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Landslide Susceptibility Mapping along the National Highway-1D, between Kargil and Lamayuru, Ladakh Region, Jammu and Kashmir

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ABSTRACT

Landslides commonly occurs in hilly areas and causes an enormous loss iof life and property every year. National highway-1D (NH-1D) is the only road link between the two districts (Kargil and Leh) of Ladakh region that connects these districts with Kashmir valley. The landslide failure record of the recent past along this sector of the highway is not available. The present study documents landslide susceptible zones and records occurrence of 60 landslides during the last 4 years showing an increasing trend in the occurrence of landslides over these years in this sector. The landslide susceptibility zonation map has been prepared based on the numerical rating of ten major factors viz. slope morphometry, lithology, structure, relative relief, land cover, landuse, rainfall, hydrological conditions, landslide incidences and Slope Erosion, categorised the area in different zones of instability based on the intensity of susceptibility. The landslide susceptibility map of the area encompassing 73.03 km^2 is divided into 150 facets. Out of the total of 150 facets, 85 facets fall in low susceptibility zone covering 43.56 km^2 which constitute about 59.65% of the total area under investigation with a record of 5 landslides; 40 facets fall in the moderate susceptibility zone covering 16.94km^2 which constitutes about 23.19% of the study area with a record of 20 landslides; and 25 facets fall in the high susceptibility zone covering 12.53 km^2 which constitute about 17.15% of the study area with a record of 35 landslides. Most of the facets which fall in HSZ are attributed to slope modification for road widening.

INTRODUCTION

Generally, landslides are triggered by the site-specific exogenic and endogenic factors such as rainfall, tectonic activity, seismicity, topography, lithology, slope, etc. In addition, human interference also plays a critical role in their initiation (Das et al. 2011). Landslides have been recognised as the significant natural disaster in the country and particularly in hilly regions (Aleotti and Chowdhury 1999) especially in the Himalayan region. The mountain areas of the Himalaya, Western Ghats and the Meghalaya plateau cover around 15% of the country's (~0.49 million km^2) landslide prone area (GSI, 2005) which triggers during monsoon season. Singh and Bhat (2010) in their study long NH-1A inferred that the problem of landslides varies differently due to a diversity of lithological conditions and processes that triggered them. Singh et al. (2011B) in their study along NH-39 in Manipur are also of the opinion that due to the inattention of geological and geotechnical factors during highway construction results in the increase of slope instability. Singh et al. (2012) in their study along NH-1B reveals that the human interference such as road construction without proper scientific study and planning has resulted in landslides.

The present study is restricted to Ladakh, the northernmost region of the state of Jammu and Kashmir which remains cut off from rest of the country for more than 6 months, due to its climatic conditions. The study area along the Kargil-Leh National Highway (NH1D) lies in NW Himalayan region which comprises of highly weathered, jointed, fractured and sheared rocks within a terrain drained by youthful rivers which consistently modify and degrade the landforms in the region. The analysis of landslides along the national highway-1D is important because this is the only lifeline of the two districts of Ladakh region (Kargil and Leh) with other parts of the state of Jammu and Kashmir but strategically also very important road network. In the recent years, it has been observed that frequency of landslides and slope failures have increased along this highway particularly during unprecedented rainfall. The real cause of triggering mechanism of the landslides in this region is unknown and no study has been carried out so far on this aspect. This study is the first attempt to study crucial landslide susceptibility zones and prepare landslide hazard zonation map along this sector of the highway between Kargil and Lamayuru.

Landslide hazard zonation (LHZ) generally a process to classify the land surface into area and ranking of these areas according to degrees of actual hazard caused by landslide within a specific period of time in given area (Varnes, 1984). Where in practice LHZ is often involves mapping depicting the classification and spatial distribution of probable landslides in the study area (Brabb, 1984) i.e., (where it is likely to be occur) and does not consider temporal probability i.e., (how and when landslide occurs), Therefore it is better to consider these as landslide susceptibility zonation (LSZ) instead of landslide hazard zonation (LHZ). Brabb (1993) inferred that 90% of landslide losses can be avoided if the problem is recognised before its initiation. Hence the study of landslide hazard assessment at different spatial scale is very important keeping in view the development activities that are taking place all along these highways in these hilly regions of the country. Guzzetti et al. (1999) reveal that landslide hazard and susceptibility zonation mapping based on various methods and scale of assessment depends on the requirement of the study. Several landslide hazard zonation mapping methods includes direct geomorphological mapping (Cardinali et al., 2002; Guzzetti et al., 2005) and analysis of landslide inventories (Guzzetti et al., 1994; Moreiras, 2004; Soeters and Van Westen, 1996), Heuristic method (Montgomery et al., 1991; Pachauri et al., 1998). Anbalgan (1992) formulated the guidelines for landslide hazard assessment and later modified by GSI (2005) is basically heuristic approach based on LHEF rating system. Based on this methodology number of workers have carried out landslide hazard zonation mapping in different parts of the country on a different scale with some revision in the methodology. The prominent works include (Sharma, 2008; Sarkar and Anbalagan, 2008; Anbalagan et al., 2008; Surendranath, 2008; Ghosh et al., 2009; Saranathan et al., 2010; Mehta et al., 2010; Kannan et al., 2011; Singh

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et al., 2011; Saranathan et al., 2012; Sharma and Mehta, 2012; Kishor Kumar et al., 2012; Malik et al., 2102; Anbazgan and Ramesh, 2014; Singh et al., 2014; Kanan et al., 2015; and Ramesh et al., 2017).

STUDY AREA

The study area lies between Kargil and Lamayuru along the National Highway (NH1D) which falls in the Indus Tectonic and Trans Himalaya zones of NW Himalaya. The study area is covered by the Survey of India toposheets 52B/2, 52B/3, 52B/7, 52B/11and 52B/15. The area is barren, rocky and comprised of incised valleys and mountains cut into very steep and narrow gorges. The highway in the study area passes through an altitude 2980 m in the valley and 4500 m on the peaks. The high mountain ranges are covered with glaciers and are characterised by snow covered peaks of Ladakh ranges. The area is partly drained by the Indus river and mainly by one of its tributaries i. e., Wakha Chu River which is fed by a number of streams of various orders flowing in the northwesterly direction. The region receives scanty annual rainfall mostly from June to September and experiences heavy snowfall from October to May. There is great variation in day and night temperatures and the average summer temperature goes up to 35°C in July while the average winter temperature dips down to 40°C below freezing point (Shafiq et al., 2013).

GEOLOGICAL SETTING

The study area comprises of the rocks of Indus Tectonic zone and adjoining Trans-Himalayan batholiths (Srikantia and Razdan 1980) (Fig. 1). The present work carried out along the national highway-1D traversing nearly NW to SE through different tectonostratigraphic units. At the western extremity of the study area, rocks of Ladakh Granite are exposed along the national highway comprising of an association of granite, granodiorite and diorite which are weathered and moderately jointed. The rocks of Sangelungma Group comprising of basalt, chert, sandstone, shale, and limestone, while as the rocks of undifferentiated Kulling-Lilang Group comprising of shale and fossiliferous limestones are the main lithotectonic units exposed in the study area.

METHODOLOGY

In landslide study, landslide inventory is the basic information that records the location, timing, date of occurrence and landslide scars in the area (Cruden 1991). In the present study, a total of 60 landslide site has been identified along the national highway 1-D through collection of data on different parameters. The type of landslide observed includes rockfall (planar, topple and wedge), debris flow and slides (Fig.2). The landslide susceptibility map of the study area was prepared on 1:50000 scale. The guidelines set by GSI (2005) and Anbalagan (2008) were followed. These guidelines provide that landslide susceptibility depicts the spatial assessment of varying degree of instability of an area based on landslide susceptibility evaluation factor (LSEF) and total estimated susceptibility (TES). LSEF is a numerical rating system in which ratings are assigned to factors like lithology, structure, slope morphometry, relative relief, landcover, landuse, landslide incidence, rainfall, hydrogeological condition, and slope erosion based on their roles in destabilising the area. A detailed rating system for the causative factors is shown in Table 1. The total estimated susceptibility of an individual facet is obtained by numerical adding of maximum rating (LSEF) of major causative factors and indicates the net probability of instability.The facet map was prepared from Survey of India topographical map on 1:50000 scale by dividing the area into zones of uniform slope. Facet is a smallest and basic unit of slope having a consistent inclination as well as direction and delineated by ridges, spurs, gullies, and drainages, etc. A total of 150 facets were delineated in this study. The facet-wise analyses were carried out according to the LHEF rating system and the final susceptibility map is classified into five zones based on the ranges of total estimated susceptibility (TES) values (Table 2). The lithological, structural, landuse, landcover, hydrogeological condition, landslide incidence and slope erosion data were collected from the field. Slope morphometry and relative relief maps were prepared from topographical map and rainfall data were acquired from the Indian Metrological Department (IMD)

CAUSATIVE FACTORS/PARAMETERS

Lithology

Lithology is one of the important internal factors which controls slope stability. Ratings to the lithological units exposed along the highway were assigned after doing necessary weathering correction and maximum rating value assigned for this parameter is 2.0 (Table 3). This study followed the geological map prepared by Srikantia and Razdan (1980) and collected filed data for assigning the rating value. The main rock types exposed in the area are granite, diorite, basalt, ophiolitic rocks, and limestone. The Rock Type 1 (igneous rock and limestone) with varying degree of weathering (Table 4) and debris and clay soil is most dominant.

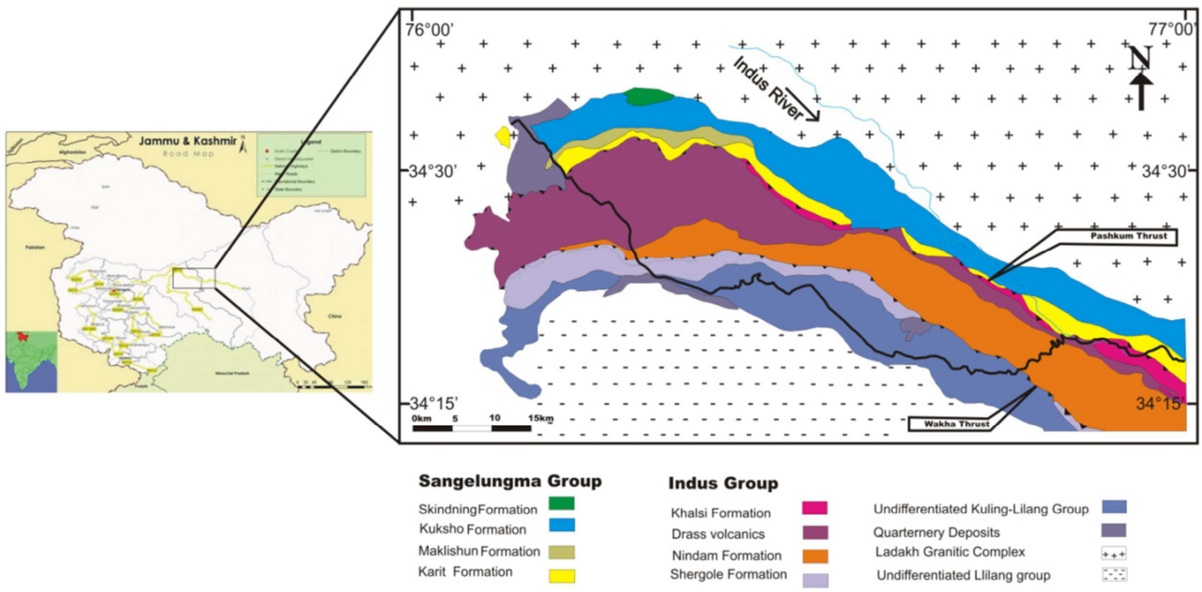

Fig.1. Geological map of study area after Srikantia and Razdan (1980)

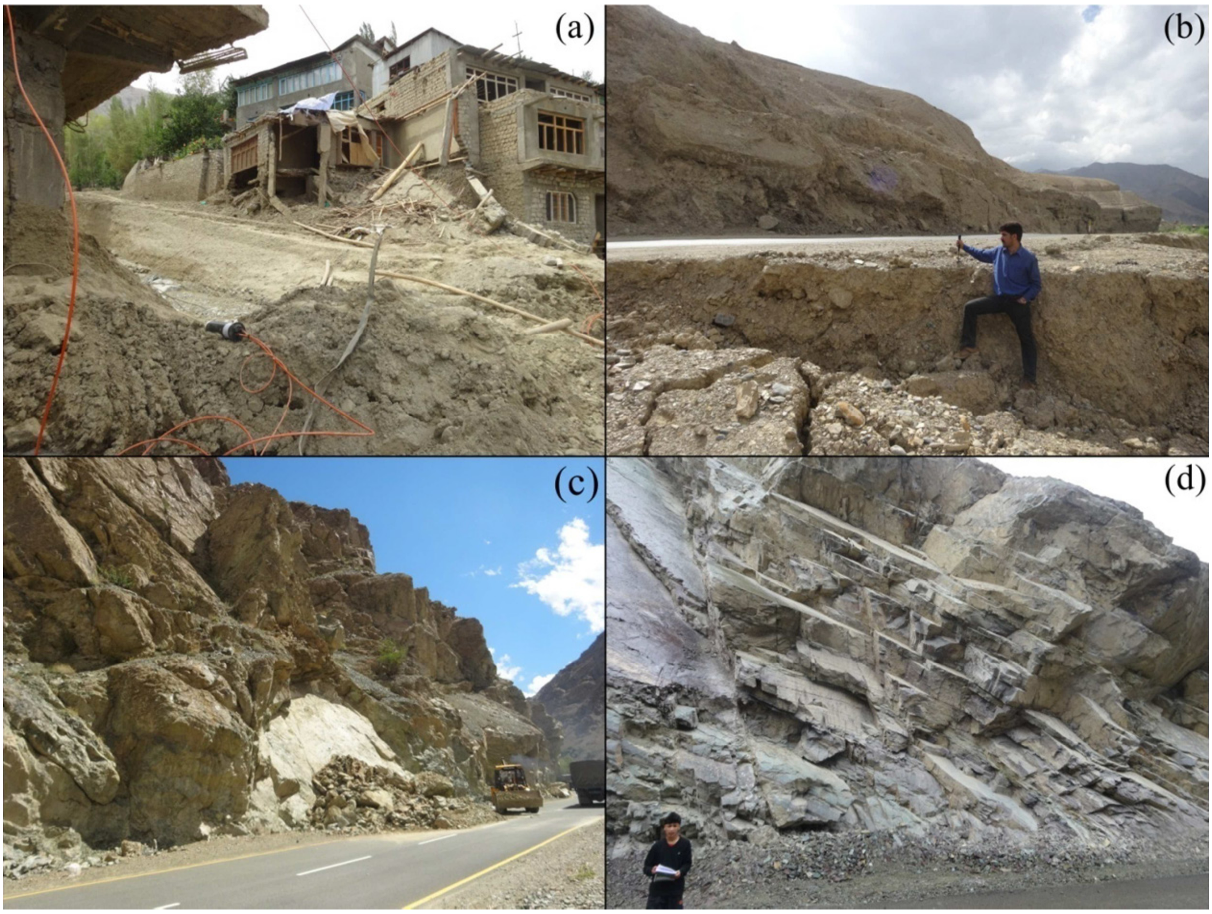

Fig 2: Field photograph of landslide occurrences (a) Debris slide at Adul Gone (b) Translational slide at Saraks (c) Plane failure at Darket (d) Wedge failure at Lamayuru

Structure

Structures such as bedding planes, joints, foliations, faults and thrusts play an important role in triggering the landslides and greatly influence slope instability in relation to slope angle. The orientation of joints and slope data were recorded and interpreted for each slope facet to find out the probable direction and mode of failure (planar, wedge and toppling). The observed three types of structural relationships between joints and slope face, i.e., (i) relationship between the direction of discontinuity and the slope, (ii) dip of the discontinuity and (iii) difference in the dip amount of discontinuity and angle of the slope. LHEF rating (Table 5) was assigned for these parameters in each facet and in the case of soil slope the thickness of the soil bed was measured and the rating value was accordingly assigned. Out of the 150 facets, 92 facets have the lowest structural rating value of 0.65 whilst 30 facets have structural rating value of 0.85; 8 facets have structural rating value of 1.60; 7 facets have structural rating value of 1.80; 4 facets have structural rating value of 2; 3 facets have structural rating value of 1.70; 2 facets have structural rating value of 1.45; 2 facets have structural rating value of 1.90 and 1 facets each have each have rating value of 1.55 and 1.75 respectively (Table 5).

Table 1. LSEF rating for causative factors/parameters after GSI (2005)

Parameters	Rating
Lithology	2
Structure	2
Slope morphometry	2
Relative relief	1
Land cover	1
Landuse	1
Slope erosion	1
Hydrogeological condition	1
Landslide incidence	2
TEHD	14

Table 2. Landslide susceptibilty zonation based on TES

Zone	TES Value	Description of Zone
I	< 4.9	Very Low Susceptible Zone (VLSZ)
II	4.91 - 7.0	Low Susceptible Zone (LSZ)
III	7.1 - 8.4	Moderate Susceptible Zone (MSZ)
IV	8.41 - 10.5	High Susceptible Zone (HSZ)
V	> 10.5	Very High Susceptible Zone (VHSZ)

Slope Morphometry

Slope morphology is another important factor which is responsible for landslide occurrence. Slope morphometry is categorised on the basis of a critical angle at which landslide occurs in an area. The slope morphometry map for every facet was prepared by calculating $\tan^{-1}$ (slope angle) of vertical interval (V) divided by the horizontal distance (H) in the facet. The vertical interval was calculated by counting the number of contours at 40 m interval in a facet, while the horizontal distance was measured on toposheet (1:50,000 scale) along the direction of slope in a facet. The facet map marked by an arrow sign represents the direction of the slope and is grouped into five sub-categories, i.e., (i) escarpment >45º; (ii) steep slope 36-45º; (iii) moderately steep slope 26-35º, (iv) gentle slope 16-25º, and (v) very gentle slope <15º. The LHEF rating for this parameter was assigned accordingly and enumerated in Table 6. The distribution of different slopes in all the 150 facets reveals that 18% fall in escarpment/cliff; 10% fall in the steep slope; 23% fall in moderate slope and 48% fall in gentle slope categories. In this study, it has been observed that 36% of

Table 3. Lithological evaluation factor rating system

Contributory Factor: Lithology				Maximum LHEF Rating: 2
Description		Category	Rating	Remarks
Rock Type	TYPE 1	Quartzite/Limestone/BHQ etc.	0.2	I) Highly weathered: Rock discoloured, joints open with weathered products, rock fabric altered to a large extent. Correction Factor – C_1
		Granite/Basalt/Charnockite etc.	0.3	
		Gneiss	0.4	
	TYPE 2	Well cemented terrigenous sedimentary rocks dominantly sandstone with minor beds of claystone.	1.0	II) Moderately Weathered:Rock discoloured with fresh rock patches, weathering more along joint planes, but rock intact in nature. Correction Factor – C_2
		Poorly cemented terrigenous sedimentary rocks dominantly sandrock with minor clayshale beds.	1.3	III) Slightly Weathered: Rock slightly discoloured along joint planes but intact in nature. Correction Factor – C_3
	TYPE 3	Slate and Phyllite	1.2	
		Schist	1.3	For Rock Type-I: $C_1 = 4$, $C_2 = 3$; $C_3 = 2$;
		Shale with interbedded clayey and non-clayey rocks.	1.8	For Rock Type-II: $C_1 = 1.5$, $C_2 = 1.25$; $C_3 = 1.0$
		Highly weathered shale, phyllite and schist.	2.0	
Soil type		Older well compacted alluvial fill material	0.8	
		Clayey soil with naturally formed surface	1.0	
		Sandy soil with naturally formed surface (Alluvial)	1.4	
		Debris comprising mostly rock pieces mixed with clayey/sandy soil (Colluvium)		
		Older well compacted	1.2	
		Younger loose material	2.0	

landslide incidence in the study area are on escarpment/cliff; followed by 30% incidence on a moderately steep slope; 10% landslide incidence on steep slope and 23% landslide incidence on a gentle slope (Table 6)..

Relative Relief

Relative relief represents the maximum height of a facet, from the base (valley floor) to top (ridge/spur) measured along the slope direction. Relative relief of a facet can simply be calculated by counting the difference between the elevations at the bottom most point of a facet to the top most point of the same, in the slope direction. In the present study, relative relief factor is categorised into three classes, i.e., (i) low <100m, (ii) medium 100-300m and (iii) High>300 m, and the ratings of 1.0, 0.6 and 0.3 were assigned to them respectively. Out of the 150 facets, 125 facets fall under medium relative relief and 25 fall in high relative relief (Table 6). In this study, it has been observed that 78% landslide incidence on the moderate relief facets and 21% on the high relief facets.

Table 4. Weathering evaluation factor rating system

Lithological units	Rating	Number of facets	No. of landslides incidence in recent years
Moderately weathered Ladakh Granite	0.9	5	6
Moderately weathered Drass Volcanics	0.9	17	11
Moderately weathered limestone	0.6	6	10
Colluvium materials	1.6	16	4
Sandy soil with naturally formed surface	1.4	7	6
Clay soil with naturally formed surface	1	95	21
Moderately weathered conglomerate	1.25	4	2

Land cover

The slope stability within an area is also governed by the vegetation cover because the slope with uniformly distributed vegetation cover is less prone to slope failures as the plant roots penetrate soil and anchor loose slope forming materials and also reduces the action of weathering and erosion. The study area falls in cold desert and most of the area is barren land. The landcover was categorised into three subcategories, i. e., (i) moderately vegetated, (ii) sparsely vegetated and (iii) barren land and the ratings of 0.4; 0.6 and 1.0 were assigned respectively (Table 6). The study inferred that 150 facets fall in the barren land category, 1 each facet fall in moderately vegetated and in sparsely vegetated categories. It has been observed 95% of landslide incidence in a barren land, 3.5% in moderately vegetated and 1.5% in sparsely vegetated.

Landuse

Landuse pattern plays an important role is slope stability. During the recent years, developmental activities including road widening by mechanical means including blasting; poor remedial measure has deteriorated slopes along the highway. The slopes in the study area remain snow-covered for 3-4 months and the melting of snow enhance weathering and erosion and result in fall of colluvial materials along the highway. This parameter has been categorised into four sub-categories. i.e., (i) populated flat land, (ii) minor modification of natural slope, (iii) major modification of slope and (iv) extensive cutting and ratings of 0.4; 0.6; 0.8; and 1.0 were assigned respectively (Table 6). It has been observed that 78% of landslide incidence is due to extensive cutting followed by 18% attributed to major modifications and 4% due to minor modifications.

Table 5. Structure evaluation factor rating system

Contributory Factor: Structure			Maximum LHEF Rating: 2	
Description	Category		Rating	Remarks
I. Relation of structural discontinuity with slope Planar (α_j-α_s) Wedge (α_i-α_s) Toppling (α_j-α_s-180)	I II III IV V	> 30° 21° -30° 11°-20° 6° -10° < 5°	0.20 0.25 0.30 0.40 0.50	Discontinuity refers to the planar discontinuity or line of intersection of two planar discontinuities whichever is important from the point of viewof stability, α_j = Dip direction of joint α_i = Dip direction of joint α_s = Direction of slope inclination β_j = Dip of joint β_i = Plunge of line of two discontinuities β_s = Inclination of slope β_j / β_i = β_j or β_i Category I : Very favourable Category II: Favourable Category III: Fair Category IV: Unfavourable Category V : Very unfavourable
II. Relationship of discontinuity and inclination of slope Planar (β_j-β_s) Wedge (β_i-β_s) Sum of the angle Topple (β_j+β_s)	I II III IV V I II III IV V	> 10° 0° - 10° 0° 0° - (10°) >-10° ≤110° 111°-130° 131°-140° 141°-160° >160°	0.30 0.50 0.70 0.70 1.00 0.30 0.50 0.70 0.70 1.00	
III. Dip of discontinuity Planar - β_j Wedge - β_i Topple - β_j	I II III IV V I II III IV V	< 15° 16° - 25° 26° - 35° 36° - 45° > 45° <50° 51° - 60° 61° - 70° 71° - 80° >80°	 0.20 0.25 0.35 0.50 0.20 0.30 0.40 0.45 0.50	
Depth of Soil Cover	> 5m 6 - 10m 11 - 15m 16 - 20m > 20m		0.65 0.85 1.20 1.50 2.00	

Hydrogeological Condition

In hilly areas, groundwater does not follow a uniform pattern and is generally channelized along structural discontinuities within the rocks. The presence of ground water generally decreases the shear strength of slope forming material and induces instability. It is very difficult to observe and assess the character of groundwater on hill slopes for individual facet over large areas. In order to make a quick assessment of ground water conditions in a facet, the surface indications shall provide valuable information on the stability of hillslopes. This parameter has been categorised into three types, i. e., (i) dry, (ii) wet and (iii) flowing and the ratings were assigned (Table 6). It has been found 136 facets fall in a dry condition, 14 facets fall in wet condition. In 136 facets falling in dry condition are affected by 90% landslide incidence and 14 facets falling in wet condition are affected by 10% of landslide incidences.

Rainfall

Rainfall is one of the most important factors responsible for initiation of slope instability. A landslide can trigger by rainfall when threshold intensity of soils involved exceed in terms of pore water pressure. The study area is rain shadow region and receives >100 mm rainfall annually. The average annual rainfall for Ladakh region for the last 6 years is 53.76 mm (Fig. 3). All the facets are assigned LHEF rating value of 0.2 (Table 6). The study area is barren and at some places sparsely vegetated. It allows rainwater to flow easily along the slopes and wash out the regolith and causes failures.

Slope Erosion

The slope erosion is a very common phenomenon in young and immature topography along the hill slopes. The most common aspects of toe erosion are deep gully, toe erosion by nalas and rivers, etc. which destabilise slopes alarmingly. This parameter has been classified into two categories. i. e., deep gully erosion/rill erosion of hill slope and severe toe erosion by nala and rivers. The rating values were assigned and results obtained are given in Table 6. The result inferred that in study area all 150 facets are affected by rill erosion.

Landslide Incidence

Landslide Incidence is one of the important parameters used in landslide susceptibility mapping. Following the GS1 guidelines (2005)

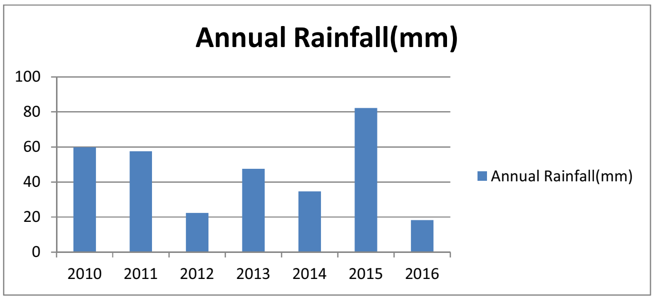

Fig.3. Rainfall distribution in the study area for last six years. Source: IMD

Table 6. Landslide Susceptibility Evaluation factor rating system causative factors and their relation to landslide incidence

Description	Category	Rating	No. of facets	No. of landslide incidence
Contributory factor: Slope Morphometry				
Escarpment	>45	2.0	27	22
Steep slope	36-45	1.7	15	6
Moderately steep slope	26-35	1.2	35	18
Gentle slope	16-25	0.8	73	14
Very gentle slope	<15	0.5		
Contributory factor; Relative relief				
Low	<100m	0.3		
Medium	100-300	0.6	125	47
High	>300	1	25	13
Contributory factor; land cover				
Moderately vegetated		o.4	1	2
Sparsely vegetated		0.6	1	1
Barren land		1	148	57
Contributory factor: land use				
Populated flat land		0.4	4	0
Minor modification of natural slope		0.6	3	2
Major modification of slope		0.8	21	11
Extensive cutting		1	122	47
Contributory factor: Hydrogeological condition				
Dry		0.2	136	54
Wet		0.5	14	6
Flowing		1		
Contributory factor: Rainfall				
Average annual rainfall	Low<500	0.2	150	60
	Medium 500-2000	0.4		
	High >2000	0.6		
	History of cloud bursts	1.0		
Contributory factor: Landslide incidence				
Landslide incidence	No landslides	0	8	
	Raveling failures	0.2	88	
	Subsidence	0.8	18	
	Rockfall	1	24	
	More than one slide in each facet (material dislodged>100m^3)	2	12	
Contributory factor: Slope erosion				
	Deep gully erosion/rill erosion of hill slope	0.5	150	60
	Severe toe erosion by nala and river	1		

slopes are classified into five categories i. e., no landslides; ravelling failures; subsidence; rock fall; and more than one slide in a facet (material dislodged >100m^3) and accordingly the ratings were assigned to each category and the results are given in Table 6.This study recorded 60 landslide incidences during the last four years (2012-2016) in the area. 88 facets were affected by the raveling failure, 24 facets by rockfall, 18 facets by subsidence, 12 facets by more than one slide in a facet; and 8 facets were not affected by any kind of landslide incidence.

LANDSLIDE SUSCEPTIBILITY ZONATION MAP

The landslide susceptibility map (Fig.5a and 5b) along the National Highway-1D encompassing an area of 73.03 km^2 from Kargil to Lamayuru has been prepared according to the guidelines provided by GSI (2005) and Anbalagan (2008). Facet map of the study area (Fig 4a and 4b) is extracted from the topographic map with natural boundaries like hill ridges, gullies, streams, and the major break in hill slopes. The area was divided into 150 facets with numbering and the directional arrow showing the slope direction. The detail Landslide susceptibility evaluation factor system (LSEF) and the numerical rating of subcategories are enumerated in (Table 3, 4, 5 and 6).The landslide susceptibility map has been prepared by adding the numerical rating of all major causative factors to each facet in order to obtain the total estimated susceptibility (TES).

In the study area, a total of 150 facets have been delineated from the topographic map and the total estimated susceptibility (TES) map prepared shows that 25 facets fall in high susceptibility zone; 40 facets fall in moderate susceptibility zone and 85 facets fall in low susceptibility zone (Fig.5a and 5b). The result inferred that the present study area falls only into three susceptibility zone i.e. low, moderate and high. The low susceptibility zone incorporates an area of 43.56 km^2 which is 59.65% of the study area and is affected by 5 landslides.

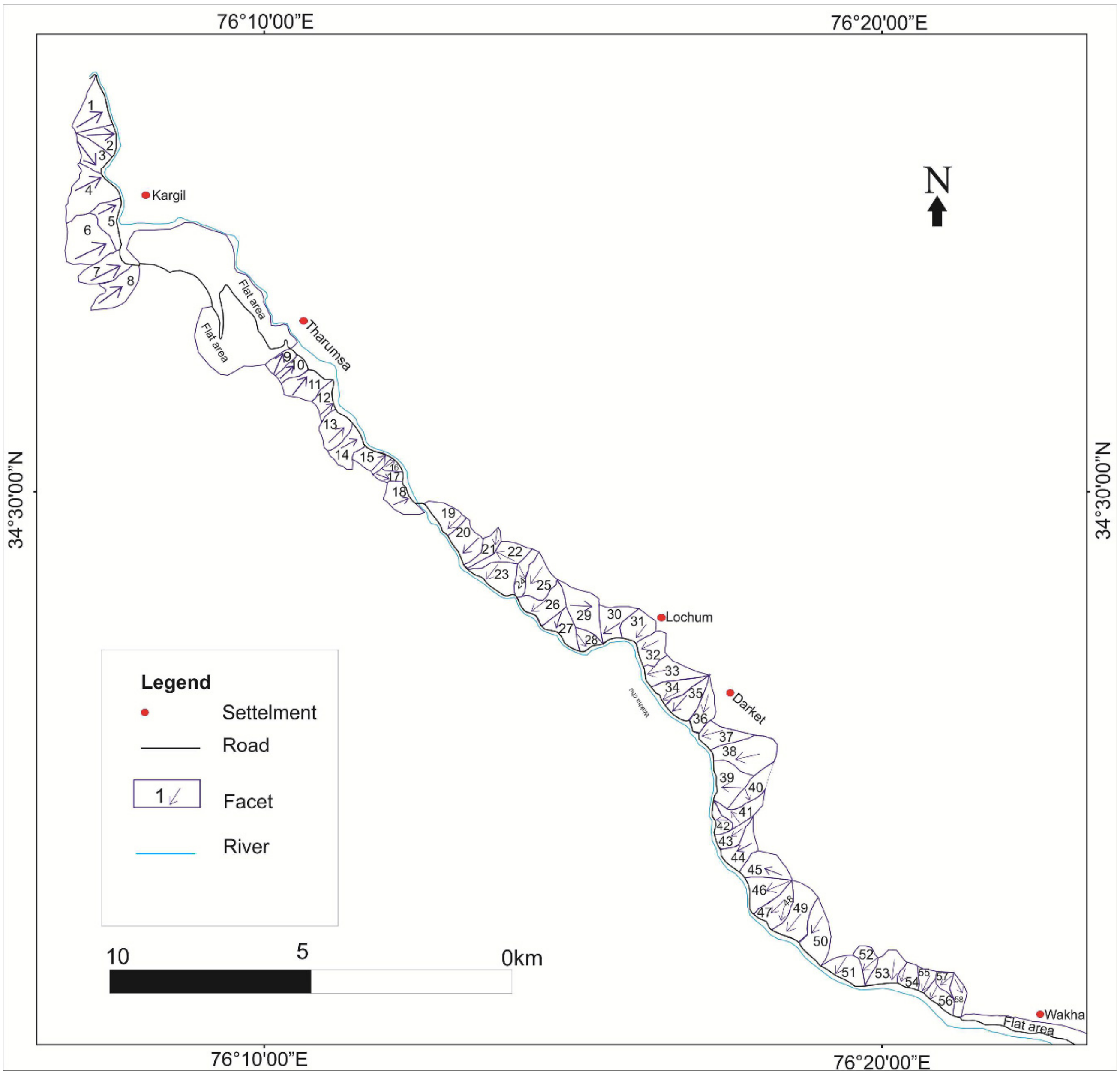

Fig 4(a): Facet map of study area.

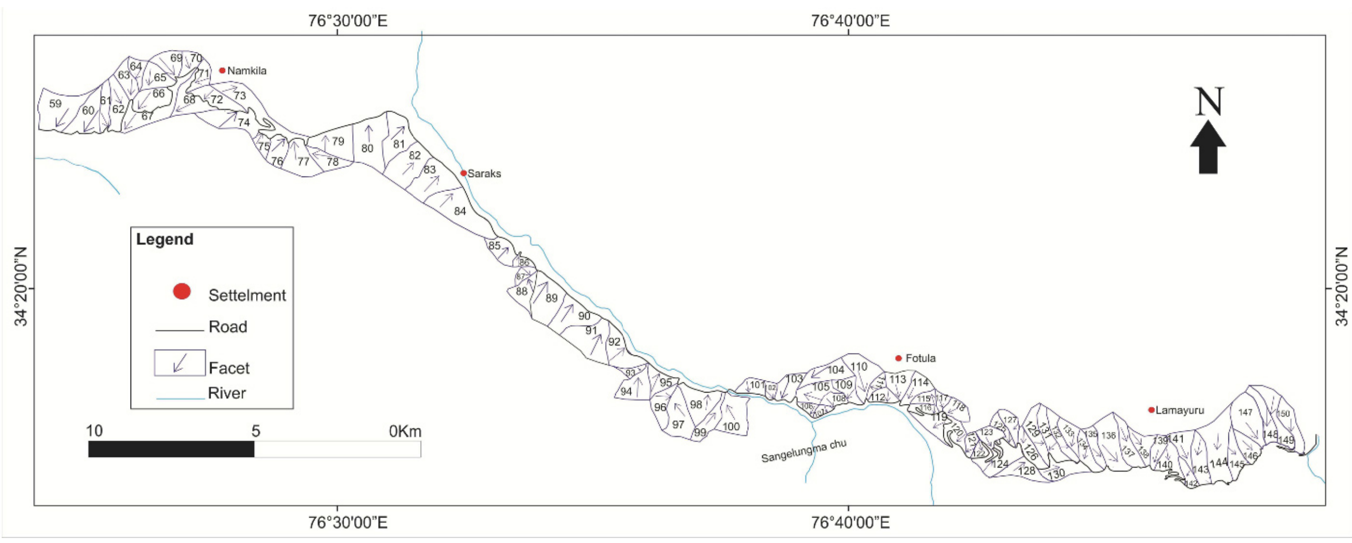

Fig 4(b). Facet map of study area.

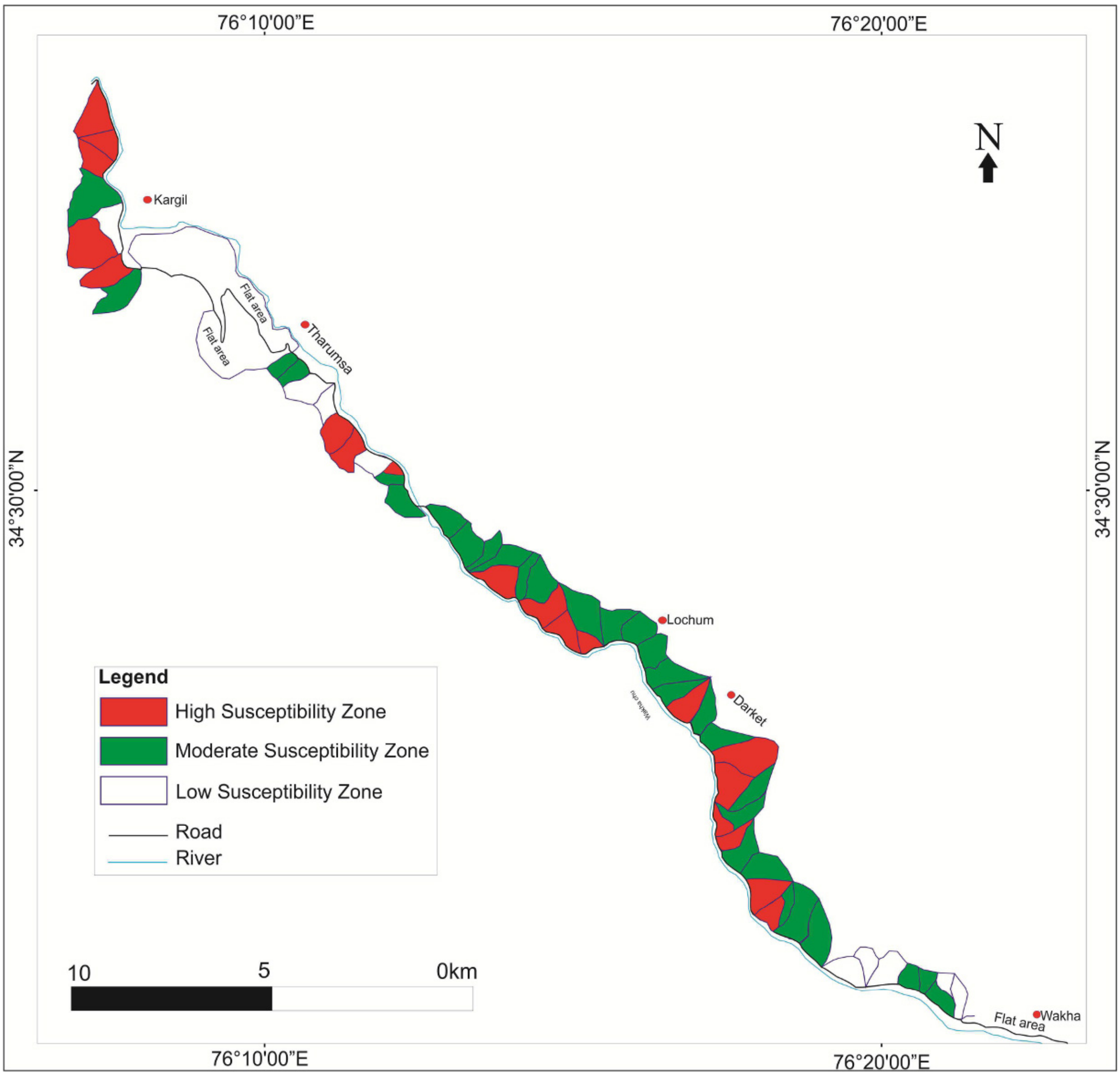

Fig 5(a): Landslide susceptibility map of study area.

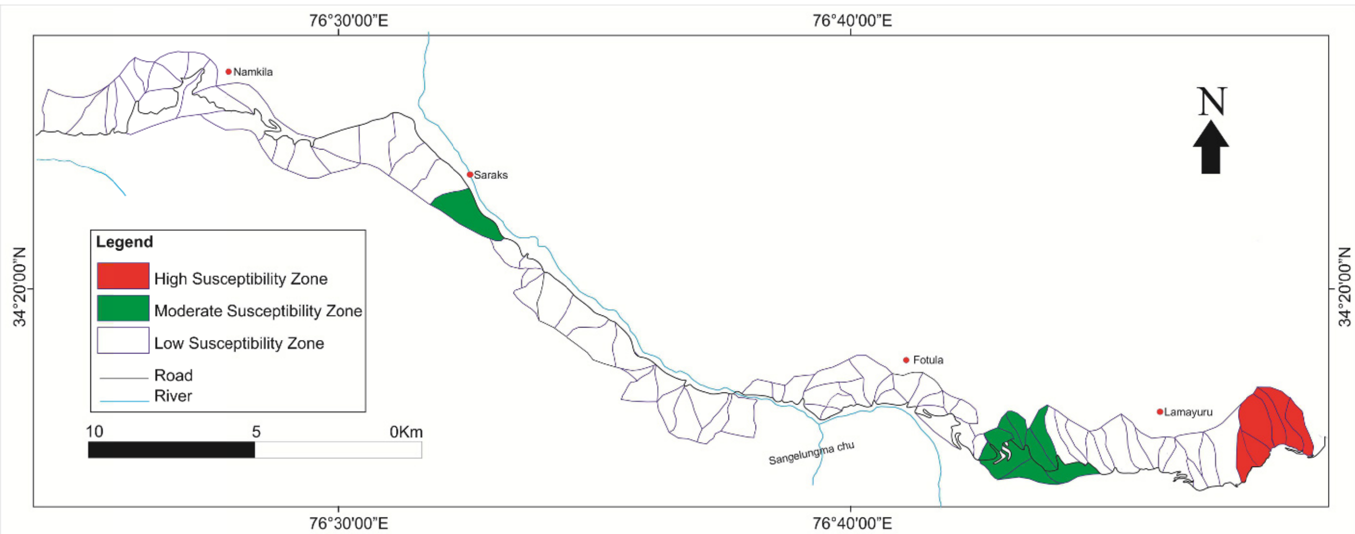

Fig 5(b): Landslide susceptibility map of study area.

Table 7. Landslide density for each susuceptibility class

Susceptibility class	Area km^2	Number of landslides	Density
LSZ	43.56	5	0.11
MSZ	16.94	20	1.18
HSZ	12.53	35	2.79

Moderate susceptibility zone incorporates 16.94 km^2 which are 23.19% of the study area and is affected by 20 landslides. High susceptibility zone comprises of 12.53 km^2 which are 17.15% of the study area and is affected by 35 landslides. A total of 25 facets falls in high susceptibility zone (1-3, 6, 7, 13, 14, 16, 23, 26-28, 35, 38, 39, 42, 43, 46, 47, 145-150) and most of these facets are attributed to slope modification i.e. road widening activities in past few years and needs immediate attention. In moderate susceptibility zone a total of 40 facets falls (4,8-10, 17-22, 24, 25, 29-34, 36, 37, 40, 41, 44, 45, 48-50, 54-56, 84, 122-130) and needs detail geotechnical investigation so that proper remedial measure can be adopted in order to avoid them to become vulnerable in the future.

The important aspects of the present study are that it reveals that habitat areas such Shilikchey to main market Kargil, Lochum to Darket village and Lamayuru village falls under high susceptibility zone. This gives an indication that the anthropogenic activities in collaboration steep slope, extensive cutting, and disposition of joints play an important role. The development activities further decrease the slope stability. The study also reveals that moderate susceptibility zone falls adjacent to high susceptibility zone at a different location and which is also a cause of concern as the development activities is increasing by each passing day. Low susceptibility zone covers 59.65% of the total area and mostly covers an area of fairly gentle slopes.

The landslide susceptibility map (Fig.5a and 5b) along the national highway serve as the predictive map used for delineating the potential zones of failure and further act as a planner map for developmental activities along the road network. This map helps to identify the stable zones and can be used as a preliminary map for future developmental and constructional activities along this sector of the highway. The low susceptibility zones (LSZ) are generally safer for developmental activities while as moderate susceptibility Zone (MSZ) may contain some local pockets of unstable slopes. On the other hand, the high susceptibility zones (HSZ) mostly consist of unstable slopes, which may be active and needs major attention before any developmental activities are undertaken. The landslide susceptibility mapping study is the first of its kind which is carried out along Kargil- Leh NH-1D. The results and findings are more useful for the planners and district administration in particular and public in general.

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