Free and Open-Source Geospatial Datasets for Early Damage Assessment: A Case of Melamchi Flood Nepal

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ABSTRACT

Nepal is considered as of the most multi hazard prone countries in the world. It is ranked 4th, 11th and 30th position in climate change, earthquake, and flood risk respectively. Monsoon in Nepal starts in June and lasts until August contributing around 80% of the annual rainfall in the country. Tens of thousands of lives and large number of properties are affected by climate induced disasters every year. On the 15th June, 2021; at onset of the year's Monsoon, Melamchi Bazar, a city around 45Km north-east of Kathmandu, was hit by heavy flash flood claiming at least 5 deaths, and millions of economic losses including major damage to ambitious Melamchi Drinking Water Supply Project that aims to bring 170 million liters of water per day to serve population in Kathmandu valley. Temporal analysis of freely available high resolution remote sensing images and geospatial datasets can help early assessment of the damages during such disasters. SRTM DEM was used for watershed delineation of Melamchi and Indrawati rivers. Pre and Post flooding inundation area was obtained from Sentinel 2B images by calculating normalized differential water index. Infrastructure database like building, road network, bridge was extracted from open street map. Landcover were taken from living atlas of ESRI global landcover 2020. The early assessment of the damage was then performed using geospatial and geostatistical analysis of the datasets. At least 300 houses, 12 bridges, and 12km of road network was found affected by the disaster. Assessment was further carried with buffer of 25m, 50m, and 75m to get further insights. The study has proven the usefulness of the freely available geospatial data and technologies for early assessment of disaster impact. Such preliminary results and findings are helpful for rapid response and rescue operation. Howver, the freely available datasets collected through croud-sourcing are not sufficient enough and there is a huge scope of further improving the quality of data collected this way. A detailed field-based assessments would improve the result for more realistic statistics.

Keywords: disaster, geospatial technology, flood, remote sensing

1. Introduction

Every year climate induced disasters cause heavy loss of lives and properties in Nepal. Globally, Nepal lies on the 4th rank in climate risk. On 15th June, 2021, during the onset of the year's monsoon, Melamchi Bazar was hti by a catastrophic flash flood from the Melamchi and Indrawati rivers claiming at least 5 deaths and 20 missing people and a major damage to Melamchi Water Supply Project (a national priority project worth at least $USD 317 million), which is supposed to supply 170 MLD of fresh water to Kathmandu valley.

The height of the debris deposition was 20m to 385m covering the area of 6.5 Square kilometer. 337 houses were fully damaged and 525 families were forced to displace (NDRRMA). It destroyed 13 suspension bridges, 7 motorable bridges and a number of road stretches. Many traut (a species of fish) firm, a hydropower and and more than 200 other infrastructures were damaged. Around 1.78 Sq km of agricultural area were damaged(Maharjan et al., 2021) . A major damage occurred in the Melamchi Water Supply Project which had started supplying water to Kathmandu valley. Due to this distruction, the future of this project is not prolonged to an indefinite time.

Since the scale of damage was too high, accurate data and statistics of the damage and loss were highly needed for the rescue and response purpose. Rapid and real time field data collection was not possible due to continuous rainfall, road and bridge blockade, connection loss of electricity and internet facilty. Remotely sensed data have been effective in various application including forest resources (Ghimire et al., 2017), healh statistics(Ghimire et al., 2021; Mishra et al., 2013; Parajuli et al., 2020), disaster assessments etc. Open Street Map (OSM), a geospatial database of various infrastrucutrue collected by the volunteers of the world carried a potential to be that first hand data unless a detailed assessment of the field could be carried out. Digital Elevation Model (DEM) data generated from the Shuttle Radar Topography Mission (SRTM), and Landcover data developed and maintained by ESRI are also freely available. Recently satellite remote sensing data with high temporal and spatial resoulution are available which have been instrumental in assessing many geo-physical status of any place. Landsat and Senetnel are popularly used satellite based remote sensing images.

This study focuses on early assessment of the loss and damage during the June 2021 flood in Melamchi using freely available spatial datasets. The results obtained are validated using in-situ rapid assessment after the event. The vulnerable buildings and infrastructures are further identified using buffer analysis of 25m, 50m and 75m.

2. Study Area

The Indrawati watershed is located in Bagmati province of Nepal, in which about 87% of watershed area is occupied in Sindhupalchok district whereas 10% in Kabhrepalanchok and remaining 3% in Kathmandu district, having catchment area of 1,228.57 sq km. The geographical extent of the study area lies between 27°37'23” to 28°10'7” N Latitude and 85°26'31” to 85°45'7” E Longitude. The pour point for identification of watershed is located at 85°42'20" E and 27°38'23" N along the river at Dolalghat. The Indrawati watershed lies within Koshi River Basin having Melamchi, Larke and Yangri as major tributaries of Indrawati river. In term of physiographics zones, Indrawati watershed consists of 33% of Middle Mountain, 47.5% of Hill and 19.5% of High Mountain to the total land area of the watershed as shown in figure. There is a variation of elevation from 610m to 6220m above mean sea level towards north. It has a range of climate classes varying from temperate to polar tundra. The major landcover pattern of the watershed is forest (55.7%) followed by shrubland (26.5%). The cultivation land occupied about 2.5% and waterbody about 0.2% of total area of the watershed.

Figure 1: Study Area of Indrawati Watershed

3. Overall Methodology

The watershed area of the Melamchi and Indrawati river was delineated from the SRTM DEM data. Sentinel-2B data were used to map pre flooding river water flow area and post-flooding inundation area. The infrastructures database such as building footprint and road networks were extracted from open street map (OSM). Landcover of the study area was obtained from ESRI 2020 which is combined with the inundation area, providing the overall statistics of the current damage assessment (infrastructures and landuse pattern) from the flood event along-with the potential vulnerable zones and physical infrastructures.

3.1. Watershed Area Delineation

The Digital Elevation Model (DEM) data of the study area were acquired from the Shuttle Radar Topography Mission (SRTM) of spatial resolution 1 arc-second (approximately 30 meters) in predefined two tiles of N27E085 and N28E085 mosaiced together. The data were preprocessed removing initial errors and small imperfections in data through fill process and followed by generation of flow direction and flow accumulation for identification of stream networks with delineation of watershed as per pour point at Dolalghat.

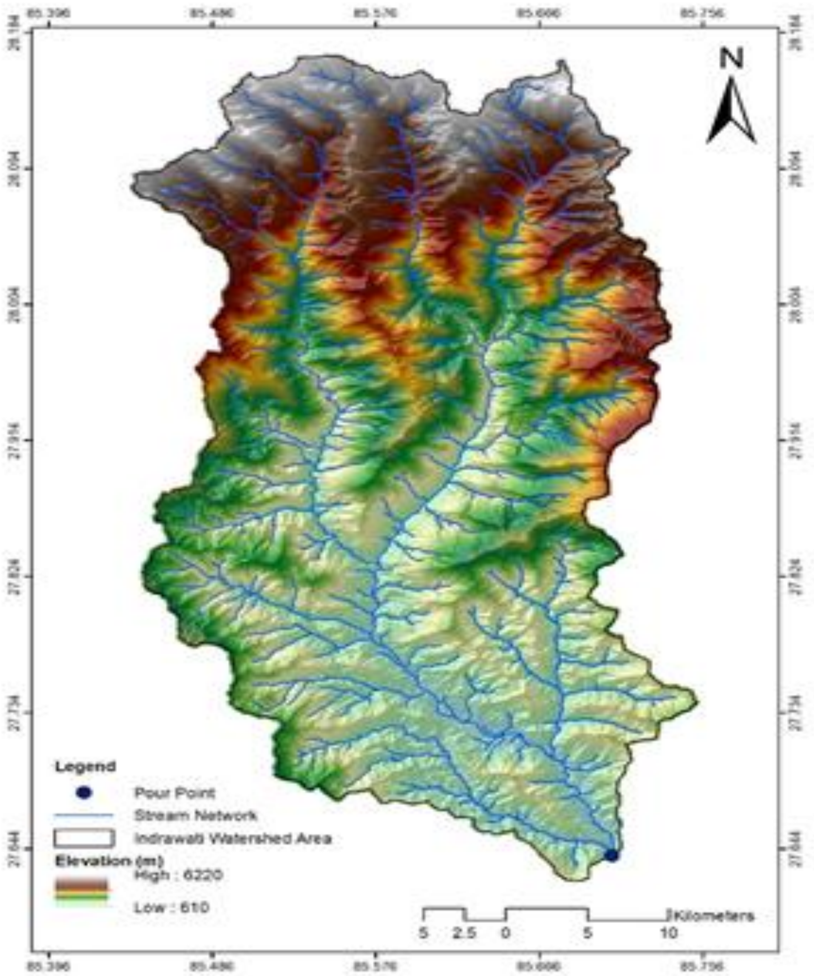

Figure:2 Indrawati Watershed Area showing stream Networks

3.2. Pre Pre-flood River-water flow area Identification

The water and non-water regions were identified by using of remote sensing satellite images of pre and post flood event to detect actual flooded areas. The identification of pre-flooding river water flow area was mapped from SENTINEL-2B image acquired on 15th May 2021 within the delineated Indrawati watershed area. Since the study mainly concerns with the changes of water flow extent pre and post flood event, the classification contained only three classes; water, non-water and sandy regions. The observed landcover along the river alignment were further improved by manual digitization to delineate exact river channel flow width.

3.3. Post-flood Inundation Area Mapping

The cloud free Landsat image of the study area was not available after the flooding event, not even along the Melamchi and Indrawati river. So, the Sentinel-2 image, dated 24th June 2021, within 10 days of the first big flood event at Melamchi region which has cloud free image along the Melamchi and Indrawati river alignments was acquired. Sentinel-2 consists of 13 spectral bands among which four bands are of 10m, six bands are of 20m and remaining three bands are of 60m spatial resolution. The Normalized Difference Water Index (NDWI) was applied to detect open water coverage areas using green and near infrared reflectance bands. Among the different landuse pattern, water has high absorbability and low radiation from visible to infrared wavelengths range. The spectral water index-based methodology is more reliable method of water coverage area mapping because of its efficient and low computational cost). So, NDWI image conversion, using green band (band-3) and near infrared band (band-8) of Sentinel-2 satellite was considered for for post-flood inundation area extraction. The raster image of NDWI is generated by means of map algebra in GIS platform by using of following expression.

$$NDWI = (Green\ Band - NIR\ Band) / (Green\ Band + NIR\ Band) \quad (1)$$

For Sentinel-2 dataset,

$$NDWI = (Band\ 3 - Band\ 8) / (Band\ 3 + Band\ 8) \quad (2)$$

The NDWI is then reclassified into water and non-water surface by setting threshold in NDWI values. The adopted threshold value was NDWI >= -0.1 for water surface extraction

3.4. Landuse/ Landcover and Infrastructures

has gre. The necessary dataset such as building footprints, road alignments, bridges, education and health facilities for post flood damage assessment within study area were collected from Open Street Map (OSM), an open-source and open-access platform, founded by Sleve Coast in 2004. Further, the existing landcover pattern was acquired from living atlas of ESRI 10-meter global landcover 2020 .

4. Results

The visible water flow area as classified from SENTINEL-2B satellite imagery into waterbody and sand landcover type along the Melamchi and Indrawati river is shown in figure 3.

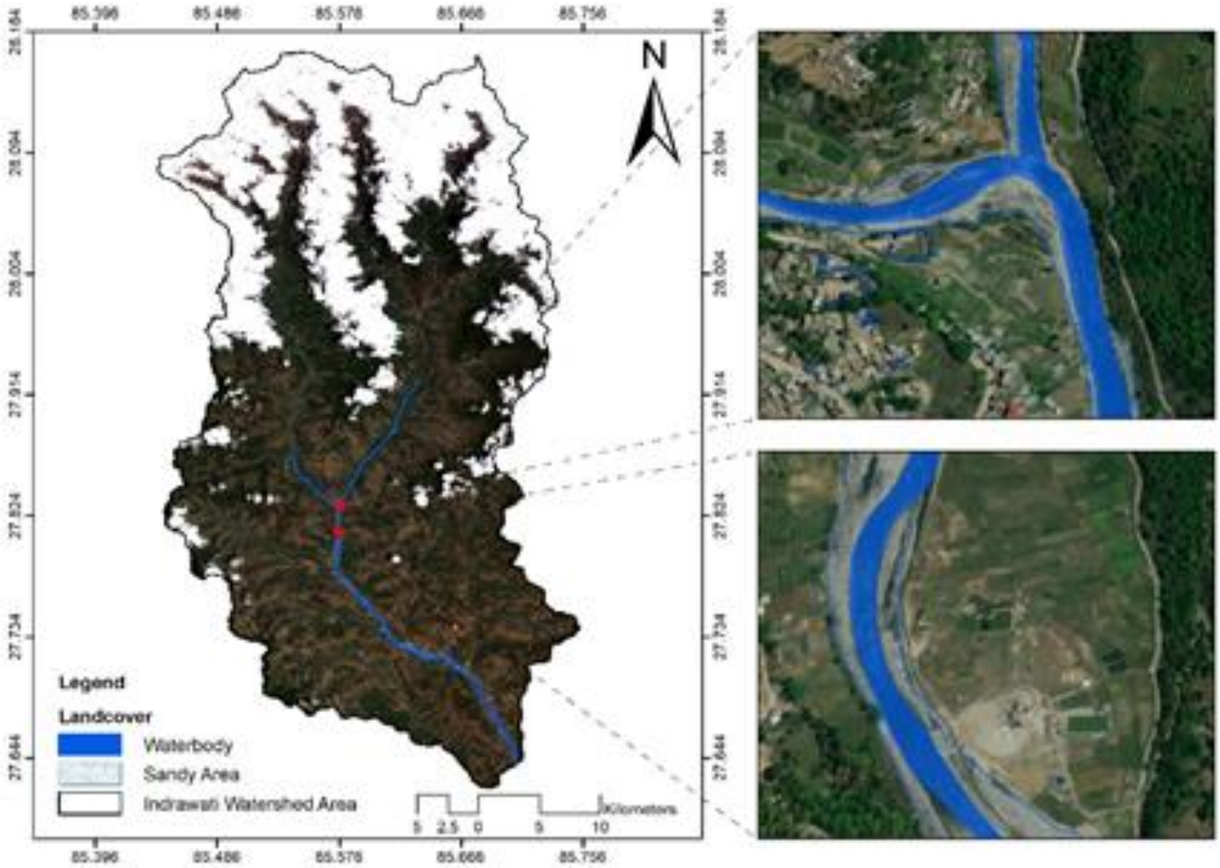

Figure 3: Pre-flood River water flow area

After cloud removal from identified water surface area calculated using NDWI , finally provides the post-flooding inundation area map along the Melamchi and Indrawati river alignment as shown in figure 4.

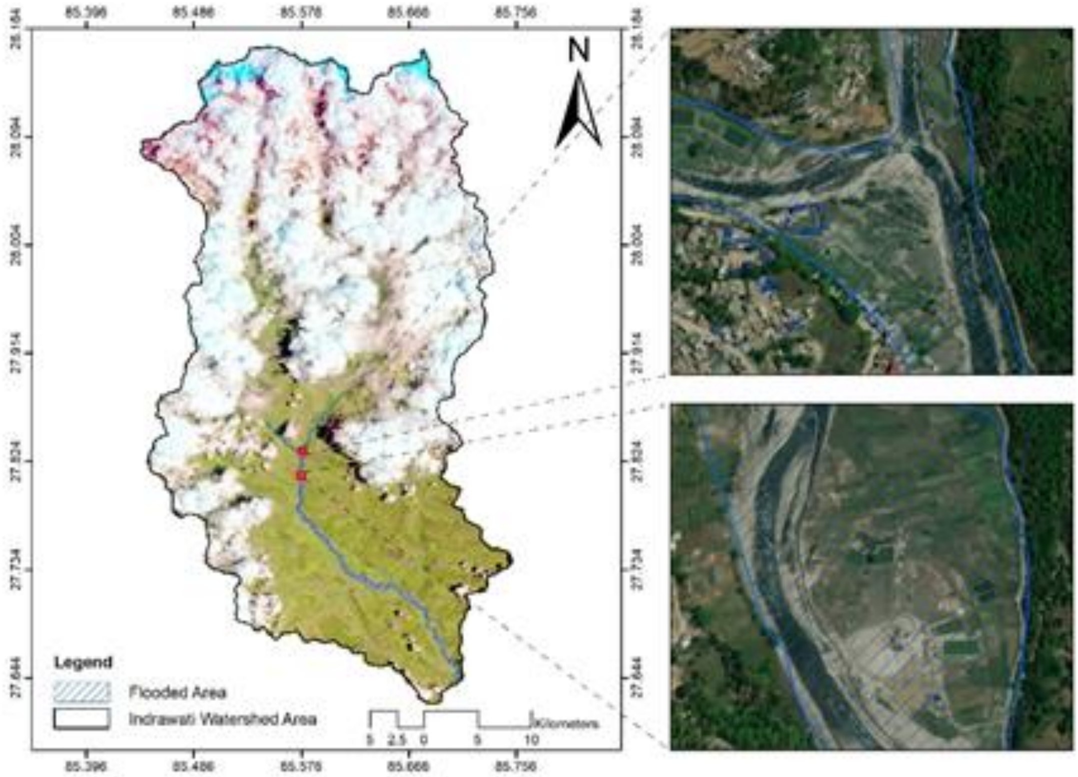

Figure 4: Post-flood Inundation Area from Sentinel-2 Imagery data

The digitized infrastructures within study area extracted Open Street Map (OSM), and existing landcover pattern acquired from living atlas of ESRI 10-meter global landcover 2020 are shown in figure 5.

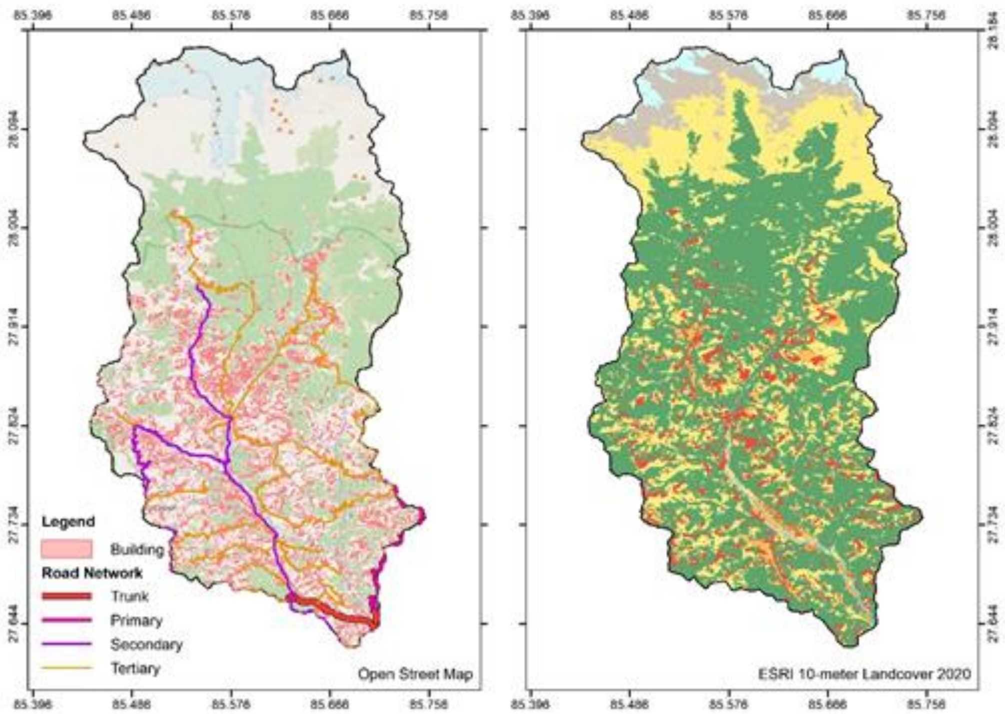

Figure 5: (a) Open Street Map showing Building footprint and Road Network within Indrawati watershed (b) ESRI Landcover Map of Indrawati watershed produced in 2020

More than 76,000 building foot frients, 308 schools, 7 health facility centres and road, bridge and other infrastrcutures were obtained by geostatistical analysis of the OSM images and land use land cover data. Other detail is presented in table 1.

Table 1: Infrastructure detaisl obtained (pre-flood) from freely available data

SN	Descriptions	Unit	Total	Remarks
1	Building/ House	No.	76577.00	
2	Education Facility	No.	308.00	
3	Health Facility	No.	7.00	
4	Road Network			
	Trunk	Km	13.61	
	Primary	Km	14.66	
	Secondary	Km	75.63	
	Tertiary	Km	280.99	
	Others	Km	2907.97	
5	Bridge	No.	118.00	
6	Landcover			
	Forest	SqKm	684.35	
	Grassland	SqKm	0.90	
	Shrub	SqKm	325.77	
	Cultivation	SqKm	30.20	
	Built Area	SqKm	83.03	
	Waterbody	SqKm	2.70	
	Barren land	SqKm	78.07	
	Snow	SqKm	23.53	

5. Discussion

Remote sensing satellite imagery data product integrated with free and open-sourced infrastructures dataset of Indrawati watershed area have provided comprehensive information for post flood damage assessment. The Indrawati watershed delineated from SRTM DEM, has occupied an area of 1228.57 Sq. Km. The prolonged rainfall during the early monsoon and the accumulation of precipitation within indrawati watershed, triggered numerous landslides and flooding events at various locations. The clear visible water flow area along Melamchi and Indrawati river upto Dolalghat before the flooding event as identified from Sentinel-2B image classification was observed as 1.96 Sq. Km. The sandy areas at various locations along the river networks were observed as 4.006 Sq. Km. After the flooding event the flooded area along the Melamchi and Indrawati river within Indrawati watershed as identified from Sentinel-2B

NDWI image conversion had covered an area of 6.92 Sq. Km. The GIS based geospatial and geostatistical analysis revealed that the flood has caused serious damages to human settlements, physical infrastructures and agriculture land within Indrawati watershed mostly along the river side. The table below summarizes the statistics from the land use and land cover data, the damage statistics caused by Melamchi flooding along with the vulnerable damage statistics which was obtained by geo-statistical analysis covered within in 25m, 50m, 60m and 75m buffer area.

SN	Descriptions	From LandCover	Effected Qty	Unit	25m Buffer	50m Buffer	75m Buffer	
1	Building/ House	76577	102	No.	217	335	496	
2	Education Facility	308	0	No.	0	0	0	
3	Health Facility	7	0	No.	0	0	0	
4	Road Network							
	Trunk	13.61	0	Km	0.28	0.88	1.26	
	Primary	14.66	0	Km	0	0	0	
	Secondary	75.63	0	Km	2.07	4.29	5.89	
	Tertiary	280.99	0.48	Km	2.15	3.47	4.14	
	Others	2907.97	11.57	Km	16.29	22.91	30.83	
5	Bridge	118	12	No.	12	12	12	
6	Landcover							
	Forest	684.35	0.039	Sq Km	0.32	0.902	1.539	
	Grassland	0.9	0	SqKm	0	0.002	0.003	
	Shrub	325.77	0.952	SqKm	1.56	2.23	2.796	
	Cultivation	30.2	0.176	SqKm	0.29	0.472	0.741	
	Built Area	83.03	0.342	SqKm	0.51	0.682	0.875	
	Barren land	78.07	3.365	SqKm	3.64	3.715	3.746	

6. Validation Field Visit

A multi-perspective reconnaissance team in the leadership of Nepal Engineers Association (NEA) (Pandey et al., 2021)visited the field during June 20-24, 2021 to report on the preliminary findings on disastrous debris flow occurred along the Malamchi river and its consequences. Later ICIMOD also performed a detailed analysis of the event. NDRRMA published a detaild report on the status of the damage. All of these studies have provided slightly different statistics. NEA provided more detailed report. The buildings, physical infrastructures, agricultures land and other utilities affected by flood event as summarized by the team is presented in table below.

SN	Damage Items	Description of Damage
1	Suspended/Beilly (Pakki) Bridges	6
2	Bridges (Jholunge)	13
3	Buildings	400 affected family
4	School	2
5	Road	Totally collapsed at Simkhet, almost all sections are scoured and damaged
6	Drinking water supply system	All submerged
7	Irrigation system	All submerged
8	Traut farm	10
9	Pig farm, Buffalo Farm,	10
10	Restaurants/ Resorts	10
11	Police Posts	Helambu and Melamchi neighborhood
12	Health Office	Melamchi Pul Bazar
13	Other Government Offices	At Talamarang and Melamchi neighborhood

14	Lives	11 killed, 3 dead body found, 25 missing, hundreds stranded
15	Cultivated and Bare lands	Almost one km cross sectional from the centerline of river basin to both side of the river) and 25 km longitudinal section
16	Nature of River	Frequently changed track in U and Meandering shape, comparatively more scored bank at upstream as the velocity of flow might be high
17	Riverbed Cross section and Depth	50 m to 1.5 km in width, and 7 ft to 50 ft. in depth variation
18	Deposited Materials	Big boulder debris deposition at upstream, All metamorphic type rocks (Quartzite, Schist, Gneiss and Phyllite) found, Mostly sand, silt and mock materials deposited at downstream near Melamchi neighborhood and Bahunepati bridge site

Though all the information captured during the field visits could not be captured by image analysis, the results obtained are comparable. Due to poor and incomplete digitization of the infrastructure, not all the affected buildings were identified by image analysis. Motorable bridges were correctly identified, however the suspension bridges could not be identified in the image, which was obvious. The water area delineated was close to correct.

7. Conclusion

Open soure data sets are useful to provide a lot of information and can be a first go to data source for early assessment of the disaster events. However, they are not sufficient enough to capture everything. Its recommended that the volunteering organizations like Humanitarian OpenStreetMap Team (HOT) need to focus more to improve the quality of the datasets they digitize.

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References

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