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A Geospatial Approach to Demarcate Flood Susceptible Zones of Rangat Watershed, Middle Andaman, India

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Abstract: **Flooding is the most prevalent global geo-epidemic, wreaking massive havoc. Five geo-environmental factors viz., slope, geology, geomorphology, soil infiltration capacity, and land-use land-cover were employed to identify the flood-prone zones of the Rangat watershed using remote and GIS. The results of the present study indicate that 0.55 Km^2 of the Rangat village is highly vulnerable to flooding during heavy monsoon followed by Dasharatpur village (0.53 Km^2). 1.98 Km^2 of the Rangat river is highly is very prone to seasonal flooding of the total 12.25 Km^2, while 1.04 Km^2 is moderately sensitive. With the ever-changing landscape pattern and climate change, the Rangat watershed is more susceptible to monsoonal flooding time and again in the future.**

Index Terms: **Flood susceptible zones, GIS, Rangat, Remote sensing.**

I. Introduction

History is evident of disaster prevalence ever since the origin of planet Earth; wreaking havoc on people's lives, property, infrastructure, economy, and developmental activities (Hoeppe 2016; Fujita and Shaw 2019; Uddin and Matin 2021). Flood is perhaps the most devastating, widespread, and frequently inflicting extensive loss of life and property, flood induced disease, disruption of socio-economic activity including transport and communication among all-natural disasters (Rosser et al. 2017; Termeh et al. 2018; Das and Gupta 2021; Uddin and Matin 2021; Sachdeva and Kumar 2022). A global estimate articulates that more than two billion people were affected by floods from 1998 to 2017 (World Health Organization-WHO 2017).

Floods are a consequence of copious rainfall within a short period and that results in heavy runoff (Das 2020; Das and Gupta 2021; Sachdeva and Kumar 2022). It is a recurrent natural phenomenon in tropical zones (Tien Bui et al. 2016; Ngo et al. 2018). Anthropogenic arbitrations such as deforestation, population growth, and development economic assets over low-lying areas vulnerable to flooding. Also, modifications of natural drainage, river basin patterns for human settlements, and infrastructural development may enhance flooding events manifolds (Billi et al. 2015; Das 2020). The incidence and magnitude of floods due to climate change are also expected to escalate in the future, therefore intensifying the existing flood risk (Das 2020; Zadeh et al. 2020; Uddin and Matin 2021).

Rangat watershed is located in middle Andaman a union territory of India bounded by the coordinates 12º 30' N to 12º 34'N and 92º 53'E to 92º 57'E covering an area of 35.35km^2 (Fig. 1). It is bestowed with a perennial river Rangat (11.92 km) covering a distance of 15.32 km from source to sink. Kalsi (282m) is the highest peak in the area under investigation. Rangat watershed has a population of 6610 (District Statistical Handbook 2010-11). It receives 3500mm of rain annually (Meteorological Statistics 2019). According to Disaster Management Plan (2016) heavy rains followed by floods disrupt normal life in Rangat every year. Also, Morphometric analysis of streams of the Rangat watershed by Shankar and Dharanirajan (2014); Shankar et al. (2015) indicates that it is vulnerable to flooding during monsoon. In the light of flood recurrence annually during heavy rains, an attempt is made to demarcate flood-prone areas in the Rangat watershed using geospatial technology.

Over the past two decades, advancement in the field of geospatial technologies has immensely expedited flood mapping and flood risk assessment. GIS and remote sensing techniques play a crucial role in flood hazard management because flood hazards are multifaceted and the spatial component is inherent. Further, geospatial technologies are cheap, reliable, cost-effective, and a candid tool for visualization of the extent of damage, modeling, predicting of flood events, relief and rehabilitation work as well (Zaharia et al. 2017; Das 2020; Msabi and Makonyo 2020; Das and Gupta 2021; Uddin and Matin 2021).

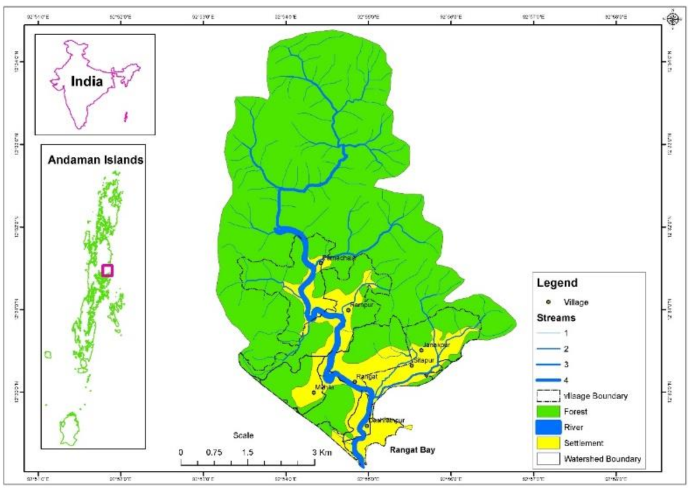

Fig.1: Study Area Map

II. MATERIALS

The objective of the present study was comprehended with the aid of the following materials. a) Survey of India (SOI) restricted toposheets on 50K scale (86D/14 & 86D/15), b) Soil resource atlas of Andaman and Nicobar Island (NBSS&LUP 1991), c) Geological Survey of India map, d) 2019 Landsat 8 satellite image, e) ASTER-GDEM (Advanced Spaceborne Thermal Emission and Reflection Radiometer- Global Digital Elevation Model), and f) Arcmap version 10.5 GIS software.

III. METHODOLOGY

Field validated data augmented with geo-spatial technologies for assessing various geo-environmental factors responsible for flooding in the area under present investigation was adhered to demarcate the flood vulnerable zones. The five geo-environmental parameters are viz., a) Land Use and Land Cover (LULC), b) Geomorphology, c) Infiltration rate of the soil, d) slope angle, and e) Geology were used to identify the flood vulnerable zones. The base map was demarcated from SOI toposheets. 2019 Landsat 8 satellite image was used to infer the LULC. Slope angle and geomorphology were inferred from ASTER GDEM. While geology and soil texture maps were depicted from the Geological Survey of India and Soil resource atlas of Andaman and Nicobar Island (NBSS&LUP 1991) respectively. All the output maps were generated on Arcmap software with similar datum (WGS84) and UTM-Zone46N projection. Each of the aforementioned feature classes was given a rank (Table 1) and these features were converted into a raster of similar pixel dimensions. Multi-parameter weighted overlay analysis was performed to derive a flood hazard map.

Table 1: Risk intensity for different classes of various geo-environmental parameters

Sl No	Class	Rank
1	**LULC**	
	Forest	1
	Settlement	2
	River	3
2	**Geomorphology**	
	Hill	1
	Drainage	2
	Flood plain and Active channel	3
3	**Infiltration rate of soil**	
	Sandy Clay Loam	1
	Sandy Clay	2
	Clay Loam	3
4	**Slope angle**	
	$>35^{o}$	1
	10^{o}-35^{o}	2
	0-10^{o}	3
5	**Geology**	
	Andaman Flysch	1

IV. RESULTS AND DISCUSSION

A. Landuse Land Cover (LULC)

Deforestation, biodiversity loss, global warming, and increased flooding events have all resulted from changes in land use/land cover due to either anthropogenic interventions or natural adjustments. (Billi et al. 2015; Hoeppe 2016; Rosser et al. 2017; Termeh et al. 2018; Das 2020; Das and Gupta 2021; Fujita and Shaw 2019; Uddin and Matin 2021; Sachdeva and Kumar 2022). Human beings play a vital role in any ecosystem and have a substantial bearing on their functions as well (Sachdeva and Kumar 2022). However, It is now considered that “human activities are influencing or even dominating many aspects of the earth’s environment and functioning” leading to the repercussion of another geological epoch, the 'Anthropocene era' (IGBP, 2001). Three types of land-use patterns were inferred from the 2019 satellite image in the Rangat watershed viz., forest, settlement, and river (Fig. 2).

Forest is the largest land use covering 84.05% (29.72 Km^2) followed by human settlement 14.71% (5.20 Km^2). Rangat river occupies just 1.22% (0.44 Km^2) having a short running length of

11.92 Km^2 before divulging into the Rangat Bay. This short running length of the river is phenomenal in causing floods during extreme hydro-meteorological events due to two main reasons. (1) Removal of protective vegetation such as forest for human settlement and related activities along the upstream periphery of the hamlets viz., Dasharatpur, Janakpur, Mithila, Parnasala, Rangat, Ramapur, and Sitapur result in excessive runoff causing floods (Siriwardena et al. 2006; Tehrany et al. 2015b; Sachdeva and Kumar 2022). (2) infra-structural developmental activity like construction of roads, buildings, pavements, etc., around these villages has led to the creation of more impermeable surfaces that do not entertain percolation of rainwater to the sub-surface resulting in floods as a consequence of increased surface runoff (White and Greer, 2006; Billi et al. 2015; Das 2020). Thus, the river is given the highest rank of three, as it is the conduit of monsoonal rains. The forest gets the least rank of one. The weightage for the individual land-use classes is depicted in table 1.

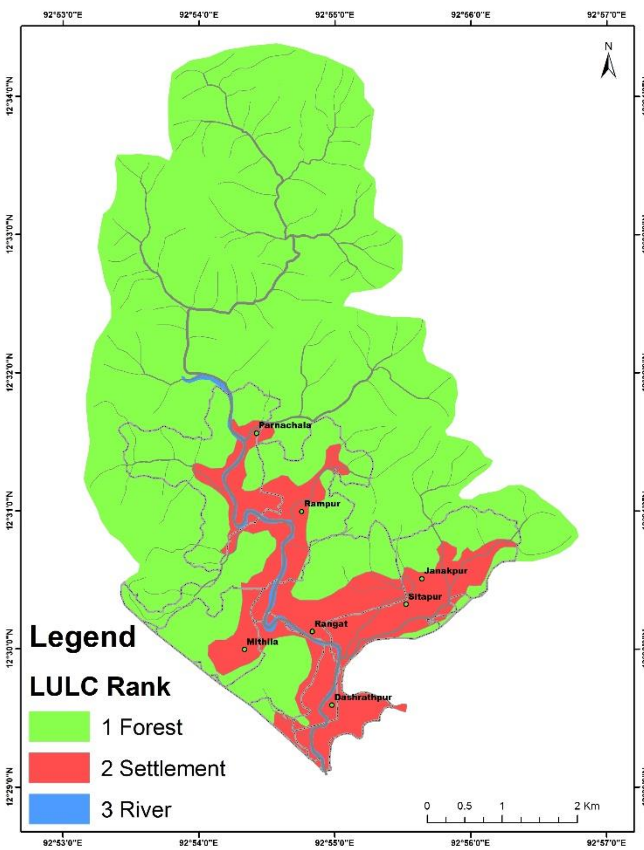

Fig.2: Land Use and Land Cover Map of Rangat

B. Soils

The soil types in any area are vital as they regulate the quantum of rainwater that can infiltrate into the sub-surface, and thus the amount of water that flows as surface runoff (Tehrany et al. 2015a; Al-Abadi 2018; Sachdeva and Kumar 2022). Different types of soil cover in different landscapes and their complex interactions with rainfall is a vital indicating parameter for floods (Sangati, 2009; Tehrany et al. 2015a; Al-Abadi 2018; Sachdeva and Kumar 2022). Two orders of soil were encountered in the Rangat watershed viz., inceptisols and Entisols. Tropepts and aqupepts are soil sub-orders of inceptisols. Entisols have only one sub-order namely orthents. Three types of soil texture were found in the area under investigation and were classified based on infiltration capacity as provided by Ganeshamurthy et al. (2000). These three types of soil texture are viz., a) sandy clay loam, b) sandy clay, and c) clay loam with infiltration capacity 1.0 to 3.5 cm/h, 1.0 to 2.0 cm/h, and 0.5 to 1.0 cm/h respectively (Fig. 3). Thus, the least rank of one was given for sandy clay loam and clay loam soil gets the highest rank of three. The ranking for infiltration capacity of different soil textures is shown in table 1. The risk of flood hazard aggravates with the drop in soil infiltration capacity, Also causes an increase in surface runoff (Tehrany et al. 2015b; Vishnu et al. 2020; Sachdeva and Kumar 2022). When the rainwater influx rate surpasses the soil's infiltration capacity, it flows down the slope as runoff ultimately leading to flooding of low-lying areas (Towfiqul et al. 2021). An overlay of soil infiltration map and LULC map indicates that the humans have settled over the soil like sandy clay and clay loam having poor infiltration capacity and susceptible to flooding during heavy monsoon. Added to it infra-structural developmental activity like construction of roads, buildings, etc., around the villages viz., Dasharatpur, Janakpur, Mithila, Parnasala, Rangat, Ramapur, and Sitapur has led to compaction and sealing of surfaces resulting in floods as a consequence of increased surface runoff (White and Greer, 2006).

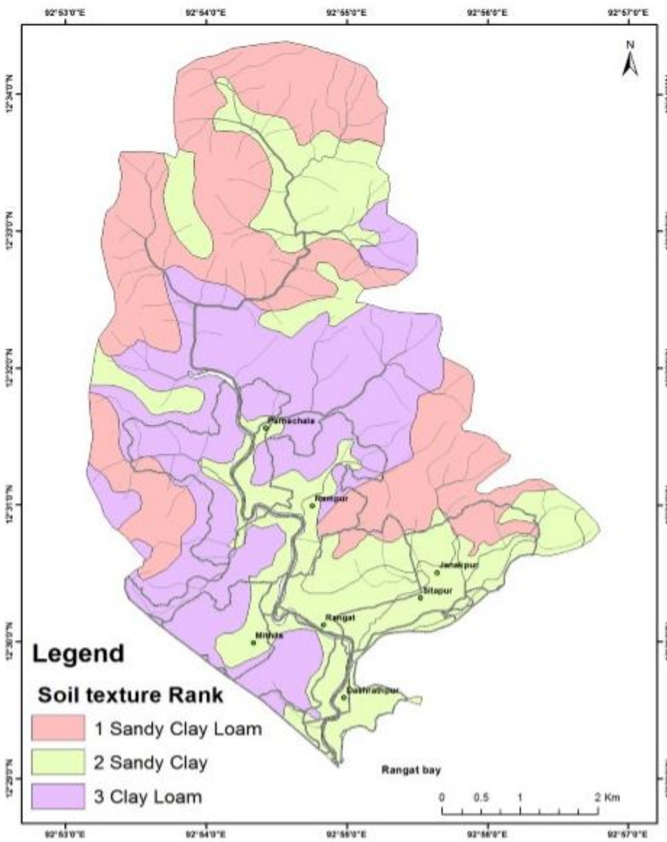

Fig.3: Soil Texture Map of Rangat

C. Slope

Elevation and slope angle vitally governs the stability of a terrain. The slope of the terrain always influences the quantum and direction of surface runoff or subsurface drainage reaching an area (Tehrany et al. 2015a; Lee et al. 2017; Al-Abadi 2018; Janizadeh et al. 2019; Sachdeva and Kumar 2022). Digital Elevation Model (DEM) is usually used to perceive topographic attributes, such as aspect, slope, and steepness by the researchers to systematically examine the variables affecting a hazard in a study area (Chowdhuri et al. 2020). The slope has a predominant influence on the involvement of rainfall in stream flow. It exercises control over the infiltration rate, duration of overland flow, and subsurface flow (Wierzbicki et al. 2018). The slope angle defines the type of the slope and its relationship with the drainage, lithology, soil type, and structure. A uniform smooth surface that permits the water to flow quickly is not desirable and results in flooding. Whereas, a greater surface roughness can retard the flood response and is desirable (Sachdeva and Kumar 2022). Smooth flat surfaces are most vulnerable to waterlogging while steeper slopes are more susceptible to surface runoff. Gentle and flat surface (0-10 degrees) get the highest rank of three as it is susceptible to waterlogging. On the other hand, a steep slope greater than 35º where runoff is high receives a rank of 1. This kind of flat terrains wherein flooding can be anticipated are encountered around the hamlets viz., Dasharatpur, Janakpur, Mithila, Parnasala, Rangat, Ramapur, and Sitapur. The slope map is shown in Fig. 4 based on the ranking as depicted in table 1

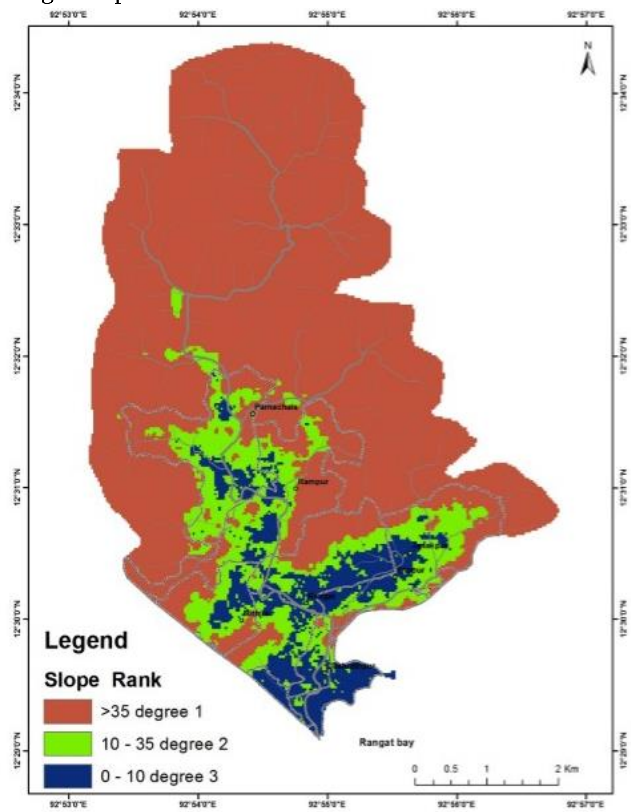

Fig.4: Slope Map of Rangat

D. Geomorphology

Four geomorphic units were observed in the Rangat watershed viz., hill, seasonal streams channels, flood plain, and active channel (Fig. 5). The largest geomorphic unit in the Rangat watershed is the hill covering 84.04% (29.71 Km^2) and it is covered by forest. The second-largest geomorphic units in the area under investigation are flood plain 14.71% (5.2 Km^2) and active channel 1.2% (0.43 Km^2). Streams are seasonal which empties itself in the perennial Rangat River. The Rangat watershed comprises of 102, 55, 22, and 21 number of streams in 1st, 2nd, 3rd, and 4th order respectively. Most of the lower order streams like the 1st and 2nd are encountered on the slopes of the hill. Whereas, the 3rd and the 4th order streams are on the flood plains accompanied by rapidly flowing streams with high velocity and high discharge rate during tropical monsoon (Shankar and Dharanirajan 2014; Shankar et al. 2015).

Human's have settled around hamlets Dasharatpur, Janakpur, Mithila, Parnasala, Rangat, Ramapur, and Sitapur on the flood plain and around the active channel of Rangat river which is vulnerable to flooding (Smith and Ward 1998). Clearance of forest around the outer periphery of these hamlets is the triggering factor of flood events during extreme hydro-meteorological events. It is relatable that high discharge during extreme meteorological events may exceed the active channel resulting in flooding of the plains and low-lying areas (Goudie 2014; Wierzbicki et al. 2018). Thus, active channel and flood plain receive the highest rank of three while hill receives the least rank of one. The weightage for individual geomorphic units is depicted in table1.

E. Geology

The study area is invariably dominated by Sedimentary rock of undifferentiated Mithakhari group belonging to Andaman flysch. This undifferentiated Mithakhari group consists of conglomerate, feldspars subordinate quartz, lithic grains, and fossils sometimes (Bandopadhyay and Ghosh 2015; Awasthi 2017). Generally, the porosity and permeability of sedimentary rocks are high when compared to other rock types. Since the study area is devoid of other litho-unit except for Andaman flysch minimum rank of unity was considered. The presence of conglomerates enhances the infiltration of rainwater (low-intensity monsoonal rains) consequently resulting in the saturation of the subsurface (Vannier et al. 2016). However, the focus area being situated in the tropical zones wherein high-intensity rains are frequently encountered resulting in increased surface runoff. Whatsoever be the intensity of the rain, the flooding tendency shall be frequently encountered seasonally in the coastal plains of the study area under investigation.

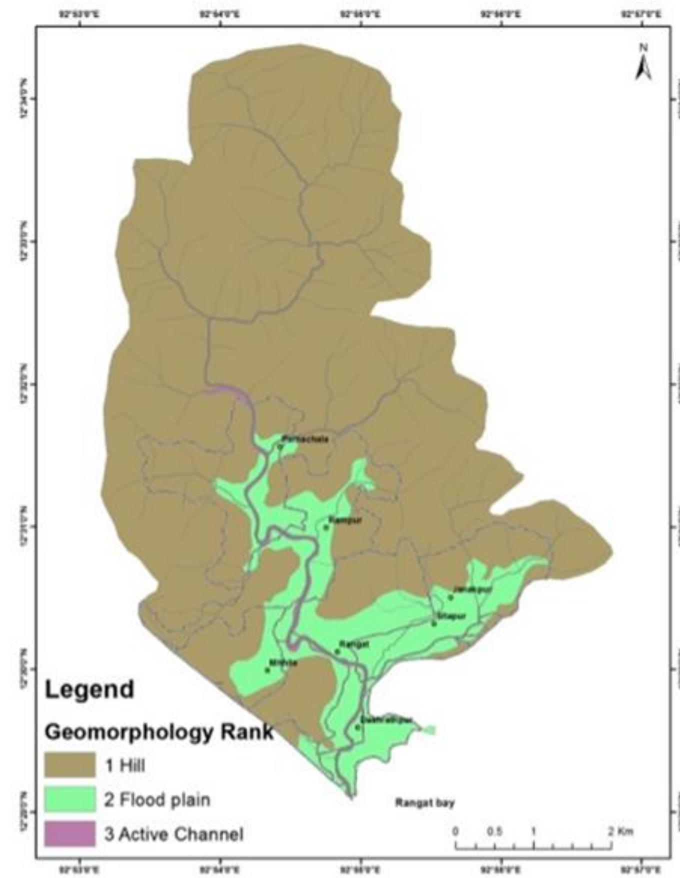

Fig.5: Geomorphology Map of Rangat

F. Flood Susceptible Zonation

The geo-environmental factors that aid in demarcating the flood susceptible zones are Landuse and land cover, geomorphology, Soil infiltration capacity, slope, and ground-truthing. The complex interaction of these geo-environmental parameters due to extreme hydrological events results in floods. The cumulative rank of individual geo-environmental factors ranged between 12 to 5. Thus the study area was classified into three risk intensity classes viz., High (8-12), Moderate (6-8), and Non (4-5) flooding zones. The results of the weighted overlay analysis with that of the village boundary map of the present investigations reveal that 1.98 Km^2 and 1.04 Km^2 of the study area are highly and moderately susceptible to flooding respectively (Fig. 6 and Fig. 7). The break-up of hamlet-wise flood susceptibility is been depicted in table 2. These hamlets cover an areal extent of 12.25 Km^2. From table 2 it is inferred that Rangat village (0.55 Km^2) is highly susceptible to flooding followed by Dasharatpur village (0.53 Km^2). Sabari village is free from any sort of flooding events. The risk of flooding increases with the coincidence of tropical monsoonal rains and astronomical tides. Because the pour point of the watershed is Rangat Bay in the Andaman Sea.

Also, inorder to either co-exist or avert loss due to flooding eventualities in the future it is strongly recommended that 1) further infrastructural developmental activities in the highly flood susceptible zone should be stopped. 2) Natural flow path of streams should not be obstructed by any means. 3) due considerations should be made by the competent authority while authorizing and approving any infrastructural developmental activities.

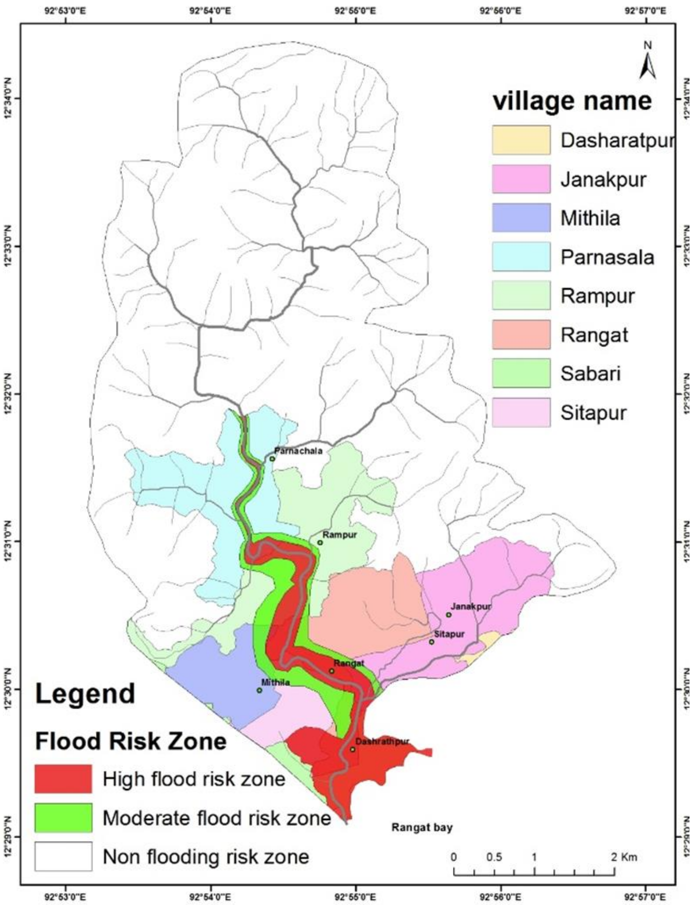

Fig.6: Flood Risk Zone Map of Rangat

Fig.7: Dasharatpur flooded in 2012

V. CONCLUSION

Many researchers unanimously opined that flood is the most common global geo-epidemic with huge devastation. Demarcation of flood vulnerable zones has been accomplished by considering complex interaction of geo-environmental parameters like LULC, Slope, Soil infiltration capacity, geomorphology, and geology. Geospatial technologies were used judiciously to comprehend the objective of the present investigation. The present investigation indicates that the Rangat locality (0.55 Km^2) is highly vulnerable to flooding during heavy monsoon followed by Dasharatpur village (0.53 Km^2). Sabari village is free from any flooding events. Owing to the sizable areal extent of 35.35 Km^2 Rangat watershed the extent by eight hamlets is just 12.25 Km^2. Out of which 1.98 Km^2 is highly susceptible and 1.04 Km^2 is moderately susceptible to seasonal flooding. Level IV classification of high-resolution satellite data in conjugation with detailed information about the type of building infrastructure and demographic data is strongly recommended for future investigation to demarcate the vulnerable infrastructure and population in the flood susceptible zones. It is also noteworthy to mention that a check on the anthropogenic activity is the need of the hour for sustainability. Also with the ever-changing landscape pattern and climate change Rangat watershed is more susceptible to monsoonal flooding time and again in the future.

Table 2: Village-wise flood vulnerable zones

Sl No	Village	Area (Km^2)	Flood Vulnerable zone (Km^2)	
			High	Moderate
1	Rampur	2.65	0.32	0.29
2	Parnasala	2.42	0.18	0.21
3	Sabari	0.17	0.00	0.00
4	Dasharatpur	0.60	0.53	0.00
5	Sitapur	0.96	0.27	0.18
6	Janakpur	2.23	0.11	0.05
7	Rangat	2.11	0.55	0.20
8	Mithila	1.11	0.02	0.11
	Total	12.25	1.98	1.04

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