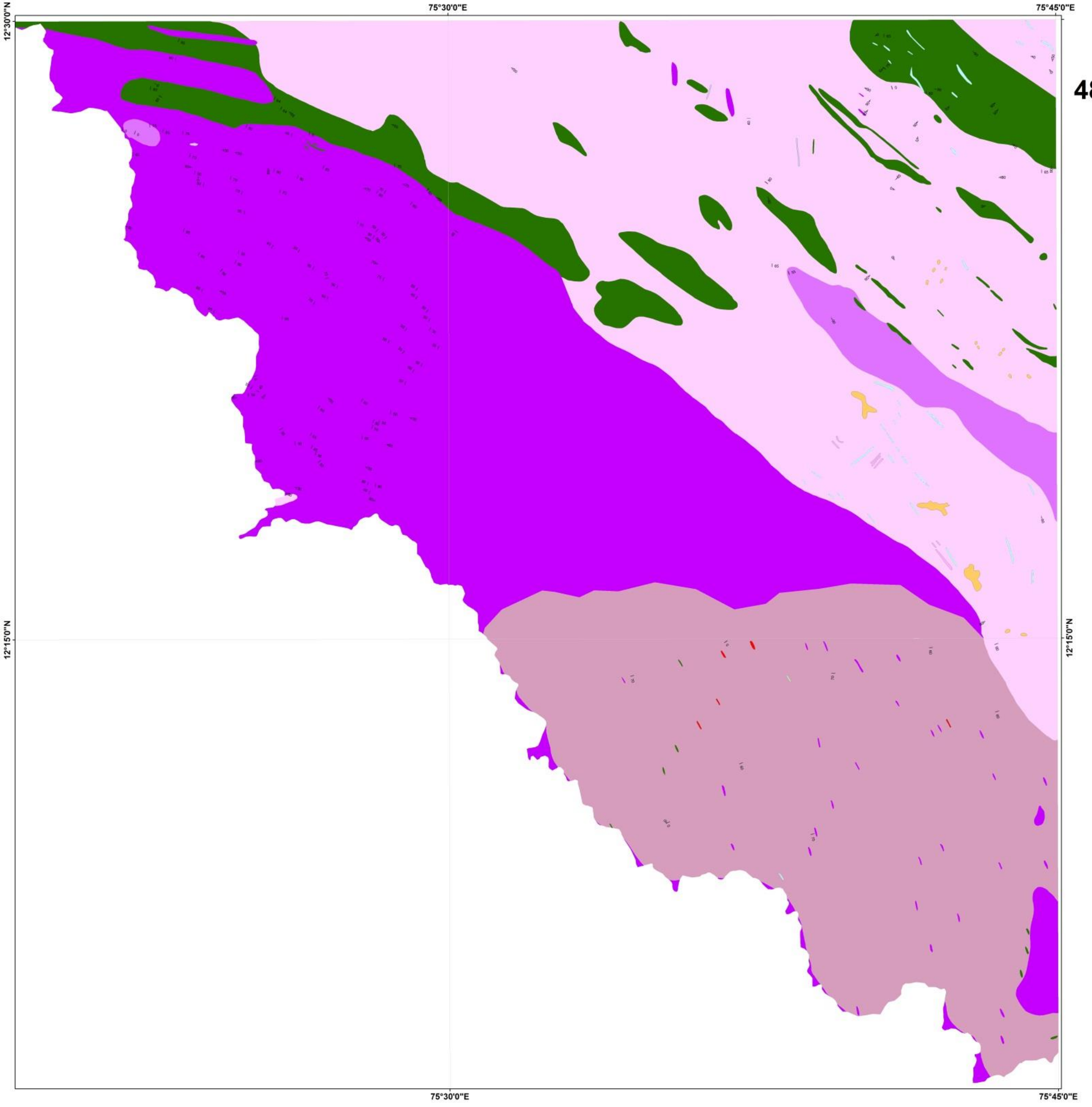
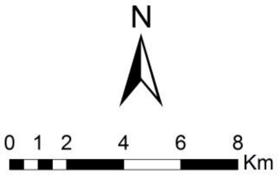


PLATE - 02

GEOLOGICAL MAP OF PARTS OF T.S. NO. 48P/07,11 & 12, KODAGU DISTRICT





INDEX

- Laterite
- Quartz vein
- Granite
- Pegmatite
- Dolerite
- Charnockite
- Calc granulite with limestone
- Granite gneiss
- Pyroxenite
- Hornblende-diopside gneiss
- Amphibolite
- Garnet-sillimanite-g... + graphite + cordierite

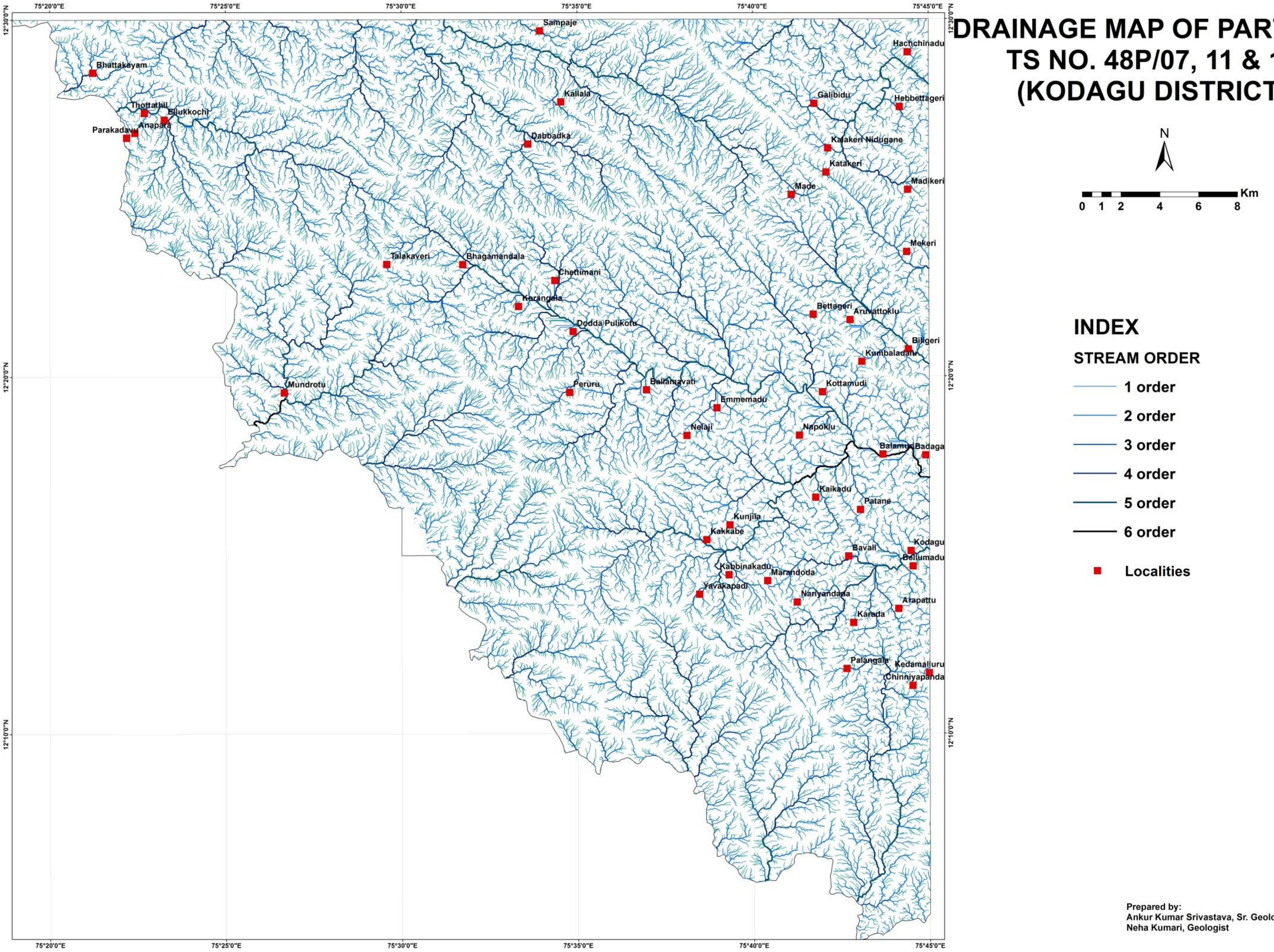
Structures

- Bedding plane
- Foliation plane
- Foliation vertical
- Joint plane
- Joint plane vertical
- Lineation

Prepared by:
GeoData Division,
GSI, Bangalore

PLATE - 03

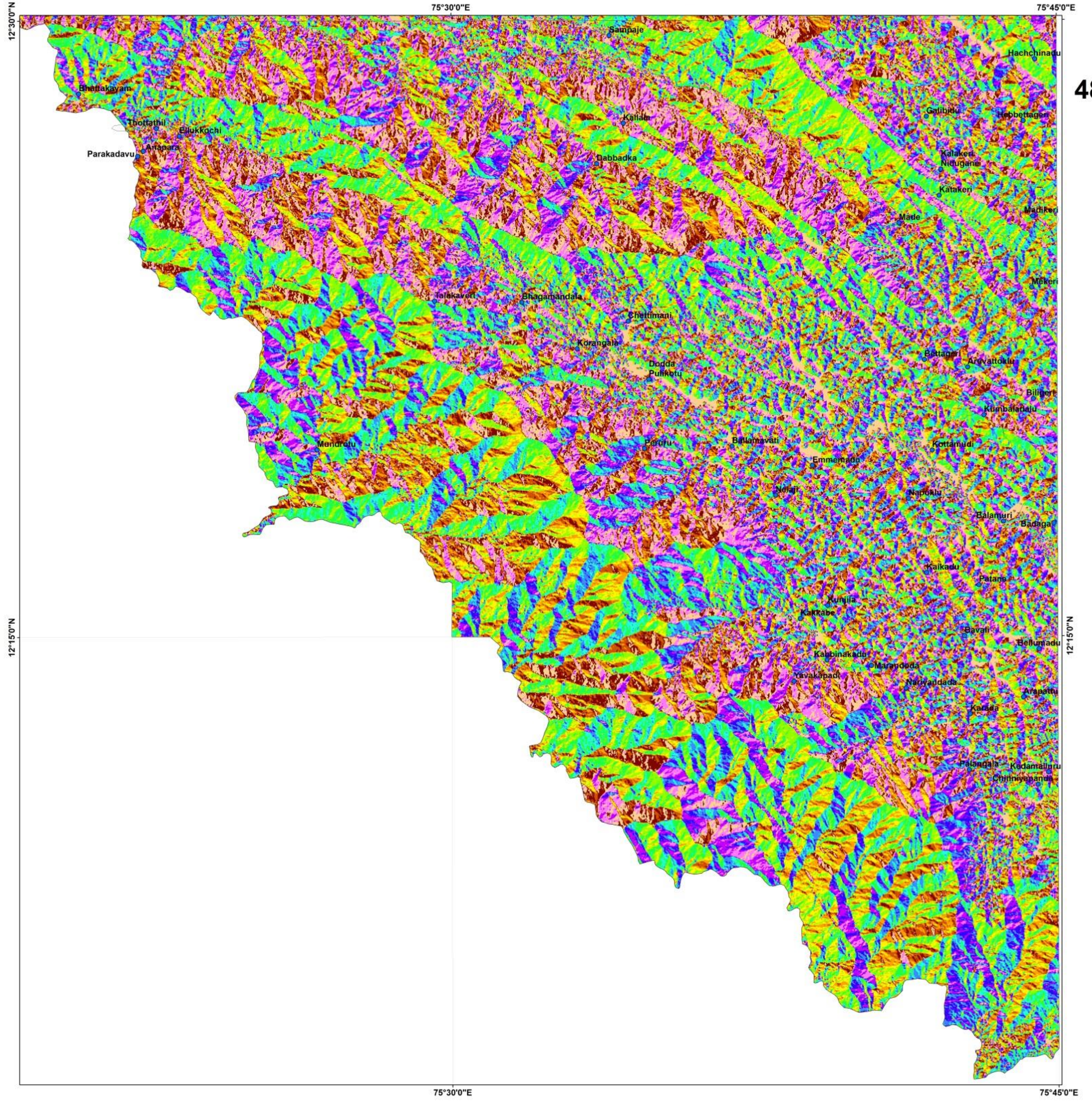
DRAINAGE MAP OF PARTS OF TS NO. 48P/07, 11 & 12 (KODAGU DISTRICT)

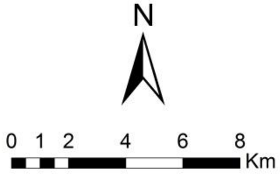


Prepared by:
Ankur Kumar Srivastava, Sr. Geologist
Neha Kumari, Geologist

PLATE - 04

SLOPE ASPECT MAP OF PARTS OF T.S. NO. 48P/07,11 & 12, KODAGU DISTRICT





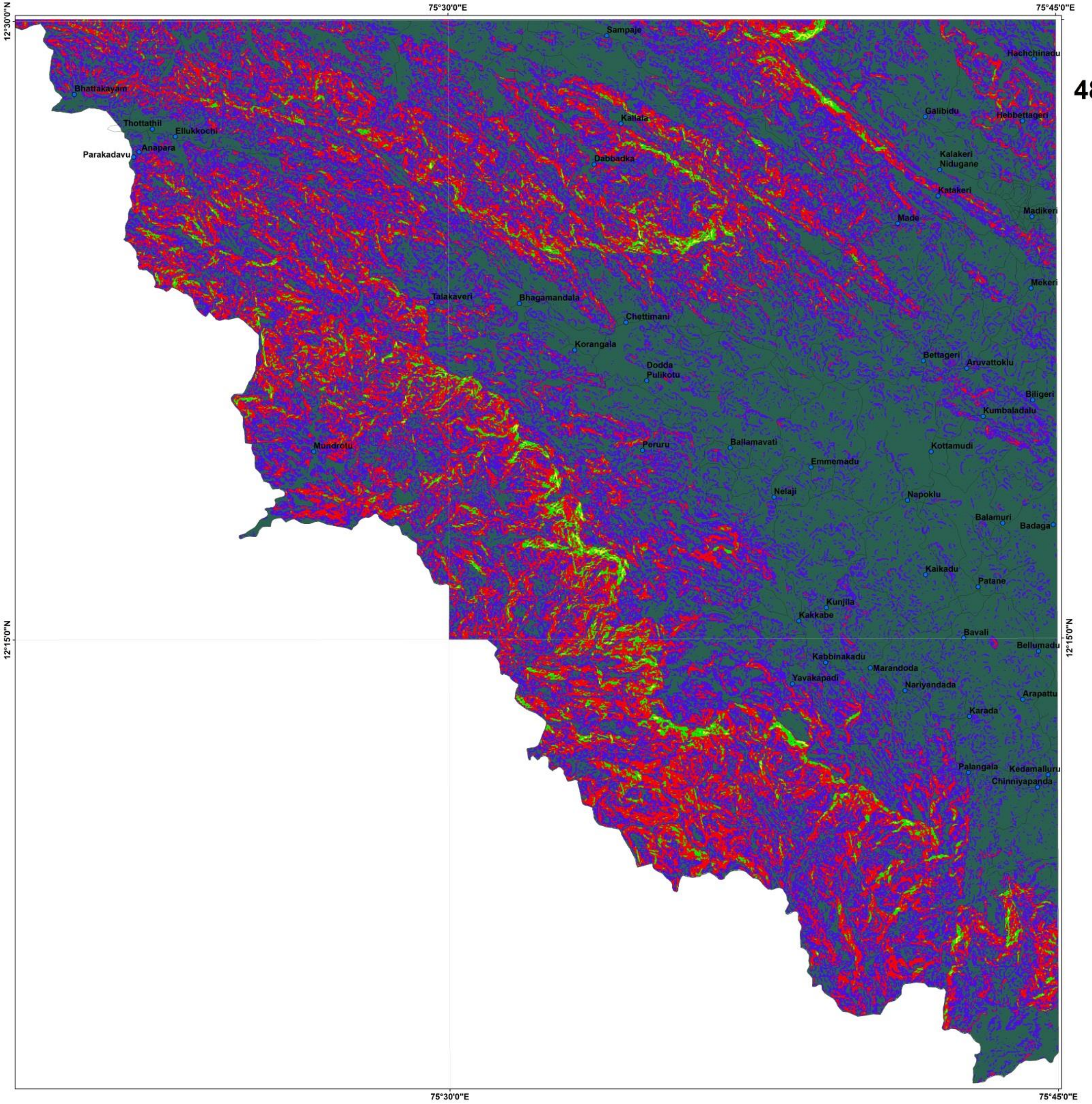
INDEX

- NNE
- NE
- ENE
- ESE
- SE
- SSE
- SSW
- SW
- WSW
- WNW
- NW
- NNW
- Localities
- Road

Prepared by:
ANKUR KUMAR SRIVASTAVA, Sr. Geologist
NEHA KUMARI, Geologist

PLATE - 05

SLOPE GRADIENT MAP OF PARTS OF T.S. NO. 48P/07,11 & 12, KODAGU DISTRICT



N

0 1 2 4 6 8 Km

INDEX

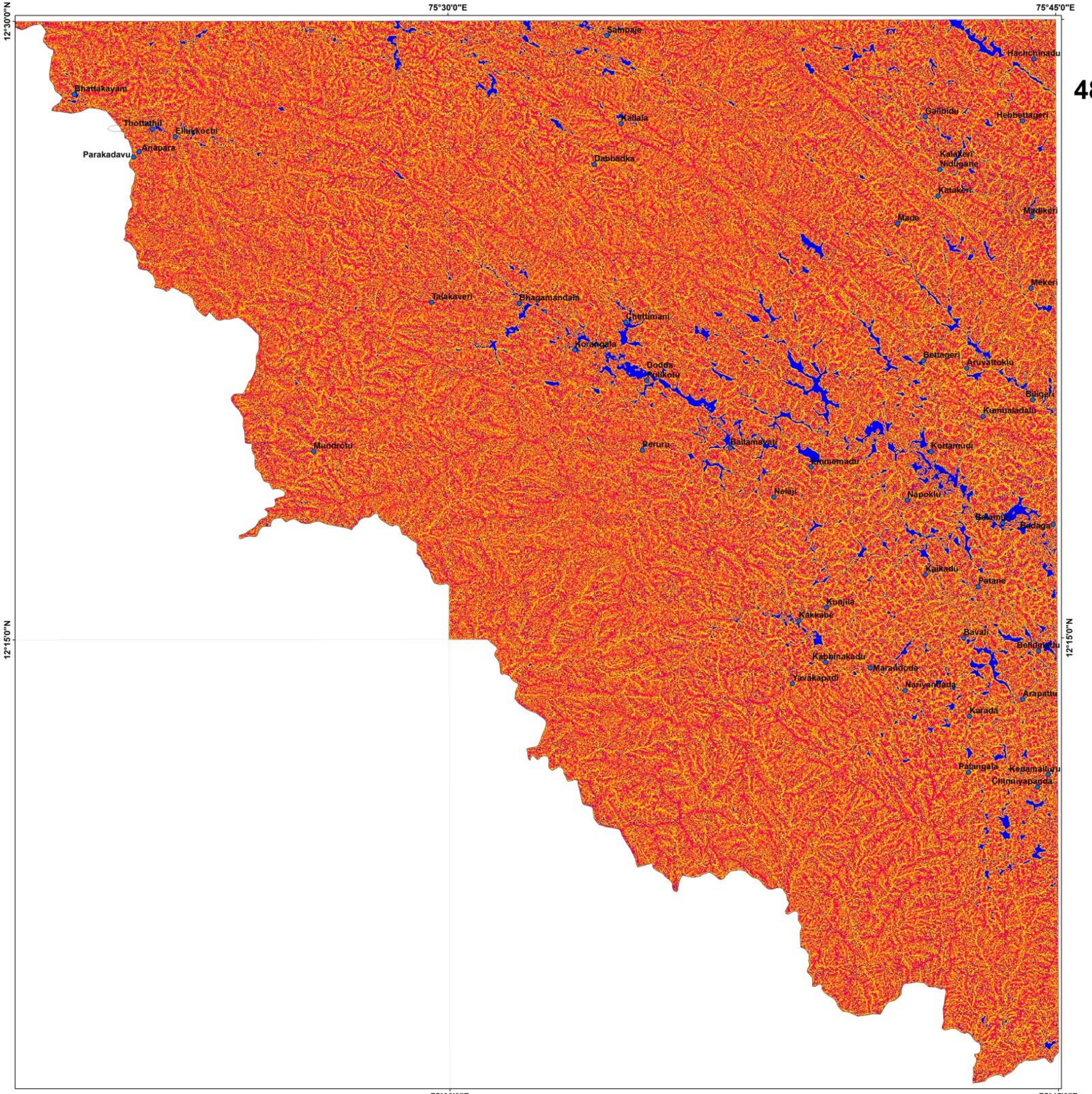
CLASS

- <15
- 15-25
- 25-35
- 35-45
- >45
- Localities
- Road

Prepared by:
ANKUR KUMAR SRIVASTAVA, Sr. Geologist
NEHA KUMARI, Geologist

PLATE - 06

SLOPE CURVATURE MAP OF PARTS OF T.S. NO. 48P/07,11 & 12, KODAGU DISTRICT



N

0 1 2 4 6 8 Km

INDEX

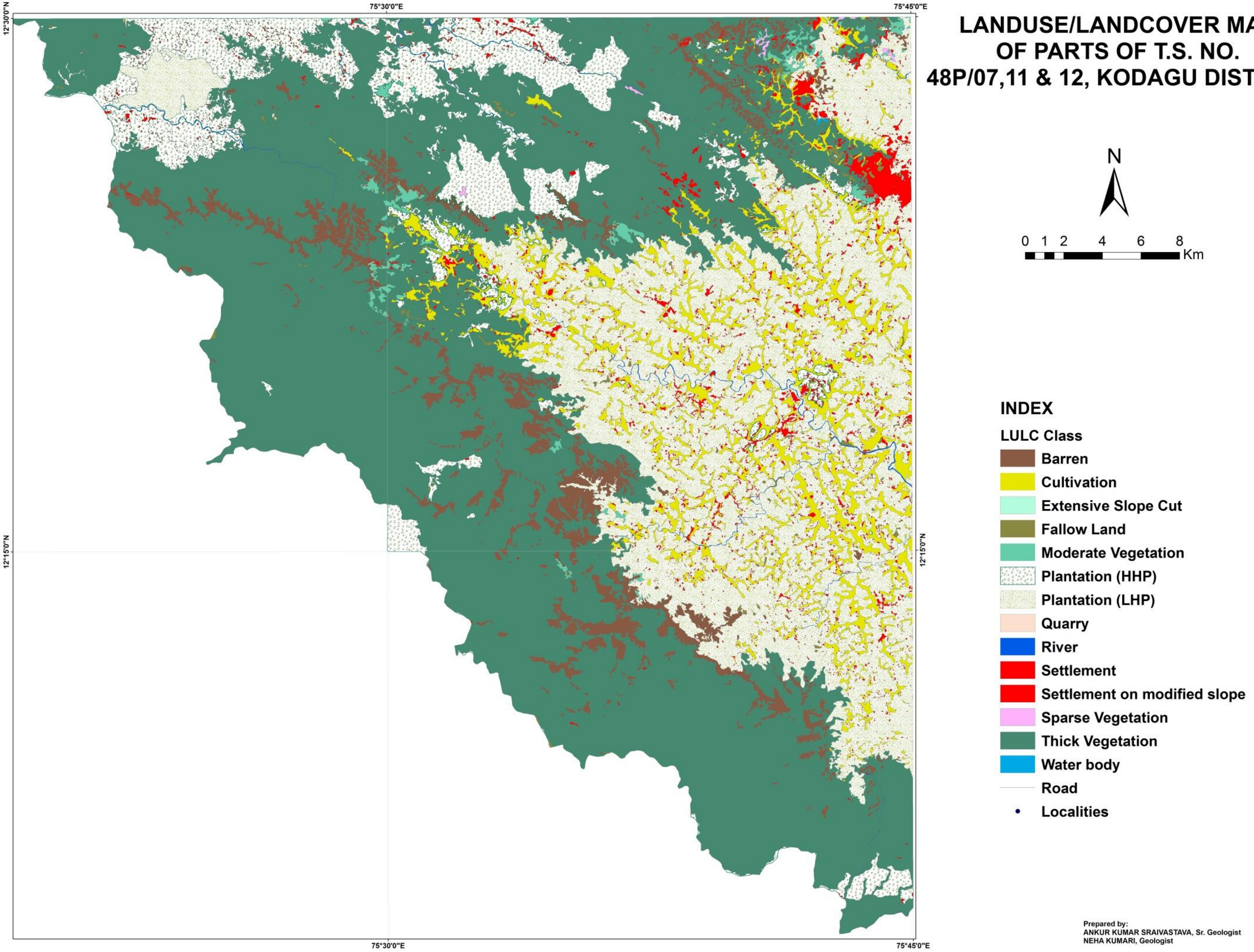
CLASS

- Concave
- Convex
- Flat
- Road
- Localities

Prepared by:
ANKUR KUMAR SRIVASTAVA, Sr. Geologist
NEHA KUMARI, Geologist

PLATE - 07

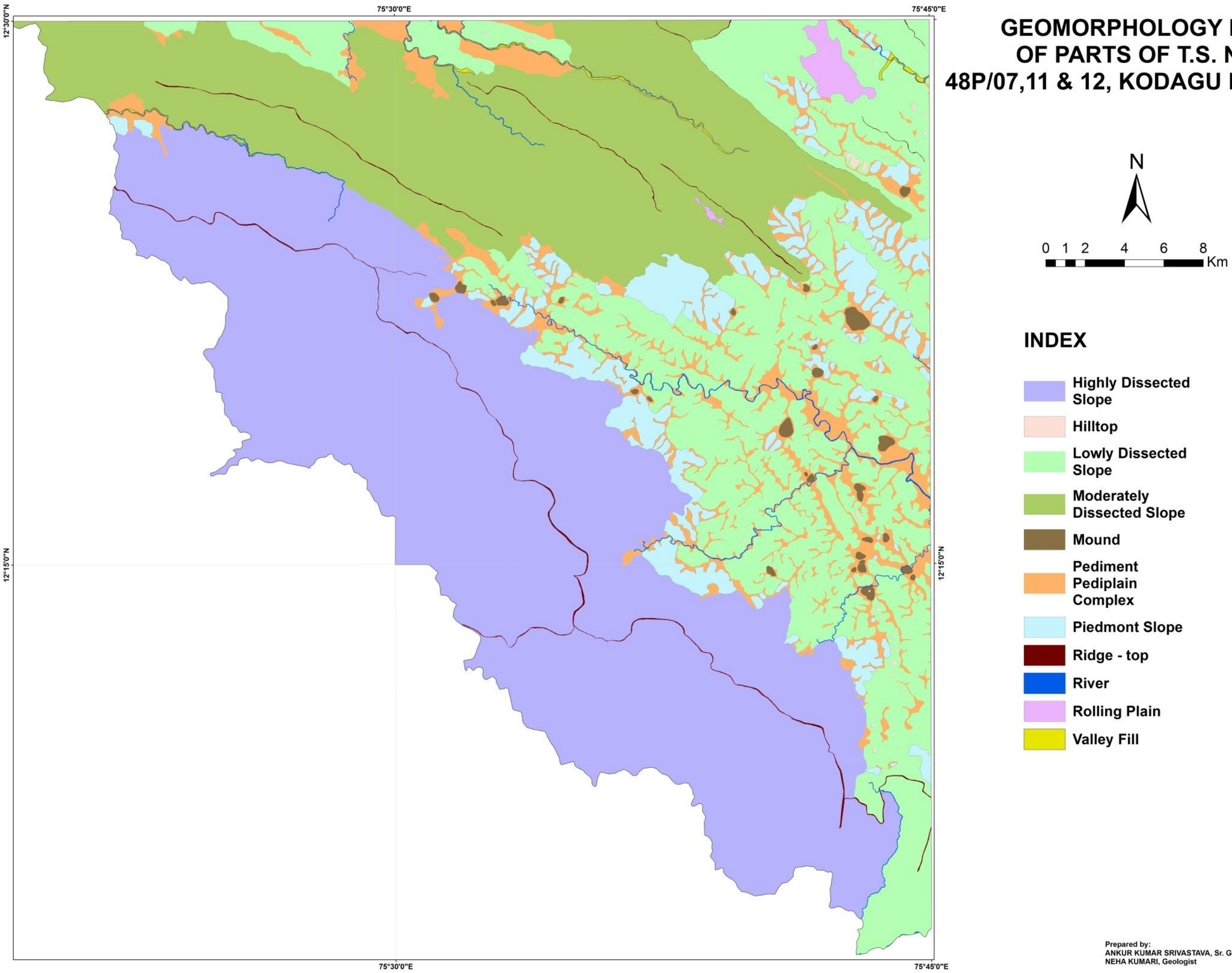
LANDUSE/LANDCOVER MAP OF PARTS OF T.S. NO. 48P/07,11 & 12, KODAGU DISTRICT



Prepared by:
ANKUR KUMAR SRAIVASTAVA, Sr. Geologist
NEHA KUMARI, Geologist

PLATE - 08

GEOMORPHOLOGY MAP OF PARTS OF T.S. NO. 48P/07,11 & 12, KODAGU DISTRICT



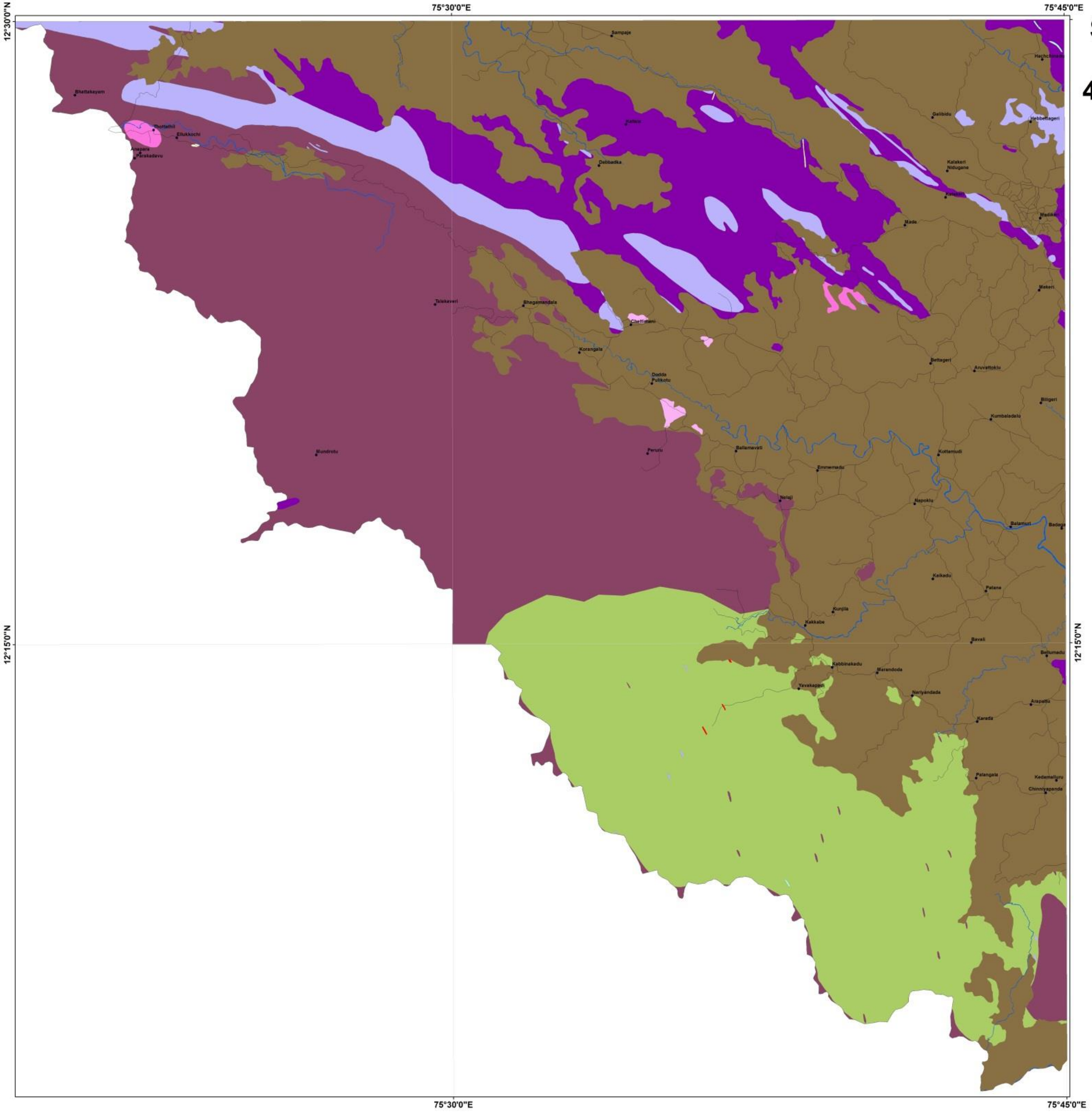
INDEX

- Highly Dissected Slope
- Hilltop
- Lowly Dissected Slope
- Moderately Dissected Slope
- Mound
- Pediment Pediplain Complex
- Piedmont Slope
- Ridge - top
- River
- Rolling Plain
- Valley Fill

Prepared by:
ANKUR KUMAR SRIVASTAVA, Sr. Geologist
NEHA KUMARI, Geologist

PLATE - 09

SLOPE FORMING MATERIAL MAP OF PARTS OF T.S. NO. 48P/07,11 & 12, KODAGU DISTRICT



N

0 1 2 4 6 8 Km

INDEX

Class

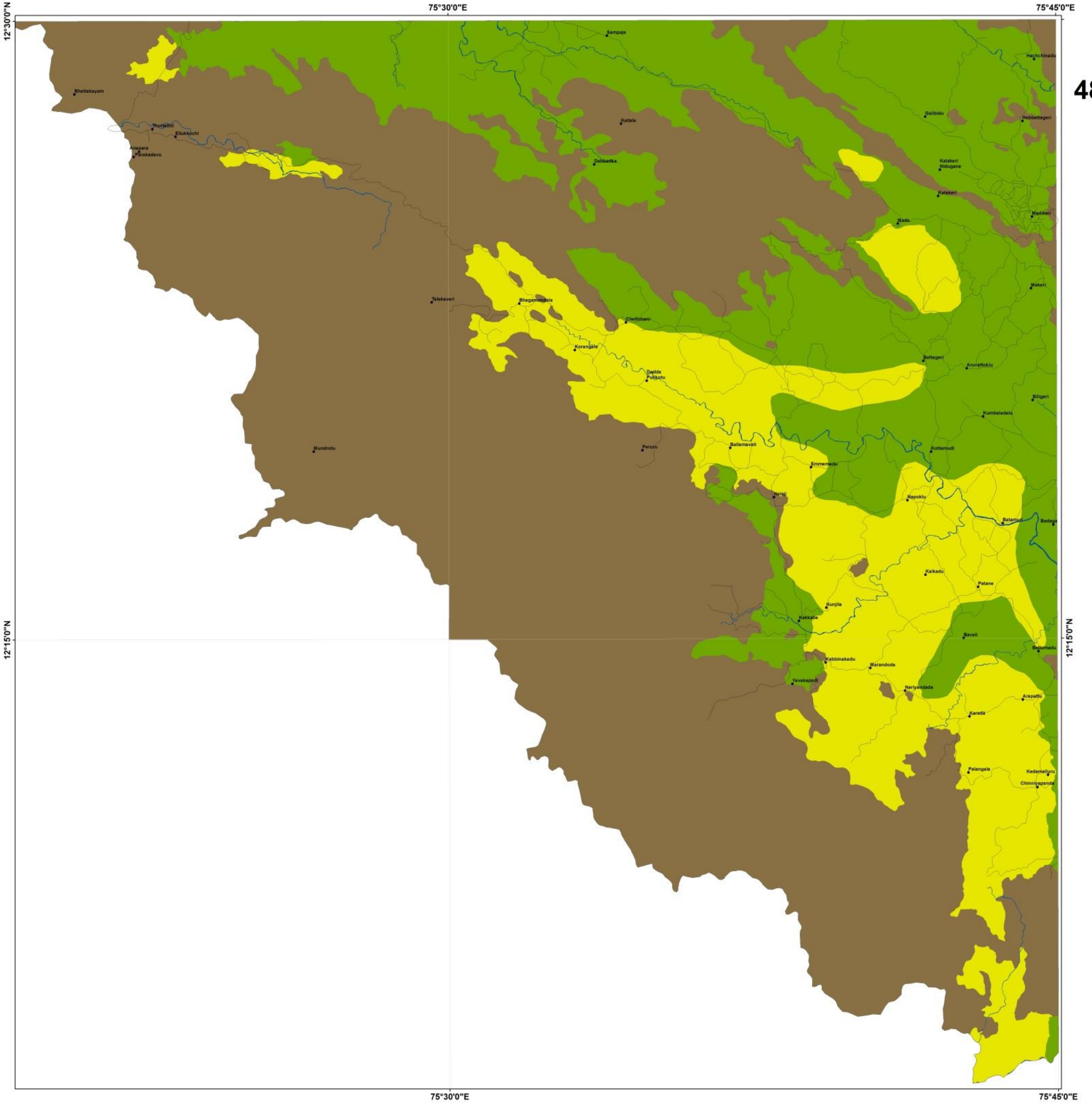
- Amphibolite
- Charnockite
- Dolerite
- Garnet-sillimanite-... + graphite + cordierite
- Granite
- Granite gneiss
- Hornblende-diopside gneiss
- In-situ soil
- Pyroxenite
- Quartz vein
- River
- Weathered Rock

- Localities
- Road

Prepared by:
ANKUR KUMAR SRIVASTAVA, Sr. Geologist
NEHA KUMARI, Geologist

PLATE - 10

REGOLITH THICKNESS MAP OF PARTS OF T.S. NO. 48P/07,11 & 12, KODAGU DISTRICT



N

0 1 2 4 6 8 Km

INDEX

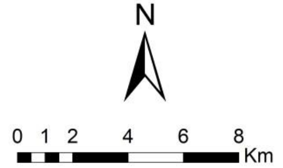
Thickness

- 0.5 - 5 m
- 5 - 10 m
- < 0.5 m
- River
- Localities
- Road

Prepared by:
ANKUR KUMAR SRIVASTAVA, Sr. Geologist
NEHA KUMARI, Geologist

PLATE - 11

LANDSLIDE INVENTORY MAP OF PARTS OF T.S. NO. 48P/07,11 & 12, KODAGU DISTRICT



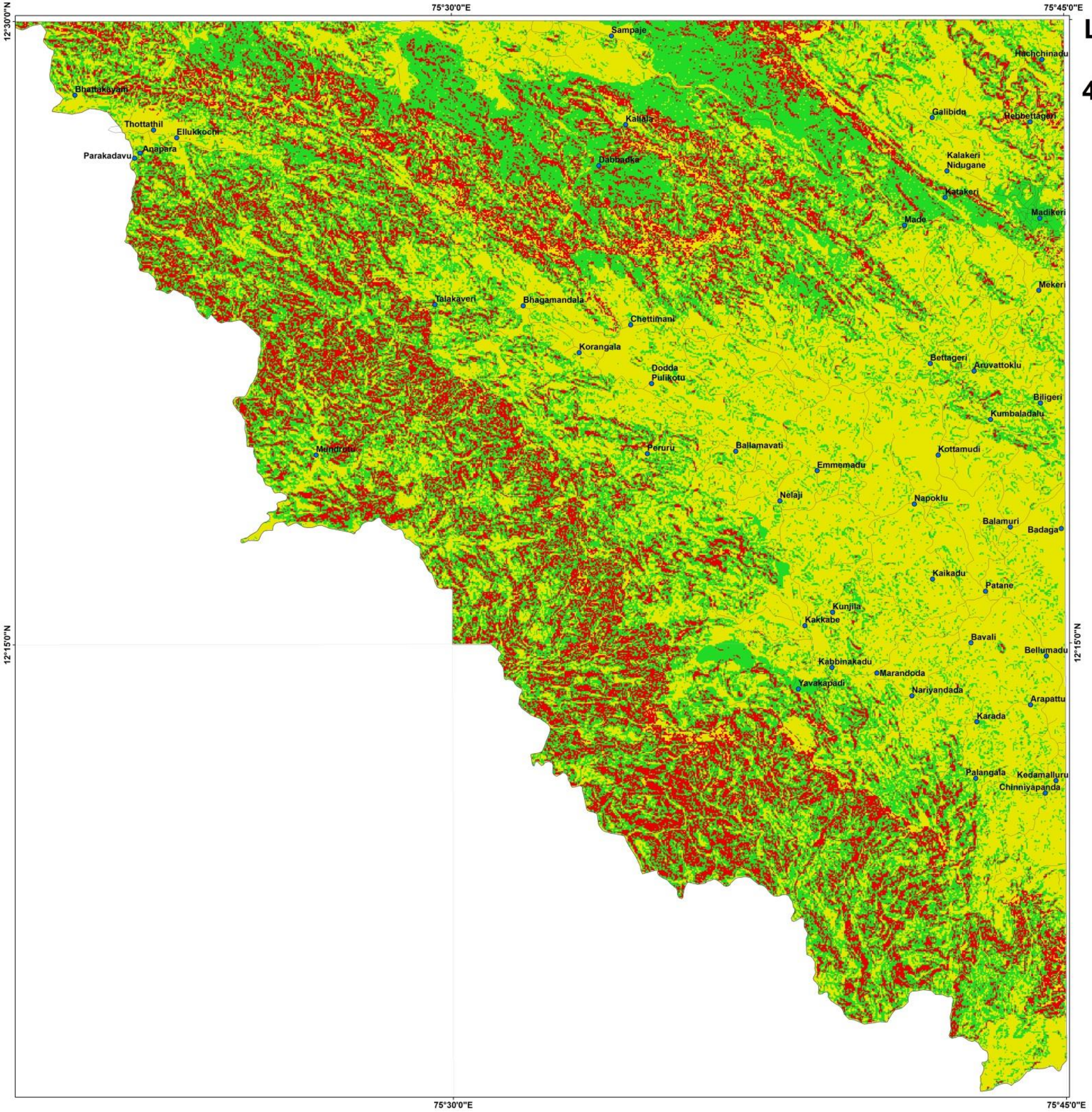
INDEX

- Landslide locations
- Localities
- Road

Prepared by:
ANKUR KUMAR SRIVASTAVA, Sr. Geologist
NEHA KUMARI, Geologist

PLATE - 12

LANDSLIDE SUSCEPTIBILITY MAP OF PARTS OF T.S. NO. 48P/07,11 & 12, KODAGU DISTRICT



N

0 1 2 4 6 8 Km

INDEX

- Low
- Moderate
- High
- Locations_P11_12_7
- Road

Prepared by:
ANKUR KUMAR SRIVASTAVA, Sr. Geologist
NEHA KUMARI, Geologist

PHOTOGRAPHS

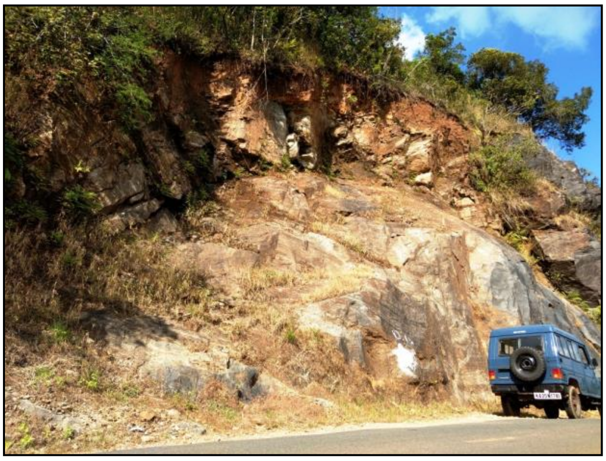


Photo: 1 Rock slide on Baghamandala – Talakaveri road, T.S. No. 48P/07.

Photo:2 Debris slide on Hacchinadu – Galibidu road, T.S. No. 48P/11.

Photo:3 Debris slide on Hacchinadu – Galibidu road, T.S. No. 48P/11.

Photo: 4 Debris slide on Talakaveri – Korangla road, T.S. No. 48P/11.

Photo:5 Old slide scar and fresh debris slide in Indiranagar, Madikeri, T.S. No. 48P/11.

Photo: 6 Small debris slide on Madikeri – Sampaje road, NH-275.

Photo:7 Landslide near Koyanadu, Madikeri – Sullya road, NH-275.

Photo:8 LULC class Cultivation, T.S No. 48P/07, near Baghamandala.

Photo:9 LULC class Extensive Cut Slope, T.S No. 48P/11, west of Made village.

Photo:10 LULC class HHP, T.S No. 48P/11, west of Sampaje village.

Photo:11 LULC class Moderate vegetation, T.S No. 48P/11, near Kattakeri village.

Photo:12 LULC class Quarry, T.S No. 48P/12, north of Tottipalam village.

Photo:13 LULC class Settlement on Modified slope, T.S No. 48P/11, Madikeri town.

Photo:14 LULC class Barren, T.S No. 48P/11, north of Made village.

Photo:15 Geomorphology class MDS, T.S No. 48P/11, West of Koyanadu village.

Photo:16 Geomorphology class LDS, T.S No. 48P/11, North of Baghamandala.

Photo:17 Geomorphology class Pediment-pediplain complex, T.S No. 48P/07, West of Talakaveri.

Photo:18 Geomorphology class Ridge top, T.S No. 48P/11, West of Koyanadu village.

Photo:19 SFM class In situ soil, T.S No. 48P/11, West of Bettegeri village.

Photo:20 SFM class Laterite (rock), T.S No. 48P/11, West of Sampaje village.

Photo:21 Regolith thickness class 5m -10m, North of Kedamullur, T.S. No.48P/12.

Photo:22 SFM class weathered rock, T.S No. 48P/11, near Korangala village.

Annexure – I: Tabular matrices for LOFS and consistency ratio calculations for six factor maps

Geofactor: Land Use Land Cover (LULC)

Rank of LULC Classes

Sl No	Class Name	Code	Rank
1	Barren	B	**1**
2	Barren Sand	BS	0
3	Cultivation	CL	**2**
4	Extensive Slope Cut	ESC	**9**
5	Fallow Land	FL	**1**
6	Moderate Vegetation	MV	**5**
7	Plantation	HHP	**4**
8	Plantation	LHP	**3**
9	Quarry	QR	**5**
10	Settlement	S	**1**
11	Settlement on modified slope	SM	**7**
12	Swamp	SW	0
13	Thick Vegetation	TV	**4**
14	Sparse Vegetation	SV	**7**
15	Water body	WB	0
16	Salt Pan	SP	0

Annexure – I: Tabular matrices for LOFS and consistency ratio calculations for six factor maps

Geofactor: Land Use Land Cover (LULC)

Matrix of Pairwise Ratings of LULC Class

LULC	B	CL	ESC	FL	MV	HHP	LHP	QR	S	SM	TV	SV
B	1.00	0.50	0.11	1.00	0.20	0.25	0.33	0.20	1.00	0.14	0.25	0.14
CL	2.00	1.00	0.13	2.00	0.25	0.33	0.50	0.25	2.00	0.17	0.33	0.17
ESC	9.00	8.00	1.00	9.00	5.00	6.00	7.00	5.00	9.00	3.00	6.00	3.00
FL	1.00	0.50	0.11	1.00	0.20	0.25	0.33	0.20	1.00	0.14	0.25	0.14
MV	5.00	4.00	0.20	5.00	1.00	2.00	3.00	1.00	5.00	0.33	2.00	0.33
HHP	4.00	3.00	0.17	4.00	0.50	1.00	2.00	0.50	4.00	0.25	1.00	0.25
LHP	3.00	2.00	0.14	3.00	0.33	0.50	1.00	0.33	3.00	0.20	0.50	0.20
QR	5.00	4.00	0.20	5.00	1.00	2.00	3.00	1.00	5.00	0.33	2.00	0.33
S	1.00	0.50	0.11	1.00	0.20	0.25	0.33	0.50	1.00	0.14	0.25	0.14
SM	7.00	6.00	0.33	7.00	3.00	4.00	5.00	3.00	7.00	1.00	4.00	1.00
TV	4.00	3.00	0.17	4.00	0.50	1.00	2.00	0.50	4.00	0.25	1.00	0.25
SV	7.00	6.00	0.33	7.00	3.00	4.00	5.00	3.00	7.00	1.00	4.00	1.00
Sum Column	**49.00**	**38.50**	**3.00**	**49.00**	**15.18**	**21.58**	**29.50**	**15.48**	**49.00**	**6.96**	**21.58**	**6.96**

Annexure – I: Tabular matrices for LOFS and consistency ratio calculations for six factor maps

Geofactor: Land Use Land Cover (LULC)

Estimated Eigen values, fraction rate and LOFS for LULC classes

LULC	B	CL	ESC	FL	MV	HHP	LHP	QR	S	SM	TV	SV	Sum Rows	Frac Weight	LOFS
B	0.0204	0.0130	0.0370	0.0204	0.0132	0.0116	0.0113	0.0129	0.0204	0.0205	0.0116	0.0205	0.2128	0.0177	0.0626
CL	0.0408	0.0260	0.0417	0.0408	0.0165	0.0154	0.0169	0.0161	0.0408	0.0239	0.0154	0.0239	0.3184	0.0265	0.0937
ESC	0.1837	0.2078	0.3332	0.1837	0.3293	0.2780	0.2373	0.3229	0.1837	0.4309	0.2780	0.4309	3.3994	0.2833	1.0000
FL	0.0204	0.0130	0.0370	0.0204	0.0132	0.0116	0.0113	0.0129	0.0204	0.0205	0.0116	0.0205	0.2128	0.0177	0.0626
MV	0.1020	0.1039	0.0666	0.1020	0.0659	0.0927	0.1017	0.0646	0.1020	0.0479	0.0927	0.0479	0.9899	0.0825	0.2912
HHP	0.0816	0.0779	0.0555	0.0816	0.0329	0.0463	0.0678	0.0323	0.0816	0.0359	0.0463	0.0359	0.6759	0.0563	0.1988
LHP	0.0612	0.0519	0.0476	0.0612	0.0220	0.0232	0.0339	0.0215	0.0612	0.0287	0.0232	0.0287	0.4644	0.0387	0.1366
QR	0.1020	0.1039	0.0666	0.1020	0.0659	0.0927	0.1017	0.0646	0.1020	0.0479	0.0927	0.0479	0.9899	0.0825	0.2912
S	0.0204	0.0130	0.0370	0.0204	0.0132	0.0116	0.0113	0.0323	0.0204	0.0205	0.0116	0.0205	0.2322	0.0194	0.0683
SM	0.1429	0.1558	0.1111	0.1429	0.1976	0.1853	0.1695	0.1938	0.1429	0.1436	0.1853	0.1436	1.9143	0.1595	0.5631
TV	0.0816	0.0779	0.0555	0.0816	0.0329	0.0463	0.0678	0.0323	0.0816	0.0359	0.0463	0.0359	0.6759	0.0563	0.1988
SV	0.1429	0.1558	0.1111	0.1429	0.1976	0.1853	0.1695	0.1938	0.1429	0.1436	0.1853	0.1436	1.9143	0.1595	0.5631

Annexure – I: Tabular matrices for LOFS and consistency ratio calculations for six factor maps

Geofactor: Land Use Land Cover (LULC)

Estimation of consistency vector (CV), consistency index (CI) and consistency ratio (CR) for LULC classes

LULC	B	CL	ESC	FL	MV	HHP	LHP	QR	S	SM	TV	SV	Sum Rows	CV
B	0.0177	0.0133	0.0315	0.0177	0.0165	0.0141	0.0129	0.0165	0.0194	0.0228	0.0141	0.0228	0.2192	12.3591
CL	0.0355	0.0265	0.0354	0.0355	0.0206	0.0188	0.0193	0.0206	0.0387	0.0266	0.0188	0.0266	0.3229	12.1696
ESC	0.1596	0.2123	0.2833	0.1596	0.4125	0.3379	0.2709	0.4125	0.1742	0.4786	0.3379	0.4786	3.7177	13.1239
FL	0.0177	0.0133	0.0315	0.0177	0.0165	0.0141	0.0129	0.0165	0.0194	0.0228	0.0141	0.0228	0.2192	12.3591
MV	0.0887	0.1061	0.0567	0.0887	0.0825	0.1126	0.1161	0.0825	0.0968	0.0532	0.1126	0.0532	1.0496	12.7240
HHP	0.0709	0.0796	0.0472	0.0709	0.0412	0.0563	0.0774	0.0412	0.0774	0.0399	0.0563	0.0399	0.6984	12.4001
LHP	0.0532	0.0531	0.0405	0.0532	0.0275	0.0282	0.0387	0.0275	0.0581	0.0319	0.0282	0.0319	0.4718	12.1921
QR	0.0887	0.1061	0.0567	0.0887	0.0825	0.1126	0.1161	0.0825	0.0968	0.0532	0.1126	0.0532	1.0496	12.7240
S	0.0177	0.0133	0.0315	0.0177	0.0165	0.0141	0.0129	0.0412	0.0194	0.0228	0.0141	0.0228	0.2439	12.6068
SM	0.1241	0.1592	0.0944	0.1241	0.2475	0.2253	0.1935	0.2475	0.1355	0.1595	0.2253	0.1595	2.0954	13.1358
TV	0.0709	0.0796	0.0472	0.0709	0.0412	0.0563	0.0774	0.0412	0.0774	0.0399	0.0563	0.0399	0.6984	12.4001
SV	0.1241	0.1592	0.0944	0.1241	0.2475	0.2253	0.1935	0.2475	0.1355	0.1595	0.2253	0.1595	2.0954	13.1358
Sum CV														151.33
Mean Consistency Vector (Mean CV) = Total CV/ Nos. Of factor class (151.33/12) =														12.6109
Consistency Index (CI) = (Mean CV - No. Of criteria/ factor class) / (No. Of factor class - 1) =														0.0555
Consistency Ratio (CR) = CI/ RI = 0.0555 / 1.49 =														0.0373

Annexure – I: Tabular matrices for LOFS and consistency ratio calculations for six factor maps

Geofactor: Geomorphology

Rank of Geomorphology Classes

Sl No	Class Name	Code	Rank
1	Denudational Slope	DS	**9**
2	Escarpment	ESC	**2**
3	Mound	MOUND	**2**
4	Colluvial Foot Slope	CFS	**3**
5	Lowly Dissected Slope	LDS	**4**
6	Moderately Dissected Slope	MDS	**6**
7	Highly Dissected Slope	HDS	**8**
8	Piedmont Slope	PIED SLOPE	**4**
9	Ridge - top	RT	0
10	Tidal Flat	TF	0
11	Colluvial Plain	CP	0
12	Plateau Top (Flat)	PT	0
13	Rolling Plain	RP	0
14	Valley Fill	VF	0
15	Alluvial Plain	AP	0
16	Beach	BE	0
17	Pediment – Pediplain Complex	PPC	0
18	Hilltop	HT	0
19	Water body	WB	0

Annexure – I: Tabular matrices for LOFS and consistency ratio calculations for six factor maps

Geofactor: Geomorphology

Matrix of Pairwise Ratings of Geomorphology Class

GEOM	DS	ESC	MOUND	CFS	LDS	MDS	HDS	PIED SLOPE
DS	1.00	8.00	8.00	7.00	6.00	4.00	2.00	6.00
ESC	0.13	1.00	1.00	0.50	0.33	0.20	0.14	0.33
MOUND	0.13	1.00	1.00	0.50	0.33	0.20	0.14	0.33
CFS	0.14	2.00	2.00	1.00	0.50	0.25	0.17	0.50
LDS	0.17	3.00	3.00	2.00	1.00	0.33	0.20	1.00
MDS	0.25	5.00	5.00	4.00	3.00	1.00	0.33	3.00
HDS	0.50	7.00	7.00	6.00	5.00	3.00	1.00	5.00
PIED SLOPE	0.17	3.00	3.00	2.00	1.00	0.33	0.20	1.00
Sum Column	**2.48**	**30.00**	**30.00**	**23.00**	**17.17**	**9.32**	**4.19**	**17.17**

Estimated Eigen values, fraction rate and LOFS for Geomorphology classes

GEOM	DS	ESC	MOUND	CFS	LDS	MDS	HDS	PIED SLOPE	Sum Rows	Frac Weight	LOFS
DS	0.4038	0.2667	0.2667	0.3043	0.3495	0.4293	0.4778	0.3495	2.8477	0.3560	1.0000
ESC	0.0505	0.0333	0.0333	0.0217	0.0194	0.0215	0.0341	0.0194	0.2333	0.0292	0.0819
MOUND	0.0505	0.0333	0.0333	0.0217	0.0194	0.0215	0.0341	0.0194	0.2333	0.0292	0.0819
CFS	0.0577	0.0667	0.0667	0.0435	0.0291	0.0268	0.0398	0.0291	0.3594	0.0449	0.1262
LDS	0.0673	0.1000	0.1000	0.0870	0.0583	0.0358	0.0478	0.0583	0.5543	0.0693	0.1947
MDS	0.1010	0.1667	0.1667	0.1739	0.1748	0.1073	0.0796	0.1748	1.1447	0.1431	0.4020
HDS	0.2019	0.2333	0.2333	0.2609	0.2913	0.3220	0.2389	0.2913	2.0729	0.2591	0.7279
PIED SLOPE	0.0673	0.1000	0.1000	0.0870	0.0583	0.0358	0.0478	0.0583	0.5543	0.0693	0.1947

Annexure – I: Tabular matrices for LOFS and consistency ratio calculations for six factor maps

Geofactor: Geomorphology

Estimation of consistency vector (CV), consistency index (CI) and consistency ratio (CR) for Geomorphology classes

GEOM	DS	ESC	MOUND	CFS	LDS	MDS	HDS	PIED SLOPE	Sum Rows	CV
DS	0.3560	0.2333	0.2333	0.3145	0.4157	0.5723	0.5182	0.4157	3.0591	8.5940
ESC	0.0445	0.0292	0.0292	0.0225	0.0231	0.0286	0.0370	0.0231	0.2371	8.1302
MOUND	0.0445	0.0292	0.0292	0.0225	0.0231	0.0286	0.0370	0.0231	0.2371	8.1302
CFS	0.0509	0.0583	0.0583	0.0449	0.0346	0.0358	0.0432	0.0346	0.3607	8.0284
LDS	0.0593	0.0875	0.0875	0.0899	0.0693	0.0477	0.0518	0.0693	0.5623	8.1146
MDS	0.0890	0.1458	0.1458	0.1797	0.2079	0.1431	0.0864	0.2079	1.2055	8.4253
HDS	0.1780	0.2042	0.2042	0.2696	0.3465	0.4293	0.2591	0.3465	2.2371	8.6338
PIED SLOPE	0.0593	0.0875	0.0875	0.0899	0.0693	0.0477	0.0518	0.0693	0.5623	8.1146
Sum CV										66.1711
Mean Consistency Vector (Mean CV) = Total CV/ Nos. Of factor class (66.1711/8) =										8.2714
Consistency Index (CI) = (Mean CV - No. Of criteria/ factor class) / (No. Of factor class - 1) =										0.0388
Consistency Ratio (CR) = CI/ RI = 0.0388 / 1.41 =										0.0275

Annexure – I: Tabular matrices for LOFS and consistency ratio calculations for six factor maps

Geofactor: Slope Forming Material (SFM)

Rank of SFM Classes

Sl No	Class Name	Code	Rank
1	Compact Slide Debris	CSD	**3**
2	In – situ Soil	IS	**4**
3	Colluvium	CL	**5**
4	Loose Slide Debris	LSD	**8**
5	Rock Class Type – I	R - I	**1**
6	Rock Class Type – II	R - II	**2**
7	Rock Class Type – III	R - III	**4**
8	Transported Soil	TS	**3**
9	Weathered Rock	WR	**6**
10	Salt	SL	0
11	Water	WT	0
12	Alluvium	AL	0
13	Barren Sand	BS	0

Annexure – I: Tabular matrices for LOFS and consistency ratio calculations for six factor maps

Geofactor: Slope Forming Material (SFM)

Matrix of Pairwise Ratings of SFM Class

SFM	CSD	IS	CL	LSD	R – I	R – II	R – III	TS	WR
CSD	1.00	0.50	0.33	0.17	3.00	2.00	0.50	1.00	0.25
IS	2.00	1.00	0.50	0.20	4.00	3.00	1.00	2.00	0.33
CL	3.00	2.00	1.00	0.25	5.00	4.00	2.00	3.00	0.50
LSD	6.00	5.00	4.00	1.00	8.00	7.00	5.00	6.00	3.00
R - I	0.33	0.25	0.20	0.13	1.00	0.50	0.25	0.33	0.17
R - II	0.50	0.33	0.25	0.14	2.00	1.00	0.33	0.50	0.20
R - III	2.00	1.00	0.50	0.20	4.00	3.00	1.00	2.00	0.33
TS	1.00	0.50	0.33	0.17	3.00	2.00	0.50	1.00	0.25
WR	4.00	3.00	2.00	0.33	6.00	5.00	3.00	4.00	1.00
Sum Column	**19.83**	**13.58**	**9.12**	**2.58**	**36.00**	**27.50**	**13.58**	**19.83**	**6.03**

Estimated Eigen values, fraction rate and LOFS for SFM classes

SFM	CSD	IS	CL	LSD	R – I	R – II	R – III	TS	WR	Sum Rows	Frac Weight	LOFS
CSD	0.0504	0.0368	0.0366	0.0645	0.0833	0.0727	0.0368	0.0504	0.0414	0.4730	0.0526	0.1506
IS	0.1008	0.0736	0.0548	0.0774	0.1111	0.1091	0.0736	0.1008	0.0552	0.7566	0.0841	0.2409
CL	0.1513	0.1472	0.1097	0.0967	0.1389	0.1455	0.1472	0.1513	0.0829	1.1706	0.1301	0.3727
LSD	0.3025	0.3681	0.4388	0.3869	0.2222	0.2545	0.3681	0.3025	0.4972	3.1409	0.3490	1.0000
R - I	0.0168	0.0184	0.0219	0.0484	0.0278	0.0182	0.0184	0.0168	0.0276	0.2143	0.0238	0.0682
R - II	0.0252	0.0245	0.0274	0.0553	0.0556	0.0364	0.0245	0.0252	0.0331	0.3073	0.0341	0.0978
R - III	0.1008	0.0736	0.0548	0.0774	0.1111	0.1091	0.0736	0.1008	0.0552	0.7566	0.0841	0.2409
TS	0.0504	0.0368	0.0366	0.0645	0.0833	0.0727	0.0368	0.0504	0.0414	0.4730	0.0526	0.1506
WR	0.2017	0.2209	0.2194	0.1290	0.1667	0.1818	0.2209	0.2017	0.1657	1.7077	0.1897	0.5437

Annexure – I: Tabular matrices for LOFS and consistency ratio calculations for six factor maps

Geofactor: Slope Forming Material (SFM)

Estimation of consistency vector (CV), consistency index (CI) and consistency ratio (CR) for SFM classes

SFM	CSD	IS	CL	LSD	R – I	R – II	R – III	TS	WR	Sum Rows	CV
CSD	0.078834	0.06305	0.065035	0.087248	0.107155	0.102422	0.06305	0.078834	0.071153	0.716781	9.09223
IS	0.157669	0.1261	0.097553	0.104697	0.142873	0.153632	0.1261	0.157669	0.09487	1.161163	9.208286
CL	0.236503	0.2522	0.195106	0.130872	0.178592	0.204843	0.2522	0.236503	0.142305	1.829123	9.375031
LSD	0.473007	0.630499	0.780423	0.523486	0.285746	0.358475	0.630499	0.473007	0.853831	5.008973	9.568486
R - I	0.026278	0.031525	0.039021	0.065436	0.035718	0.025605	0.031525	0.026278	0.047435	0.328822	9.205977
R - II	0.039417	0.042033	0.048776	0.074784	0.071437	0.051211	0.042033	0.039417	0.056922	0.466031	9.100245
R - III	0.157669	0.1261	0.097553	0.104697	0.142873	0.153632	0.1261	0.157669	0.09487	1.161163	9.208286
TS	0.078834	0.06305	0.065035	0.087248	0.107155	0.102422	0.06305	0.078834	0.071153	0.716781	9.09223
WR	0.315338	0.378299	0.390212	0.174495	0.21431	0.256054	0.378299	0.315338	0.28461	2.706955	9.511097
Sum CV											83.36187
Mean Consistency Vector (Mean CV) = Total CV/ Nos. Of factor class (83.36187/9) =											9.26243
Consistency Index (CI) = (Mean CV - No. Of criteria/ factor class) / (No. Of factor class - 1) =											0.032804
Consistency Ratio (CR) = CI/ RI = 0.032804/ 1.45 =											0.022623

Annexure – I: Tabular matrices for LOFS and consistency ratio calculations for six factor maps

Geofactor: Regolith Thickness

Rank of Regolith Thickness Classes

Sl No	Class Name	Code	Rank
1	< 0.5 m	< 0.5 m	0
2	0.5 m – 5 m	0.5 m – 5 m	**7**
3	5 m – 10 m	5 m – 10 m	**4**
4	> 10 m	> 10 m	**2**

Matrix of Pairwise Ratings of Regolith Thickness Class

Regolith Thickness	0.5 – 5 m	5 – 10 m	> 10 m
0.5 – 5 m	1.00	4.00	6.00
5 – 10 m	0.25	1.00	3.00
> 10 m	0.17	0.33	1.00
Sum Column	**1.42**	**5.33**	**10.00**

Annexure – I: Tabular matrices for LOFS and consistency ratio calculations for six factor maps

Geofactor: Regolith Thickness

Estimated Eigen values, fraction rate and LOFS for Regolith Thickness classes

Regolith Thickness	0.5 – 5 m	5 – 10 m	> 10 m	Sum Rows	Frac Weight	LOFS
0.5 – 5 m	0.705882	0.75	0.6	2.055882	0.685294	1.0000
5 – 10 m	0.176471	0.1875	0.3	0.663971	0.221324	0.3230
> 10 m	0.117647	0.0625	0.1	0.280147	0.093382	0.1363

Estimation of consistency vector (CV), consistency index (CI) and consistency ratio (CR) for Regolith Thickness classes

Regolith Thickness	0.5 – 5 m	5 – 10 m	> 10 m	Sum Rows	CV
0.5 – 5 m	0.685294	0.885294	0.560294	2.130882	3.109442
5 – 10 m	0.171324	0.221324	0.280147	0.672794	3.039867
> 10 m	0.114216	0.073775	0.093382	0.281373	3.013123
Sum CV					9.162433
Mean Consistency Vector (Mean CV) = Total CV/ Nos. Of factor class (9.162433/3) =					3.054144
Consistency Index (CI) = (Mean CV - No. Of criteria/ factor class) / (No. Of factor class - 1) =					0.027072
Consistency Ratio (CR) = CI/ RI = 0.027072 / 0.58 =					0.0467

Annexure – I: Tabular matrices for LOFS and consistency ratio calculations for six factor maps

Geofactor: Slope Angle

Rank of Slope Angle Classes

Sl No	Class Name	Code	Rank
1	< 15°	< 15°	**4**
2	15° - 25°	15° - 25°	**6**
3	25° - 35°	25° - 35°	**8**
4	35° - 45°	35° - 45°	**5**
5	> 45°	> 45°	**4**

Matrix of Pairwise Ratings of Slope Angle Class

Slope Class	< 15°	15° - 25°	25° - 35°	35° - 45°	> 45°
< 15°	1.00	0.33	0.20	0.50	1.00
15° - 25°	3.00	1.00	0.33	2.00	3.00
25° - 35°	5.00	3.00	1.00	4.00	5.00
35° - 45°	2.00	0.50	0.25	1.00	2.00
> 45°	1.00	0.33	0.20	0.50	1.00
Sum Column	**12.00**	**5.17**	**1.98**	**8.00**	**12.00**

Annexure – I: Tabular matrices for LOFS and consistency ratio calculations for six factor maps

Geofactor: Slope Angle

Estimated Eigen values, fraction rate and LOFS for Slope Angle classes

Slope Class	< 15°	15° - 25°	25° - 35°	35° - 45°	> 45°	Sum Rows	Frac Weight	LOFS
< 15°	0.083333333	0.064516129	0.100840336	0.0625	0.083333333	0.394523132	0.078904626	0.1631
15° - 25°	0.25	0.193548387	0.168067227	0.25	0.25	1.111615614	0.222323123	0.4597
25° - 35°	0.416666667	0.580645161	0.504201681	0.5	0.416666667	2.418180175	0.483636035	1.0000
35° - 45°	0.166666667	0.096774194	0.12605042	0.125	0.166666667	0.681157947	0.136231589	0.2817
> 45°	0.083333333	0.064516129	0.100840336	0.0625	0.083333333	0.394523132	0.078904626	0.1631

Estimation of consistency vector (CV), consistency index (CI) and consistency ratio (CR) for Slope Angle classes

Slope Class	< 15°	15° - 25°	25° - 35°	35° - 45°	> 45°	Sum Rows	CV
< 15°	0.078904626	0.074107708	0.096727207	0.068115795	0.078904626	0.396759962	5.028348531
15° - 25°	0.236713879	0.222323123	0.161212012	0.272463179	0.236713879	1.129426072	5.080110684
25° - 35°	0.394523132	0.666969368	0.483636035	0.544926358	0.394523132	2.484578025	5.13728888
35° - 45°	0.157809253	0.111161561	0.120909009	0.136231589	0.157809253	0.683920665	5.02027957
> 45°	0.078904626	0.074107708	0.096727207	0.068115795	0.078904626	0.396759962	5.028348531
Sum CV							**25.29438**
Mean Consistency Vector (Mean CV) = Total CV/ Nos. Of factor class (25.68495/5) =							**5.05888**
Consistency Index (CI) = (Mean CV - No. Of criteria/ factor class) / (No. Of factor class - 1) =							**0.01472**
Consistency Ratio (CR) = CI/ RI = 0.034248 / 1.12 =							**0.01314**

Annexure – I: Tabular matrices for LOFS and consistency ratio calculations for six factor maps

Geofactor: Slope Curvature

Rank of Slope Curvature Classes

Sl No	Class Name	Code	Rank
1	< -0.1	Concave	**4**
2	-0.1 – 0.1	Flat	**2**
3	> 0.1	Convex	**6**

Matrix of Pairwise Ratings of Slope Curvature Class

Slope Curvature	Concave	Flat	Convex
Concave	1.00	3.00	0.33
Flat	0.33	1.00	0.20
Convex	3.00	5.00	1.00
Sum Column	**4.33**	**9.00**	**1.53**

Annexure – I: Tabular matrices for LOFS and consistency ratio calculations for six factor maps

Geofactor: Slope Curvature

Estimated Eigen values, fraction rate and LOFS for Slope Curvature classes

Slope Curvature	Concave	Flat	Convex	Sum Rows	Frac Weight	LOFS
Concave	0.230769	0.333333	0.217391	0.781494	0.260498	0.4113
Flat	0.076923	0.111111	0.130435	0.318469	0.106156	0.1676
Convex	0.692308	0.555556	0.652174	1.900037	0.633346	1.0000

Estimation of consistency vector (CV), consistency index (CI) and consistency ratio (CR) for Slope Angle classes

Slope Curvature	Concave	Flat	Convex	Sum Rows	CV
Concave	0.260498	0.318469	0.211115	0.790082	3.032969
Flat	0.086833	0.106156	0.126669	0.319658	3.011202
Convex	0.781494	0.530782	0.633346	1.945621	3.071973
Sum CV					**9.116144**
Mean Consistency Vector (Mean CV) = Total CV/ Nos. Of factor class (9.116144/3) =					**3.038715**
Consistency Index (CI) = (Mean CV - No. Of criteria/ factor class) / (No. Of factor class - 1) =					**0.019357**
Consistency Ratio (CR) = CI/ RI = 0.019357 / 0.58 =					**0.0334**

Annexure – I: Tabular matrices for LOFS and consistency ratio calculations for six factor maps

Factor Class

Rank of Factor Classes

Sl No	Factor Class Name	Code	Rank
1	Slope	SLP	**9**
2	Curvature	CUR	**2**
3	Slope Forming Material	SFM	**6**
4	Land Use Land Cover	LULC	**8**
5	Geomorphology	GEOM	**6**
6	Regolith Thickness	RT	**4**

Matrix of Pairwise Ratings of Factor Class

Factor Class	SLP	CUR	SFM	LULC	GEOM	RT
SLP	1.00	8.00	4.00	2.00	4.00	6.00
CUR	0.13	1.00	0.20	0.14	0.20	0.33
SFM	0.25	5.00	1.00	0.33	1.00	3.00
LULC	0.50	7.00	3.00	1.00	3.00	5.00
GEOM	0.25	5.00	1.00	0.33	1.00	3.00
RT	0.17	3.00	0.33	0.20	0.33	1.00
Sum Column	**2.29**	**29.00**	**9.53**	**4.01**	**9.53**	**18.33**

Annexure – I: Tabular matrices for LOFS and consistency ratio calculations for six factor maps

Factor Class

Estimated Eigen values, fraction rate and Weight for Factor classes

Factor Class	SLP	CUR	SFM	LULC	GEOM	RT	Sum Rows	Frac Weight	Weight
SLP	0.43636	0.27586	0.41958	0.49881	0.41958	0.32727	2.37747	0.396245271	12.86527835 ~ 13
CUR	0.05455	0.03448	0.02098	0.03563	0.02098	0.01818	0.18480	0.030799588	1 ~ 1
SFM	0.10909	0.17241	0.10490	0.08314	0.10490	0.16364	0.73807	0.123011111	3.993920696 ~ 4
LULC	0.21818	0.24138	0.31469	0.24941	0.31469	0.27273	1.61107	0.268510868	8.718001981 ~ 9
GEOM	0.10909	0.17241	0.10490	0.08314	0.10490	0.16364	0.73807	0.123011111	3.993920696 ~ 4
RT	0.07273	0.10345	0.03497	0.04988	0.03497	0.05455	0.35053	0.058422051	1.896845233 ~ 2

Estimation of consistency vector (CV), consistency index (CI) and consistency ratio (CR) for Factor classes

Factor Class	SLP	CUR	SFM	LULC	GEOM	RT	Sum Rows	CV
SLP	0.396245271	0.246396703	0.492044445	0.537021735	0.492044445	0.350532308	2.514284907	6.345274237
CUR	0.049530659	0.030799588	0.024602222	0.038358695	0.024602222	0.019474017	0.187367404	6.083438671
SFM	0.099061318	0.153997939	0.123011111	0.089503623	0.123011111	0.175266154	0.763851256	6.209611865
LULC	0.198122635	0.215597115	0.369033334	0.268510868	0.369033334	0.292110257	1.712407542	6.377423591
GEOM	0.099061318	0.153997939	0.123011111	0.089503623	0.123011111	0.175266154	0.763851256	6.209611865
RT	0.066040878	0.092398763	0.041003704	0.053702174	0.041003704	0.058422051	0.352571274	6.034900625
Sum CV								**37.2603**
Mean Consistency Vector (Mean CV) = Total CV/ Nos. Of factor class (37.2603/6) =								**6.210043**
Consistency Index (CI) = (Mean CV - No. Of criteria/ factor class) / (No. Of factor class - 1) =								**0.042009**
Consistency Ratio (CR) = CI/ RI = 0.042009 / 1.24 =								**0.033878**

Annexure –II: Tabular Field data collection sheet.

S.No.	***Location***	***Toposheet no***	***Latitude***	***Longitude***	***Geomorphological Process***	***GEOM***	***Bed rock***	***SFM***	***DEPTH***	***LU/LC***	***Weathering***	***Remarks***
L1	Kalugundi	48P/11	12.50	75.55	Gravitational	Lowly Dissected slope		Laterite	5-10m	HHP	High	
L2	Aladka	48P/11	12.50	75.55	Gravitational	Lowly Dissected slope		Lateritic soil/insitu soil	0.5-5m	HHP & Settlement	Moderate	
L3	200 mtrs from L02	48P/11	0.00	0.00	Gravitational	Lowly Dissected slope	Laterite	Weathered rock/insitu soil	<0.5m	HHP	Moderate	
L4	Sampajje	48P/11	12.49	75.56	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	HHP		
L5	NH-275	48P/11	12.49	75.57	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	HHP		
L6	NH-275	48P/11	12.49	75.57	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	Settlement on modified slope		Extensive Cut slope
L7	Koyanadu near school	48P/11	12.48	75.58	Gravitational	Lowly Dissected slope		Laterite	0.5-5m	HHP		Extensive Cut slope
L8	Koyanadu NH-275	48P/11	12.47	75.60	Gravitational	Lowly Dissected slope		Rock	<0.5m	Thick Vegetation	Moderate	
L9	NH-275	48P/11	12.47	75.61	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	Thick Vegetation		
L10	NH-275	48P/11	12.46	75.62	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	Thick Vegetation		
L11	Devarakolli	48P/11	12.46	75.63	Gravitational	Lowly Dissected slope		Rock	<0.5m	HHP	Moderate	
L12	Devarakolli	48P/11	12.45	75.64	Gravitational	Lowly Dissected slope	Granite gneiss	Weathered rock	<0.5m	Thick Vegetation		
L13	Devarakolli/ Todpal	48P/11	12.44	75.65	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	HHP		

Annexure –II: Tabular Field data collection sheet.

S.No.	***Location***	***Toposheet no***	***Latitude***	***Longitude***	***Geomorphological Process***	***GEOM***	***Bed rock***	***SFM***	***DEPTH***	***LU/LC***	***Weathering***	***Remarks***
L14	Jodpal	48P/11	12.44	75.65	Gravitational	Lowly Dissected slope	Granite gneiss	Rock	<0.5m	Thick Vegetation	Moderate	
L15	Jodpal	48P/11	12.44	75.67	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	Thick Vegetation		Extensive Cut slope
L16		48P/11	12.43	75.67	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	Thick Vegetation		Extensive Cut slope
L17	Madenadu	48P/11	12.43	75.67	Gravitational	Lowly Dissected slope		Rock	<0.5m	LHP		
L18	Madenadu (50m from L17)	48P/11	12.43	75.68	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	Moderate vegetation		Extensive Cut slope
L19		48P/11	12.42	75.70	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		
L20	Kallugundi	48P/11	12.50	75.54	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	HHP		
L21		48P/11	12.49	75.54	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	HHP		
L22		48P/11	12.49	75.54	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	HHP		
L23		48P/11	12.50	75.55	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	HHP		
L24	Sampajje	48P/11	12.49	75.56	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	HHP		
L25	Sampajje-Urvalu road	48P/11	12.48	75.55	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	HHP		
L26		48P/11	12.48	75.55	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	HHP		
L27		48P/11	12.48	75.54	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	HHP		

Annexure –II: Tabular Field data collection sheet.

S.No.	***Location***	***Toposheet no***	***Latitude***	***Longitude***	***Geomorphological Process***	***GEOM***	***Bed rock***	***SFM***	***DEPTH***	***LU/LC***	***Weathering***	***Remarks***
L28	Urvalu	48P/11	12.49	75.53	Gravitational	Lowly Dissected slope		in-situ soil/Lateritic soil	0.5-5m	HHP		
L29		48P/11	12.49	75.53	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	HHP		
L30	Balambi	48P/11	12.49	75.53	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	HHP		
L31	Chembu	48P/11	12.48	75.52	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	HHP		
L32		48P/11	12.48	75.51	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	HHP		
L33		48P/11	12.48	75.51	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	HHP		
L34		48P/11	12.47	75.50	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	HHP		
L35		48P/11	12.46	75.50	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	HHP		
L36		48P/11	12.50	75.47	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	HHP		
L37		48P/11	12.49	75.48	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	HHP		
L38	Todikana/Malikarjuna Temple	48P07	12.48	75.48	Gravitational	Valley fill		In-situ soil	0.5-5m	HHP		
L39	Adiyadka	48P07	12.50	75.48	Gravitational	Mound		In-situ soil	0.5-5m	HHP		
L40	Madikeri	48P/11	12.42	75.52	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	HHP		
L41	NH-275	48P/11	12.41	75.73	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	HHP		Extensive Cut slope (25m wide)

Annexure –II: Tabular Field data collection sheet.

S.No.	*Location*	*Toposheet no*	*Latitude*	*Longitude*	*Geomorphological Process*	*GEOM*	*Bed rock*	*SFM*	*DEPTH*	*LU/LC*	*Weathering*	*Remarks*
L42	NH-275	48P/11	12.41	75.73	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	LHP		Extensive Cut slope (100m wide)
L43	NH-275	48P/11	12.44	75.73	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		
L44	Abbey Fall road	48P/11	12.45	75.73	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	Moderate vegetation		
L45	NH-275	48P/11	12.45	75.73	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		
L46	NH-275	48P/11	12.46	75.74	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		Extensive Cut slope (100m wide)
L47	NH-275	48P/11	12.47	75.74	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP/HHP (Acacia)		
L48	NH-275	48P/11	12.48	75.73	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m			Extensive Cut slope (200m wide), H=15m
L49	NH-275	48P/11	12.49	75.73	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		Damp
L50	NH-275	48P/11	12.49	75.74	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	Thick Vegetation		
L51	Nidavattu	48P/11	12.49	75.73	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	Thick Vegetation		Damp
L52	Madikere	48P/11	12.49	75.73	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	Cultivation		
L53	Kalluru	48P/11	12.49	75.72	Gravitational	Rolling Plain on hilltop		in-situ soil	0.5-5m	LHP		Damp
L54	Gadibidu/100m south of this location	48P/11	12.49	75.72	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	Cultivation		Extensive Cut slope (200m wide), H=15m

Annexure –II: Tabular Field data collection sheet.

S.No.	***Location***	***Toposheet no***	***Latitude***	***Longitude***	***Geomorphological Process***	***GEOM***	***Bed rock***	***SFM***	***DEPTH***	***LU/LC***	***Weathering***	***Remarks***
L55	100 south of the location of nala	48P/11	12.49	75.72	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	Cultivation		
L56		48P/11	12.48	75.71	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		Damp
L57	Gaalibeedu	48P/11	12.47	75.71	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	LHP		
L58		48P/11	12.47	75.71	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	Moderate vegetation		
L59	Gaalibeedu	48P/11	12.00	0.00	Gravitational	Lowly Dissected slope		in-situ soi	0.5-5m	LHP		Damp
L60		48P/11	12.45	75.71	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	Thick Vegetation		
L61		48P/11	12.44	75.72	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		
L62	Madikeri	48P/11	12.44	75.72	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		Extensive Cut slope (100m wide),H=17m
L63	Galibeedu	48P/11	12.46	75.70	Gravitational	Rolling Plain on hilltop		in-situ soil	0.5-5m	Cultivation		
L64	Galibeedu	48P/11	12.47	75.68	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		Damp
L65		48P/11	12.47	75.68	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	Thick Vegetation		Damp/ECS: 100m towards left of last location
L66		48P/11	12.48	75.67	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	Thick Vegetation		
L67	Onchalla	48P/11	12.49	75.66	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		

Annexure –II: Tabular Field data collection sheet.

S.No.	***Location***	***Toposheet no***	***Latitude***	***Longitude***	***Geomorphological Process***	***GEOM***	***Bed rock***	***SFM***	***DEPTH***	***LU/LC***	***Weathering***	***Remarks***
L68		48P/11	12.48	75.59	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		
L69	Annehalla/Balambi-Chembu/Bhagmandala road	48P/11	12.48	75.53	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	HHP		Damp
L70		48P/11	12.48	75.53	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	HHP		
L71	Annehalla	48P/11	12.47	75.53	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	HHP		Damp
L72	Kantabylu	48P/11	12.46	75.54	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	HHP		Damp
L73		48P/11	12.46	75.55	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	Thick Vegetation		
L74	Dabbadka	48P/11	12.45	75.55	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	Thick Vegetation		Extensive Cut slope (50m wide)/rock on upper contour
L75	Dabbadka	48P/11	12.44	75.56	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	Thick Vegetation		
L76		48P/11	12.44	75.55	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	Thick Vegetation		Damp
L77		48P/11	12.43	75.55	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	Thick Vegetation		Damp
L78		48P/11	12.43	75.55	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	Thick Vegetation		
L79		48P/11	12.43	75.55	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	Thick Vegetation		
L80		48P/11	12.42	75.55	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		

Annexure –II: Tabular Field data collection sheet.

S.No.	*Location*	*Toposheet no*	*Latitude*	*Longitude*	*Geomorphological Process*	*GEOM*	*Bed rock*	*SFM*	*DEPTH*	*LU/LC*	*Weathering*	*Remarks*
L81		48P/11	12.42	75.55	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		
L82		48P/11	12.41	75.55	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	Settlement /LHP		
L83		48P/11	12.40	75.55	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	Settlement /LHP		
L84		48P/11	12.39	75.56	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		
L85	Chettimane	48P/11	12.38	75.57	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		
L86		48P/11	12.42	75.71	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		
L87	Madikeri/kattikeri	48P/11	12.40	75.71	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		Damp
L88		48P/11	12.56	75.72	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		
L89		48P/11	12.39	75.71	Gravitational	valley Fill		in-situ soil	0.5-5m	Cultivation/LHP		
L90		48P/11	12.36	75.70	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	Settlement /LHP		
L91		48P/11	12.36	75.69	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		
L92		48P/11	12.35	75.68	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		
L93	Karugunda	48P/11	12.35	75.66	Gravitational	Hilltop		in-situ soil	5-10m	LHP		
L94		48P/11	12.36	75.65	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		

Annexure –II: Tabular Field data collection sheet.

S.No.	***Location***	***Toposheet no***	***Latitude***	***Longitude***	***Geomorphological Process***	***GEOM***	***Bed rock***	***SFM***	***DEPTH***	***LU/LC***	***Weathering***	***Remarks***
L95	Cherambane	48P/11	12.37	75.63	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		
L96		48P/11	12.37	75.62	Gravitational	Hilltop		weathered rock	<0.5m	LHP		Damp
L97	Kopatti	48P/11	12.37	75.61	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		
L98		48P/11	12.37	75.60	Gravitational	Hilltop		in-situ soil	5-10m	LHP		
L99		48P/11	12.38	75.59	Gravitational	Hilltop		weathered rock	<0.5m	LHP		
L100		48P/11	12.38	75.59	Gravitational	Hilltop		weathered rock	<0.5m	LHP		
L101	Chettimane	48P/11	12.38	75.57	Gravitational	valley Fill		in-situ soil	0.5-5m	LHP		
L102		48P/11	12.38	75.57	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	LHP		
L103		48P/11	12.38	75.56	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		
L105	Bhagmandala	48P/11	12.38	75.54	Gravitational	Mound		weathered rock	<0.5m	LHP		
L106	Bhagmandala	48P/11	12.39	75.54	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	LHP		
L107	Bhagmandala	48P/11	12.39	75.53	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		
L108	Bhagmandala	48P/11	12.39	75.53	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	LHP	Moderate	
L109		48P/11	12.40	75.52	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		
L110		48P/11	12.41	75.52	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	Moderate vegetation	Moderate	

Annexure –II: Tabular Field data collection sheet.

S.No.	***Location***	***Toposheet no***	***Latitude***	***Longitude***	***Geomorphological Process***	***GEOM***	***Bed rock***	***SFM***	***DEPTH***	***LU/LC***	***Weathering***	***Remarks***
L111		48P/11	12.41	75.51	Gravitational	Mound		weathered rock	<0.5m	Moderate vegetation	High	
L112		48P/11	12.41	75.50	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L113	Adyakada	48P07	12.50	75.49	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	HHP		
L114		48P07	12.50	75.49	Gravitational	Lowly Dissected slope		Laterite	<0.5m	HHP		
L115		48P07	12.49	75.50	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	HHP		
L116		48P07	12.49	75.50	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	Moderate vegetation		
L117	Pettaje	48P/11	12.49	75.50	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	HHP		
L118	Todikana	48P/11	12.47	75.48	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	HHP		Damp
L119	Madikeri	48P/11	12.41	75.74	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	Sparse vegetation	High	Damp
L120	Madikeri	48P/11	12.43	75.74	Gravitational	Lowly Dissected slope		in-situ soil	<0.5m	Moderate vegetation	High	Damp/ECS - 150m width
L121	Madikeri	48P/11	12.41	75.74	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	Moderate vegetation	High	
L122	Madikeri	48P/11	12.39	75.76	Gravitational	Pediment-Pediplain Complex		in-situ soil	0.5-5m	LHP		Damp
L123	Biligeri road	48P/11	12.38	75.75	Gravitational	Pediment-Pediplain Complex		in-situ soil	0.5-5m	LHP		Damp
L124	Kagoddalu village	48P/11	12.38	75.74	Gravitational	Mound		in-situ soil	0.5-5m	LHP		
L125	Biligeri road	48P/11	12.37	75.74	Gravitational	Pediment-Pediplain Complex		in-situ soil	5-10m	LHP		Damp

Annexure –II: Tabular Field data collection sheet.

S.No.	*Location*	*Toposheet no*	*Latitude*	*Longitude*	*Geomorphological Process*	*GEOM*	*Bed rock*	*SFM*	*DEPTH*	*LU/LC*	*Weathering*	*Remarks*
L126		48P/11	12.36	75.73	Gravitational	Pediment-Pediplain Complex		in-situ soil	0.5-5m	LHP		Damp
L127		48P/11	12.36	75.73	Gravitational	Pediment-Pediplain Complex		in-situ soil	5-10m	LHP		Damp
L128		48P/11	12.37	75.73	Gravitational	Pediment-Pediplain Complex		in-situ soil	0.5-5m	LHP		
L129	Betoli	48P/07	12.50	75.39	Gravitational	Pediment-Pediplain Complex		weathered rock	<0.5m	HHP	Moderate	wet
L130		48P/07	12.49	75.39	Gravitational	Mound		in-situ soil	0.5-5m	HHP		Damp
L131		48P/07	12.49	75.39	Gravitational			weathered rock	5-10m	HHP		
L132		48P/07	12.48	75.38	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		
L133	Kallapally	48P/07	12.48	75.38	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	LHP		
L134		48P/07	12.47	75.38	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	HHP		Damp
L135	Panathur	48P/07	12.47	75.38	Gravitational	Lowly Dissected slope		Rock	<0.5m	HHP	Moderate	Damp
L136		48P/07	12.47	75.37	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	HHP		Damp
L137		48P/07	12.46	75.37	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	HHP		Damp
L138	Panathur	48P/07	12.46	75.37	Gravitational	Pediment-Pediplain Complex		in-situ soil	0.5-5m	HHP		Damp
L139	Karike	48P/07	12.45	75.39	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	HHP		Damp
L140	Karike	48P/07	12.45	75.39	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	HHP		Damp

Annexure –II: Tabular Field data collection sheet.

S.No.	***Location***	***Topos heet no***	***Latit ude***	***Longit ude***	***Geomorphol ogical Process***	***GEOM***	***Bed rock***	***SFM***	***DEPT H***	***LU/LC***	***Weatheri ng***	***Remarks***
L141		48P/07	12.45	75.40	Gravitational	Lowly Dissected slope		Rock	<0.5m	HHP		Damp
L142		48P/07	12.45	75.40	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	HHP		Damp
L143		48P/07	12.45	75.41	Gravitational	Lowly Dissected slope		Rock	<0.5m	HHP		Damp
L144		48P/07	12.45	75.41	Gravitational	Lowly Dissected slope		Rock	<0.5m	HHP		Damp
L145		48P/07	12.45	75.43	Gravitational	Lowly Dissected slope		Rock	<0.5m	HHP		Damp
L146		48P/07	12.45	75.43	Gravitational	Lowly Dissected slope		Rock	<0.5m	Thick Vegetation		Damp
L147	Chettukaya	48P/07	12.44	75.44	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	Thick Vegetation		Damp
L148		48P/07	12.45	75.45	Gravitational	Lowly Dissected slope		Rock	<0.5m	Thick Vegetation		Damp
L149		48P/07	12.44	75.45	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	Thick Vegetation		Damp
L150		48P/07	12.44	75.46	Gravitational	Lowly Dissected slope		Rock	<0.5m	Thick Vegetation		Damp
L151		48P/07	12.44	75.46	Gravitational	Lowly Dissected slope		Rock	<0.5m	Thick Vegetation		Damp
L152		48P/07	12.44	75.46	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	Thick Vegetation		Damp
L153		48P/07	12.44	75.47	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	Thick Vegetation		Damp
L154		48P/07	12.43	75.47	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	Thick Vegetation		Damp
L155		48P/07	12.43	75.48	Gravitational	Lowly Dissected slope		weathere d rock	<0.5m	Thick Vegetation		Damp

Annexure –II: Tabular Field data collection sheet.

S.No.	*Location*	*Toposheet no*	*Latitude*	*Longitude*	*Geomorphological Process*	*GEOM*	*Bed rock*	*SFM*	*DEPTH*	*LU/LC*	*Weathering*	*Remarks*
L156	Patti Road	48P/07	12.43	75.48	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	Thick Vegetation		Damp
L157		48P/07	12.42	75.49	Gravitational	Lowly Dissected slope		Rock	<0.5m	Thick Vegetation		Damp
L158		48P/07	12.42	75.49	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	Thick Vegetation		Damp
L159		48P/07	12.42	75.49	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	Thick Vegetation		Damp
L160		48P/07	12.42	75.50	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	Thick Vegetation		
L161		48P/07	12.42	75.69	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		Damp
L162		48P/07	12.42	75.68	Gravitational	Mound		in-situ soil	5-10m	LHP		
L163		48P/07	12.76	75.67	Gravitational	Mound		weathered rock	<0.5m	LHP		
L164		48P/07	12.41	75.67	Gravitational	Mound		in-situ soil	0.5-5m	LHP		
L165		48P/07	12.41	75.67	Gravitational	Mound		in-situ soil	0.5-5m	LHP		
L166		48P/07	12.41	75.66	Gravitational	Mound		weathered rock	<0.5m	Thick Vegetation		
L167		48P/11	12.41	75.66	Gravitational	Mound		Rock	<0.5m	Moderate vegetation		
L168		48P/11	12.41	75.65	Gravitational	Mound		in-situ soil	0.5-5m	LHP		
L169		48P/11	12.41	75.64	Gravitational	Mound		weathered rock	<0.5m	LHP		
L170	Bettanur	48P/11	12.40	75.64	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		

Annexure –II: Tabular Field data collection sheet.

S.No.	***Location***	***Toposheet no***	***Latitude***	***Longitude***	***Geomorphological Process***	***GEOM***	***Bed rock***	***SFM***	***DEPTH***	***LU/LC***	***Weathering***	***Remarks***
L171		48P/11	12.41	75.64	Gravitational	Pediment-Pediplain Complex		in-situ soil	0.5-5m	LHP		
L172	Kalagaddu	48P/11	12.39	75.63	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	LHP		
L173		48P/11	12.38	75.63	Gravitational	Pediment-Pediplain Complex		in-situ soil	0.5-5m	LHP		
L174		48P/11	12.38	75.64	Gravitational	Mound		in-situ soil	0.5-5m	LHP		
L175		48P/11	12.37	75.64	Gravitational	Mound		in-situ soil	0.5-5m	LHP		
L176	Cherambane	48P/11	12.37	75.63	Gravitational	Mound		in-situ soil	0.5-5m	LHP		
L177	Appangala	48P/11	12.38	75.70	Gravitational	Mound		in-situ soil	0.5-5m	LHP		
L178			12.38	75.70	Gravitational	Mound		in-situ soil	5-10m	LHP		
L179			12.39	75.69	Gravitational	Mound		in-situ soil	5-10m	LHP		
L180	Appangala-katakeri		12.40	75.69	Gravitational	Pediment-Pediplain Complex		in-situ soil	5-10m	LHP		
L181			12.40	75.69	Gravitational	Mound		in-situ soil	5-10m	LHP		
L182	Katakeri		12.41	75.70	Gravitational	Mound		in-situ soil	0.5-5m	LHP		
L183			12.42	75.70	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		
L184	Bolamadi		12.35	75.66	Gravitational	Mound		in-situ soil	0.5-5m	LHP		
L185			12.34	75.66	Gravitational	Mound		in-situ soil	5-10m	LHP		

Annexure –II: Tabular Field data collection sheet.

S.No.	*Location*	*Toposheet no*	*Latitude*	*Longitude*	*Geomorphological Process*	*GEOM*	*Bed rock*	*SFM*	*DEPTH*	*LU/LC*	*Weathering*	*Remarks*
L186	Cherambane		12.36	75.63	Gravitational	Mound		in-situ soil	0.5-5m	LHP		
L187	Cherambane		12.36	75.64	Gravitational	Mound		in-situ soil	5-10m	LHP		
L188			12.35	75.64	Gravitational	Mound		in-situ soil	5-10m	LHP		
L189			12.35	75.64	Gravitational	Mound		in-situ soil	0.5-5m	LHP		
L190			12.34	75.64	Gravitational	Mound		in-situ soil	0.5-5m	LHP		
L191			12.34	75.63	Gravitational	Mound		in-situ soil	0.5-5m	LHP		
L192			12.35	75.63	Gravitational	Mound		in-situ soil	0.5-5m	LHP		
L193			12.35	75.64	Gravitational	Mound		in-situ soil	0.5-5m	LHP		
L194			12.38	75.53	Gravitational	Pediment-Pediplain Complex		in-situ soil	0.5-5m	LHP		
L195	Thalkaveri		12.38	75.52	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	LHP		
L196			12.38	75.52	Gravitational	Lowly Dissected slope		Rock	<0.5m	Thick Vegetation		
L197			12.38	75.51	Gravitational	Lowly Dissected slope		Rock	<0.5m	Thick Vegetation		
L198			12.38	75.51	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	LHP		
L199			12.38	75.50	Gravitational	Lowly Dissected slope		Rock	<0.5m	Moderate vegetation		
L200	Napoklu road/Bettgeri		12.35	75.70	Gravitational	Pediment-Pediplain Complex		in-situ soil	0.5-5m	Cultivation/LHP		Damp

Annexure –II: Tabular Field data collection sheet.

S.No.	*Location*	*Toposheet no*	*Latitude*	*Longitude*	*Geomorphological Process*	*GEOM*	*Bed rock*	*SFM*	*DEPTH*	*LU/LC*	*Weathering*	*Remarks*
L201	Kottumadi		12.33	75.70	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		
L202	Napoklu road		12.31	75.70	Gravitational	River channel/valley		in-situ soil	5-10m	Moderate vegetation		Damp
L203	Napoklu-Murnad road		12.31	75.71	Gravitational	Pediment-Pediplain Complex		in-situ soil	0.5-5m	LHP		
L204	Napoklu-Murnad road		12.32	75.72	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L205	Napoklu-Murnad road		12.31	75.74	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		Damp
L206	Kadanka		12.23	75.75	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L207	Kadanka		12.22	75.73	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L208	Kadanka		12.22	75.72	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L209	Kadanka		12.22	75.72	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	LHP		Damp
L210	SH-90		12.22	75.70	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L211	Cheyyandane		12.23	75.69	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L212	Cheyyandane		12.23	75.69	Gravitational	Lowly Dissected slope		Rock	<0.5m	LHP	Moderate	Damp
L213	Cheyyandane		12.23	75.68	Gravitational	Lowly Dissected slope		Rock	<0.5m	LHP	Moderate	
L214	Kabbinkad		12.24	75.67	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp

Annexure –II: Tabular Field data collection sheet.

S.No.	***Location***	***Topos heet no***	***Latit ude***	***Longit ude***	***Geomorphol ogical Process***	***GEOM***	***Bed rock***	***SFM***	***DEPT H***	***LU/LC***	***Weatheri ng***	***Remarks***
L214 a			12.24	75.66	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L215			12.24	75.65	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L215 a			12.24	75.65	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L216			12.24	75.64	Gravitational	Lowly Dissected slope		weatherd rock/in-situ soil	0.5-5m	LHP		Damp
L217	Nalkand palace road		12.24	75.64	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		Damp
L218			12.23	75.64	Gravitational	Lowly Dissected slope		weathere d rock	<0.5m	LHP		Damp
L219	Napaklu road		12.25	75.65	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L220	Kakkabe		12.26	75.64	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		Damp
L221	Kakkabe		12.26	75.63	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		Damp
L222			12.26	75.63	Gravitational	Lowly Dissected slope		weathere d rock	<0.5m	LHP		Damp
L223			12.26	75.62	Gravitational	Moderately Dissected slope		weathere d rock	<0.5m	LHP		
L224			12.26	75.62	Gravitational	Moderately Dissected slope		weathere d rock	<0.5m	LHP		
L225			12.26	75.62	Gravitational	Moderately Dissected slope		Rock	<0.5m	LHP		
L226			12.25	75.63	Gravitational	Lowly Dissected slope		Rock	<0.5m	LHP		Damp

Annexure –II: Tabular Field data collection sheet.

S.No.	*Location*	*Toposheet no*	*Latitude*	*Longitude*	*Geomorphological Process*	*GEOM*	*Bed rock*	*SFM*	*DEPTH*	*LU/LC*	*Weathering*	*Remarks*
L227			12.25	75.63	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		Damp
L228			12.25	75.64	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		Damp
L229			12.25	75.65	Gravitational	Pediment-Pediplain Complex		in-situ soil	0.5-5m	LHP		
L230			12.24	75.65	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		Damp
L231	Tamara resort road		12.24	75.65	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	LHP		Damp
L232			12.23	75.65	Gravitational	Lowly Dissected slope		Rock	<0.5m	LHP		
L233			12.24	75.65	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		
L234			12.23	75.65	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	LHP		Damp
L235			12.23	75.69	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		
L236			12.24	75.70	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		
L237			12.25	75.70	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L238			12.25	75.71	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		Damp
L239	Kadanka		12.25	75.71	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		Damp
L240			12.24	75.72	Gravitational	Pediment-Pediplain Complex		in-situ soil	0.5-5m	LHP		Damp
L241			12.24	75.72	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp

Annexure –II: Tabular Field data collection sheet.

S.No.	*Location*	*Toposheet no*	*Latitude*	*Longitude*	*Geomorphological Process*	*GEOM*	*Bed rock*	*SFM*	*DEPTH*	*LU/LC*	*Weathering*	*Remarks*
L242			12.23	75.73	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L243	Kadanka		12.23	75.73	Gravitational	Lowly Dissected slope		Rock	<0.5m	LHP		
L244	Kedamullur		12.19	75.75	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L245			12.19	75.74	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L246			12.20	75.73	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L247			12.19	75.72	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L248			12.20	75.71	Gravitational	Lowly Dissected slope		Rock	<0.5m	LHP		Damp
L249			12.21	75.71	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	LHP		Damp
L250			12.21	75.71	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	LHP		Damp
L251			12.20	75.70	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	LHP	High	Damp
L252	Temple road		12.20	75.70	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	LHP		Damp
L253			12.19	75.70	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	LHP		Damp
L254	Thora road		12.18	75.74	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L255			12.17	75.74	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L256	Thora road		12.17	75.72	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp

Annexure –II: Tabular Field data collection sheet.

S.No.	*Location*	*Toposheet no*	*Latitude*	*Longitude*	*Geomorphological Process*	*GEOM*	*Bed rock*	*SFM*	*DEPTH*	*LU/LC*	*Weathering*	*Remarks*
L257	Thora road		12.16	75.72	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		100m back weathered rock
L258			12.16	75.72	Gravitational	stream channel/valley		in-situ soil		LHP		
L259			12.15	75.73	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	LHP		Damp
L260			12.16	75.73	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L261			12.16	75.74	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		
L262	Kedamullur		12.20	75.74	Gravitational	Pediment-Pediplain Complex		in-situ soil	5-10m	LHP		Damp
L263			12.21	75.74	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		Damp
L264			12.23	75.74	Gravitational	Pediment-Pediplain Complex		in-situ soil	0.5-5m	LHP		Damp
L265			12.24	75.75	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		Damp
L266			12.25	75.74	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L267	Bellumadu		12.26	75.73	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L268			12.27	75.73	Gravitational	Pediment-Pediplain Complex		in-situ soil	0.5-5m	LHP		Damp
L269			12.26	75.72	Gravitational	Pediment-Pediplain Complex		in-situ soil	0.5-5m	LHP/Settlement		Damp
L270	Napaklu road		12.26	75.71	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		Damp
L271	Napaklu road		12.28	75.70	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp

Annexure –II: Tabular Field data collection sheet.

S.No.	*Location*	*Toposheet no*	*Latitude*	*Longitude*	*Geomorphological Process*	*GEOM*	*Bed rock*	*SFM*	*DEPTH*	*LU/LC*	*Weathering*	*Remarks*
L272			12.29	75.70	Gravitational	Pediment-Pediplain Complex		in-situ soil	0.5-5m	LHP/Cultivation		Damp
L273			12.29	75.70	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L274	Napaklu road		12.30	75.68	Gravitational	Pediment-Pediplain Complex		in-situ soil	0.5-5m	LHP/Cultivation		Damp
L275	Napaklu road		12.29	75.67	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L276	Napaklu road		12.28	75.67	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	LHP		Damp
L277	Kolkeri		12.28	75.66	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L278	Kolkeri		12.27	75.66	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP/Settlement		Damp
L279	Kunjilla		12.26	75.65	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP/Settlement		Damp
L280	Kola		12.27	75.67	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP/Settlement		Damp
L281			12.27	75.67	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L282			12.26	75.67	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L283			12.25	75.67	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		Damp
L284			12.25	75.68	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L285	Kabbake		12.27	75.64	Gravitational	Lowly Dissected slope/Mound		in-situ soil	0.5-5m	LHP		Damp
L286			12.28	75.64	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp

Annexure –II: Tabular Field data collection sheet.

S.No.	*Location*	*Toposheet no*	*Latitude*	*Longitude*	*Geomorphological Process*	*GEOM*	*Bed rock*	*SFM*	*DEPTH*	*LU/LC*	*Weathering*	*Remarks*
L287			12.28	75.64	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	LHP		Damp
L288	Nelaji		12.30	75.63	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L289	Nelaji		12.31	75.63	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	LHP	High	Damp
L290	Peroor		12.31	75.63	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	LHP	High	Damp
L291	Ballamanati		12.31	75.62	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L292	Ballamanati		12.32	75.61	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L293			12.32	75.61	Gravitational	Lowly Dissected slope		Rock	<0.5m	LHP/Thick vegetation		Damp
L294			12.32	75.61	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		Damp
L295			12.33	75.61	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L296	Bhagmandala road		12.33	75.60	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	LHP	Moderate	Damp
L297			12.34	75.59	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		Damp
L298			12.34	75.59	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L299			12.33	75.59	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	LHP	High	Damp
L300			12.34	75.59	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L301			12.35	75.58	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	Moderate Vegetation		Damp

Annexure –II: Tabular Field data collection sheet.

S.No.	***Location***	***Toposheet no***	***Latitude***	***Longitude***	***Geomorphological Process***	***GEOM***	***Bed rock***	***SFM***	***DEPTH***	***LU/LC***	***Weathering***	***Remarks***
L302			12.35	75.56	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L303	Korangla		12.37	75.55	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
S.No.	***Location***	***Toposheet no***	***Latitude***	***Longitude***	***Geomorphological Process***	***GEOM***	***Bed rock***	***SFM***	***DEPTH***	***LU/LC***	***Weathering***	***Remarks***
L304	Bhagmandala road		12.38	75.54	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	LHP		Damp
L305	Bhagmandala road		12.31	75.63	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L306	Bhagmandala- Napoklu road		12.30	75.64	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L307			12.31	75.65	Gravitational	Pediment-Pediplain Complex		in-situ soil	0.5-5m	LHP		Damp
L308	Durga shareef road		12.31	75.65	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP/Settlement		Damp
L309	Yemmenadu road		12.32	75.65	Gravitational	Pediment-Pediplain Complex		in-situ soil	5-10m	LHP		Damp
L310			12.32	75.66	Gravitational	Mound		in-situ soil	0.5-5m	LHP		Damp
L311			12.32	75.66	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		Damp
L312			12.32	75.67	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		Damp
L313	Napaklu road		12.31	75.67	Gravitational	Pediment-Pediplain Complex		in-situ soil	0.5-5m	LHP		Damp
L314	Napaklu road		12.31	75.69	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP/Settlement		

Annexure –II: Tabular Field data collection sheet.

S.No.	***Location***	***Toposheet no***	***Latitude***	***Longitude***	***Geomorphological Process***	***GEOM***	***Bed rock***	***SFM***	***DEPTH***	***LU/LC***	***Weathering***	***Remarks***
L315	Napaklu road		12.32	75.68	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		Damp
L316	Bollamadu road		12.31	75.72	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L317	Bollamadu road		12.30	75.73	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L318	Kadanga road		12.29	75.72	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L319			12.28	75.73	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L320			12.28	75.72	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L321			12.27	75.72	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L322			12.26	75.73	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L323			12.25	75.74	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L324			12.24	75.75	Gravitational	Pediment-Pediplain Complex		in-situ soil	5-10m	LHP		Damp
L325	Makutta		12.07	75.72	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L326	Peraje		12.09	75.72	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	HHP		Damp
L327			12.09	75.70	Gravitational	Lowly Dissected slope		Rock	<0.5m	Thick Vegetation		
L328			12.09	75.67	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	HHP		Damp
L329			12.10	75.68	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp

Annexure –II: Tabular Field data collection sheet.

S.No.	*Location*	*Toposheet no*	*Latitude*	*Longitude*	*Geomorphological Process*	*GEOM*	*Bed rock*	*SFM*	*DEPTH*	*LU/LC*	*Weathering*	*Remarks*
L330	Makutta		12.07	75.73	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	Thick Vegetation		Damp/ECS 50m back
L331			12.45	75.42	Gravitational	Lowly Dissected slope		in-situ soil+rock	5-10m	HHP		Damp/ECS 50m back
L332			12.45	75.43	Gravitational	Lowly Dissected slope		in-situ soil+rock	0.5-5m	Thick Vegetation		Damp
L333			12.45	75.45	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	Thick Vegetation		Damp
L334	Patti ghat section		12.44	75.46	Gravitational	Moderately Dissected slope		in-situ soil	0.5-5m	Thick Vegetation	Moderate	Damp
L335			12.38	75.51	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L336			12.37	75.52	Gravitational	valley Fill		in-situ soil	5-10m	Cultivation		Damp
L337	Korangla road		12.37	75.52	Gravitational	Lowly Dissected slope		weathered rock	5-10m	Cultivation		Damp
L338			12.37	75.52	Gravitational	Lowly Dissected slope		in-situ soil+weatherd rock	<0.5m	Thick Vegetation		
L339			12.36	75.53	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	Thick Vegetation		Damp
L340			12.36	75.53	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	Thick Vegetation		Damp
L341	Korangla road		12.37	75.54	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	LHP		Damp
L342			12.37	75.53	Gravitational	Lowly Dissected slope		in-situ soil	0.5-5m	LHP		Damp
L343			12.39	75.52	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp

Annexure –II: Tabular Field data collection sheet.

S.No.	*Location*	*Toposheet no*	*Latitude*	*Longitude*	*Geomorphological Process*	*GEOM*	*Bed rock*	*SFM*	*DEPTH*	*LU/LC*	*Weathering*	*Remarks*
L344			12.39	75.51	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	LHP	Moderate	Damp
L345	Bhagmandala		12.39	75.51	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	Thick Vegetation	Moderate	Damp
L346			12.39	75.50	Gravitational	mound		in-situ soil	0.5-5m			
L347			12.44	75.68	Gravitational	mound		in-situ soil	5-10m	LHP		Damp
L348			12.44	75.68	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L349			12.44	75.68	Gravitational	Lowly Dissected slope/Mound		in-situ soil+weatherd rock	5-10m	Moderate Vegetation		Damp
L350			12.44	75.68	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	LHP		Damp/100 extension along road
L351			12.45	75.67	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	LHP	Moderate	Damp
L352			12.45	75.67	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L353			12.45	75.66	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp
L354			12.44	75.66	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	LHP	Moderate	Damp
L355			12.45	75.36	Gravitational	Lowly Dissected slope		weathered rock	<0.5m	HHP	Moderate	Damp
L356	Kumanpalli		12.45	75.36	Gravitational	Lowly Dissected slope		Rock	<0.5m	HHP	Moderate	Damp
L357	Ramipuram road		12.45	75.36	Gravitational	Mound		Rock	<0.5m	HHP	Moderate	Damp

Annexure –II: Tabular Field data collection sheet.

S.No.	***Location***	***Toposheet no***	***Latitude***	***Longitude***	***Geomorphological Process***	***GEOM***	***Bed rock***	***SFM***	***DEPTH***	***LU/LC***	***Weathering***	***Remarks***
L358			12.43	75.72	Gravitational	Lowly Dissected slope		Rock	<0.5m	Moderate Vegetation	Moderate	Damp
L359			12.43	75.71	Gravitational	Lowly Dissected slope/Mound		in-situ soil	0.5-5m	Moderate Vegetation	Moderate	Damp
L360			12.43	75.71	Gravitational	Lowly Dissected slope/Mound		weathered rock	<0.5m	Moderate Vegetation	High	Damp
L361			12.38	75.39	Gravitational	Lowly Dissected slope		Rock	<0.5m	HHP	Moderate	
L362	Tayankallu beta		12.35	75.40	Gravitational	Lowly Dissected slope		Rock	<0.5m	HHP	Low to Fresh	Escarpment to the east of this point
L363			12.50	75.40	Gravitational	Lowly Dissected slope		in-situ soil+weatherd rock	0.5-5m	HHP		Damp
L364	Kammadi estate		12.50	75.41	Gravitational	Lowly Dissected slope		Rock	<0.5m	HHP	Moderate	Damp
L365	monnangeri		12.44	75.67	Gravitational	Lowly Dissected slope		in-situ soil	5-10m	LHP		Damp

Rainfall as a trigger for landslides

Rainfall data has been collected for seven rain gauge stations in the study area for the past ten years. Western Ghats receives an average annual rainfall of about 4000 mm. Of the seven rain gauge stations namely Talakaveri, Bhagmandala, Sampaje, Dabbadka, Napoklu, Madikeri and Galibidu, Talakaveri received the maximum average annual rainfall of about 6918.1 mm from year 2006 to 2015.

A positive correlation has been observed between rainfall and occurrence of landslides. There have been some landslide events in the year 2006 and 2013 around Madikeri area which can be attributed to heavy rainfall in the preceding days.

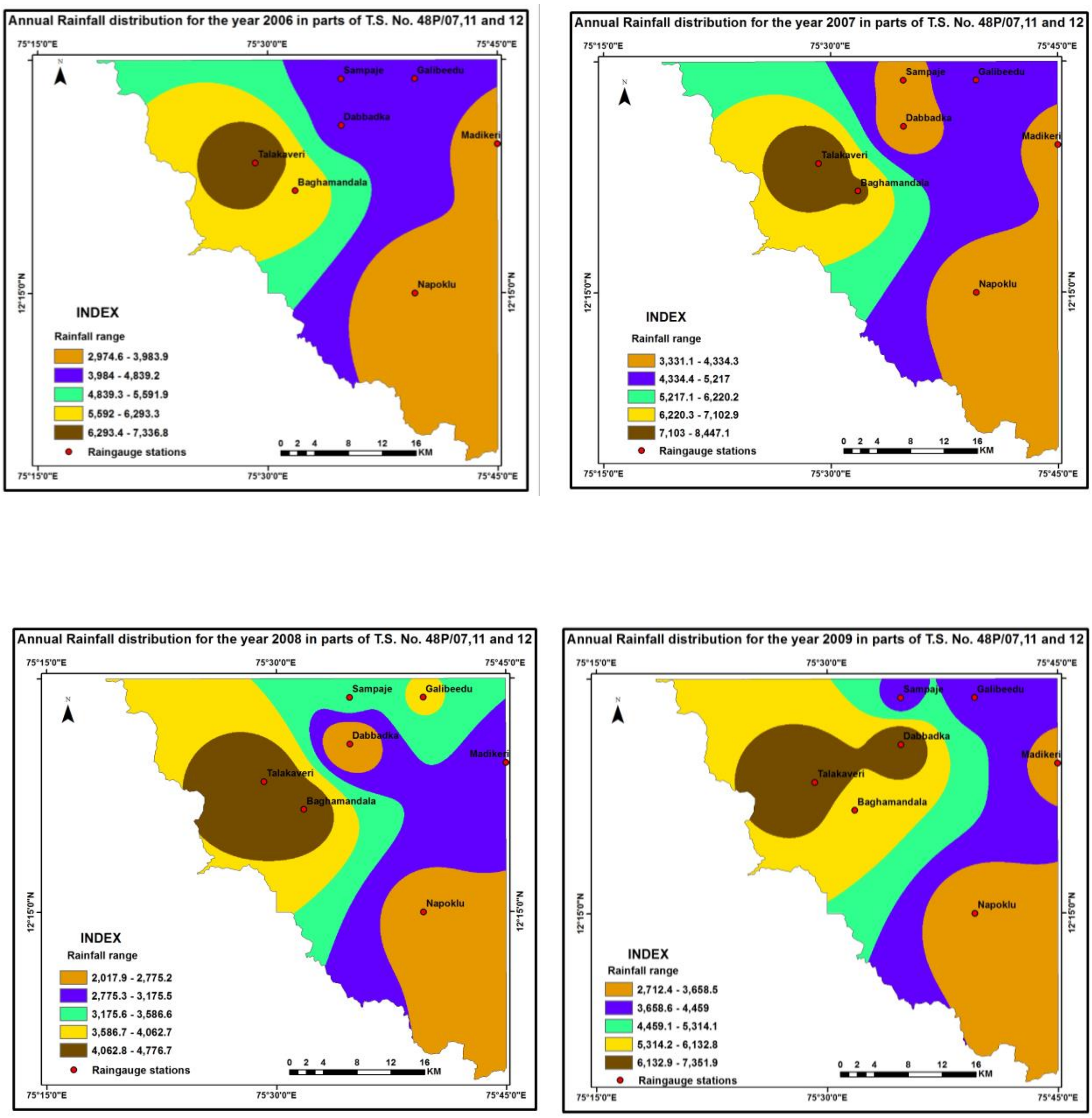
In the year 2006, a landslide occurred in Mangala Devi nagar, Madikeri town killing six people (source: Deccan Herald- Internet edition) on 4th of July. As per rainfall data obtained from District Statistical Department (Annexure - III), the preceding week prior to this witnessed an average rain of about 60 mm per day. The failure occurred on modified slope. This proves that heavy rainfall acted as a trigger for this landslide.

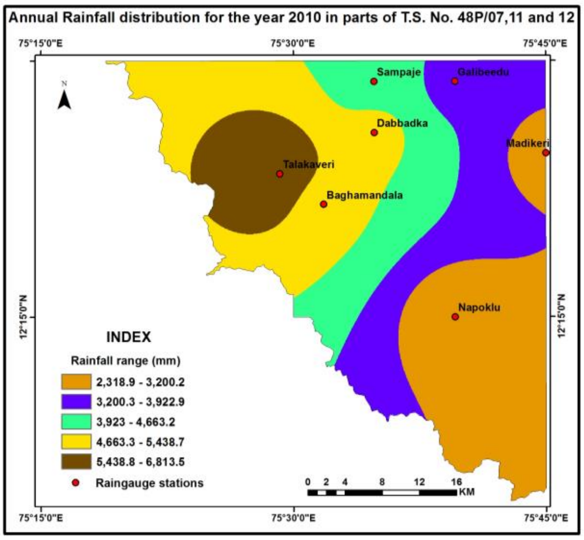
Similarly, in the year 2013, in the month of July a series of landslides and ground cracks were reported around Madikeri area around 20 to 23rd July (Maruthi K.V, Kumar V., 2013). Rainfall data indicates a cumulative rainfall of about 572 mm during the period 19th to 24th July (Annexure - III). It is clear that here also rainfall acted as the trigger for the slope failures and land subsidence.

Heavy rainfall acts as a dynamic trigger that alters groundwater conditions on slopes rendering them weak. Particularly for shallow landslides, rainfall is the most common source for groundwater fluctuations that trigger failure or movement (Van Asch et al., 1999). Fluctuations in groundwater can alter slope stability by influencing pore water pressures and also changing the inherent strength of materials. This does not imply that one factor alone may be the sole reason for slope failure. Most slopes undergo several dynamic events, not necessarily resulting in failure but in reducing the inherent strength, the loss in cohesiveness of overburden material. Vegetation removal is perhaps the most common such factor especially for the development of shallow failures causing both, loss of cohesion as well as rainfall interception. As observed in field there has been widespread removal of natural vegetation and slope modification. Annual rainfall variation over the study area for the past ten years has been shown by preparing interpolated surfaces using Inverse Distance Weighted

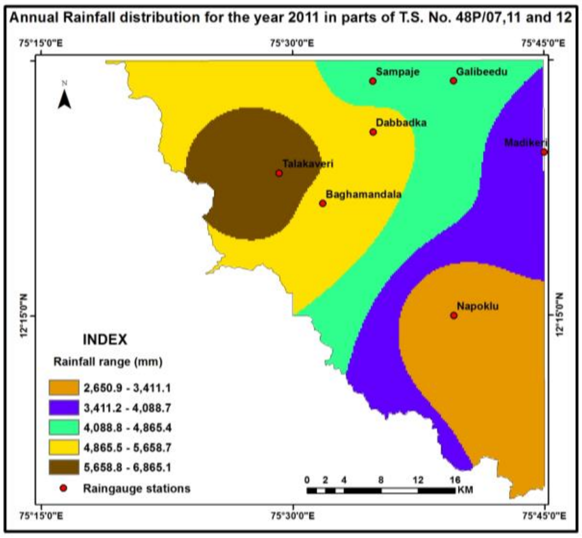
(IDW) method in Arc GIS 10.2. (Fig. 2)

Fig. 2 Rainfall variation for the past ten years in the study area (parts of T.S. No. 48P/07, 11 and 12)

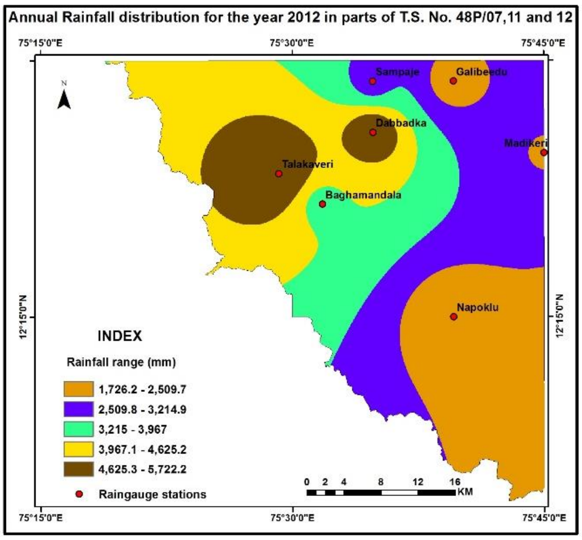




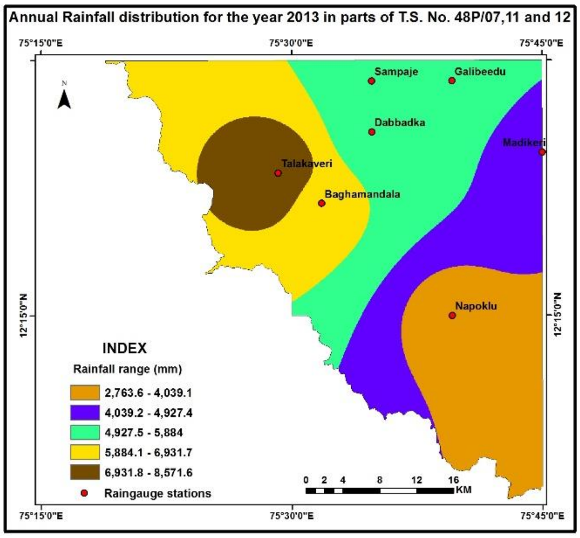
Annual Rainfall distribution for the year 2010 in parts of T.S. No. 48P/07,11 and 12



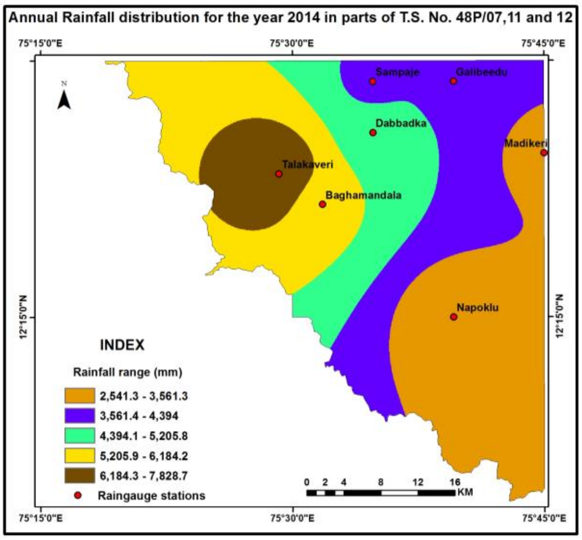
Annual Rainfall distribution for the year 2011 in parts of T.S. No. 48P/07,11 and 12



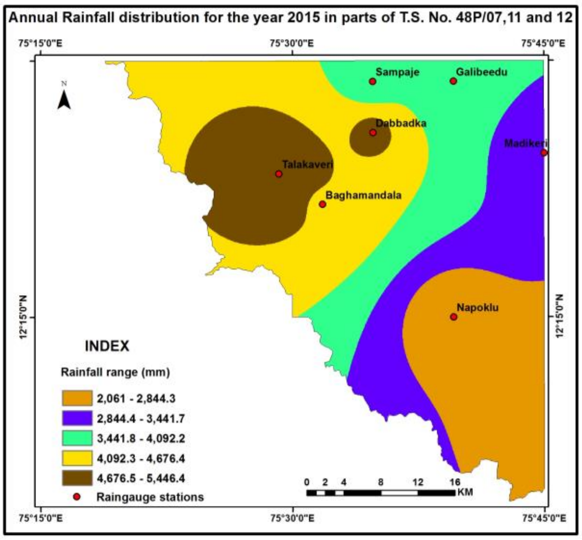
Annual Rainfall distribution for the year 2012 in parts of T.S. No. 48P/07,11 and 12



Annual Rainfall distribution for the year 2013 in parts of T.S. No. 48P/07,11 and 12



Annual Rainfall distribution for the year 2014 in parts of T.S. No. 48P/07,11 and 12

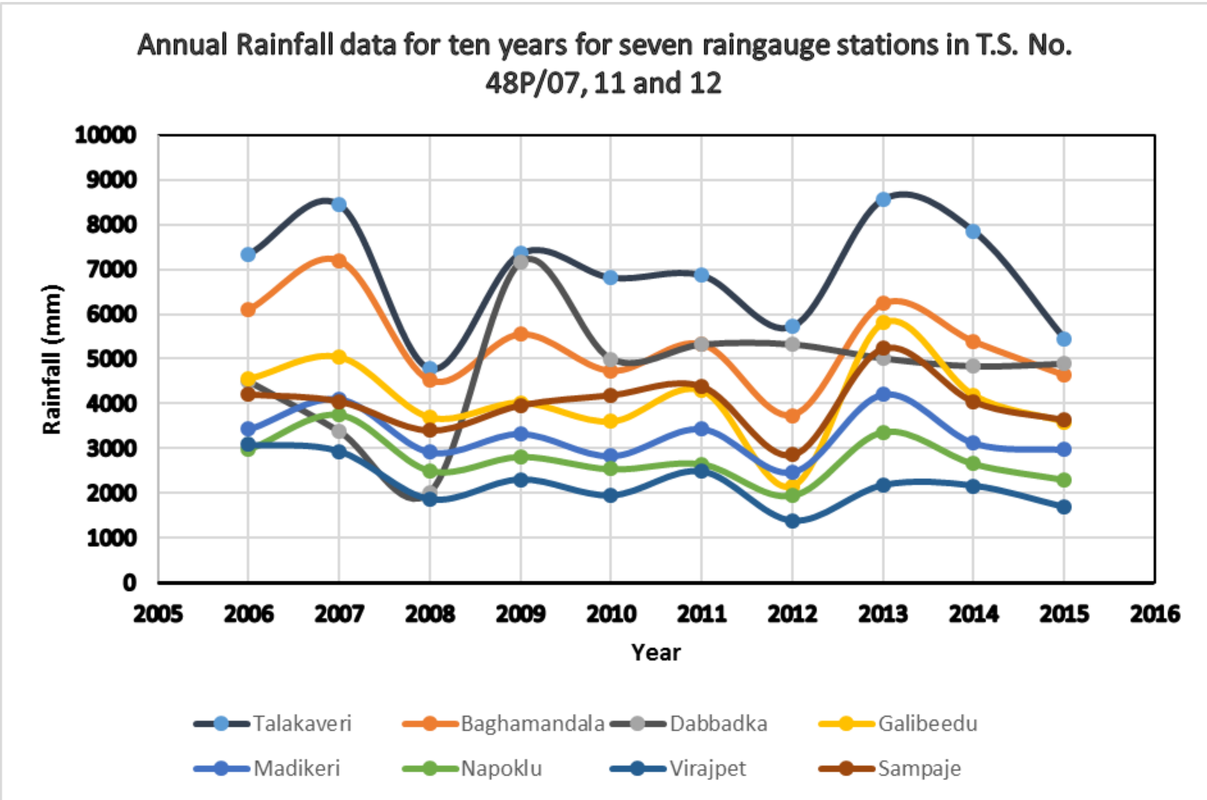


Annual Rainfall distribution for the year 2015 in parts of T.S. No. 48P/07,11 and 12

Annexure - III

Annual Rainfall Data for seven rain gauge stations from 2006 to 2015

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Talakaveri	7336.8	8447.2	4776.7	7351.9	6813.6	6865.6	5722.2	8571.7	7849.6	5446.4
Baghamandala	6101.2	7199.9	4514.5	5547.3	4727.9	5324.7	3738.6	6239.6	5381.1	4628.7
Dabbadka	4492.4	3373.7	2017.9	7161.6	4991.8	5317	5317	5006.1	4829.1	4885.6
Galibeedu	4554.1	5043.8	3694.8	4023.2	3600.3	4293.4	2156.8	5811.7	4183.4	3591
Madikeri	3429.8	4110.2	2923.8	3334.8	2836.6	3442	2478	4218.4	3123.6	2976.8
Napoklu	2974.6	3747.9	2505.4	2816.3	2539.9	2650.8	1953.6	3365.6	2656.2	2303.4
Sampaje	4209.2	4053	3404.2	3965.9	4190.4	4383.5	2859.2	5229.5	4039.1	3635.8



Month wise rainfall data for Baghamandala rain gauge station from 2006 to 2015										
Year	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
January					*5.8*					
February			*31.2*			*27.4*		*7.6*		*17.6*
March	*42.6*		*230.5*	*177.7*	*19.6*	*23*	*11.2*	*8.4*		*53.4*
April	*45.9*	*68.4*	*56*	*79.6*	*97.8*	*151.2*	*205.6*	*35.4*	*103.9*	*125.3*
May	*1096*	*122.6*	*142*	*150*	*161.8*	*121.2*	*31.2*	*121.5*	*289.6*	*232.4*
June	*1058.4*	*1434*	*1178*	*496.8*	*804*	*1514.2*	*657.4*	*1681.4*	*606.4*	*1851.31*
July	*1798.2*	*2624.8*	*1203*	*2820.8*	*1379.6*	*1237.6*	*1002*	*2269.4*	*2204.4*	*967.8*
August	*1115.8*	*1633.4*	*1034.2*	*541.6*	*971.6*	*1137.4*	*1055.4*	*1174.2*	*1372*	*601.3*
September	*532.9*	*966.7*	*385*	*629.8*	*526.2*	*728.8*	*519*	*514.2*	*609.6*	*328.4*
October	*267*	*233.2*	*252*	*341.6*	*481.9*	*297.9*	*111*	*426.5*	*170.8*	*280.8*
November	*143.2*	*114.8*	*2.6*	*165.2*	*279.6*	*86*	*140.8*	*1*	*24.4*	*143.2*
December	*1.2*	*2*		*144.2*			*5*			*27.2*

Annexure - III

Monthwise rainfall data for Dabadka rain gauge station from 2006 to 2015										
Year	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
January					60.7					
February			30				119.7			
March	27.6	13.2	163.5	90	23.3		182.9		1.4	14.4
April	6.2	152.5	32	37.4	80.8	119.7	909.7	38.6	46.5	66.8
May	234.1	78.2	39.5	32.6	339.1	182.9	1298.6	34.3	274	221.1
June	767	493.5	492.9	392.6	501.6	909.7	1277.5	1195.5	588.1	956.9
July	1455.3	1261.7	410.7	3028.9	1348.4	1298.6	666.7	1912.9	1915.4	1042.8
August	1145.7	767.7	614.2	910.6	1180.4	1277.5	532.6	1172.5	1289	864.6
September	467.3	373.2	148	1601.4	616.2	666.7	329.3	348.9	575.7	743.8
October	231.5	72.9	87.1	710.3	380.6	532.6		260.9	139	725.8
November	156.4	160.8		205.6	460.7	329.3		42.5		249.4
December	1.3			152.2						

Monthwise rainfall data for Galibeedu raingauge station from 2006 to 2015										
Year	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
January									5	
February			32			25		56		
March	77		204	82		70		53		6
April	11	78	90.2	58	36	59.2	161.5		31	126.2
May	777.2	70	7	56	125.6	117.2	15	148.5	167.2	139.2
June	711	984	607.2	245.5	533.6	813.3	336.2	1241.4	491.9	1147.6
July	1329.9	1614.9	1121.5	1829.5	1219.7	1158.5	804.2	2457.6	1561.2	997.6
August	1133	1374.5	1207.5	592.5	811.2	1179.4	180.8	1080.9	1199.7	770.5
September	308.5	640.6	239.2	680.5	444.9	614.6	376.1	508.6	593.4	220.4
October	159	240.8	186.2	299.5	308.9	151.2	102	245.5	134	145.8
November	47.5	41		77.3	120.4	105	181	20.2		35.7
December				102.4						2

Monthwise rainfall data for Madikeri rain gauge station from 2006 t 2015										
Year	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
January										
February			16.3		0	11.6		33.4		
March	49.1		187.8	62	5	8	7.8	110		1.2
April	35.1	26.4	43.4	57.5	81.2	99	143.4	5.3	49.6	80.9
May	539.1	36.2	27.1	56	121.2	72.2	8.8	72.3	181.2	185
June	560	859.6	635	256.8	350.9	778	394.3	858.4	311.6	1098.2
July	968.7	1312.2	747.4	1608	864.5	853.3	567.1	1878.5	1118.8	712
August	691.2	1076.5	790.2	437.8	628.4	866.4	731.8	792.6	807.2	421.4
September	332.7	539.6	245.4	455.8	329.8	542.2	350.1	353.7	591.4	273.6
October	150.1	204.8	219.2	205.1	295.2	150.8	100.1	100	63.8	128.9
November	101.3	49.9	12	93	149	60.3	164.6	6.8		63.4
December	2.5	5		102.8	11.4	0.2	10	7.4		12.2

Monthwise rainfall data for Napoklu raingauge station from 2006 to 2015										
Year	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
January					17.2					
February			30.2			27.8		20.8		8.2
March	55.6	39	213.6	156.8	12.8	16	8.4	83.5	14.2	90.7
April	84.4	178.2	176.4	88.8	197	230.8	145.2	13.6	148.2	187.2
May	528	128.4	27.2	111.8	114.8	179.4	24.8	127.4	296	173.4
June	508.2	756.1	562	231	345.5	590.8	294.8	852.3	291	866.6
July	784.2	1318.1	562.9	1277.4	619.4	530	401.6	1194.2	993.6	332.2
August	523	772.8	568.3	222	403.2	394.6	623.6	517.8	544.2	187.5
September	302.2	413.5	175	371.3	237.2	255.5	205.6	352.6	317.6	244.4
October	80.6	89.6	186.6	115.4	268.6	333.1	142.8	198.8	49.6	130.2
November	108.4	49.6	2	205.6	324.2	92.8	100.2	4.6	1.8	80.8
December		2.6	1.2	36.2			6.6			2.2

Monthwise rainfall data for Sampaje raingauge station from 2006 to 2015										
Year	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
January					32.8	6.4				
February			43.8					64.5		3.2
March	58.6	5	198.8	155	56.8	11.6	1.2	58	3.6	71.3
April	7.2	97.6	48.9	175.8	54.2	160	158.2	64.8	50.8	59.6
May	544.6	104	27.6	136.2	268.7	124	38.2	86.4	389	240.8
June	713.4	709.6	642.8	275.1	494.3	932.6	479.2	1225.2	397.6	682
July	1043.6	1334	899.6	1296.7	1114.5	989	532.2	1955.4	1310.3	1079.1
August	833.4	961	958	690.7	958.2	1086	1007.2	976.8	1132.8	812.7
September	428.4	563.4	297.5	710	399.2	529.9	328.6	347.2	548.6	218.5
October	446.2	175.2	284	248.2	379.5	344.2	152.8	399	177	342.2
November	131.4	103.2		137.2	432.2	199.8	157.2	52.2	29.4	114.6
December	2.4		3.2	141			4.4			11.8

Monthwise rainfall data for Talacauvery rain gauge station from 2006 to 2015										
Year	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
January					16					
February			35.2							
March	76.4	1.8	238	165.3	22.3	9.6	18.5			60
April	39	114.5	86.6	52	89	100.9	183		54.4	63
May	1520.5	130.7	110.5	141.1	233.6	112.6	60.2	40	464.2	301.2
June	1109.7	2053.1	1557.8	781.4	1221	1957.4	1063.2	2239.4	1231.1	1818.1
July	1996.7	2851.6	1246.6	3599.9	1920.4	1693.6	1431.9	3426.6	3116.6	1427.4
August	1338.4	1770.4	858.9	887.6	1473	1535.2	1815.2	1625.4	1876.8	882.3
September	827.5	1159.8	267.9	872.2	789.4	1024	814.8	817.3	856.1	398.8
October	220.1	358	368.9	471	587.1	317.1	234	420	250.4	322.8
November	208.5	7.3	6.3	212.2	461.8	115.2	101.4	3		172.8
December				169.2						

Annexure –IV: Tabular 41-point geo-parametric sheet for landslide inventory data of major landslides.

Slide_No	T.S. No.	Lat	Long	Geomorphological process	Geomorphological form	Rocktype	Weathering	LULC	Hydrological condition	Overburden	Overburden Thickness	Erosion	Length	Width	Height	Type_of_Material	Type of movement	Failure plane	Activity	Disturbuti	Style	Failure mechanism	History	Morphometry (upslope)	Morphometry (downslope)	Triggering	Geoscienti	Remedial_m	Qualitativ
KAR/KOD/2016/01	48P11	12.49	75.57	Gravitational	LDS			HHP	Damp	In-situ soil	0.5-5m		12m	20m	1m	Debris	Slide	Shallow (>5m)	Inactive	Retrogressive	Single	Shallow Translational	Old	15	70	Rain fall	Increase in pore pressure (Damp), slope disturbance	Lined drainage; slope contouring	risk to communication line, life and property
KAR/KOD/2016/02	48P11	12.45	75.643	Gravitational	MDS	Dolerite	Moderate	Thick Vegetation	Damp		<0.5m		17m	34m	1m	Debris	Slide	Shallow (>5m)	Active	Widening and enlarging	Single	Shallow Translational	Old	15	70	Rain fall	Increase in pore pressure (Damp), slope disturbance/ECS	Lined drainage; slope contouring	risk to communication line, life and property
KAR/KOD/2016/03	48P11	12.45	75.64	Gravitational	MDS	Granite gneiss	Moderate	Thick Vegetation	Damp		<0.5m		15m	30m	1.5m	Debris	Slide	Shallow (>5m)	Active	Widening and enlarging	Single	Shallow Translational	Old	15	70	Rain fall	Increase in pore pressure (Damp), slope disturbance/ECS	Lined drainage; slope contouring	risk to communication line, life and property
KAR/KOD/2016/04	48P11	12.44	75.659	Gravitational	MDS			LHP	Damp	In-situ soil	0.5-5m		15m	31m	1.5m	Debris	Slide	Shallow (>5m)	Inactive	Retrogressive	Single	Shallow Translational	Old	25	75	Rain fall	ECS/extensive cut slope failure	Lined drainage; slope contouring	risk to communication line, life and property
KAR/KOD/2016/05	48P11	12.44	75.659	Gravitational	MDS			LHP	Damp	In-situ soil	0.5-5m		10m	24m	2m	Debris	Slide	Shallow (>5m)	Inactive	Retrogressive	Single	Shallow Translational	Old	25	75	Rain fall	Toe removal	Lined drainage; slope contouring	risk to communication line, life and property
KAR/KOD/2016/06	48P11	12.44	75.659	Gravitational	MDS			LHP	Damp	In-situ soil	0.5-5m		20m	42.20m	3m	Debris	Slide	Shallow (>5m)	Active	Retrogressive	Single	Shallow Translational	Old	25	70	Rain fall	Toe removal	Lined drainage; slope contouring	risk to communication line, life and property
KAR/KOD/2016/07	48P11	12.44	75.66	Gravitational	MDS	Granite gneiss	Moderate	Thick Vegetation	Damp		<0.5m		12m	35.10m	1.5m	Debris	Slide	Shallow (>5m)	Inactive	Retrogressive	Single	Shallow Translational	Old	25	70	Rain fall	Toe removal	Slope benching and proper drainage at the toe part	risk to communication line, life and prop

Annexure –IV: Tabular 41-point geo-parametric sheet for landslide inventory data of major landslides.

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KAR/KOD/2016/08	48P11	12.44	75.661	Gravitational	MDS	Granite gneiss	Moderate	Thick Vegetation	Damp		<0.5m		10m	25m	1m	Debris	Slide	Shallow (>5m)	Active	Retrogressive	Single	Shallow Translational	Old	15	75	Rain fall	Toe removal	Slope benching and proper drainage at the toe part	risk to communication line, life and property
KAR/KOD/2016/09	48P11	12.44	75.664	Gravitational	MDS	Granite gneiss	Moderate	Thick Vegetation	Damp		<0.5m		10m	23m	1.5m	Debris	Slide	Shallow (>5m)	Active	Retrogressive	Single	Shallow Translational	Old	25	70	Rain fall	slope modification	Slope benching and proper drainage at the toe part	risk to communication line, life and property
KAR/KOD/2016/10	48P11	12.44	75.666	Gravitational	MDS	Granite gneiss	Moderate	Thick Vegetation	Damp		<0.5m		12m	55m	2m	Debris	Slide	Shallow (>5m)	suspended	Retrogressive	Single	Shallow Translational	Old	15	80	Rain fall	damp/water saturation/jointed rock	Slope benching and proper drainage at the toe part	risk to communication line, life and property
KAR/KOD/2016/11	48P11	12.44	75.669	Gravitational	MDS			Settlement	Damp	In-situ soil	5-10m		12m	23.30m	1.5m	Debris	Slide	Shallow (>5m)	Inactive	Retrogressive	Single	Shallow Translational	Old	15	80	Rain fall	damp/water saturation/jointed rock	Slope benching and proper drainage at the toe part	risk to communication line, life and property
KAR/KOD/2016/12	48P11	12.44	75.667	Gravitational	MDS	Granite gneiss	Moderate	Thick Vegetation	Damp		5-10m		15m	37.40m	2m	Debris	Slide	Shallow (>5m)	Inactive	Retrogressive	Single	Shallow Translational	Old	15	85	Rain fall	damp/water saturation/jointed rock	Slope benching and proper drainage at the toe part	risk to communication line, life and property
KAR/KOD/2016/13	48P11	12.43	75.506	Gravitational	MDS	Granite - Siilimanite gneiss+graphite+cordierite	Moderate	Thick Vegetation	Damp		<0.5m		15m	40.60m	2m	Debris	Slide	Shallow (>5m)	Inactive	Retrogressive	Single	Shallow Translational	Old	35	70	Rain fall	damp/water saturation	Slope benching and proper drainage at the toe part	risk to communication line, life and property

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KAR/KOD/2016/14	48P11	12.43	75.672	Gravitational	MDS			Thick Vegetation	Damp	In-situ soil	0.5-5m		20m	43.50m	2.3m	Debris	Slide	Shallow (>5m)	Inactive	Retrogressive	Single	Shallow Translational	Old	15	75	Rain fall	damp/water saturation/plantation	Lined drainage; slope contouring	risk to communication line, life and property
KAR/KOD/2016/15	48P11	12.43	75.678	Gravitational	MDS	Granite gneiss	Moderate	LHP	Damp		<0.5m		15m	26.60m	2m	Debris	Slide	Shallow (>5m)	Inactive	Widening and enlarging	Single	Shallow Translational	Old	35	70	Rain fall	damp/water saturation/plantation	Lined drainage; slope contouring	risk to communication line, life and property
KAR/KOD/2016/16	48P11	12.42	75.682	Gravitational	MDS	Granite gneiss	Moderate	LHP	Damp		<0.5m		30m	64m	4.5m	Debris	Slide	Shallow (>5m)	Inactive	Retrogressive	Single	Shallow Translational	Old	25	80	Rain fall	slope modification	Lined drainage; slope contouring	risk to communication line, life and property
KAR/KOD/2016/17	48P07	12.50	75.481	Gravitational	LDS			Thick Vegetation	Damp	In-situ soil	0.5-5m		10m	18m	7m (VH)	Debris slump	Subsidence	Shallow (>5m)	Active	Widening and enlarging	Single	Shallow Translational	Old	15	80	Rain fall	damp/water saturation	Lined drainage; slope contouring	risk to communication line, life and property
KAR/KOD/2016/18	48P11	12.42	75.689	Gravitational	MDS			Thick Vegetation	Damp	In-situ soil	0.5-5m		12m	16m	1m	Debris	Slide	Shallow (>5m)	Inactive	Retrogressive	Single	Shallow Translational	Old	25	70	Rain fall	damp/water saturation	Lined drainage; slope contouring	risk to communication line, life and property
KAR/KOD/2016/19	48P11	12.42	75.691	Gravitational	MDS			Thick Vegetation	Damp	In-situ soil	0.5-5m		10m	18m	8m (VH)	Debris slump	Subsidence	Shallow (>5m)	Active	Widening and enlarging	Single	Shallow Translational	Old	25	70	Rain fall	damp/water saturation	Lined drainage; slope contouring	risk to communication line, life and property
KAR/KOD/2016/20	48P11	12.42	75.693	Gravitational	MDS			LHP	Damp	In-situ soil	0.5-5m		12m	10m	1.5m	Debris	Slide	Shallow (>5m)	Active	Widening and enlarging	Single	Shallow Translational	Old	25	75	Rain fall	damp/water saturation	Lined drainage; slope contouring	risk to communication line, life and property

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KAR/KOD/2016/21	48P11	12.42	75.695	Gravitational	MDS			LHP	Damp	In-situ soil	0.5-5m		15m	26.60m	1.5m	Debris	Slide	Shallow (>5m)	Inactive	Retrogressive	Single	Shallow Translational	Old	25	70	Rain fall	slope modification	Lined drainage; slope contouring	risk to communication line, life and property
KAR/KOD/2016/22	48P11	12.42	75.707	Gravitational	MDS			LHP	Damp	In-situ soil	0.5-5m		10m	24.20m	2m	Debris	Slide	Shallow (>5m)	Active	Widening and enlarging	Single	Shallow Translational	Old	15	75	Rain fall	damp/water saturation	Lined drainage; slope contouring	risk to communication line, life and property
KAR/KOD/2016/23	48P11	12.42	75.707	Gravitational	MDS			LHP	Damp	In-situ soil	0.5-5m		10m	32m	1.5m	Debris	Slide	Shallow (>5m)	Active	Widening and enlarging	Single	Shallow Translational	Old	25	80	Rain fall	Toe removal	Lined drainage; slope contouring	risk to communication line, life and property
KAR/KOD/2016/24	48P11	12.41	75.73	Gravitational	MDS			Moderate vegetation	Damp	In-situ soil	0.5-5m		12m	30m	1.2m	Debris	Slide	Shallow (>5m)	Active	Widening and enlarging	Single	Shallow Translational	old slide	25	80	Rain fall	Toe removal	Lined drainage; slope contouring	risk to communication line, life and property
KAR/KOD/2016/25	48P11	12.41	75.737	Gravitational	MDS	Granite - Siilimanite gneiss+graphite+cordierite	Moderate	LHP	Damp		<0.5m		50m	26m	2.5m	Debris	Slide	Shallow (>5m)	Inactive	Retrogressive	Single	Shallow Translational	old slide	35	75	Rain fall/slope modification	damp/water saturation	Lined drainage is provided at toe part of the cut slope	risk to communication line, life and property
KAR/KOD/2016/26	48P11	12.41	75.738	Gravitational	MDS	Granite - Siilimanite gneiss+graphite+cordierite	Moderate	LHP	Damp		<0.5m					Debris	Slide	Shallow (>5m)	Active	Widening and enlarging	Single	Shallow Translational	Old	25	75		weathered rock; increase in pore water pressure	Lined drainage is provided at toe part of the cut slope	risk to communication line, life and property
KAR/KOD/2016/27	48P11	12.41	75.739	Gravitational	LDS	Granite - Siilimanite gneiss+graphite+cordierite	Moderate	LHP	Damp		<0.5m					Debris	Slide	Shallow (>5m)	Inactive	Retrogressive	Single	Shallow Translational	Old	35	80	Rain fall	weathered rock; increase in pore water pressure	Slope benching and proper drainage at the toe part	risk to communication line, life and property

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KAR/ KOD/2 016/28	48P1 1	12.4 1	75.7 39	Grav itatio nal	LDS	Gran ite - Siili mani te gnei ss+ grap hite+ cordi erite	Mod erate	LHP	Dam p		<0.5m			16m		Debris	Slide	Shallow (>5m)	Inactive	Retrogressi ve	Single	Shallow Translation al	Old	35	75		weather ed rock; increase in pore water pressure	Slope benchin g and proper drainage at the toe part	risk to com muni catio n line, life and prop erty
KAR/ KOD/2 016/29	48P1 1	12.4 1	75.7 39	Grav itatio nal	LDS	Gran ite gnei ss	Mod erate	LHP	Dam p		<0.5m		30m	29m		Debris	Slide	Shallow (>5m)	Active	Widening and enlarging	Single	Shallow Translation al	Old	35	70	Rain fall	weather ed rock; increase in pore water pressure	Slope benchin g and proper drainage at the toe part	risk to com muni catio n line, life and prop erty
KAR/ KOD/2 016/30	48P1 1	12.4 4	75.7 34	Grav itatio nal	LDS			Thick Vegetati on	Dam p	In- situ soil	0.5-5m		11m	10m	50m	Debris	Slide	Shallow (>5m)	Active	Widening and enlarging	Single	Shallow Translation al	Old	15	80	Rain fall	loose in- situ soil; slope disturba nce	Slope benchin g and proper drainage at the toe part	risk to com muni catio n line, life and prop erty
KAR/ KOD/2 016/31	48P1 1	12.4 6	75.7 21	Grav itatio nal	LDS			LHP	Dam p	In- situ soil	0.5-5m		15m	42m	1.5m	Debris	Slide	Shallow (>5m)	Active	Widening and enlarging	Single	Shallow Translation al	old slide	45	80	Rain fall	loose in- situ soil; slope disturba nce	Slope benchin g and proper drainage at the toe part	risk to com muni catio n line, life and prop erty
KAR/ KOD/2 016/32	48P1 1	12.4 6	75.7 2	Grav itatio nal	LDS			LHP	Dam p	In- situ soil	0.5-5m		8m	5m		Debris slump	Subside nce	Shallow (>5m)	Active	Widening and enlarging	Single	Shallow Translation al	old slide	15	75	Rain fall	loose in- situ soil; slope disturba nce	Slope benchin g and proper drainage at the toe part	risk to com muni catio n line, life and prop erty
KAR/ KOD/2 016/33	48P1 1	12.4 6	75.7 2	Grav itatio nal	LDS			LHP	Dam p	In- situ soil	0.5-5m		6m	14m	5m	Debris slump	Subside nce	Shallow (>5m)	Inactive	Retrogressi ve	Single	Shallow Translation al	old slide	25	70	Rain fall	loose in- situ soil; slope disturba nce	Slope benchin g and proper drainage at the toe part	risk to com muni catio n line, life and prop erty
KAR/ KOD/2 016/34	48P1 1	12.5 0	75.7 24	Grav itatio nal	LDS			Moderat e vegetati on	Dam p	In- situ soil	<0.5m		8m	28.40m	1.5m	Debris slump	Subside nce	Shallow (>5m)	Active	Widening and enlarging	Single	Shallow Translation al	old slide	35	70	Rain fall	loose in- situ soil; slope disturba nce	Slope benchin g and proper drainage at the toe part	risk to com muni catio n line, life and prop erty

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KAR/KOD/2016/35	48P11	12.49	75.716	Gravitational	LDS			LHP	Damp	In-situ soil	0.5-5m		10m	14m	1.7m	Debris	Slide	Shallow (>5m)	Active	Widening and enlarging	Single	Shallow Translational	old slide	35	75	Rain fall	ECS/extensive cut slope failure	Slope benching	risk to communication line, life and property
KAR/KOD/2016/36	48P11	12.48	75.712	Gravitational	LDS			LHP	Damp	In-situ soil	0.5-5m		25m	50m	3m	Debris	Slide	Shallow (>5m)	Active	Widening and enlarging	Single	Shallow Translational	old slide	35	70	Rain fall	loose in-situ soil; slope disturbance	Slope benching	risk to communication line, life and property
KAR/KOD/2016/37	48P11	12.48	75.712	Gravitational	LDS			LHP	Damp	In-situ soil	0.5-5m		22m	60m	2m	Debris	Slide	Shallow (>5m)	Active	Widening and enlarging	Single	Shallow Translational	old slide	35	70	Rain fall	loose in-situ soil; slope disturbance	Slope benching	risk to communication line, life and property
KAR/KOD/2016/38	48P11	12.48	75.713	Gravitational	LDS			LHP	Damp	In-situ soil	0.5-5m		22m	55m	2m	Debris	Subsidence	Shallow (>5m)	Active	Widening and enlarging	Single	Shallow Translational	old slide	25	75	Rain fall	ECS/extensive cut slope failure	Slope benching	risk to communication line, life and property
KAR/KOD/2016/39	48P11	12.45	75.714	Gravitational	LDS			Thick Vegetation	Damp	In-situ soil	0.5-5m		10m	37.50m	1.5m	Debris	Slide	Shallow (>5m)	Active	Widening and enlarging	Single	Shallow Translational	old slide	15	75	Rain fall	loose in-situ soil; slope disturbance	Slope benching and proper drainage at the toe part	risk to communication line, life and property
KAR/KOD/2016/40	48P11	12.47	75.678	Gravitational	PPC			Thick Vegetation	Damp	In-situ soil	0.5-5m		8m	27.60m	1.5m	Debris slump	Subsidence	Shallow (>5m)	Active	Widening and enlarging	Single	Shallow Translational	old slide	15	70	Rain fall	loose in-situ soil; slope disturbance	Slope benching and proper drainage at the toe part	risk to communication line, life and property
KAR/KOD/2016/41	48P11	12.47	75.678	Gravitational	PPC			Thick Vegetation	Damp	In-situ soil	0.5-5m		16m	20.50m	1.2m	Debris	Slide	Shallow (>5m)	Inactive	Widening and enlarging	Single	Shallow Translational	old slide	15	70	Rain fall	loose in-situ soil; slope disturbance	Slope benching and proper drainage at the toe part	risk to communication line, life and property

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KAR/KOD/2016/42	48P11	12.44	75.559	Gravitational	MDS			HHP	Damp	In-situ soil	0.5-5m		20m	38.80m	3.5m	Debris	Slide	Shallow (>5m)	Active	Widening and enlarging	Single	Shallow Translational	old slide	15	75	Rain fall	loose in-situ soil; slope disturbance	Slope benching and proper drainage at the toe part	risk to communication line, life and property
KAR/KOD/2016/43	48P11	12.38	75.707	Gravitational	LDS			LHP	Damp	In-situ soil	0.5-5m		7m	21.60m	VH=7m	Debris	Slide	Shallow (>5m)	Active	Widening and enlarging	Single	Shallow Translational	old slide	15	85	Rain fall	loose in-situ soil; slope disturbance	Slope benching and proper drainage at the toe part	risk to communication line, life and property
KAR/KOD/2016/44	48P11	12.41	75.517	Gravitational	MDS			Thick Vegetation	Damp	In-situ soil	5-10m		10m	32m	1m	Debris	Slide	Shallow (>5m)	Inactive	Widening and enlarging	Single	Shallow Translational		35	80	Rain fall	loose in-situ soil; slope disturbance	Slope benching and proper drainage at the toe part	risk to communication line, life and property
KAR/KOD/2016/45	48P07	12.47	75.479	Gravitational	LDS			HHP	Damp	In-situ soil	0.5-5m		13m	15.30m	1.5m	Debris	Slide	Shallow (>5m)	Active	Widening and enlarging	Multiple	Shallow Translational	old slide	25	80	Rain fall	loose in-situ soil; slope disturbance	Lined drainage; slope contouring	
KAR/KOD/2016/46	48P11	12.42	75.743	Gravitational	PPC			LHP	Damp	In-situ soil	0.5-5m		7m	29.90m	1.5m	Debris	Slide	Shallow (>5m)	Active	Widening and enlarging	Single	Shallow Translational	old slide	15	75	Rain fall	loose in-situ soil; slope disturbance	Lined drainage; slope contouring	
KAR/KOD/2016/47	48P11	12.50	75.743	Gravitational	LDS	Granite gneiss	Moderate		Wet		<0.5m		12m	29.30m	3.5m	Debris	Slide	Shallow (>5m)	Active	Widening and enlarging	Single	Shallow Translational	old slide	15	70	Rain fall	weathered jointed rock; slope disturbance	Lined drainage; slope contouring	
KAR/KOD/2016/48	48P11	12.41	75.743	Gravitational	LDS			LHP	Damp	In-situ soil	0.5-5m		16m	50m	2.7m	Debris	Slide	Shallow (>5m)	Active	Widening and enlarging	Single	Shallow Translational	old slide	25	75	Rain fall	loose in-situ soil; slope disturbance	Lined drainage; slope contouring	50m down weathered rock and loose material
KAR/KOD/2016/49	48P11	12.41	75.743	Gravitational	LDS	Granite gneiss	Moderate	LHP	Damp		<0.5m		20m	37.5m	2.5m	Debris	Slide	Shallow (>5m)	Active	Widening and enlarging	Single	Shallow Translational	old slide	25	80	Rain fall	weathered jointed rock; slope disturbance	Lined drainage; slope contouring	Weathered rock
KAR/KOD/2016/50	48P11	12.41	75.744	Gravitational	LDS	Granite gneiss	Moderate	LHP	Damp		<0.5m		50m	45.3	1m	Debris	Slide	Shallow (>5m)	Active	Widening and enlarging	Single	Shallow Translational	old slide	15	80	Rain fall	weathered jointed rock; slope disturbance	Lined drainage; slope contouring	Weathered rock

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KAR/KOD/2016/51	48P11	12.41	75.744	Gravitational	LDS	Granite gneiss	Moderate	LHP	Damp		<0.5m		48m	50m	2m	Debris	Slide	Shallow (>5m)	Inactive	Widening and enlarging	Single	Shallow Translational	old slide	15	75	Rain fall	weathered jointed rock; slope disturbance	Lined drainage; slope contouring	
KAR/KOD/2016/52	48P11	12.41	75.741	Gravitational	LDS			LHP	Damp	In-situ soil	0.5-5m		15m	29.5m	2.5m	Debris	Slide	Shallow (>5m)	Active/Reactivated	Widening and enlarging	Single	Shallow Translational	old slide	35	75	Rain fall	loose in-situ soil; slope disturbance	Lined drainage is to be provided at toe part as well as diverging of drainage away from crown.	
KAR/KOD/2016/53	48P07	12.50	75.394	Gravitational	LDS	Granite - Siilimanite gneiss+graphite+cordierite	Moderate	HHP	Damp		<0.5m		50m	25m	2m	Debris	Slide	Shallow (>5m)	Active	Widening and enlarging	Single	Shallow Translational	15 yrs old	25	70	Rain fall	weathered jointed rock; slope disturbance	Lined drainage is to be provided at toe part as well as diverging of drainage away from crown.	
KAR/KOD/2016/54	48P07	12.45	75.434	Gravitational	MDS			Thick Vegetation	Damp	In-situ soil	0.5-5m		15m	25m	2m	Debris	Slide	Shallow (>5m)	Active	Widening and enlarging	Single	Shallow Translational	old slide	35	70	Rain fall	loose in-situ soil; slope disturbance	Lined drainage is to be provided at toe part as well as diverging of drainage away from crown.	rock on both side of the slide
KAR/KOD/2016/55	48P07	12.44	75.434	Gravitational	MDS			Thick Vegetation	Damp	In-situ soil	5-10m		18m	26m	1.5m	Debris	Slide	Shallow (>5m)	Active	Widening and enlarging	Single	Shallow Translational	old slide	35	70	Rain fall	loose in-situ soil; slope disturbance	Lined drainage is to be provided at toe part as well as diverging of drainage away from crown.	
KAR/KOD/2016/56	48P07	12.45	75.448	Gravitational	MDS	Granite - Siilimanite gneiss+graphite+cordierite	Moderate	Thick Vegetation	Damp		<0.5m		15m	23.40m	1m	Debris	Slide	Shallow (>5m)	Active	Widening and enlarging	Single	Shallow Translational	old slide	25	75	Rain fall/ Anthropogenic	weathered jointed rock; slope disturbance	Lined drainage is to be provided at toe part as well as diverging of drainage away from crown.	
KAR/KOD/2016/57	48P07	12.44	75.463	Gravitational	MDS	Charnockite	Moderate	Thick Vegetation	Damp		<0.5m		12.5m	35.60m	1m	Debris	Slide	Shallow (>5m)	Inactive	Widening and enlarging	Multiple	Shallow Translational	old slide	35	75	Rain fall	weathered jointed rock; slope disturbance	Slope benching and proper drainage at the toe part	

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KAR/KOD/2016/58	48P07	12.44	75.465	Gravitational	MDS	Charnockite	Moderate	Thick Vegetation	Damp		<0.5m		20m	41.40m	3m	Debris	Slide	Shallow (>5m)	Inactive	Widening and enlarging	Single	Shallow Translational	old slide	35	80	Rain fall	weathered jointed rock; slope disturbance	Slope benching and proper drainage at the toe part	
KAR/KOD/2016/59	48P07	12.41	75.5	Gravitational	MDS	Charnockite	Moderate	Thick Vegetation	Damp		<0.5m		15m	24.6m	1.5m	Debris	Slide	Shallow (>5m)	Active	Widening and enlarging	Single	Shallow Translational	old slide	35	80	Rain fall/ no vegetation on slope	weathered jointed rock; slope disturbance	Slope benching and proper drainage at the toe part	
KAR/KOD/2016/60	48P11	12.38	75.516	Gravitational	HDS	Charnockite	Moderate	Thick Vegetation	Damp		<0.5m		22m	31.60m	2.5m	Rock	Slide	Shallow (>5m)	Active	Retrogressive	Single	Shallow Translational	old slide	35	75	Rain fall	weathered jointed rock; slope disturbance	Slope benching and proper drainage at the toe part	
KAR/KOD/2016/61	48P07	12.39	75.493	Gravitational	HDS	Charnockite	Moderate	Settlement	Damp		<0.5m		19m	30m	2m	Debris	Slide	Shallow (>5m)	Inactive	Widening and enlarging	Single	Shallow Translational	old slide	35	75	Rain fall	weathered jointed rock; slope disturbance	Slope benching and proper drainage at the toe part	about 100 m on either side slumps observed. .about 5m wide and 6m length.
KAR/KOD/2016/63	48P07	12.45	75.433	Gravitational	MDS			Thick Vegetation	Damp	In-situ soil	0.5-5m		36.40m	18m	2m	Debris	Slide	Shallow (>5m)	Inactive	Retrogressive	Single	Shallow Translational	old slide	35	70	Rain fall	loose in-situ soil; slope disturbance	Slope benching and proper drainage at the toe part	150 m zone is susceptible
KAR/KOD/2016/64	48P07	12.45	75.447	Gravitational	MDS	Charnockite	Moderate	Thick Vegetation	Damp		<0.5m		17m	100m	1.5m	Debris	Slide	Shallow (>5m)	Inactive	Retrogressive	Single	Shallow Translational	old slide	35	70		weathered jointed rock; slope disturbance	Slope benching	
KAR/KOD/2016/65	48P07	12.44	75.463	Gravitational	MDS	Charnockite	Moderate	Thick Vegetation	Damp		<0.5m		15m	150m	2.5m	Debris	Slide	Shallow (>5m)	Inactive	Retrogressive	Multiple	Shallow Translational	old slide	25	70		weathered jointed rock; slope disturbance	Slope benching	
KAR/KOD/2016/66	48P11	12.36	75.534	Gravitational	HDS	Charnockite	Moderate	Thick Vegetation	Damp		<0.5m		22m	75m	2.5m	Rock slide	Slide	Shallow (>5m)	Active	Widening and enlarging	Single	Shallow Translational	new slide	15	75	Rain fall	Anthropogenic due to steep vertical road cut, adversely oriented joint pattern, damp and seepage along weaker plane	Slope benching	

Annexure –IV: Tabular 41-point geo-parametric sheet for landslide inventory data of major landslides.

KAR/KOD/2016/67	48P11	12.39	75.511	Gravitational	HDS	Charnockite	Moderate	Thick Vegetation	Damp		<0.5m		14m	30m	1.5m	Shallow translational debris slide	Slide	Shallow (>5m)	Inactive	Retrogressive	Single	Shallow Translational	old slide	25	75		weathered jointed rock; slope disturbance	Slope benching	
KAR/KOD/2016/68	48P11	12.44	75.671	Gravitational	MDS			HHP	Damp	In-situ soil	5-10m		13.5m	50m	2.5m	Debris	Slide	Shallow (>5m)	Inactive	Widening and enlarging	Single	Shallow Translational	old slide	25	80		loose in-situ soil; slope disturbance	Proper drainage along the toe part.	120m retaining wall of 1m height constructed and lined drainage provided.
KAR/KOD/2016/69	48P11	12.43	75.713	Gravitational	MDS	Granite - Siilimanite gneiss+graphite+cordierite	Moderate	HHP	Damp		<0.5m		15m	9m	1m	Debris	Slide	Shallow (>5m)	Active	Widening and enlarging	Single	Shallow Translational	new slide	15	80	Rain fall	highly jointed and fractured rock with 3 sets of adversely oriented joints	Slope benching	highly susceptible zone for failure, sprsely vegetated
KAR/KOD/2016/70	48P11	12.41	75.736	Gravitational	LDS			LHP	Damp	In-situ soil	0.5-5m		10m	32m	1m	Debris	Slide	Shallow (>5m)	Inactive	Widening and enlarging	Single	Shallow Translational	old slide	25	75	anthropogenic triggered by rainfall	Extensive slope cut, loose slope forming material, plantation, mostly barren	Slope benching	
KAR/KOD/2016/71	48P11	12.41	75.744	Gravitational	LDS			Settlement on modified slope	Damp	In-situ soil	0.5-5m					Debris	Slide	Shallow (>5m)	Inactive	Widening and enlarging	Single	Shallow Translational	old slide	25	70	anthropogenic triggered by rainfall	modified slope with settlement near drainge /nala	Slope benching	
KAR/KOD/2016/72	48P11	12.41	75.745	Gravitational	PPC				Damp	In-situ soil	0.5-5m					Debris	Slide	Shallow (>5m)	Inactive	Widening and enlarging	Single	Shallow Translational	old slide	35	80	anthropogenic triggered by rainfall	modified slope with settlement near drainge /nala	Slope benching	settlement at top and downslope are at high risk.