International Journal Of Advance Research, Ideas And Innovations In Technology
ISSN: 2454-132X
Impact factor: 6.078
(Volume 6, Issue 4)
Available online at: https://www.ijariit.com

Flood modelling of Patu river in Tulsipur city of Nepal and analysis of flooding impact on encroached settlement along the river

K. Basnet
Pashchimanchal Campus, Institute of Engineering, Tribhuvan University, Nepal

B. B. Sadadev
Pashchimanchal Campus, Institute of Engineering, Tribhuvan University, Nepal

B. Sherchan
Pashchimanchal Campus, Institute of Engineering, Tribhuvan University, Nepal

ABSTRACT

Patu River flowing through the western part of Tulsipur city in Nepal has been encroached severely by human settlements during the last fifteen years. The settlements and infrastructures are at high risk when the river gets heavily flooded. With the help of images obtained from Google Earth, Landsat images and application of ARC GIS, the land cover changes during the years 2004, 2010, 2015 and 2019 were observed. Since Patu is an ungauged river, the peak flood was estimated as 109.9 m³/s, 132.9 m³/s and 158.1 m³/s for 25, 50 and 100 years return period by Catchment Area Ratio method referring historical flood data of gauged Sharada River. Through the application of HEC-RAS modeling, the flood mapping was obtained for 25, 50 and 100 years return period. The inundation of settlement area back in 2004 was observed as just 0.009 km2 which was found to have been increased to 0.043 km², 0.070 km² and 0.096 km² in the years 2010, 2015 and 2019 respectively following the linear trend with R^2 value of 0.99. The risk of flood in the settlement has been accelerating with increasing urbanization around the river. It can be concluded that the inundation of settlement could be increased to 0.16 km² in 2024 if similar trend follows for the next five years. Before the situation worsens, it is necessary to provide enough embankments on both sides of the river and control the haphazard urbanization around the river. In conclusion, river training and proper planning of the city has been found to be critical for controlling inundation which could increase more in the coming years.

Keywords: *River Encroachment, River Flooding, Flood Management, Inundation, HEC-RAS*

1. INTRODUCTION

Tulsipur is a Sub-Metropolitan City in Dang District of Province No. 5 of Nepal. Large number of people from Salyan, Rolpa and Rukum migrate to this place. The economic activities are at high pace. Patu River flows through the western part of the city. The major watershed lies from Kapurkot and Dhanwang region of Salyan to Ranagaun and Barahkhali region. Around 2 km length of Patu River lies at Tulsipur region which eventually meets with Babai River in South approximately 11 km from main city (Fig 1). The human settlement has been established illegally and haphazardly there without proper planning due to which Patu river area has been swallowed by the city. The newly constructed bus park, auto villages and plotted lands just lie at the river. Within the last decade the flood plains and the river sides have been densely covered with settlements. As a result, the natural watercourse has been disturbed. The river has been polluted and the ecosystem too has been damaged. The extraction of river bed materials nearby has made the river bed deeper. The river side areas lack proper embankments. In case the river gets heavily flooded there is high chance of inundation of western Tulsipur city set up at river bank. Thus the encroachment has affected the river flow pattern and the encroached settlement is at high risk of river flooding.

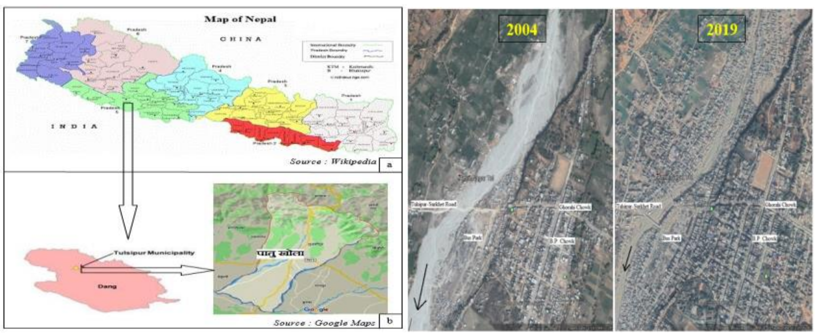

Fig. 1: Study area showing Patu River in Tulsipur City (left frame) of Nepal and encroachment of Patu River from Year 2004 to 2019 (right frame)

The main aim of this study is to assess the trend of encroachment of Patu River by settlements and analyze variation in flooding pattern accordingly. The study is intended to determine the change in land use/land cover of Patu River and its flood plains, estimate the river discharge during flooding and prepare floodplain mapping so as to assess the impact of flood on the land that surface that has been encroached.

As a result, the natural watercourse has been disturbed. The river has been polluted and the ecosystem too has been damaged. The extraction of river bed materials nearby has made the river bed deeper. The river side areas lack proper embankments. In case the river gets heavily flooded there is high chance of inundation of western Tulsipur city set up at river bank. Thus the encroachment has affected the river flow pattern and the encroached settlement is at high risk of river flooding. The main aim of this study is to assess the trend of encroachment of Patu River by settlements and analyze variation in flooding pattern accordingly. The study is intended to determine the change in land use/land cover of Patu River and its flood plains, estimate the river discharge during flooding and prepare floodplain mapping so as to assess the impact of flood on the land that surface that has been encroached.

2. METHODOLOGY

2.1 Assessment of Patu River Encroachment by Informal Settlements

The assessment of Patu river encroachment has been done by collecting the primary data accompanied by the secondary data. The primary data was obtained through site visit, and an interview to the locals about the past flow pattern of the river and the status of the land features associated. The residents dwelling since the decades were asked to obtain general understanding about the land cover/ land use changes and the water channel. The various stages of encroachment by growing human settlement have been studied since 2004 to present. The change in land use pattern has been determined for the years 2004, 2010, 2015 and 2019. For the analysis of encroachment trend, the different land cover classes of the study area have been grouped into five categories for easy analysis and assessment of change detection. The classes include River area, Bare Land, Settlement/ Infrastructures, Forests & Trees, and Fields.

The first step was to get the number of pixels for each class. For change analysis, the satellite imagery of 2004, 2010, 2015 and 2019 was used. The image obtained for those years were loaded into Arc GIS. There are normally two methods of image classification, i.e., supervised and unsupervised classification. Supervised classification can generate desired classes of land-cover based on ground-truth data, while unsupervised classification attempts to classify the pixels with the same characteristics based on statistical criteria. In this study, a supervised classification method was used, in which training samples and spectral signatures of known categories, such as urban, croplands, vegetation, forest and others, have to be developed. The original satellite image and the supervised classification image were compared side by side to know the actual class the land use falls into. The land use pattern was classified into number of classes which were finally merged into five different classes as mentioned earlier. Based on the attribute table, the number of pixels the class occupies gives the actual area of the class of land use. Thus for different years, the area occupied by River area, Bare Land, Settlement/ Infrastructures, Forests & Trees, and Fields were obtained and the change was studied.

2.2 Flood Analysis in Patu River at Tulsipur Section

This study involves the different comparative method for flood flow calculation. Sharada River has been used to obtain the discharge for Patu River. Sharada River and Patu River are the tributaries of the Babai River whose flow is at the opposite side of the same hill. The flood data of Sharada River has been obtained from Department of Hydrology and Meteorology from the year 2001 to 2018. The catchment area has been obtained by watershed delineation of the DEM of 30m resolution obtained for Patu River and Sharada River. The peak flood has been obtained by WECS/DHM method, Rational Method, Dickens Method, Gumbels and Log Pearson III methods. The Catchment Area Method was used to determine the discharge of the Patu River based on the discharges obtained for Sharada River. Patu River has been obtained through field survey which has been provided as an input to HEC-RAS. The Manning's Roughness Coefficient has been provided as an input based on Cowan's approach. In this method, six roughness elements affecting flow resistance are individually considered and then integrated into the final roughness coefficient for a specified river reach. The HEC RAS model has been calibrated based on the Manning's Value obtained through Cowan's approach. The so obtained Manning's value of the Left over Bank, Right over Bank and Main channel was varied. For the measured discharge by floating method, floating method compared the depth measured compared with the simulated depth of river at various reaches. The combination of Manning's value producing the least difference between simulated and measured depth has been used in the model.

For the year 2019, as the land features have changed and the river been encroached, the flow data and cross sections obtained will be used for obtaining flood plain maps for different return periods (25 yrs, 50 yrs and 100 yrs). The area of inundation due to Patu river flood and the severity of risk to different classes of land cover have been identified. The inundation boundary of 2019 flood has been used to calculate the inundation land covers for previous years. For validation of the obtained results, the values of discharges were measured for different dates. For those discharges, the depth was measured at the particular cross section. The section for measuring the depth has been chosen as the end of Bus Park. For every discharge measured, the depth was measured at that section. So, there were the sets of discharges measured and the corresponding water surface elevation. The HEC-RAS model was run for all those measured discharges and the corresponding depths simulated were compared with measured one. The relation between the measured and simulated water surface elevation was used for the validity of the model.

3. RESULTS AND DISCUSSIONS

3.1 Patu River Encroachment through the Years

The study of Patu River encroachment has been done based on the supervised maximum likelihood classification of the satellite images of the years 2004, 2010, 2015 and 2019. The land use land cover has been divided into five different classes which are

River area, Bare Land, Settlement/ Infrastructures, Forests & Trees, and Fields and the changes through the years has been observed. The supervised classified images of the study area through the years show high variation in land use land change pattern. Fig 4 displays Land Cover Map obtained for the years 2004, 2010, 2015, and 2019. While the river area has been in continuous decreasing trend, the settlement has been increasing. The settlement areas seem to have been heavily congested around the river with the years progressing. While the other land classes Forest/ Trees, fields and the bare land have shown both increasing and decreasing pattern both. At 2004, the river area at the study location was measured to be 488073 m2.As shown in figure, the river flow area decreased to 244142 m2 in the year 2010 and it is further decreased to 158752 m2 and it got constricted to 137958 m2 in 2019. The settlement and infrastructures area on the other hand increased from 204600 m2 to 374413 m2 which is 85% increment in area occupied in those 6 years period. And the settlement and infrastructures areas at the year 2019 have increased to 960712 m2. In these 15 years, the area occupied by bare land has been increased while the area of the fields has been decreased. The rapid increment in settlement and infrastructures has resulted in constriction of river area by 69.2%.

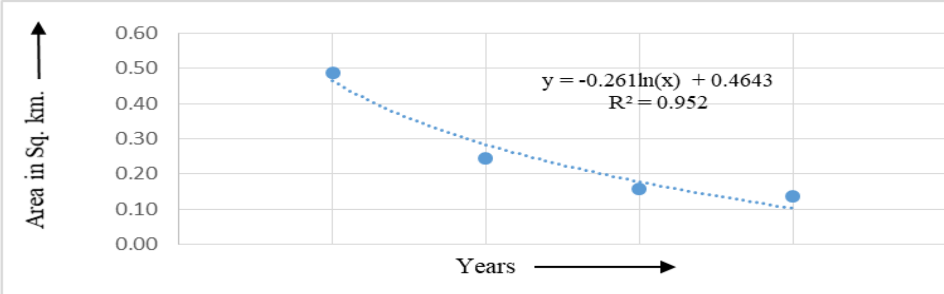

Fig. 2: Change in river area with years

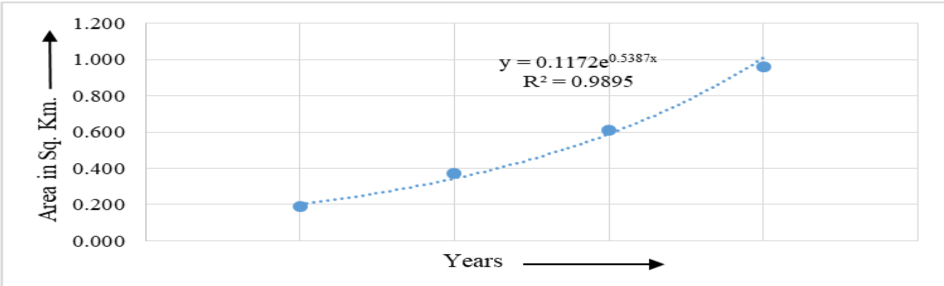

Fig. 3: Change in river area with years

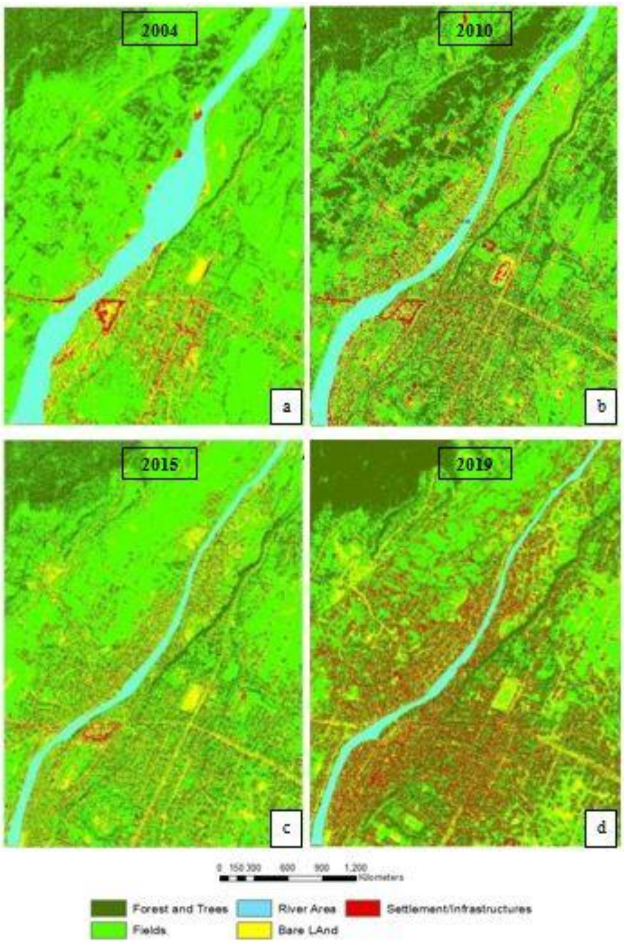

Fig. 4: Land cover map of the study area; a) 2004; b) 2010; c) 2015; and d) 2019

3.2 Flood Estimation of Patu River

The historical flood data of Sharada River has been collected from Department of Hydrology and Meteorology at Station no 286 situated at Daredhunga cableway station. The maximum instantaneous flood data from the year 2001 to 2018 has been used.

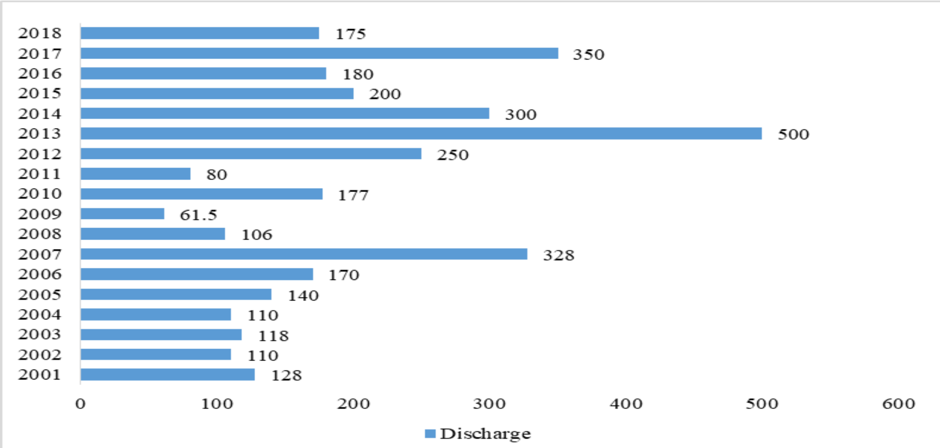

Fig. 5: Flood data (m³/s) of the Sharada River from 2001 to 2018

The peak flood of 25, 50 and 100 years return period has been estimated by WECS/DHM method, Rational formula, Dickens method, Gumbel and Log Pearson III methods. WECS/DHM, Rational and Modified Dickens method are ungauged methods of peak flood calculation. Among these methods, WECS/ DHM method provide the maximum values of flood for different return periods for both Sharada and Patu River and the Rational method provide the lowest flood values for both the rivers. The 25 years, 50 years and 100 years peak flood for Sharada River has been obtained as 602.89 m^3/s, 749.95 m3/s and 871.31 m^3/s respectively whereas the 25 years, 50 years and 100 years peak flood for Patu River has been obtained as 157.81 m^3/s, 205.87 m^3/s and 245.68 m^3/s respectively. Regarding the gauged methods of peak flood calculation, the real flood data is used. Gumbels method and Log Pearson III method has been used to calculate peak discharge of gauged Sharada River. The discharge value as obtained by Gumbels method is higher than that by Log Pearson III method.

Table 1: Discharge value for three different return periods by ungauged and gauged methods

Return Period (years)	Discharge (m^3/s)							
	WECS/DHM		Rational		Modified Dickens		Gumbels	Log Pearson III
	Sharada	Patu	Sharada	Patu	Sharada	Patu	Sharada	Sharada
25	602.89	157.81	169.90	45.00	562.00	134.45	554.7	454
50	749.95	205.87	190.22	50.39	656.00	154.16	633.82	549
100	871.31	245.68	212.97	56.41	749.00	173.88	712.94	653

Since the gauged methods are more appropriate as they rely on actual discharge values and using Easy Fit 5.6 Professional, it has been found that Log Pearson III holds better in probability test of goodness of fit. Thus the flood values for different return periods (25, 50 and 100 years) obtained from the Log Pearson III method has been used for Sharada River. The flood values of 454 m^3/s, 549 m^3/s and 653 m^3/s for 25, 50 and 100 years flood respectively have been used to calculate the flood of Patu river by catchment area ratio method. The catchment areas of the Sharada River and Patu River have been calculated through watershed delineation of DEM of 30m resolution in Arc GIS.

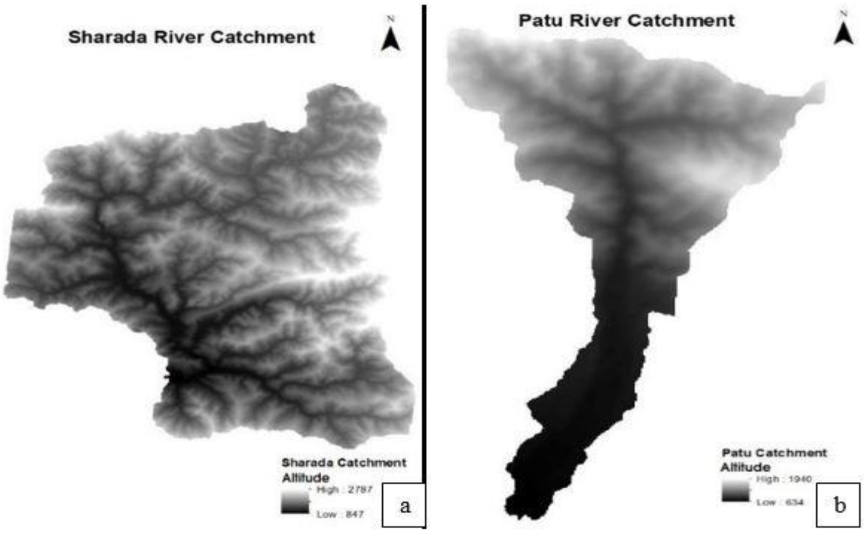

Fig. 6: Catchment; a) Sharada River catchment; and b) Patu River catchment

The outlet point for Sharada river has been chosen at Daredhunga station and for Patu River, the outlet point is at the Southern end of the newly built Bus Park at Tulsipur, Dang. The catchment area of Sharada River has been obtained as 188.96 km^2 whereas the catchment area of Patu River was obtained as 45.753 km^2. The catchment area ratio has been found to be 4.13. The peak discharge for Patu River has been obtained as 109.9 m^3/s, 132.9 m^3/s and 158.1 m^3/s for 25, 50 and 100 years return period flood respectively. The ratio of discharges measured by ungauged methods for Sharada River and Patu River and the one obtained from Gauged method by CAR method for both the rivers seemed to follow normal distribution. The standard deviation (б) of the measured and the obtained discharges was obtained to be 0.27 and the variance was 0.073. In this case, the standard error of the mean (SEM) can be calculated using the following equation:

$$бx = б/\sqrt{N} = 0.135 \qquad (1)$$

Based on the SEM, the ratio of discharges in Sharada river and Patu River differ as 3.915 ±0.265 and the margins of error at a confidence level of 95% was obtained to be ±6.78%. Since the SEM is small, the discharge given by CAR could be used.

3.3 Geometrics of Patu River

The field survey has been carried out so as to obtain the geometric characteristics of Patu River. For this 3.764 km stretch of Patu river where the river encroachment since the past years is severe, has been surveyed. The longitudinal profile and cross section data were collected and obtained through survey. The survey data were used to obtain different cross sections along the stretch at an interval of every 20 meters. All together 187 number of cross sections has been taken as an entry to HEC RAS. The Manning's Roughness Coefficient (n) value has been applied depending upon the land cover pattern in which the cross section falls into. For this, the Cowan's approach has been used (Coon, 1995). The Manning's Roughness Coefficient (n) was used to calibrate the model. For this, the value of discharge in Patu River was measured by float method. The discharge was measured to be 4.9 m^3/s for the day 3/21/2020. For the measured discharge, the depths were measured at seven different cross sections of river. The measured discharge was provided as an input to the model. The seven different sections where the depths were recorded are: 1) at the beginning, 2) at trial bridge, 3) at mid reach, 4) at the beginning of bus park area, 5) at RCC bridge, 6) at the end of bus park area, and 7) at the end section.

Table 2: Determination of Manning's roughness coefficient (n)

Reach	Left over Bank						Channel						Right over Bank					
	n1	n2	n3	n4	n5	n	n1	n2	n3	n4	n5	n	n1	n2	n3	n4	n5	n
Start to Trail Bridge	0.02	0.005	0	0.01	0.012	0.047	0.024	0	0	0	0	0.024	0.02	0.005	0	0.01	0.013	0.048
Trail Bridge to Beginning of Bus Park	0.02	0.005	0	0.03	0.01	0.065	0.024	0	0	0	0	0.024	0.02	0.005	0	0.02	0.012	0.057
Beginning of Bus Park to End of Bus Park	0.02	0.005	0	0.03	0.007	0.062	0.024	0.005	0	0.01	0	0.039	0.02	0.005	0	0.03	0.007	0.062
End of Bus Park to Final Cross Section	0.02	0.005	0	0.03	0.007	0.062	0.024	0	0	0	0	0.024	0.02	0.005	0	0.015	0.012	0.052

The five different combination of Manning's Roughness Coefficient (n) was used and the depths at those seven different sections as given by the model were noted. Firstly, the previously obtained Manning's values were used. Then ROB and LOB Manning's value were increased by 10% keeping channel Manning's fixed and then decreased by 10% in the third trial. In fourth trial, the LOB and ROB Manning's value as obtained from Cowans method were kept unaltered whereas the channel Manning's was increased by 10% in fourth trial and decreased by 10% in fifth trial. The value of depth in the seven cross sections were noted and compared with the measured depth at corresponding sections. The combination with least value of Root Mean Square Deviation (RMSD) was used for the study.

Table 3: Trail for fixing Manning's coefficient at different reaches

Trial	Reach	Mannings Value (n)			Measured Depth							Simulated Depth							
		LoB	Ch	RoB	1	2	3	4	5	6	7	1	2	3	4	5	6	7	RMSD
1	Start to Trail Bridge	0.0470	0.0240	0.0480	0.25	0.20	0.25	0.22	0.20	0.30	0.20	0.25	0.22	0.28	0.22	0.20	0.30	0.23	0.0177
	Trail Bridge to Beginning of Bus Park	0.0650	0.0240	0.0570															
	Beginning of Bus Park to End of Bus Park	0.0620	0.0390	0.0620															
	End of Bus Park to Final Cross Section	0.0620	0.0240	0.0520															
2	Start to Trail Bridge	0.0517	0.0240	0.0528								0.25	0.22	0.28	0.22	0.20	0.30	0.23	0.0177
	Trail Bridge to Beginning of Bus Park	0.0715	0.0240	0.0627															
	Beginning of Bus Park to End of Bus Park	0.0682	0.0390	0.0682															
	End of Bus Park to Final Cross Section	0.0682	0.0240	0.0572															
3	Start to Trail Bridge	0.0423	0.0240	0.0432								0.25	0.22	0.28	0.22	0.20	0.30	0.23	0.0177
	Trail Bridge to Beginning of Bus Park	0.0585	0.0240	0.0513															
	Beginning of Bus Park to End of Bus Park	0.0558	0.0390	0.0558															
	End of Bus Park to Final Cross Section	0.0558	0.0240	0.0468															
4	Start to Trail Bridge	0.0470	0.0264	0.0480								0.25	0.23	0.28	0.23	0.20	0.31	0.23	0.0204
	Trail Bridge to Beginning of Bus Park	0.0650	0.0264	0.0570															
	Beginning of Bus Park to End of Bus Park	0.0620	0.0429	0.0620															
	End of Bus Park to Final Cross Section	0.0620	0.0264	0.0520															
5	Start to Trail Bridge	0.0470	0.0216	0.0480								0.25	0.21	0.28	0.20	0.19	0.31	0.23	0.0189
	Trail Bridge to Beginning of Bus Park	0.0650	0.0216	0.0570															
	Beginning of Bus Park to End of Bus Park	0.0620	0.0351	0.0620															
	End of Bus Park to Final Cross Section	0.0620	0.0216	0.0520															

From the above trials, the measured and simulated water surface elevations don't differ much in all 5 trials. For the first three trials, the RMSD has found to remain the same. But as the Channel Manning's increases the value of RMSD increases slightly and vice versa. The model has been calibrated with the least value of RMSD as obtained from the first trial. For the four classified reaches, the Manning's Coefficient from trial 1 has been used for LOB, Channel and ROB.

3.4 Floodplain Mapping of Patu River

Patu River flows from Kapurkot region of Salyan district to plains of Tulsipur city. As the river descends to plain Terai zone, its velocity decreases and the width of flow increases. While descending in the hills, the surrounding lands are at higher. Thus there are very few chances of land getting inundated. But in case of plain areas, as the surrounding land is at considerably at little height from the river, the chances of land getting inundated is high even if there is small flood. The height difference of encroached part of Patu River where the settlement has been established is very less. So the risk factor considering the flood is high. The peak flood obtained from Log Pearson III method has been provided as an input to calculate 25 years, 50 years and 100 years return period flood. The risk of flood in the severe encroachment zone of 2km stretch has been observed. For this 3.76 km of the length of river has been taken for which the variation of depth and inundation boundary has been studied.

The 1 in 25 years flood plot has been presented in figure. As the river travels downstream the width of river goes on increasing. It has been found that the settlement area just close to north part of Tulsipur-Surkhet road and left of Patu river to be at higher risk of inundation. As the river crosses the bridge at Tulsipur- Surkhet road, the depth seems to be higher which may cause erosion of river bed and can affect bridge as well. As the river travels downstream, due to embankments constructed, it has been observed that the river flows in trained path. The 1 in 50 years flood further widens the inundation increasing the severity at the settlements north to Tulsipur Bus Park. At this flood the inundation even touches the boundary of Bus Park. The depth has also been increasing in comparison to previous flood. While the 1 in 100 years flood increases the inundation at the mid of the study area. At this place the major land cover is the fields and agricultural land. The settlements to both sides of river at upstream of bridge are observed to be at risk. However, the embankment zone downstream of Bus Park leads river in trained path without disturbing the surrounding land.

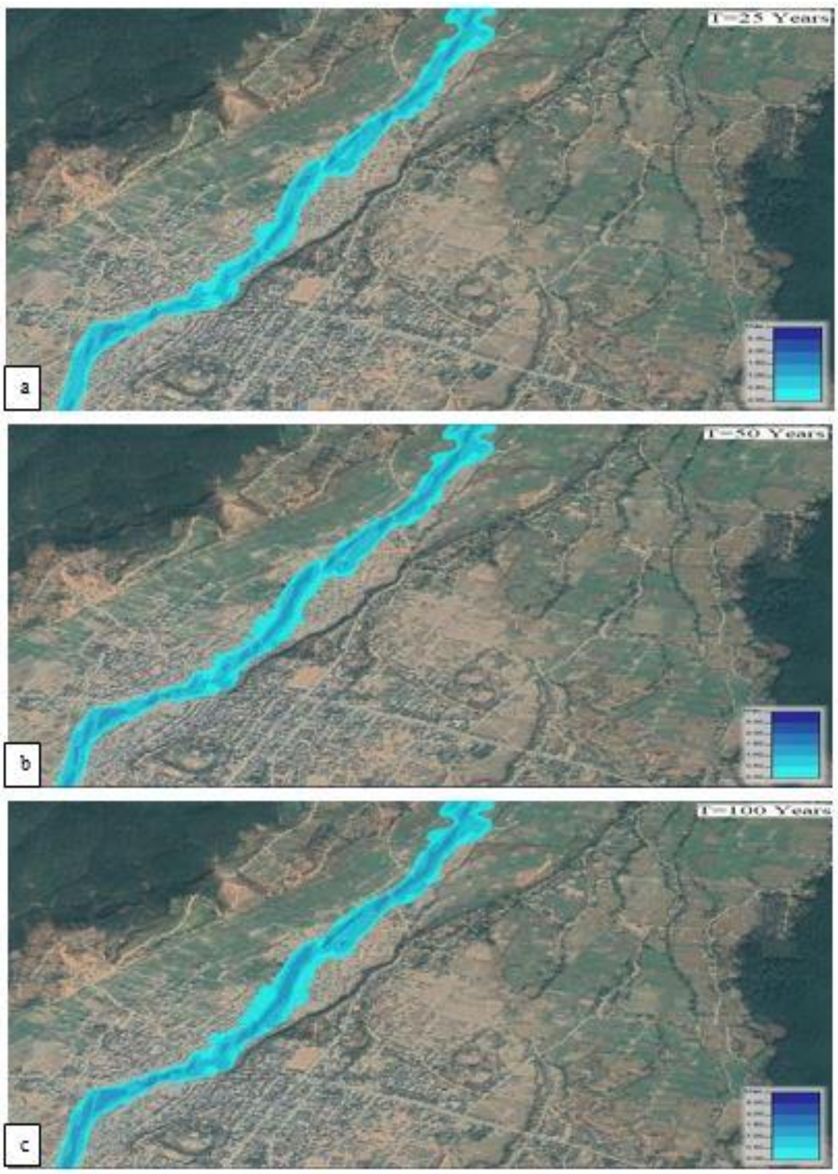

Fig. 7: Flood mapping of the Patu River for a) 25, b) 50 and c) 100 years flood laid over Google Earth Image

Regarding the 25 years return period flood, the maximum depth is of 2.60 m and the average depth at flood is 2.01 m. While the 50 years flood has maximum depth of 2.69 m and it is 2.09 m for 50 years return period flood. For the 100 years flood, the maximum depth simulated is 2.79 m and the average depth is 2.18 m. Regarding the depth, since the adjoining land where the settlement has been built up is at considerably at very low height difference, the increment in small water surface level could cause flooding of water into the settlements. Also the slope (0.017) there provides higher speed causes water to flow at high speed. The extraction of river bed materials is also high there (length between the cross sections 91 to 181) which could pose problem of bed and side erosion.

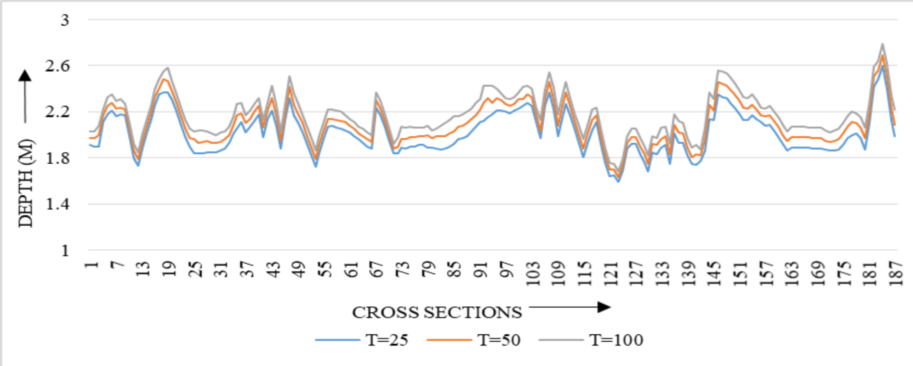

Fig. 8: Variation in depth of the Patu River along various cross-sections (Between Upper Patu to End of Bus Park Area) for the flood of 25, 50 and 100 years

In the stretch of 3.76 km of river, the total area of inundation due to flood of different return periods of 25, 50 and 100 years has been found to be 0.404 km^2, 0.426 km^2 and 0.448 km^2 respectively. Out of which fields share the maximum proportion of inundated land cover. It has been found that 29.84%, 30.25% and 30.61% of fields get drowned due to 25 years, 50 years and 100 years flood. It has been observed that 20.66%, 21.11% and 21.31% of settlements are at risk due to the respective floods. The inundation of bare land and forest and trees is comparatively low. This indicates that the flood could pose problem to the settlement nearby and the agricultural land as well. The inundation area has been presented in terms of 5 different land cover classes. The settlement at the north of Bus Park is at risk in all three flooding. As the intensity goes on increasing, the risk of flooding on settlement is found to have been increasing at the mid of the stretch of river under study. Since the river is meandering there too, it might be more problematic as well. The fields and agricultural lands at the initial part of the stretch is observed to have been at problem when there is a flood.

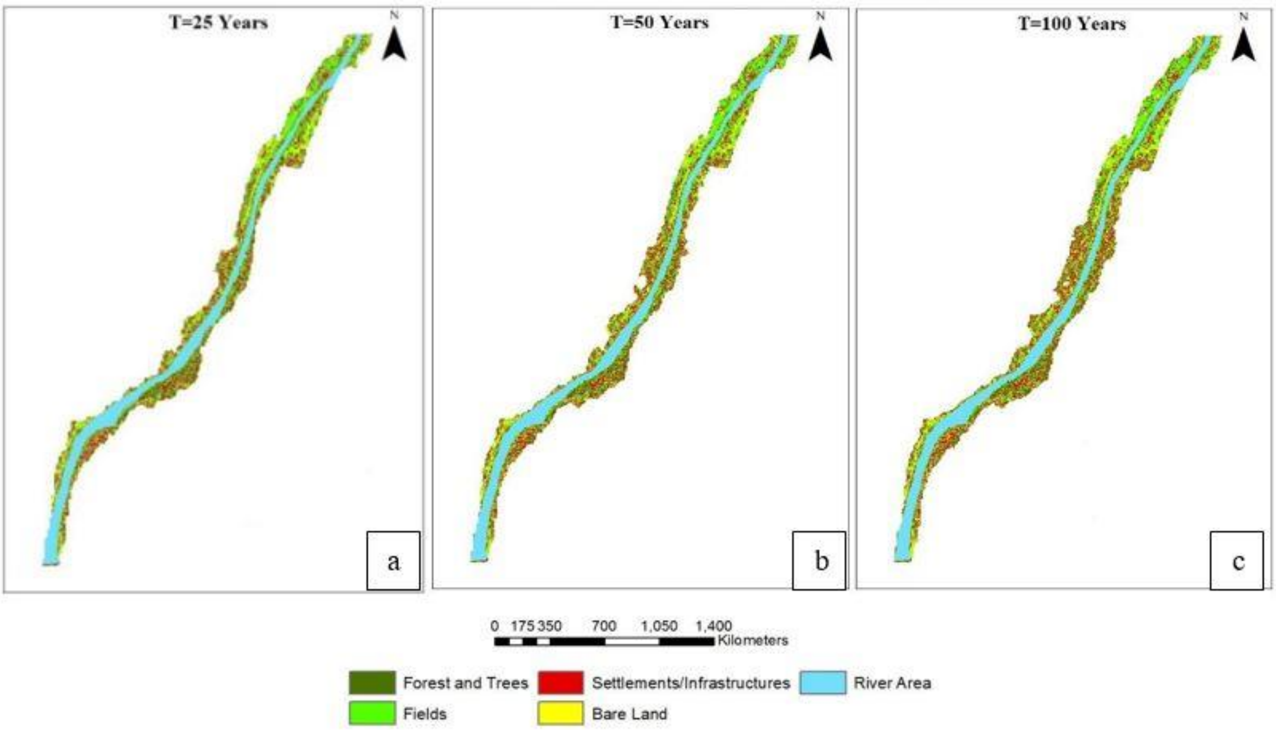

Fig. 9: Inundated Land Covers due to Flood of T=25,50 and 100 years in the Year 2019

The figures below depict the pattern of inundation for the land cover of previous years. The effect of flooding with the changing land covers has been studied for the year 2004, 2010, 2015 and 2019 for which the inundation boundary of 100 years return period flood has been used for the land cover of previous three years. It has been clearly observed that as the passage of years, the land covers within the inundation boundary has been changing. In the year 2004, there is domiance of river area. So even the river had 100 years of flooding just a few settlement and fields would have been drowned. But with passage of years, those river areas has been found to have been converted into more settlements, fields and agricultural land which exactly lie under inundation territory.

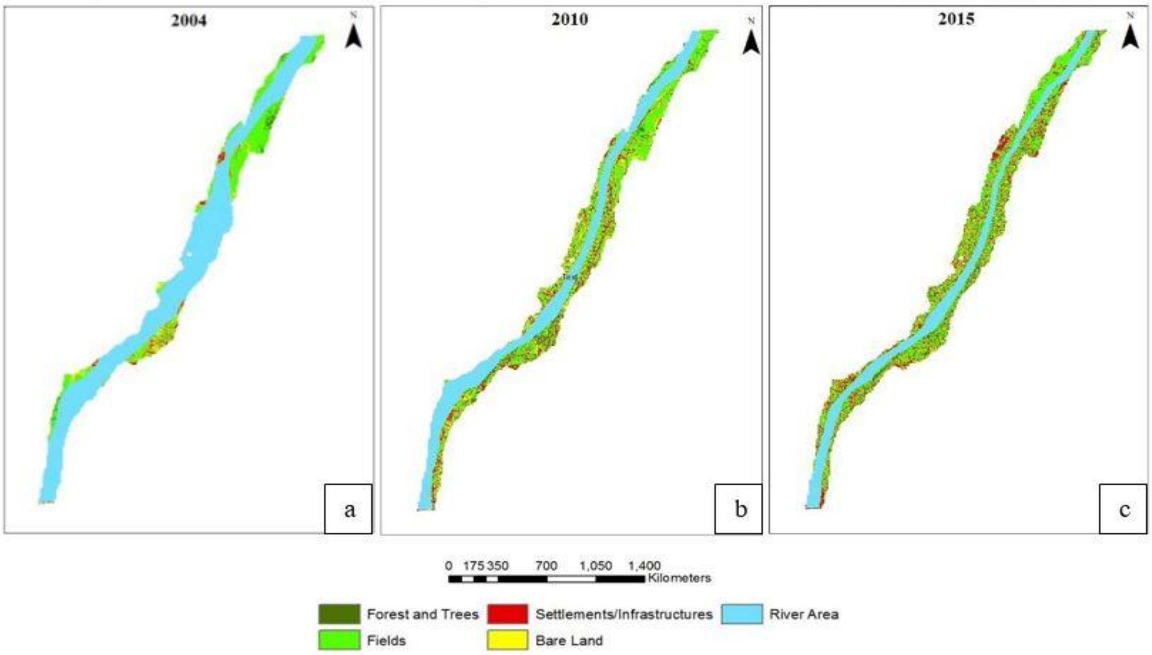

Fig. 10: Change in inundated land covers in the year a) 2004, b) 2010 and c) 2015

The trend of change of land cover within the zone of inundation has been depicted in charts below. The inundation of settlement area back in 2004 was observed as just 0.009 km^2. In the year 2010, 2015 and 2019, the inundation of the settlement has been increased to 0.043 km^2, 0.070 km^2 and 0.096 km^2 respectively. Whereas the fields and agricultural lands that used to get inundated back in 2004 was observed to be 0.085 km^2 which has now been increased to 0.137 km^2. This indicates the conversion of river area into agriculatural land and fields. The inundation of forests and trees, and bare land has been found to be 0.034 km^2 and 0.043 km^2 respectively in 2019.

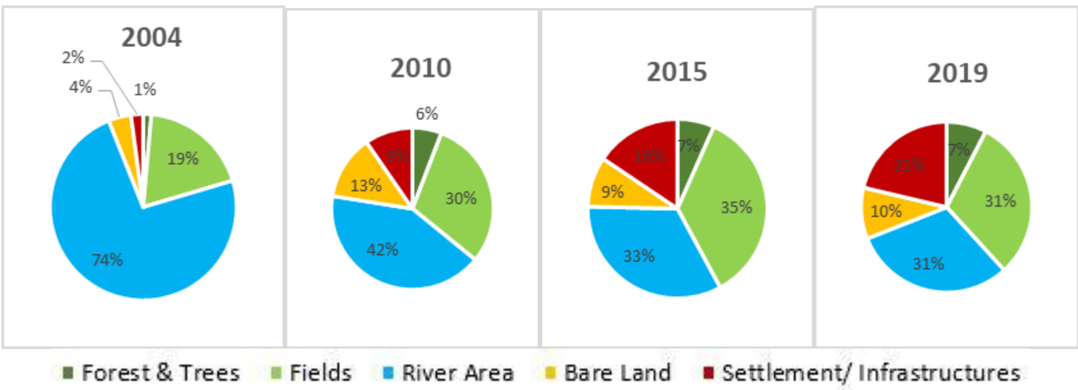

Fig. 11: Variation in inundated land covers for the year 2004, 2010, 2015 and 2019

Hence, with the years passing by, the settlements are increasing. The risk of flood in the settlement has been increasing with increasing urbanization in the river and has been found to follow the linear trend with R^2 value of 0.99. It has been depicted that, if the trend follows and in the next five as the settlement in the river expands, the inundation of settlement increases from 0.096 km^2 to 0.16 km^2 in 2024. To counteract the flood, the first activity to be done is the proper management of urbanization there. Since the permanent structures have been built there, the construction of the protection work is the must. The embankment need to be constructed on both sides of river.

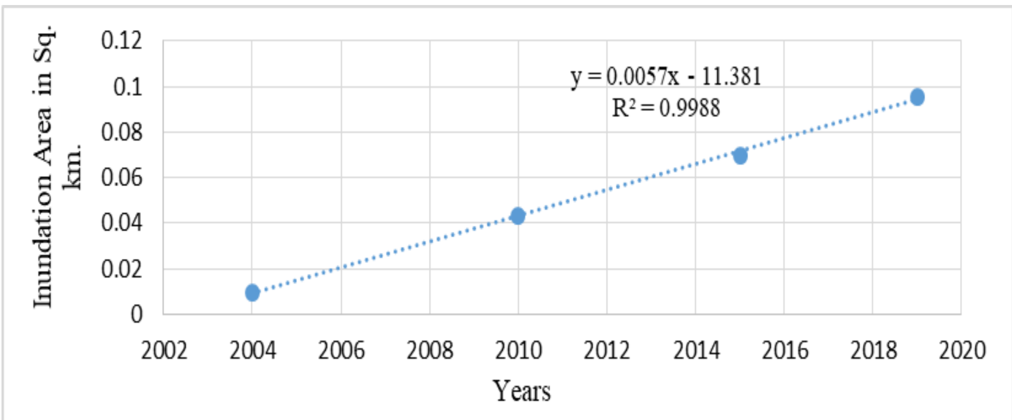

Fig. 12: Trend of inundation of settlements at the vicinity of the Patu River

3.5 Validation of Results

For the validation of the simulated results, the discharge has been measured in the river through float method for five different dates. The discharge of Patu River measured on 3/21/2020 was 4.9 m^3/s, 3/29/2020 was 4.14 m^3/s, 4/5/2020 was 4.96 m^3/s, 4/25/2020 was 8.34 m^3/s and on 5/1/2020 was 4.48 m^3/s. At the same day, the depth of the river at the end of the Bus Park was measured for the corresponding discharges. The model was executed for these five sets of discharges and the simulated depth of the river at the end of Bus park (Ch 640.3) was noted. Validation was performed in order to check the suitability of a single value for the Manning's Coefficient with several values of flow rates. The comparison between observed and predicted values of water level for these flow rates is shown in figure above. Depending on the value of the coefficient of determination (R^2), 0.91, the elected Manning’s n has been found to have given an acceptable matching between observed and predicted water levels.

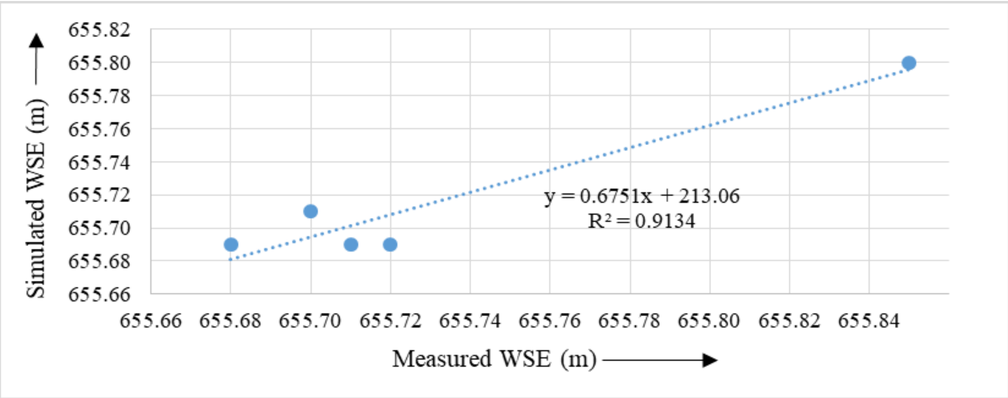

Fig. 13: Comparison of measured and simulated water surface elevations (WSE)

4. CONCLUSION

There are numerous cities in Nepal situated at the bank of small and big rivers. The land cover around the river has been changing continuously due to rapid urbanization. Tulsipur city is one of the major socio-economic hubs of Mid-West Nepal which is in developing phase. The problem is the city is being concentrated more around Patu River. The stretch of 3.76 km of Patu river has been taken for study for which the river area has been reduced to 0.138 km^2 (153.6% less than in the year 2004). The settlement is being built haphazardly at the vicinity of river and it has been found to be at high risk of flood.

The study area has been surveyed and the required inputs have been provided to HEC-RAS model. Since Patu is an ungauged river, the discharge has been obtained as 109.9 m^3/s, 132.9 m^3/s and 158.1 m^3/s for 25, 50 and 100 years flood by catchment area ratio method based on the catchment of nearby gauged river Sharada. The value of the Manning’s coefficient has been altered dividing the study stretch into four areas and the model has been calibrated. The model has been run for flood of 25, 50 and 100 years return period. The inundation boundary has been found to be of 0.448 km^2 for which 0.096 km2 include settlement areas. The same inundation boundary has been used for the land cover of years 2004, 2010 and 2015 obtained by most likelihood supervised classification method through Arc GIS. The inundation of settlement area back in 2004 was observed as just 0.009 km^2. In the year 2010 and 2015, the inundation of the settlement has been increased to 0.043 km^2 and 0.070 km^2 respectively. Whereas the fields and agricultural lands that used to get inundated back in 2004 was observed to be 0.085 km^2 which has now been increased to 0.137 km^2. This indicates the conversion of river area into agricultural land and fields. The inundation of forests and trees, and bare land has been found to be 0.034 km^2 and 0.043 km^2 respectively in 2019. As the trend follows, in the next five as the settlement in the river expands, the inundation of settlement could increase from 0.096 km^2 to 0.16 km^2 in 2024. To counteract the flood, proper protection work is needed. And for better urbanization, effective plans and decision making is needed. Based on the SEM, the ratio of discharges in Sharada river and Patu River differ as 3.915 ±0.265 and the margins of error at a confidence level of 95% was obtained to be ±6.78%. So, this CAR method for this reason shall be used to find peak flood for different return period. Also, this discharge of Patu River can be used for further studies. Thus constructed floodplain map could be used as the basic floodplain map for general information where the information is scarce. This floodplain mapping could also be used in the, preparing flood hazard maps, preplanning of disaster, planning phase of the different infrastructures, projects, programs within the boundary of the floodplain analysis. This study could be the reference for the further study in same type of research fields. It is highly recommended that, during the detail design of such infrastructures, projects and programs, a precise topographic data should be used. The study has been done with survey through total station. The researchers can use drone surveying methods or DEM of higher resolution. The impact of flooding due to debris transportation and extraction of river bed materials could also be done.

5. REFERENCES

[1] Abbas, S. A., Al-Aboodi, A. H., & Ibrahim, H. T. (2020). Identification of Manning’s Coefficient Using HEC-RAS Model: Upstream Al-Amarah Barrage. Journal of Engineering (United Kingdom)

[2] Ashraful, M., Chowdhury, I., Amir, M., Bhuyain, H., & Kabir, M. M. (2015). Assessment of river encroachment and land-use patterns in Dhaka city and its peripheral rivers using GIS techniques. International Journal of Geomatics and Geosciences

[3] Asquith, W. H., Roussel, M. C., & Vrabel, J. (2006). Statewide Analysis of the Drainage-Area Ratio Method for 34 Streamflow Percentile Ranges in Texas. USGS, Scientific Investigations Report

[4] Azamathulla, H. M., Ahmad, Z., & Ab. Ghani, A. (2013). An expert system for predicting Manning’s roughness coefficient in open channels by using gene expression programming. Neural Computing and Applications

[5] Basnet, K. & Acharya, D. (2019). Flood Analysis at Ramghat, Pokhara , Nepal Using HEC-RAS. Technical Journal, Nepal Engineers' Association, Gandaki Province 1: 41-53. Nepal Journals Online
[6] Basnet K., Acharya D., Bhandari K.P., & Sadadev B.B. (2019). Flood Plain Mapping Using HEC-RAS (A Case Study of Seti River, Pokhara). Preprint.
[7] Coon, W. F. (1995). Estimates of roughness coefficients for selected natural stream channels with vegetated banks in New York.
[8] Dangol, S. & Bormudoi, A. (2002). Flood Hazard Mapping and Vulnerability Analysis of Bishnumati River, Nepal. Nepalese Journal on Geoinformatics, Survey Department.
[9] El-Naqa, A., & Jaber, M. (2018). Floodplain Analysis using ArcGIS, HEC-GeoRAS and HEC-RAS in Attarat Um Al-Ghudran Oil Shale Concession Area, Jordan. Journal of Civil & Environmental Engineering.
[10] Hatzigiannakis, E., Pantelakis, D., Hatzispiroglou, I., Arampatzis, G., Ilias, A., & Panagopoulos, A. (2014). Variation of the Manning roughness coefficient in the river Strymonas in Northern Greece. Proceedings of the 12th International Conference on Protection and Restoration of the Environment.
[11] Mahmood, S., Nourin, F. T. J., Siddika, A., & Khan, T. F. (2017). Encroachment of the Buriganga River in Bangladesh. Journal of Minerals and Materials Characterization and Engineering.
[12] Panahi, A., Alijani, B., & Mohammadi, H. (2010). The Effect of the Land Use/Cover Changes on the Floods of the Madarsu Basin of Northeastern Iran. Journal of Water Resource and Protection.
[13] Prajwal, K., & Lamichhane, N. (2018). Flood Inundation Mapping of Babai Basin using HEC-RAS & GIS Flood Inundation Mapping of Babai Basin using HEC-RAS & GIS.
[14] Shrestha, B. B. (2019). Approach for Analysis of Land-Cover Changes and Their Impact on Flooding Regime.
[15] Shrestha, S. (2015). Assessment of Bagmati River Encroachment through Arc GIS.
[16] Study, A. C., Banstola, P., & Sapkota, B. (2019). Flood Risk Mapping and Analysis Using Hydrodynamic Model HEC-RAS.
[17] Yusuf Y.O., Iguisi, E.O., & Abdulsalam, S. (2011). A Comparative Analysis of Discharge Measurement on a First Order Stream in Zaria using the Current Metre and Float Methods. Conference of the Science Association of Nigeria (SAN).

