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भारतीय भूवैज्ञानिक सर्वेक्षण

GOVERNMENT OF INDIA
GEOLOGICAL SURVEY OF INDIA

कर्नाटक राज्य के दक्षिण कन्नड़ जिले में भूआकृति संख्या ४८ एल / १३ , एल / १४ एवं ४८ पी / १ , पी / २ के कुछ हिस्सों में वृहद पैमाने पर (१:५०,०००) भूस्खलन संवेदनशीलता का मानचित्रण

(कोड सं: एल एस एम / एस आर / के जी / २०१६ / ११२)

(कार्य सत्र २०१६-१७)

MACRO-SCALE (1:50,000) LANDSLIDE SUSCEPTIBILITY MAPPING IN PARTS OF TOPOSHEET NO. 48 L/13, L/14, P/1 & P/2, DAKSHIN KANNADA DISTRICT, KARNATAKA

(CODE NO : LSM/SR/KG/2016/112)

(Field Season 2016-17)

द्वारा / *BY*

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Project

भूस्खलन संवेदनशीलता मानचित्रण
Landslide Susceptibility Mapping

राज्य इकाई: कर्नाटक व गोवा, दक्षिणी क्षेत्र

State Unit: Karnataka and Goa Southern Region

बेंगलुरू / Bengaluru
२०१७ / 2017

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PROJECT: NLSM
STATE UNIT: KARNATAKA & GOA
2017

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(**कूट:** एल एस एम / एस आर / के जी / 2016 /112)

(कार्य सत्र: 2016 -17)

ज़मीर अहमद शाह, भूवैज्ञानिक

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सारांश

टोपोशीट संख्या L/13, 14, 48 P/1 एवं P/2 के भागों में 1: 50,000 पैमाने पर पर्याप्त रिमोट सेंसिंग डेटा और विषयगत परतों जैसे कि Arc GIS में भूमि उपयोग / भूमि कवर (एलयूएलसी), भूआकृति, ढाल बनाने की सामग्री (SFM), ढाल ढलान और ढलान वक्रता का उपयोग करते हुए बहु-अस्थायी गूगल इमेजरी की विज़ुअल व्याख्या के माध्यम से भूस्खलन संवेदनशीलता मानचित्रण किया गया।

भूस्खलन संवेदनशीलता मानचित्रण क्षेत्र की ढलान विफलताओं का एक गुणात्मक अध्ययन है जो कम, मध्यम और उच्च पैमाने पर भूस्खलन के लिए अतिसंवेदनशील क्षेत्रों की पहचान करने पर ध्यान केंद्रित करता है। जीआईएस प्लेटफार्म पर भारित मल्टीक्लास इंडेक्स ओवरले का उपयोग करके भूस्खलन की संवेदनशीलता को मान्य करने के लिए विषयगत परतों के रूप में विभिन्न कारक नक्शों का उपयोग किया जाता है।

LULC के संदर्भ में क्षेत्र को उच्च ऊंचाई बागान (एचएचपी), मध्यम वनस्पति, खेती, घनी वनस्पति, बंजर, व्यापक ढाल कटाव, फॉलॉउ भूमि, कम ऊँचाई बागान (एलएचपी), खदान, आबादी क्षेत्र, विरल वनस्पति, आबादी संशोधित ढलान और जल निकाय आदि में विभाजित किया जाता है। अधिकांश क्षेत्र उच्च ऊंचाई बागान विशेष रूप से नारियल द्वारा घिरा हुआ है। जांच के क्षेत्र में एलयूएलसी कक्षाओं की एक विस्तृत श्रृंखला प्रदान की गई है जिसमें पूरे इलाके में व्यापक रूप से शहरीकरण के ढांचे हैं जिसमें से से कुछ छोटे ढलान क्षेत्र हैं। कुछ शहरी समूहों में सजीपामुडा, गोलथामाजल, बाल्थिला और बन्नूर ग्रामीण शामिल हैं। क्षेत्रीय अध्ययन कार्यों के दौरान किया गया एक विशिष्ट अवलोकन यह है कि संशोधित ढलान वाले क्षेत्रों में वनस्पति कवर को हटाने से लेकर ईंट भट्टों की स्थापना के बाद एक विशिष्ट परिवर्तन होता है और अंत में क्षेत्र को समतल करने के बाद आबादी क्षेत्र के तहत लाया जाता है।

भू-भौगोलिक दृष्टि से, अध्ययन क्षेत्र कई स्थानों पर पेडिएंट-पेडीप्लेन कॉम्प्लेक्स के साथ घुमावदार ऊंचा-नीचा है। इलाके में वर्चस्व वाले भौगोलिक आकृतियां रोलिंग समतल, पेडिमेंट-पेडीप्लेन कॉम्प्लेक्स हैं जोकि कम विच्छेदित ढलान, मध्यम विच्छेदित ढलान, घाटी भरण, पठार शीर्ष (समतल), रिज टॉप, माउंड और पुल के मैदानों मे आता है।

आईआरएस लिस III आंकडों के दृश्य व्याख्या और बहु-अस्थायी गूगल इमेजरी के माध्यम से Arc GIS में भू-उपयोग / भूमि आवरण (एलयूएलसी), भूआकृति, ढलान बनाने वाली सामग्री (एसएफएम), नालें, ढाल ढलान, ढलान वक्रता और ढलान के पहलुओं के लिए प्री-फील्ड मानचित्र तैयार किए गए। गूगल इमेजरी के उपयोग करने के साथ ढलान बनाने वाली सामग्रियों (SFM) जोकि भूविज्ञान, एलयूएलसी और भू-आकृति विज्ञान के नक्शे को एकीकरण करके और क्षेत्र के डेटा और तैयार ढलान के साथ अद्यतित करके भरोसेमंद भविष्यवाणी की गयी। क्षेत्र में ढाल बनाने वाली सामग्री (SFM) को (एम्फीबोलाइट, डोलेराइट, गैब्रो, गार्-बायो-सिल, नाइस + ग्रेफाइट + क्यानाइट, गार्नेट-सिलीमानाइट-नाइस + ग्रेफाइट + कुड्येराइट, पाइरॉक्सिन ग्रानुलाइट, ग्रेनाइट, लेटराइट एवं पाइरिबोलाइट), कम्ज़ोर चट्टान, बिखरा मलबा, जलोढ़ मिट्टी और बिना खिसकी मिट्टी आदि में वर्गीकृत किया जा सकता है। ढलान मार्फोमेट्री जोकि ढाल ढलान और ढलान से परिभाषित डिजिटल एलिवेशन मोडेल से जी एच आर एम सेल, सी एच क्यू द्वारा प्राप्त किया गया। अधिकांश भूस्खलन 15 डिग्री से कम और 15 -25 डिग्री की ढलान सीमा के अंदर देखी जाती हैं। वक्रता नक्शों को 3 वर्गों में वर्गीकृत किया जाता है यानी उत्तल, समतल और अवतल ढलान, जो कि वक्रता <-0.1, -0.1 से 0.1 और > 0.1 के लिए हैं।

वर्तमान ज्ञान के अनुसार, इस अनेक क्षेत्रों में भूस्खलन संभवत: मानव बस्तियों के लिए ढलान संशोधन और सड़क विस्तार के कारण हुए है। क्षेत्र में कटी हुई ढलानें लगभग 5 मीटर ऊंची हैं जो ऊर्ध्वाधर ढलान कोण के साथ 80^o और 90^o के बीच हैं। टूटी फूटी चट्टानों के साथ कटी हुई ढलानों का ढांचा अधिक संवेदनशील प्रतीत होता है। क्षेत्र में सभी कट ढलान विफलताओं का मूल कारण मानवनिर्मित है, हालांकि इसके बाद का कारण वर्षा है। वनस्पतियां कई क्षेत्रों मे घने पैच के साथ मध्य घनी पर्तीत होती हैं विशेष रूप से निचले इलाकों में। रिगोलिथ मोटाई सामान्य रूप

से 0.5 से 5 मीटर तक परिवर्तित होती है और छिटपुट रूप से 5 मीटर से 10 मीटर तक परिवर्तित होती है। ढलान बनाने वाली सामग्री (SFM) लैटेरिटिक इंसीटू मिट्टी और ग्रेनिटिक नाइस से निर्मित है जोकि ढलान के साथ ढीले पदार्थों के किसी भी संभावित खिसकने का मूल्यांकन करते समय बहुत महत्वपूर्ण कारक है।

कुल क्षेत्रफल में अठारह (क्षेत्र के दक्षिण-पश्चिमी किनारों के बाहर एक भूस्खलन भी शामिल है) क्षेत्र में ढलान विफलताओं की पहचान की गई है। इस क्षेत्र में भूस्खलन उथले प्रकृति के हैं और अधिकतर लेटेराइट कैपिंग वाले क्षेत्रों तक ही सीमित हैं। अधिकतर भूस्खलन मलबे वाली हैं और यह संयुक्त रूप से मानव गतिविधियों के कारण हो सकती है और बारिश से भी हो सकती है।

इन ढलान विफलताओं को रिकॉर्ड करते हुए जो कि मानव गतिविधियों का परिणाम है और अध्ययन क्षेत्र की संवेदनशीलता का क्षेत्रीकरण करना अत्यधिक पक्षपाती होगा। क्षेत्र में अपर्याप्त भूस्खलन संबंधी आंकडों के कारण, संवेदनशीलता मॉडलिंग विश्लेषणात्मक पदानुक्रम प्रक्रिया (एएचपी) द्वारा की जाती है जिसमें विशेषज्ञ या ज्ञान-आधारित तकनीकों का उपयोग करते हुए व्यक्तिगत कारकों के लिए रेटिंग और इंटर-प्रेडिक्टर वेट दिए गए हैं। मात्रात्मक मैट्रिक्स में ज्ञान-आधारित रेटिंग / वेट आसानी से ए एच पी का प्रयोग करके गणितीय तरीके से जोकि विभिन्न भौगोलिक कारक वर्गों के लिए गुणात्मक युग्म-संबंधी महत्व मैट्रिक्स तैयार करने / निर्णय लेने के बाद स्थानीय विशेषज्ञों और भूस्खलन में भूस्खलन अध्ययन में लगे वैज्ञानिकों से प्राप्त टिप्पणियों के बाद ही क्षेत्र में निर्धारित किया जा सकता है। लगभग 1.0 9% (लगभग 14.76 वर्ग किमी) क्षेत्र उच्च संवेदनशीलता क्षेत्र के अंतर्गत आ रहा है जबकि लगभग 17.63% (240.15 वर्ग किमी) क्षेत्र मध्यम संवेदनशीलता क्षेत्र के अंतर्गत आ रहा है और शेष क्षेत्र कम संवेदनशीलता क्षेत्र के अंतर्गत आ रहा है।

Macro - scale (1:50,000) Landslide Susceptibility Mapping in parts of Toposheet no's 48 L/13, 14, 48 P/1 & P/2, Dakshin Kannada district, Karnataka.

CODE: LSM/SR/KG/2016/112

(Field Season 2016-17)

By

Zameer Ahmad Shah, Geologist

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ABSTRACT

Landslide Susceptibility Mapping in parts of Toposheets no. 48 L/13, 14, P/1 and 2, was carried out on 1:50000 scale using adequate remote sensing data and thematic layers like Land use/ Land Cover (LULC), Geomorphology, Slope Forming Material, Slope gradient and Slope Curvature in Arc GIS through visual interpretation of multi-temporal Google Imagery.

Landslide Susceptibility Mapping is a qualitative study of slope failures in an area with focus on identifying zones susceptible to landslides on low, moderate and high scale. Various factor maps in the form of thematic layers are being used to validate landslide susceptibility using weighted multiclass index overlay on GIS platform.

The area in terms of LULC is divided into: High Height Plantation (HHP), Moderate Vegetation, Cultivation, Thick Vegetation, Barren, Extensive Slope Cut, Fallow Land, Low Height Plantation (LHP), Quarry, Settlement, Sparse Vegetation, Settlement on modified slope and Water Body. Most of the area is covered by High Height Plantation especially coconut. The area under investigation provides a wide range of LULC classes with urbanization agglomerations widespread throughout the entire area, many but small among them on sloppy areas. Some of the urban agglomerations include Sajipamuda, Golthamajal, Balthila and Bannur Rural. A typical observation made during field work is that areas with modified slope undergo a typical transformation ranging from removal of vegetation cover followed by establishment of lateritic brick kilns and finally the area is brought under settlement after levelling.

Geomorphologically, study area is undulating with rolling plains followed by pediment-pediplain complexes at many locations. The dominating geomorphic features in the area are Rolling plain, Pediment-pediplain complex followed by Lowly dissected slope, Moderately dissected slope, Valley fill, Plateau top (Flat), Ridge top, Mound and Alluvial plain.

Pre-field maps for Land use/ Land Cover (LULC), Geomorphology, Slope Forming Material (SFM), Drainage, Slope gradient, Slope Curvature and Slope aspect were prepared in ArcGIS through visual interpretation of IRS LISS III data and multi-temporal Google Imagery. In addition to using Google imagery, judicious prediction of slope forming material was made by integrating geology, LULC and geomorphology maps and updated with field data and prepared slope forming material map. Slope Forming Material in the area can be classified into rock (including amphibolite, dolerite, gabbro, gar-bio-sill gneiss+graphite+kyanite, garnet-sillimanite-gneiss+graphite+cordierite, pyroxene granulite, granite, laterite and pyribolite), weathered rock, loose debris, alluvium and in-situ soil. Slope morphometry defined by slope gradient and curvature were derived from Digital Elevation

Model (DEM) provided by GHRM Cell, CHQ. Most of the slides are observed to have occurred in less than 15° followed by slope range of 15°-25°.Curvature map is classified into 3 classes, i.e., convex, flat and concave slopes corresponding to curvatures < -0.1, -0.1 to 0.1 and >0.1.

As per the present knowledge, Landslides in the area are probably the outcome of slope modification for human settlements and at places for road extension. The cut slopes in the area are about 5m high with a vertical slope angle between 80º and 90º. Cut slopes with weathered rocks seem to be more vulnerable. The root cause of all the cut slope failures in the area is anthropogenic although the later movement could be triggered by rainfall. Vegetation seems to be of moderately dense with dense patches at places especially in low lying areas. Regolith thickness, in general varies from 0.5 to 5 m and sporadically attains a thickness of 5 m to 10 m. Slope forming material, which is very vital factor while assessing any possible movement of loose material along slope, is lateritic in situ soil and granitic gneiss.

A total of eighteen (including one slide falling just outside the south western margin of the area) slope failures were identified in the area. The slides in the area are of shallow translational nature and are mostly confined to the areas having laterite capping. The slides are mostly debris slides and may be due to the combined effect of anthropogenic activities and triggered by rainfall.

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. Due to insufficient landslide data in the area, the susceptibility modelling is carried out by Analytical Hierarchy Process (AHP) wherein ratings and inter-predictor weights were 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 pair-wise importance matrix for different geo factor classes and comments received from local experts and landslide scientists engaged in landslide studies in the area. Approximately, 1.09 % (about 14.76 sq. km) area is falling in high susceptibility zones while about 17.63 % (240.15 sq. km) area is falling in moderate susceptibility zone. Rest of the area falls in low susceptibility zone.

Macro - scale (1:50,000) Landslide Susceptibility Mapping in parts of Toposheet nos. 48 L/13, 14, 48 P/1 & 2, Dakshin Kannada district, Karnataka.

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(Field Season 2016-17)
By

Zameer Ahmad Shah, Geologist
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I. INTRODUCTION

1.1 Background:

Landslides in Western Ghats is a recurring problem for years, causing disruption in communication routes, damaging properties and killing people. The road development, the shifting of agricultural practice from orthodox seasonal crops to cash crops has put tremendous pressure on the natural slopes of the Western Ghats. With passage of time the modification of slopes due to human interference in the natural slope has deteriorated the equilibrium attained by nature. While not every landslide results in catastrophe, the damage from many small ones may equal or exceed the impact of a single major failure. Thus, both large and small landslides are capable of causing significant damage and loss of life. With every passing monsoon over the Western Ghats, a number of landslides are triggered. The blockade, damage and disruption of traffic along important roads linking the major cities create lot of inconvenience for the public.

Geological Survey of India (GSI), being the nodal agency for Landslides in India since 2004, started integrated approach towards landslide hazard studies which included site specific landslide studies, landslide hazard zonation along important road corridors, around townships and preparation of landslide inventory.

GSI has been carrying out landslide susceptibility zonation/mapping on macro scale (1:50,000/ 25,000) since last 3 to 4 decades. However, compared to the available landslide-prone areas in India (~0.42 Million sq. km spreading over 1112 Survey of India 1: 50,000 scale Topographic Sheets), the target achieved so far by GSI (~60,000 sq. km) is quite lesser. This warrants GSI, being the nodal agency for landslide studies in India, to impart maximum stress towards completion of this basic data generation work on landslides by aiming to complete the remaining task much at a faster pace than what has been followed by GSI so far. This matter was deliberated in detail at the Regional Workshop on Landslide Disaster Management at Shillong on 22-23 November, 2014 and the Joint Secretary, Ministry of Mines has also directed GSI to revamp and fasten its endeavour for this important task for completing the remaining targets of landslide susceptibility mapping/zonation as early as possible.

Accordingly, since FS 2014-15, GSI undertook a national programme on landslide susceptibility mapping – **Macro scale (1:50,000) National Landslide Susceptibility Mapping (NLSM)** with an aim to cover the remaining targets expeditiously. This national programme was formally launched by Shri Dinesh Patel, Hon’ble Minister of Mines, Government of India on 5th February, 2014 at the 53rd Central Geological Programming Board Meeting, New Delhi.

Landslide Susceptibility Mapping in parts of Toposheets no. 48 L/13, L/14, P/1 and P/2, parts of Dakshin Kannada District, Karnataka 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 as per the annual programme of Geological Survey of India for field season 2016-17 vide CODE NO: LSM/SR/KG/2016/112.

1.2 Present Work:

The present work was carried out with following objectives:

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

ii) To prepare Toposheet wise 1:50000 scale spatial database for geofactors of landslides for use as input thematic maps.

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

The nature and target of work envisaged for field season programme 2016-17 and the achievements are given in Table 1.

Table 1 Nature of work, quantum and achievements.

Nature of work	**Total Work Load envisaged**	**Target for FS 2016-17**	**Achievement**
1. Pre-field preparation			
i) Preparation of Thematic maps (in GIS on scale 1:50,000)	1356 sq. km	-	-
a) Slope Forming Material map		1356 sq. km	1356 sq. km
b) Geomorphology & Lineament map		1356 sq. km	1356 sq. km
c) Slope Morphometry (slope, aspect & curvature) map		1356 sq. km	1356 sq. km
d) Landuse / Landcover map		1356 sq. km	1356 sq. km
e) Drainage map		1356 sq. km	1356 sq. km
f) Regolith depth/thickness map		1356 sq. km	1356 sq. km
ii) Preparation of Landslide Inventory Map		1356 sq. km	1356 sq. km
2. Field-based studies			
i) Field-checking of all thematic maps	1356 sq. km	1356 sq. km	1356 sq. km
ii) Field validation of landslide inventory and collection of recent and historic landslides		1356 sq. km	1356 sq. km

(using archives, old reports, road register etc)			
iii) Collection of landslide inventory and damage data as per 41 point geo parametric data sheet	1356 sq. km	1356 sq. km	1356 sq. km
3. Post-field studies & modeling			
i) Updation of thematic and inventory maps in GIS	1356 sq. km	1356 sq. km	1356 sq. km
ii) Preparation of Landslide Susceptibility Map in GIS		1356 sq. km	1356 sq. km
iii) Validation of landslide susceptibility map at important locations	1356 sq. km	1356 sq. km	1356 sq. km
4. Collection of rainfall data from available rain stations	1356 sq. km	1356 sq. km	1356 sq. km

Note: *As per the NQT, the total area under study is **1356 sq. km**, but after some discussion with supervisory officer and keeping the terrain conditions on south-west and north-west of the area under consideration, the area on the same sides was incorporated into the present investigation and the total area for which susceptibility was carried-out is 1398 sq. km and all the calculations in the report are made with respect to **1398 sq. km** area.*

Table 2 Details of the man-days spent in the filed

Name	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Total Days
Zameer Ahmad Shah	02	19	20	18	20	04	-	83
Kapil Singh	02	19	20	18	20	04	-	83
J. Srihari	-	-	-	-	01	01	-	02

Table 2 gives details of total man-days spent in the field. A total of 83 man-days were spent in the field, including two days of field inspection by supervisory officer (Director), Shri J. Srihari.

1.3 Study Area:

The area forming part of Karnataka State, is bounded by latitudes 12°34'00" and 13°00'00"N and longitudes 74°49'52" and 75°15'00"E falling in Survey of India Toposheet No's 48 L/13, L/14, P/1 and P/2 in the district of Dakshin Kannada. The area is well connected to Mangalore by NH-17 and Puttur by NH-48 (Plate 1). Most of the villages and towns of the area are well connected by metalled and non-metalled roads. The administrative offices of the area are located at Bantval and main head offices in Mangalore. The Mangalore Railway Junction (South Central Railway main line) is the nearest railway station in the area. The study area can be approached by Mangalore – Bantval state Highway and many other state roads. The nearest airport to the study area is at Mangalore. The behavior of average rainfall pattern and its distribution over the past ten years in the area are well depicted in Annexure-III and Plate 13.

1.4 Physiography:

The study area has an undulating topography with higher peaks found near kodandur and Bandaje in the South-East. The area shows a maximum elevation of 235 m above mean sea level. The area has temperate climate and the forest type is semi evergreen forest.

The major river in the study area is Netravati flowing from East to West direction. The Netravati River is a structure-controlled river, as it follows the Netravati lineament that has formed by a fault, and all the short E-W lineaments observed in the imagery represent small segments of the Netravati fault lineament. All these segments jointly represent the major Netravati lineament. The drainage pattern of the area is mainly dendritic, sub-dendritic and trellis (Plate 10).

1.5 General Geology:

The area under investigation forms part of Western Ghats that grade into a plateau towards east. Geologically the area exposes rocks of Late Archean (<3000 ma), Peninsular gneiss-I of Tonalite-Trondjhemite-Granodiorite composition, Middle Archean (>3000 ma) Sargur Group, with ultramafic-mafic intrusive complex, serpentinised komatitic and amphibolites, etc. and lower to Middle Archean (~3400 ma) older Gneisses. Western Ghat belt preserves an ideal succession of Bababudan Group, which is exposed in the mountainous region of Kudremukh, Agumbe and Kodchadri. The Sargur Group is represented by a number of enclaves within gneisses and granites and the enclaves are quartzite, amphibolite, iron formation, garnetiferous mica schist, kyanite-staurolite schist, silimanite-garnet schist, calc-silicate rock and ultramafics.

1. Older metamorphics of Sargur Group is represented by garnetiferous-sillimanite ± graphite schist and garnetiferous amphibolite rock. Garnetiferous sillimanite ± graphite schist is medium grained, grey in colour and consists quartz, feldspar, biotite, garnet, sillimanite and sometimes graphite.

2. Lenticular bodies of amphibolite permeated with quartzo-feldspathic material occur associated within peninsular gneisses and granite. They are seen along slopes or top of hill ranges around hillocks .364, .350, .372, .320, .531, .608, .500 hill ranges in the southeastern part of the area. The amphibolite is dark green, granular, fine to medium grained. It consists of hornblende, microcline, plagioclase, biotite, muscovite and quartz. Apatite and zircon occur as accessories.

The Peninsular Gneiss of this region is a complex of migmatitic gneiss and granitoids and includes biotite gneiss, hornblende-biotite gneisses and hornblende gneiss. The Peninsular Gneiss is unconformably overlain by the Dharwar Supergroup (Bababudan

Group). Bababudan Group is represented by four formations, namely (a) Walkunje Formation, (b) Kudremukh Formation, (c) Kodchadri Formation, and d) Narasiparvata Formation. The Walkunje Formation represents the lower arenaceous and argillaceous member of the Bababudan Group. Other rock units associated with it are quartzites, quartz-sericite schist, greywacke, arkose and quartz-biotite-chlorite schist. Kudremukh Formation comprises amygdular metavolcanics, amphibolite, actinolite-chlorite schist, meta-gabbro and ultramafics with interbeds of quartzites, quartz-sericite schist and chlorite schist. Kodchadri Formation comprises of Banded magnetite quartzite and quartz-chlorite-sericite schist. The Narasiparvata Formation comprises of acid porphyries, chlorite quartz schist and iron stones. Numerous dykes, varying in texture from coarse to fine grained, are reported from various localities. The laterite cover is extensive in the area between the coastal plains and the intermediate range of hills below the Western Ghats (Awasthi, 1981; Davay, 1968; Gopal Reddy et.al 1984).

The rocks of Sargur Group, Peninsular Gneiss-I of PGC and Charnockite suite are traversed by acid and basic intrusives of Paleo-Proterozoic age and Periyar Formation of Quaternary age. Laterite occurs as cappings over most of the hills as well as plains in the area. It is extensively larterised showing dark brown in colour, hard, compact and cavaernous. Both ferruginous and aluminous laterite occur in the area (Plate 2).

Foliation /gneissosity in the gneiss varies from ENE-WSW in the central part to WNW-ESE in the southern part to NW-SE in northern part. The dips vary from vertical to 65^0 75^0 on either side. Joints are parallel, across and oblique to the foliation.

The granite, gneisses and laterite are extensively quarried for construction of roads, buildings, etc.

1.6 Land use and Land cover:

The Landuse/cover pattern of a region is an outcome of natural and socio-economic factors and their utilization by man in time and space. The increase in density of population is directly proportional to the Landuse and Landcover. Land Use and Land Cover map was prepared in ArcGIS through visual interpretation of IRS LISS III data and multi-temporal Google Imageries of the area. The area in terms of LULC is divided in to following classes: High Height Plantation (HHP), Moderate Vegetation, Cultivation, Thick Vegetation, Barren, Extensive Slope Cut, Fallow Land, Low Height Plantation (LHP), Quarry, Settlement, Sparse Vegetation, and Water Body. Most of the area is covered by High Height Plantation especially coconut. Steep cut slopes in the study area are most affected by slope failures as far as land use /land cover is concerned.

1.7 Methodology:

The method employed in the present study is primarily knowledge – driven where ratings of factor classes and weights of the geofactor themes has been estimated through Analytical Hierarchy Process(AHP). It is followed by GIS based modelling approach for integration of all selected and weighted thematic maps to prepare 1:50,000 scale landslide susceptibility maps. Areas having scarce prior landslide information, any one of the following approaches can be taken into consideration as per the preferences or the conditions of the terrain or even discussion with the local experts/workers.

a) An investigation in the nearby area with frequent landslide data will serve as base for individual ratings for geofactor classes and weights of geofactors. 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 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.

Methodology adopted can be broadly grouped as follows:

1.7.1 Pre-field Map Preparation: Total eight pre-field thematic maps were generated by using different data capturing sources. The slope morphometry maps viz. Slope aspect, Slope curvature, Slope gradient and Drainage map were prepared from 30m CARTO DEM (Digital Elevation Model). Geomorphology and Landuse Landcover (LULC) maps were prepared with the help of Google imagery (Multi temporal images has been used for digitisation of Geomorphology and LULC) that later processed in ArcGIS platform. The proxy of Slope Forming Material (SFM) map was prepared using integration of LULC, Geomorphology & Geology thematic maps in Arc GIS software. Landslide inventory map was prepared by collecting the data from old GSI landslide reports and local newspapers.

1.7.2 Field-based Studies:

- Validation of pre-field maps: Geomorphology, LULC, Slope Forming Material (SFM) and Landslide Inventory map
- Preparation of Regolith Thickness map and
- Augmentation of existing landslide database by identifying new slope failure incidences and recording 41 geo-parametric sheet at each of the identified sites.

1.7.3 Post-field Modeling: The post-field studies were aimed at:

A. Updation of Pre-field Maps: In response to the field validation, the modifications in the pre-field map were done wherever it was required. Corrections were attended in Arc GIS Platform by updating the polygons of a particular class/attribute in accordance with the observations in the field. Ultimately, maps for all thematic layers viz. Geomorphology, LULC, Slope Forming Material and Regolith thickness map were finalized.

B. Landslide Susceptibility Modeling: In the Karnataka state, owing to the lesser number of landslides originating on/along natural slopes, Analytical Hierarchy Process (AHP) was used for landslide analysis and preparation of Landslide Susceptibility Map, instead of Statistical Analysis by using landslide incidences. The AHP is multi criteria decision making process of measurement through pairwise comparison and it relies on the judgment of the experts to drive priority scale (Saaty 2008). The entire process of landslide susceptibility modeling is given below:

B1. Criteria for assigning ranks to Geo-factor Classes and Maps: Ranking to each geo-factor class was assigned on the basis of expert opinion, knowledge, field experience and observations by different knowledge-experts working in landslide domain in different parts of southern and western India. Similarly average rank to every geo-factor map was assigned based on its importance in inducing a slope failure. This consensus of rankings was developed in order to bring out the uniformity in landslide susceptibility mapping zones at a PAN India level. The 9 point ranking scale, ranging from 0 (lowest ranking) to 9 (highest ranking) was finalized and each class/ geo-factor was ranked accordingly. Classes/ Maps more susceptible or inducing failures were assigned relatively higher rankings and vice versa.

B2. AHP Modeling: For AHP modeling, pair-wise comparison matrix of geo-factor classes was executed following calculation of eigen values, fraction rate values and Landslide Occurrence Favorability Score ratings (LOFS). The LOFS values of each factor classes was determined by dividing the fraction rate values of a particular class by the maximum fraction rate value in the corresponding matrix. After determination of LOFS ratings for each geo-factor class of a particular geo-factor map, integer weights of individual geo-factor maps were calculated following the similar procedure of pair-wise comparison matrix of average ranks (assigned during interactive sessions by knowledge-experts), i.e., normalizing by its weight. A raw susceptibility score map was generated using integer weights and LOFS derived from AHP, which was finally classified based on the logic of providing mutual comparison expert-driven ranking of High, Moderate and Low categories/ classes.

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II. PREVIOUS WORK ON LANDSLIDE STUDIES

In India, preliminary studies in the field of landslide zonation were initiated by Oldham (1880), Middlemiss (1890) and Holland (1897). Seshagiri et.al. (1982) considering five parameters carried out landslide hazard zonation by categorizing each parameters and assigning Landslide Susceptibility Index (LSI) on the basis of percentage of Landslides in each category. Anbalagan (1992) used lithology, structure, slope, relief, land use, land cover and ground water condition to prepare zonation map. In Karnataka, Mishra et al. (2010) carried out zonation of Madikeri Township in a Geographical Information system (GIS) environment. Mishra et al. (2010)[1] also carried out a zonation in GIS environment of road corridor of Charmudi Ghat section from Charmudi to Kotigehara, Kotigehara to Kalasa and Shiradi Ghat section from Sakleshpur to Uppinangadi. Maruthi and Chandran (2013) has carried out zonation on Macro-scale using modified BIS guidelines between Virajpet-Madikeri-Sulya road corridor.

As per the literature almost all landslides in the area appear to have been caused due to the human inference in modifying the existing natural slopes. The specific causes of landslide in Western Ghats in general are removal of support by toe cutting of hill slopes for the construction of road, for human settlement, presence of weathered and loose rock mass, heavy and frequent rain etc. 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. 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. Overall, landslides studied in the area are few and small in size, but are mostly confined to roads and seem to be triggered by anthropogenic activities in addition to the role of rainfall in the area. They are mostly of shallow translational type and are confined to slopes that have been modified for settlement establishments.

Some of the landslide data occurrences in recent years collected from local newspapers are mentioned below:

1.The slide of Thotlaguri Bajpe that triggered the collapse of two houses on 21st June, 2013 was the outcome of dumping of mud while doing some constructional work regarding Mangalore Special Economic Zone Limited (MSEZL). The dumping of mud in and around houses causes the blocking of the drainage network that lead to the collapse of the houses. (Coastal Digest.com, Daily Newspaper, 15th December, 2016).

2. The slide of Pudu village Bantval, on 09th July, 2015 was triggered due to heavy incessant rains. The slide caused the death of 7 years old boy. (Daijiworld Media Network, Daily Newspaper, 11th July, 2015).

3. The slide of Farangipet, which claimed the lives of three workers on 16th July, 2015, was due to the heavy showers which caused the soil slid from the nearby mountain and buried three workers. (Kannadiga World, Daily Newspaper, 15th December, 2016).

4. Construction labourers were trapped in a landslip that occurred at Derebail, Konchady behind AJ hospital on 20th November, 2012. The slide caused one casualty and

another was seriously injured when they were working near a hill-lock during heavy rainfall. (Daijiworld Media Network, Daily Newspaper, 20th November, 2012).

5. Landslide at NH-17 on 31st July, 2010 near Padil caused a major traffic disruption up to 3 kms from Padil to Valachil village. An excavation work on a hill at padil adjacent NH-17 and heavy rains resulted in landslide and blocking of traffic in the region. (ICARE, Live News Network, 31st July, 2010).

III. LANDSLIDE INVENTORY

A landslide inventory map records the location and, where known, the date of occurrence and the types of mass movements that have left discernable traces in an area (Guzzetti et al., 2000). Generation of such inventory is a difficult task as landslides occur individually and have to be identified, mapped and inventoried. A Landslide inventory 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 interview. In this study, satellite images 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.

In the present study, it was not possible to identify landslides from Google Earth as the area is thickly vegetated and if any landslide of recordable dimension is present is masked by the canopy in the area. Around 15 landslides were identified in the present investigation.

3.2 Inventory mapping:

The following steps were used for mapping a landslide in the field and building its inventory attribute.

1. For each landslide identified in the field, the attributes such as name, state, district, taluka, toposheet number, initiation, slide type, slide material, length, width, surface area, cause, land use and element at risk were recorded. Archival data were used for naming and defining the cause of the landslides.

2. The morphological signatures left by landslides on slopes were used to identify the shape of landslides.

3. 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, regolith thickness, Geology, probable cause, and damage details were also added to the inventory.

3.3 Landslides in the Area:

During field only 18 landslides or rather slope failures (including one slide falling just out-side the boundary of the studied area) identified in the study area are inventoried which are concentrated mainly along roads and other transportation corridors (Plate 11). Overall landslides studied in the area are few and small in size, but are mostly confined to roads and seem to be triggered by anthropogenic activities in addition to the role of rainfall in the area. Most of the landslides affecting the road originate from cut slopes, which are left unsupported and become prone to failure during rains. They are mostly of shallow translational type and are confined to the slopes that have been modified indiscriminately for settlements. 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 are observed in the area, the usually applied method of modelling 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.

Out of 18 cut slope failures, 11 were recorded in toposheet no. 48 P/1 (Plate 11). All mapped landslides (cut slopes) are debris/earth slides triggered by extensive slope cutting followed by spells of rain. The sliding material mostly consists of younger loose debris mixed with debris of weathered rock. Failures are common during rains when the exposed overburden mass resting on the cut slopes slips downslope. Moreover, the movement of the loose material is confined to the loose humps (loose debris) in the area.

The spatial distribution of mapped landslides is shown in Annexure-I, which gives detailed inventory of 18 landslides for which 41-point inventory data were prepared. Cut slope failures (Photos 1 to 4) are very much wide spread along modified slopes and roads in the area. Many of the cut slope transform into landslides during rainy season in the area.

IV. LANDSLIDE SUSCEPTIBILITY ANALYSIS

This chapter deals with the material and methods of landslide susceptibility analysis using Analytical Hierarchy Process method.

4.1 Background:

A quantitative or qualitative assessment of the spatial distribution of landslides in an area depicts the landslide susceptibility of that area. Generally, landsliding is expected to occur in the most susceptible areas. One of the drawback of the landslide susceptibility analysis is that it does not take time frame and magnitude into consideration. A susceptibility map therefore gives only the qualitative or quantitative estimation that the mapping unit (e.g., a pixel, slope unit or facet) will be affected by a future landslide. Therefore, using the term “landslide hazard analysis” instead of “landslide susceptibility analysis”, for methods of spatial prediction of landslide-prone areas may not be correct.

In GIS-based data-driven methods such as Weighted Multiclass Index Overlay, spatial factors (or layers of evidence) are integrated with a landslide inventory map (target) using various mathematical/statistical integration techniques (Bi-variate, Multivariate, Artificial Neural Network etc) that can model relationships among layers of evidence with respect to targets (Bonham-Carter, 1994).

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 prior 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 et al., 2010).

In the study area, landslides are mostly debris slides affecting natural slopes and are smaller in size. Keeping in consideration the landslide characteristics, seven factor maps were prepared that are considered to be the main spatial causal factors for landslides in the area. Out of the seven factor maps, three 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:

Landslides occur when the shearing stress along the failure plane exceeds the shearing strength of rock/debris mass (Varnes, 1978). This can be controlled by the dynamic nature of various parameters such as i) physical state of slope such as slope gradient, slope aspect, and slope curvature, ii) lithology or physical characteristics of slope forming mass, iii) spatial variation in thickness of slope forming material, iv) geomorphological forms and processes, v) rock structure: orientation of planar/linear discontinuities in the rock mass in relation to topography, vi) geohydrology and vii) land use/cover including road and other physical features mappable on 1:50,000 scale. Based on the estimation of above pre-disposing geofactors, the following factors and its possible factor classes are considered for preparation of geo-factor databases for the GIS-based analysis of susceptibility to landsliding. 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 evaluated through slope gradient, slope aspect and slope curvature (Plate 3, 4 and 8). In the present investigation, Slope aspect was not taken into consideration keeping in view its least significance.

Slope gradient:

Slope gradient is an essential component of slope stability analysis. As the slope gradient increases, the level of gravitation-induced shear stress in the colluviums or residual soils increases as well. Gentle hillslopes are expected to have a low frequency of landslides because of the generally lower shear stresses associated with low gradients. Slope gradient, the maximum rate of change of elevation of the surface, was then reclassified into five classes: <15º, 15 –25 º, 25–35º, 35–45 º and > 45°.

The slope angle maps were derived from the 30m CARTO DEM using ArcGIS 10.3. Slope gradient in the study area varies between 0° and 35°. In general, landslide frequency increases with the slope gradient until the maximum frequency is reached in the 15–25° category, followed by a decrease (Plate 3).

About 95% of the area exhibit slope gradient up to 25°. The area coverage in pixels along with LOFS and rank is given below in table 3.

Table 3 LOFS, Rank and area coverage in pixels for Slope gradient of T. S. No. 48 L/13, L/14, P/1 & P/2

CLASS	RANK	LOFS	Area Coverage (in pixels)	Area Coverage (%)
<15	2	0.1631	133326	43.872
15-25	4	0.4597	158011	51.994
25-35	8	1.0000	12407	4.083
35-45	6	0.2817	156	0.051

Slope Curvature:

Slope Curvature (Profile curvature) shows the curvature of the surface perpendicular to the slope direction for each cell, and thus determines the shape of a slope in profile. Slope shape was also derived from 30m CARTO DEM using ArcGIS 10.3. 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 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. The curvature maps were reclassified into three classes viz, concave, flat and convex (Plate 8). The area coverage in pixels along with LOFS and rank is given below in table 4.

Table 4 LOFS, Rank and area coverage in pixels for Slope curvature of T. S. No. 48 L/13, L/14, P/1 & P/2

CLASS	RANK	LOFS	Area Coverage (in pixels)	Area Coverage (%)
Concave	4	0.4113	748170	49.751
Flat	2	0.1676	151108	10.048
Convex	6	1.0000	604563	40.201

4.3.2 Landuse and Landcover:

Mapping or delineating areas prone to landsliding is very essential for land-use activities and management decision making in hilly or mountainous regions. The land use and land cover (LULC) map was prepared from the Google Earth considering 2012 data. Following the generally used mapping procedure in Google Earth, first the polylines of different land use/cover were drawn and the same were imported in ArcGIS 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. Finally, the boundary of the individual LULC class was corrected from SPOT images available as base map in ArcGIS 10.2. The obtained pre-field LULC map was checked in the field in all accessible locations and all necessary modifications in the boundary and name of the LULC class were incorporated. Plate 5 shows the LULC map for parts of toposheets 48 L/13, L/14, P/1 and P/2. The area in terms of LU/LC can be divided into following classes: High Height Plantation (HHP), Moderate Vegetation, Cultivation, Thick Vegetation (Photo 7), Barren, Extensive Slope Cut, Fallow Land, Low Height Plantation (LHP), Quarry (Photo 6), Settlement, Sparse Vegetation, and Water Body (Plate 5). Most part of the area is covered with HHP. Extensive cut slopes in the study area are the direct out-come of settlements on modified slopes (Photo 5) which are most affected by slope failures as far as land use /land cover is concerned. Landslide occurrences favorability score (LOFS), rank and percentage for various LULC classes is given in table 5.

Table 5 LOFS, Rank and area coverage in pixels for Landuse/Landcover of T. S. No. 48 L/13, L/14, P/1 & P/2

CLASS	RANK	LOFS	Area Coverage (in pixels)	Area Coverage (%)
Barren	1	0.0626	4437	0.794
Cultivation	2	0.093665322	47813	8.559
Fallow Land	1	0.062608459	5565	0.996
Moderate Vegetation	5	0.291198809	105386	46.762
Plantation (HHP)	4	0.198819231	261228	46.762
Plantation (LHP)	3	0.136611174	438	0.078
Quarry	5	0.291198809	444	2.056
River	0	0	11484	2.056

Settlement	1	0.0683	91648	16.406
Sparse Vegetation	7	0.5631	11823	2.116
Thick Vegetation	4	0.1988	16300	2.918
Water body	0	0	5	0.001
Settlement on modified slope	7	0.5631	1683	0.301
Extensive Slope Cut	9	1	375	0.067

4.3.3 Geomorphology:

The present landscape of the study area under consideration is viewed as the manifestation of a chain of interactions between fluvial and denudational processes operating on underlying geology that has been subjected to past vertical tectonics. Field and laboratory studies indicate that the geomorphology of the study area is marked by ridges with steep slopes, denuded surfaces and sinuous valleys suggesting the considerable period has elapsed during the development of the landforms. Each landform signifies the processes operated in the evolution of the landforms.

Geomorphological map was prepared in ArcGIS through visual interpretation of multi-temporal Google images of the area. National Geomorphological and Lineament Mapping (NGLM) data supplied by GHRM cell was also taken into account while preparing the geomorphology map of the study area. Gemorphologically, the area can be divided into rolling plain, pediment-peneplain complex, alluvial Plain, moderately/lowly dissected slope, plateau top (flat), ridge top, mound and valley fill.

The method used for geomorphology mapping is same as that of LULC map. The obtained pre-field geomorphology map was validated in the field at all accessible locations and related necessary modifications in the boundary and name of the geomorphology class were incorporated. Plate 6 shows the geomorphology map of parts of toposheets 48 L/13, L/14, P/1 and P/2. Most part of the area is covered by lowly dissected slope followed by moderately dissected and rolling plains respectively. The area coverage for each class in pixels, LOFS and rank is given in table 6.

The details of geomorphic features are given as follows:

Pediment – Pediplain Complex: A complex landform where both pediplain and pediments occur and it is difficult to separate them (Photo 9).

Alluvial Plain: A level or gently sloping tract or a slightly undulating land surface produced by extensive deposition of alluvium, usually adjacent to a river that periodically overflows its banks; (Photo 12). (NGLM Manual, 2010).

Lowly/Moderately Dissected Slopes: These slopes are defined by the intensity of linear features dissecting the landscape of the area (Photo 8).

Rolling Plain: Rolling plain is assigned to areas with hummocky appearance where most of the area is generally flat with some minor wavy undulations.

Table 6 LOFS, Rank and area coverage in pixels for Geomorphology of T. S. No. 48 L/13, L/14, P/1 & P/2

CLASS	RANK	LOFS	Area Coverage (in pixels)	Area Coverage (%)
Alluvial Plain	0	0	19370	3.467
Lowly Dissected Slope	4	0.1947	71682	12.831
Moderately Dissected Slope	6	0.402	64726	11.586
Mound	2	0.0819	5796	1.037
Pediment Pediplain Complex	0	0	180121	32.242
Plateau Top (Flat)	0	0	15194	2.720
River	0	0	11484	2.056
Rolling Plain	0	0	188632	33.765
Valley Fill	0	0	1647	0.295
Water body	0	0	5	0.001

4.3.4 Slope Forming Material (SFM):

Slope Forming Material (SFM) map was prepared in ArcGIS 10.1 through visual interpretation of multi-temporal Google Imagery of the area and collection of data for material present on slopes. The study area in terms of Slope Forming Material (SFM) can be classified in to following classes: rock, weathered rock and in-situ soil (Plate 7).

Areas with visible soil profile were categorized under in-situ soil category. On slopes, barren rock is present at places where the slope angle in general is more than 35 degrees. Most of the study area is covered by In-situ (lateritic soil), soil of granitic origin (Photo 11). Some old outcrops which represent old quarries were observed near village Manjalvadi (Photo 10). Weathered exposures were observed on Farangipet-Nagori road with blackish and reddish soil representing the underlying lithology i,e charnockites and granites. At places, humps of loose debris which are left un-treated are found on barren slopes (Photo 15). The area covered in pixels LOFS and rank in given in table 7.

Table 7 LOFS, Rank and area coverage in pixels for Slope Forming Material of T. S. No. 48 L/13, L/14, P/1 & P/2

CLASS	RANK	LOFS	Area Coverage (in pixels)	Area Coverage (%)
Alluvium	0	0	19370	3.467
Amphibolite	4	0.2409	11	0.002
Dolerite	1	0.0682	376	0.067
Gabbro	1	0.0682	4	0.001
Gar-bio-sill gneiss + graphite + kyanite	1	0.0682	32	0.006
Garnet-sillimanite-gneiss + graphite + cordierite	1	0.0682	1079	0.193
Granite	1	0.0682	1175	0.210

Granite gneiss	1	0.0682	27516	4.926
In-situ soil	4	0.2409	463887	83.040
Laterite	4	0.2409	33181	0.007
Loose Debris	8	1	37	0.007
Pyribolite	1	0.0682	274	0.049
Pyroxene granulite	4	0.2409	46	0.008
River	0	0	11484	2.056
Weathered Rock	6	0.5437	160	0.029

4.3.5 Regolith Thickness:

The regolith thickness depends on a large variety of factors, one important being the local variation in terrain morphology; and therefore prediction of the thickness of regolith over a large area is extremely difficult. Ideally, for thickness modelling, a large number of observations (such as drill holes, outcrops or geophysical measurements) are required. However, on a catchment scale, this approach is difficult to implement. Given the above limitations, regolith thickness map was prepared based on field observations and value observations. Assessment of thickness of regolith cover at different sites was made by studying the exposures along the road, streams and landslide scars. Thickness of Overburden is directly controlled by slope forming material (SFM), geomorphology, land use & land cover and slope gradient. An attempt is made to get the approximate overburden thickness and it is observed that in low dissected hill slope with low slope gradient, the overburden thickness is relatively more (approx. 2-5 m or >5m) where as in low dissected slopes having steeper slope gradient, the overburden thickness varies from 1-2m to occasionally up to 5m. In the study area it can be classified into two classes: <0.5 m and 0.5m to 5 m (Plate 9). Along the moderate & steep slopes thickness of overburden in general is less while along major weathered profiles regolith thickness is more, these areas are more prone for landslides. Regolith thickness of <0.5m depth is observed on rocky, steep slopes (Photo 13) and classified under rock. Areas with comparatively gentle slope with weathered outcrops exhibit overburden of 0.5 to 5 (Photo 14). The area covered by each factor class in terms of pixels, LOFS and rank is given below in table 8.

Table 8 LOFS, Rank and area coverage in pixels for Regolith Thickness of T. S. No. 48 L/13, L/14, P/1 & P/2

CLASS	RANK	LOFS	Area Coverage (in pixels)	Area Coverage (%)
< 0.5 m	0	0	63280	11.326
0.5 - 5 m	7	1	483893	86.611
5 - 10 m	4	0.32296	37	0.007
River	0	0	11484	2.056

4.4 Landslide Susceptibility Analysis:

Landslides 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 are observed elsewhere in the area, the generally used 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.

Methodology: The Analytic Hierarchy Process (AHP), developed by Saaty (1977) 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.

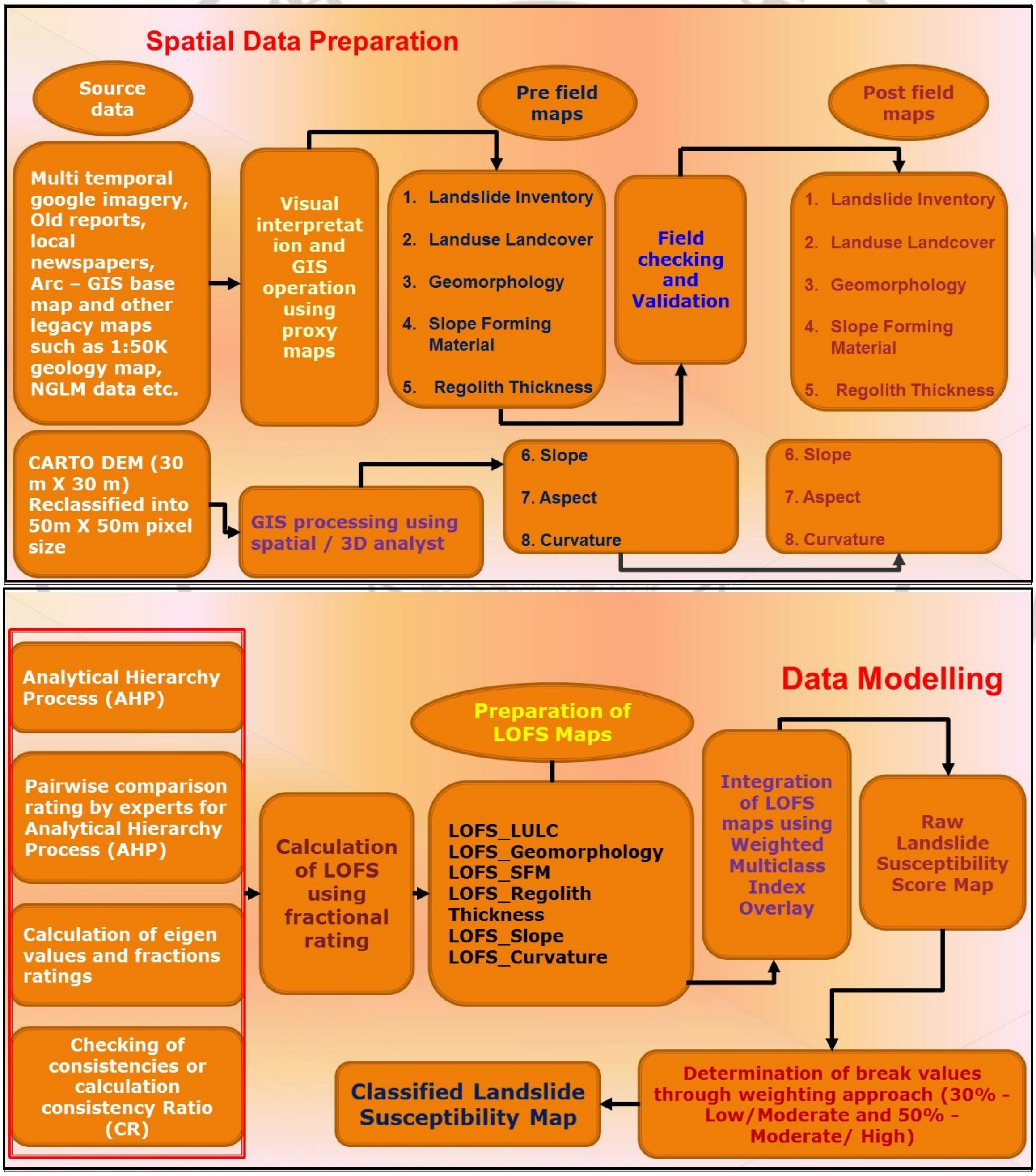

Fig.1 Process of Landslide susceptibility analysis by AHP model

The AHP method is appropriate 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 shown in Table:

S.No.	**Preference Level**	**Numerical Value**
1	Equally Preferred	1
2	Equally to Moderately Preferred	2
3	Moderately Preferred	3
4	Moderately to Strong Preferred	4
5	Strongly Preferred	5
6	Strongly to Very Strongly Preferred	6
7	Very Strongly Preferred	7
8	Very Strongly to Extremely Preferred	8
9	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 of the area 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.

Methods followed for Susceptibility Analysis:

Following steps were taken in the susceptibility analysis (as shown in Fig.1),which ultimately led to the susceptibility map preparation:

a. Conversion of six geo-factor thematic maps (LULC, Geomorphology, SFM, Slope Angle, Slope Aspect and Slope Curvature) into raster maps of 50m X 50m pixel size.

b. Calculation of ratings for each geo-factor classes and integer weights of all geo-factor thematic maps in excel, using pair-wise comparison rating matrix, calculation of eigen values, fraction rate values and Landslide Occurrence Favorability Score (LOFS) ratings for six geo-factor maps (provided in Annexure-I).

c. Joining of excel table with the geo-factor maps in ArcGIS.

d. Generation of LOFS rating maps for all geo-factor themes.

e. Combining LOFS rating maps and Integer Weights to obtain raw Landslide Susceptibility Score Map and determination of classification/ break pixel values for classification of susceptibility classes, using logic of providing mutual comparison by expert-driven ranking.

Example of LULC for calculation of Landslide Occurrence Favorability Score (LOFS) is given

below in Table:

Table 9 Generic Table showing mutual comparison rank of LULC factor classes

Calculation of LOFS for LULC

Barren (B)	1
Barren Sand (BS)	0
Cultivation (CL)	2
Extensive Slope Cut (ESC)	9
Fallow Land (FL)	1
Moderate Vegetation (MV)	5
Plantation (HHP)	4
Plantation (LHP)	3
Quarry (QR)	5
Settlement (S)	1
Settlement on modified slope (SM)	7
Settlement with Cultivation (SC)	0
Settlement with Vegetation (SV)	0
Swamp (SW)	0
Thick Vegetation (TV)	4
Sparse Vegetation (SV)	7
Waterbody (WB)	0
Salt Pan (SP)	0

Table 10 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 11 Table Showing eigen values, fraction rate and LOFS values for LULC classes

LULC	B	CL	ESC	FL	MV	HHP	LHP	QR	S	SM	TV	SV	Sum rows	Frac rate	LOFS
B	0.020	0.013	0.037	0.020	0.013	0.012	0.011	0.013	0.020	0.021	0.012	0.021	0.213	0.018	0.063
CL	0.041	0.026	0.042	0.041	0.016	0.015	0.017	0.016	0.041	0.024	0.015	0.024	0.318	0.027	0.094
ESC	0.184	0.208	0.333	0.184	0.329	0.278	0.237	0.323	0.184	0.431	0.278	0.431	3.399	0.283	1.000
FL	0.020	0.013	0.037	0.020	0.013	0.012	0.011	0.013	0.020	0.021	0.012	0.021	0.213	0.018	0.063
MV	0.102	0.104	0.067	0.102	0.066	0.093	0.102	0.065	0.102	0.048	0.093	0.048	0.990	0.082	0.291
HHP	0.082	0.078	0.056	0.082	0.033	0.046	0.068	0.032	0.082	0.036	0.046	0.036	0.676	0.056	0.199
LHP	0.061	0.052	0.048	0.061	0.022	0.023	0.034	0.022	0.061	0.029	0.023	0.029	0.464	0.039	0.137
QR	0.102	0.104	0.067	0.102	0.066	0.093	0.102	0.065	0.102	0.048	0.093	0.048	0.990	0.082	0.291
S	0.020	0.013	0.037	0.020	0.013	0.012	0.011	0.032	0.020	0.021	0.012	0.021	0.232	0.019	0.068
SM	0.143	0.156	0.111	0.143	0.198	0.185	0.169	0.194	0.143	0.144	0.185	0.144	1.914	0.160	0.563
TV	0.082	0.078	0.056	0.082	0.033	0.046	0.068	0.032	0.082	0.036	0.046	0.036	0.676	0.056	0.199
SV	0.143	0.156	0.111	0.143	0.198	0.185	0.169	0.194	0.143	0.144	0.185	0.144	1.914	0.160	0.563

Table 12 Table showing estimation of consistency vector (CV).

LULC	B	CL	ESC	FL	MV	HHP	LHP	QR	S	SM	TV	SV	Sum rows	CV
B	0.018	0.013	0.031	0.018	0.016	0.014	0.013	0.016	0.019	0.023	0.014	0.023	0.2191981	12.36
CL	0.035	0.027	0.035	0.035	0.021	0.019	0.019	0.021	0.039	0.027	0.019	0.027	0.3229031	12.17
ESC	0.16	0.212	0.283	0.16	0.412	0.338	0.271	0.412	0.174	0.479	0.338	0.479	3.7177267	13.12
FL	0.018	0.013	0.031	0.018	0.016	0.014	0.013	0.016	0.019	0.023	0.014	0.023	0.2191981	12.36
MV	0.089	0.106	0.057	0.089	0.082	0.113	0.116	0.082	0.097	0.053	0.113	0.053	1.0496105	12.72
HHP	0.071	0.08	0.047	0.071	0.041	0.056	0.077	0.041	0.077	0.04	0.056	0.04	0.698393	12.4
LHP	0.053	0.053	0.04	0.053	0.027	0.028	0.039	0.027	0.058	0.032	0.028	0.032	0.4718235	12.19

QR	**0.089**	**0.106**	**0.057**	**0.089**	**0.082**	**0.113**	**0.116**	**0.082**	**0.097**	**0.053**	**0.113**	**0.053**	**1.0496105**	**12.72**
S	**0.018**	**0.013**	**0.031**	**0.018**	**0.016**	**0.014**	**0.013**	**0.041**	**0.019**	**0.023**	**0.014**	**0.023**	**0.2439453**	**12.61**
SM	**0.124**	**0.159**	**0.094**	**0.124**	**0.247**	**0.225**	**0.193**	**0.247**	**0.135**	**0.16**	**0.225**	**0.16**	**2.0954329**	**13.14**
TV	**0.071**	**0.08**	**0.047**	**0.071**	**0.041**	**0.056**	**0.077**	**0.041**	**0.077**	**0.04**	**0.056**	**0.04**	**0.698393**	**12.4**
SV	**0.124**	**0.159**	**0.094**	**0.124**	**0.247**	**0.225**	**0.193**	**0.247**	**0.135**	**0.16**	**0.225**	**0.16**	**2.0954329**	**13.14**
													Sum CV	**151.3**

Table 13 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	**12.6**	
Consistency Index (CI) =		**(Mean CV-number of themes)/(No of themes -1)**
CI	0.06	
Consistency Ratio (CR) =		**CI/RI**
CR	0	
CR should never be more than 0.1		

In the same manner for all the 6 factor maps (not consider Aspect map for LOFS calculation) calculation of LOFS and consistency ratio (CR) was done (Annexure-II). After calculation of LOFS values for all the factor classes of all the factor maps, LOFS maps were prepared using Arc GIS by joining the LOFS tables to the individual maps respectively.

Table 14 Weightage of different Geo-factors considered for AHP modeling and mutual comparison ranks

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

Table 15 Table showing mutual comparison ranks of factor maps.

Factor	**Slope**	**Curvature**	**SFM**	**LULC**	**Geom**	**RT**
Slope	**1.00**	**8.00**	**4.00**	**2.00**	**6.00**	**6.00**
Curvature	**0.13**	**1.00**	**0.20**	**0.14**	**0.33**	**0.33**
SFM	**0.25**	**5.00**	**1.00**	**0.33**	**3.00**	**3.00**

LULC	**0.50**	**7.00**	**3.00**	**1.00**	**5.00**	**5.00**
Geom	**0.17**	**3.00**	**0.33**	**0.20**	**1.00**	**1.00**
RT	**0.17**	**3.00**	**0.33**	**0.20**	**1.00**	**1.00**
Sum Clmn	**2.21**	**27.00**	**8.87**	**3.88**	**16.33**	**16.33**

Table 16 Table showing mutual comparison of individual factor maps and weights.

Factor	Slope	Curvature	SFM	LULC	Geom	RT	Sum rows	Frac rate	Weight	Weight W N
Slope	**0.45283**	**0.296296**	**0.451128**	**0.515971**	**0.367347**	**0.367347**	**2.450919**	**0.408486**	**12.64217**	**13**
Curvature	**0.056604**	**0.037037**	**0.022556**	**0.036855**	**0.020408**	**0.020408**	**0.193869**	**0.032311**	**1**	**1**
SFM	**0.113208**	**0.185185**	**0.112782**	**0.085995**	**0.183673**	**0.183673**	**0.864517**	**0.144086**	**4.459293**	**4**
LULC	**0.226415**	**0.259259**	**0.338346**	**0.257985**	**0.306122**	**0.306122**	**1.69425**	**0.282375**	**8.73917**	**9**
Geom	**0.075472**	**0.111111**	**0.037594**	**0.051597**	**0.061224**	**0.061224**	**0.398223**	**0.06637**	**2.054087**	**2**
RT	**0.075472**	**0.111111**	**0.037594**	**0.051597**	**0.061224**	**0.061224**	**0.398223**	**0.06637**	**2.054087**	**2**

The integer weight or rating and weights derived from AHP were used to obtain landslide susceptibility map. The output map is then regrouped into three susceptibility class (high, moderate and low).

V. LANDSLIDE SUSCEPTIBILITY MAP

The Landslide susceptibility map (Plate 12) of Toposheet 48 L/13, L/14, P/1 and P/2 was obtained using AHP method. This map was generated after creating LOFS maps for all the factor classes and generating raw susceptibility score map. The raw susceptibility score map prepared by using multi-class index overlay method combined with AHP calculation. The final raw susceptibility score map has been reclassified into three susceptibility zones based on the cut-off margin of 50% for "High" and "Moderate" and 30% for "Moderate" and "Low" categories respectively. Approximately 1.09% (about 14.76 sq. Km's) area is falling in high susceptibility zones, while about 17.63% (240.15 sq. Km's) area is falling in moderate susceptibility zone. Rest of the area is indicated as low susceptibility zone. Areas with more susceptible zone coverage falls in south west of toposheet no. P/2, central parts of P/1, Middle parts of L/13 and some parts in P/2 around Delantamajalu. Areas with high susceptible character in toposheet P/1 lie around central areas in the vicinity of Vogga, Penyar, south west of P/1 toposheet around Arebettu, Kukkila and Nirpaje. The high susceptible zones in P/2 lie around Sarvtodi, Suradka and Kollatadka. In L/13, high susceptible areas are demarcated around Farangipet, Kurnad, Kambla and Kaikambi. Although the present investigation includes a small part of toposheet 48 L/14, yet the areas which are highly susceptible are marked around Kaniyur. Areas having moderate susceptibility mostly fall in toposheets L/13 and along south west margins of toposheet P/2.

Table 17 Showing Landslide Susceptibility Zones and the area covered in pixels and percentage by each class

CLASS	Area Coverage (in pixels)	Area Coverage (%)	Area Coverage (Sq km)
Low	453959	81.274	1143.09
Moderate	98513	17.637	240.15
High	6082	1.089	14.76

VI. CONCLUSIONS AND RECOMMENDATIONS

The applicability of 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.

About 1.09% (14.76 sq. km) area is grouped under high susceptibility zone in the study area. Most of this area lies around transportation corridors, along areas where slope has been modified extensively for settlements and extensive slope cut areas in addition to areas with steep slopes which too fall in the realm of moderate to high susceptible zones.

The susceptibility map thus obtained using Analytical hierarchy process (AHP) gives a qualitative indication of the study area about particular mapping units being susceptible to landslide occurrence under the cumulative effect of geo factors under consideration. This does not have any time connotation and also it is assumed that the same geo-environmental conditions will prevail in the future that augmented the present slope failures. The entire susceptibility and demarcation of the weak zones from landslide point of view is discussed in following points:

1. Some areas in the South – Western parts of toposheet No. 48 P/2 are falling in high susceptibility zones, Sarvtodi, Suradka, Nirpaje and Kollatadka. Many among these susceptible zones are located on modified slopes which render the adjacent areas more prone to slope failures. As far as the settlements are concerned, a peculiar observation made during the field work is that settlements are made without taking care of local geo-environmental conditions. These settlements are developed in no time by modifying steep slopes leaving the steep slopes without any support or treatment. This is very alarming and has caused many casualties in last few years and has to be conveyed to the concerned authorities and preventive measures like slope terracing, construction of retaining walls etc. should be taken up.
2. The loose material named as loose debris in the slope forming material map is highly vulnerable to slides especially during rainy season. This material generated in laterite quarries, rock quarries and in areas under excavation and some constructional works is dumped indiscriminately on slopes. Some of these loose humps in toposheet 48 L/13 are near Bajpe, Farangipet in central parts, Mudungarukatte and in toposheet 48P/1 near Nujibail and Loretto. These loose humps are very risky especially during rainy season and have caused few casualties in the recent past like that of Derebail, Konchady behind AJ hospital on 20th November, 2012. Dumping of any loose material in any area must be done with proper care especially in areas with small settlements near slopes when the slope modification for settlements is unscientific. The vulnerability of these loose humps is enhanced when extensive cut slopes and weathered rock materials are nearby.
3. Slopes along roads generated during road extension must be dealt properly as the same could cause sliding leading to traffic jams during rainy season, like that of Padil landslide at NH-17 on 31st July, 2010 caused a major traffic disruption up to 3 km from Padil to Valachil village. Although these faces have been treated at few places like near Padil after that slide, but still the slopes near most of the roads needs to be taken care of. Moreover,

many settlements in the area are well located on modified (called settlements on modified slopes) slopes like that near Nandavar and Panemangalor, there should be no any further slope modifying activity near such settlements as the same could cause slope failure.

4. As most of the area is covered by high height plantation, any deforestation may lead to loosening of the overburden which can trigger a slide during rainy season. Moreover, running streams that cut across the roads pose a considerable risk to the road during rainy season. Proper drainage along the road and diversion of drainage on the top of the slope should be done. Slope stability measures are also required to minimise the risk. Preventive measures like slope stabilisation and conservation of forests need to be taken up so that the highway is kept safe from any damage.

5. 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.

6. 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 should be given due attention while executing civil constructions.

7. 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. In the event if a disaster strikes, then 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.

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Locality Index

S.No.	Village	Longitude(E)	Latitude(N)
1	Bajpe	74.88514712	12.98484023
2	Bantval	75.03450239	12.89812959
3	Farangipet	74.95096796	12.87664694
4	Kakkepdavu	75.17871294	12.884855
5	Kalladka	75.07628904	12.84571297
6	Kukkale	75.1639282	12.80828724
7	Kuvettu	75.23291724	12.97842728
8	Manchi	75.03002325	12.81660603
9	Mittur	75.14250923	12.80061669
10	Nirpadi	75.23320696	12.68821453
11	Puttur	75.19271399	12.76340706
12	Sarvtodi	75.2437058	12.59602706
13	Sirpadi	75.10524185	12.88055607
14	Vittal	75.0982356	12.7637846
15	Vittalkodi	75.03406626	12.8434945

SYNOPSIS OF WORK DONE

1	**Title of the report**	Macro - scale (1:50,000) Landslide Susceptibility Mapping in parts of Toposheet nos. 48 L/13, 14, 48 P/1 & 2, Dakshin Kannada district, Karnataka.
2	**FSP Code No**	LSM/SR/KG/2016/112
3	**Field Season**	2016 – 17
4	**Date of Commencement**	06th September, 2016
5	**Date of Completion**	05th February, 2017
6	**Officers associated with the investigation and no. of days spent in the field**	Zameer Ahmad Shah, Geologist (83 days) Kapil Singh., Geologist (83 days)
7	**Quantum of work done**	

1. Pre-field preparation	
(i) Slope Forming Material map	1356 sq. Km
(ii) Geomorphology & Lineament map	1356 sq. Km
(iii) Slope Morphometry (slope, aspect & curvature) map	1356 sq. Km
(iv) Landuse / Landcover map	1356 sq. Km
(v) Drainage map	1356 sq. Km
(vi) Regolith thickness map	1356 sq. Km
(vii) Preparation of Landslide Inventory Map	1356 sq. Km
2. Field-based studies	
(i) Field-checking of all thematic maps	1356 sq. Km
(ii) Field validation of landslide inventory and collection of recent and historic landslides (using archives, old reports, road register etc.)	1356 sq. Km
(iii) Collection of landslide inventory and damage data as per 41 point geo parametric data sheet	1356 sq. Km (18 nos. of landslides)
3. Post-field studies & modelling	
(i) Updation of thematic and inventory maps in GIS	1356 sq. Km
(ii) Preparation of Landslide Susceptibility Map in GIS	1356 sq. Km
(iii) Validation of landslide susceptibility map at important locations	1356 sq. Km
4. Collection of rainfall data from available rain-gauge stations	1356 sq. Km (Collected for 10 years for three rain gauge stations)

FIVE POINT PROFORMA

Title of the report: Macro - scale (1:50,000) Landslide Susceptibility Mapping in parts of Toposheet nos. 48 L/13, 14, 48 P/1 & 2, Dakshin Kannada 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/2016/112 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/2016/112 Item No: **162**
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.	06th September, 2016 1. Zameer Ahmad Shah, **83 Days** 2. Kapil Singh, **83 Days** **Total 166 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

Annexure – I: 41 Point Geo-parametric Data Format for Landslides

1	Name	KAR/DK/48P01/2016/01
2	Latitude (N) (DMS)	12° 59′ 06.27″
3	Longitude (E) (DMS)	75° 02′ 56.12″
4	Toposheet No	48P01
5	Village Name	East of Sittakadde road (Maddame village)
6	Road	Moodabidri-Bantval road
7	Geomorphic Process	Gravitational
8	Geomorphic Form	Moderately Dissected Slope
9	Rock	Granite Gneiss
10	Weathering	Moderate
11	Rock Character	Massive
12	Dip Foliation	*Data Not Available*
13	Dip Direction Foliation	*Data Not Available*
14	Dip J1	*Data Not Available*
15	Dip Direction J1	*Data Not Available*
16	Overburden Type	Weathered Rock
17	Thickness	< 0.5 m
18	Landuse	Extensive Slope Cut
19	Hydrology	Damp
20	Erosion	Base removal/Toe cutting Erosion
21	Susceptibility	High
22	Risk	Moderate
23	Landslide Length	15 m
24	Landslide Width	12 m
25	Landslide Height	11 m
26	Landslide Run Out	5 m
27	Landslide Material	Debris
28	Movement Type	Slide
29	Failure Depth	2 m
30	Landslide Activity	Inactive
31	Landslide Distribution	Retrogressive
32	Landslide Style	Single
33	Landslide Mechanism	Shallow Translational Failure
34	Landslide Initiation	*Data Not Available*
35	Upslope	40°
36	Downslope	80°
37	Triggering Factor	Toe cutting (Channel flowing at the base of Slide)
38	Casualties	*Data Not Available*
39	Geo Scientific Cause	Toe cutting
40	Remedial Measures	Retaining wall and free flow of the channel
41	Remarks	Nil

1	Name	KAR/DK/48P01/2016/02
2	Latitude (N) (DMS)	12°54'20.96"
3	Longitude (E) (DMS)	75° 2'28.37"
4	Toposheet No	48P01
5	Village Name	Bantval
6	Road	Moodabidri-Bantval road
7	Geomorphic Process	Gravitational
8	Geomorphic Form	Moderately Dissected Slope
9	Rock	Granite Gneiss
10	Weathering	Moderate
11	Rock Character	Massive
12	Dip Foliation	*Data Not Available*
13	Dip Direction Foliation	*Data Not Available*
14	Dip J1	*Data Not Available*
15	Dip Direction J1	*Data Not Available*
16	Overburden Type	Soil
17	Thickness	> 0.5 m
18	Landuse	Extensive Slope Cut
19	Hydrology	Damp
20	Erosion	Toe Erosion
21	Susceptibility	High
22	Risk	High
23	Landslide Length	18 m
24	Landslide Width	11 m
25	Landslide Height	13 m
26	Landslide Run Out	*Data Not Available*
27	Landslide Material	Debris
28	Movement Type	Slide
29	Failure Depth	3 m
30	Landslide Activity	Active
31	Landslide Distribution	Retrogressive
32	Landslide Style	Complex
33	Landslide Mechanism	Shallow Translational Failure
34	Landslide Initiation	*Data Not Available*
35	Upslope	55°
36	Downslope	85°
37	Triggering Factor	Anthropogenic
38	Casualties	*Data Not Available*
39	Geo Scientific Cause	Toe cutting of the slope, due to toe cutting by local people.
40	Remedial Measures	Growing vegetation on entire slope and prohibition any excavation on entire slope.
41	Remarks	Anthropogenic, due to base removal by the local people for land grabbing.

1	Name	KAR/DK/48P01/2016/03
2	Latitude (N) (DMS)	12° 53′ 14.81″
3	Longitude (E) (DMS)	75° 06′ 41.55″
4	Toposheet No	48P01
5	Village Name	East of Ferringipet
6	Road	Local road
7	Geomorphic Process	Gravitational
8	Geomorphic Form	Moderately Dissected Slope
9	Rock	Laterite
10	Weathering	Moderate
11	Rock Character	Massive
12	Dip Foliation	*Data Not Available*
13	Dip Direction Foliation	*Data Not Available*
14	Dip J1	*Data Not Available*
15	Dip Direction J1	*Data Not Available*
16	Overburden Type	Laterite capping
17	Thickness	< 0.5 m
18	Landuse	Extensive Slope Cut
19	Hydrology	Damp
20	Erosion	Toe Erosion
21	Susceptibility	High
22	Risk	Moderate
23	Landslide Length	5 m
24	Landslide Width	6 m
25	Landslide Height	4 m
26	Landslide Run Out	*Data Not Available*
27	Landslide Material	Debris
28	Movement Type	Slide
29	Failure Depth	6 m
30	Landslide Activity	Inactive
31	Landslide Distribution	Retrogressive
32	Landslide Style	Single
33	Landslide Mechanism	Shallow Translational Failure
34	Landslide Initiation	*Data Not Available*
35	Upslope	45°
36	Downslope	80°
37	Triggering Factor	Anthropogenic
38	Casualties	*Data Not Available*
39	Geo Scientific Cause	Toe cutting of the slope for road extension
40	Remedial Measures	Retaining wall with weep holes
41	Remarks	Nil

1	Name	KAR/DK/48P01/2016/04
2	Latitude (N) (DMS)	12°52'51.35"
3	Longitude (E) (DMS)	75° 8'57.79"
4	Toposheet No	48P01
5	Village Name	East of Maninalkuru village
6	Road	On Maninalkuru Naibelu road
7	Geomorphic Process	Gravitational
8	Geomorphic Form	Moderately Dissected Slope
9	Rock	Granite Gneiss
10	Weathering	Moderate
11	Rock Character	Massive
12	Dip Foliation	*Data Not Available*
13	Dip Direction Foliation	*Data Not Available*
14	Dip J1	*Data Not Available*
15	Dip Direction J1	*Data Not Available*
16	Overburden Type	Rock
17	Thickness	< 0.5 m
18	Landuse	Extensive Slope Cut
19	Hydrology	Damp
20	Erosion	Toe Erosion
21	Susceptibility	High
22	Risk	High
23	Landslide Length	14 m
24	Landslide Width	8 m
25	Landslide Height	11 m
26	Landslide Run Out	*Data Not Available*
27	Landslide Material	Debris
28	Movement Type	Slide
29	Failure Depth	5 m
30	Landslide Activity	Active
31	Landslide Distribution	Retrogressive
32	Landslide Style	Multiple
33	Landslide Mechanism	Shallow Translational Failure
34	Landslide Initiation	*Data Not Available*
35	Upslope	45°
36	Downslope	80°
37	Triggering Factor	Anthropogenic
38	Casualties	*Data Not Available*
39	Geo Scientific Cause	Toe cutting of the slope
40	Remedial Measures	Benching
41	Remarks	Nil

1	Name	KAR/DK/48P01/2016/05
2	Latitude (N) (DMS)	12° 55′ 17.08″
3	Longitude (E) (DMS)	75° 05′ 52.02″
4	Toposheet No	48P01
5	Village Name	Kodabetu
6	Road	NH - 64
7	Geomorphic Process	Gravitational
8	Geomorphic Form	Moderately Dissected Slope
9	Rock	Granite Gneiss
10	Weathering	Moderate
11	Rock Character	Massive
12	Dip Foliation	*Data Not Available*
13	Dip Direction Foliation	*Data Not Available*
14	Dip J1	*Data Not Available*
15	Dip Direction J1	*Data Not Available*
16	Overburden Type	Rock
17	Thickness	< 0.5 m
18	Landuse	Extensive Slope Cut
19	Hydrology	Damp
20	Erosion	Toe Erosion
21	Susceptibility	High
22	Risk	Moderate
23	Landslide Length	12 m
24	Landslide Width	14 m
25	Landslide Height	10 m
26	Landslide Run Out	5 m
27	Landslide Material	Debris
28	Movement Type	Slide
29	Failure Depth	4 m
30	Landslide Activity	Active
31	Landslide Distribution	Retrogressive
32	Landslide Style	Single
33	Landslide Mechanism	Shallow Translational Failure
34	Landslide Initiation	*Data Not Available*
35	Upslope	35°
36	Downslope	80°
37	Triggering Factor	Anthropogenic
38	Casualties	*Data Not Available*
39	Geo Scientific Cause	Toe cutting of the slope
40	Remedial Measures	Benching
41	Remarks	Nil

1	Name	KAR/DK/48P01/2016/06
2	Latitude (N) (DMS)	12° 56′ 56.52″
3	Longitude (E) (DMS)	75° 10′ 22.81″
4	Toposheet No	48P01
5	Village Name	Punjakatte
6	Road	NH - 64
7	Geomorphic Process	Gravitational
8	Geomorphic Form	Moderately Dissected Slope
9	Rock	Weathered Granite
10	Weathering	Moderate
11	Rock Character	Massive
12	Dip Foliation	*Data Not Available*
13	Dip Direction Foliation	*Data Not Available*
14	Dip J1	*Data Not Available*
15	Dip Direction J1	*Data Not Available*
16	Overburden Type	Rock
17	Thickness	< 0.5 m
18	Landuse	Extensive Slope Cut
19	Hydrology	Damp
20	Erosion	Toe Erosion
21	Susceptibility	High
22	Risk	Moderate
23	Landslide Length	12 m
24	Landslide Width	14 m
25	Landslide Height	9 m
26	Landslide Run Out	8 m
27	Landslide Material	Rock
28	Movement Type	Slide
29	Failure Depth	4 m
30	Landslide Activity	Active
31	Landslide Distribution	Retrogressive
32	Landslide Style	Single
33	Landslide Mechanism	Shallow Translational Failure
34	Landslide Initiation	*Data Not Available*
35	Upslope	45°
36	Downslope	80°
37	Triggering Factor	Anthropogenic
38	Casualties	*Data Not Available*
39	Geo Scientific Cause	Toe cutting of the slope
40	Remedial Measures	Retaining wall with weep holes
41	Remarks	Nil

1	Name	KAR/DK/48P01/2016/07
2	Latitude (N) (DMS)	12° 56′ 57.85″
3	Longitude (E) (DMS)	75° 11′ 06.26″
4	Toposheet No	48P01
5	Village Name	Modanteyar
6	Road	Near Uppinangady cross road
7	Geomorphic Process	Gravitational
8	Geomorphic Form	Moderately Dissected Slope
9	Rock	Granite Gneiss
10	Weathering	Moderate
11	Rock Character	Massive
12	Dip Foliation	*Data Not Available*
13	Dip Direction Foliation	*Data Not Available*
14	Dip J1	*Data Not Available*
15	Dip Direction J1	*Data Not Available*
16	Overburden Type	Rock
17	Thickness	< 0.5 m
18	Landuse	Extensive Slope Cut
19	Hydrology	Damp
20	Erosion	Toe Erosion
21	Susceptibility	High
22	Risk	Moderate
23	Landslide Length	14 m
24	Landslide Width	10 m
25	Landslide Height	10 m
26	Landslide Run Out	*Data Not Available*
27	Landslide Material	Debris
28	Movement Type	Slide
29	Failure Depth	3 m
30	Landslide Activity	Inactive
31	Landslide Distribution	Retrogressive
32	Landslide Style	Single
33	Landslide Mechanism	Shallow Translational Failure
34	Landslide Initiation	*Data Not Available*
35	Upslope	45°
36	Downslope	85°
37	Triggering Factor	Anthropogenic
38	Casualties	*Data Not Available*
39	Geo Scientific Cause	Toe cutting of the slope
40	Remedial Measures	Retaining wall with weep holes
41	Remarks	Nil

1	Name	KAR/DK/48P01/2016/08

2	Latitude (N) (DMS)	12° 59′ 01.80″
3	Longitude (E) (DMS)	75° 09′ 04.08″
4	Toposheet No	48P01
5	Village Name	Ultar
6	Road	Local road near Ultar
7	Geomorphic Process	Gravitational
8	Geomorphic Form	Moderately Dissected Slope
9	Rock	Granite Gneiss
10	Weathering	Moderate
11	Rock Character	Massive
12	Dip Foliation	*Data Not Available*
13	Dip Direction Foliation	*Data Not Available*
14	Dip J1	*Data Not Available*
15	Dip Direction J1	*Data Not Available*
16	Overburden Type	Rock
17	Thickness	< 0.5 m
18	Landuse	Extensive Slope Cut
19	Hydrology	Damp
20	Erosion	Toe Erosion
21	Susceptibility	High
22	Risk	High
23	Landslide Length	9 m
24	Landslide Width	35 m
25	Landslide Height	7 m
26	Landslide Run Out	6 m
27	Landslide Material	Debris
28	Movement Type	Slide
29	Failure Depth	3 m
30	Landslide Activity	Active
31	Landslide Distribution	Retrogressive
32	Landslide Style	Single
33	Landslide Mechanism	Shallow Translational Failure
34	Landslide Initiation	*Data Not Available*
35	Upslope	45°
36	Downslope	80°
37	Triggering Factor	Anthropogenic
38	Casualties	*Data Not Available*
39	Geo Scientific Cause	Toe cutting of the slope
40	Remedial Measures	Retaining wall with weep holes
41	Remarks	Nil

1	Name	KAR/DK/48P01/2016/09
2	Latitude (N) (DMS)	12° 50′ 55.39″
3	Longitude (E) (DMS)	75° 12′ 36.49″
4	Toposheet No	48P01
5	Village Name	Barya
6	Road	Near Barya road
7	Geomorphic Process	Gravitational
8	Geomorphic Form	Moderately Dissected Slope
9	Rock	Granite Gneiss
10	Weathering	Moderate
11	Rock Character	Massive
12	Dip Foliation	*Data Not Available*
13	Dip Direction Foliation	*Data Not Available*
14	Dip J1	*Data Not Available*
15	Dip Direction J1	*Data Not Available*
16	Overburden Type	Rock
17	Thickness	< 0.5 m
18	Landuse	Extensive Slope Cut
19	Hydrology	Damp
20	Erosion	Toe Erosion
21	Susceptibility	High
22	Risk	Moderate
23	Landslide Length	10 m
24	Landslide Width	14 m
25	Landslide Height	9 m
26	Landslide Run Out	7 m
27	Landslide Material	Debris
28	Movement Type	Slide
29	Failure Depth	3 m
30	Landslide Activity	Active
31	Landslide Distribution	Retrogressive
32	Landslide Style	Single
33	Landslide Mechanism	Shallow Translational Failure
34	Landslide Initiation	*Data Not Available*
35	Upslope	45°
36	Downslope	75°
37	Triggering Factor	Anthropogenic
38	Casualties	*Data Not Available*
39	Geo Scientific Cause	Toe cutting of the slope for road widening
40	Remedial Measures	Retaining wall with weep holes
41	Remarks	Nil

1	Name	KAR/DK/48P01/2016/10
2	Latitude (N) (DMS)	12° 55′ 05.94″
3	Longitude (E) (DMS)	75° 02′ 22.59″
4	Toposheet No	48P01
5	Village Name	East of Loreito
6	Road	Near Moodabidri-Bantval road
7	Geomorphic Process	Gravitational
8	Geomorphic Form	Moderately Dissected Slope
9	Rock	Granite Gneiss
10	Weathering	Moderate
11	Rock Character	Massive
12	Dip Foliation	*Data Not Available*
13	Dip Direction Foliation	*Data Not Available*
14	Dip J1	*Data Not Available*
15	Dip Direction J1	*Data Not Available*
16	Overburden Type	In situ Soil
17	Thickness	0.5 - 5 m
18	Landuse	Extensive Slope Cut
19	Hydrology	Damp
20	Erosion	Toe Erosion
21	Susceptibility	High
22	Risk	Moderate
23	Landslide Length	17 m
24	Landslide Width	11 m
25	Landslide Height	12 m
26	Landslide Run Out	*Data Not Available*
27	Landslide Material	Debris
28	Movement Type	Slide
29	Failure Depth	3 m
30	Landslide Activity	Inactive
31	Landslide Distribution	Retrogressive
32	Landslide Style	Single
33	Landslide Mechanism	Shallow Translational Failure
34	Landslide Initiation	*Data Not Available*
35	Upslope	40°
36	Downslope	85°
37	Triggering Factor	Anthropogenic
38	Casualties	*Data Not Available*
39	Geo Scientific Cause	Toe cutting of the slope
40	Remedial Measures	Retaining wall with weep holes
41	Remarks	Nil

1	Name	KAR/DK/48P01/2016/11
2	Latitude (N) (DMS)	12° 45′ 07.42″
3	Longitude (E) (DMS)	75° 01′ 54.55″
4	Toposheet No	48P01
5	Village Name	Kaniyoor
6	Road	Puttur - Manjeshwar road
7	Geomorphic Process	Gravitational
8	Geomorphic Form	Moderately Dissected Slope
9	Rock	Granite Gneiss
10	Weathering	Moderate
11	Rock Character	Massive
12	Dip Foliation	*Data Not Available*
13	Dip Direction Foliation	*Data Not Available*
14	Dip J1	*Data Not Available*
15	Dip Direction J1	*Data Not Available*
16	Overburden Type	Rock
17	Thickness	< 0.5 m
18	Landuse	Extensive Slope Cut
19	Hydrology	Damp
20	Erosion	Toe Erosion
21	Susceptibility	High
22	Risk	High
23	Landslide Length	15 m
24	Landslide Width	19 m
25	Landslide Height	12 m
26	Landslide Run Out	*Data Not Available*
27	Landslide Material	Debris
28	Movement Type	Slide
29	Failure Depth	4 m
30	Landslide Activity	Active
31	Landslide Distribution	Retrogressive & Widening
32	Landslide Style	Single
33	Landslide Mechanism	Shallow Translational Failure
34	Landslide Initiation	*Data Not Available*
35	Upslope	40°
36	Downslope	80°
37	Triggering Factor	Anthropogenic
38	Casualties	*Data Not Available*
39	Geo Scientific Cause	Toe cutting of the slope
40	Remedial Measures	Retaining wall with weep holes
41	Remarks	Trees are well bended near crown

1	Name	KAR/DK/48P02/2016/12
2	Latitude (N) (DMS)	12° 41′ 39.60″
3	Longitude (E) (DMS)	75° 03′ 54.71″
4	Toposheet No	48P02
5	Village Name	NW of Manila
6	Road	Manila – Peruvai road
7	Geomorphic Process	Gravitational
8	Geomorphic Form	Moderately Dissected Slope
9	Rock	Granite Gneiss
10	Weathering	Moderate
11	Rock Character	Massive
12	Dip Foliation	*Data Not Available*
13	Dip Direction Foliation	*Data Not Available*
14	Dip J1	*Data Not Available*
15	Dip Direction J1	*Data Not Available*
16	Overburden Type	Rock
17	Thickness	0.5 - 5 m
18	Landuse	In situ Soil
19	Hydrology	Damp
20	Erosion	Toe Erosion
21	Susceptibility	High
22	Risk	Moderate
23	Landslide Length	18 m
24	Landslide Width	16 m
25	Landslide Height	12 m
26	Landslide Run Out	7 m
27	Landslide Material	Debris
28	Movement Type	Slide
29	Failure Depth	4 m
30	Landslide Activity	Active
31	Landslide Distribution	Retrogressive
32	Landslide Style	Single
33	Landslide Mechanism	Shallow Translational Failure
34	Landslide Initiation	*Data Not Available*
35	Upslope	35°
36	Downslope	75°
37	Triggering Factor	Anthropogenic
38	Casualties	*Data Not Available*
39	Geo Scientific Cause	Toe cutting of the slope
40	Remedial Measures	Retaining wall with weep holes
41	Remarks	Nil

1	Name	KAR/DK/48P01/2016/13
2	Latitude (N) (DMS)	12° 45′ 33.97″
3	Longitude (E) (DMS)	75° 11′ 52.52″
4	Toposheet No	48P01
5	Village Name	Near Kemmai
6	Road	Mangalore – Mysore Highway
7	Geomorphic Process	Gravitational
8	Geomorphic Form	Moderately Dissected Slope
9	Rock	Granite Gneiss
10	Weathering	Moderate
11	Rock Character	Massive
12	Dip Foliation	*Data Not Available*
13	Dip Direction Foliation	*Data Not Available*
14	Dip J1	*Data Not Available*
15	Dip Direction J1	*Data Not Available*
16	Overburden Type	In situ Soil
17	Thickness	0.5 - 5 m
18	Landuse	Extensive Slope Cut
19	Hydrology	Damp
20	Erosion	Toe Erosion
21	Susceptibility	High
22	Risk	Moderate
23	Landslide Length	19 m
24	Landslide Width	23 m
25	Landslide Height	16 m
26	Landslide Run Out	*Data Not Available*
27	Landslide Material	Debris
28	Movement Type	Slide
29	Failure Depth	6 m
30	Landslide Activity	Active
31	Landslide Distribution	Retrogressive
32	Landslide Style	Single
33	Landslide Mechanism	Deep Translational Failure
34	Landslide Initiation	*Data Not Available*
35	Upslope	40°
36	Downslope	85°
37	Triggering Factor	Anthropogenic
38	Casualties	*Data Not Available*
39	Geo Scientific Cause	Toe cutting of the slope for road widening
40	Remedial Measures	Retaining wall with weep holes
41	Remarks	Nil

1	Name	KAR/DK/48P01/2016/14
2	Latitude (N) (DMS)	12° 45′ 01.26″
3	Longitude (E) (DMS)	75° 12′ 01.28″
4	Toposheet No	48P01
5	Village Name	South east of Tenkila
6	Road	Near Mangalore – Mysore Highway
7	Geomorphic Process	Gravitational
8	Geomorphic Form	Moderately Dissected Slope
9	Rock	Granite Gneiss
10	Weathering	Moderate
11	Rock Character	Massive
12	Dip Foliation	*Data Not Available*
13	Dip Direction Foliation	*Data Not Available*
14	Dip J1	*Data Not Available*
15	Dip Direction J1	*Data Not Available*
16	Overburden Type	Rock
17	Thickness	< 0.5 m
18	Landuse	Extensive Slope Cut
19	Hydrology	Damp
20	Erosion	Toe Erosion
21	Susceptibility	High
22	Risk	Moderate
23	Landslide Length	50 m
24	Landslide Width	24 m
25	Landslide Height	34 m
26	Landslide Run Out	26 m
27	Landslide Material	Debris
28	Movement Type	Slide
29	Failure Depth	3 m
30	Landslide Activity	Active
31	Landslide Distribution	Retrogressive
32	Landslide Style	Single
33	Landslide Mechanism	Shallow Translational Failure
34	Landslide Initiation	*Data Not Available*
35	Upslope	40°
36	Downslope	85°
37	Triggering Factor	Anthropogenic
38	Casualties	*Data Not Available*
39	Geo Scientific Cause	Toe cutting of the slope
40	Remedial Measures	Retaining wall with weep holes
41	Remarks	The area is still going under step-wise excavation.

1	Name	KAR/DK/48L13/2016/15
2	Latitude (N) (DMS)	12° 52′ 20.36″
3	Longitude (E) (DMS)	74° 58′ 42.8″
4	Toposheet No	48L13
5	Village Name	South - West of Thambe
6	Road	Feringipet – Benjen padavu road
7	Geomorphic Process	Gravitational
8	Geomorphic Form	Moderately Dissected Slope
9	Rock	Granite Gneiss
10	Weathering	Moderate
11	Rock Character	Massive
12	Dip Foliation	*Data Not Available*
13	Dip Direction Foliation	*Data Not Available*
14	Dip J1	*Data Not Available*
15	Dip Direction J1	*Data Not Available*
16	Overburden Type	Rock
17	Thickness	< 0.5 m
18	Landuse	Extensive Slope Cut
19	Hydrology	Damp
20	Erosion	Toe Erosion
21	Susceptibility	High
22	Risk	Moderate
23	Landslide Length	16 m
24	Landslide Width	13 m
25	Landslide Height	14 m
26	Landslide Run Out	*Data Not Available*
27	Landslide Material	Debris
28	Movement Type	Slide
29	Failure Depth	5 m
30	Landslide Activity	Inactive
31	Landslide Distribution	Retrogressive
32	Landslide Style	Single
33	Landslide Mechanism	Shallow Translational Failure
34	Landslide Initiation	*Data Not Available*
35	Upslope	45°
36	Downslope	75°
37	Triggering Factor	Anthropogenic
38	Casualties	*Data Not Available*
39	Geo Scientific Cause	Toe cutting of the slope
40	Remedial Measures	Retaining wall with weep holes
41	Remarks	Nil

1	Name	KAR/DK/48P01/2016/16
2	Latitude (N) (DMS)	12° 46′ 25.02″
3	Longitude (E) (DMS)	75° 03′ 15.09″
4	Toposheet No	48P01
5	Village Name	North east of Kolnadu village
6	Road	Bakrabail – Salethur – Vittala Road
7	Geomorphic Process	Gravitational
8	Geomorphic Form	Lowly Dissected Slope
9	Rock	Granite Gneiss
10	Weathering	Moderate
11	Rock Character	Massive
12	Dip Foliation	*Data Not Available*
13	Dip Direction Foliation	*Data Not Available*
14	Dip J1	*Data Not Available*
15	Dip Direction J1	*Data Not Available*
16	Overburden Type	In situ Soil
17	Thickness	0.5 - 5 m
18	Landuse	Extensive Slope Cut
19	Hydrology	Damp
20	Erosion	Toe Erosion
21	Susceptibility	High
22	Risk	High
23	Landslide Length	9 m
24	Landslide Width	7 m
25	Landslide Height	8 m
26	Landslide Run Out	*Data Not Available*
27	Landslide Material	Debris
28	Movement Type	Slide
29	Failure Depth	3 m
30	Landslide Activity	Active
31	Landslide Distribution	Retrogressive & Wiedning
32	Landslide Style	Single
33	Landslide Mechanism	Shallow Translational Failure
34	Landslide Initiation	*Data Not Available*
35	Upslope	40°
36	Downslope	85°
37	Triggering Factor	Anthropogenic
38	Casualties	*Data Not Available*
39	Geo Scientific Cause	Toe cutting of the slope
40	Remedial Measures	Retaining wall with weep holes
41	Remarks	Nil

1	Name	KAR/DK/48P02/2016/17
2	Latitude (N) (DMS)	12° 38′ 48.62″
3	Longitude (E) (DMS)	75° 08′ 32.00″
4	Toposheet No	48P02
5	Village Name	North east of Bairakada village
6	Road	Panaje – Swarga – Perla Road
7	Geomorphic Process	Gravitational
8	Geomorphic Form	Lowly Dissected Slope
9	Rock	Granite Gneiss
10	Weathering	Moderate
11	Rock Character	Massive
12	Dip Foliation	*Data Not Available*
13	Dip Direction Foliation	*Data Not Available*
14	Dip J1	*Data Not Available*
15	Dip Direction J1	*Data Not Available*
16	Overburden Type	In situ Soil
17	Thickness	0.5 - 5 m
18	Landuse	Extensive Slope Cut
19	Hydrology	Damp
20	Erosion	Toe Erosion
21	Susceptibility	High
22	Risk	High
23	Landslide Length	7 m
24	Landslide Width	5 m
25	Landslide Height	6 m
26	Landslide Run Out	*Data Not Available*
27	Landslide Material	Debris
28	Movement Type	Slide
29	Failure Depth	3 m
30	Landslide Activity	Active
31	Landslide Distribution	Retrogressive & Wiedning
32	Landslide Style	Single
33	Landslide Mechanism	Shallow Translational Failure
34	Landslide Initiation	*Data Not Available*
35	Upslope	40°
36	Downslope	85°
37	Triggering Factor	Anthropogenic
38	Casualties	*Data Not Available*
39	Geo Scientific Cause	Toe cutting of the slope
40	Remedial Measures	Retaining wall
41	Remarks	Nil

1	Name	KAR/DK/48P01/2016/18
2	Latitude (N) (DMS)	12° 57$^{/}$ 02.85$^{//}$
3	Longitude (E) (DMS)	75° 05$^{/}$ 17.83$^{//}$
4	Toposheet No	48P01
5	Village Name	East of Pelinayar
6	Road	Near Vamadapadu Road jn.
7	Geomorphic Process	Gravitational
8	Geomorphic Form	Lowly Dissected Slope
9	Rock	Granite Gneiss
10	Weathering	Moderate
11	Rock Character	Massive
12	Dip Foliation	*Data Not Available*
13	Dip Direction Foliation	*Data Not Available*
14	Dip J1	*Data Not Available*
15	Dip Direction J1	*Data Not Available*
16	Overburden Type	In situ Soil
17	Thickness	0.5 - 5 m
18	Landuse	Extensive Slope Cut
19	Hydrology	Damp
20	Erosion	Toe Erosion
21	Susceptibility	High
22	Risk	High
23	Landslide Length	12 m
24	Landslide Width	30 m
25	Landslide Height	9 m
26	Landslide Run Out	*Data Not Available*
27	Landslide Material	Debris
28	Movement Type	Slide
29	Failure Depth	5 m
30	Landslide Activity	Active
31	Landslide Distribution	Retrogressive
32	Landslide Style	Single
33	Landslide Mechanism	Shallow Translational Failure
34	Landslide Initiation	*Data Not Available*
35	Upslope	40°
36	Downslope	85°
37	Triggering Factor	Anthropogenic
38	Casualties	*Data Not Available*
39	Geo Scientific Cause	Toe cutting of the slope
40	Remedial Measures	Benching
41	Remarks	Nil

Annexure – II: Calculation of LOFS and consistency ratio (CR) for all 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

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

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

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

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

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

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**

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

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**

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**

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**

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**

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**

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-III Average Rainfall pattern in the area from 2007 to 2016.

Taluk	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Mangalore	3314.2	2661	3146	4500.7	3416	3394.08	3915.5	3254.2	2751.3	2919.9
Bantwal	4115	3683	4100	4228	4093.2	3272.9	3839.5	3554.3	3127	2875.6
Puttur	3764.8	3127	3652	3684.7	3864.3	3301	4231	3277.7	3277.7	2714
Sulya	4280.6	3199	3167	3731.8	4144.9	2795.7	3845.4	3000	3000	2720.9
Beltangadi	4884.6	4044	4818	4601.1	4590.5	3974.4	5163.4	3179.7	3179.7	3596.1

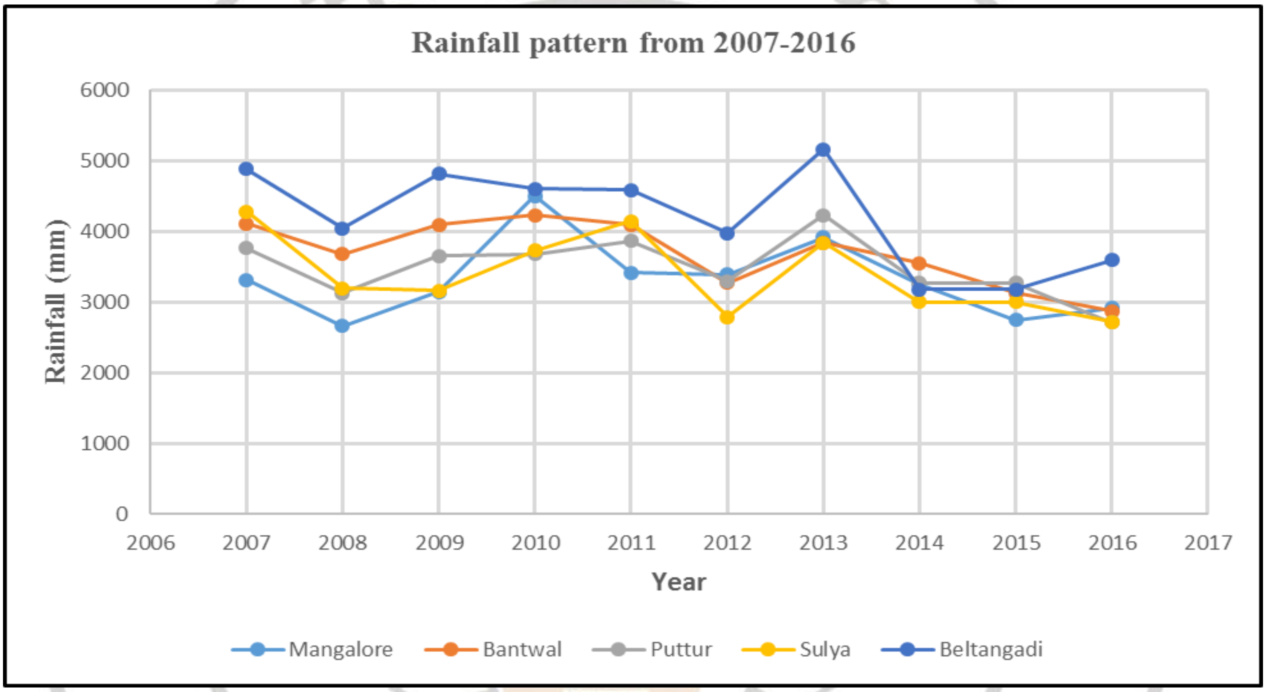


PLATE 1

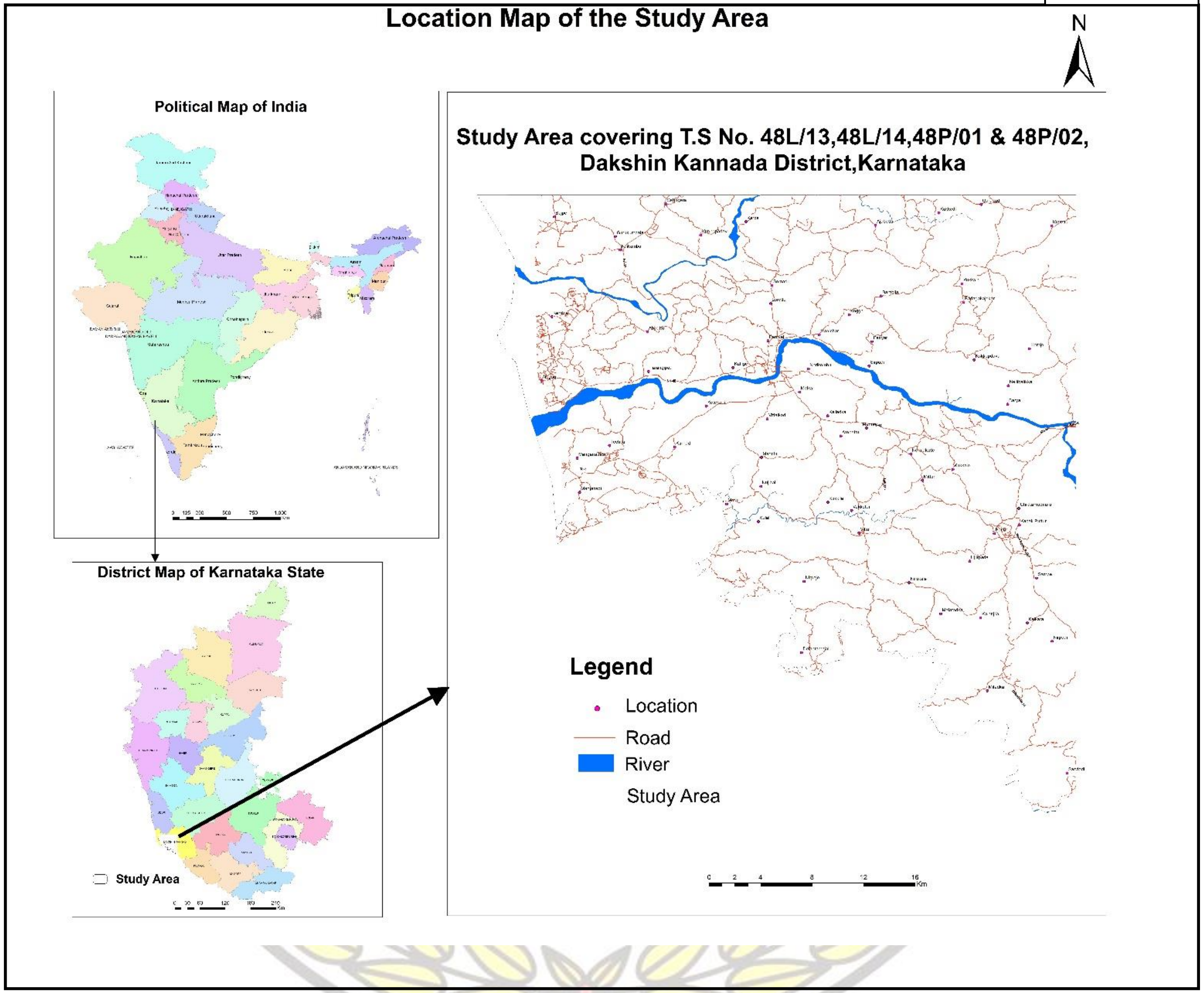

Location Map of the Study Area
N
Political Map of India
District Map of Karnataka State
Study Area
Study Area covering T.S No. 48L/13,48L/14,48P/01 & 48P/02,
Dakshin Kannada District,Karnataka
Legend
Location
Road
River
Study Area
Km

PLATE 2

Geology Map of T.S No. 48L/13,48L/14,48P/01 & 48P/02,Dakshin Kannada District,Karnataka

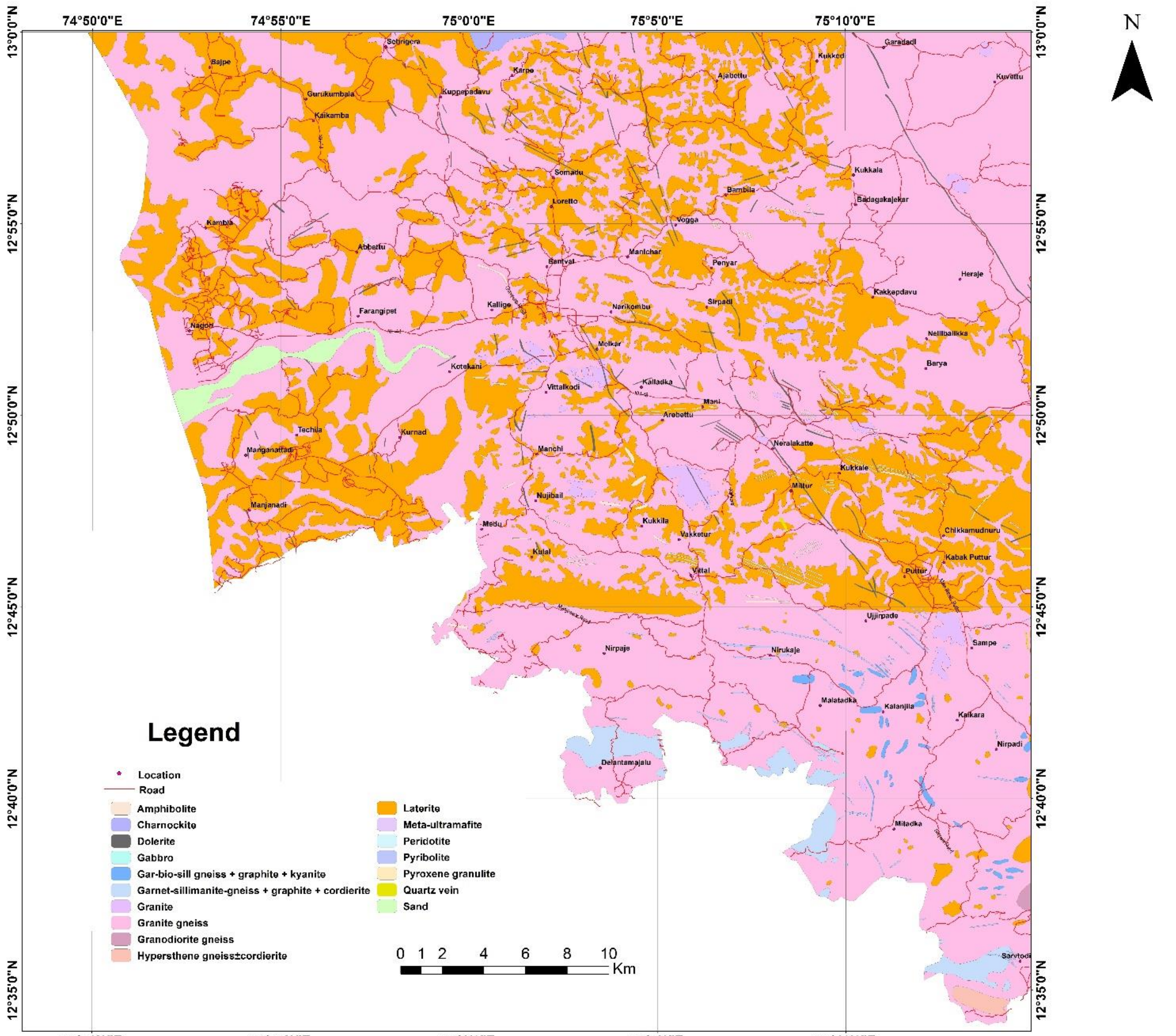


Plate 3

Slope Gradient Map of T.S No. 48L/13,48L/14,48P/01 & 48P/02,Dakshin Kannada District,Karnataka

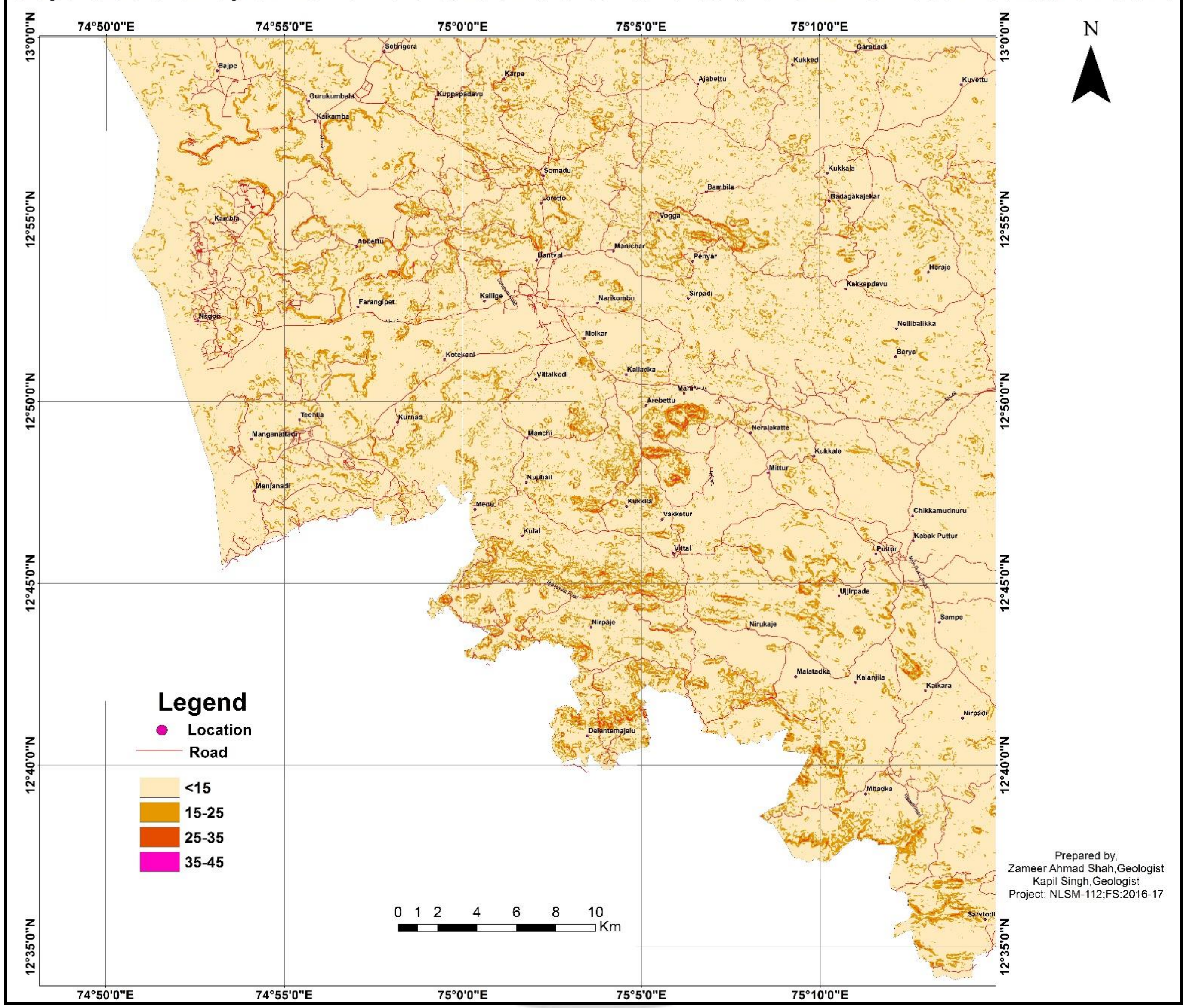


Plate 4

Slope Aspect Map of T.S No. 48L/13,48L/14,48P/01 & 48P/02,Dakshin Kannada District,Karnataka

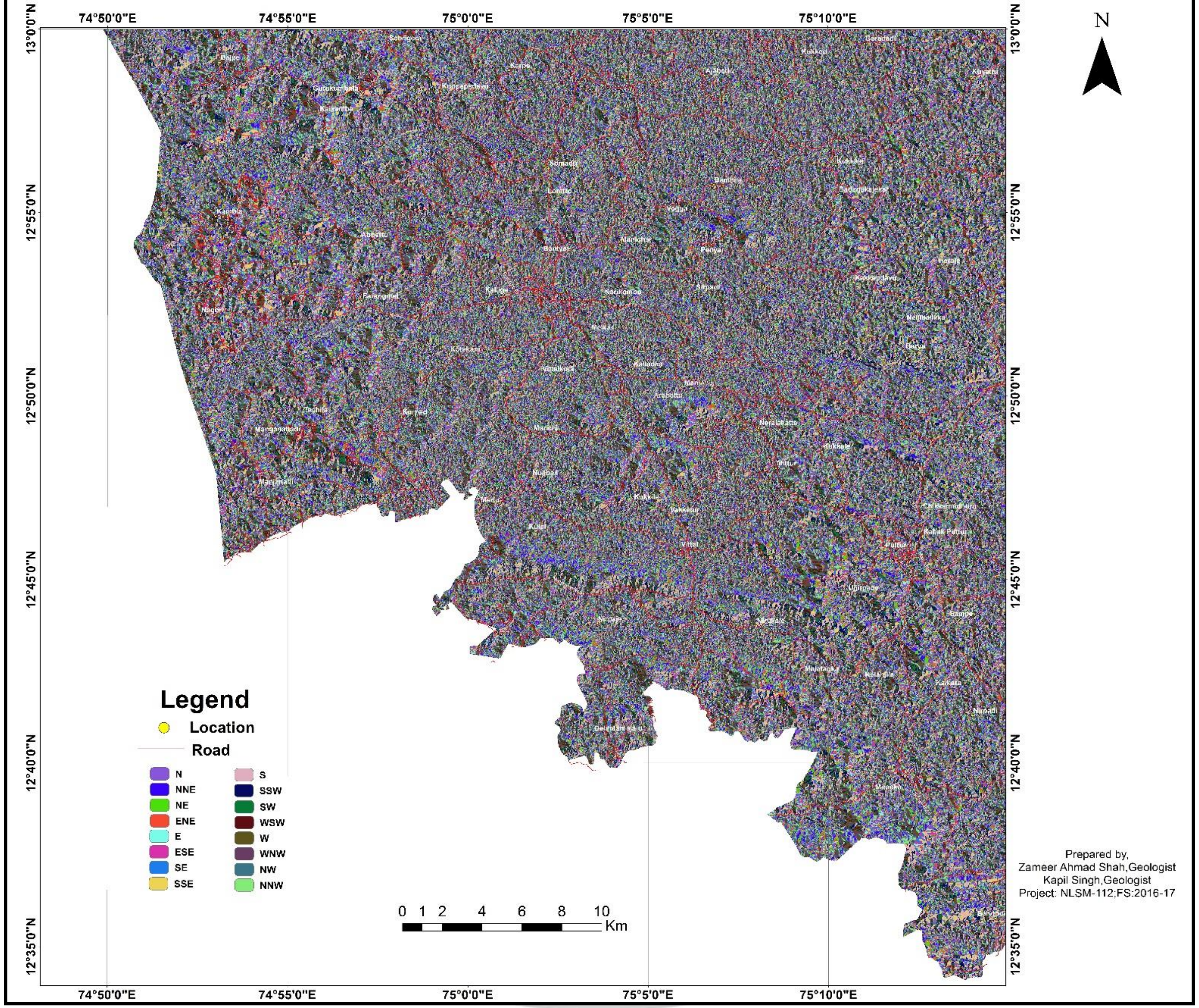


Plate 5

Land Use Land Cover Map of T.S No. 48L/13,48L/14,48P/01 & 48P/02,Dakshin Kannada District,Karnataka

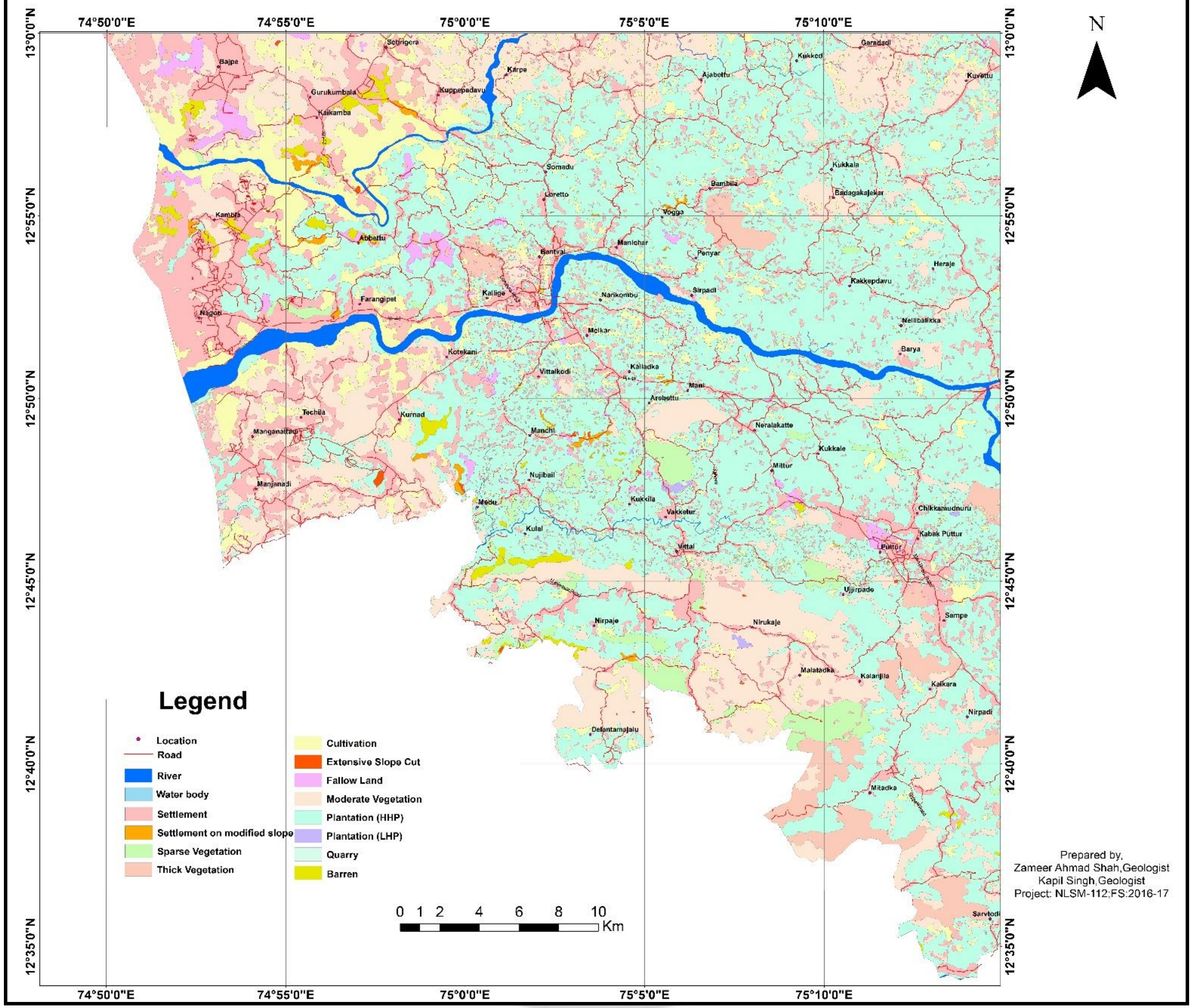


Plate 6

Geomorphology Map of T.S No. 48L/13,48L/14,48P/01 & 48P/02,Dakshin Kannada District,Karnataka

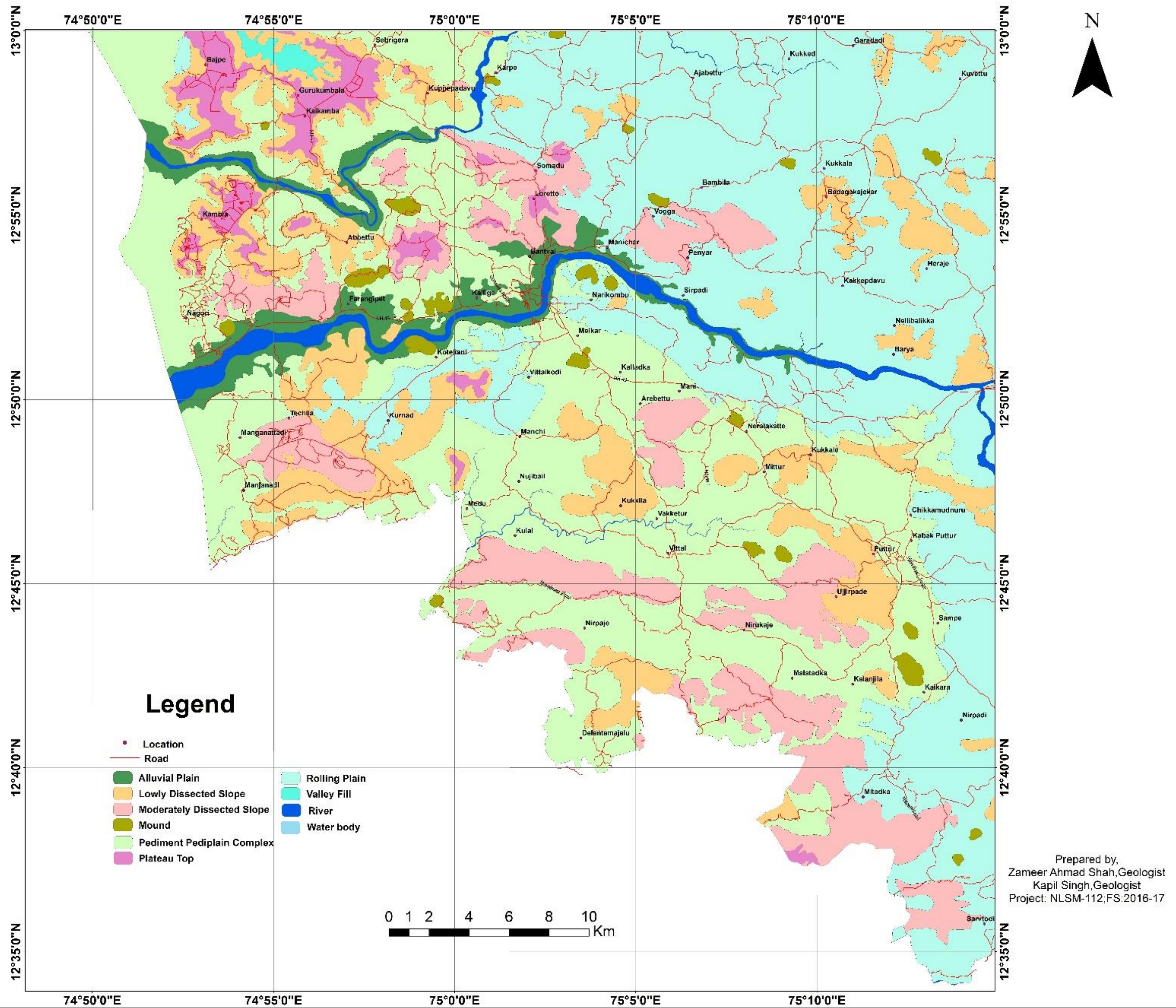


Plate 7

Slope Forming Material Map of T.S No. 48L/13,48L/14,48P/01 & 48P/02,Dakshin Kannada District,Karnataka

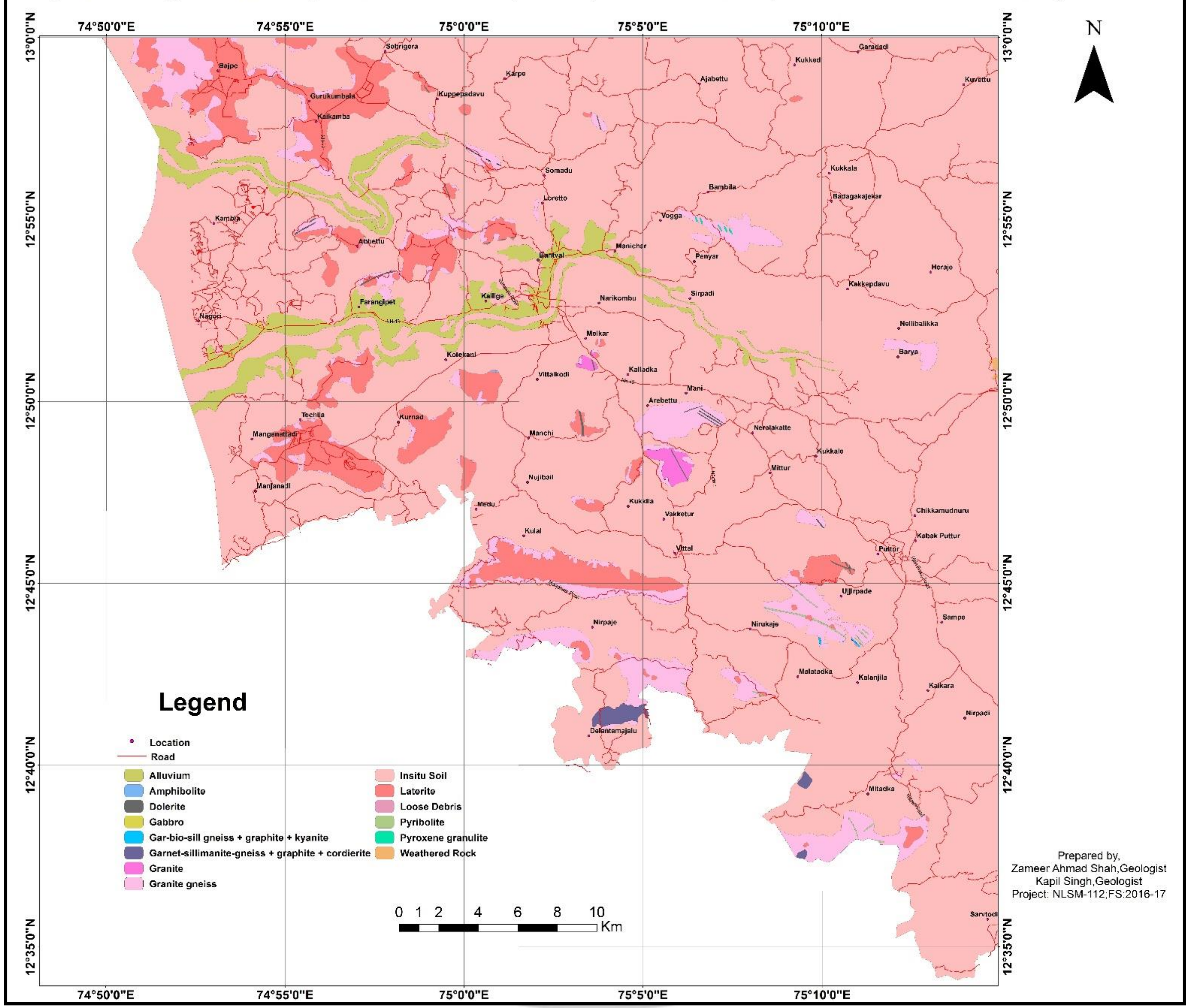


Plate 8

Slope Curvature Map of T.S No. 48L/13,48L/14,48P/01 & 48P/02,Dakshin Kannada District,Karnataka

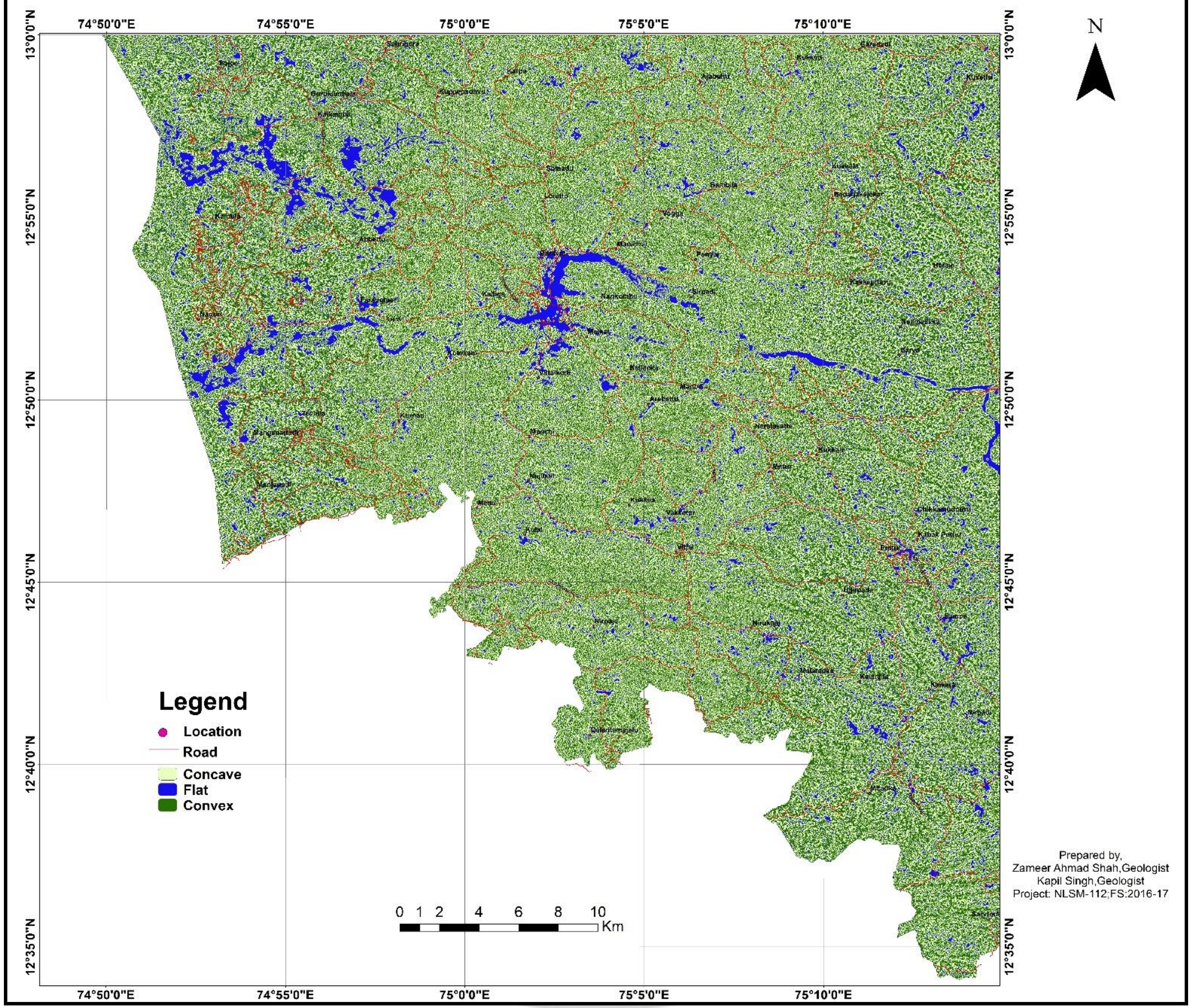
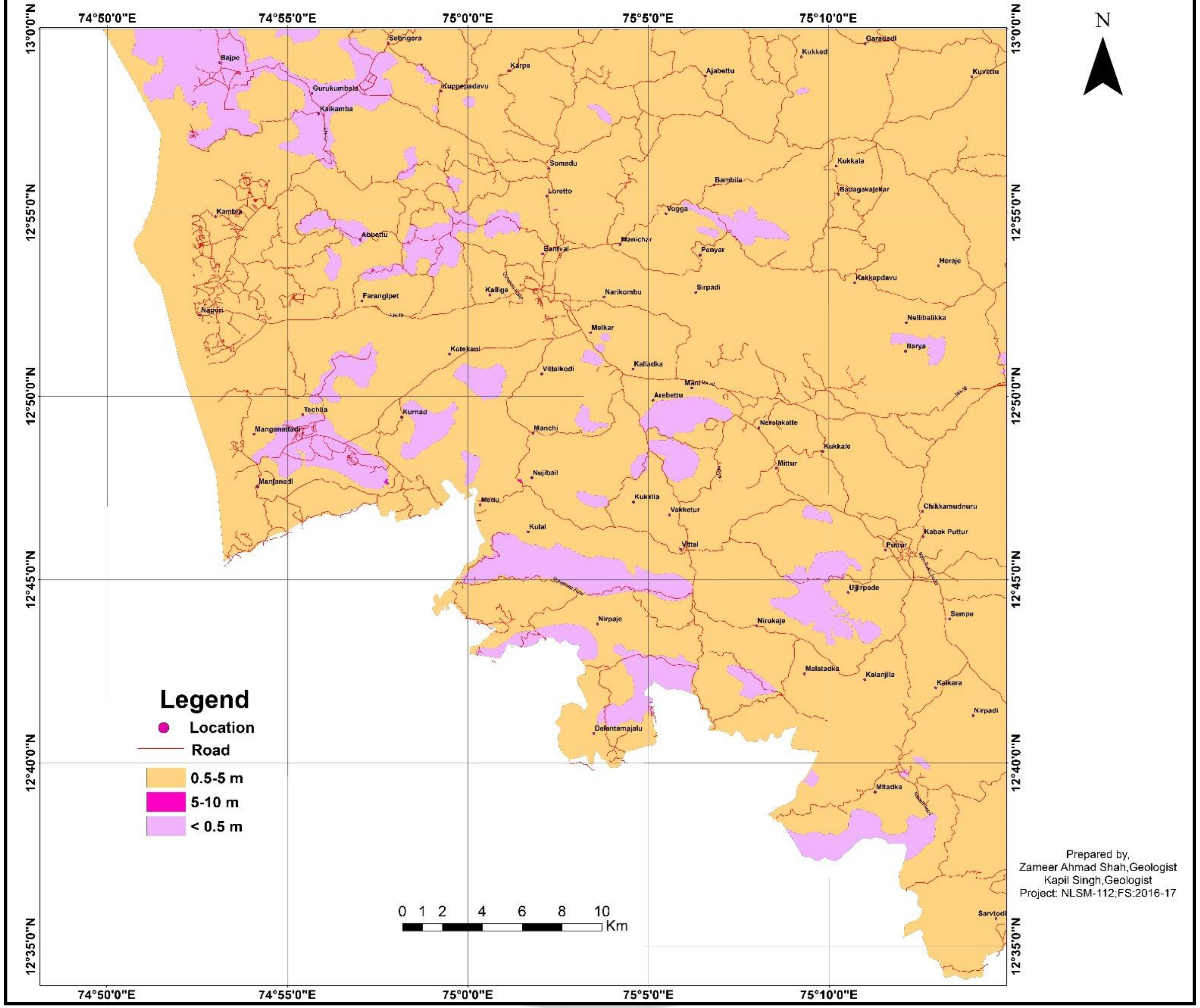


Plate 9

Regolith Thickness Map of T.S No. 48L/13,48L/14,48P/01 & 48P/02,Dakshin Kannada District,Karnataka



Prepared by,
Zameer Ahmad Shah,Geologist
Kapil Singh,Geologist
Project: NLSM-112;FS:2016-17

PLATE 10

Drainage Map of T.S No. 48L/13,48L/14,48P/01 & 48P/02,Dakshin Kannada District,Karnataka

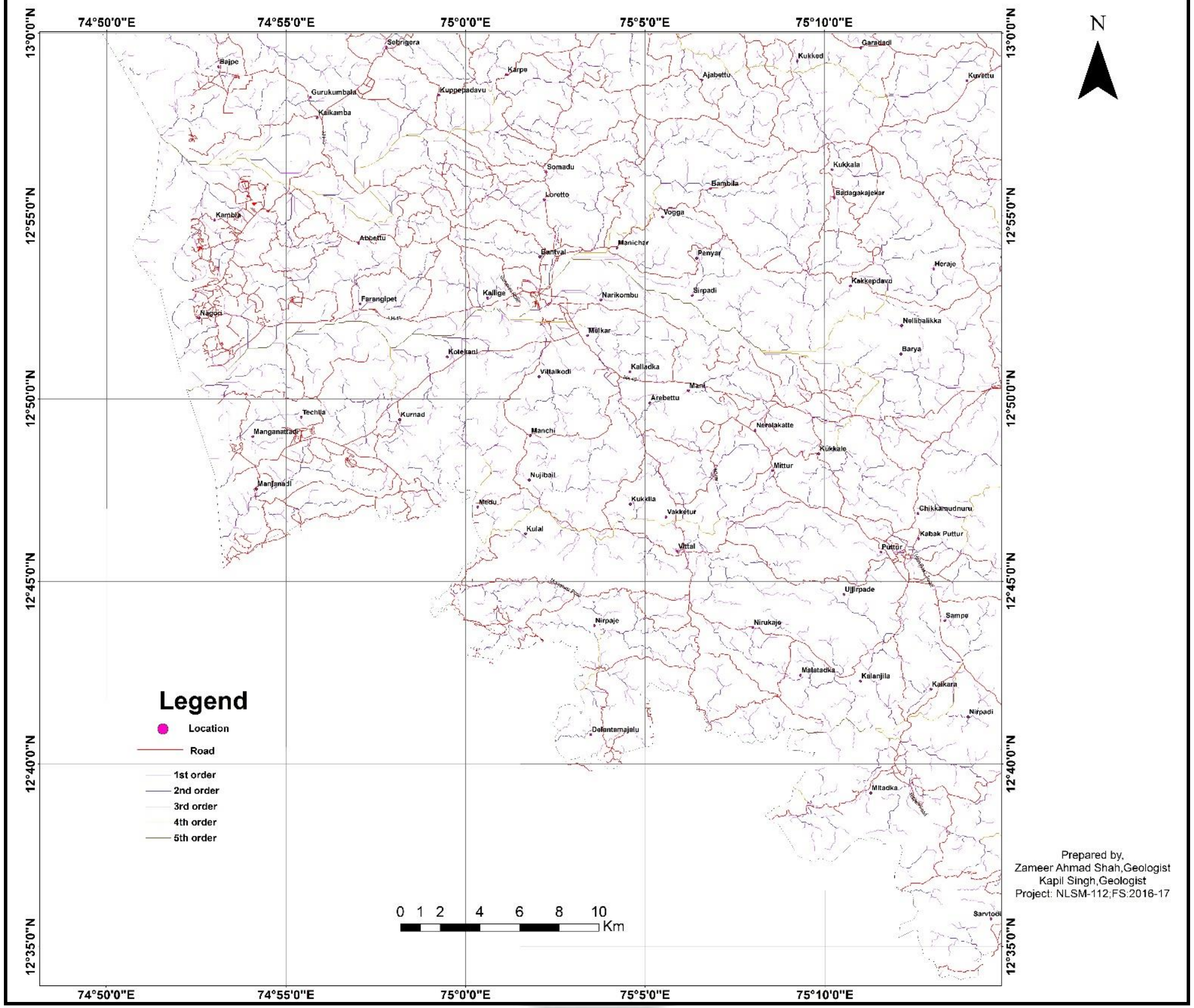


PLATE 11

Landslide Inventory Map of T.S No. 48L/13,48L/14,48P/01 & 48P/02,Dakshin Kannada District,Karnataka

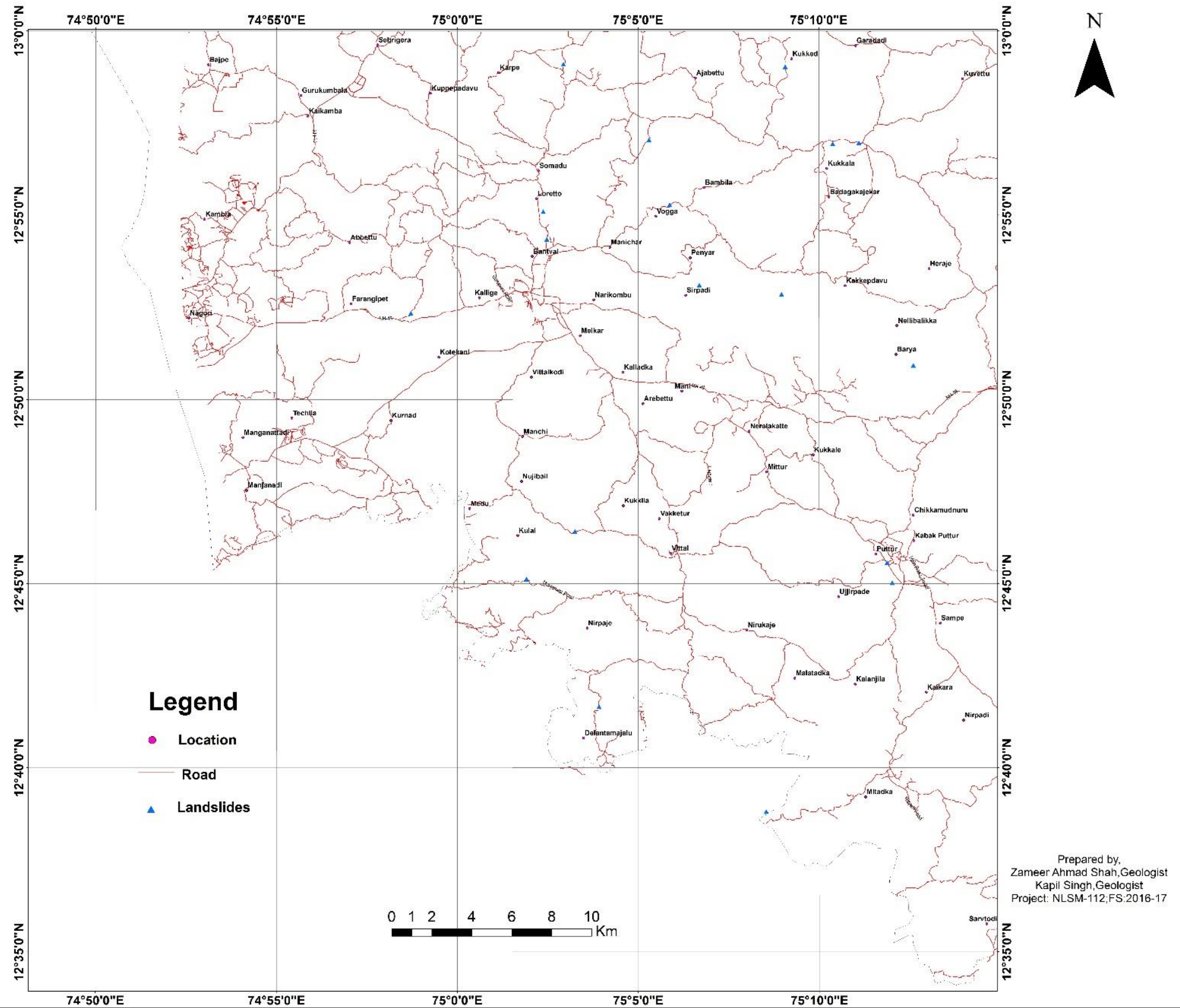
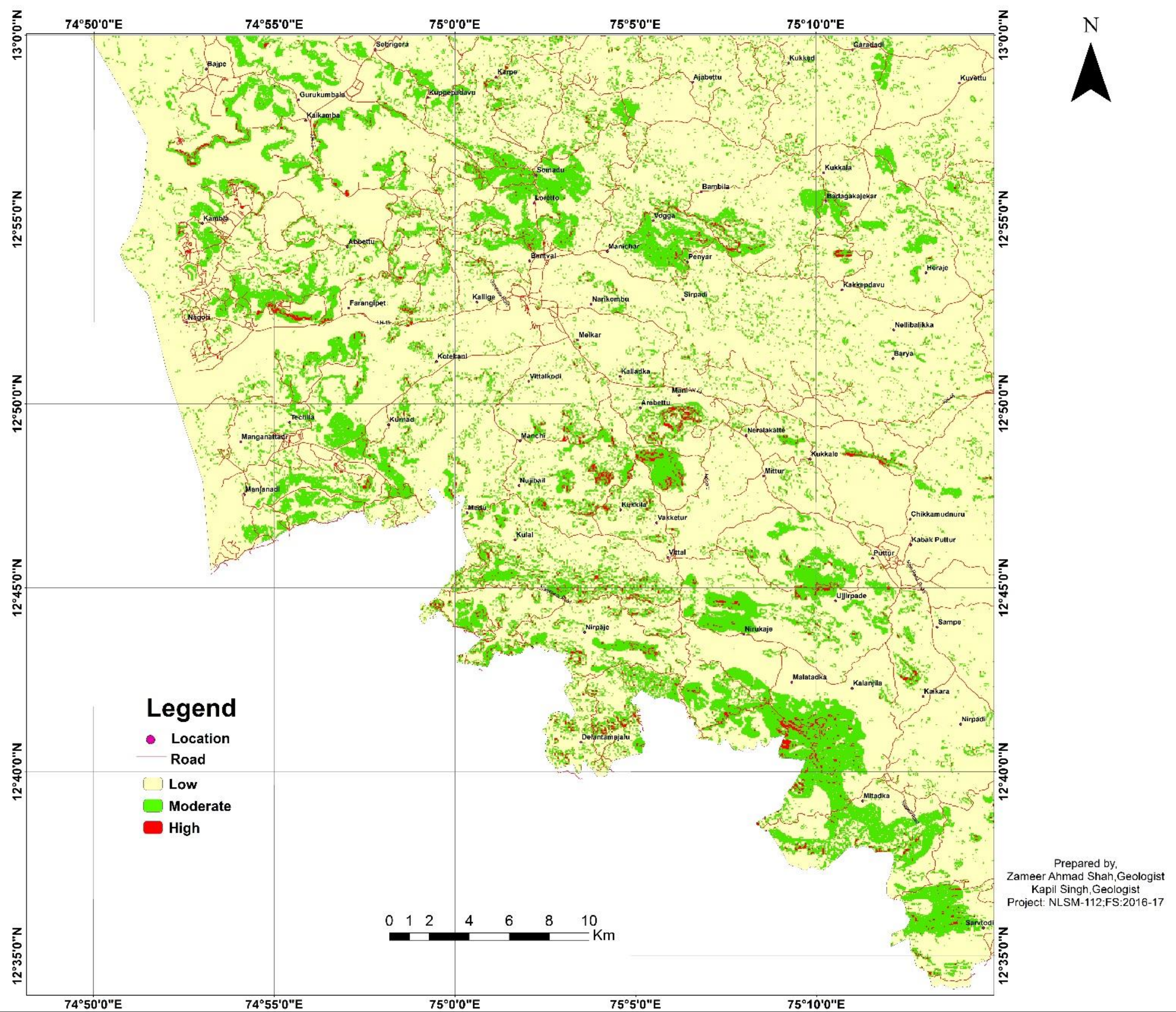


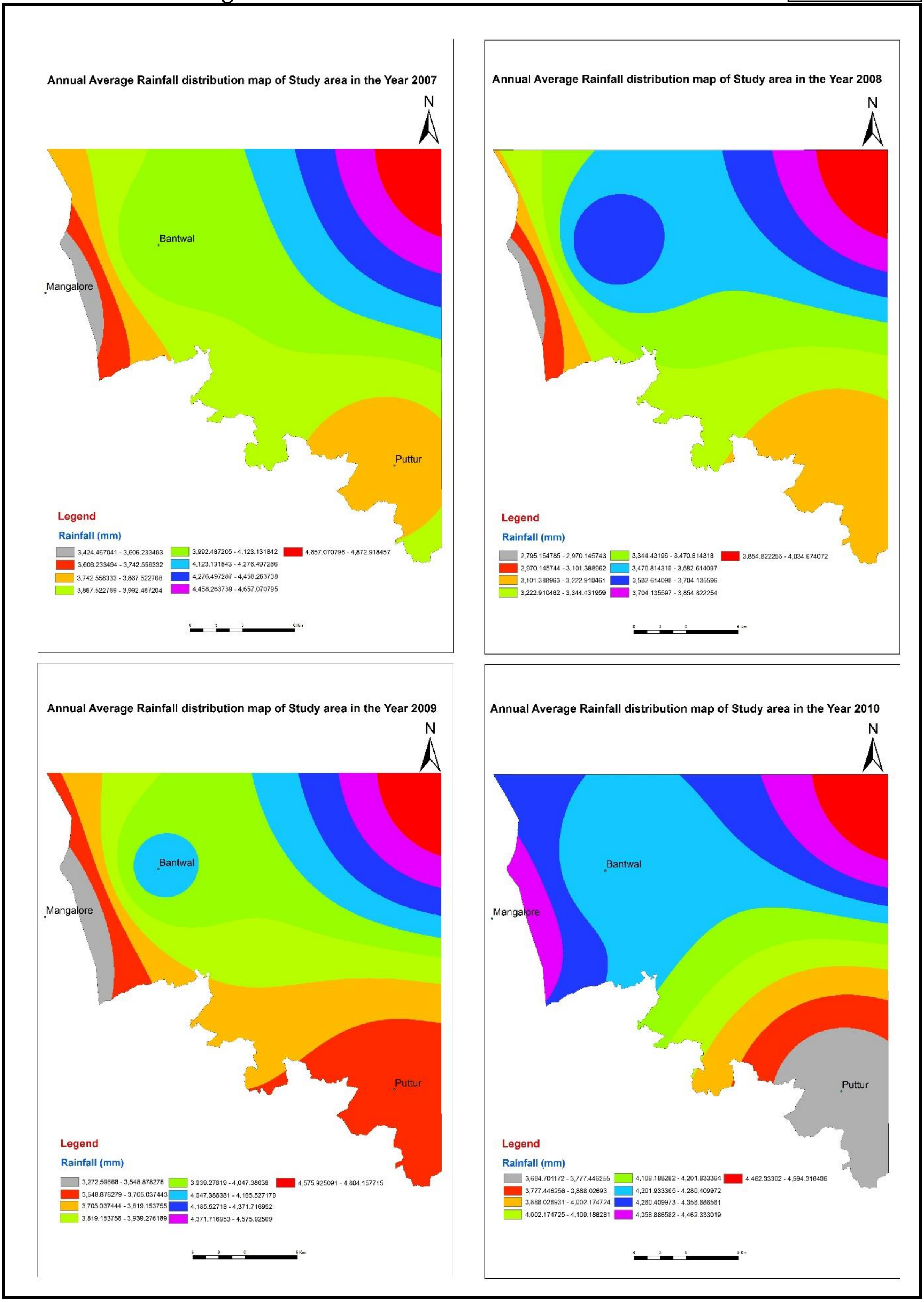
PLATE 12

Landslide Susceptibility Map of T.S No. 48L/13,48L/14,48P/01 & 48P/02,Dakshin Kannada District,Karnataka

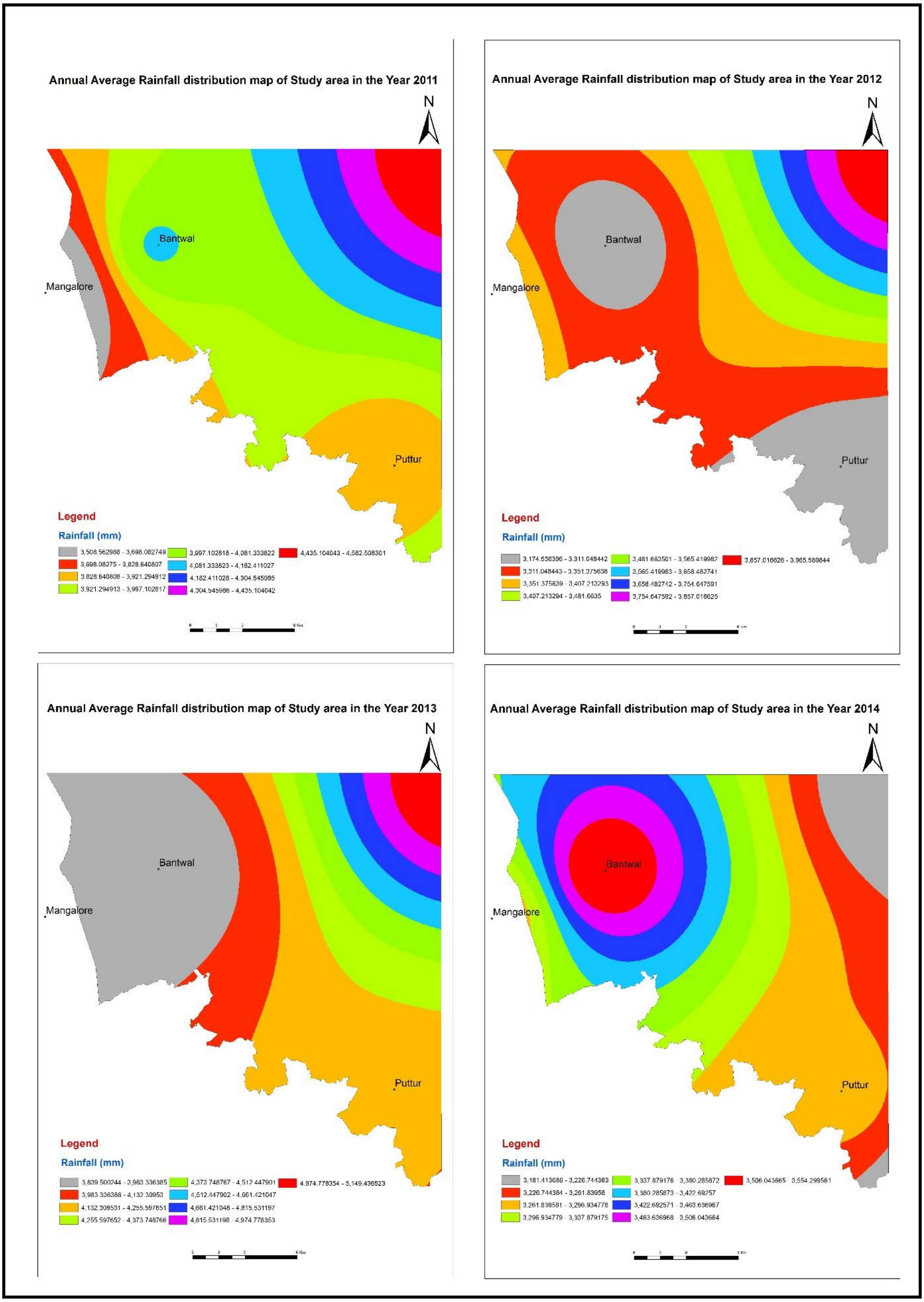


Annual Average Rainfall Distribution from 2007- 2016

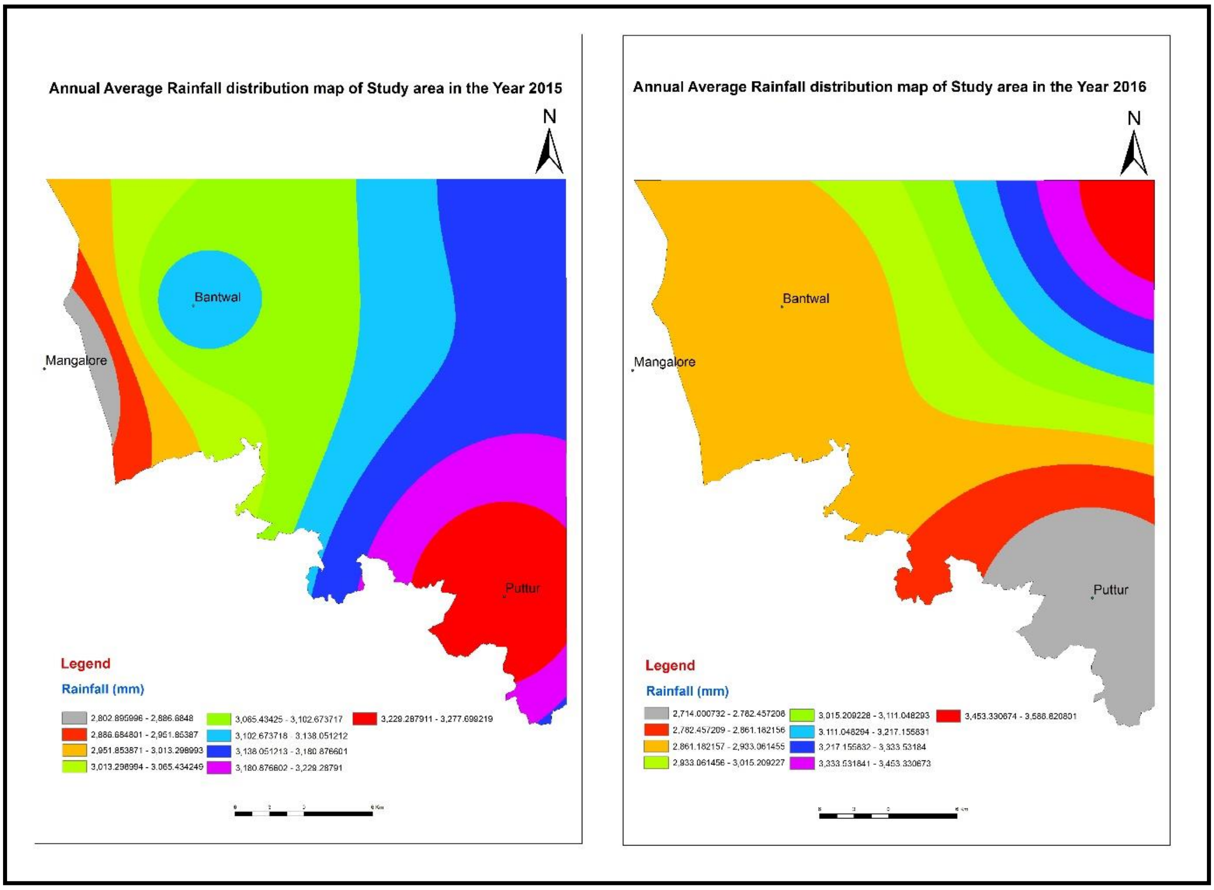
PLATE 13



Source: *Deputy Commissioner & District Magistrate's Office, Mangaluru*



Source: *Deputy Commissioner & District Magistrate's Office, Mangaluru*



Source: *Deputy Commissioner & District Magistrate's Office, Mangaluru*

Photo 1: Extensive cut slope in soil near Punjalkatte

Photo 2: Extensive cut slope in soil along Kalladka-Melkar Road section

Photo 3: Extensive cut slope along Bantval-Lorettopadavu Road section

Photo 4: Extensive cut slope along Bantval-Amtadi Road section

Photo 5: Settlements on modified slope near old road bridge on Netravati river

Photo 6: Rock quarry Near Harekallu river

Photo 7: Remotely sensed Thick Vegetation cover from Mavinkatte-Maninalkuru Road section

Photo 8: Remotely sensed lowly dissected slope from Palligadde-Barebettu Road section

Photo 9: Pediment-Pediplain Complex near Palligadde

Photo 10: Exposed rock near Manjalvadi (Old Quarry)

Photo 11: Lateritic(Insitu)soil near Maragadangadi

Photo 12: Alluvial plain near Nandavar

Photo 13: Regolith thickness less than 0.5m along the road connecting Bantval to NH-48

Photo 14: Regolith thickness greater than 0.5m near Navur-Bantval road junction

Photo 15: Loose debris hump on the downslope side along the road, North of Farangipet

Photo 16: Loose debris dump on the downslope side along the Bantval-Lorettopadavu road section

Photo 17: Slope modification for settlement on the road, North of Farangipet

Photo 18: Slope modification through quarrying of lateritic soil for brick making near Dambe

Photo 19: Retention wall being constructed near Vamajoor for prevention of loose material from sliding

Photo 20: Rock bolting along NH-48 near Padil for stabilizing slope

Photo 21: Debris slide initiated by excavation for settlement along the Bantval road connecting to NH-48 (Earlier reported in local newspaper; causes collapse of the houses and loss of life)

Photo 22: Debris slide initiated by road cutting along the road near Modanthyar

Photo 23: Debris slide caused due to toe removal along Bantval-Lorettopadavu Road section

Photo 24: Debris slide initiated by road cut ,triggered by rainfall along the Kollatadaka-Delantamajalu road

Photo 25: Debris slide along the road section Kabela-NH-48