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भारत सरकार

भारतीय भूवैज्ञानिक सर्वेक्षण

GOVERNMENT OF INDIA
GEOLOGICAL SURVEY OF INDIA

टोपोशीटस संख्या 48P/06 और 48P/10 दक्षिण कन्नड़ जिले, कर्नाटक, के कुछ हिस्सों में (1: 50,000), वृहद पैमाने पर भूस्खलन संवेदनशीलता मानचित्रण की रिपोर्ट ।

क्षेत्र सत्र : 2016-2017

(मद कोड सं: एल एस एम / एस आर / क और जी / 2016/ 110)

MACRO-SCALE (1: 50,000) LANDSLIDE SUSCEPTIBILITY MAPPING IN PARTS OF TOPOSHEET NOS. 48P/06 AND 48P/10 DAKSHIN KANNAD DISTRICT, KARNATAKA.

FIELD SEASON: 2016-17
CODE NO: LSM/SR/KG/2016/110

By/ द्वारा

कौशिक शुक्ला, वरिष्ठ भूविज्ञानी
KOUSHIK SHUKLA, SENIOR GEOLOGIST
&
राहुल कुमार चौरसिया, भूविज्ञानी
RAHUL KUMAR CHAURASIA, GEOLOGIST

PROJECT: NLSM / परियोजना: एन एल एस एम्
STATE UNIT: KARNATAKA AND GOA/ राज्य इकाई: कर्नाटक एवं गोवा
2017

इस प्रतिवेदन का कोई हिस्सा महानिदेशक, भारतीय भूवैज्ञानिक सर्वेक्षण की पूर्व लिखित अनुमति के बिना प्रतिलिपित नहीं किया जाना चाहिए

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GOVERNMENT OF INDIA
GEOLOGICAL SURVEY OF INDIA

MACRO-SCALE (1: 50,000) LANDSLIDE SUSCEPTIBILITY MAPPING IN PARTS OF TOPOSHEET NOS. 48P/06 48P/10 DAKSHIN KANNAD DISTRICT, KARNATAKA

CODE NO: LSM/SR/KG/2016/110

(Final Report for the Field Season 2016-17)

By

Koushik Shukla, Senior Geologist,

&

Rahul Kumar Chaurasia, Geologist.

PROJECT: NLSM
STATE UNIT: KARNATAKA AND GOA
2017

MACRO-SCALE (1: 50,000) LANDSLIDE SUSCEPTIBILITY MAPPING IN PARTS OF TOPOSHEET NOS. 48P/06 AND 48P/10 DAKSHIN KANNAD DISTRICT, KARNATAKA

CODE NO: LSM/SR/KG/2016/110

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Koushik Shukla, Senior Geologist & Rahul Kumar Chaurasia, Geologist

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भूस्थल मानचित्र संख्या ४८पी/०६ और ४८पी/१० के उत्तर गोवा और दक्षिण गोवा जिले, गोवा के आंशिक भागों का बड़े (१: ५०,०००) पैमाने पर भूस्खलन संवेदनशीलता का मानचित्रण

(मद कोड सं: एल एस एम / एस आर / क और जी / २०१६ /११०)

(क्षेत्र सत्र: २०१६ – २०१७)

द्वारा
कौशिक शुक्ला, वरिष्ठ - भूवैज्ञानिक
राहुल कुमार चौरसिया, भूवैज्ञानिक

सारांश

भूस्थल मानचित्र संख्या ४८पी/०६ और ४८पी/१० के अंतर्गत कर्नाटक के दक्षिण कन्नड़ जिले में भूस्खलन संवेदनशीलता मानचित्रण (एनएलएसएम) १:५०,००० पैमाने पर निरंतरतायुक्त संवेदनशीलता मानचित्र पर्याप्त सुदूर संवेदी और क्षेत्र आगत से निष्पादित किया गया/ पूर्व-कार्य क्षेत्र मानचित्र जैसे- लैंड यूज़ - लैंड कवर, मार्ग, भूआकृति, नति/ढ़ाल बनाने वाले अवसादी मानचित्र, प्रवाह तंत्र, नति ढलाव, नति वक्रता और नति अवस्था मानचित्र लिस, आई आर एस - II आँकड़े और बहु-लौकिक गूगल चित्रों को आर्क जी आई एस के दृश्यता स्पष्टीकरण से तैयार किया गया/

सभी विषयक मानचित्र बनाये गए और अलग अलग वर्गो के वर्गीकृत किये गए जैसे - लैंड यूज़ / लैंड कवर; मानचित्र निम्नलिखित भागों में रखा गया - पौधाकरण, उच्च-पौधाकरण और निच्च-पौधाकरण, मरुभूमि, बस्ती, विरल जंगल, मध्यम जंगल, सघन जंगल, नदी, दलदल, पौधाकरण और खली जगह/ समूह जो कि पूर्व कार्य क्षेत्र से लिए गए थे वो कार्य क्षेत्र में लिए गए क्षेत्र निहित सीमित आगत से सत्यापित किये गए/ नदियों के किनारों से लगे क्षेत्र और घाटियों के सन्निकट क्षेत्र जलोढ़ मृदा से आच्छादित हैं और खेती के उद्देश्य के लिए इस्तेमाल हो रहे हैं/ नति/ढ़ाल बनाने वाले अवसाद बड़े तौर पर अन्तर्निहित मृदा, शैल और लाई गए मृदा में रखे जा सकते हैं/

अन्तर्निहित मृदा क्षेत्र के अधिकांश भागों में निहित है जो कि शैलों के अन्तर्निहित छरण से खेती के उद्देश्य से लाई गयी परिवहन माध्यम से लाई गयी मृदा जो कि शैलीय सतह, पर्वत के मध्य, घाटी और मरू भूमि से अनावृत है/ भूस्थलीय तौर पर सख्त भौगोलिक आकृत दर्शाता है/ अधिकांश क्षेत्र निम्न-विच्छेदन पहाड़ दर्शाते हैं जो कि पेनीप्लान - पेडीमेंट समूह से और मध्य-विच्छेदन पहाड़ से निहित हैं/ समूह जो कि पूर्व कार्य क्षेत्र से लिए गए थे वो कार्य क्षेत्र आगत से सत्यापित किये गए/

भूविज्ञानिक तौर पर मानचित्र संख्या ४८पी/०६ और ४८पी/१० के अंतर्गत क्षेत्र सरगूर समूह के शैल, पीजीसी-I के शैलों जो की पीजीसी का है और आर्कियन उम्र के चर्नोकईट को दर्शाता है: दाखलीय ग्रेनाइट जो की क्लोजपेट ग्रेनाइट के आर्कियन उम्र के समकक्ष हैं और प्रोटेरोज़िक दाखलीय छार और क्वार्टरनरी लेटराइट अवधि के हैं/

प्राथमिक स्तर पर अनुकरण किया जाने वाला तरीका भूस्खलन आधारित रास्टर जी आई एस आधारित प्रतिरूपण भूस्थल मानचित्र के जो की बहु विषयक है और १:५०,००० पैमाने पर अलग अलग भार वाला मानचित्र है/ उन क्षेत्रों में जहाँ पर अनुभव आधारित भूस्खलन या तो नगण्य है या तो बहुत ही कम है ए एच पी आधारित प्रतिरूपण किया जाना है/

इस क्षेत्र का भूस्खलन संवेदनशीलता मानचित्र अल्प-संवेदनशील, मध्यम-संवेदनशील और उच्च-संवेदनशील वर्गों में बांटा गया है/ मुख्य आवासीय क्षेत्र जैसे सुल्लिया, बेल्लारे, पाईचर, गोनाडका, बड़दका, अलेट्टी, अज्जावारा और इसके समीपवर्ती क्षेत्र उच्च-संवेदनशील वर्ग में आते हैं जबकि अन्य भाग अल्प-संवेदनशील और मध्यम-संवेदनशील वर्ग में आते हैं/ कार्य क्षेत्र में मार्ग मडिकेरी – सुल्लिया – पाईचर और पाईचर – सुभ्रमण्या मुख्यतया सड़क नति कटान और निर्माणाधीन गतिविधियों से प्रभावित हैं/ मुख्य जलीय प्रवाह जैसे कुमारधारी और पाश्चानी नदियाँ और इनकी सहायक धाराएं मध्यम-संवेदनशील से अल्प-संवेदनशील वर्ग में आतीं हैं और भूस्खलन के प्रति निम्न संवेदनशील हैं/

MACRO-SCALE (1: 50,000) LANDSLIDE SUSCEPTIBILITY MAPPING IN PARTS OF TOPOSHEET NOS. 48P/06 AND 48P/10 DAKSHIN KANNAD DISTRICT, KARNATAKA

CODE NO: LSM/SR/KG/2016/110

(Report for the Field Season 2016-17)
By
Koushik Shukla, Senior Geologist & Rahul Kumar Chaurasia, Geologist

ABSTRACT

Landslide Susceptibility Mapping in parts of Toposheet Nos. 48P/06 and 48P/10, Dakshin Kannad District, Karnataka was carried out to prepare a seamless landslide susceptibility map and spatial (GIS-based) landslide database on 1: 50,000 scale using adequate remote sensing data and field inputs. Pre-field maps for Land Use/ Land Cover (LU LC), Roads, Geomorphology, Slope Forming Material (SFM), Drainage, Slope Gradient (SG), Slope Curvature (SC) and Slope Aspect (SA) were prepared using ArcGIS tool through visual interpretation of IRS LISS III data and multi-temporal Google Imageries.

Each thematic map prepared was classified into different classes viz, Landuse/Landcover (LULC) in the area can be broadly categorized in to following classes; plantation viz: High Height Plantation (HHP) and Low Height Plantation (LHP), barren, cultivation, settlements, sparse vegetated areas, moderate vegetated area, thick vegetated areas, river, swamps, plantation and fallow land. Classes identified in pre-field work were validated in the fieldwork with limited fieldwork traverses. The areas along river banks is covered with alluvial material and along low lying valleys is covered with overburden material and are being used for cultivation. Slope Forming Material (SFM) in the area can broadly be categorized in to In-situ Soil, Rock and Transported Soil.

In-situ soil is present in large part of the area due to in-situ weathering of the rocks used for cultivation purpose while transported soil is present in between the hills, in the vallies, rock outcrops are present at escarpments as barren exposures. Geomrphologically, the area represents rugged topography. Majority of the area is covered by lowly dissected hills followed by peneplain – pediment complex and moderately to highly dissected hills. Classes identified in the pre-field work validated and updated as pre-field inputs.

Geologically, the area in parts of 48P/06 and 48P/10 exposes rocks of Sargur Group, PGC-I of PGC and charnockite suites of Archean age; intrusive granites which are equivalent

to Closepet Granite of Archean to Paleoproterozoic age and by acid and basic intrusives of Paleoproterozoic and laterite of quaternary period.

The method to be followed is primarily landslide dependent following a raster – based GIS modelling approach for integration of all selected and weighted thematic maps to prepare 1:50,000 scale landslide susceptibility maps. For areas where a-prior knowledge of landslide is missing or scarce and/or insufficient, AHP modelling has to be done. Due to the insufficient of landslides in the study area, AHP modelling has been done.

Landslide susceptibility map of the area was classified into high, medium and low susceptible areas. Prominent settlement locations like Sullia, Bellare, Paicher, Gonadka, Badadka, Alleti, Ajjavara and its surroundings was grouped into high susceptible zones while rest of the area is under medium to low susceptible category. In the study area; route from Madikeri-Sullia-Puttur, Paicher-Subramanya is most affected by road construction activities and prone for landslides. Major drainages like Kumardhari and Piaschani and their tributaries are under medium to low susceptible category and are least prone to landslides.

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Koushik Shukla, Senior Geologist & Rahul Kumar Chaurasia, Geologist

1. INTRODUCTION

1.1 Background Information:

Geological Survey of India (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 Km^2 spreading over 1112 Survey of India 1: 50,000 scale Topographic Sheets), the target achieved so far by GSI (~60,000 $^{Km^2}$) is quite less. This warrants GSI, being the nodal agency for landslide studies in India, to impart maximum efforts towards completion of this basic data generation work on landslides by aiming to complete the remaining task 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 endeavor 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 on (1: 50,000) with an aim to cover the remaining targets expeditiously. This national programme i.e. National Landslide Susceptibility mapping (NLSM) was formally launched by Shri Dinsha Patel, Hon’ble Minister of Mines, Government of India on 5th February, 2014 at 53rd Central Geological Programming Board Meeting, New Delhi.

The NLSM programme of GSI, has an objective to (i) prepare landslide inventory database using high resolution remote sensing data and field inputs, (ii) to prepare Toposheet-wise 1: 50,000 scale spatial database for geofactors of landslides for use as input maps, (iii) to prepare landslide susceptibility map using multi-class index overlay method in a GIS platform. The present study was carried out as per the annual programme of GSI for F.S. 2016–17 wide code No. LSM/SR/KG/2016/110.

1.2 Present Work

Landslide susceptibility mapping was carried out on 1: 50,000 scale covering 1445 Km^2 The nature and quantum of work and the achievements are given in the Table 1.

Nature of Work	Target: F.S. 2016-17 (Km^2)	Achievement
1. Pre-field Map Preparation		
a) Slope Forming Material Map	1445 Km^2	1445 Km^2
b) Geomorphology and Lineament Map	1445 Km^2	1445 Km^2
c) Slope Morphometry (slope, aspect and curvature) map	1445 Km^2	1445 Km^2
d) Landuse/Landcover Map	1445 Km^2	1445 Km^2
e) Drainage map	1445 Km^2	1445 Km^2
f) Regolith Depth map	1445 Km^2	1445 Km^2
g) Preparation of Landslide Inventory Map	1445 Km^2	1445 Km^2
2. Field Based Studies		
i) Field Validation of all Thematic Maps	1445 Km^2	1445 Km^2
ii) Field Checking of Landslide Inventory and Collection of Recent and Historic Landslides.	1445 Km^2	1445 Km^2
iii) Collection of Landslide Inventory	1445 Km^2	1445 Km^2
3. Post Field Work		
i) Updation of Thematic and Inventory Maps in GIS	1445 Km^2	1445 Km^2
ii) Preparation of Landslide Susceptibility Map in GIS	1445 Km^2	1445 Km^2
iii) Validation of Landslide Susceptibility Map at Important Locations	1445 Km^2	1445 Km^2
4. Collection of Rainfall Data	1445 Km^2	

Table 1, Nature of work, quantum and achievements.

1.3 Study Area:

The study area forms the part of Toposheet Nos. 48P/06 and 48P/10, Dakshin Kannad district of Karnataka State (plate 1). The area is bounded by latitude 12°30'00" to 12°45'00"N and longitudes 75°15'00" to 75°45'00"E and falls in Puttur and Sullia taluks of Dakshin Kannad district, Coorg, Somvarapur and Mercara taluks of Coorg districts and Sakleshpur taluk of Hassan districts. Some part in SW corner of toposheet no. 48P/06 is falling in Kerala state. Sullia, Jalsuru, Bellare, Subramanya, Guttigar and Padikallu are major urban agglomerations in the area (plate 2). Mangalore-Bangalore highway, Jalsuru – Subramanya, Sirakal – Subramanya and Puttur – Subramanya are the main communication corridors of the area, while interior places are well connected by all-weather roads and car tracks.

1.4 Climate:

Area receives moderate to heavy rainfall, weather remains pleasant in Coorg district while in South Kannad district in summer temperature rises up to 30 degrees with humidity where as in winter it remains pleasant.

1.5 Physiography:

The area is an undulating highly rugged terrain comprising steep hills and valleys covered with dense forest. The highest elevation is 1712 m above MSL and lowest elevation is 96 m above MSL 2 km northwest of Puddottu. The area is drained by rivers Payaswami, Kumardhara and Gourihole and their tributaries. The main streams flow westerly while the tributaries follow the foliation trend of the rock formations giving rise to trellis pattern of drainage. And rainfall data has been collected as available for the study area (Annexure - 4).

1.6 Geology of the Study Area:

Geologically the area in parts of Toposheet Nos. 48P/06 and 48P/10 exposes rocks of Sargur Group (plate 3 & plate 4), PGC-I of PGC and Charnockite Suites of Archean age, intrusive granites equivalent to Closepet Granite of Archean to Paleoproterozoic age and by acid & basic intrusives of Paleoproterozoic age and laterite of quaternary period.

Older metamorphics of Sargur Group, occuring as enclaves within PGC throughout the area. PGC-I of PGC is represented by migmatite gneiss occupies 90% of the area. PGC is overlained by charnockite and pyroxene granulite. Charnockite is occur as tabular/lensoidal bodies within PGC and mostly exposed in northeastern quadrant, while pyroxene granulite occurs as narrow linear bands within PGC. Basic dykes represented by fine to medium grained. Dolerite trending N-S, NW-SE, NE-SW are exposed mainly in the eastern part and NW quadrant. Laterite cappings are seen in PGC terrain in the western half of the area.

According to Radhakrishna (1967) Western Ghats represent the edge of an upraised and disrupted continental block formed in early Miocene during which there was pronounced upwarp of the continent, subjected to fissuring and drifting apart from the western half. This is amplified by the absence of sediment older than the Miocene on western coast. Thus laterite on Western Ghats could have formed only during post-Miocene to Quaternary.

1.7 Geomorphology of the Area:

Geomrphologically, the area is an undulating highly rugged terrain comprising steep hills and valleys. Majority of the area is covered by highly dissected hills followed by peneplain

– pediment complex and moderately to low dissected hills. The geomorphic expression of the area is governed by development of hills and ridges which depends on the lithology and structural elements. Bedding, joints, shear planes and fault zones have given rise to major lineaments in the area. The slopes in the toe part are characterized by laterite and saprolite development. The rugged topography is developed by PGC and granites whereas the areas covered by incompetent rocks exhibit broad crested ridges and mature topography. At places the ridges are occupied by basic intrusives such as dolerite and gabbro dykes.

1.8 Previous Work on Landslide Studies:

Landslide studies in the area have been carried out only along transportation corridors (NHs and SHs) in and around Western Ghats. Temporal data for these slides is not available as far as the study area is concerned. Landslides in the study area generally occurred frequently from untreated cut slopes. They are usually small in size but pose considerable risk to life and property. Several landslides have been reported along roads (Local Taluk roads, State Highways and National Highways) almost every year during the monsoons indicating that the triggering factor for these landslides may be rainfall besides anthropogenic activities.

FSP Year	**T.S. No.**	**Location (DK District)**	**Type of slide**	**Dimension (in m)**			**Slope Condition**	**History**	**Triggering Factor**
				Length	**Width**	**Depth**			
2008-09	48P/06	SH – 88	Debris slump	13.00	30.00	01.00	Cut slope	New	Rain Fall
2008-09	48P/06	SH – 88	Earth slump	10.00	8.00	01.00	Cut slope	New	Rain Fall
2008-09	48P/06	SH – 88	Earth slump	07.00	25.00	00.50	Cut slope	New	Rain Fall
2008-09	48P/06	SH – 88	Earth slump	10.00	15.00	00.50	Cut slope	New	Rain Fall
2008-09	48P/06	SH – 88	Earth slump	10.00	15.00	00.50	Cut slope	New	Rain Fall
2008-09	48P/06	SH – 88	Earth slump	12.00	18.00	00.50	Cut slope	New	Rain Fall
2008-09	48P/06	SH – 88	Earth slump	10.00	13.00	00.50	Cut slope	New	Rain Fall

2008-09	48P/06	SH – 88	Earth slump	07.00	18.00	01.00	Cut slope	New	Rain Fall
2008-09	48P/06	SH – 88	Earth slump	08.00	38.00	01.00	Cut slope	New	Rain Fall
2008-09	48P/06	SH – 88	Earth slump	07.00	18.00	01.00	Cut slope	New	Rain Fall

Table 2, Historical landslide data reported in FS 2008-2009.

During F.S. 2008 – 09 landslide inventory work was carried out in the study area by Shri K. V. Maruthi et. al., along SH – 88. Along this SH – 88 total 10 landslides (table 2) have been reported which falls under the toposheet no. 48P/06. Later on along Madikere – Sullia road section 24 landslides were reported during 2012 – 13 and along Sullia- Subramanya road section (district road) total 7 landslides were reported by Shri K. V. Maruthi et. al., The study reveals that most of the landslides are shallow (< 2m depth) debris slides/slumps with the height of the cut-slope and inclination are playing a major role in triggering the slides as the slides are confined to cut-slopes. The study also reveals that majority of the slides are restricted to the cut slopes having more than 10m height and quite a steep slope angle varying between 70° and 90°. The relative relief of the cut-slope has also been low to moderate varying between 5m to 20m at all sections with overburden varying from 0.5 – 4.0 m. The main causes of landslide in the Western Ghats are toe-cutting of hill slopes for the construction of road and slope modification for human settlements. In addition, the presence of highly weathered rock mass and the impact of heavy rainfall may be the aiding factors. Intense action of water is known to favor weathering of rocks that would in turn cause drop in the shearing resistance.

2. METHODOLOGY:

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

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

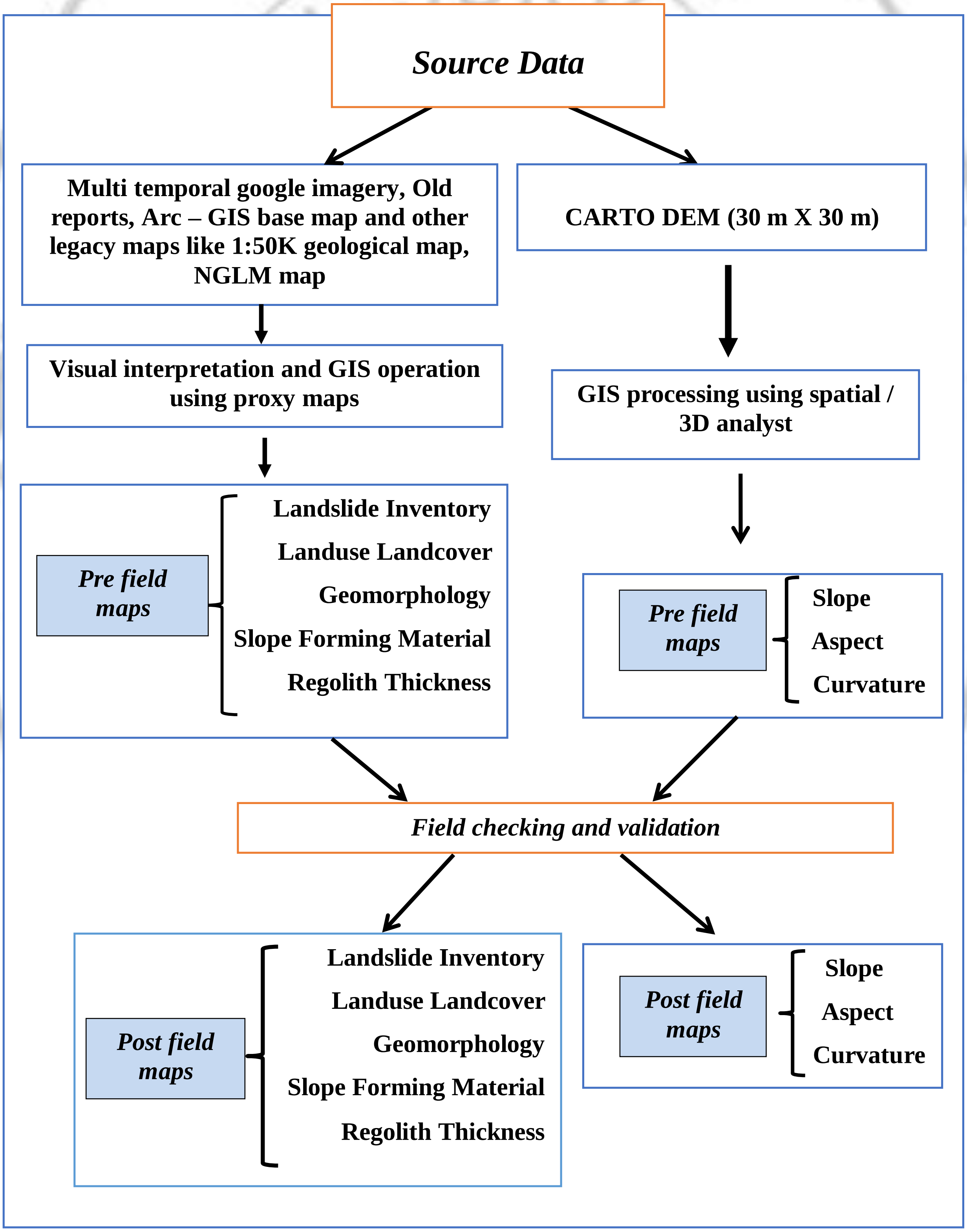
2.8.1) RS Inputs and Preparation of Thematic Maps Using Remote Sensing (RS) and GIS tools:

Indian Space Research Organization (ISRO) has a number of satellites having very high resolution (VHR) sensors. Out of them, the Multi-spectral optical sensors such as P-4 (LISS-IV) having 5 m resolution are useful RS tool, that can be utilized as source data for picking up spatial land-use/ cover and historic landslide incidence data. These digital images nowadays have larger scene coverage and cost-wise quite cheaper too, which should be used to prepare thematic maps like land use/cover and landslide incidences maps etc. For slope morphometric themes any of the freely-downloadable 1-Arc (90 m resolution) Shuttle Radar Topographic Mission (SRTM) or 25 m resolution ASTER Digital Elevation Model (DEM) or CARTODEM of 30m resolution may be used.

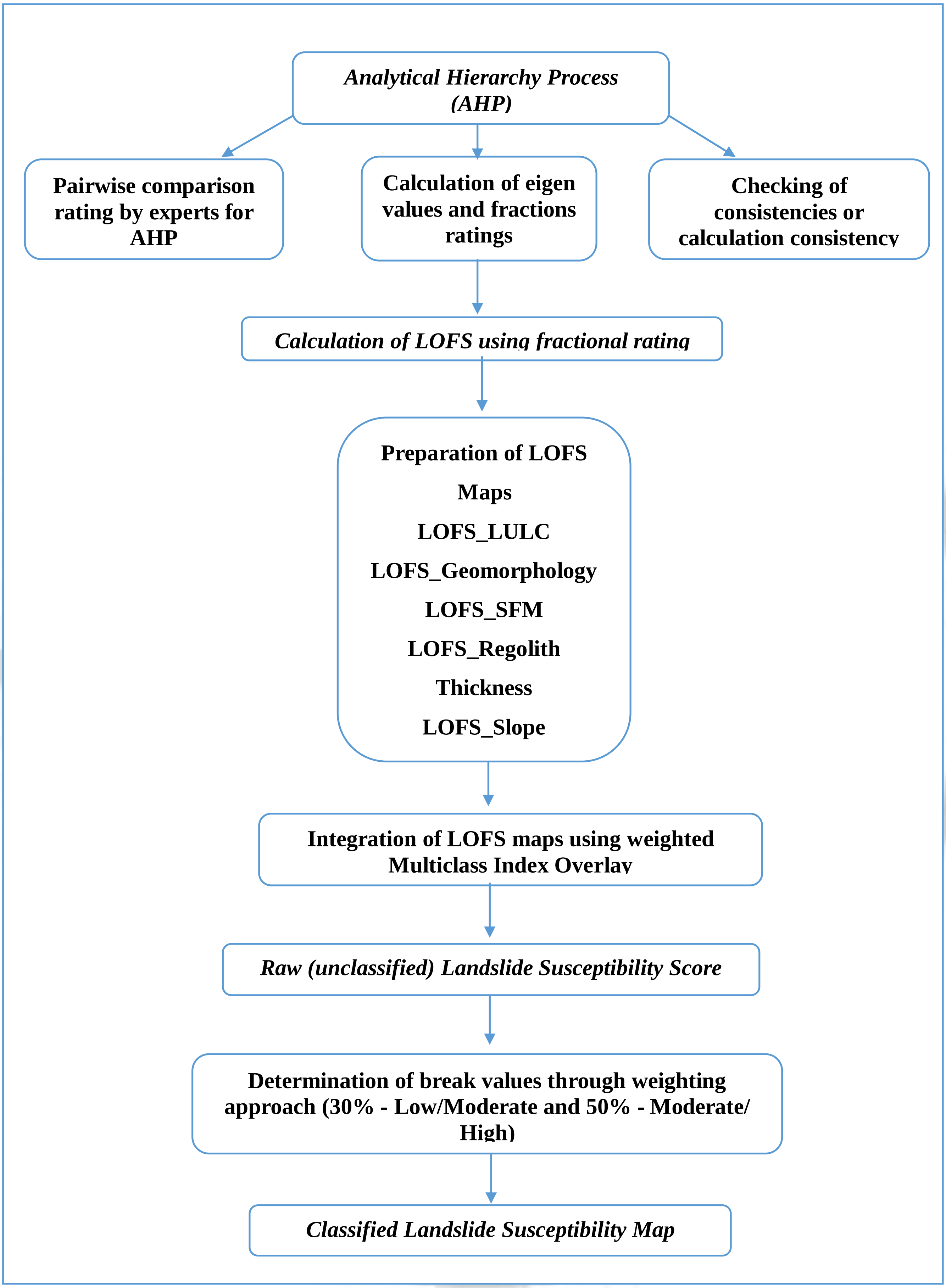
In this work we have used 30 m resolution Carto DEM obtained from Bhuvan Portal. Using this DEM or elevation data, through simple GIS functionalities of Arc GIS (Spatial Analyst/ 3D Analyst) or ILWIS 3.X, slope and aspect maps would be generated and used as different thematic maps for slope morphometry. Excepting the above, simple GIS functionalities are also capable of doing many analytical operations through which buffer around drainage lines; lineament, road etc. would be prepared and be used as thematic input maps for landslide susceptibility. Use of these tools and GIS techniques would immensely reduce the man-hours required for this type of spatial studies for preparation of analog maps. Generation and availability of such pre-field maps beforehand would facilitate better planning and focusing of field studies. These process can understand by given flow chart.

Flow diagram showing process of Landslide Susceptibility Mapping

Spatial Data Preparation



Data Modelling



2.8.2) Field Studies and Landslide Inventory:

Field studies to be undertaken for this study can be divided into two parts – i). field validation / updating of pre-field thematic maps like slope forming material, geomorphology, regolith, thickness, land use / cover and landslide incidences including collection of landslide inventory data for the new / fresh landslides which are not recognizable in the RS source data used for this purpose because of its smaller dimensions or has only developed after the acquisition of that particular satellite data. Field studies in selected stretches in later phases of any such project may also be required for validation of final landslide susceptibility maps with actual ground situation.

Since the proposed methodology of 1: 50,000 scale landslide susceptibility mapping (LSM) would be mainly landslide dependent unlike the existing BIS method, therefore, in the proposed exercise, one of the prime thrusts is to understand the landslides, its types, failure mechanisms and give maximum reliance to understand its dependence of prevalent geofactors. This prime task of the field geologist is aimed to study individual landslides in field in greater detail so that each and every information covered under sheet for landslide inventory are collected/ documented. This exercise being an important part of the landslide susceptibility mapping would help in generating a good account of landslide inventory of the area simultaneously. Since, many places, within a Topographical Map Sheet in general is inaccessible, to augment the landslide incidence data prepared in field, use of high resolution RS data is extremely essential. As proposed, the IRS LISS-IV Multispectral imagery (5 m resolution) is an excellent optical product of relevant resolution from which, medium to large landslides in the landslide-prone areas can easily be picked-up/ mapped. However, understanding landslide types and failure mechanisms using only the RS data may not always be helpful for which later field validation, even viewing the landslides from a greater distance, would be quite useful. However, literature studies indicate that some basic and vital genetic parameters of any landslide such as material-involved, type etc, are determinable, if 3-D views of the terrain is observed using some advanced GIS functionality (such as anaglyph formation of high-resolution imagery using DEM background). Moreover, using digital and geo referenced imagery as input in a GIS, the location, dimension of any landslide to be mapped can be picked up in a more exact and accurate way than that identified and extrapolated at site during fieldwork. However, for 1: 50,000 scale landslide susceptibility mapping, depicting a landslide by a point data in a GIS may also be sufficient as far as scale of work is concerned. However, while locating landslide points in a GIS thematic layer, utmost care should be taken so that the same is plotted roughly at the center of zone of depletion or crown area to demonstrate the landslide initiation points.

2.8.3) Data Integration, Preparation of Susceptibility Map and Validation:

Use of GIS from the initial level of data acquisition, processing and preparation of thematic maps/ layers has always been helpful and worthy during integrating all the thematic maps with / without landslides in a GIS. Preparation of such spatial geo database in a GIS helps in easy updation and modification of geofactor maps at any point of the work. For integration, several simple bi-variate and multi-variate methods of data integration in a GIS are available and are accepted worldwide, not only in the field of landslide susceptibility mapping but also for the preparation of predictive maps of mineral prospectivity etc. These are robust and well-tested statistical/ mathematical techniques, which can be applied in Indian conditions too wherever, there are perennial and sufficient number of landslides.

However, GIS could also be equally helpful in processing and integrating thematic maps in situations where knowledge on a-priori landslides is scanty. In such cases, it is always advisable to apply ratings of geofactors developed in similar geo environment in nearby locations in those types of landslide-scarce study areas for application of more terrain-specific ratings/ weights. However, any predictive map of landslide susceptibility, prepared by whatsoever methods need validation, preferably quantitatively, not only by physically overlapping landslide incidence maps over the final landslide susceptibility maps but also through applying some internationally-accepted validation techniques followed elsewhere in case similar studies of predictive modelling. Formalization of this quantitative validation techniques following preparation of Success/ Prediction rate curves, Confusion matrix, creation of ROC curves etc. using both calibrating and validating landslide data can easily be accomplished in GIS using their normal functionalities, which, on an analog map format is almost impossible.

2.8.4) Acknowledgements:

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3. LANDSLIDE INVENTORY

The generation of a landslide inventory is a tedious work as landslides occur individually and have to be identified, mapped and inventoried. Landslide inventories contain basic information about landslides such as location, classification, morphology, volume, run-out distance, activity and date of occurrence/activity etc. and can be prepared through various methods such as detailed geomorphologic study, mapping from remote sensing data and topographic maps, historical archive studies and interviews. 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; Hansen, 1984). These signatures are mostly visible as morphological changes such as changes in slope type, breaks in slopes, hummocky surfaces, etc. These morphological signs are interpreted here to determine important landslide information such as type of failure, the surface area, cause and the run-out distance. Detailed and systematic field work was carried out to generate the 41-point attribute data for landslides.

Preparation of the landslide inventory commenced with the search of archival data sources, particularly published and unpublished reports of GSI. The SPOT images available as a base map in ESRI Arc GIS 10.3 (up to the resolution of 30cm), high resolution Google Earth data of different time periods (from 2002 to 2016) and LISS III data were used as the main data product for generating the multi-temporal landslide inventory.

3.2 Inventory Mapping:

The following steps are to be followed for mapping a landslide polygon in Arc GIS 10.3 and building its inventory attribute.

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

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

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

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

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

6. After identifying the landslides in the field, the morphological parameters (landslide scar length, width and depth) were noted carefully after measuring them in the field using a meter tape. Additional data such as landslide type, run-out distance, present land use, regolith thickness, probable cause, and damage details were also added to the inventory. The volume of mapped landslides was recalculated by multiplying the morphological parameters. Any new landslides identified were plotted in the topographic maps and were digitized as polygons or points and entered in a geo-database of Arc GIS.

Due to smaller dimension of the slides and heavy vegetation in the study area, pre-field demarcation of the slides through visual interpretation of SPOT images available as a base map in ESRI Arc GIS 10.3 (up to the resolution of 30cm), high resolution Google Earth data of different time periods (from 2002 to 2016) and in LISS III is not possible.

3.3 Spatial Distribution of Landslides:

A total of 31 landslide incidences were identified and reported earlier (K V Maruthi and K V Chandran, 2013; K.V. Maruthi et al., 2010). As per earlier reports most of the slides are in thick overburden. Landslides in the area are primarily due to extensive slope cut along roads. In this area major slides are observed along SH-88, Madikere –Sullia and Sullia- Subramanya road sections. The slides present in the area are mostly shallow translational failure of debris type but at places rock falls are also present.

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. The study area receives a good amount of rainfall which has resulted in high degree of weathering and laterisation over the years, causing good amount of overburden development. Slope failures in the area generally occur in this overburden part of the slope causing road blockage and sometimes damage to life and property. During field at relevant and accessible locations data for landslides and damage for recent as well as old slides was collected as per geo-parametric data sheet (Annexure - I). The slides occurring in the area are mostly translational failure of debris type. Validation of landslide inventory map was also done in field. (Photos – 1, 2, 3,4,5,6,7, & 8)

Almost all landslides studied in the area appear to have been caused due to the human interference of modifying the existing natural slopes. The specific causes of landslides in Western Ghat in general as well the study area in particular are ‘toe cutting’ of hill slopes for the construction of road, modification for human settlement, presence of weathered and loose rock mass, heavy and frequent rain etc. All slides are triggered by heavy rainfall mainly in rainy seasons extending for 4 months from May to August. The ubiquitous presence of water is favorable for intense weathering of rocks causing appreciable drop in their shearing resistance. The heavy rainfall during monsoon is the major triggering factors for all the slides. Due to non-availability of date of occurrence the landslides were grouped in to new, old and reactivated based on the morphological features observed on hill slopes with fresh surface having less plant growth on debris categorized as new slides and rest are grouped as old slides. Most of the landslides in the area are grouped as old and reactivated slides. Cut slope angle and height appear to have played a major role in slope failure. The Overburden thickness is around 1-4 m consisting of mostly soil and weathered rock in most of the cases.

4. LANDSLIDE SUSCEPTIBILITY ANALYSIS

4.1 Background Information:

The method to be followed is primarily landslide dependent following a raster-based GIS modelling approach for integration of all selected and weighted thematic maps to prepare 1: 50,000 scale landslide susceptibility maps. As prior knowledge of landslide is missing in the area, AHP has to be applied for preparation of final susceptibility map.

4.2 Selection of Preparatory Factors:

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

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

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

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

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

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

4.3 Geo-factor Themes:

Following geo-factor themes has been used for analysis: -

4.3.1 Slope Morphometry:

Slope morphometry is defined by slope gradient and slope curvature (plate 6 & plate 9). The data for these factors was derived from CARTO DEM data downloaded from BHUVAN portal which was originally supplied by NRSC. For the slope gradient map as a derivative of DEM, the area was classified in to 05 classes ranging from 15 degree up to > 45 degrees and the details are given in Table – 4. Curvature map is classified in to 3 classes' i.e., convex, flat and concave and the details are given in Table – 3.

Classess	Rank	LOFS	Area Covered (in Pixels)	Area covered (in %)
Concave	4	0.4113	761946	47.44
Flat	2	0.1676	137402	08.55
Convex	6	1.0000	706650	44.00

Table 3, LOFS map and area coverage in pixels for slope curvature map of parts of T.S. Nos. 48P/06 and 48P/10.

Referring to the above table it is very much clear that 47.44 % area is covered by concave slope curvature whereas 08.55 % area is falling under flat terrain in the study area and rest of the 44.00 % area is falling under the convex slope curvature.

Classess	Rank	LOFS	Area Covered (in Pixels)	Area covered (in %)
<15	2	0.1631	1047718	65.23
15-25	4	0.4597	395277	24.61
25-35	8	1.0000	141865	08.83
35-45	6	0.2817	17558	01.09
>45	2	0.1631	3580	00.22

Table 4, LOFS map and area coverage in pixels for slope gradient map of parts of T.S. Nos. 48P/06 and 48P/10.

Slope gradient and it's distribution in the study area is given in the above table no. 4 which explains that most of the area falls under the gradient less than 15°. In the table it has been classified in to five classes.

4.3.2 Geomorphology:

Geomorphological map was prepared in Arc GIS through visual interpretation of IRS LISS III data and multi-temporal Google images of the area. NGLM data (supplied by Southern Region, Hyderabad) was also taken into account while preparing the geomorphology map of the study area (plate 4). Gemorphologically the study area can be classified in to ridges, highly/moderately/low dissected escarpments, pediment-peneplain complex and anthropogenic terrains (slope cuts, settlement, etc.). Extensive road cuts are the main sites for slope failures in the study area, with rare occurrences of slides caused by toe erosion due to nalas and streams. The details of geomorphic features are given as follows in Table – 5.

Classess	Rank	LOFS	Area Covered (in Pixels)	Area covered (in %)
Escarpment	2	0.0819	1590	00.27
Lowly Dissected Slope	4	0.1947	211734	36.61
Moderately Dissected Slope	6	0.4020	136253	23.56
Ridge - top	0	0	4106	00.71
River	0	0	3573	00.61
Rolling Plain	0	0	199333	34.46
Valley Fill	0	0	17480	03.02
Pediment Pediplain Complex	0	0	4213	00.72

Table 5, LOFS map and area coverage in pixels for geomorphology map of parts of T.S. Nos. 48P/06 and 48P/10.

Geomorphologically area is covered by different classes as given in the above table 4. Three classes namely moderately dissected slope, lowly dissected slope and rolling plain are the major geomorphologic classes which covers 23. 56 %, 36.61 % and 34.46 % area of the total area.

Ridge:

This is the topmost part of the hills/mountains which is formed by the intersection of two escarpments from the opposite directions (Photo – 4).

Scarp (Escarpment):

A long, more or less continuous cliff or relatively steep slope face facing in one general direction, breaking the general continuity of the land by separating two level or gently sloping surfaces, and produced by erosion or by faulting. Depending on the degree of dissection it can be classified in to highly/moderately/low dissected escarpments (Photo – 4).

Pediment-Peneplain complex:

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

Alluvial plain:

A flat 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; it may be situated on a flood plain, a delta, or alluvial fan.

Alluvial Terrace:

A stream terrace composed of unconsolidated alluvium (including gravel), produced by renewed down cutting of the flood plain or the valley floor by a rejuvenated stream, or by the later covering of a terrace with alluvium.

4.3.3 Landuse/Land Cover:

Landuse/Land Cover map (plate 10) was prepared in Arc GIS through visual interpretation of IRS LISS III data and multi-temporal Google Imageries of the area. The area in terms of LU/LC can be divided in to following classes: Barren, Cultivation, settlements, sparse vegetated areas, thick vegetated areas, river, swamps, plantation and Fallow land. The areas along river banks is covered with alluvial material and along low lying valleys is covered with overburden material and are being used for cultivation. Major part of the area is covered with thick vegetation/forest. In the study area slopes along the road corridors, are most affected by slope failures due to the construction activities (mainly road widening and road lengthening) (Photo – 2).

Land Use Land Cover map (plate 10) was prepared in Arc GIS through visual interpretation of IRS LISS III data and multi-temporal Google Imageries of the area. The area in terms of LU/LC can be divided in to following classes: Barren, Cultivation, settlements, sparse vegetated areas, thick vegetated areas, river, swamps, plantation and Fallow land. The areas along river banks is covered with alluvial material and along low lying valleys is covered with overburden material and are being used for cultivation. Major part on the eastern margin of the area is covered with thick vegetation/forest. In the study area slopes along the road corridors, are most affected by slope failures due to the construction activities.

Classess	Rank	LOFS	Area Covered (in Pixels)	Area covered (in %)

Barren	1	0.0626	18657	03.22
Cultivation	2	0.0937	21946	03.79
Extensive Slope Cut	9	1.0000	15	00.0025
Fallow Land	1	0.0626	512	00.0885
Moderate Vegetation	5	0.2912	101874	17.61
Plantation (HHP)	4	0.1988	63743	11.02
Plantation (LHP)	3	0.1366	15892	02.74
Quarry	5	0.2912	414	00.0715
Settlement	1	0.0683	30894	05.34
Settlement on modified slope	7	0.5631	18	00.00311
Thick Vegetation	4	0.1988	287845	49.77
Sparse Vegetation	7	0.5631	32884	05.68
Water body	0	0.0000	15	00.0025
River	0	0.0000	3573	00.61

Table 6, LOFS and area coverage in pixels for Landuse/land cover map of parts of T.S. Nos. 48P/06 and 48P/10.

Distribution of the Landuse/Landcover classes as it has been classified in the study is mostly covered by thick vegetation which covers 49.77 % of the total area followed by moderate vegetation which covers 17.61 % of the total area. For the further detailed study of the total area covered by the Landuse/Landcover classes it can be understand by better way referring to the Table – 6.

4.3.4 Slope Forming Material (SFM):

Slope Forming Material (SFM) map (plate 5) was prepared in Arc GIS through visual interpretation of multi-temporal Google Imageries of the area and collection of data for material present on slopes. The area in terms of Slope Forming Material (SFM) can be divided in to following classes: Rock, Colluvium, Alluvium, In-situ soil and laterite.

On slopes, rock is present at places where the slope angle in general is more than 35 degrees, Colluvium is accumulated on the lower slopes due to gravitational action while alluvium is accumulated due to the fluvial action, in-situ soil is present at places where erosional activities are not too much in action & laterite is present in areas where weathered profiles are well developed.

Classess	**Rank**	**LOFS**	**Area Covered (in Pixels)**	**Area covered (in %)**
In-situ soil	4	0.2409	495128	85.62
Meta-ultramafite	1	0.0682	7	00.0012
Dolerite	1	0.0682	54	00.0093
Granite gneiss	1	0.0682	41672	07.20
Granodiorite gneiss	1	0.0682	430	00.074
Banded magnetite quartzite	1	0.0682	2	00.0003

Garnet-biotite gneiss	1	0.0682	178	00.037
Pyribolite	1	0.0682	1	00.00017
Gar-bio-sill gneiss + graphite + kyanite	1	0.0682	127	00.021
Garnet-sillimanite-gneiss + graphite + cordierite	1	0.0682	11489	01.98
Charnockite	1	0.0682	660	00.11
Amphibolite	4	0.2409	1279	00.22
Laterite	4	0.2409	51	00.0088
Garnet-sillimanite schist	4	0.2409	27	00.0046
Pyroxene granulite	4	0.2409	122	00.021
Transported Soil	3	0.1506	23482	04.06
River	0	0.0000	3573	00.61

Table 7, LOFS map and area coverage in pixels for SFM map of parts of T.S. Nos. 48P/06 and 48P/10.

Different classes of SFM are given in Table – 7 which clarifies that most of the area falls under the in-situ soil and covers 85.62 % area of the study area. Rest of the area is covered by the other 16 classes in the study area which have been given in the above Table – 7.

4.3.5 Regolith Thickness:

Thickness of overburden is directly controlled by Slope Forming Material (SFM), geomorphology, Landuse/Land cover and slope gradient. Regolith thickness (plate 7) map has been prepared on ArcGIS platform using RS data and field inputs. In the study area it can be classified in to 3 classes: <0.5 m, 0.5-5 m and 5 – 10 m. Along the moderate and 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.

Classess	Rank	LOFS	Area Covered (in Pixels)	Area covered (in %)
< 0.5 m	0	0	56108	09.70
0.5 - 5 m	7	1	517660	89.51
5 - 10 m	4	0.32296	941	00.16
River	0	0	3573	00.61

Table 8, LOFS map and area coverage in pixels for regolith thickness map of parts of T.S. Nos. 48P/06 and 48P/10.

With the help of above Table – 8 it is very much clear that most of the area is covered by the 0.5 to 5 m class and is 89.51 % of the total area. 09.70 % area is covered by< 0.5 m thickness and rest of the area is falling under thickness 5 – 10 m.

4.4 Landslide Susceptibility Analysis (AHP):

Landslides or rather slope failures in the study area are concentrated mainly along roads and other transportation corridors. Recording these slope failures which are a result of anthropogenic activities and considering them for susceptibility zonation of the study area would be highly biased. Since very few slides (only 9) have been observed elsewhere in the area, the landslide based method of modeling cannot be used here. In this situation, ratings and inter-predictor weights can only be determined using expert or knowledge driven techniques by implementing one of the following alternatives or by combining knowledge derived from attempting all the alternatives.

Alternative 1: Finalization of ratings and weights in a smaller neighboring area-

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

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

In situation of complete non-availability of landslide inventory data, there is absolutely no other way than utilizing complete expert or knowledge driven ratings and weights into susceptibility modeling despite its subjectivity. However, this knowledge-driven ratings/ weights in quantitative metrices can easily be determined mathematically using AHP (Saaty, 1977; Ghosh et al., 2011; Yalcin et al., 2011; Kayastha et al., 2013), after preparing/ deciding on the qualitative pairwise importance matrix for different geofactor classes and amongst different geofactors for inter-predictor weights, obtained so far through discussion and comments received from local experts and landslide scientists engaged in landslide investigation of the area. The procedures of application of AHP through some examples are demonstrated through some illustration below.

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

4.4.1 Procedure:

The Analytic Hierarchy Process (AHP), developed by Saaty (1981) 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 achieve the goal and the third level is to find out how each of the alternatives contributes to each of the criteria.

The AHP method is appropriate 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 the 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 A. J. Miller and D. Miller, human beings cannot simultaneously compare more than seven objects. The Standard Preference Scale used is as follows:

Preference Level	Numerical Value
Equally Preferred	1
Equally to Moderately Preferred	2
Moderately Preferred	3
Moderately to Strong Preferred	4
Strongly Preferred	5
Strongly to Very Strongly Preferred	6
Very Strongly Preferred	7
Very Strongly to Extremely Preferred	8
Extremely Preferred	9

Using the above Standard Preference scale, a group of geoscientists (all the geoscientists involved in NLSM project at SR), 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, 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 were calculated.

Example of LULC for calculation of LOFS is given below :(values are arbitrary)

Example-Calculation of LOFS for LULC

CLASS	Rank	LOFS
Barren	1	0.0626
Cultivation	2	0.0937
Extensive Slope Cut	9	1.0000
Fallow Land	1	0.0626
Moderate Vegetation	5	0.2912
Plantation (HHP)	4	0.1988

Plantation (LHP)	3	0.1366
Quarry	5	0.2912
Settlement	1	0.0683
Settlement on modified slope	7	0.5631
Swamp	0	0.0000
Thick Vegetation	4	0.1988
Sparse Vegetation	7	0.5631
Water body	0	0.0000
River	0	0.0000

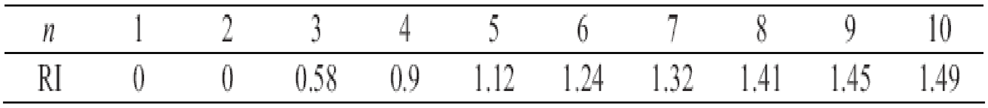
Table 9, Generic Table showing mutual comparison rank of LULC factor classes.

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

Table 11, Table Showing Fraction rate and LOFS values.



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

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

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

Table 13, Table showing calculation of consistency index (CI) and consistency ratio (CR).

In the same manner for all the 6 factor maps calculation of LOFS (Annexure - 1) and consistency ratio (CR) was done. 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.

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

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

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

Table 14, Table showing mutual comparison of individual factor maps and weights.

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

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

For generation of “Raw (unclassified) Landslide Susceptibility Score Map” in Arc – GIS, “raster calculation” command under map algebra is used. For “Raw Landslide Susceptibility Score Map” the following formula is used. ***Susc Score*** **=** *(LOFS_Factor1*weight of Factor1 + LOFS_Factor2*weight of Factor2 + LOFS_Factor3*weight of Factor3 + ………. + LOFS_Factor*$_n$ **weight of Factor*$_n$*) / Sum of inter – predictor weight*

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

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

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

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

Once break values (BrMH and BrLM) are calculated, Classified Landslide Susceptibility Map is prepared by reclassifying the Raw Landslide Susceptibility Score Map using reclassify command in Arc – GIS. In reclassification window, three classes are chosen and in break values, 2nd topmost value given as the first value (Class 1), 1st topmost value is given as the second value (Class 2) and third value (Class 3) is given as one. Now the Raw Landslide Susceptibility Score Map is classified into the following categories: Class 1 stands for "*Low Susceptibility*", Class 2 stands for "*Moderate Susceptibility*" and Class 3 stands for "*High Susceptibility*" (Plate 12).

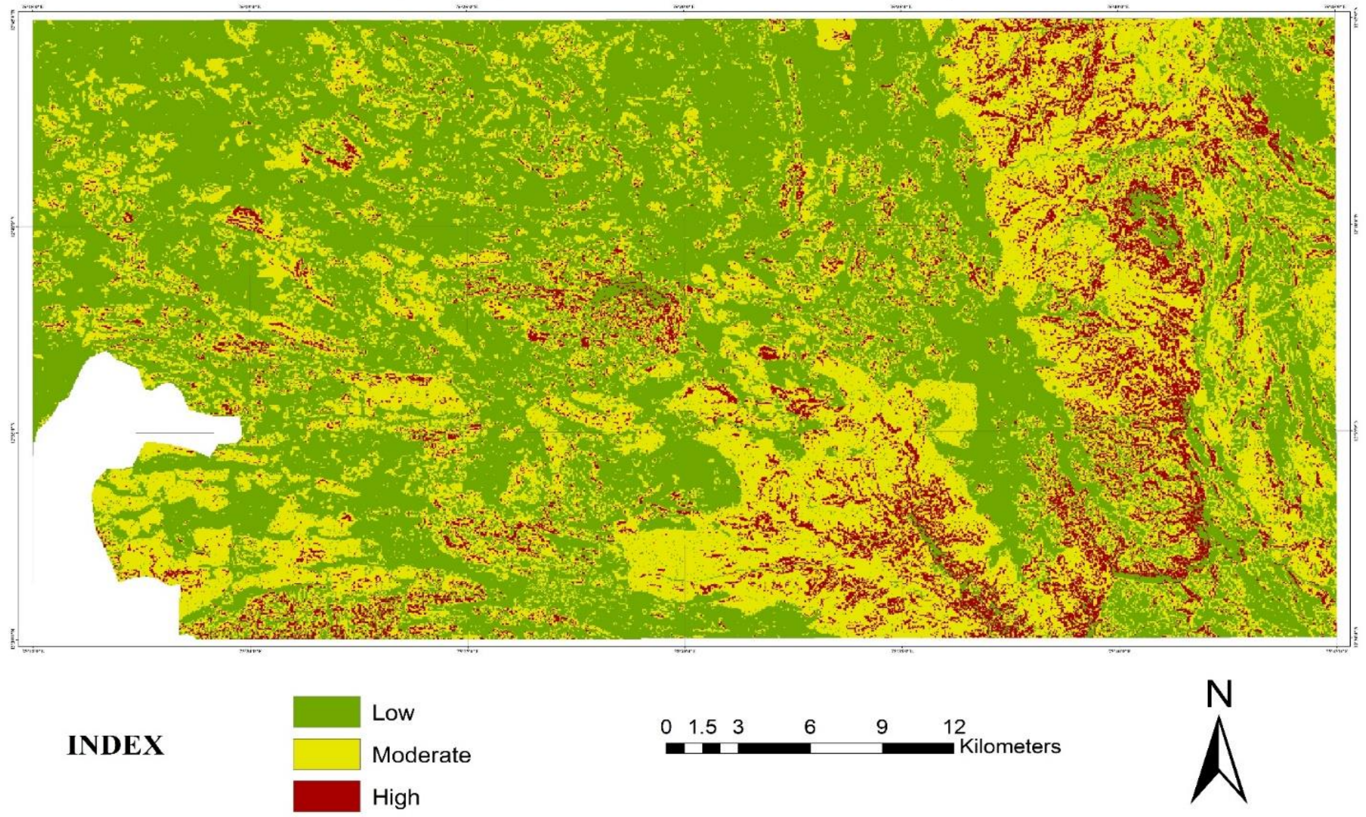
The integer weight or rating and weights derived from AHP were used to obtain landslide susceptibility score map. The output map is then regrouped into three susceptibility class (high, moderate and low).

4.5 Landslide Susceptibility Map:

Landslide susceptibility map (plate 12) can be classified into high, medium and low susceptible areas, as per AHP analysis, prominent settlement locations like Sullia, Bellare, Jalsuru, Paicher, Panja, Gonadaka, Badadaka, Alleti, Ajjavarah, Subramanya and its surroundings can be grouped in to moderate susceptible zones while rest of the area is under medium to low susceptible category. In the area road transportation corridor route from Sullia-Panja, Paicher-Jalsuru and Paicher-Subramanya are most affected by road construction activities and are prone for landslides. Major drainages (plate 8) like Kumardhari and Piaschani and their tributaries are under low susceptible category and least prone for landslides.

In the same continuation the area lying east of the study area is more prone to failure but those areas are aside of the prominent settlements. These areas are further northeast, east and southeast of the study area. Northern and northwester parts are categorized as low susceptible zone where as southern and south of southeastern part are quite moderate zone and falls under moderate zone. As per the classification of landslide susceptible zones in the study area are low, high and moderate categories which are covering 51.28%, 39.37% and 9.44% respectively.

LANDSLIDE SUSCEPTIBILITY MAP OF PARTS OF T.S. NO. 48P/06 AND 48P/10, DAKSHIN KANNAD DISTRICT



5. CONCLUSIONS AND RECOMMENDATIONS

Landuse/Land Cover (LULC), Geomorphology, Slope Forming Material, Slope gradient, Slope Curvature and Regolith thickness are various thematic classes which have a direct or indirect control over landslide susceptibility. In the area denudated hills and lowly dissected hills having extensive cut slopes are the most prone to the landslides.

Landslide susceptibility map can be classified into high, medium and low susceptible zones, as per AHP analysis, prominent settlement locations like Sullia, Bellare, Jalsuru, Paicher, Panja, Gonadaka, Badadaka, Alleti, Ajjavarah, Subramanya and its surroundings can be grouped into high susceptible zones while rest of the area is under medium to low susceptible category. In the study area transportation corridor from Sullia-Panja and Picher-Subramanya is the most affected by road construction activities and prone to landslides. Major drainages like Kumardhari and Piaschani and their its tributaries are under medium to low susceptible category and least prone for landslides but development along the banks of these drainages needs special post construction maintenance and monitoring.

Final landslide susceptibility map as an end product can be classified as high, moderate and low susceptibility zone. These susceptibility zones have a direct influence on land use planning and development of land use regulations on the regional scale as it is obvious that zones or areas like Hebbel, Morse, Nirgod, Mahime, Gonavati, Tumboli & its surroundings can be grouped into high susceptible zones and not suitable for planners in comparison to the rest of the area which is under medium to low susceptible category.

In the area route from Paicher – Subramanya is most affected by road construction activities and prone for landslides, and are least suitable for development for planners; these areas need special attention from developers and administration for proper land use planning.

5.1 Conclusions

1) The susceptibility map on 1: 50,000 scale gives the qualitative estimation that the mapping unit will be affected by a future landslide source, but the “future” here is not connected to a time frame. It only indicates the stability status of a slope irrespective of a time of an event to occur.

2) The susceptibility model used to predict the spatial location of potential landslides is based on certain assumptions. It is assumed that landslides will occur in future under the same

conditions and triggering factors that produced them in past. However, we would like to state that to some extent the assumption holds true for the study area.

3) The preparatory factors (e.g., slope, curvature, geomorphology and drainage) are not expected to change significantly in a short time period, Local morphological changes may occur due to landsliding, 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.

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

5.2 Recommendations:

1) The assessment of the landslide susceptibility is extremely important for such high vulnerable areas because it gives basic construction standards for new roads or buildings, helps to assess the impact of future landslides and can also be used to locate key facilities like hospitals, fire stations, etc. As a general recommendation, if end users intend to use only the susceptibility map for land use planning, then no public or personal utility projects should be considered in highly susceptible areas, strict building safety regulations should be followed in moderate susceptible areas and constructions with simple slope stability measures be allowed in low susceptible areas. This is a general recommendation related to the landslide susceptibility based on the present land use condition; however, the susceptibility values can be lowered if proper mitigation measures are adopted such that a high susceptible area can be made less vulnerable to land sliding. Therefore, it is recommended that the susceptibility map should be interpreted accordingly and the degree of susceptibility or hazard in response of mitigation measures should be worked out judiciously. In this regard cost-benefit analysis may be carried out for better planning.

2) It is also recommended that the susceptibility map showing the potential landslide area should not be considered as standalone map for planning; the run out of potential debris flows be also considered for the specific planning.

3) The susceptibility map is generally meant for regional application because the information is shown on scale 1: 50,000; however, they are still of considerable significance from the point of specific land use and urban planning. Nevertheless, it is recommended that a

detailed site-specific study may be duly conducted before planning and execution of the civil construction works. Areas with high susceptibility falling under high hazard should be given due attention while executing civil constructions.

4) 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.

5) In the event if a disaster strikes, then loss would be immense if buildings are not safely and properly located. The only economical way of reducing “at least” the loss of life is by making people aware of the inherent risk. Therefore, it is recommended that more priority should be given in increasing awareness amongst people through Community Based Disaster Management Programme (CBDMP). The villages or communities located in and around high hazard areas should be given priority in holding CBDMP.

6) 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

Sl. No.	Name of Locality	Location Type	Longitude	Latitude
1	Adikehithlu	village	75.49469757	12° 34' 39.329" N
2	Ainekidu	village	75.62470245	12° 38' 0.473" N
3	Ankathadka	village	75.31099701	12° 41' 7.790" N
4	Arani	village	75.70230103	12° 43' 47.901" N
5	Arantodu	village	75.47109985	12° 31' 9.894" N
6	Ariyadka	village	75.26280212	12° 40' 18.648" N
7	Baddadka	village	75.39630127	12° 30' 24.243" N
8	Balila	village	75.40920258	12° 40' 3.701" N
9	Balpa	village	75.51239777	12° 40' 28.095" N
10	Bangikodi	village	75.38880157	12° 36' 35.242" N
11	Bantra	village	75.50800323	12° 44' 37.098" N
12	Bellare	village	75.36959839	12° 39' 54.460" N
13	Bengamale	village	75.39720154	12° 36' 28.833" N
14	Bolubailu	village	75.36949921	12° 35' 4.384" N
15	Boranamane	village	75.72039795	12° 44' 37.670" N
16	Devinagara	village	75.2888031	12° 41' 15.779" N
17	Doddathota	village	75.44409943	12° 35' 51.371" N
18	Dugaladka	village	75.42579651	12° 35' 36.961" N
19	Enekallu	village	75.5605011	12° 40' 18.998" N
20	Enmuru	hamlet	75.42669678	12° 41' 10.902" N
21	Guddadka	village	75.30560303	12° 37' 15.277" N
22	Indraje	hamlet	75.42050171	12° 40' 4.155" N
23	Jalsuru	village	75.33480072	12° 35' 40.994" N
24	Kadaba	village	75.46440125	12° 44' 32.951" N
25	Kalanja	village	75.32649994	12° 36' 19.335" N
26	Kalanja	village	75.3884964	12° 39' 27.724" N
27	Kaluru	hamlet	75.70130157	12° 30' 57.566" N
28	Kaniyoor	village	75.3655014	12° 43' 8.846" N
29	Kanyana	village	75.27850342	12° 33' 9.722" N
30	Kattattaru	village	75.28269958	12° 41' 50.373" N
31	Kavu	village	75.27539825	12° 38' 35.851" N
32	Kedambadi	village	75.26010132	12° 42' 20.042" N
33	Kemmara	village	75.31960297	12° 39' 0.622" N
34	Kenya	hamlet	75.50009918	12° 41' 31.367" N
35	Keyyur	village	75.2990036	12° 41' 17.964" N
36	Kodiyala	village	75.37210083	12° 41' 13.846" N
37	Kolchar	village	75.33059692	12° 31' 10.344" N
38	Kollamogru	village	75.60829926	12° 34' 33.551" N
39	Kukke Subrahmanya	village	75.61319733	12° 40' 4.032" N
40	Kulkunda	village	75.60959625	12° 41' 16.843" N
41	Kumbaragadige	hamlet	75.73390198	12° 36' 21.713" N
42	Kutkunja	hamlet	75.47460175	12° 40' 0.937" N
43	Madnuru	village	75.27619934	12° 38' 9.540" N
44	Mandekolu	village	75.29910278	12° 33' 10.900" N
45	Manikkara	village	75.32230377	12° 41' 4.780" N
46	Mankanahalli	village	75.71289825	12° 43' 55.011" N
47	Mogappe	village	75.33270264	12° 39' 36.273" N

48	Mukkodlu	hamlet	75.73729706	12° 30' 38.823" N
49	Mupperiya	hamlet	75.41919708	12° 40' 16.073" N
50	Muroor	village	75.29889679	12° 34' 17.747" N
51	Nalkuru	hamlet	75.56529999	12° 38' 26.467" N
52	Nettaru	village	75.35099792	12° 39' 58.609" N
53	Noojibailu	village	75.25219727	12° 35' 33.262" N
54	Paimbechalu	village	75.32900238	12° 31' 43.728" N
55	Panja	village	75.47109985	12° 40' 37.619" N
56	Panjikkal	village	75.31659698	12° 34' 24.755" N
57	Papemajalu	village	75.25430298	12° 42' 0.000" N
58	Perlampady	village	75.31700134	12° 38' 45.194" N
59	Peruvaje	village	75.35279846	12° 40' 38.520" N
60	Pilikodi	village	75.35839844	12° 35' 0.276" N
61	Savanur	town	75.3144989	12° 44' 10.974" N
62	Sullia	town	75.39080048	12° 33' 27.592" N
63	Thingalady	village	75.27709961	12° 42' 12.980" N
64	Vanaguru	village	75.74469757	12° 43' 47.171" N
65	Yelimale	village	75.47679901	12° 35' 59.253" N

SYNOPSIS OF WORK DONE

1	**Title of the report**	"Macro-scale (1: 50,000) Landslide Susceptibility Mapping In Parts Of Toposheets Nos. 48P/06 and 48P/10 Dakshin Kannad District, Karnataka".
2	**FSP Code No.**	LSM/SR/KG/2016/110
3	**Field Season**	2016 – 17
4	**Date of Commencement**	22nd October – 2016
5	**Date of Completion**	17th March – 2017
6	**Officers associated with the investigation and no. of days spent in the field**	1. Koushik Shukla, Senior Geologist – 54 Days 2. Rahul Kumar Chaurasia, Geologist – 68 Days

7 Quantum of work done

1. Pre-field preparation	
(i) Slope Forming Material map	1445 Km^2
(ii) Geomorphology & Lineament map	1445 Km^2
(iii) Slope Morphometry (slope, aspect & curvature) map	1445 Km^2
(iv) Landuse / Landcover map	1445 Km^2
(v) Drainage map	1445 Km^2
(vi) Regolith thickness map	1445 Km^2
(vii) Preparation of Landslide Inventory Map	1445 Km^2
2. Field-based studies	
(i) Field-checking of all thematic maps	1445 Km^2
(ii) Field validation of landslide inventory and collection of recent and historic landslides (using archives, old reports, road register etc.)	1445 Km^2
(iii) Collection of landslide inventory and damage data as per 41 point geo parametric data sheet	1445 Km^2 (09)
3. Post – field studies and modelling	
(i) Updation of thematic and inventory maps in GIS	1445 Km^2
(ii) Preparation of Landslide Susceptibility Map in GIS	1445 Km^2
(iii) Validation of landslide susceptibility map at important locations	1445 Km^2
4. Collection of rainfall data from available rain stations	1445 Km^2

8 **Expenditure**

Wages (Rs.)	79, 377.00/=
OC (Rs.)	27, 500.00/=
POL(Rs.)	14, 500.00/=
Total (Rs.)	**1, 21, 377.00/=**

FIVE POINT PROFORMA

Title of the Item: “Macro-Scale (1:50,000) Landslide Susceptibility Mapping In Parts Of Toposheets Nos. 48P/06 and 48P/10 Dakshin Kannad 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: FSP; Code No: LSM/SR/KG/2016/110 to prepare seamless LSM of India.
2. Whether the item of investigation was included in the approved programme for the year concerned. If so, particulars, such as item No. page reference etc. may be given.	Yes FSP Code No: LSM/SR/KG/2015/110 Item No: 160
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.	22nd October – 2016 **1.** Koushik Shukla ………… 54 days **2.** Rahul Kumar Chaurasia …68 days Total 122 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

PLATES

Plate - 1

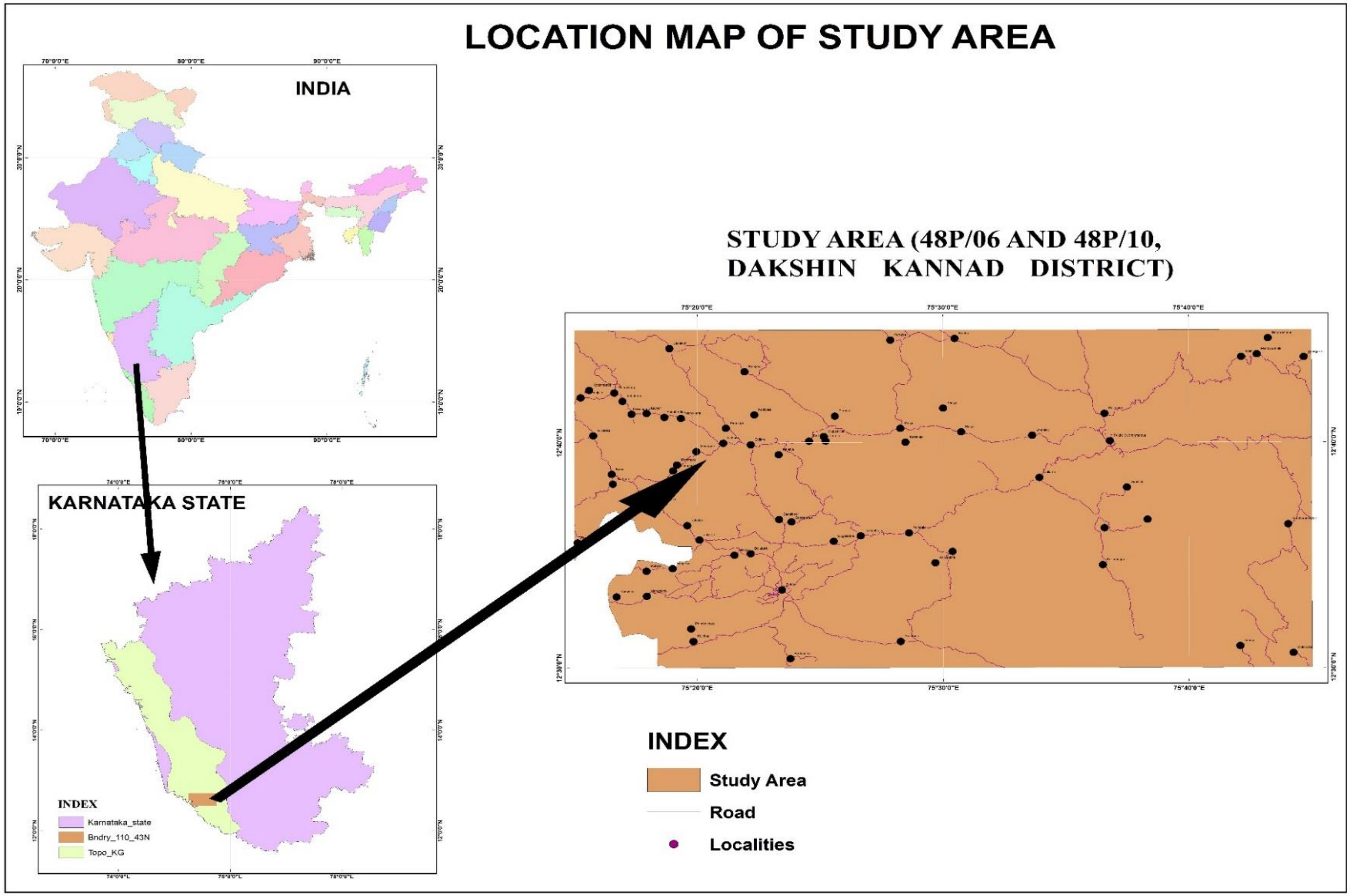


Plate - 2

LOCATION MAP OF PARTS OF T.S. NO. 48P/06 AND 48P/10, DAKSHIN KANNAD DISTRICT

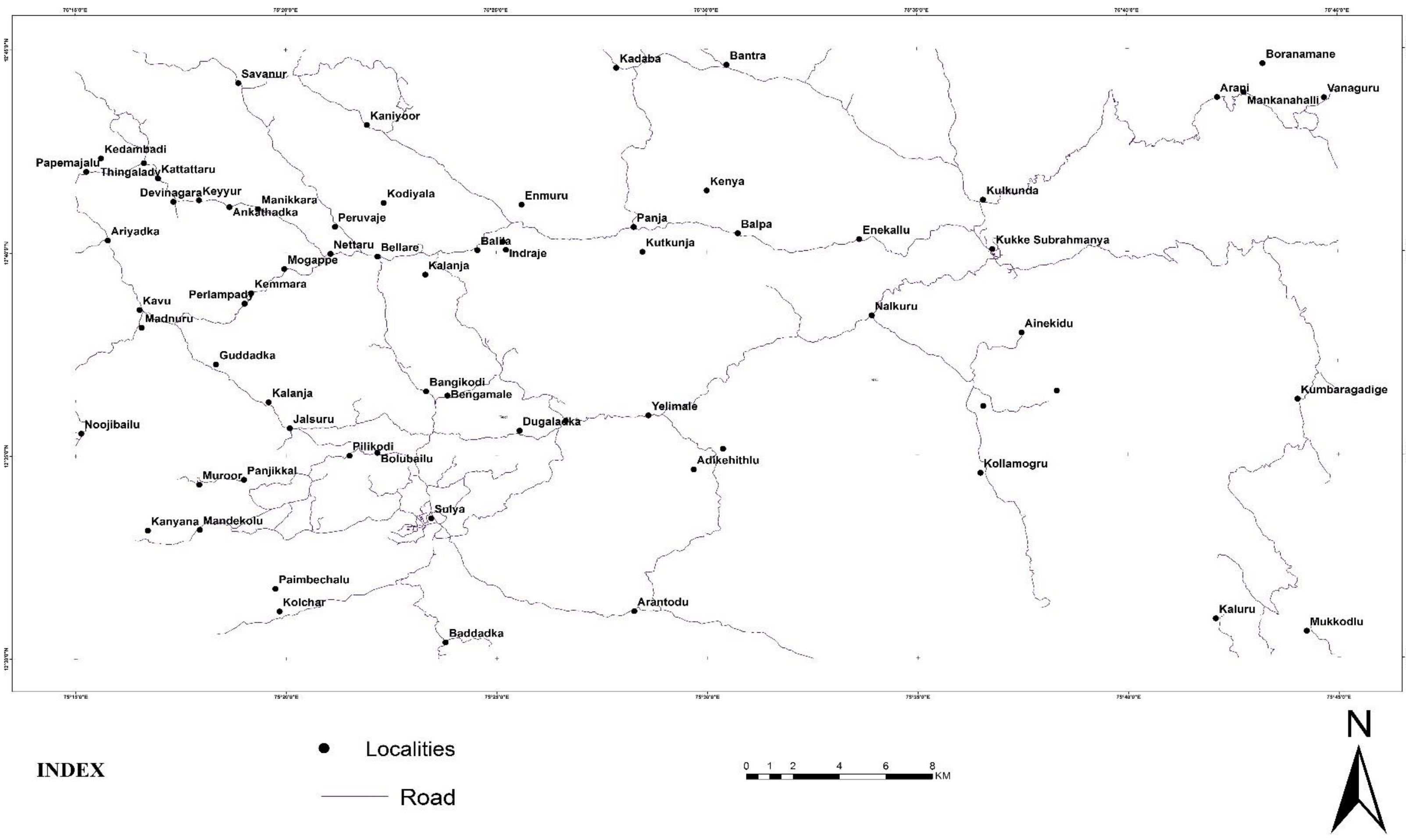
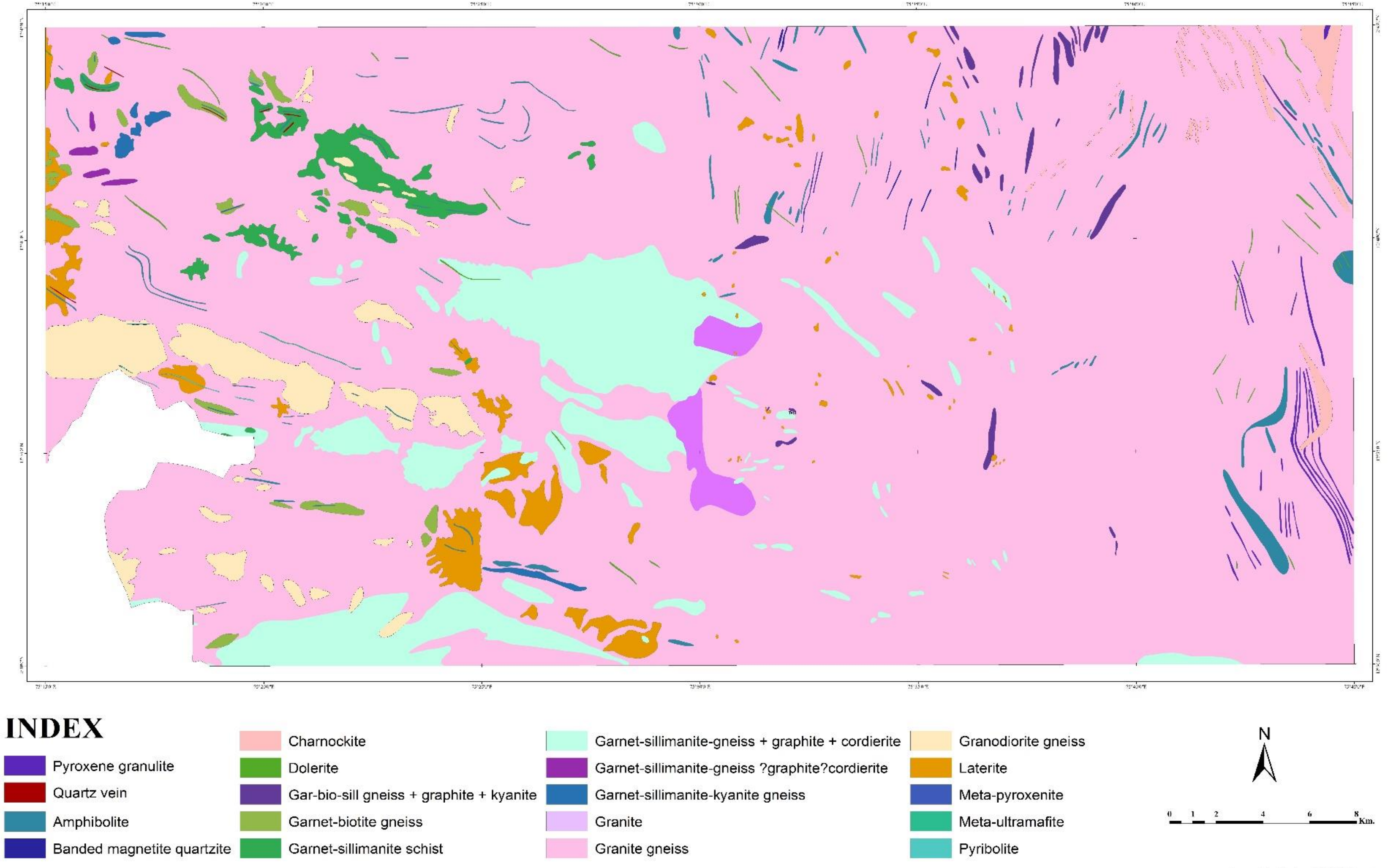


Plate - 3

GEOLOGICAL MAP OF PARTS OF T.S. NO. 48P/06 AND 48P/10, DAKSHIN KANNAD DISTRICT



Prepared by Geodata SU: K&G, Bengaluru

Plate - 4

GEOMORPHOLOGY MAP OF PARTS OF T.S. NO. 48P/06 AND 48P/10, DAKSHIN KANNAD DISTRICT

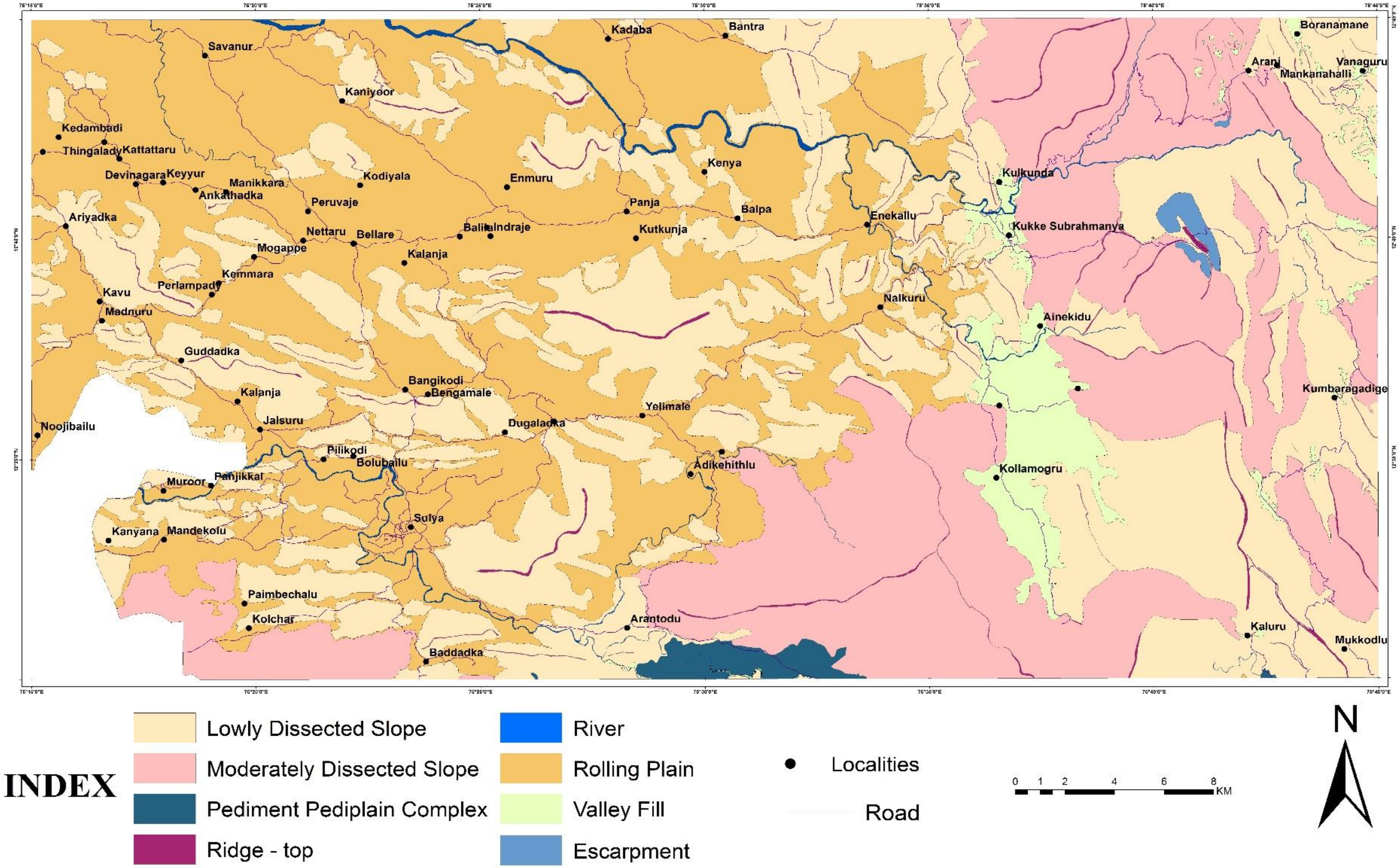


Plate - 5

SLOPE FORMING MATERIAL MAP OF PARTS OF T.S. NO. 48P/06 AND 48P/10, DAKSHIN KANNAD DISTRICT

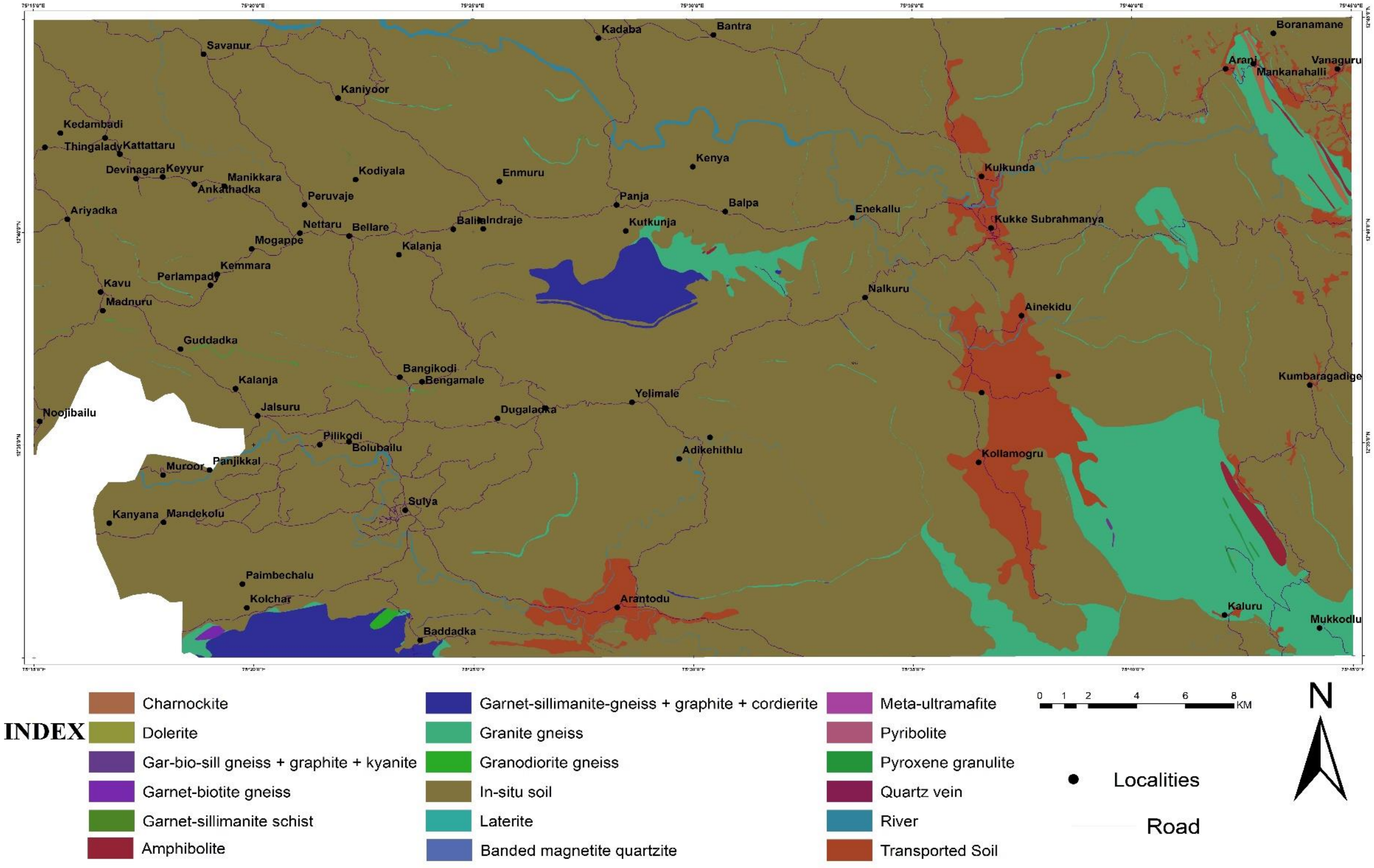
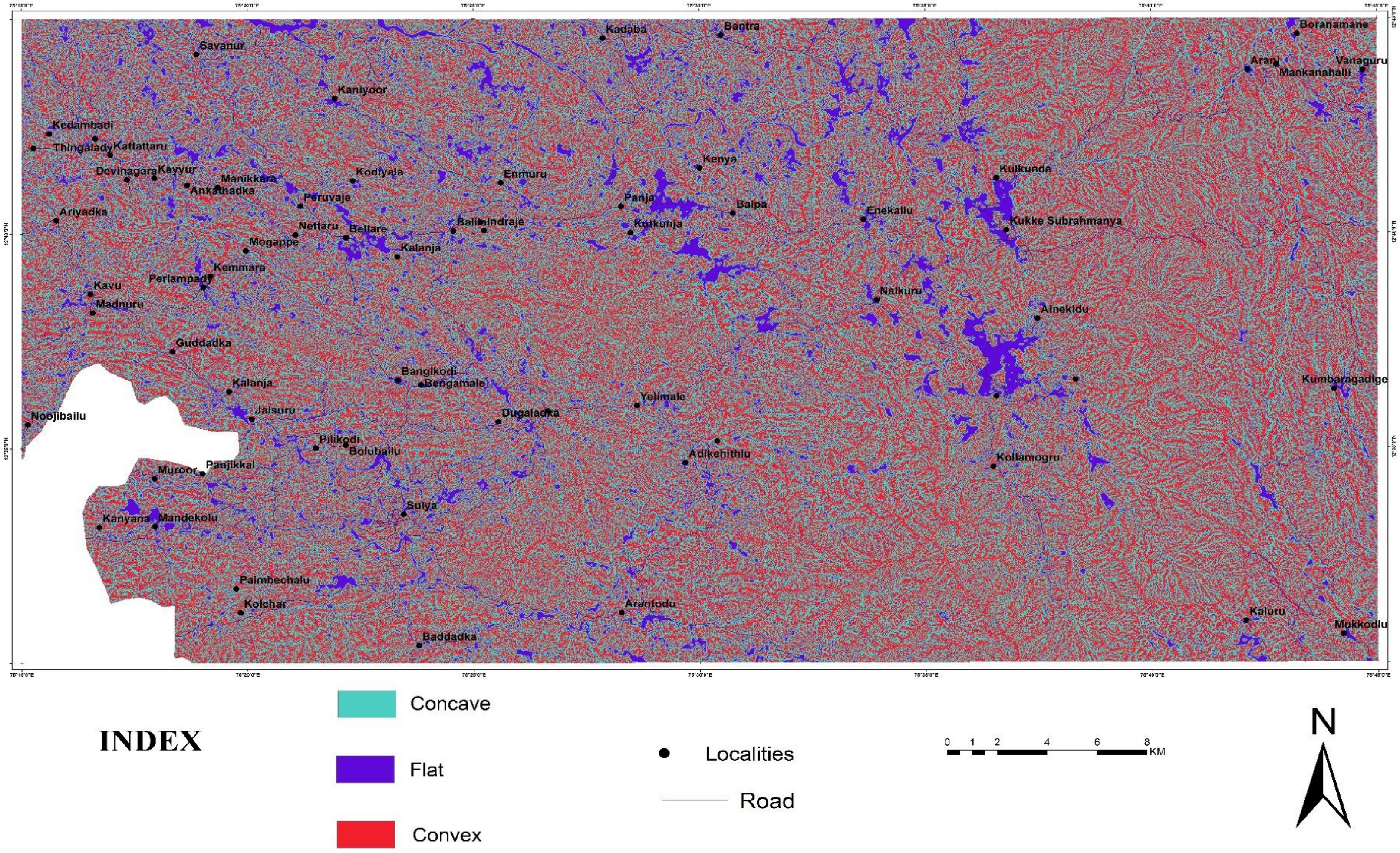


Plate - 6

CURVATURE MAP OF PARTS OF T.S. NO. 48P/06 AND 48P/10, DAKSHIN KANNAD DISTRICT



REGOLITH THICKNESS MAP OF PARTS OF T.S. NO. 48P/06 AND 48P/10, DAKSHIN KANNAD DISTRICT

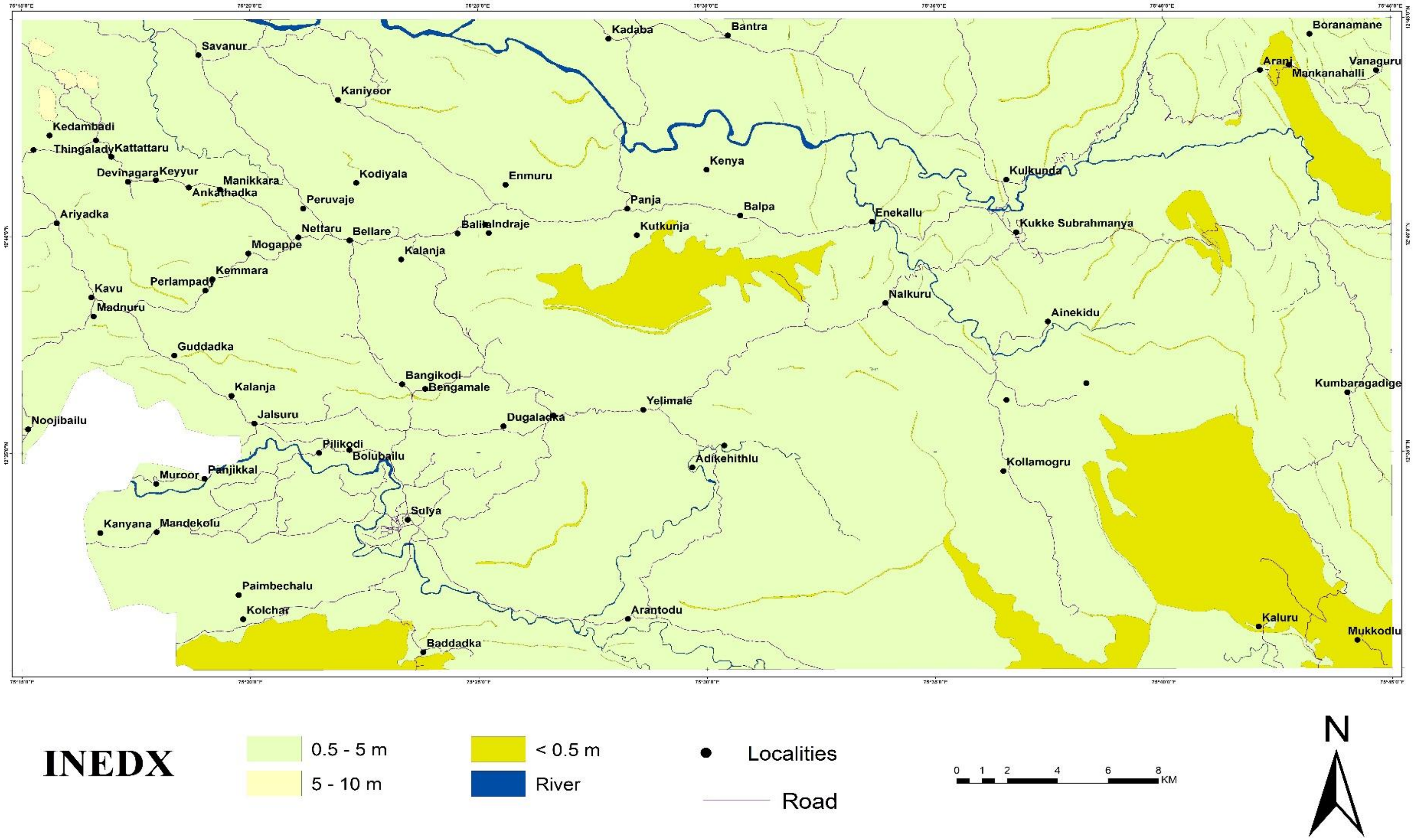


Plate - 8

DRAINAGE MAP OF PARTS OF T.S. NO. 48P/06 AND 48P/10, DAKSHIN KANNAD DISTRICT

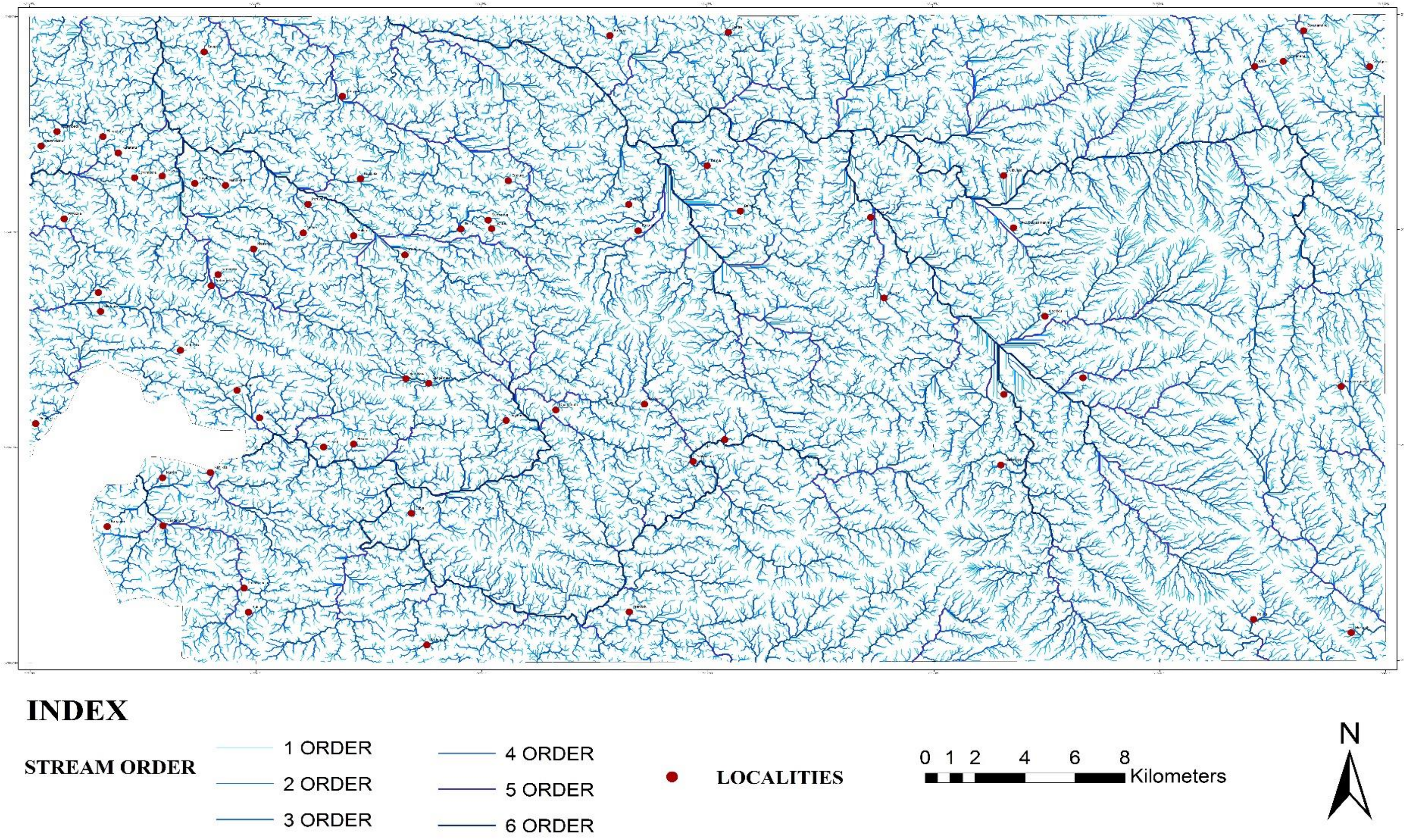


Plate - 9

SLOPE GRADIENT MAP OF PARTS OF T.S. NO. 48P/06 AND 48P/10, DAKSHIN KANNAD DISTRICT

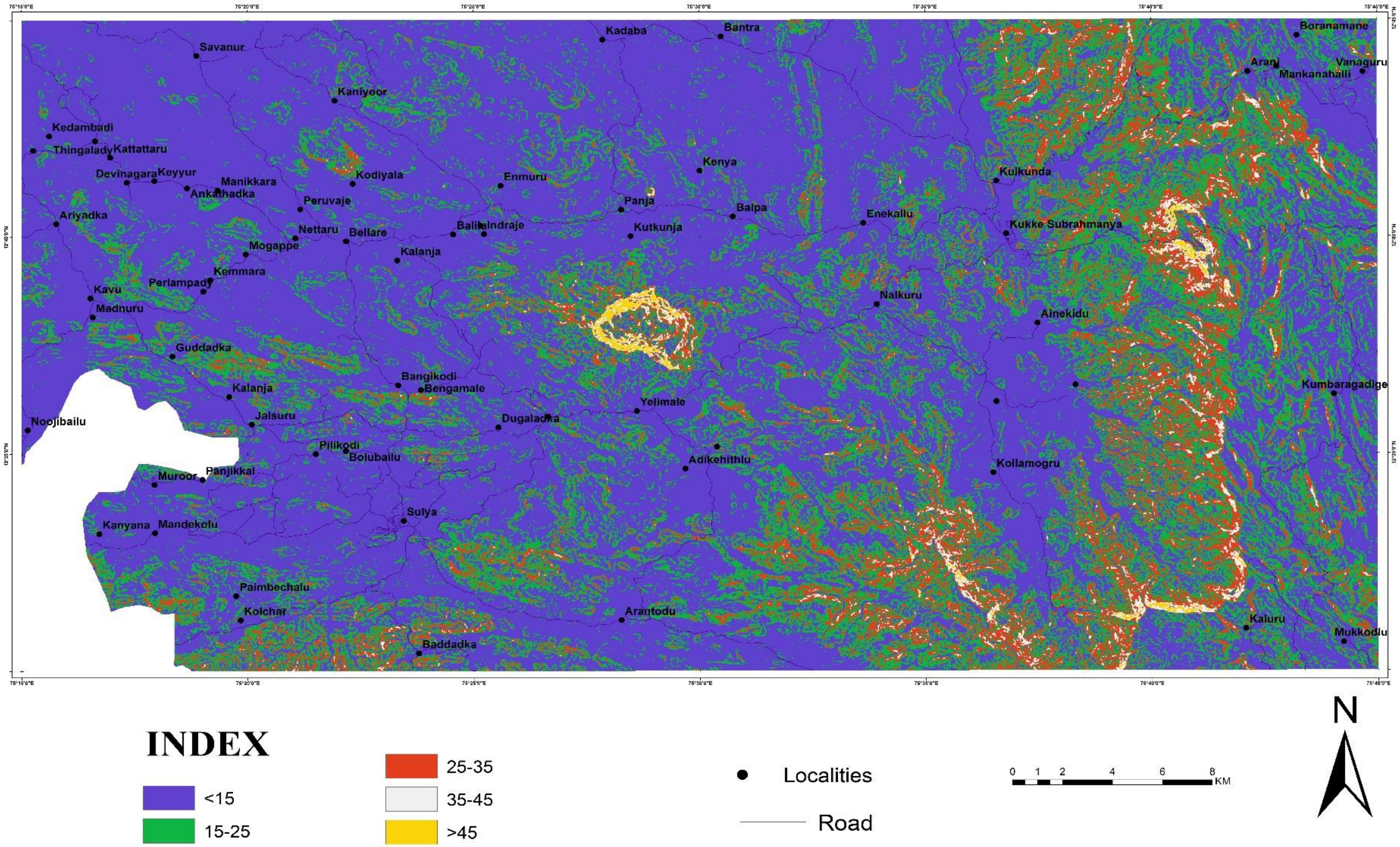
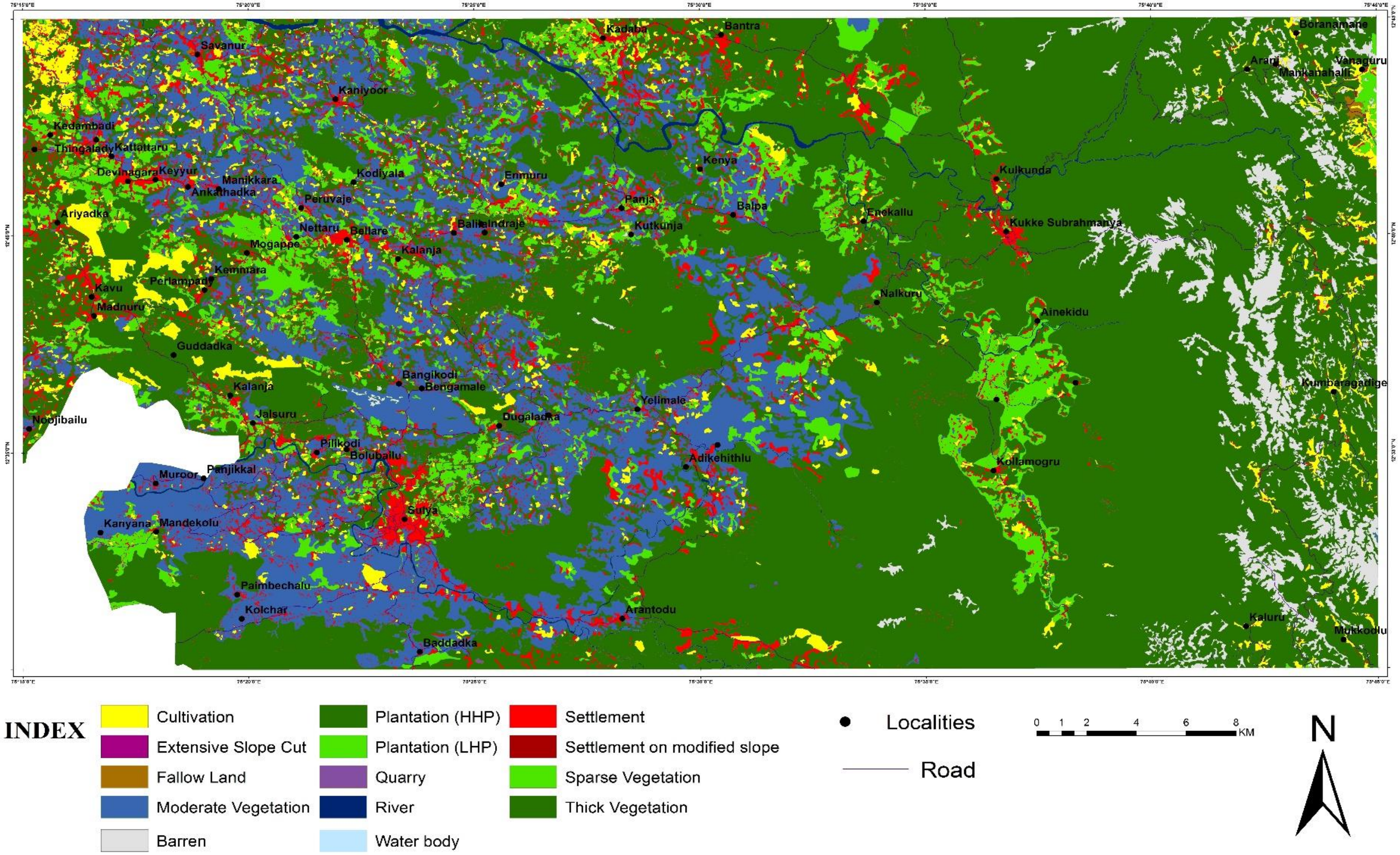


Plate - 10

LANDUSE/LANDCOVER MAP OF PARTS OF T.S. NO. 48P/06 AND 48P/10, DAKSHIN KANNAD DISTRICT



LANDSLIDE INVENTORY MAP OF PARTS OF T.S. NO. 48P/06 AND 48P/10, DAKSHIN KANNAD DISTRICT

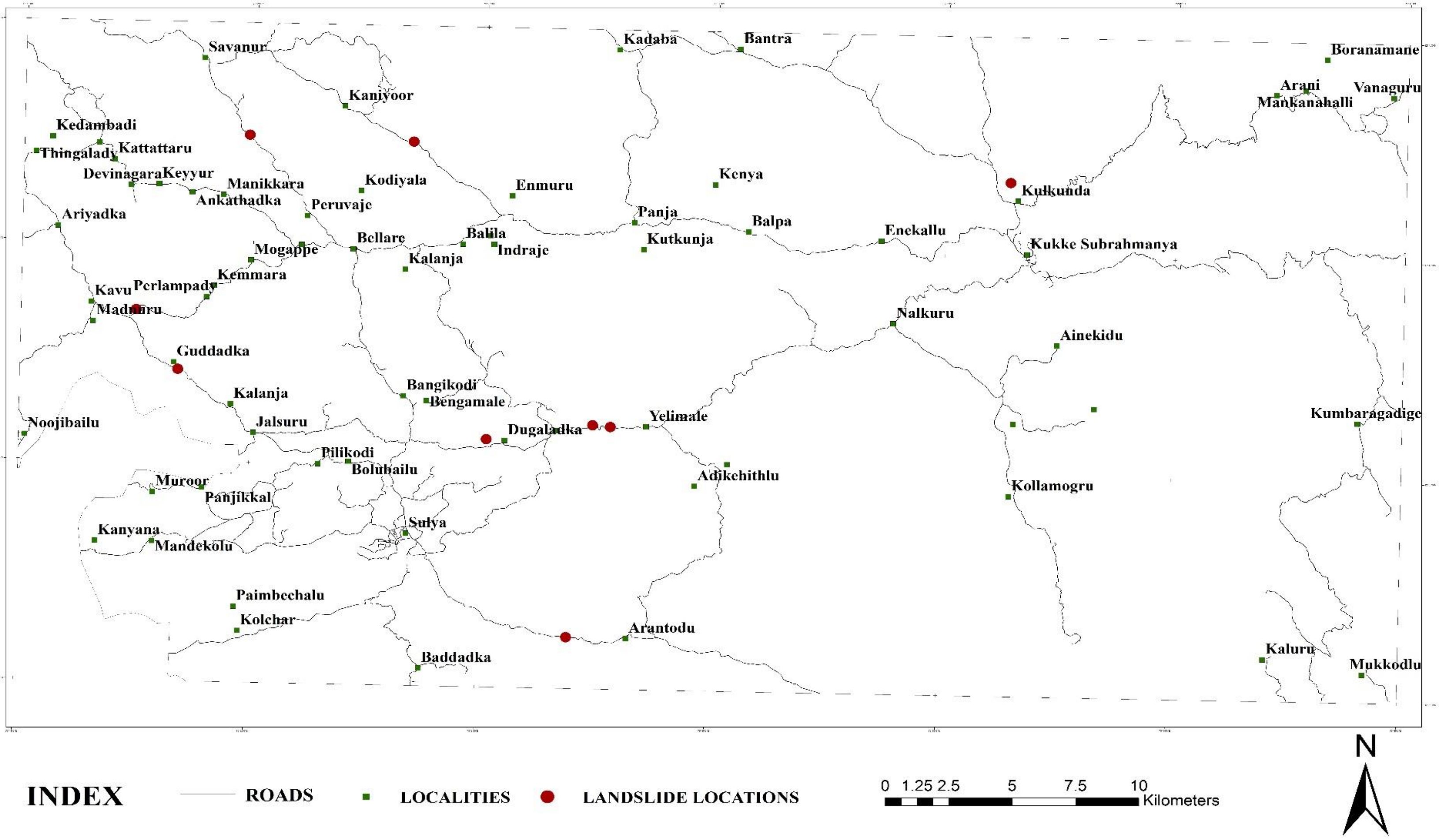
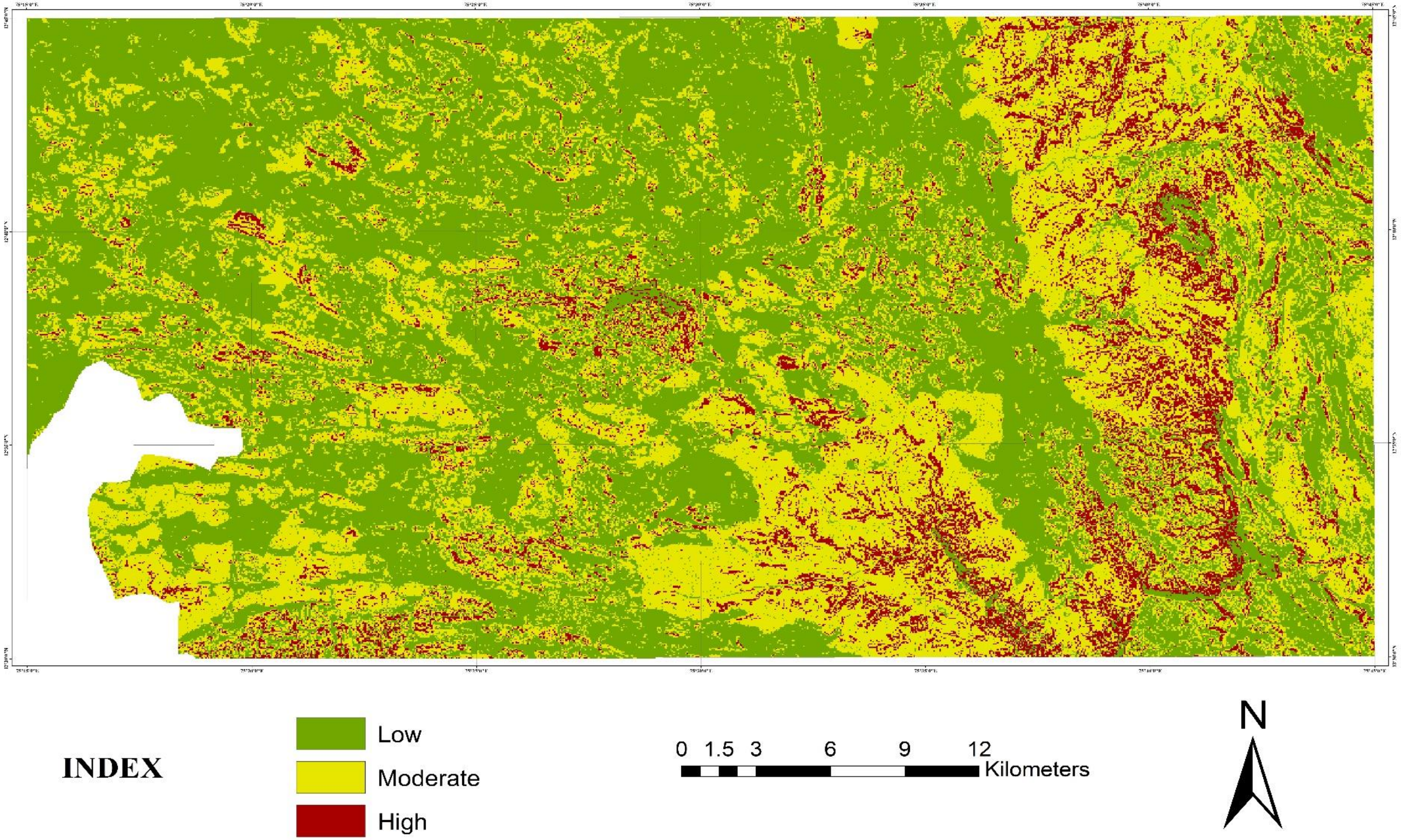


Plate - 12

LANDSLIDE SUSCEPTIBILITY MAP OF PARTS OF T.S. NO. 48P/06 AND 48P/10, DAKSHIN KANNAD DISTRICT



PHOTOGRAPHS

Photo: 1, Cultivation/Plantation on modified slope

Photo: 2, Road cut failure due to toe disturbance.

Photo: 3, An exposure of In-situ lateritic soil.

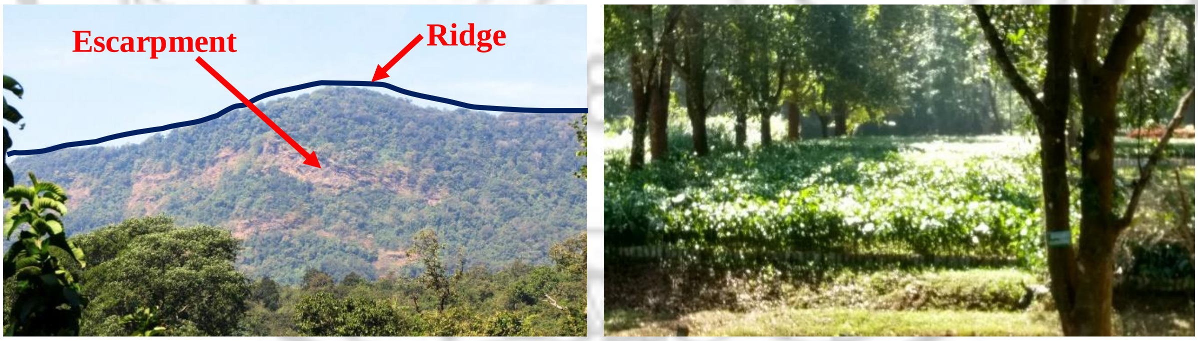


Photo: 4, Hill top ridge, escarpment and nursery for different types of plantation in the study area.

Photo: 5, High Height Plantation (HHP) and Low Height Plantation (LHP) in the study area.

Photo: 6, Slides due to extensive cut slope in the study area.

Photo: 7, Cultivation in the study area.

Photo: 8, Thick Vegetation and Moderate Vegetation in the study area.

Annexure – 1: LOFS Calculations
Geofactor: Land Use Land Cover (LULC)
Rank of LULC Classes

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

Geofactor: Land Use Land Cover (LULC)
Matrix of Pairwise Ratings of LULC Class

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

Geofactor: Land Use Land Cover (LULC)

Estimated Eigen values, fraction rate and LOFS for LULC classes

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

Geofactor: Land Use Land Cover (LULC)

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

LULC	B	CL	ESC	FL	MV	HHP	LHP	QR	S	SM	TV	SV	Sum Rows	CV
B	0.0177	0.0133	0.0315	0.0177	0.0165	0.0141	0.0129	0.0165	0.0194	0.0228	0.0141	0.0228	0.2192	12.3591
CL	0.0355	0.0265	0.0354	0.0355	0.0206	0.0188	0.0193	0.0206	0.0387	0.0266	0.0188	0.0266	0.3229	12.1696
ESC	0.1596	0.2123	0.2833	0.1596	0.4125	0.3379	0.2709	0.4125	0.1742	0.4786	0.3379	0.4786	3.7177	13.1239
FL	0.0177	0.0133	0.0315	0.0177	0.0165	0.0141	0.0129	0.0165	0.0194	0.0228	0.0141	0.0228	0.2192	12.3591
MV	0.0887	0.1061	0.0567	0.0887	0.0825	0.1126	0.1161	0.0825	0.0968	0.0532	0.1126	0.0532	1.0496	12.7240
HHP	0.0709	0.0796	0.0472	0.0709	0.0412	0.0563	0.0774	0.0412	0.0774	0.0399	0.0563	0.0399	0.6984	12.4001
LHP	0.0532	0.0531	0.0405	0.0532	0.0275	0.0282	0.0387	0.0275	0.0581	0.0319	0.0282	0.0319	0.4718	12.1921
QR	0.0887	0.1061	0.0567	0.0887	0.0825	0.1126	0.1161	0.0825	0.0968	0.0532	0.1126	0.0532	1.0496	12.7240
S	0.0177	0.0133	0.0315	0.0177	0.0165	0.0141	0.0129	0.0412	0.0194	0.0228	0.0141	0.0228	0.2439	12.6068
SM	0.1241	0.1592	0.0944	0.1241	0.2475	0.2253	0.1935	0.2475	0.1355	0.1595	0.2253	0.1595	2.0954	13.1358
TV	0.0709	0.0796	0.0472	0.0709	0.0412	0.0563	0.0774	0.0412	0.0774	0.0399	0.0563	0.0399	0.6984	12.4001
SV	0.1241	0.1592	0.0944	0.1241	0.2475	0.2253	0.1935	0.2475	0.1355	0.1595	0.2253	0.1595	2.0954	13.1358

Sum CV 151.33

Mean Consistency Vector (Mean CV) = Total CV/ Nos. Of factor class (151.33/12) = 12.6109

Consistency Index (CI) = (Mean CV - No. Of criteria/ factor class) / (No. Of factor class - 1) = 0.0555

Consistency Ratio (CR) = CI/ RI = 0.0555 / 1.49 = 0.0373

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 – 2: 41 Point Geo-Parametric Data Format for Landslides

1	Name	KAR/DK/SUL/L1/2016
2	Latitude (N) (DMS)	12° 31' 10"
3	Longitude (E) (DMS)	75° 26' 58"
4	Toposheet No.	48P06
5	Village Name	East of Sullia
6	Road	NH - 275
7	Geomorphic Process	Gravitational
8	Geomorphic Form	Moderately Dissected Slope
9	Rock	In-situ laterite
10	Weathering	Moderate
11	Rock Character	Massive
12	Dip Foliation	Not available
13	Dip Direction Foliation	Not available
14	Dip J1	Not available
15	Dip Direction J1	Not available
16	Overburden Type	Weathered Laterite
17	Thickness	> 5 m
18	Landuse	Extensive Slope Cut
19	Hydrology	Damp
20	Erosion	Toe Erosion
21	Susceptibility	High
22	Risk	Moderate
23	Landslide Length	80 m
24	Landslide Width	6 m
25	Landslide Height	12 m
26	Landslide Run Out	Not available
27	Landslide Material	Debris
28	Movement Type	Fall
29	Failure Depth	Deep seated (> 5m)
30	Landslide Activity	Active
31	Landslide Distribution	Enlarging
32	Landslide Style	Single
33	Landslide Mechanism	Shallow Translational Failure
34	Landslide Initiation	Not available
35	Upslope	30°
36	Downslope	70°
37	Triggering Factor	Anthropogenic
38	Casualties	Not available
39	Geo Scientific Cause	Road cutting
40	Remedial Measures	Retaining wall with weep holes
41	Remarks	It may be active due to intense rain fall

1	Name	KAR/DK/SUL/L2/2016

2	Latitude (N) (DMS)	12° 35' 28"
3	Longitude (E) (DMS)	75° 25' 9"
4	Toposheet No.	48P06
5	Village Name	East of Sullia
6	Road	NH - 275
7	Geomorphic Process	Gravitational
8	Geomorphic Form	Moderately Dissected Slope
9	Rock	In-situ laterite
10	Weathering	Moderate
11	Rock Character	Massive
12	Dip Foliation	Not available
13	Dip Direction Foliation	Not available
14	Dip J1	Not available
15	Dip Direction J1	Not available
16	Overburden Type	Weathered Laterite
17	Thickness	.5 m
18	Landuse	Extensive Slope Cut
19	Hydrology	Damp
20	Erosion	Toe Erosion
21	Susceptibility	High
22	Risk	Moderate
23	Landslide Length	9 m
24	Landslide Width	110 m
25	Landslide Height	18 m
26	Landslide Run Out	Not available
27	Landslide Material	Soil
28	Movement Type	Slide
29	Failure Depth	Shallow (<= 5m)
30	Landslide Activity	Active
31	Landslide Distribution	Widening
32	Landslide Style	Single
33	Landslide Mechanism	Shallow Translational Failure
34	Landslide Initiation	Not available
35	Upslope	35°
36	Downslope	60°
37	Triggering Factor	Anthropogenic + Rainfall
38	Casualties	Not available
39	Geo Scientific Cause	Road cutting
40	Remedial Measures	Retaining wall may be built
41	Remarks	It may be active due to intense rain fall

1	Name	KAR/DK/SUL/L3/2016
2	Latitude (N) (DMS)	12° 42' 22"
3	Longitude (E) (DMS)	75° 23' 26.5"
4	Toposheet No.	48P06
5	Village Name	East of Sullia

6	Road	NH - 275
7	Geomorphic Process	Gravitational
8	Geomorphic Form	Moderately Dissected Slope
9	Rock	In-situ laterite
10	Weathering	Moderate
11	Rock Character	Massive
12	Dip Foliation	Not available
13	Dip Direction Foliation	Not available
14	Dip J1	Not available
15	Dip Direction J1	Not available
16	Overburden Type	Soil
17	Thickness	.5 m
18	Landuse	Extensive Slope Cut
19	Hydrology	Damp
20	Erosion	Toe Erosion
21	Susceptibility	High
22	Risk	Moderate
23	Landslide Length	15 m
24	Landslide Width	70 m
25	Landslide Height	10 m
26	Landslide Run Out	Not available
27	Landslide Material	Soil
28	Movement Type	Subsidence
29	Failure Depth	Shallow (<= 5m)
30	Landslide Activity	Active
31	Landslide Distribution	Widening
32	Landslide Style	Single
33	Landslide Mechanism	Shallow Translational Failure
34	Landslide Initiation	Not available
35	Upslope	45°
36	Downslope	75°
37	Triggering Factor	Road widening
38	Casualties	Not available
39	Geo Scientific Cause	Road cutting
40	Remedial Measures	Easing of slope
41	Remarks	

1	Name	KAR/DK/SUL/L4/2016
2	Latitude (N) (DMS)	12° 42' 27"
3	Longitude (E) (DMS)	75° 19' 53"
4	Toposheet No.	48P06
5	Village Name	Near Sullia
6	Road	NH - 275
7	Geomorphic Process	Gravitational
8	Geomorphic Form	Moderately Dissected Slope
9	Rock	In-situ laterite

10	Weathering	Moderate
11	Rock Character	Massive
12	Dip Foliation	Not available
13	Dip Direction Foliation	Not available
14	Dip J1	Not available
15	Dip Direction J1	Not available
16	Overburden Type	Soil
17	Thickness	.5 m
18	Landuse	Extensive Slope Cut
19	Hydrology	Damp
20	Erosion	Toe Erosion
21	Susceptibility	High
22	Risk	Moderate
23	Landslide Length	15 m
24	Landslide Width	70 m
25	Landslide Height	10 m
26	Landslide Run Out	Not available
27	Landslide Material	Soil
28	Movement Type	Subsidence
29	Failure Depth	Shallow (<= 5m)
30	Landslide Activity	Active
31	Landslide Distribution	Widening
32	Landslide Style	Single
33	Landslide Mechanism	Shallow Translational Failure
34	Landslide Initiation	Not available
35	Upslope	50°
36	Downslope	70°
37	Triggering Factor	Road widening
38	Casualties	Not available
39	Geo Scientific Cause	Widening of road
40	Remedial Measures	Retaining wall
41	Remarks	

1	Name	KAR/DK/SUL/L5/2016
2	Latitude (N) (DMS)	12° 25' 58"
3	Longitude (E) (DMS)	75° 27' 50"
4	Toposheet No.	48P06
5	Village Name	South of Arantodu
6	Road	NH - 275
7	Geomorphic Process	Gravitational
8	Geomorphic Form	Moderately Dissected Slope
9	Rock	In-situ laterite
10	Weathering	Moderate
11	Rock Character	Massive
12	Dip Foliation	Not available
13	Dip Direction Foliation	Not available

14	Dip J1	Not available
15	Dip Direction J1	Not available
16	Overburden Type	Soil
17	Thickness	.5 m
18	Landuse	Extensive Slope Cut
19	Hydrology	Damp
20	Erosion	Toe Erosion
21	Susceptibility	High
22	Risk	Moderate
23	Landslide Length	15 m
24	Landslide Width	100 m
25	Landslide Height	10 m
26	Landslide Run Out	Not available
27	Landslide Material	Soil
28	Movement Type	Subsidence
29	Failure Depth	Shallow (<= 5m)
30	Landslide Activity	Active
31	Landslide Distribution	Widening
32	Landslide Style	Single
33	Landslide Mechanism	Shallow Translational Failure
34	Landslide Initiation	Not available
35	Upslope	50°
36	Downslope	70°
37	Triggering Factor	Road widening
38	Casualties	Not available
39	Geo Scientific Cause	Widening of road
40	Remedial Measures	Retaining wall
41	Remarks	

1	Name	KAR/DK/SUL/L6/2016
2	Latitude (N) (DMS)	12° 36' 58"
3	Longitude (E) (DMS)	75° 27' 27"
4	Toposheet No.	48P06
5	Village Name	SE of Arantodu
6	Road	NH - 275
7	Geomorphic Process	Gravitational
8	Geomorphic Form	Moderately Dissected Slope
9	Rock	In-situ laterite
10	Weathering	Moderate
11	Rock Character	Massive
12	Dip Foliation	Not available
13	Dip Direction Foliation	Not available
14	Dip J1	Not available
15	Dip Direction J1	Not available
16	Overburden Type	Soil
17	Thickness	.5 m

18	Landuse	Extensive Slope Cut
19	Hydrology	Damp
20	Erosion	Toe Erosion
21	Susceptibility	High
22	Risk	Moderate
23	Landslide Length	20 m
24	Landslide Width	100 m
25	Landslide Height	15 m
26	Landslide Run Out	Not available
27	Landslide Material	Soil
28	Movement Type	Subsidence
29	Failure Depth	Shallow (<= 5m)
30	Landslide Activity	Active
31	Landslide Distribution	Widening
32	Landslide Style	Single
33	Landslide Mechanism	Shallow Translational Failure
34	Landslide Initiation	Not available
35	Upslope	45°
36	Downslope	70°
37	Triggering Factor	Road widening
38	Casualties	Not available
39	Geo Scientific Cause	Widening of road
40	Remedial Measures	Easing of slope, benching
41	Remarks	

1	Name	KAR/DK/SUL/L7/2016
2	Latitude (N) (DMS)	12° 38' 26"
3	Longitude (E) (DMS)	75° 17' 30"
4	Toposheet No.	48P06
5	Village Name	SE of Kavu
6	Road	SH
7	Geomorphic Process	Gravitational
8	Geomorphic Form	Moderately Dissected Slope
9	Rock	In-situ laterite
10	Weathering	Moderate
11	Rock Character	Massive
12	Dip Foliation	Not available
13	Dip Direction Foliation	Not available
14	Dip J1	Not available
15	Dip Direction J1	Not available
16	Overburden Type	Soil
17	Thickness	.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	110 m
25	Landslide Height	8 m
26	Landslide Run Out	Not available
27	Landslide Material	Soil
28	Movement Type	Subsidence
29	Failure Depth	Shallow (<= 5m)
30	Landslide Activity	Active
31	Landslide Distribution	Widening
32	Landslide Style	Single
33	Landslide Mechanism	Shallow Translational Failure
34	Landslide Initiation	Not available
35	Upslope	40°
36	Downslope	90°
37	Triggering Factor	Road widening
38	Casualties	Not available
39	Geo Scientific Cause	Widening of road
40	Remedial Measures	Retaining wall
41	Remarks	

1	Name	KAR/DK/SUL/L8/2016
2	Latitude (N) (DMS)	12° 37' 5.7"
3	Longitude (E) (DMS)	75° 18' 25.6"
4	Toposheet No.	48P06
5	Village Name	Near Kalanja
6	Road	SH
7	Geomorphic Process	Gravitational
8	Geomorphic Form	Moderately Dissected Slope
9	Rock	In-situ laterite
10	Weathering	Moderate
11	Rock Character	Massive
12	Dip Foliation	Not available
13	Dip Direction Foliation	Not available
14	Dip J1	Not available
15	Dip Direction J1	Not available
16	Overburden Type	Soil + Rock
17	Thickness	.5 m
18	Landuse	Extensive Slope Cut
19	Hydrology	Damp
20	Erosion	Toe Erosion
21	Susceptibility	High
22	Risk	Moderate
23	Landslide Length	15 m
24	Landslide Width	80 m

25	Landslide Height	15 m
26	Landslide Run Out	Not available
27	Landslide Material	Soil
28	Movement Type	Slide
29	Failure Depth	Shallow (<= 5m)
30	Landslide Activity	Active
31	Landslide Distribution	Widening
32	Landslide Style	Single
33	Landslide Mechanism	Shallow Translational Failure
34	Landslide Initiation	Not available
35	Upslope	40°
36	Downslope	80°
37	Triggering Factor	Road widening
38	Casualties	Not available
39	Geo Scientific Cause	Widening of road
40	Remedial Measures	Stepping
41	Remarks	

1	Name	KAR/DK/SUL/L9/2016
2	Latitude (N) (DMS)	12° 41' 41.6"
3	Longitude (E) (DMS)	75° 36' 24.4"
4	Toposheet No.	48P06
5	Village Name	East of Arantodu
6	Road	NH275
7	Geomorphic Process	Gravitational
8	Geomorphic Form	Moderately Dissected Slope
9	Rock	In-situ laterite
10	Weathering	Moderate
11	Rock Character	Massive
12	Dip Foliation	Not available
13	Dip Direction Foliation	Not available
14	Dip J1	Not available
15	Dip Direction J1	Not available
16	Overburden Type	Soil + Rock
17	Thickness	.5 m
18	Landuse	Extensive Slope Cut
19	Hydrology	Damp
20	Erosion	Toe Erosion
21	Susceptibility	High
22	Risk	Moderate
23	Landslide Length	15 m
24	Landslide Width	80 m
25	Landslide Height	15 m
26	Landslide Run Out	Not available
27	Landslide Material	Soil
28	Movement Type	Slide

29	Failure Depth	Shallow (<= 5m)
30	Landslide Activity	Active
31	Landslide Distribution	Widening
32	Landslide Style	Successive
33	Landslide Mechanism	Shallow Translational Failure
34	Landslide Initiation	Not available
35	Upslope	35°
36	Downslope	85°
37	Triggering Factor	Road widening
38	Casualties	Not available
39	Geo Scientific Cause	Widening of road
40	Remedial Measures	Retaining wall
41	Remarks	

Annexure – 3: Field Data Collection Sheet

Sl. No.	Latitude	Longitude	TS No.	Village	Geomorphic Process	Geomorphic Form	Weathering	Overburden Type	Landuse Type	Thickness	Hydrology	Erosion	Susceptibility	Risk
1	12.58222	75.3817	48P/06	Paichar	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	Settlement	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
2	12.58389	75.3722	48P/06	Bolubailu	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	Settlement	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
3	12.58472	75.3633	48P/06	Pilikodi	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	Settlement	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
4	12.59917	75.3311	48P/06	NW of Jalsur	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	Settlement	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
5	12.60389	75.3261	48P/06	4 km NW of Jalsur	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	Settlement	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
6	12.61472	75.3106	48P/06	2 km SE of Duggaladka	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
7	12.62111	75.3003	48P/06	Near Duggaladka	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	MV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
8	12.64333	75.2761	48P/06	Kavu	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	Settlement	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
9	12.65528	75.2681	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	MV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
10	12.595	75.3439	48P/06	E of Jalsur	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	Settlement	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
11	12.59667	75.3614	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
12	12.60056	75.3733	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
13	12.59861	75.3912	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
14	12.62222	75.3769	48P/06	Ivarnadu	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	Settlement	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate

15	12.65056	75.3714	48P/06	S of Bellare	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
16	12.66333	75.3481	48P/06	Nettare	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	Settlement	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
17	12.65333	75.3256	48P/06	SW of Mogappe	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
18	12.63944	75.3128	48P/06	SW of Perampaddy	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
19	12.64222	75.2944	48P/06	SE of Kavu	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
20	12.57317	75.4017	48P/06	East of Paichar	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	Settlement	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
21	12.57722	75.4133	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
22	12.59028	75.4336	48P/06	Duggaladka	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
23	12.59833	75.4492	48P/06	East of Doddathota	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
24	12.59944	75.4808	48P/06	Yelimale	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	Settlement	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
25	12.60389	75.4919	48P/06	Taluru	Fluvial	LDS	Low		Settlement	<0.5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
26	12.54778	75.3994	48P/06	SE of Suliya	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
27	12.53028	75.4144	48P/06	N of Paldka	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
28	12.52389	75.425	48P/06	N of Paldka	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
29	12.51944	75.4494	48P/06	Biliyavu	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	TV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
30	12.51944	75.4778	48P/06	Arantodu	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate

31	12.51361	75.5078	48P/06	1 km E of Gonadka	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	MV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
32	12.51333	75.4711	48P/06	1 km S of Nagadai	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	TV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
33	12.50444	75.4808	48P/06	3 km SE of Nagadai	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
34	12.54292	75.3914	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	MV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
35	12.53056	75.3797	48P/06	1 km N of Gundya	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
36	12.51778	75.3886	48P/06	Gundya	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
37	12.50778	75.3972	48P/06	Baddadka	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
38	12.52806	75.3706	48P/06	Narkodu	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
39	12.52389	75.3556	48P/06	Kombakodu	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
40	12.51778	75.3356	48P/06	Kolucharu	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
41	12.51	75.3078	48P/06	Kelaginakanaw	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	TV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
42	12.52972	75.3281	48P/06	Paimbechalu	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
43	12.54167	75.3306	48P/06	N of Munchal	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	TV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate

44	12.55028	75.3367	48P/06	Ajjavara	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
45	12.55583	75.3611	48P/06	SW of Tudiadka	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	MV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
46	12.55722	75.3736	48P/06	NE of Tudiadka	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
47	12.58556	75.3292	48P/06	SW of Jalsuru	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
48	12.57944	75.3061	48P/06	NE of Muroor	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
49	12.56222	75.3	48P/06	N of Mandukolu	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	TV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
50	12.55083	75.2964	48P/06	Mandukolu	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	MV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
51	12.54861	75.2733	48P/06	W of Kanyana	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	TV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
52	12.55361	75.2789	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	TV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
53	12.56444	75.2842	48P/06	NE of Kanyana	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	TV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
54	12.55494	75.3103	48P/06	Kenaje	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
55	12.55333	75.3239	48P/06	NW of Adpangaya	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	TV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
56	12.56389	75.32	48P/06	Kenaje	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
57	12.525	75.4786	48P/06	Krilia	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	TV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate

58	12.54167	75.4811	48P/06	W of Chukradka	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	TV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
59	12.54972	75.4958	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	TV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
60	12.56806	75.5039	48P/10	Pannebail	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
61	12.585	75.5022	48P/10	Chevaje	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
62	12.5925	75.4889	48P/06	Jerumukki	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
63	12.66611	75.3844	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
64	12.66806	75.4075	48P/06	Pajpalla	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
65	12.67806	75.4272	48P/06	Yenmuru	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
66	12.67139	75.4286	48P/06	Nindikali	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
67	12.66278	75.4328	48P/06	N of Kachila	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
68	12.64861	75.4353	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
69	12.64139	75.4386	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
70	12.62833	75.4364	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
71	12.62167	75.4236	48P/06	Ajjanadka	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
72	12.60694	75.3986	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
73	12.58972	75.4039	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
74	12.67222	75.4425	48P/06	Karikada	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	Settlement	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
75	12.67583	75.4658	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate

76	12.67861	75.49	48P/06	E of Panaja	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Wet	Toe erosion by Nala	Meta-stable	Moderate
77	12.66139	75.4889	48P/06	Kutukunja	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	MV	0.5-5m	Damp	Toe erosion by Nala	Stable	Moderate
78	12.65056	75.4986	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Low
79	12.64028	75.5169	48P/10	Mogra	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp		Stable	Low
80	12.6825	75.4192	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp		Stable	Low
81	12.69333	75.4025	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	SV	0.5-5m	Damp		Stable	Low
82	12.70611	75.3903	48P/06	Punchutaru	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	SV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
83	12.72389	75.3628	48P/06	Kaniyoor	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp		Stable	Low
84	12.7325	75.3453	48P/06	Belandoor	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	SV	0.5-5m	Dry		Meta-stable	Moderate
85	12.72778	75.3175	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	SV	0.5-5m	Dry		Stable	Low
86	12.71194	75.3283	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp		Meta-stable	Moderate
87	12.6925	75.3453	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	TV	0.5-5m	Damp		Stable	Low
88	12.67833	75.3536	48P/06	Peruvaju	Fluvial	Rolling Plain	Moderate	In-situ Soil(Lateritic)	Settlement	0.5-5m	Damp		Stable	Low
89	12.67111	75.3428	48P/06	NW of Manikar	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp		Meta-stable	Moderate
90	12.68639	75.3181	48P/06	Paltadi	Fluvial	Rolling Plain	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp		Stable	Low
91	12.68792	75.3	48P/06		Fluvial	Rolling Plain	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp		Stable	Low
92	12.69556	75.2856	48P/06	Kattaturu	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp		Meta-stable	Moderate
93	12.70861	75.2781	48P/06	Thingalady	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	SV	5-10m	Damp		Meta-stable	Moderate

94	12.72083	75.2769	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp		Meta-stable	Moderate
95	12.72917	75.2869	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	MV	0.5-5m	Damp		Meta-stable	Moderate
96	12.745	75.3067	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp		Meta-stable	Moderate
97	12.69472	75.4281	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp		Stable	Low
98	12.71389	75.4397	48P/06	Yedmangla	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	Settlement	0.5-5m	Damp		Stable	Low
99	12.71028	75.4711	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	TV	5-10m	Damp		Meta-stable	Moderate
100	12.72806	75.4722	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	TV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
101	12.70056	75.4686	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	TV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
102	12.69056	75.4692	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
103	12.51472	75.5004	48P/10		Fluvial	MDS	Moderate	In-situ Soil(Lateritic)	HHP	5-10m	Damp	Toe erosion by Nala	Meta-stable	Moderate
104	12.51056	75.5197	48P/10		Fluvial	MDS	Moderate	In-situ Soil(Lateritic)	MV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
105	12.50139	75.5611	48P/10		Fluvial	MDS	Moderate	In-situ Soil(Lateritic)	MV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
106	12.50944	75.5639	48P/10		Fluvial	MDS	Moderate	In-situ Soil(Lateritic)	TV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
107	12.51906	75.5781	48P/10		Fluvial	MDS	Moderate	In-situ Soil(Lateritic)	TV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
108	12.51722	75.5819	48P/10		Fluvial	MDS	Moderate	In-situ Soil(Lateritic)	TV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
109	12.61444	75.5022	48P/10		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
110	12.62556	75.5144	48P/10		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
111	12.63306	75.5525	48P/10	NE of Halemajlu	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate

112	12.65361	75.5808	48P/10	Kallaje	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
113	12.65611	75.6014	48P/10		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
114	12.67722	75.5019	48P/10		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	TV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
115	12.67083	75.5222	48P/10	ESE of Bapla	Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	TV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
116	12.66722	75.5367	48P/10		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	TV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
117	12.66917	75.5481	48P/10		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	MV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
118	12.67	75.57	48P/10		Fluvial	Rolling Plain	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
119	12.67194	75.5861	48P/10		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	TV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
120	12.66111	75.61	48P/10		Fluvial	Pediment-Pediplain Complex	Moderate	In-situ Soil(Lateritic)	Settlement	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
121	12.68806	75.6042	48P/10		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	TV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
122	12.70333	75.5956	48P/10		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	TV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
123	12.705	75.58	48P/10		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	TV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
124	12.72306	75.5578	48P/10	Nettana	Fluvial	Rolling Plain	Moderate	In-situ Soil(Lateritic)	MV	5-10m	Damp	Toe erosion by Nala	Meta-stable	Moderate
125	12.7375	75.5361	48P/10	Sunkadkatte	Fluvial	Rolling Plain	Moderate	In-situ Soil(Lateritic)	MV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
126	12.74139	75.5114	48P/10		Fluvial	Rolling Plain	Moderate	In-situ Soil(Lateritic)	MV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
127	12.73917	75.4722	48P/10		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	MV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
128	12.63789	75.5675	48P/10		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	TV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
129	12.62694	75.585	48P/10		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	TV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate

130	12.60778	75.6042	48P/10		Fluvial	Pediment-Pediplain Complex	Moderate	Transported Soil	Settlement	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
131	12.60083	75.6056	48P/10		Fluvial	MDS	Moderate	In-situ Soil(Lateritic)	TV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
132	12.57944	75.6106	48P/10		Fluvial	MDS	Moderate	In-situ Soil(Lateritic)	MV	0.5-5m	Damp	Toe erosion by Nala	Stable	Moderate
133	12.56361	75.6217	48P/10		Fluvial	Pediment-Pediplain Complex	Moderate	Transported Soil	TV	0.5-5m	Damp	Toe erosion by Nala	Stable	Moderate
134	12.54972	75.6267	48P/10		Fluvial	Pediment-Pediplain Complex	Moderate	Transported Soil	TV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
135	12.52417	75.6339	48P/10		Fluvial	Pediment-Pediplain Complex	Moderate	Transported Soil	TV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
136	12.60944	75.5033	48P/10		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
137	12.60278	75.5186	48P/10		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
138	12.60667	75.5356	48P/10		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
139	12.61528	75.5397	48P/10		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
140	12.59278	75.4408	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
141	12.58139	75.4422	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
142	12.57028	75.4325	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
143	12.56	75.4181	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
144	12.55333	75.405	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
145	12.55694	75.3985	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
146	12.61639	75.4158	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	TV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate

147	12.62944	75.4108	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	MV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
148	12.6475	75.4011	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	TV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
149	12.66028	75.3936	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	MV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
150	12.61278	75.4406	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	MV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
151	12.60722	75.4336	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
152	12.61722	75.4314	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	TV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
153	12.62722	75.4358	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
154	12.64611	75.435	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	MV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
155	12.66333	75.4303	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
156	12.58278	75.3525	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	MV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Low
157	12.57167	75.3433	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	TV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
158	12.54944	75.3322	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	TV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
159	12.71472	75.5958	48P/10		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	TV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
160	12.74278	75.5939	48P/10		Fluvial	Rolling Plain	Moderate	In-situ Soil(Lateritic)	TV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
161	12.50111	75.7475	48P/10		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	TV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
162	12.51167	75.7364	48P/10		Fluvial	MDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
163	12.52722	75.7322	48P/10		Fluvial	MDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
164	12.58222	75.7461	48P/10		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
165	12.59833	75.7378	48P/10		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate

166	12.61556	75.7469	48P/10		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
167	12.58944	75.4497	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
168	12.57278	75.4664	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
169	12.5625	75.4858	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	TV	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
170	12.56639	75.5022	48P/10		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
171	12.55833	75.505	48P/10		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
172	12.54583	75.4919	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate
173	12.57403	75.4039	48P/06		Fluvial	LDS	Moderate	In-situ Soil(Lateritic)	HHP	0.5-5m	Damp	Toe erosion by Nala	Meta-stable	Moderate

Annexure – 4: Annual Rain Fall Data of the Study Area

Year **Station**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Ivrnadu	3967	4345.6	3285.7	3434.6			3025.54	4652.1	4054.2	2784.7
Kolladu							2960.6			
Airvathoklu		4147.3			5334.1		3073			
Sullia Kasba	4061.5	4280.6	3198.6	3166.8	3800.4	4156.3	2768.4	3889.04		3092.8
Subramanya	49256	4268.6	4412	5747.4	5333.2	4905.8	3861.6	6917.2	4371.6	4108.4
Jalsuru	3571.1	4130.6			3447.1		2466.5		3872.8	3097.5
Gotadka								4275.2		
Isollehar								3612.1		
Panja			3383.6	4225.7		3424		4310		
Sunkakatte										3434.5
Aletty		4070.3			3458.3					
Peeranadu						4468.28				
Kolwor						4522.4				
Gurtalli						3160.11				
Beltangady			4043.5							
Kolcharu	4065.8		3205	3440.3						
Gonadaka	4036.4		2844.2	2897.6						
Kadaba				4234.5						
Kollanogru	4289.9									
Sirodi		5286.3								