GEOG30880 Project in GIS
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Topographic Conditions of Indrawati River Catchment Area and Settlements Risk of Flooding Downstream in the Central Region of Nepal.

Introduction

The global climate is changing rapidly in recent years and it is said that climate change has greater implications for water resources systems. IPCC report in 2007 reported that precipitation increases in the Asian and Australian monsoon. Whereas it will decrease in West Africa, Mexico, and Central America. The IPCC report also predicted that warming will reach to well above the global mean level in south Asia and the Tibetan Plateau during this century (IPCC, 2007). Even though climate change is a global phenomenon the impacts are mostly local and developing countries like Nepal are more susceptible and vulnerable to climate change and its impacts due to their limited coping capacity (Aksha et al. 2019)). In recent years, Nepal is experiencing an increase in surface temperature, rapid glacier melts, changes in the weather pattern, and drastic changes in monsoon rainfall whether too much or too little which has led to an increased risk of flooding and landslides across the country (Thapa et al 2020). And the most realized hazard is river flooding as Nepal has complex river systems throughout the country.

In this essay, I will study the risks of Indrawati River flooding where, on the 14th of June in 2021, a big flood event took place and lasted for several days. The flooding event is known as Melamchi Flooding. Floodwater with thick sediments and debris gushed into settlements downstream of the main economic hub Melamchi Bazar. It killed more than two dozen people, swiped away basic infrastructure like bridges, and swamped many villages downstream. It also completely damaged the most anticipated development of the drinking water supply for Kathmandu city. This project had been built in the upper part of the river. The major impact of this flooding was at the Melamchi Bazar in Sindhupalchok District, where settlement is relatively more intense and has been built on the river floodplain. The flood displaced over one hundred families in the Melamchi Bazar alone. It is said that the flooding was caused by extensive and excessive rainfall leading to multiple landslides upstream. The landslides upstream blocked the river flow and built dams. Due to the volume of water and mud eventually, the dams broke out and caused massive flooding downstream (The Kathmandu Post, 2021) (The Himalayan Times, 2021).

The capital city Kathmandu is only about 60 km from the river has a population of about 3 million and has been facing water scarcity for a long time. The current water demand of Kathmandu is 350 million litters a day but only 131 million litters in the wet season and 94 million litters in the dry season are

supplied (Shrestha et al. 2017). To ease this situation, the Melamchi Water Supply Project (MWSP) was introduced as the long-term solution to this crisis in 1998. The project was designed to divert 170 million liters of freshwater a day from the Melamchi River to Kathmandu valley through a 26-km tunnel with the aim to complete the project by 2008. Due to institutional weaknesses, poor management and governance in construction sectors, and lack of coordination across the organizations involved, all have contributed to 12 more years of delay in the completion of the project (Phuyal et al. 2020). The USD 320 million project completed in March 2021. But the river flood completely destroyed the water dam and remains under thick layers of sediments and debris. Overall the flooding was very costly in both economic and social terms.

Methodology and Materials

Firstly this study specifically focuses on the settlement in Melamchi village and its risk of flooding as it is located at the Indrwawati River catchment area. I will discuss more the Melamchi village in the study area section below.

As it is said that the changing patterns of monsoon rain have been the major cause of landslides and river flooding in Nepal to observe these changes in monsoon rainfall in the study area over time, rainfall data for the past 40 years is used to visualize monsoons' mean rainfall. The data is displayed in a line graph. Monsoon rainfall data between 1981–and 2021 of the sindupalchok district (figure 3) was taken from the Department of Hydrology and Meteorology, Government of Nepal, and Open Data Nepal obtained from the NASA Langley Research Centre, data links are listed at the end of this paper. The rainfall data contained twelve months of monthly mean rainfall over 40 years but for the study purpose, I extracted only four monsoon months data from June to August and calculated the mean value of only these four months each year over the 40 years. The data shows that there are significant variations in the rainfall over the years but the past two years have been the wettest year in the period of data taken.

To assess the Melamchi village's risk of Indrwawati River flooding I used the scenario of 25 meters from either side of the banks as exposure to the risk of flooding. For this, I used three different sets of data 1) the local administration level small area boundary of Nepal 2) rivers catchment data of the country, and 3) digitized building features in the polygon of the country all being vector data. These datasets are accessed from the Humanitarian Data Exchange (HDX), which is a metadatabase and the links are listed at the end. Since this study is in a very specific location I selected only 2.50 km length of the lower part of the river and building features in the Melamchi village through the feature selection process in Arc Map. Then built 25 meters buffer zone around the selected section of the river through geoprocessing tool buffer. This scenario implicates the building being at risk of flooding. one of the

reasons that I used building features instead of people is inconsistency and lack of population data of this area.

Topography plays a very important role in river flooding. Therefore to map the topographic condition of the river Indrawati catchment I used the raster data, the Nepal Digital Elevation Model (DEM) data with the 90-meter resolution to create a topographic map of the Indrawati river catchment area. This data is also taken from the metadatabase Humanitarian Data Exchange (HDX). The map captures all of the River Indrawati basins before its confluence with another river. The map shows the degree of steepness of the area with classification, as the river extends from an elevation just 625 meters above sea level to as high as 5850 meters. This slope map is created through a geoprocessing tool. Firstly, extracting the selected area by masking the selected catchment boundary with Digital Elevation Model (DEM) data. The accuracy of the created DEM was confirmed with the freely available open street map in Arc GIS.

The vector data map performed spatial analysis to depict the risks of flooding in Melamchi village in the lower basin of Indrawati river. Whereas, the raster data map performed spatial analysis to display the possibilities of risk of landslides and flooding under topographic conditions. All the spatial analyses were performed in Arc GIS 10.3.1 environment.

To understand the study area better I will next discuss the geo-climatic conditions of the country in a bigger picture.

Geoclimatic Conditions of Nepal Overall Picture

Nepal is a high mountainous country elevation starting from about 57 meters above sea level to over 8800 meters. Hence its climate varies from tropical in the low land to high alpine in the high land mountains. It experiences five different climatic seasons summer, monsoon, autumn, winter, and spring. The monsoon makes two clear dry and wet seasons in the country. Topographically, Nepal is divided into three distinct ecological regions mountains, hills, and plains(Terai).

Figure 1.

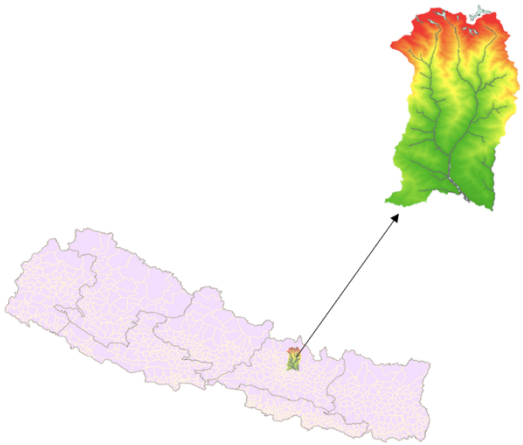
Source: ResearchGate: https://www.researchgate.net/figure/Ecological-zone-map-of-Nepal_fig1_265388488

The mountain region is at an altitude of about 3,500 meters above sea level. The hills region is an altitude between about 2,000 meters to 3,500, which is extremely terraced for agriculture. The plain region is below 2,000 meters, the southern part of the county, is the densely populated region and produces most of the country's food, and shares its border with India (Bhattarai, 2009). Due to these geographic and topographic conditions, Nepal has diverse climatic conditions and diverse networks of river systems. Nepal is also a hot spot for earthquakes as it lies on the active tectonic fault line between the Indian and Eurasian Plates. Together with climate change's impact on monsoon precipitation, steep topography and earthquake make the country prone to frequent landslides (Nakata, T.1989).

Study Area

Indrawati and Melamchi River Catchment area in Sindhupalchok District Nepal

Figure 2.



Indrawatui River is about 60 km away to the North-East of the Kathmandu valley, located in the central development region of Nepal. It originates in the Himalayas at the base of Jugal mountain near Tibet, at an elevation of about 5850 m high above sea level, and discharges into the Sunkoshi River at an elevation of about 625 meters. It then feeds into the Koshi River, which is the biggest river in Nepal, and then eventually goes out to the Brahmaputra delta in Bangladesh out to the Indian ocean. The length of the Indrawati River from its origin to its confluence point with Sunkoshi is about 59 km with the catchment area about 1240 km2. Indrawati River runs through two districts in the region before joining the other river. The upper area of the river is in the Sindhupalchok district, the basin covers approximately 43% area of the district. The lower part of the river is in the Kavrepalanchok district, which covers 11% area of this district (Rajkarnikar, 2000). It has many tributaries and one of them is the Melamchi River. The lower part of the river is also known as the Melamchi River as it runs through the Melamchi village market where human settlements are relatively dense as it is an economic hub of this area. This village had to face the most destruction of 2021 monsoon flooding.

This river provides drinking water supply, sanitation, irrigation, fisheries, small hydropower electricity generation, consumption for forest and vegetation, and watermills along the way downstream. Primarily the river is fed by Snowmelts and spring waters. Similar to many other river basins in Nepal the Indrawati river catchment also receives a huge volume of rainwater and runoff during the monsoon. Therefore, the river flow is low during dry seasons and very high during the monsoon (Gurung and Bharati, 2012).

River Flooding and Risk in The Context of Nepal and Indrawati River

Generally, flooding is known as an overflow of water beyond the river channel. This is when a river exceeds its bank-full capacity and spills out onto its floodplain and adjacent land. In alluvial channels floodplain is an integral part of the river system. When rivers flood they do most of their

geomorphological work such as moving materials like sediment, grabbles, debris, boulders, and nutrients and depositing elsewhere downstream. These activities are a very important part of river systems and flooding is an important component of rivers' catchments that transform and reset their system. Flooding reflects how river systems function (Fleming, 2002). In the context of the Himalayas region, like Nepal glaciers melting in summer coincides with the monsoon rainfall, which intensifies water flow in the Himalayan rivers downstream. This causes annual flooding and this is a natural phenomenon in this region. The Indrawati river is one of them.

Flooding is also good as it creates fertile land alongside its banks through sediment deposition processes. People take advantage of this phenomenon and start using the fertile land by farming and even building a settlement on it. However, the excessive flow of water becomes a problem when it brings along disaster. The excessive flow of water becomes a hazard when it harms people and the economy. This means if people do not build houses on flood-prone lands there is no flood risk involved. Therefore, the impact of floods, whether bad or good, varies considerably depending on the location and extent (Fleming, 2002). Usually, people build settlements, where lands are plain and fertile. In geography like Nepal, this kind of land is available only by rivers' banks or on rives' floodplains. The fertile land on floodplains would appeal to people to encroach onto it. Once they take start settling in this kind of geographic setting they become exposed to flood risk as they would naturally become inundated by water when there gets excessive and extensive rainfall. The Melamchi Bazaar flooding is one example of this. Sometimes there is also another story to it. Rivers are starting to encroach on areas they would not have before as a result of climate change. In both scenarios flood risk involves. (Seneviratne et al. 2012) argue that it is far more likely that humans are now building on floodplains rather than rivers encroaching on people's settlements.

The importance of Monsoon Rainfall in Nepal

Nepal is experiencing an increase in surface temperature, rapid glacier melts, changes in weather patterns, and drastic changes in monsoon whether too much or too little rainfall. Hazardous events of river flooding and landslides have become more frequent and intense in recent years. It is considered that the changing patterns of monsoon rainfall due to global warming is one of the major causes of river flooding in a country like Nepal (Seneviratne, S. et al. 2012). Since 2000, warming in Nepal has been steadily going up at an average of 0.06ºC. Monsoon precipitation also becoming heavier and more unpredictable (Gentle et al. 2014). Nepal faces numerous natural hazards every year. The most obvious hazards are river flooding, landslides, and droughts. These events are becoming more frequent and intense in recent years. Monsoon is very important for this country as most people in rural Nepal, about 60% of the total population rely on subsistence farming, and this kind of farming heavily relies on monsoon rain (Aksha et al, 2019). It means without monsoon the country would go to starvation and

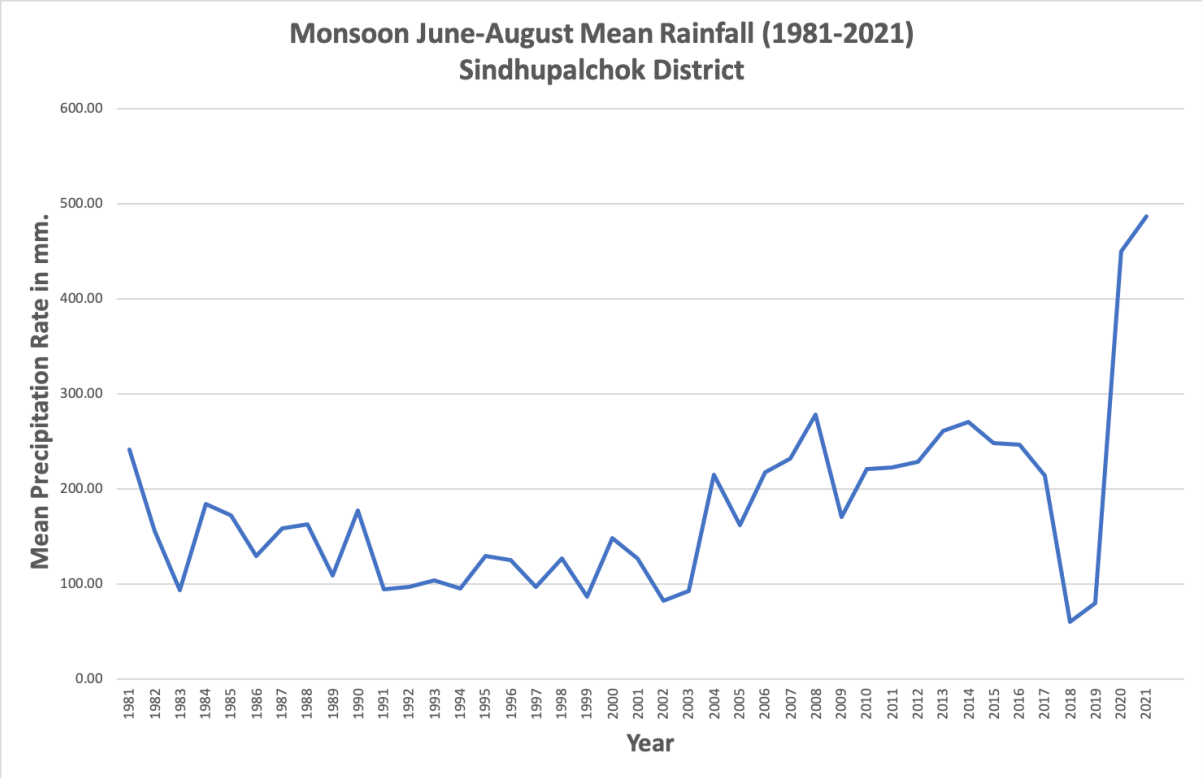
the changing pattern of weather and the changing pattern in monsoon rainfall is extremely damaging for poor people in the country.

Monsoon Rainfall Over 40 Years of the study area district Sindhupalchok

The graph below displays 40 years period of mean rainfall in monsoon seasons in the sindhupalchok district. This is the district the Indrawati river basin covers about 43% of its area. The data is taken from the open data Nepal and the department of hydrology and meteorology of the Nepal government.

Average monsoon rainfall over 40 years from 1981 to 2021

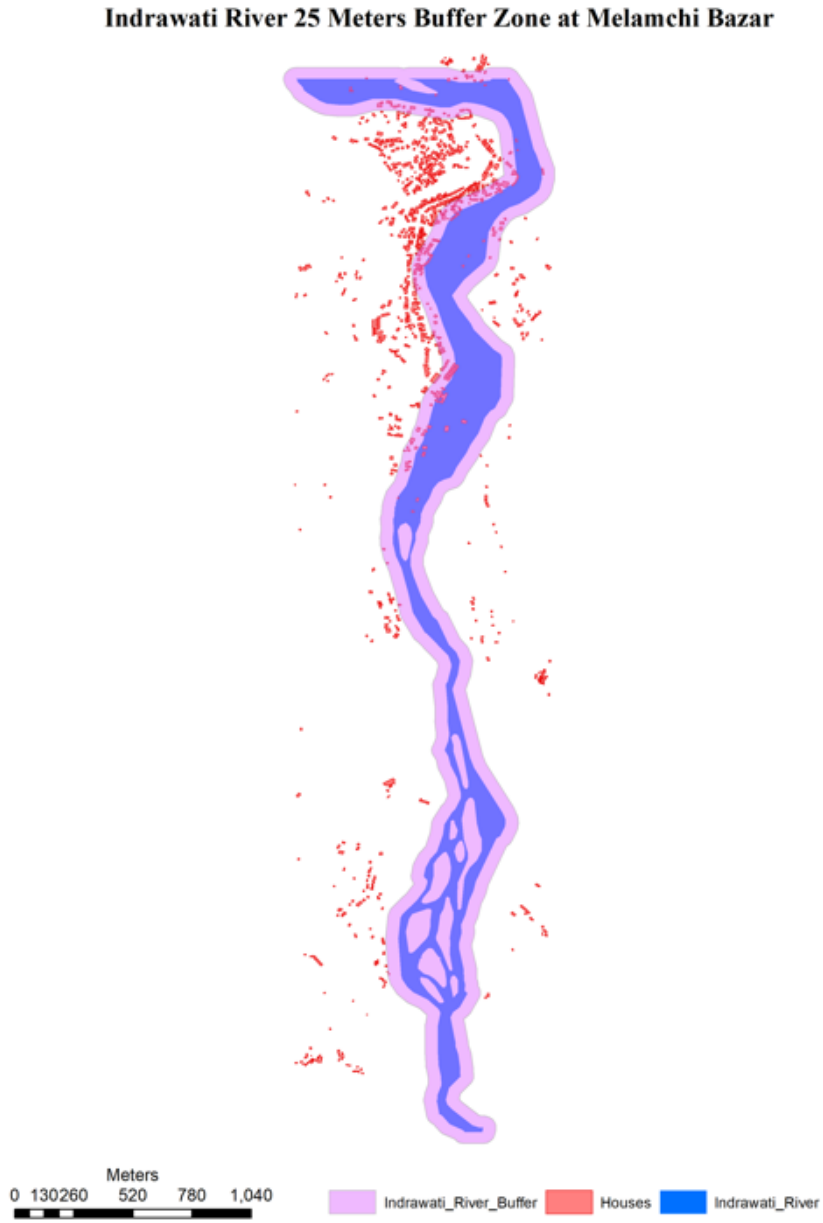
Figure 3.

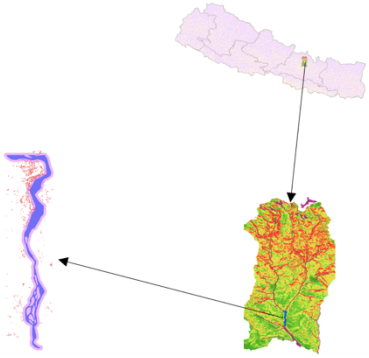


The monsoon season in Nepal starts in early June and lasts until the end of August. This is a very important period of the year for farmers in Nepal. However, this data is only from Sindhupalchok District. The line graph shows the trend of rainfall from 1981 until 2021. The monsoon rainfall seems to have been quite steady before 2001 and stayed just between 100 to around 180mm (millimeters) on average. There may have been a drought situation in 2002 and 2003 in the district as the mean monsoon rainfall goes below 100mm. From 2004 to 2017 it increased significantly to twice as much in 2017. 2018 and 2019 seem to have faced drought again with a sudden decrease in monsoon rainfall. However, in 2020 the rainfall rose to 450 mm from just around 80 mm and 2021 was the wettest year ever in the district.

Vulnerability and Exposure of Melamchi Village to Flooding Risk

Figure 4





This is a raster map. It contains two different attributes the river channel and building features attributes. The selected river channel is a small section of the river Indrawati at the lower part of the river. The selected part of this river channel is 2.50 km in length lies at 27.46ºN and 85.34ºE and elevation between 788 meters to 833 meters above sea level in Melamchi village. The location is shown on the right. The blue color represents the river channel. The red polygonal features represent an individual hosing nearby the

river channel in Melamchi village. The purple color shows represent the 25-meter buffer zone of the channel. This map visualizes the risk of flooding in the scenario of within 25 meters of the river channel on either side. The top section of the map shows the intense settlement alongside the river meandering. The land is created by the river flood by virtue of the river system. The map also depicts some houses in the blue water are houses that are built on sediment deposited on small islands. This section of the river is braided. The braided channel is visible on the google pro map. It is the indication of a high erosional river system. It means the settlement is been built on the active river floodplain. So it is not surprising the flood in 2021 killed a couple of dozen people and displaced more than a hundred households in this village.

Topographic Condition of The River Indrawati Catchment Area.

Figure 5

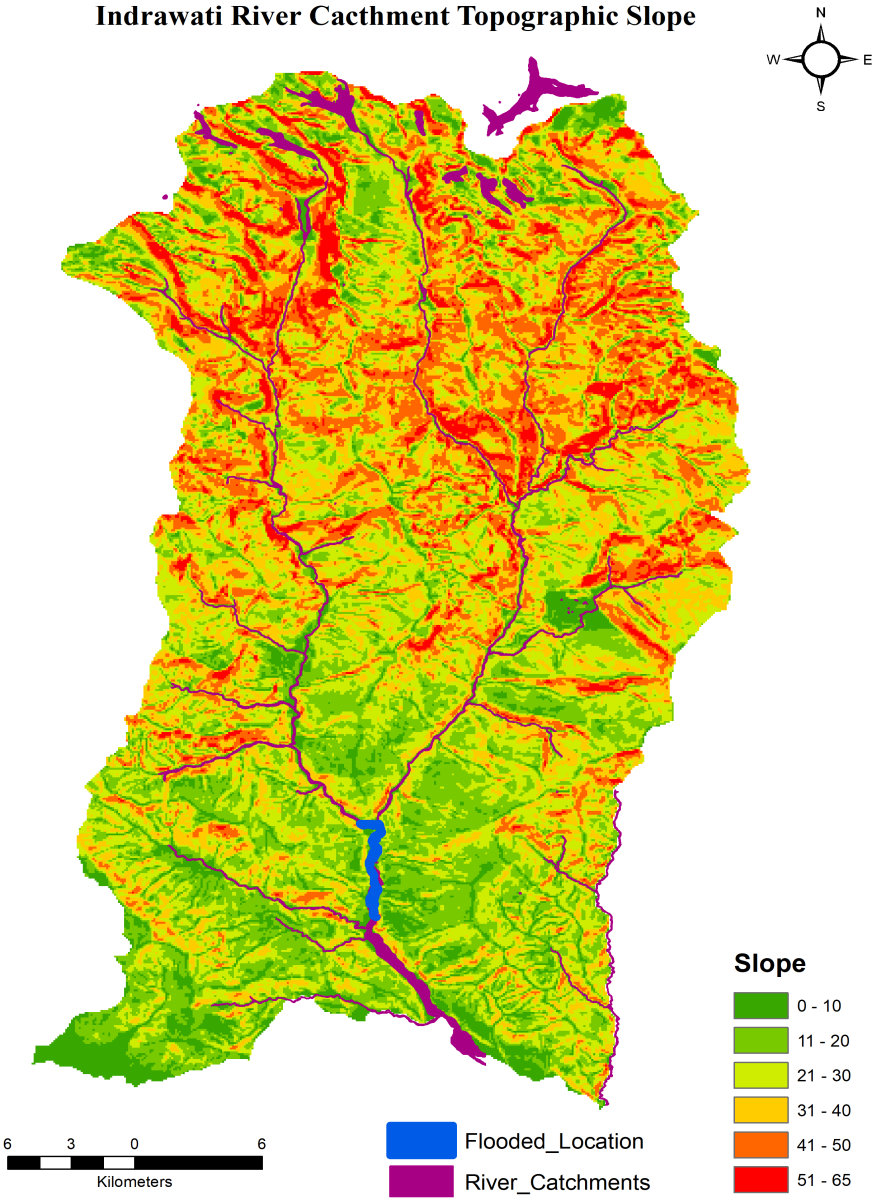


Figure 5 is the topographic map of the Indrawati river catchment area in the Sondhupalchok District. This is a raster map created using Nepal Digital Elevation Model (DEM) data. It shows the steepness of the physical geography in degree slope. As already mentioned the range of altitude of the area above, so in this section I mapped the steepness of the topography. The map depicts where the lands are more vertical or more flat. The topographies of the areas are classified into six classes by their degree of steepness. The green colors represent more flat and the reds represent steeper landscapes. The slope ranges from 1 degree of flat land to 65 degrees of almost vertical land formation. As the map shows there are very few plains and most lands are very steep. The purpose of this slope map is to identify flood-prone areas in the river catchment. This area has very steep topography all around. This means, that when the area gets heavy rainfall there will be a very high volume of runoff to the river channel. This causes floods downstream. And settlement that is built in floodplains like Melamchi village is very exposed to flooding. Apart from flooding this area is also very prone to landslides due to its condition of topography, which also lies in an active earthquake zone.

Conclusion

In the context of global climate-changing countries like Nepal faces multiple types of climate change impacts. Most realized impacts are changes in monsoon rain rates and landslides. The agrarian county heavily relies on monsoon rain for its subsistence agriculture which 60% of its population lives on. The most faced climate hazard is river flooding. One example of hazardous flooding was the Melamchi flooding in 2021. The area, which is selected for this study. The flooding risk in Melamchi village was visualized in a vector map and displayed the patterns of settlement along the river channel showing the venerability and exposure to flood risk. The topographic conditions of the Indrawati river catchment area were mapped and visualized in a raster map showing the diverse topography with very few plains and very steep land domination. This kind of land is prone to landslides. Overall this study of flood risk in the indrawati river catchment area shows that the catchment area topography is naturally prone to floods and landslides. However, the human encroachment in the floodplain downstream makes the natural phenomena sometimes hazardous.

Data sources

- https://data.humdata.org/dataset/nepal-watercourses-rivers (River data for Nepal)
- https://data.humdata.org/dataset/hotosm_npl_buildings (This theme includes all building features in this area matching polygon)
- https://data.humdata.org/dataset/nepal-digital-model-elevation-dem (This is Nepal digital model elevation with 90 meter resolution based on Shuttle Radar Topography Mission imagery clipped to Nepal boundary)
- https://data.humdata.org/dataset/administrative-boundaries-of-nepal (This data sets contains administrative boundaries of federal Nepal)
- https://opendatanepal.com/dataset/district-wise-daily-climate-data-for-nepal (The dataset contains data on Nepal's climate on different parameters. These data were obtained from the NASA Langley Research Center (LaRC) POWER Project funded through the NASA Earth Science/Applied Science Program and extracted using NASA's power access API)
- http://www.dhm.gov.np/climate/

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Source: ResearchGate: https://www.researchgate.net/figure/Ecological-zone-map-of-Nepal_fig1_265388488