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# Spatial multi criteria-based assessment of susceptibility of flood using open-source data in ungauged local government region: A case of Dhangadhi Sub-metropolitan city, Nepal

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## ABSTRACT

A plethora of literature regarding flood susceptibility is available but very few of them have considered local places distant from capital cities. Furthermore, the data driven models that use physically based models have limited applicability in data scarce regions. So, this research work attempts to estimate the flood susceptibility of data scarce local government using open source data in frequently inundated Dhangadhi sub metropolitan city in the far western southern plain of Nepal. The relevant factors responsible for flood namely, elevation, slope, aspect, precipitation, distance from river and LULC were identified. Using AHP method, the pairwise comparison matrix was prepared and weights for each factor and their sub class was estimated. Finally, the flood susceptibility map was prepared in open source QGIS environment dividing the region into five zones of very low, low, medium, high and very high susceptibility. The findings show that about 0.74% (1.93 sq. Km) area lies in the very low zone, 5.44% (14.24 sq. Km) in low, 41.13% (107.69 sq. Km) in medium, 51.22% (134.09 sq. Km) in high and 1.45% (3.84 sq. Km) in very high zone. The output of this research work could be helpful for leadership of local government, policy makers and academicians to strengthen flood risk management. It could be the baseline for future studies on flood susceptibility.

**Keywords:** Flood susceptibility; Dhangadhi; Open source data; Flood risk management

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## INTRODUCTION

Flood is one of the catastrophic disasters globally causing huge loss of lives and properties (Mshelia et al. 2024). It is reported that flood has caused millions of fatalities in the twentieth century, tens of billions of dollars of direct economic loss each year and serious disruption to global trade (Merz et al. 2021). Having access to accurate information is key to preventing floods or at least reducing their harmful effects (Yariyan et al. 2020). In spite of its significance, the process of flood modeling is a tough task due to the chaotic nature of flooding (Bulti and Abebe, 2020). The process of identification and detection of the flood-prone areas require high-quality flood susceptibility map which is a crucial management tool to mitigate the consequences of flood events (Sahraei et al. 2023).

Flood susceptibility mapping is defined as a quantitative or qualitative assessment of the classification, area, and spatial distribution of flood, which prevails or possess the potential occur in an area (Rahman et al. 2019). It is the primary process to predict and mitigate the future occurrences of flooding (Nachappa et al. 2020). Some of the commonly used flood susceptibility mapping analysis techniques include multi-criteria decision analysis, logistic regression, frequency ratio approach, weight of evidences equations, k-nearest neighbor logic and analytic network process framework (Swain et al. 2020).

Different research works have explored varied methods to estimate the flood susceptibility. Dey et al. (2024) have mapped the risk of flood in Texas of the United States using machine learning models. Muthu and Ramamoorthy (2024) assessed the urban flood susceptibility using bivariate statics. Similarly, Yang et al. (2024) identified flood susceptibility by proposing a multi model approach. Kurugama et al (2024) applied the machine learning methods to compute the flood susceptibility in Rathnapura district of Sri Lanka. The Brahmaputra Basin has been considered as the study area by Debnath et al (2023) to evaluate the impacts of flooding. The prevailing flood modeling approaches have been reviewed by Kumar et al. (2023) and listed out the merits and demerits of each of them. Moreover, Mahato et al. (2023) have assessed the performance of multi-criteria decision making techniques in flood susceptibility mapping. In other studies, Salvati et al (2023) in Iran, Osei et al. (2021) in Ghana, Akay and Baduna Koçyiğit (2020) in Turkey, Shah and Ai (2024) in Pakistan and Vilasan and Kapse (2022) in India have explored different methods of analyzing the floods and their impacts.

Nepal is vulnerable to a range of hydro-meteorological and geophysical hazards such as floods, landslides, glacial lake outburst floods, and earthquakes. (Budimir et al. 2020). It is a highly flood-prone nation and ranks 20th worldwide in terms of flood-affected populations (Thakuri et al. 2022). In recent years, it has been witnessing erratic and unpredictable monsoon rainfall patterns which has led to severe and frequent flood disasters (Shrestha et al. 2021). A devastating flash flood in Melamchi in June, 2021 triggered huge destruction to lives and properties (Adhikari et al. 2023). The disastrous flood in Bagmati province in 2024 claimed the live of more than 200 people and caused a big damage to properties and infrastructures (The Kathmandu Post, 2024). Hence, the assessment of flood risk and susceptibility in the context of Nepal has been more important now than ever.

There have been several studies on assessing flood susceptibility in Nepal. For instance, Maharjan et al (2024) used the machine learning approach to estimate flood susceptibility in the Mohana-Khutiya river of far western region. Likewise, Chaudhary et al (2024) applied the Analytical Hierarchy Process (AHP) to conduct flood susceptibility mapping of Kathmandu valley watershed. By using Support Vector Machine, Random Forest and Artificial Neural Network techniques, Duwal et al (2023) have analyzed the flood susceptibility in Karnali river basin. The Multi Criteria Decision Making tool was adopted by Chaulagain et al  (2023) to map the flood susceptibility of Kathmandu metropolitan city. These research works have rich contribution towards the flood studies. However, they have only considered either the region surrounding to federal capital city or wider river basins without delving into details of the local context. It has been observed that detailed literatures focusing on flood susceptibility of local governments which are far from federal administration have been limited. Furthermore, the data driven models that use machine learning and physically based models in Geographical Information System (GIS), though popular, have limited applicability in data scarce regions (Paudyal et al. 2021).

Against this backdrop, this study aims at mapping the flood susceptibility by using the freely available data and open source software QGIS. For the purpose, Dhangadhi sub metropolitan city in the southern plain of far west of Nepal is considered as case study. The study area is a data scarce, repeatedly menaced by flood inundation and also one the emerging urban areas of Nepal. This research work uses the AHP method to assess the flood susceptibility. In addition to the local governments, the findings can be useful for different stakeholders of flood risk management to mitigate the impacts of flood.The research article is divided into five sections. After the introduction, section two describes about the study area. It is followed by materials and methods, results and discussion. Finally, the conclusion is presented.

## STUDY AREA

Dhangadhi sub metropolitan city is the most significant trading center of far west region of Nepal and one of the major economic centers of the country. It is located at 28.6852º N latitude and 80.6216º E longitude. The total area covered by the sub metropolitan city is 262 sq. km. and there are altogether 19 wards. In the south, it shares the international boundary with India. The elevation of the study area ranges between 156 to 222 meters. The average annual precipitation is 1851.3 mm and the mean temperature is 30.6  (Government of Nepal, 2024). The study area has the tropical climate (Maharjan et al. 2024). Its total population 2,04,788 with 32,249 households (Central Bureau of Statistics, 2022). The city has been repeatedly affected by severe inundation triggering damages to human lives and properties (myRepublica, 2022; The Rising Nepal, 2024). The map of study area and the impacts of flooding have been demonstrated in Fig.-1.

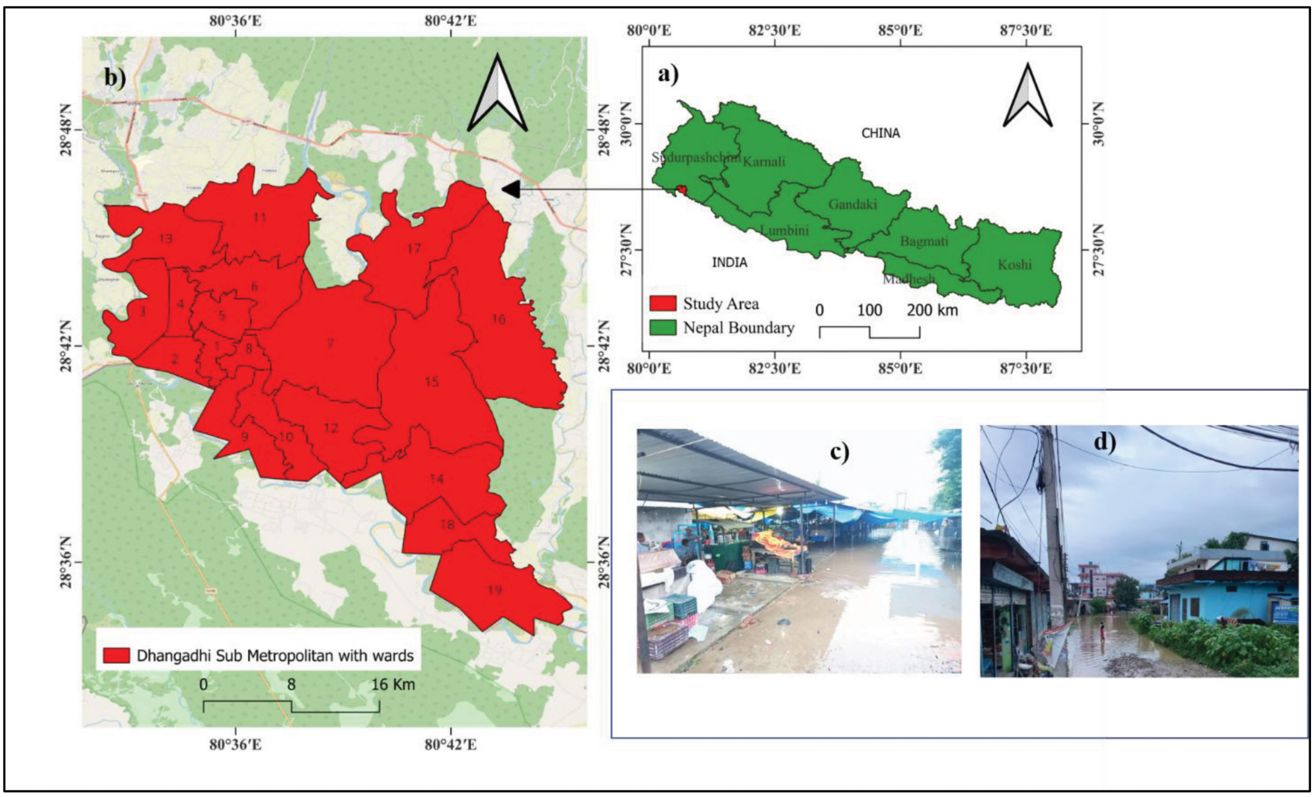


**Fig. 1: Study area:  a) Boundary of Nepal with provinces and study area, b) ward wise Dhangadhi Sub Metropolitan City with open street map background, c) condition of vegetable market of ward number 3 due to inundation triggered by heavy precipitation on 12th September 2024, and d) inundation in ward number 3 residential area due to same precipitation (Photographs were taken by the author on 13th September 2024).**

## MATERIALS AND METHODS

This study has used the openly available data and open source software QGIS for the mapping of flood susceptibility. The overall methodology diagram is demonstrated in Fig. 2. The details are discussed in following sub sections.

### Data

The first step in the process involved the identification of parameters that could have influence in the flood susceptibility of the study area. For the purpose, literature review (Chaulagain et al. 2023; Chowdhury, 2024; Pham et al. 2020) was conducted and expert opinion was sought out. The experts included the researchers, academicians and professionals on the sector of flood risk management. Some of the identified parameters were not relevant for this study as their data was not available. Altogether six parameters were selected which are elevation, slope, aspect, precipitation, distance from river and Land Use Land Cover (LULC) (Details in Table-1). It was followed by the collection and acquirement of data. Since this research is aiming to evaluate the flood susceptibility through open data sources, the relevant information was acquired from freely available sources.

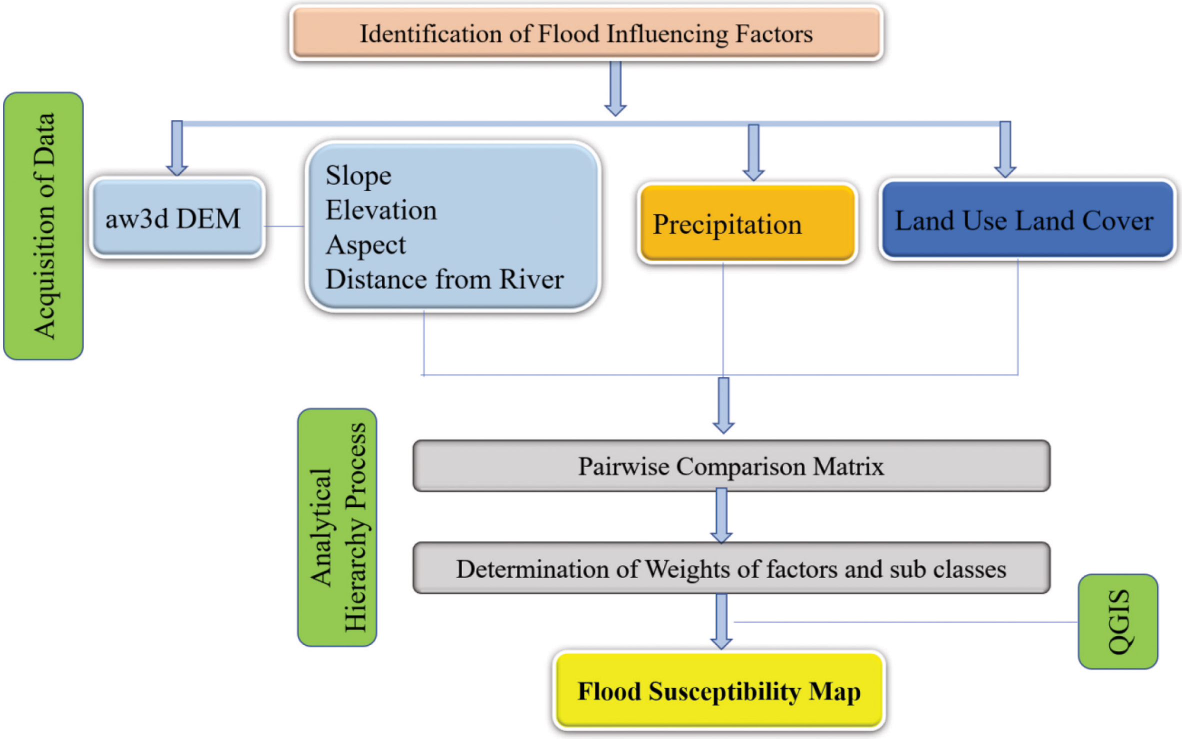


**Fig. 2: Overall Methodology Diagram.**

The Digital Elevation Model (DEM) of 30 meters resolution was acquired from aw3d website. Studies (Nonomura et al. 2020; Talchabhadel et al. 2021) have shown that in terms of accuracy and performance, aw3d DEM is better than other. Moreover, the 30m resolution data is freely available and easy to acquire. The slope, aspect and distance from river were derived using the DEM. Similarly, from the regional data base of ICIMOD, the LULC raster was obtained (ICIMOD, 2022).

The average annual precipitation data for the surrounding stations were acquired from Department of Hydrology and Metrology. Using the Inverse Distance Weight (IDW) technique (Hammami et al. 2019; Shadmaan and Hassan, 2024) in QGIS, the distribution of precipitation in the study area was estimated. The administrative boundary of the study area was acquired from opendatanepal.com.

**Table 1: List of data used for the analysis**

| SN | Data | Source | Resolution |
|---|---|---|---|
| 1 | Digital Elevation Model (DEM) | aw3d | 30m |
| 2 | Land Use Land Cover Map | ICIMOD | 30m |
| 3 | Average Annual Precipitation (in mm) | Department of Hydrology and Meteorology (DHM) | |
| 4 | Shapefile of boundary of Study Area | Opendatanepal | |
| 5 | Open Street Map | OSM | |

## Application of Analytical Hierarchy Process (AHP)

It has to be noted that the influence of each factors identified did not have same degree of influence in flood generation. So, to estimate the weightage for each factor, the AHP method was applied. It is a widely used and relatively easy process proposed by Thomas L Saaty (Saaty, 1984). There are three main steps in the process (i)generation of hierarchal tree structure for each criteria (ii) computation of weights for each criterion through pairwise matrix comparison (iii) determination of consistency of the judgement (Table-2) (Saaty, 1984)

The weights are based on Saaty's Table as shown in Table-3. Afterwards, class weight and Consistency Index (CI) (shown in Equation 1) were computed. In order to ensure consistency is maintained, the consistency ratio was estimated (Equation -2). The study used the direct approach to assess the weightage of sub class using the opinions of experts which ranged from 1 to 5 where 1 means the least influence and 5 means very high influence (Paudyal et al. 2021). Finally, using the raster calculator in QGIS, the susceptibility was estimated using Equation 3.

$$CI = \frac{\lambda_{max} - n}{n-1} \quad \text{............. Eq. (1 )}$$

Where, CI= Consistency Index

$\lambda_{max}$ = Maximum Principal Eigen Value

n= Number of Parameters

$$CR = \frac{CI}{RI} \quad \text{................ Eq (2)}$$

Where, CR= Consistency Ration

CI=Consistency Index

RI= Random Inconsistency Index

$$FS = \sum_{i=1}^{n} W_i \; R_i \quad \text{............... (3)}$$

Where, FS= Flood Susceptibility

$W_i$=Weight of each factors

$R_i$=Weight corresponding of sub factors

n= number of factors

Equation (3) could be rewritten as

$$FS = 0.05 * Elevation + 0.08 * Slope + 0.07 * Aspect + 0.29 * Precipitation + 0.32 * Distance\ from\ River + 0.19 * LULC \quad \text{............ (4)}$$

Finally, the obtained raster of flood susceptibility was reclassified into very low, low, medium, high and very high region.

**Table 2: Random Inconsistency Indices**

| n | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|
| RI | 0.58 | 0.9 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 | 1.49 |

**Table 3: Intensity scale of saaty**

| Scale | Degree of Importance | Description |
|---|---|---|
| 1 | Equal | Contribute Equally |
| 3 | Moderate | Favor moderately over another action |
| 5 | Strong | Favor strongly over another action |
| 7 | Very Strong | Very Strong Importance |
| 9 | Extreme | Completely better than another action |
| 2,4,6,8 | Intermediate | Intermediate Values |
| Reciprocals | | Inverse Comparison |

## Flood Influencing Factors

Elevation is one of the significant factors in flood susceptibility analysis. Since water flows from higher elevation to lower, there is constant threat of flash flood in the lower region (Choudhury et al. 2022) . The elevation has been categorized as 156-170m, 171-185m, 86-200m, 201-215m and 216-230m (Fig. 3a). Slope is the angle of any feature concerning the horizontal plane (Shadmaan and Hassan, 2024). It plays a vital role in deciding the areas where there could be serious threats of flood (Hammami et al. 2019) .The slope map for this study is prepared from the aw3D DEM . It varies between 0 to 18.44 degrees. The raster layer of slope is reclassified into sub groups as 0-3.68º, 3.69-7.38º, 7.39-11º, 11.1-14.76º and 14.77-14.44º (Fig. 3b). Similarly, aspect affects the occurrence of flood by regulating the amount of rainfall received and rainfall generation (Chowdhury, 2024). For the purpose of this study the aspect raster has been classified as 0-22.5º, 22.5-67.5º, 67.5-112.5º,112.5-157.5º, 157.5-202.5º, 202.5-247.5º, 247.5-292.5º, 292.5-337.5º and 337.5-360º (Fig. 3c).

Precipitation is considered the most significant factor for contributing to flood occurrence (Dano et al. 2019; Dutta et al. 2023) . For this study purpose the average annual precipitation has been categorized as 1534-1597.4 mm, 1597.5-1660.8 mm, 1660.9-1724.2 mm, 1724.2.6-1787.6mm and 1787.7-1851mm (Fig. 3d). Likewise, flooding gets initiated in the riverbeds and spreads throughout the surrounding area (Selvam and Jebamalai, 2023). That is why near the distance to river implies more susceptible to flood. The distance to river layer has been categorized into 0-1. 079 Km, 1. 080-2. 158 Km, 2. 159-3. 237 Km, 3. 238-4. 316 Km and 4. 316-5. 395 Km (Fig. 3e). The alteration of land use could lead to change in flooding pattern of a region (Pham et al. 2020). In this study, the land cover layer has been classified into five sub groups namely, water bodies, built up area, barren soil, agricultural land and forest area (Fig. 3f).

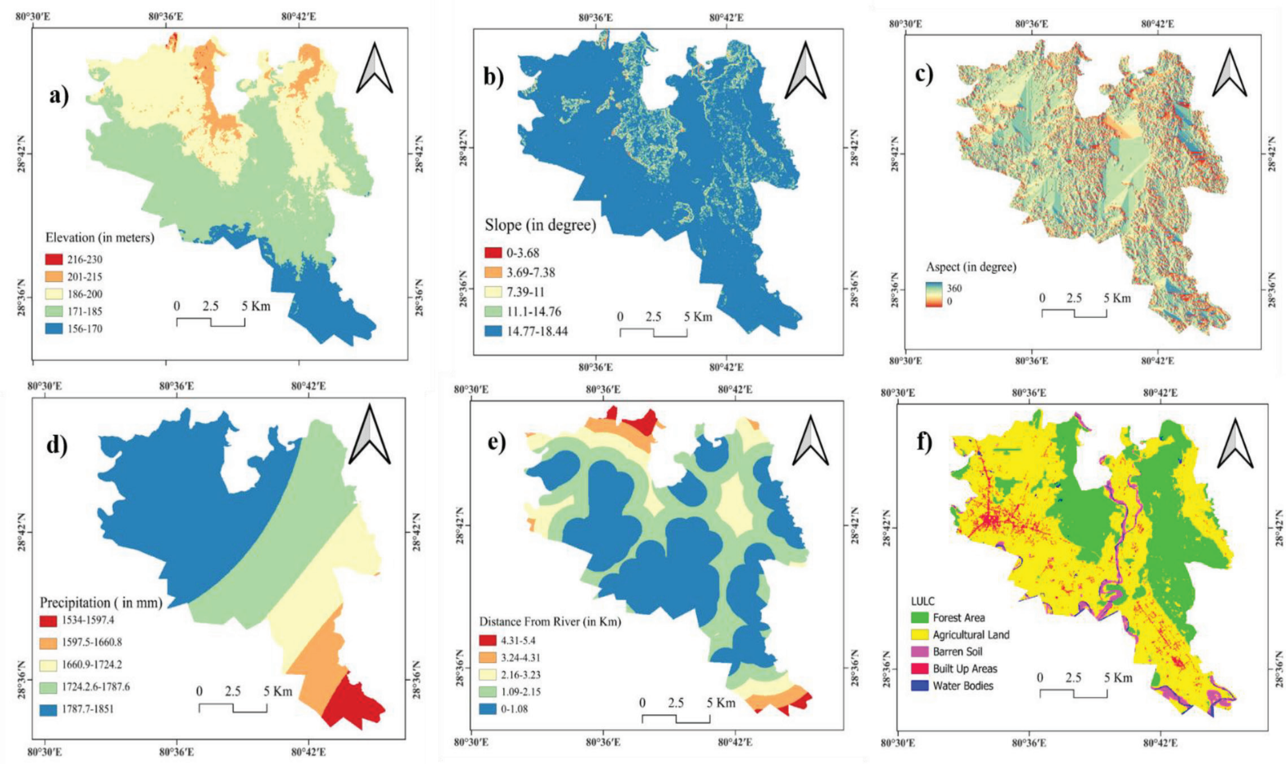


**Fig. 3: Factors influencing flood: a) Elevation, b) slope, c) aspect, d) precipitation, e) distance from river, and f) LULC.**

**Table 4: Pairwise comparison matrix**

| Parameter | Elevation | Slope | Aspect | Precipitation | River Dist. | LULC |
|---|---|---|---|---|---|---|
| Elevation | 1 | 1/2 | 1/2 | 1/3 | 1/7 | 1/3 |
| Slope | 2 | 1 | 2 | 1/3 | 1/7 | 1/2 |
| Aspect | 2 | 1/2 | 1 | 1/3 | 1/6 | 1/3 |
| Precipitation | 3 | 3 | 3 | 1 | 2 | 2 |
| River Distribution | 7 | 7 | 6 | 1/2 | 1 | 2 |
| LULC | 3 | 5 | 3 | 1/2 | 1/2 | 1 |

## RESULTS

### Area of Flood Susceptibility

Through opinion of expert and literature review six parameters namely elevation, slope, aspect, precipitation, distance from river and LULC had been identified for estimating the flood susceptibility map. Pairwise matrix comparison of AHP was applied (Table-4) to compute the weights of class (Table-5). The maximum principal eigen value computed was 6.48 and consistency ratio (CR) was equal to 0.077. Since CR<0.1 is considered acceptable (Shadmaan and Hassan, 2024), it is concluded that the comparison is consistent in this case. The flood susceptibility map was prepared and classified into five zones namely very low, low, medium, high and very high (Fig. 5).

It was observed that 0.74% (1.93 sq. Km) area lies in the very low zone, 5.44% (14.24 sq. Km) in low, 41.13% (107.69 sq. Km) in medium, 51.22% (134.09 sq. Km) in high and 1.45% (3.84 sq. Km) in very high zone (Fig. 4). The very high flood susceptible areas mainly lie in ward number 1, 2,3, 4, 5, 8, 9,12 and 13 (Fig. 6). Out of them ward number 1 and 8 have dense concentration of very high susceptibility areas. Similarly, ward 14, 16 and 18 seem to have more areas with medium susceptibility. The wards 11,17 and 19 have more places that exhibit low or very low susceptibility.

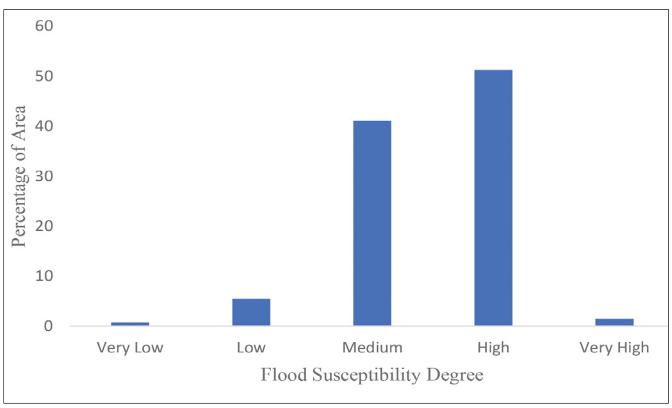


**Fig. 4: Flood susceptibility degree and percentage of area.**

**Table 5: Weights of parameters and the sub classes**

| SN | Parameters | Parameter Weight | Sub Class | Sub Class Weight |
|---|---|---|---|---|
| 1 | Elevation | 0.05 | 156-170 | 5 |
| | | | 171-185 | 4 |
| | | | 186-200 | 3 |
| | | | 201-215 | 2 |
| | | | 215-230 | 1 |
| 2 | Slope | 0.08 | 0-3.68 | 5 |
| | | | 3.69-7.38 | 4 |
| | | | 7.38-11 | 3 |
| | | | 11.1-14.76 | 2 |
| | | | 14.77-18.44 | 1 |
| 3 | Aspect | 0.07 | 0-22.5 | 1 |
| | | | 22.5-67.5 | 3 |
| | | | 67.5-112.5 | 2 |
| | | | 112.5-157.5 | 2 |
| | | | 157.5-202.5 | 5 |
| | | | 202.5-247.5 | 5 |
| | | | 247.5-292.5 | 4 |
| | | | 292.5-337.5 | 4 |
| | | | 337.5-360 | 1 |
| 4 | Precipitation | 0.29 | 1534-1597.4 | 1 |
| | | | 1597.5-1660.8 | 2 |
| | | | 1660.9-1724.2 | 3 |
| | | | 1724.2.6-1787.6 | 4 |
| | | | 1787.7-1851 | 5 |
| 5 | Distance from River | 0.32 | 0-1079 | 5 |
| | | | 1080-2158 | 4 |
| | | | 2159-3237 | 3 |
| | | | 3238-4316 | 2 |
| | | | 4316-5395 | 1 |
| 6 | LULC | 0.19 | Water Bodies | 5 |
| | | | Built up Area | 4 |
| | | | Barren Soil | 3 |
| | | | Agricultural Land | 2 |
| | | | Forest Area | 1 |

### Validation of susceptibility map

The validation of the susceptibility map was carried out through indirect method. Random spots (n=8) were selected that covered diverse places of the study area. Filed visit, google earth application and reports from news portals were utilized to compare the degree of estimated flood susceptibility and the actual flood that have occurred in the past in the respective place. Barring two, all other spots exhibited a good match with the finding. It is concluded that the prepared susceptibility map is well validated. Similar method of indirect validation has been adopted by Bhattarai et al (2022) for flood spots and Paudyal et al. (2021) for landslide spots.

## DISCUSSION

### Flood susceptibility

This research work used the AHP model to estimate the susceptibility of flood. In the study area, precipitation and proximity to river are found to be the significant factors to influence the flood. Likewise, the factors such as elevation, slope and aspect exhibited relatively less significance. Studies such as (Chithra et al. 2024; Kader et al. 2024; Vilasan and Kapse, 2022) show that the selection of these factors and their weightage value might vary as per the region. It has been observed that the areas in the north and central region and part of central south of Dhangadhi lie in the blend of very high, high and medium susceptibility zone. It can be attributed to high precipitation distribution and proximity to river (Dutta et al. 2023). The south eastern part and a chunk of forests in the northern part exhibit low degree of susceptibility. The studies by Chaulagain et al (2023) in Kathmandu of Nepal, Saikia et al (2024) in Assam of India , Shadmaan and Hassan (2024) in Sylhet of Bangladesh and Shah and Ai (2024) in Pakistan confirm the findings of this research work that settlement areas proximal to water bodies and receiving high rainfall have been more susceptible to flood.

The study conducted by Maharjan et al (2024) which has considered the wider Mohana river basin of which a section of Dhangadhi is also a part, depict that the western and central south part of the town are moderately and highly susceptible to flood (in line with findings of this research). With some exceptions, it has categorized the central region as low susceptible (contrast to findings of this research). The contrast can be attributed to the difference in approach of two studies and the varying degree of flood susceptibility. The Mohana basin research work has not considered precipitation as contributing factor and used three zones of flood susceptibility. This research work, on the other hand, considers precipitation as a significant factor and has categorized five susceptibility zones.

However, there is necessity to understand the result of this research with appropriate context. It is because some forest areas especially the eastern part have demonstrated medium susceptibility of flood. It might be due to high weightage of high rainfall distribution and nearer distance to the river in such areas. But the impact of flood severity might be low in these regions as there are no settlements and other infrastructures.

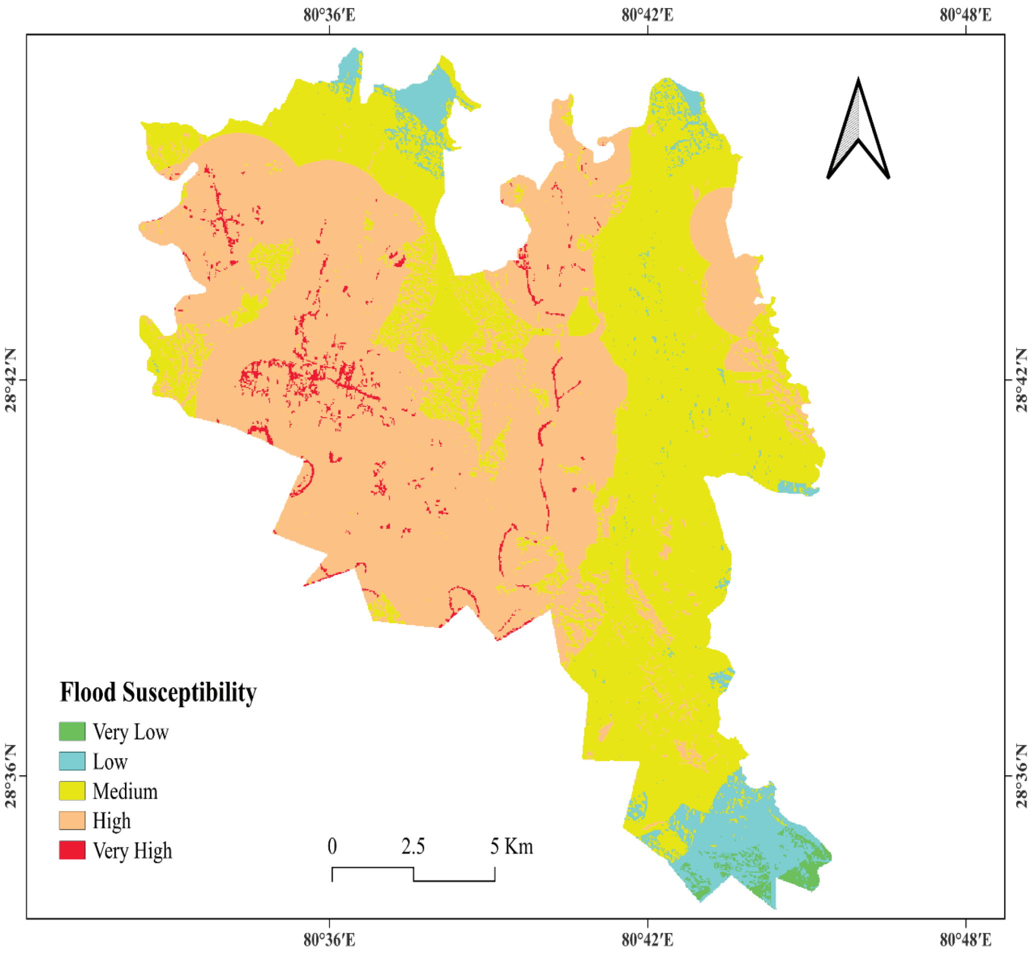


**Fig. 5: Flood susceptibility map of Dhangadhi Sub Metropolitan City.**

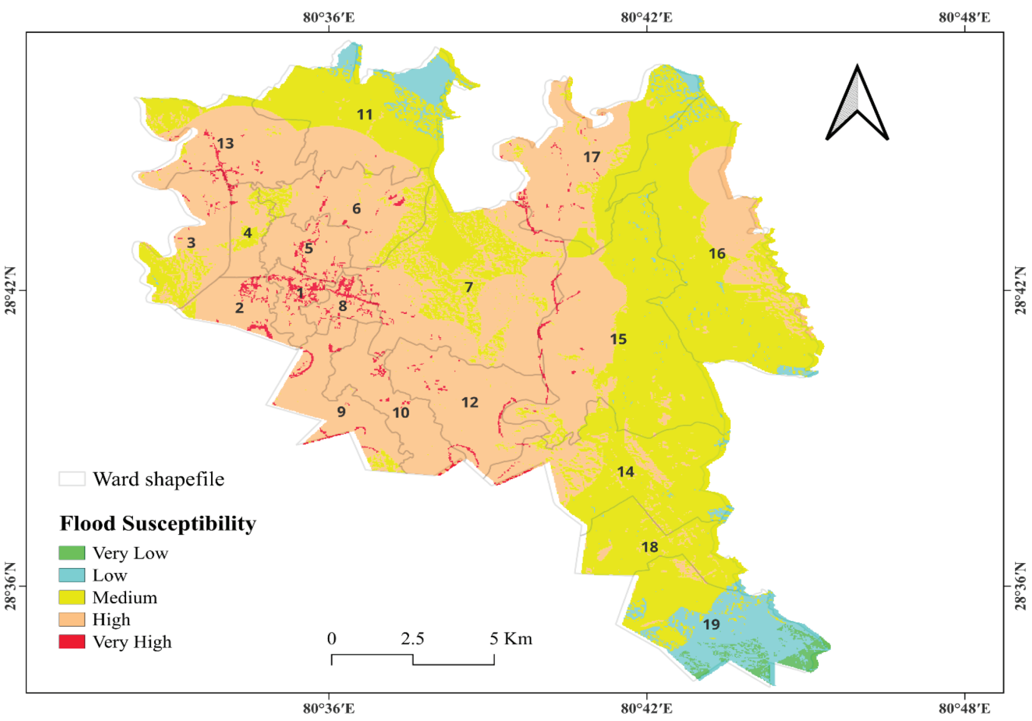


**Fig. 6: Ward wise flood susceptibility map.**

### Local context and data availability

Dhangadhi is located far from the federal capital city of Nepal, Kathmandu. That might be one of the reasons that there are very few prior studies that solely focus on its flood zonation mapping. The research works that have considered wider basins would encounter difficulty to capture the unique geographical as well as the local administrative context. A big portion of the city is prone to medium, high and very high-level flood which poses challenge to the local government. In addition to it, the city has witnessed rapid increase of built up area in between the year 1990 to 2020 (Devkota et al. 2023) due to migration of people from the hilly belts of Sudurpaschim province (Bista, 2021).

During the field visit, it was observed that the city lacks the proper drainage system. While some drainage construction works were also undergoing, there were also some roads which did not have drains at all. There has been conflict in the past in between the neighboring wards regarding the construction and blockage of drainage (The Kathmandu Post, 2021).The systematic solving of drainage problem in the city can reduce the problem of inundation by huge margin. The research by Chaudhary et al (2024) in Kathmandu valley corroborate the conclusion. Some senior locals informed that the increased encroachment of river side, lakes and ponds which is leading to repeated inundation of the town.

The local governments in Nepal are relatively novel institutions as there have been just two elections since the restructuring of country into federal system in 2015 (Bhusal and Acharya, 2024). So, it is obvious that they have a long way to go in terms of building institutions, formulating flood resilience policies as well as accumulating necessary human and financial resources (Subedi and Subedi, 2021). The sub metropolitan city has enacted the Local Disaster Risk Management Act. However, its implementation still faces questions since a number of incidents of inundation and consequent losses are reported every year (myRepublica, 2022). Moreover, Disaster Preparedness and Response Plan (DPRP) which envisions the overall disaster management planning, is yet to be formulated by Dhangadhi Sub metropolitan city.

While the precipitation data is collected in the station of Dhangadhi airport, the scarcity of hydrological data in the study area is a burning issue. In Nepal, the Department of Hydrology and Meteorology (DHM) provides the information of precipitation, hydrological discharge, temperature and wind speed (Thakuri et al. 2022). In fact, the DHM has been disseminating flood and high rainfall forecast every day. For example, it had correctly predicted a big rainfall in Dhangadhi and surrounding regions of Sudurpaschim province on 11$^{th}$ and 12$^{th}$ of September, 2024. However, there is necessity to further explore to what extent have these forecasting been reaching to target people and how effective have they been in mitigating the impacts of flood. Furthermore, Nepal does not have an ample number of hydrological stations for flood forecasting (Pangali Sharma et al. 2021). Notably, the rivers that flow through Dhangadhi are not gauged. The understanding, simulation and mitigation of flooding scenarios in small and ungauged region represent an open challenge for researchers and floodplain managers (Grimaldi et al. 2021). The highly accurate hydro metrological data required for detailed analysis are not easy to access as they are not open source. So, the researchers are compelled to resort to empirical methods to develop the flood modeling for the region.

The limitation of this research work is that it has not considered the drainage density of the study area. The data related to drainage of the sub metropolitan city is not available. Moreover, it has to be noted that there is no standard guideline to choose the factors when employing the multi criteria decision making for flood susceptibility (Mshelia et al. 2024). So, there might be the chance of subjective biasness in the assessment.

## CONCLUSION

The main aim of this study is to estimate the flood susceptibility of data scarce local government using open source data. Dhangadhi sub metropolitan city in the far western southern plain of Nepal was considered as the study area due to the frequent flooding incidents in the region. Afterwards, the relevant factors responsible for flood were identified. They include elevation, slope, aspect, precipitation, distance from river and LULC. Using AHP method, the pairwise comparison matrix was prepared and weights for each factor and their sub class was estimated. It was found out that distance to river (weight=0.32) and precipitation (weight=0.29) are the major influencing factors for flood in the study area. Finally, the flood susceptibility map was prepared in open source QGIS environment dividing the region into five zones of very low, low, medium, high and very high susceptibility.

The findings show that about 0.74% (1.93 sq. Km) area lies in the very low zone, 5.44% (14.24 sq. Km) in low, 41.13% (107.69 sq. Km) in medium, 51.22% (134.09 sq. Km) in high and 1.45% (3.84 sq. Km) in very high zone. The very high and high susceptible areas include the residential areas which have proximity to river and water bodies and which receive more rainfall. Likewise, moderate precipitation and elevation have been the characteristics moderate region. Finally, the vegetation or forest areas which are relatively far from the river and receive low rainfall are the low and very low flood susceptible regions. It is recommended that the local governments should prioritize flood hazard mapping and implement the measures to reduce the impacts of flood in the identified susceptible areas. The output of this research work could be helpful for leadership of local government, policy makers and academicians to strengthen flood risk management. It can act as the baseline for future studies on the subject matter.

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