

# Mapping Floods Risk and Assessing Flood Vulnerability for Settlement Areas

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## Research

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## **Abstract**

## **Background**

The impact of flooding rises due to unplanned settlements, especially in developing and underdeveloped countries. This study tries to address these issues by mapping flood risk places and assessing their impact on population and household.

## **Methods**

This study used the dataset available in Google Earth Engine (GEE), Food and Agriculture Organization (FAO), Central Bureau Statistics (CBS), Earth Data for preparing slope, drainage density, digital elevation model, rainfall, land use map, and soil map. These maps create using GEE and QGIS through overlay analysis that has two factors. The one is influence and other slopes, and it has provided high and low value according to its role on flooding.

## **Results**

The risk assessment shows around twenty-four percent population is at higher risk, whereas more than three thousand settlements are prone to flooding. It depicts a significant increasing trend of floods in the Morang district.

## **Conclusion**

This settlement risk map can help determine the flood safe and very high-risk areas in the Morang district. It will support residential places' planning by the local government, urban planners, and community people to reduce flooding risk.

### **1. Introduction**

The flood-affected more than 2 billion people worldwide from 1998 to 2017 (Floods, n.d.). It damages property, loss of life, and other infrastructure such as schools, hospitals. The people living near the flood plain are prone to this calamity due to a lack of residential planning, early warning system, and awareness (51370\_icimodcbfews016.Pdf, n.d.). Several studies regarding disasters like floods have shown a significant increase in flood worldwide and might be more recent. This upcoming trend is due to climate change and unplanned settlements in flood-prone areas. Poor people of developing countries are overexposing residence in very high-risk areas (Poorly Planned Urban Development | PreventionWeb.Net, n.d.). More than hundreds of people die in Nepal every summer, and monsoon rains trigger flooding in lower terrain and higher terrain landslides (150623\_monsoon\_hazard\_analysis\_final\_. Pdf, n.d.; Petley et al., 2007). Few studies mapped flood risk and its vulnerability to the population and household (De Risi et al., 2020; Mioc et al., 2015; Rufat et al., 2015).

Several studies find that the government lacks a flood risk map and assesses its vulnerability on population, household, and places to provide permission for settlement on a specific area (13627\_Local Governments and Disaster Risk Redu.Pdf, n.d.;150623\_monsoon\_hazard\_analysis\_final\_. Pdf, n.d.; Aksha et al., 2020; World Bank, 2003). This study prepares a flood risk map of Morang district for settlement areas using six criteria: land use, drainage density, slope, rainfall, Dem, and soil. It will provide spatial information about very high risk and safe places for settlement that would support informed decision-making by the government and policymakers to minimize flood risk. Using such an approach, they can reduce the risk by restricting human settlement on very high risk and high-risk areas or shifting those who lived already through awareness campaigns and relief packages.

### **2. Materials And Methods**

#### **2.1. Study Area**

Nepal's Morang district is at high risk of flooding where more than dozen villages faced due to flooding in Ratuwa, Bakraha, Lohandra, Chisang, Keshliya, and Singiya rivers (Over a Dozen Villages Prone to Flooding in Morang - Nepal, n.d.-a; Over Dozen Villages Prone to Flooding in Morang - MyRepublica - The New York Times Partner, Latest News of Nepal in English, Latest News Articles, n.d.). It shows a significant increase of floods every year and is kept in flagship four by Nepal Risk Reduction Consortium (Morang | Flagship 4 - Nepal Risk Reduction Consortium, n.d.; Nepal, n.d.). This hazard impacted more than two thousand families displaced, hundred killed in the last five years. This study finds the high-risk and low-risk regions that will help people, communities, and local governments prepare settlements in safer places.

#### **2.2. Data Collection**

The study used historical past rainfall data from 2000 to 2019. Other datasets acquire from different sources, such as land use uses from Google Earth Engine (GEE) and soil data from the Food and Agriculture Organization (FAO). The drainage density, slope, Population, household data from Central Bureau Statistics (CBS, 2011), and Dem from earth data (Table 2.1).

Table 2.1  
The datasets used for the modelling.

Datasets	Data Source
CBS	Population, Household <a href="https://nada.cbs.gov.np/index.php/catalog/54">https://nada.cbs.gov.np/index.php/catalog/54</a>
Earth Data	DEM, Drainage Density, Slope <a href="https://earthdata.nasa.gov/">https://earthdata.nasa.gov/</a>
FAO	Soil Data <a href="http://www.fao.org/geonetwork/srv/en/metadata.show%3Fid=14116">http://www.fao.org/geonetwork/srv/en/metadata.show%3Fid=14116</a>
GEE	Land use, Rainfall <a href="https://earthengine.google.com/">https://earthengine.google.com/</a>

## 2.3. Methods

This study used data from Earth data, GEE, and FAO data repository as described in Table 2.1 for preparing land use, soil, digital elevation, rainfall, drainage density, and slope map (Fig. 2.2). From this data, the respective layers' maps generate using Google Earth Engine for risk assessment on the residential areas of Morang.

The overlay analysis has two basic terms influence and scale. Influence is fundamental for analysis from six layers (Table 2.2); used land use is the highest influencer as proper land use planning in this study area can reduce flood impacts. It is overall critical of the layer. In contrast, the soil is less significant compared to the other five parameters.

Evaluation criteria:

Table 2.2  
The data layers used for flood risk analysis.

Layers	Influence(100%)
Land use	24
Slope	10
Soil	8
Digital Elevation model	18
Rainfall	20
Drainage density	20

For attribute of the data:

Classified into five categories, weightage 5 to 1, In this analysis scale from 1 to 5 is used to evaluate the layer's importance of attribute. Here one means less significance, and five means most important. The scale is an essential attribute for flood risk mapping and assessment.

Table 2.3  
The attribute used for flood risk analysis.

Attribute	Scale
Rainfall	Higher rainfall higher the scale. That is lower rainfall value is 1 followed by highest elevation 5
Digital elevation model	Higher value is less important as compare to lower elevation
Slope	Lower slope more chance of flood so more important
Soil	Soil towards higher elevation is less important
Land use	Urban are taken more important. Agriculture land with important Waterbodies with moderate important Openforest with less important Dense forest with least important
Drainage density	Higher the drainage density more the important

### 3. Results

The overlay analysis (Table 2.2) and attribute (Table 2.2) criteria prepare a flood risk analysis map of Morang District (Fig. 3.1). The average population and settlement risk and total are calculates using the zonal statistics tool, shown in the graph, chart, and map. The data of central bureau statics of population and household (CBS, 2011) with soil, land use, drainage density, slope, Dem, rainfall map uses for creating settlement at risk in the Morang district.

In the Morang district, around twenty-four percent population is at higher risk, whereas about more than three thousand settlements are prone to flooding. The terrain with closer proximity has chances of a flood, and higher elevation is safer than the lower one. This study shows significant results that almost more than fifty percent of district areas are prone to flood. Therefore, people should be aware of this scenario by local government, a non-profit organization, international non-profit organization to provide equal land in other safer places from floods. It includes valuable information regarding land use planning, risk perception, settlement areas to the decision-maker, local government, and other stakeholders to plan residential regions of safer places.

### 4. Discussion

Flood impact rises every year due to land-use changes, unplanned residential areas, and climate change. This increasing trend of a flood is worldwide causing the lives of millions of people (). It is a rapid growth of urbanization without proper study of its terrain and risk of disaster in developing countries (Asian Development Bank, 2013; Disaster Risk Management in South Asia - A Regional Overview.Pdf, n.d.; Gu & Division, n.d.; World Bank, 2003b). Few studies try to understand the most common natural disaster like floods, landslides, and earthquakes locally, regionally, and nationally in Nepal (1321.Pdf, n.d.; Thapa, 2021; Tuladhar et al., 2015). Even proper study information is unable to capture these uncertainties that exist in these hazards and vulnerability. The research will depend on multiple assumptions, incomplete datasets, and imperfect models that lead to an error during risk analysis and assessment to minimize this risk. While performing risk analysis, should select careful consideration and impact factors such as sloping and influence regarding the specific study area (Rogelis et al., 2014; Vulnerability of Human Settlements to Flood Risk in the Core Area of Ibadan Metropolis, Nigeria, n.d.). A spatial approach plays a vital role in risk analysis and assessing its vulnerability of residential places (Lindley et al., 2007; Thapa, 2021; Westen, 2013). The results show Uralabari, Ratuwamau, Sunwarshi, Patahri are the municipality highly prone to flood whereas Letang, Kerbari municipality are flood safer area (150623\_monsoon\_hazard\_analysis\_final\_Pdf, n.d.; Importance of Risk Analysis and Management – The Case of Australian Real Estate Market | IntechOpen, n.d.; Incessant Rainfall Wreaks Havoc in Tarai, 2017; Over a Dozen Villages Prone to Flooding in Morang - Nepal, n.d.-b; Over Dozen Villages Prone to Flooding in Morang - MyRepublica - The New York Times Partner, Latest News of Nepal in English, Latest News Articles, n.d.). It will provide information about the location of very high risk, high-risk areas to support disaster management program. Therefore, remotely sensed data with geospatial technologies such as google earth engine and QGIS prepare maps and assess analysis regarding the risk of flood on settlement areas. This study introduces a spatial technique to identify the risk in the Morang district.

### 5. Conclusions

The flood risk map and assessment determine safer places from flood such as Letang, Kerbari municipality, where people can settle. Uralabari, Ratuwamau, Sunwarshi, Patahri are the municipality prone to upcoming flood. From this response, local government, residence, disaster management teams, security forces should be prepared during every summer and monsoon of these municipalities to reduce the loss of lives and property damage. Similar studies need the whole country for better preparedness, response, recovery, and natural disaster reduction. However, the government and exposed people to these prone are unaware of this due to lack of economic and human resources, and people no place to shift their

settlement. Despite significant input from nonprofit organizations, international organizations warning people about a flood and its impact through awareness, there is an increasing number of deaths and property damage every year. This study suggests that more people live in a very high, high-risk area, increasing the risk every summer and monsoon. The solution might be living in safer places and performing other low and medium-risk activities such as farming and forest in high flood risk places to reduce its risk.

## 6. Abbreviations

CBS- Central Bureau Statistics

DEM- Digital Elevation Model

FAO- Food and Agriculture Organization

GEE- Google Earth Engine

QGIS- Quantum Geographic Information System

## 7. Declarations

- **Consent for publication**

I agreed to submit final manuscript for this Journal and approved the submission.

- **Ethics approval and consent to participant**

Not applicable.

- **Availability of data and materials**

The data used are cited with their sources, if data used in manuscript are not clear, the author is agreed for clarification and sending of dataset on request.

- **Competing interests**

There are no competing interests.

- **Funding**

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- **Authors' contributions**

Conceptualization, T.P and T.N. methodology, T.P and T.N.; analysis, T.N.; assessment, T.P; resources, T.P; datasets, T.N.; writing—original draft preparation, T.P; writing—review and editing, T.P and T.N.; visualization, T.N.; supervision, T.P. All authors are agreed to the published version of the manuscript.

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- **Authors' information (optional)**

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## Figures

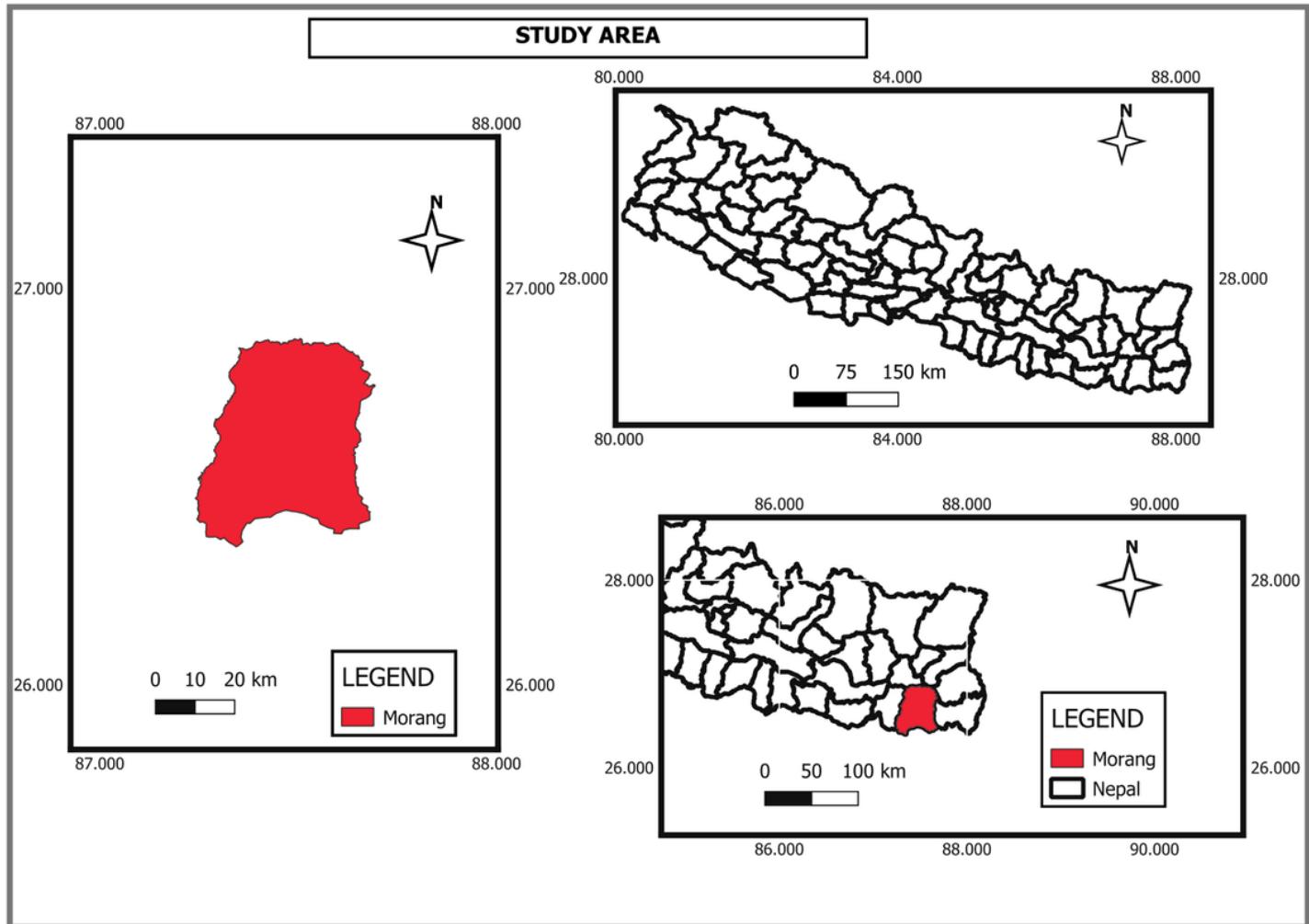


Figure 1

Study area used for predication COVID 19.

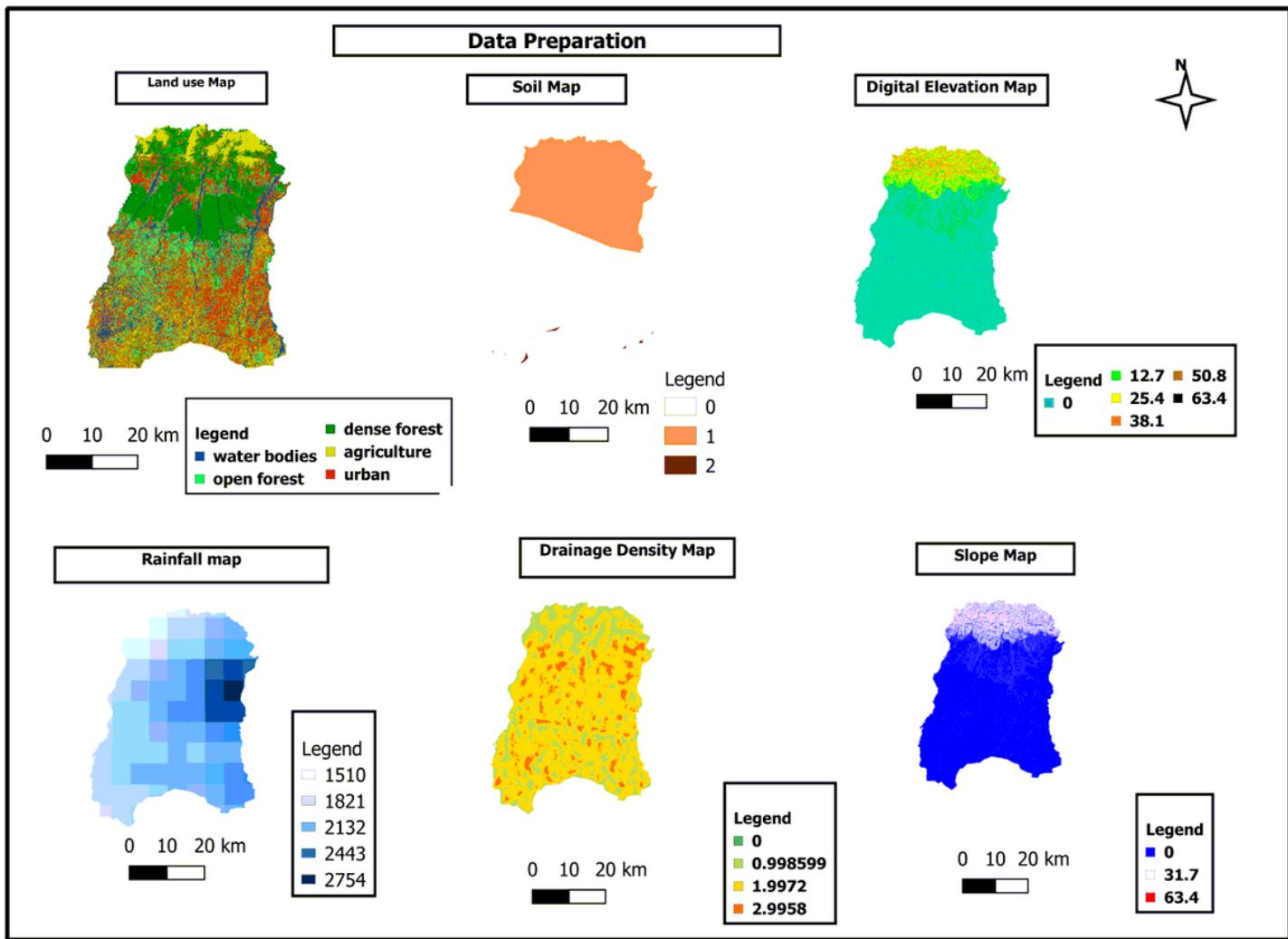
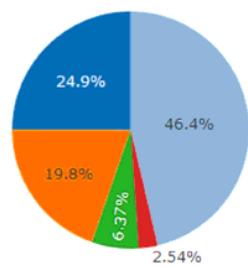


Figure 2

Six maps to estimate the risk of flood in Morang district

## FLOOD RISK ANALYSIS OF MORANG

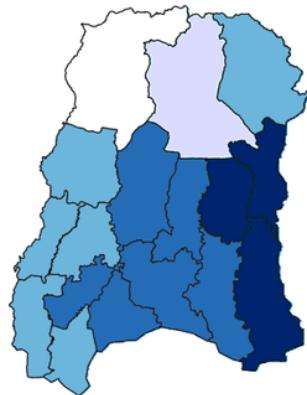
**Percentage of population at risk**



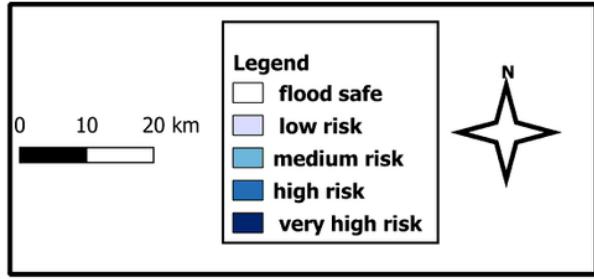
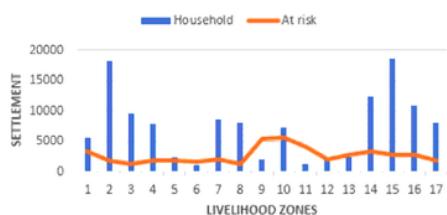
**Legend**

- medium risk
- flood safe
- low risk
- At risk
- High risk
- very high risk

**Settlement at risk**



**Settlement at risk**



**Figure 3**

Flood risk analysis (left) pie chart of population at risk (right) settlement at risk