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Impacts of floods in land use land cover change: A case study of Indrawati and Melamchi River, Melamchi and Indrawati municipality, Nepal

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Abstract
Every year, flood affects millions of people worldwide causing an imbalance in social, economic, and natural harmony as it is one of the most destructive natural hazards. Floods occur when the river channel overflows and extends across the surrounding topography. Nepal is highly vulnerable to floods. We studied the impacts of flood that occurred on 15 June, 2021 in the Melamchi- Indrawati river basin which is the second highest flood prone area zone in Sidhupalchowk district. We used a pre, post-event, and present land use and cover (LULC) map of the study area to quantify the impacts in the study area. We used Sentinel 2 imagery from 2019-02-01 to 2019-03-01, 2021-07-01 to 2021-08-01, 2022-02-01 to 2022-03-01 and the google earth engine to study the LULC change. We used a random forest classifier to run supervised classification and build 5 classes: built-up, cropland, barren land, water bodies, and forest in our LULC map. We found overall accuracy of 94.26% for the LULC 2019 map, 92.18% for the 2021 LULC map, and 92.72% for the 2022 LULC map. We found the highest impact of floods on agriculture/crops in the study area as the agriculture area reduced by 90.48 % following the flood event. Similarly, the barren areas grew by 78.58%. The built-up area was reduced by 70.61 %. The forest area was reduced by 93.06% in the flooded zone. Government should introduce effective policies like mandatory insurance on the risk-prone land to cover the losses after natural hazards.

Keywords: Floods, google earth engine, policy, natural hazard, land use landcover

1. Introduction

People prefer to live by the river as the river offers many benefits such as fertile soil, access to water, food, energy and transportation routes (Rahman *et al*., 2021; Mousavi *et al*., 2019) [20, 14]. In addition, river provides several health benefits such as fresh air, less noise, and traffic (Tickner *et al*., 2017; Crouse *et al*., 2018) [33, 5]. However, living near the river has some disadvantages of which the most obvious one is the threat of floods. Every year, flood affects millions of people worldwide causing an imbalance in social, economic, and natural harmony. Floods occur when the river channel overflows and extends across the surrounding topography (Kundzewicz *et al*., 2013) [12]. It occurs more frequently during the time of heavy rains, when/if the dams break. River floods affect approximately 21 million people worldwide annually (Lehman, 2015). Flood influences land use and land cover change (LULC) as flood disturb the relationship between people and land. Land use is defined as the purpose for which land is used (Prasai *et al*., 2021) [19]. It describes human activities with the land. The land cover provides aggregate information on land. For example, a forest is a landcover but the type of the forest is land use. The threat of flood is the major factor that discourages people to live near the river (Rahman *et al*., 2021; Mousavi *et al*., 2019) [20, 14].
According to the Global Climate Risk Index, Nepal ranks 4th in terms of climate risk (Adhikari *et al*., 2021; Eckstein, *et al*., 2019) [1] and ranks 30th country concerning relative vulnerability to flooding (Eckstein, *et al*., 2019). Geographically Nepal is located on the lap of active mountain ranges-the Himalaya-which is formed by two active tectonic plates (Rana, 2021) [24].

As a result, the country is prone to natural hazards like flooding, landslides, debris flow, and earthquakes. In addition, the country receives excessive rainfall and precipitation during monsoon making the regions near the rivers highly risk prone for the settlement (K.C., 2013; Prasai, 2022a; Adhikari *et al*., 2021) [17, 1]. According to the Department of Hydrology and Meteorology (DHM), Nepal receives an annual average rainfall of 55 inches. Nepal receives more than 80% of the total rain during the monsoon season (June-September) only (Hamal *et al*., 2020) [9]. Also, the high-intensity rainfall over a short duration causes the detrital deposits leading to floods and landslides (Rana, 2021) [24]. In addition, several anthropogenic activities like deforestation, mining, and tunneling are the other factors following the floods and landslides in the country (Subedi *et al*., 2021) [30]. Among many vulnerable zones in the country, the Indrawati-Melamchi municipalities of Sindhupalchowk district are the most hazard-prone areas (Figure 1, 2, 3). Heavy rainfall on 15 June, 2021 in the Indrawati river basin damaged many of the public and private buildings, killing seven people.

We studied the consequences of flood on land use land cover (LULC) of Melamchi-Indrawati river basin in this research project. It is one of the most flood-prone river basins in Melamchi and Indrawati municipalities (Gaire *et al*., 2015) [7]. These municipalities lie in Sindhupalchowk district of Nepal. During the monsoon season, the width of the river expands which results in a high flood risk in the places nearby river zone (Figure 1). The average annual rainfall is 2800 mm in this river basin. The record shows that the rainfall amount is increasing in Indrawati and Melamchi municipalities for the last four years. Figure 3 shows that Melamchi and Indrawati municipalities have the highest floods frequency in Sindhupalchowk district. Recent flood events of 23rd August, 2017 and 12 July, 2019 in the Indrawati and Melamchi River Basin had serious effects on LULC and people's livelihood. We plan to study detailed consequences of flood events in LULC in these regions considering the patterns and statistics of the Indrawati and Melamchi river flooding.

2. Study area

The Melamchi river originates from the high snowy mountain of the Jugal Himal at an elevation of 5875m. Our study area lies in the geographic coordinates of 85.53°E, 27.70°N, 85.67°E, and 27.87°N and consists of 800 m buffer zone from the centerline to either side of the Indrawati and Melamchi rivers covering both Melamchi and Indrawati municipalities.

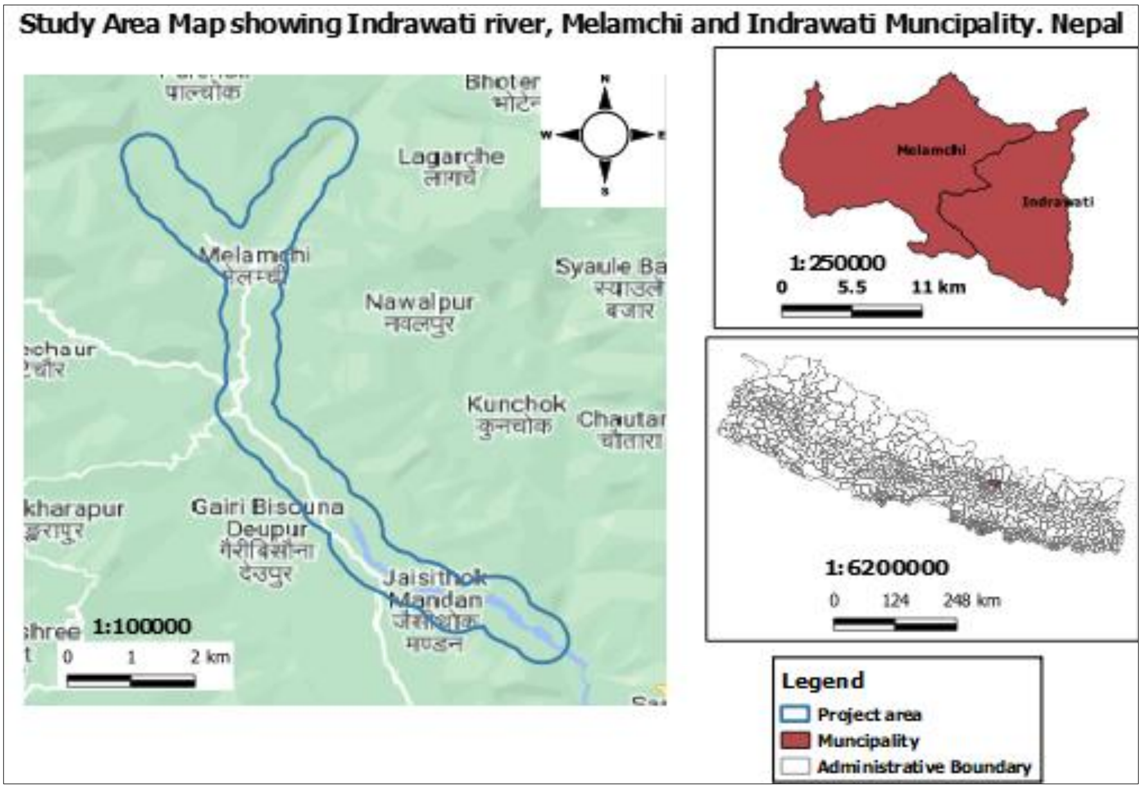

Fig 1: Location and administrative division of our study area: Melamchi- Indrawati river basin

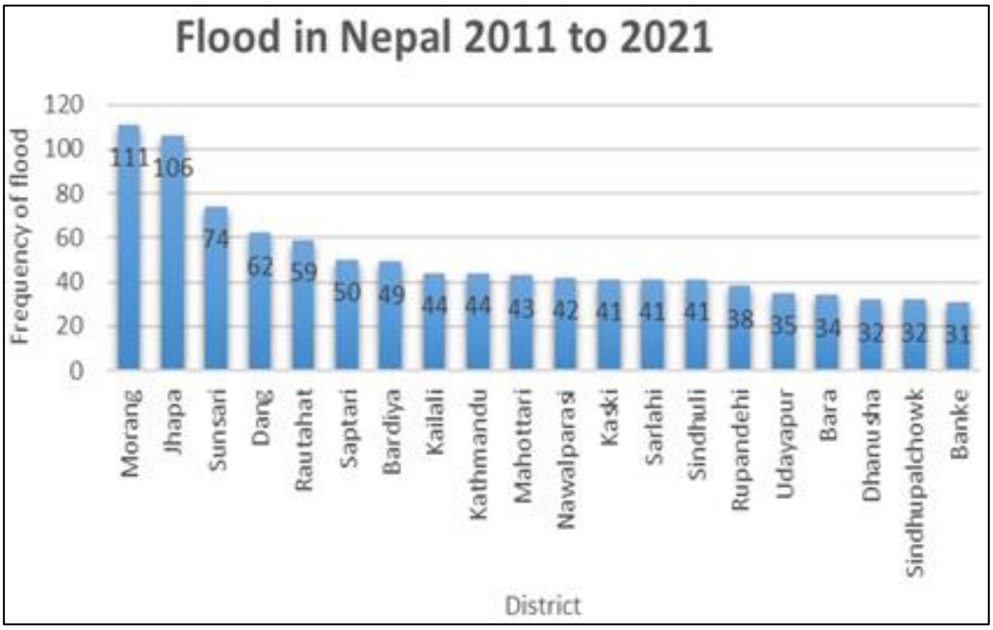

Fig 2: Statistical record of the flood events by districts in Nepal

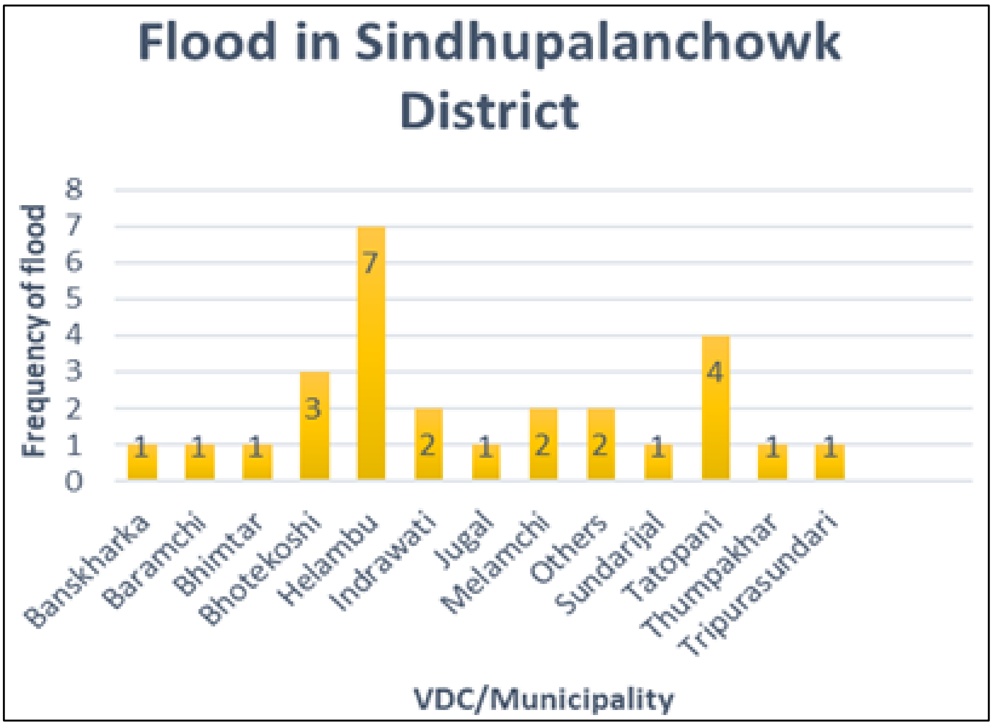

Fig 3: Flood events in Sindhupalanchowk district

3. Methodology

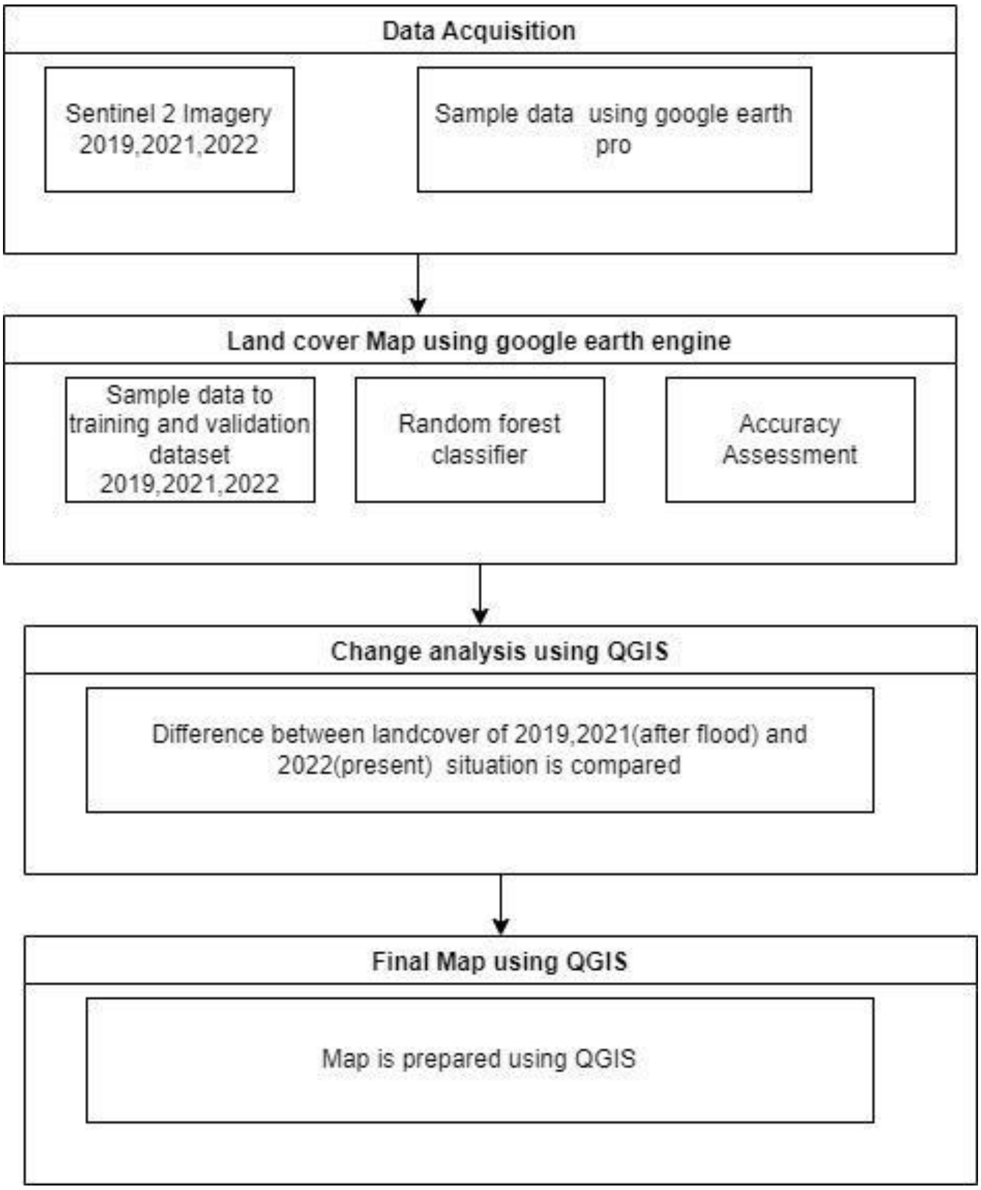

Fig 4: Methodological framework of our research project

3.1 Data acquisition

We imported Sentinel 2 imagery from 2019-02-01 to 2019-03-01, 2021-07-01 to 2021-08-01, 2022-02-01 to 2022-03-01 into the google earth engine (GEE) (Figure 4). Open source nature of GEE and its high computation capabilities is attracting researchers to use this platform for simple to advanced analyses (Prasai *et al*., 2021; Prasai, 2022b) [19, 18]. We used GEE to compute supervised classification and prepare LULC maps of our study area. The flood event occurred on the 15 June, 2021. We used the first image from 2019-02-01 to 2019-03-01 image collections to prepare a LULC map and for the post-event LULC map, we used the first image from 2021-07-01 to 2021-08-01 collections. We used the first image from 2022-02-01 to 2022-03-01 image collections to compare the present condition. We used the imagery with less than 5 % cloud cover for our study. Our LULC map contained 5 broad classes: Built up, Waterbodies, Cropland, Forest, and Barren (Table 1).We collected a total of 50,000 sample data with 10,000 of each sample data for each year.

Table 1: Land use land cover classes classification criteria

Land use /Land cover types	Description
Forest	Farmland trees, Mountain Forest, Roadside tree, Trees around water bodies
Water Body	River, Stream, Flowline, lake, pound, reservoir, wetland, place with snow and glacier
Barren	Uncultivated land, open spaces
Built-up	Permanent and Temporary houses
Crop	Cultivated land

3.2 Landcover Map using google earth engine

We divided the sample data into training and validation data by 80-20 approaches. We used 80 % of the data for training the image classifier and 20% for validating classified images. Among the different supervised classifiers, we used a random forest classifier (RF) to classify the Sentinel 2 imagery. RF is a classifier in supervised classification which produces multiple decision trees, using a randomly selected subset of training samples and variables (Sarica *et al*., 2017) [25]. Owing to its precision of classifications, it is most commonly used in remote sensing (Prasai et. al., 2021) [19]. In addition, RF classifiers could successfully handle high data dimensionality and multicollinearity, being both fast and insensitive to overfitting if provided valid training sample points (Chibani & Coudert, 2020) [4]. We prepared the classified map using an RF model with 200 trees. Table 1 shows the classification criteria used for the classification of the classes. We used the validation dataset to validate our results.

3.3 Change analysis using QGIS

Change detection techniques using digital imagery involve calculating spatial-temporal variation that exists between two datasets. We evaluated and quantified the differences between classified maps to know the pre and post-effects on land cover in the study area. We prepared the final classified map using QGIS.

4. Results

Table 2: Accuracy Assessment of Landcover map 2019

S.N	Classes	Built-Up	Barren	Cropland	Forest	Waterbodies	Total	User Accuracy
1	Built-Up	975	65	11	2	0	1053	0.9259
2	Barren	30	600	1	0	2	633	0.9478
3	Cropland	2	22	940	40	8	1012	0.9288
4	Forest	5	11	22	850	3	891	0.9539
5	Waterbodies	2	10	3	5	643	663	0.9698
6	Total	1014	708	977	897	656	4252	
7	Producer Accuracy	0.9615	0.8474	0.9621	0.9647	0.980		
8	Kappa coefficient							0.92
9	Overall accuracy							94.26%

Table 3: Accuracy assessment of Landcover map 2021

S.N	Classes	Built-Up	Barren	Cropland	Forest	Waterbodies	Total	User Accuracy
1	Built-Up	969	60	11	5	0	1045	0.9272
2	Barren	31	632	82	0	7	752	84.04
3	Cropland	2	22	942	40	9	1015	0.928
4	Forest	5	11	22	953	2	993	0.9597
5	Waterbodies	2	10	3	5	643	663	0.9308
6	Total	1007	735	1082	1005	665	4494	
7	Producer Accuracy	0.962	0.8598	0.8706	0.9482	0.9729		
8	Kappa coefficient							0.9016
9	Overall accuracy							92.18%

Table 4: Accuracy assessment of Landcover map 2022

S.N	Classes	Built-Up	Barren	Cropland	Forest	Waterodies	Total	User Accuracy
1	Built-Up	662	9	86	60	1	818	0.8092
2	Barren	0	704	2	0	1	707	0.9957
3	Cropland	18	1	740	25	0	784	0.9438
4	Forest	7	0	35	780	1	823	0.9477
5	Waterbodies	6	7	5	5	541	564	0.9592
6	Total	693	721	868	870	544	3427	
7	Producer Accuracy	0.9552	0.9764	0.8525	0.8965	0.9944		
8	Kappa coefficient							0.9086
9	Overall accuracy							92.72%

Table 2, 3, 4 show the overall accuracy with kappa coefficient for the produced LULC maps. We obtained satisfactory accuracy % for all the maps that could be used for the further analysis.

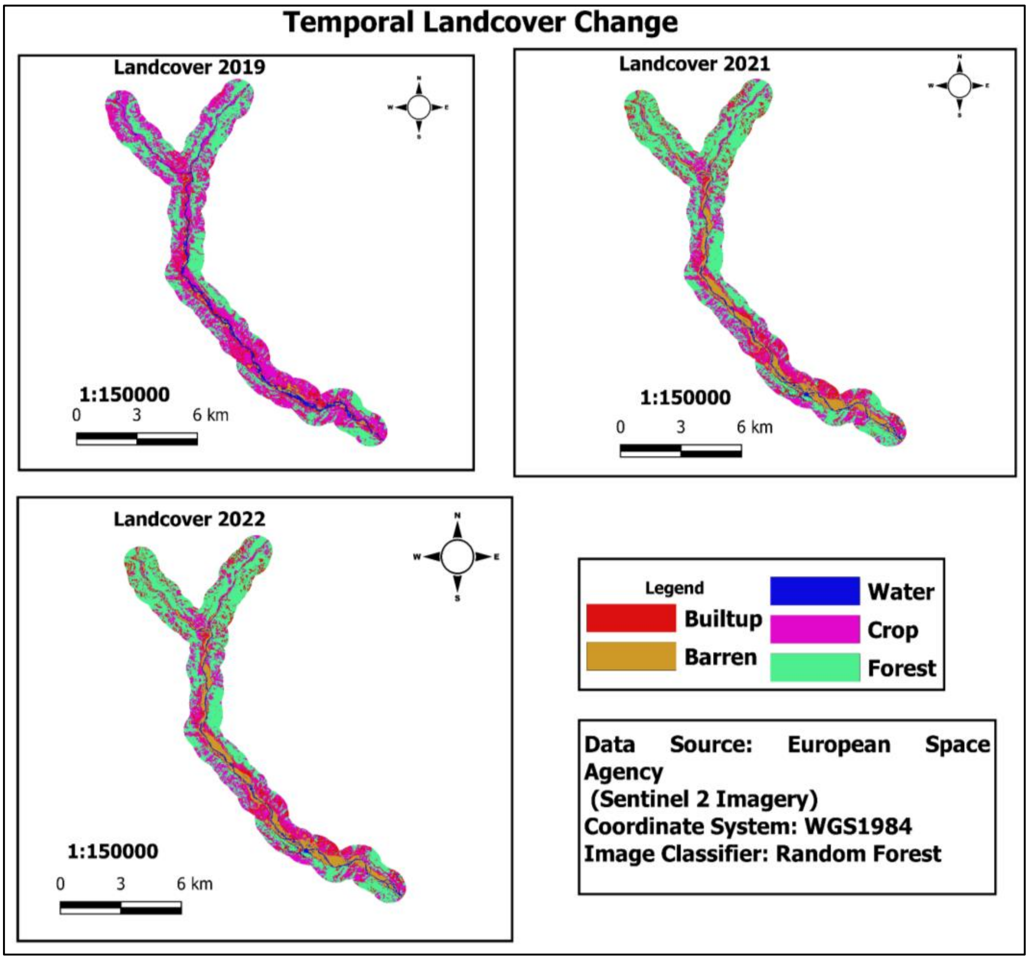

Fig 5: Temporal land cover change map in Melamchi-Indrawati river basin

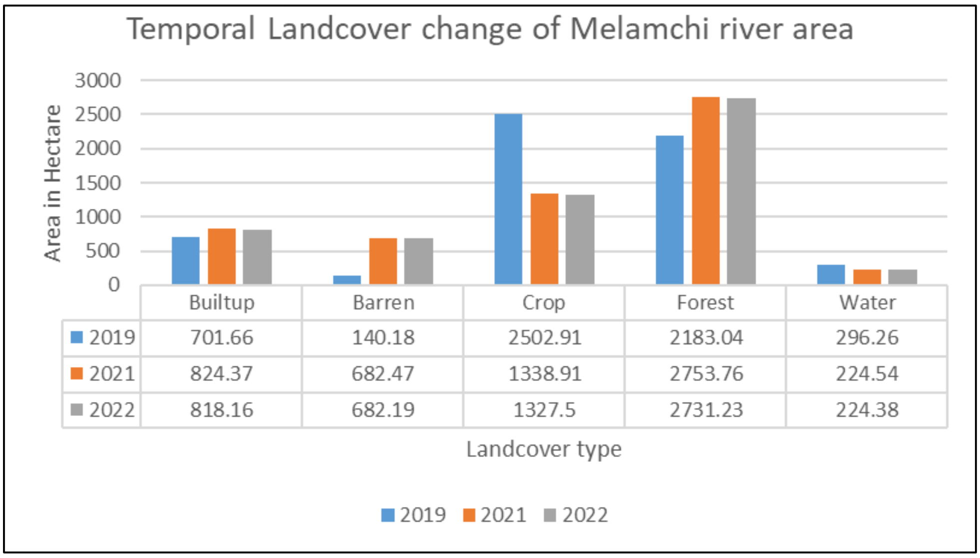

Fig 6: Bar graph showing land cover change from 2019-2022 in Melamchi-Indrawati river basin

Before the flood occurred (2021-06-15) in the Melamchi, the Built-up, Barren land, Cropland, Forest area, and Waterbodies in hectares were 701.66, 140.18,2502.91, 2183.04, and 296.26 respectively. Barren land area was the lowest and cropland was highest among the landcover classes. After the flood occurred, built-up area that was increasing rapidly from the years, 2019 to 2021 was found to be 824.37 hectares. Post-flood made the Melamchi area more sandy resulting in the increase of Barren Land to 682.47 hectares. Similarly, cropland decreased to 1338.91 hectares as most of the area near the river bank was damaged due to the flood. Our study shows that the forest area increased as compared to 2019. As compared to 2021 and 2022 there is not a significant change in the barren land, cropland, forest area, and water bodies. However, built-up areas decreased as people cleaned the damaged houses and involved less in agriculture. Also, forest areas are decreasing as people are re-constructing new infrastructures like houses, highways, and bridges in forest and agricultural land.

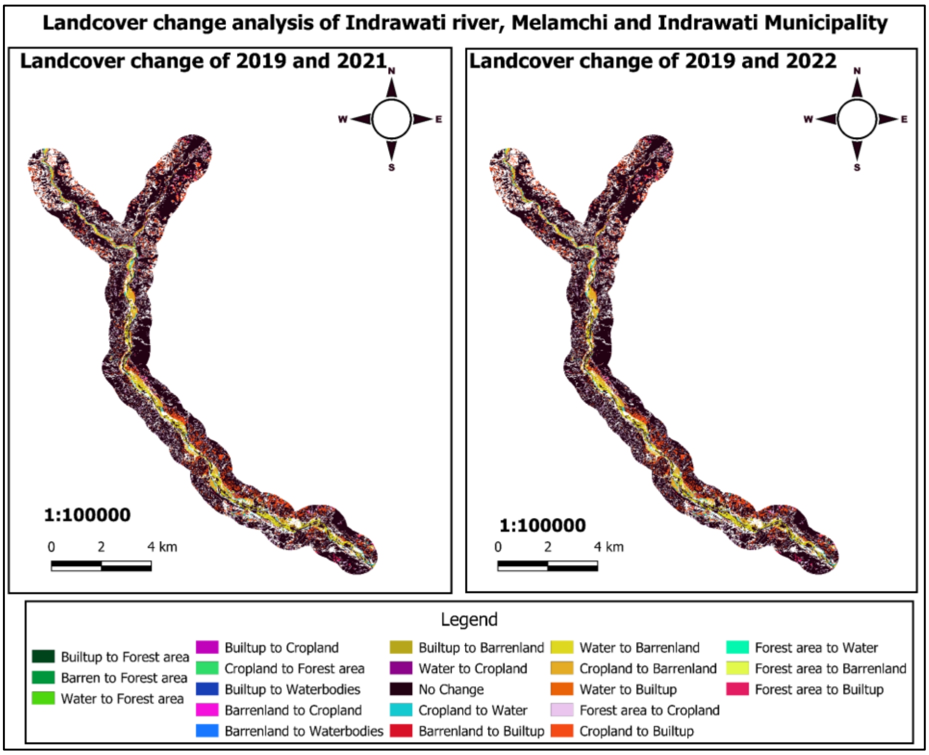

Fig 7: Land cover change analysis in Melamchi-Indrawati river basin, Melamchi Indrawati Municipality

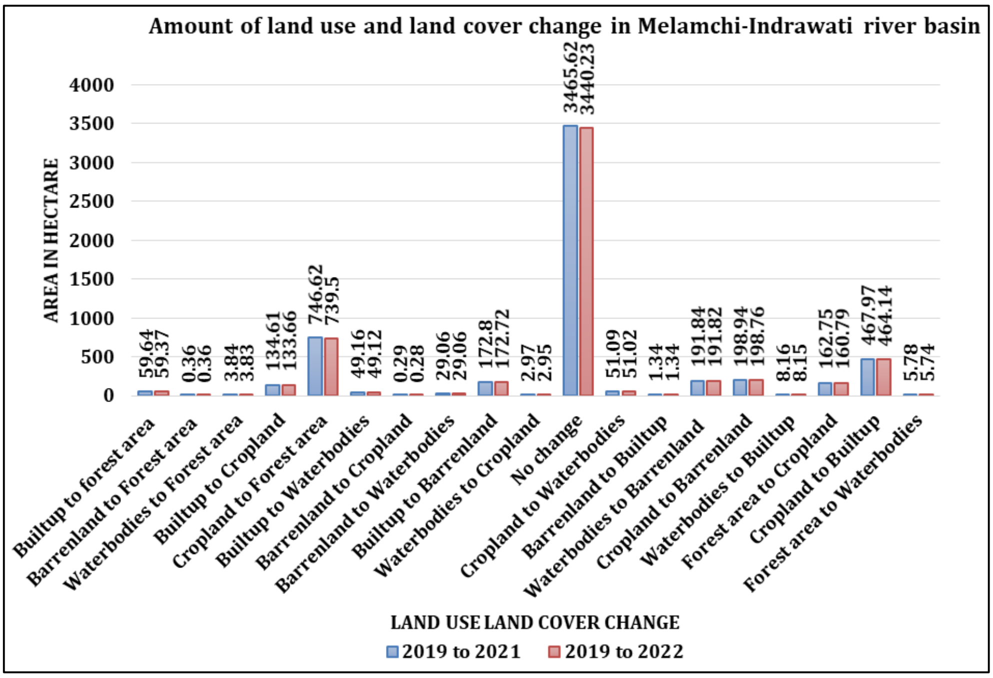

Fig 8: Bar graph showing the amount of land use and land cover change in Melamchi- Indrawati river basin

Figure 5, 6 and 7 show that the agricultural class is affected most due to flood events. The prime reason is the migration as people from the upstream side (rural) of the river are moving towards the downstream side (urban) of the river and the forest area is expanding in upstream and decreasing in downstream. One of the reasons behind it is the sandy area near the bank of the river. There is a low possibility of the sandy areas being converted into forest areas. In the downstream area (Melamchi and Indrawati Bazaar), the change in landcover is opposite. Most part of the forest area is converted to cropland and only few water bodies are converted to cropland. This shows there is a rapid growth of urbanization which is leading to high deforestation and an increase in agriculture area. In addition, most of the cropland area is converted into the built-up area and few of the bare land area is converted to the built-up area.

A major portion of the cropland and built-up are being converted to Barren land (Figure 6, 7) after the sandy flood. Therefore, Barren land area is increasing (Figure 6 and Figure 7). Similarly, the forest and water bodies are also being converted into Barren land. This shows that most of the LULC classes were damaged due to the monsoon flood. Most of the cropland, built-up areas which was near the Melamchi and Indrawati river were damaged by the flood. Our result shows (Figure 8, 9) that the river changed its flow direction and flowed in the built-up and barren land cover classes of 2019 after the flood.

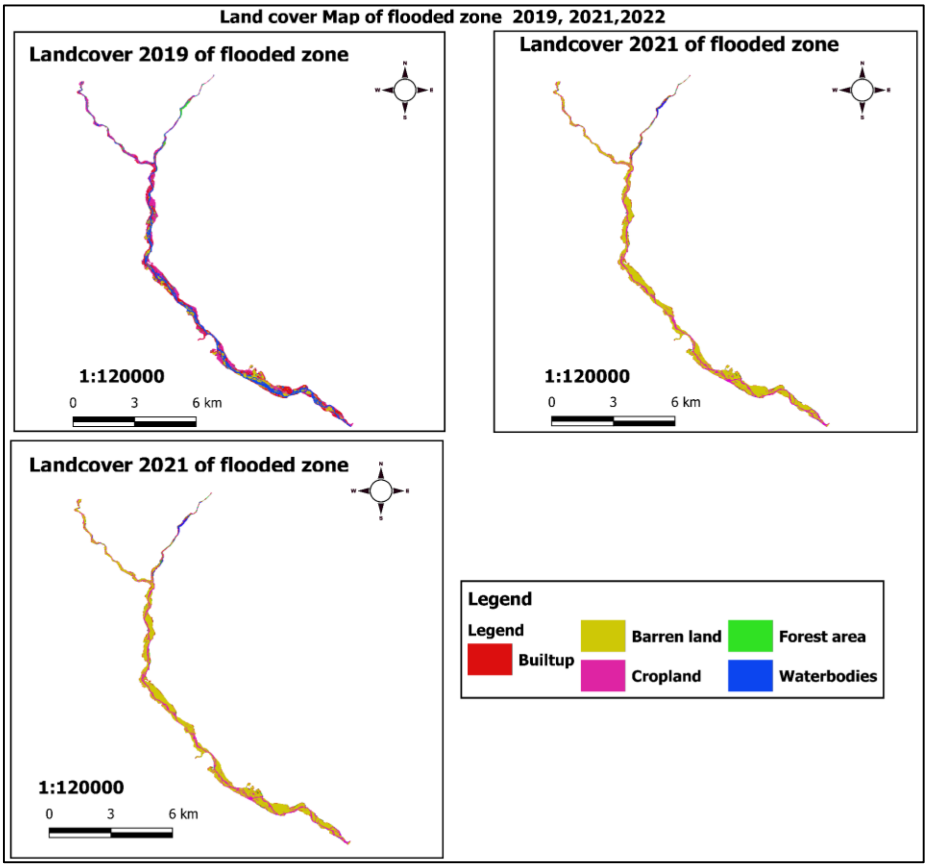

Fig 9: The land cover map of the flooded zone in Melamchi-Indrawati river basin

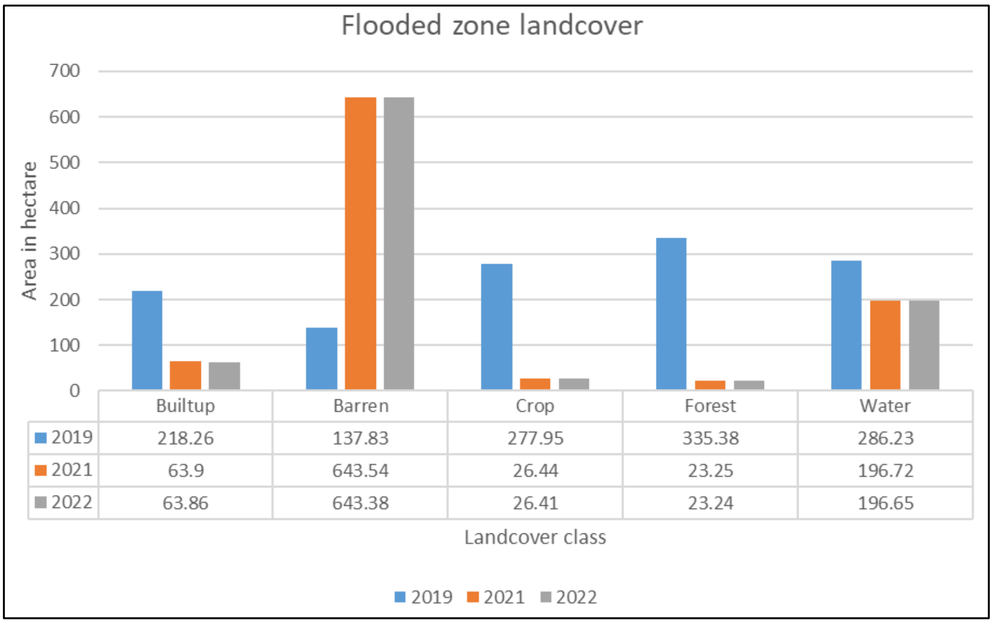

Fig 10: Bar graph showing the amount of land cover change in the flooded zone of Melamchi-Indrawati river basin

5. Discussion

We prepared three land cover maps using RF and sentinel2 imagery for 2019,2021,2022 in this research project. The overall accuracy of landcover maps for 2019, 2020, and 2021 were 94.26%, 92.18%, and 92.72% respectively. In the downstream area, the urbanization is growing rapidly. Facilities like education, job opportunities, hospitals, transportation and agriculture attracts the people living around upstream towards downstream of our study area. Our study shows that the change in built-up area in the downstream region from 2019 to 2021 is by 123 hectares (increasing). The map of 2021 shows that the central business/downstream area is expanding towards the Melamchi and Indrawati rivers. However following the floods of June 15, 2021, the growth of urban areas is disturbed. Our study shows the decreasing trend of built up area from 2021 when we compare that with the map of 2022. This may be due to the increasing migration of people from the region. Our study shows that the forest area is increasing from 2019 to 2021 in upstream area. It suggests the inclination of people towards the forest. Local people might be expecting benefits like reduction in soil erosion, increase in property values, and income. Forest provides resources for biodiversity conservation, habitat restoration (Prasai, 2021) [19], economic and community development (Thapa *et al*, 2020) [32]. On the other hand, our study shows that the cropland area decreased in 2021 as compared to 2019 (Figure 10). In addition, floods increased sands in the river bank which has become a new source of income for the people in this region as they are utilizing accumulated sand and operating Construction Company. Sand has great business value in Nepal and is mostly used for the construction of buildings. However, the decrease in cropland area is raising the food scarcity in this region. The record shows that this place used to be rich in agriculture products and used to supply food materials to other places until 2019 (van der Geest, 2018) [34]. People need motivation and compensation schemes from the government to invest in the agriculture sector after the flood. Government should make a strong policy to address this issue in this region and stop the imbalanced/random migration of people to other places.

The zone of the river should be defined based on scientific research and field surveys so that there will be no/fewer impacts of floods in the future. Service boundary must be defined to stop unplanned settlements near the river bank. Tax penalties can be implemented to restrict the settlement near the river. Education and health facilities should not only be limited to the central business district and distributed proportionally to all remote areas. Government should plan campaigns, and policy programs to make people aware of the potential flood risks and mitigation methods.

6. Conclusion

We studied the changes in LULC in the Melamchi-Indrawati river basin after the flood occurred in the region on 15 June 2021. We found a severe impact in the agriculture sector due to the flood in the region. An increase in barren land is another serious concern along with increasing migration of people to the other region. In addition, people are still not aware of the flood risk and random and unplanned housing in these regions is increasing (Delalay *et al*., 2018) [6]. Our research shows that limited research and records, lack of insurance/compensation schemes to the locals are the factors causing people's random migration. Government should bring a strong policy to address these issues and invest in scientifically driven law.

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