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Future Sediment Transport Ability and its Consequences in the Urbanized River Basin

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Abstract

The urbanization process of the Kathmandu Valley has a significant impact on LULC change, river runoff, and sediment transport capability. The historical sediment flow pattern indicates that the sediment transport capacity of the basin has increased even when precipitation and river discharge decreased. So, the sediment regression model is developed in this study in relation to discharge, precipitation, and built-up area change. Model parameters are calibrated and validated through the measured sediment discharge of the basin and the performance of the model is evaluated through NSE, PBIAS, and R2. In the future, the sediment transport capacity of the channel is projected for average monthly, maximum, and minimum flow conditions by +4.33%, +6%, and -2.66% respectively per decade due to the rise in the urban area (+6% per decade). Increasing the rigid ground surface through urbanization reduces the sediment generation through the watershed and balances the sediment transport capability, excess erosion is produced in the river channel causing a change in the river morphology. The findings of this study will be useful for planning and management of the river basin and the river structures.

Keywords: - Kathmandu Valley, LULC change, Sediment, Rating curve, Regression analysis

1. Introduction

The world urbanization process was sensed since the 1950s [1]. People migrate for better opportunities and economic activities that increase the population growth rate and are concentrated mainly in the city area, which shows more investment and use for management and fulfilling human needs. Limited availability of land is one of the key resources, and its management is challenging especially in urban areas. The urbanization process alters the Land Use/ Land Cover (LULC) change by raising the built-up area and reducing the open (forest, agriculture, barren, and shrub) land. The LULC changes have a direct impact on the hydrological process and variation in the sediment transport capacity of the basin [2], [3], which ultimately impacts the channel water carrying capacity. Rapidly changing LULC practices within the basin may have positive and

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negative consequences on erosion and sedimentation. The use of agricultural practice and deforestation have a positive [4], and the escalating population growth and increase in the urban built-up area have a negative impact on soil erosion [5]. LULC change, and its implication in river runoff and sediment handling capacity are critical issues in global ecology and environment as well as in highly urbanized basins like Kathmandu Valley. In this context, several researchers have developed a detailed understanding of the identification of sediment driving forces, their effect on river runoff, and sediment generation for the sustainable management of watersheds [6].

Rating curve techniques are a simple method for finding the sediment concentration in the river corresponding to discharge. It is just a graphical or numerical relation between sediment transport capacities with the corresponding stream discharge. This method is more reliable for finding the past or missing sediment data in the river system [7]. The rating curve and its generated data trend of the sediment are often very important for determining the effect and causes of change in the river basin [8].

Kathmandu valley is a highly urbanized area in Nepal. Historical urbanization [9], future changes in LULC [10] variation of river discharge [11], groundwater recharge scenario [12], and basin runoff characteristics [13] were studied in various objectives. Pokhrel (2018) assessed that the historical LULC change in the Kathmandu valley increased the river runoff and sediment concentration in the drainage system under a well-calibrated and validated SWAT model. Six percentage rises in a built-up area between 2000 to 2010 generates 5% and 27% more sediment and discharge respectively in the river system. From the observation of sub-watershed results, the cumulative variation has occurred throughout the whole basin. But, according to Lane's theory, the sediment discharge and the discharge in the channel were balanced by the effect of sediment size and the slope of the channel [15]. So, finding the sediment or channel equilibrium condition, Lane's balance equation has been commonly used with the principle of dynamic equilibrium in the channel that can exist through the sediment and stream discharge as per Eq. 1.

$$Q_s \times d_{50} \approx Q \times S \text{ .... } 1$$

Where Q_s, d_{50}, Q, and S represents the sediment discharge capacity, the mean grain size of the sediment, the discharge of the river, and the slope of the river channel. The significance of the mass balance theory, if the discharge of the channel is increased, then it balances by increasing the sediment discharge or decreasing the slope of the channel [15]But in the urban area, the watershed cannot support the further erosion from the basin due to the rise in concrete area and balance will be achieved through the channel erosion.

Hydrological modeling, regression modeling, and statistical analysis are the key methods to be used for computing LULC change and its effect on river runoff and sediment transport capacity [16] . Various hydrological models (like HEC-HMS [17], SWAT [3], [14], PRMS [18], MIKE SHE [19], HBV [20], etc.) are commonly used to assess the impacts of LULC change and response in river hydrology and sediment discharge capacity of the basin across the world. In hydrological modeling, many governing parameters, complex model structures, big data sources, and high-speed solving tools are needed to calibrate model parameters with the complex solving process. Therefore, for simplicity, regression analyses are commonly used techniques, which requires limited parameters [21]. The least-square regression model is the alternate reliable approach to overcome such problem and correlating to the governing factor with sediment concentration [22]. So, the empirical model is established with the relation of the limited parameters like precipitation, discharge, and LULC change with sediment transport capacity. Numerous multivariate regression approaches were used to generate the effect of climatic and physical environmental changes in the basin on sediment yield [6], [23]–[25]. Huilan et al (2019) assessed the effect of LULC and climate change on the river sediment and runoff by using the hydrological model and statistical model, from the analysis the hydrological model gave a better performance due to various associated parameters, but the statistical analysis is simple and fast technique and also provides reliable information. Zhang et al (2020) concluded that partial least squares regression (PLSR) approach delivers the more significant outputs of sediment yield in the basin with respect to climatic and LULC variation. The analysis was conducted in the 16 catchments of the Chinese Loess Plateau (CLP) from 1961 to 2015 for finding the suspended sediment yield of each basin. The increasing or decreasing of the sediment yield in catchment is varied with the change in land-use practices. The multiple environmental factors are associated with quantifying the sediment yield in the basin-like soil, land use practice, climatic factors, topography and anthropogenic disturbance occurs [25] and all these factors are also exist in the Kathmandu Valley basin.

From the aforementioned studies, various information and driving factors have been considered for the identification of hydrological processes concerning the sediment transport capacity of the basin. The comprehensive study of sediment yield in the basin, relation to the driving factors, and sediment equilibrium condition in river reach have not been studied yet in the Bagmati River basin in the Kathmandu Valley. The scientific consensus between driving factors to the sediment yield magnitude has been still unjustified. The benefit and risks in the river reach through the changing value of the influencing parameters are still unknown. Therefore, the formation of the rating curve generates the missing and misrepresented data during observation, and the results of the seasonal variation of the sediment transport can provide the trend and its future concequences in the basin. Sediment regression analysis provides a better understanding of the driving factors such as precipitation, discharge, and LULC change, and the sediment handling capability. Future sediment flows characteristics in the river reach are found through the input value of future discharge which is taken from SWAT model analysis output with the comparison of the base period and generates the overall picture of sediment flow in the basin with corresponding impacts. The results from the outputs can provide broad knowledge to future sediment magnitude and the way forward in the Bagmati River basin management.

2. Material and methods

2.1 Basin

Kathmandu Valley basin was used for the analysis and the basin represents the all-urban part of the three: Kathmandu, Lalitpur, and Bhaktapur districts. The topographical features, seasonal climatic changes, and LULC change characteristics of the valley basin vary the runoff and the corresponding impact on the sediment transport capacity. The watershed area (613 km^2) of the basin was delineated in the 30 m ASTER DEM in the GIS environment at the Katuwal Daha outlet point as shown in Fig. 1. For the analysis, river flow and sediment data were selected at the Khokana gauging station (Station no 550.5) just upstream of the outlet point. The Bagmati River is a single drainage network of the basin having major tributaries such as Bishnumati, Manohara, Nakhhu Khola, Balkhu Khola, etc. Spring-fed and heavy monsoon rainfall characteristics (75% of total annual rainfall) of the basin reflect through the maximum runoff and sediment discharge during this season. Mostly four seasons are assumed for the seasonal variation such as spring (March, April, and May), summer (June, July, and August), autumn (September, October, and November), and winter (December, January, and February).

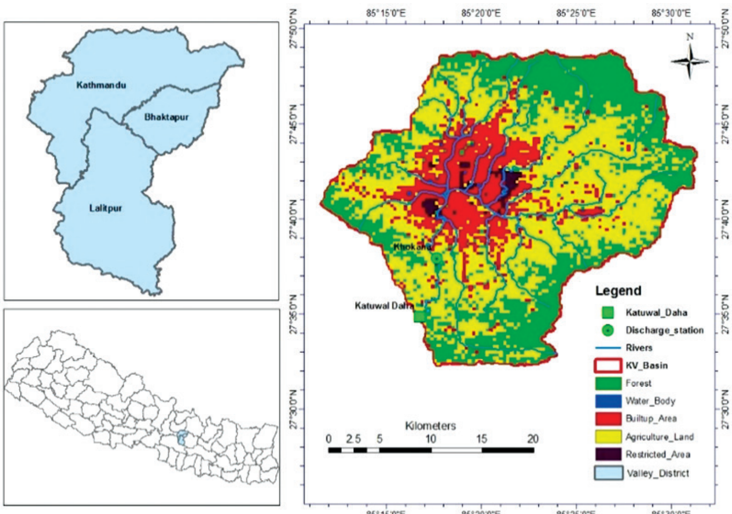

Figure 1: Location and associated details of the Kathmandu Valley watershed in the uppermost part of the Bagmati River Basin

2.2 Methodological framework

For the understanding of the precipitation, corresponding river runoff, LULC change, and sediment variability of the basin were analyzed through the historical information from various sources, and the projected sediment carrying behaviors, based on seasonal, annual, and decadal of the basin has been quantifying by the simple regression analysis by using the SWAT model runoff data. The sediment-carrying characteristics were analyzed based on seasonal, annual, and decadal variations. All the overall methodological process is presented in Fig-2.

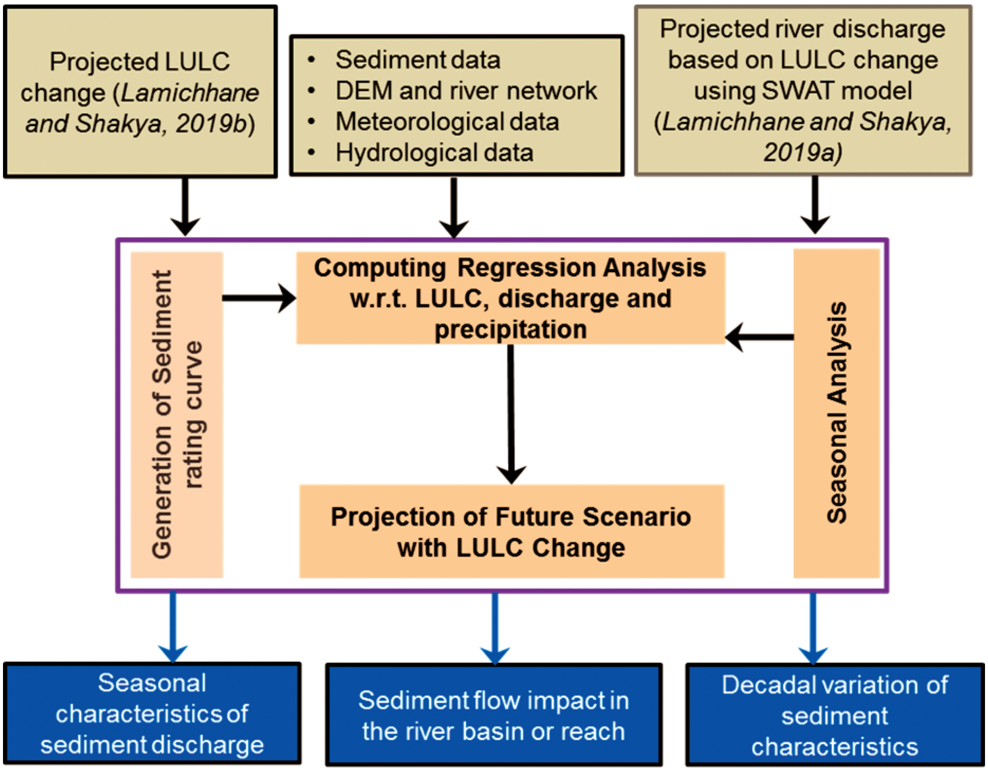

Figure 2: Methodological framework

2.3 Sediment Rating Curve

Various sampling techniques such as direct (grab, pump, isokinetic, etc.), optical, nuclear, acoustics, laser diffraction, tracer, etc. are used for the measurement of the sediment concentration in the river reach [26]. The intensive sampling of the river system in daily measurement of the suspended load is more complicated, time-consuming, and costly for all locations of the country. So once formulate the sediment rating curve (relation between sediment and river flow), can be used to generate the long-term records corresponding to the river discharge. The relation between the river discharge and the concentration of the sediment has the power relation [27] and it is expressed in Eq. 2

$$C = \alpha Q^{\beta} \text{ .... } 2$$

Where C and Q represent the concentration of sediment (mg/lit) and corresponding river discharge (m^3/s), α and β are the regression coefficients that represent the all-secondary integrated effect in the river reach that influences the quantity of sediment. The coefficients of the equation are obtained through the measured suspended sediment flow data and its corresponding measured discharge in the same location. The liar and the missing value of the sediment data are also generated through the rating equation.

2.3 Monthly, seasonal, and yearly sediment transport characteristics of the river basin

The relationship between the sediment discharge changes in the river basin channel with the variation of the river runoff monthly, seasonally, and yearly is assessed through graphical analysis from 2000 to 2017. Four seasons (spring, summer, autumn, and winter) are considered for the analysis. The variation of sediment and precipitation characteristics in the basin with respect to historical LULC change is also evaluated through the comparison.

2.4 Formation of the regression equation

The sediment transport from the basin to the river reach mainly depends on the LULC type, slope, precipitation characteristics (frequency, duration, and depth), and runoff of each sub-basin. Due to urbanization, the surface land use areas are stronger (or non-erodible) and the runoff tendency is increasing day by day. Such variation of basin characteristics estimates the sediment volume in the river reach is more complicated, so the regression analysis and its coefficient provide a better understanding of basin sediment characteristics. In this analysis, the major factors influencing the sediment transport capacity of the basin and channel is considered as LULC change, precipitation, and runoff of the basin. Other minor influencing factor effects are integrated through the regression coefficients as per Eq. 3.

$Si = \alpha \times Qi\beta \times Pi\gamma \times (\Delta B \times n)i\lambda$ 3

Where, S, Q, P, ΔB, and n and represent the sediment discharge (mg/lit), river reach discharge (m^3/s), depth of precipitation (mm), rate of change in the built-up area of the basin (km^2), and time interval of the rate of change respectively with i time series. , , and are the regression coefficients of the discharge, precipitation, and built-up area respectively. Similarly, is also a regression coefficient and that represents the integrated effects in the sediment concentration in the basin by the other sources, all the limitation of the analysis is bonded through this coefficient. The complex regression equations are solved through the simple logistics regression equation as per Eq. 4.

$\log(Si) = \log(\alpha) + \beta\log(Qi) + \gamma\log(Pi) + \lambda\log(\Delta B \times n)$ 4

The coefficients value is generated through the observed sediment and river discharge data and generated data from the corresponding coefficients were validated through measured data also. Such a type of analysis is more valuable where the sediment records are nominal or less.

2.5 Calibration and the validation of the model parameters

Two models are used during the analysis, one is the SWAT model which generates the discharge of the river corresponding to future LULC change and future monthly generated river discharge data is used for the analysis. The future climatic characteristics are taken from the past observed scenario. Lamichhane and Shakya (2019a) well-calibrated and validated (2000 to 2014) SWAT model and its output is used for future scenario analysis. On the other hand, the regression model is used for the sediment analysis by using SWAT model outputs. The regression coefficients or parameters are calibrated and validated through the observed data of the basin. The calibration is done through the ten years (2000-2010) of observed data and the validation is carried out for the seven years of data (2011-2017). The performance of the output is evaluated through the statistical indicators of Nash–Sutcliffe simulation efficiency (NSE), volume bias (VB), and coefficient of determination (R^2) methods [28]–[30]. The threshold range of the indicator represents the model efficiency.

2.6 Future sediment analysis

By using the well calibrated and validated two models, the output is used for the analysis. The data i.e. river runoff and corresponding LULC change in that duration which is generated from the SWAT analysis from the previous study by Lamichhane & Shakya, (2019b) and Lamichhane & Shakya, (2019a)Nepal. Study focus: The focus of this study is to project future LULC, delineate potential recharge areas, and evaluate encroachment in recharge areas due to future changes in LULC. New hydrological insights for this region: The consequences of urbanization in Kathmandu Valley (KV are taken respectively. Also, the decadal, yearly, monthly and seasonal variation of the future sediment yield in the river channel is analyzed through baseline data.

2.7 Data Sources

For finding the outputs of river discharge, precipitation, land use type, and sediment discharge, a list of the data type and sources was used during the study.

Table 1: - Data sources for the study

Type of data	Sources	Resolution	Year/ Length	Processing tools
DEM	ASTER GDEM version 2	30 m		ArcGIS – 10.2
Land use/ cover (LULC)	Lamichhane & Shakya, (2019a)Nepal. Study focus: The focus of this study is to project future LULC, delineate potential recharge areas, and evaluate encroachment in recharge areas due to future changes in LULC. New hydrological insights for this region: The consequences of urbanization in Kathmandu Valley (KV	30 m	2010 – 2018	ArcGIS – 10.2
River runoff	DHM	Daily	2000-2017	Khokana (st no:- 550.5)
Future discharge	Lamichhane & Shakya, (2019b)	Daily, Monthly	2015 to 2054	Khokana (st no:- 550.5
Precipitation	DHM	Daily	2000-2017	21 station
Sediment	DHM	Daily	2000-2017	Khokana (st no:- 550.5)
Population	CBoS, Nepal		1991,2001, 2011	

3. Results and discussions

3.1 Historical sediment characteristics and rating curve

The historical sediment data was taken from the observed Khokana station (550.5) from 2000 to 2017. Some missing values and the liar data were deleted from the long-term time-series data and a relationship was developed between the discharge and its corresponding sediment concentration in the river reach called a rating curve. The empirical relation was found as per below.

!Unexpected End of Formula

The application of the rating curve in the calculation of sediment volume is quite reliable before checking the statistical indicator. The coefficient of determination value of 0.79 provides a strong relation between them and the reliable performance of the rating curve as per Fig. 4(b). After the formation of the rating curve, the missing data was generated through the equation and historical monthly precipitation, river runoff, and sediment discharge were prepared. The correlation between sediment flow, precipitation, and its corresponding river discharge was seen in Fig. 3.

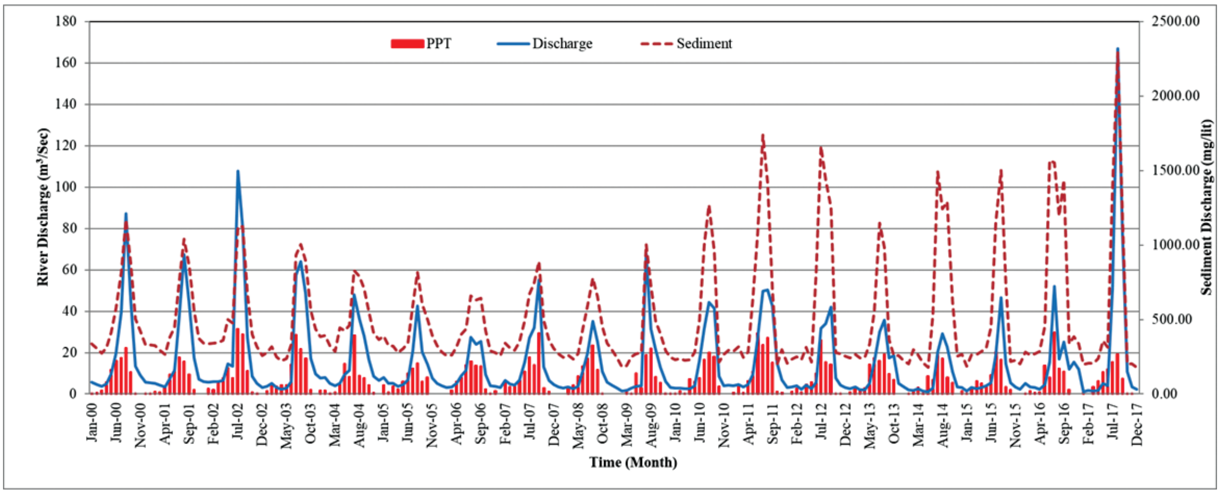

Figure 3: Observed sediment, discharge, and precipitation of the study area

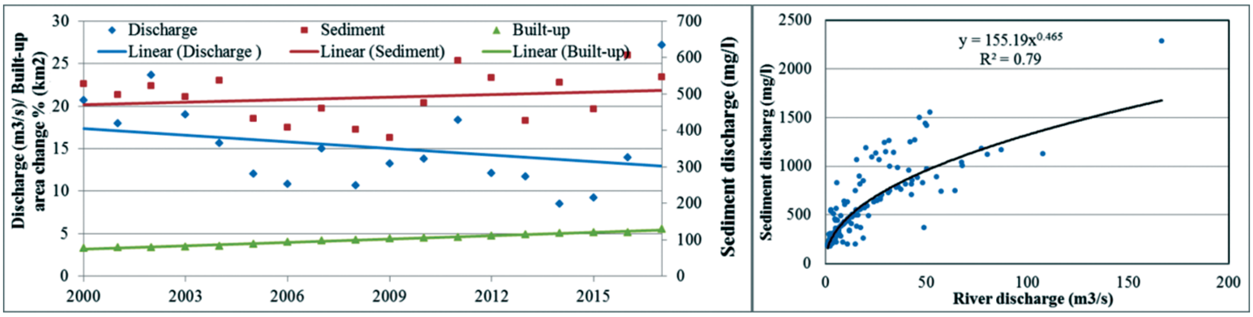

Figure 4: a) Annual flow series of discharge, sediment, and change in built-up area percentage b) Rating curve

The urbanization pattern of the valley reduced the sediment transport from the basin to the river reach due to surface hardness. Excess water is runoff through the built-up area, and it cannot flow through the exposed sediment area. But from the observation of the graph and the data, the sediment rate in the river reach is not decreased even though the discharge was declining. The annual series (Fig. 4(a)) indicate that the sediment concentration in the river reach is increasing trend due to the rise in built-up area as well as runoff characteristic change.

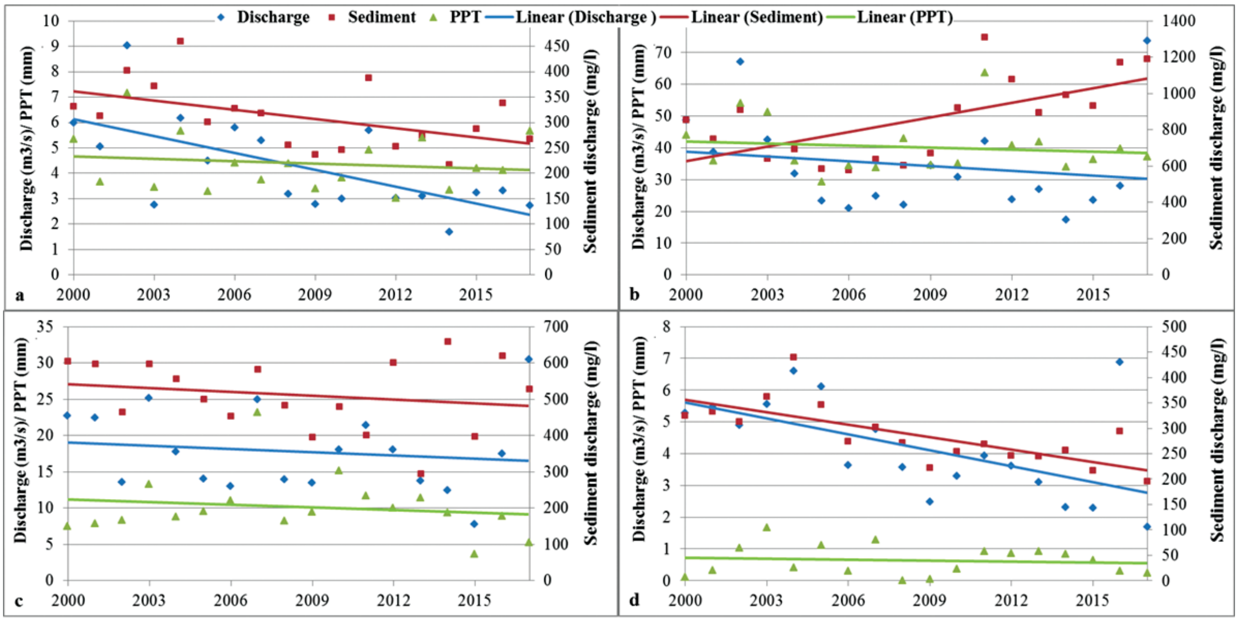

Figure 5: Seasonal graphs between discharge, sediment, and precipitation (PPT) a) spring b) summer c) autumn d) winter

In the seasonal analysis, due to the high rate of discharge decreasing trend in the basin in spring creates the decline of sediment concentration but the trend in sediment flow pattern is less than the river runoff. High rate of urbanization, less recharge, and a high rate of pumping in the basin decline the groundwater table and reduce the groundwater flow contribution to the river system [12]. That creates the declining nature of river flow as well as sediment. Similar types of characteristics are also shown in autumn and winter. But in the summer, the rate of precipitation was greater than the other and creates more runoff and sediment transport capacity in the channel. Therefore, the sediment concentration or transport capacity of the basin is mostly varied with the precipitation characteristics, runoff generation, and the LULC change characteristics of the basin.

3.2 Relation between sediment, discharge, precipitation, and LULC change

The LULC change induced the variation of runoff characteristics of the basin, precipitation induced the runoff generation, and triggered sediment transport. The soil type, moisture content, slope of the land, and other factors are also play a role in variation in sediment transport capacity. The major factors precipitation, discharge, and LULC change are considered and the relation between them was found by the regression analysis, and the other affecting parameter was considered through the constant parameters in Eq. 3. Regression analysis was done by using 2000 to 2017 measured discharge, LULC change, and precipitation data of the basin. The logistic regression analysis indicated the discharge was more sensitive than the other parameters as shown in Table 2.

Table 2: Calibrated value of regression coefficient parameters.

S.N.	Coefficients	Parameters	Values
1	β	Discharge	0.4208
2	γ	Precipitation	0.0425
3	λ	LULC change	0.021
4	α	Constant or other	138.27

After using the regression equation, the calibration and the validation were done, and the performance model was evaluated through the indicators. The calibrated and validated regression equation easily generates the sediment transport capacity of the basin with corresponding input values.

3.3 Model performance evaluation

Future flow simulation of the basin was done by the SWAT model and the generated discharge was used in the simulation for finding the sediment transport capacity of the basin with the future LULC change and historical decadal precipitation characteristics.

Flow simulation

The parameters of the SWAT model were calibrated and validated through the daily and monthly measured discharge at the Khokana station (Station no. 550.5) of the Bagmati River basin. The performance of the model was evaluated through statistical indicators (NSE, PBIAS, and R2). The calibration of the model parameters was done from 2002 to 2010 data and validation was performed from 2011 to 2014 observed data. Initially, two years of data were skipped for reducing the uncertainty of the model outputs. The analysis of the study is focused on the monthly and seasonal variation of flow in the river basin so monthly performance indicators NSE, PBIAS, and R2 values are 0.96, 0.16, and 0.83 respectively indicating the better performance of the model. The positive biased value indicates a slight overestimation.

Sediment simulation

Sediment regression model parameters were calibrated and validated through the measured and refined sediment data at the Khokana station of Bagmati River. 2000 to 2010 observed data was used for the calibration and from 2011 to 2017 data was used for the validation of the sediment parameter. The evaluation of model performance was done through the NSE, PBIAS, and R2 values as listed in Table 3 and Fig. 6 and 7.

Table 3:- Statistical parameters value during calibration and validation

Parameters	Calibration	Validation
NSE	0.96	0.90
VB	-0.04	0.14
SD	256.68	283.61
R2	0.84	0.86

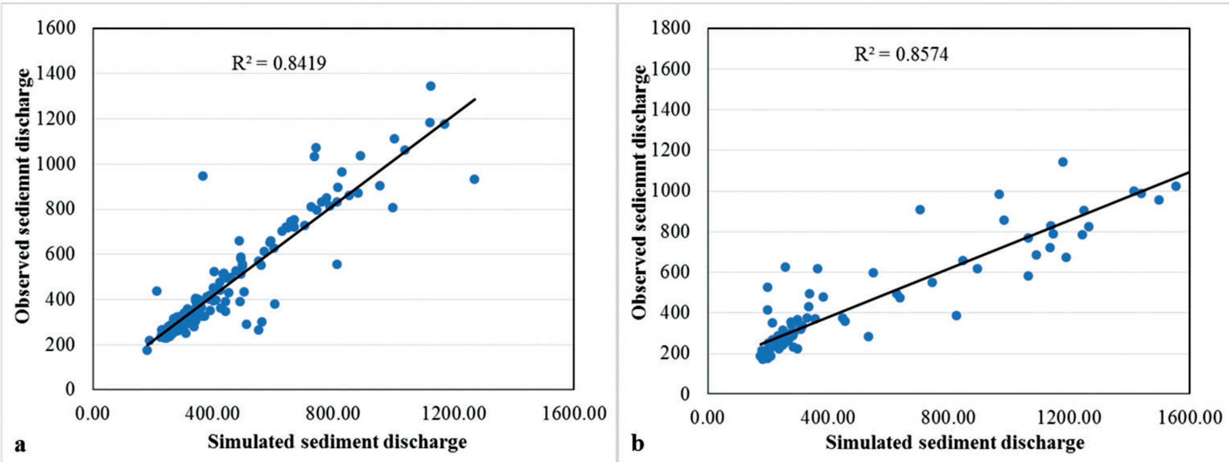

Figure 6:- scatter plot during a) calibration b) validation

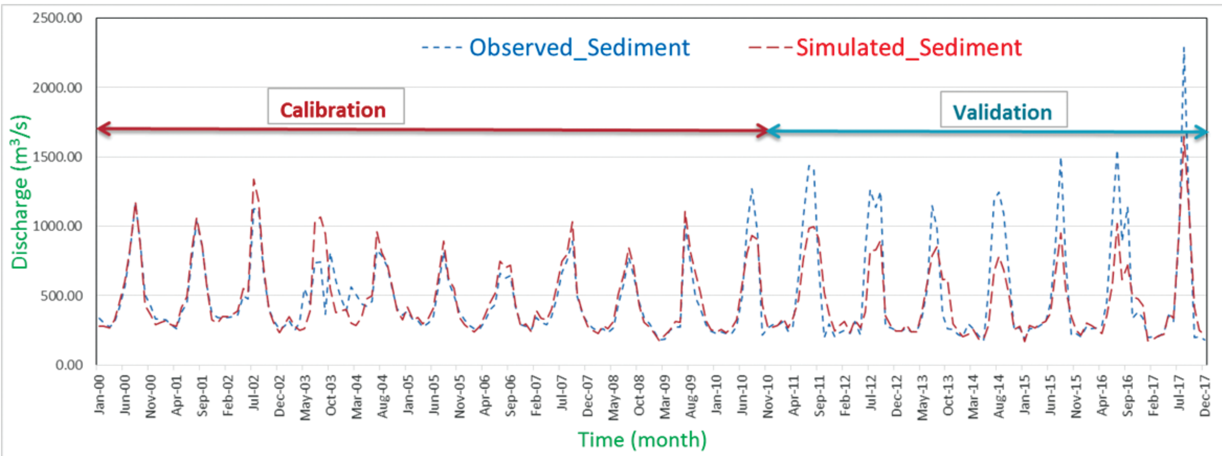

Figure 7:- Calibration and validation of sediment data

From the observation and value of performance indicators clearly indicates that the regression model parameters provide better performance. The positive biased value indicates partial overestimation.

3.4 Impact of LULC change on sediment production and transport

For future analysis, monthly discharge with LULC change scenario and LULC change projection pattern was taken as input from the output of the previous study by Lamichhane & Shakya, (2019b, 2019a)LULC and integrated change considering both factors, with KV watershed in central Nepal as a case study. Historical LULC data were extracted from satellite image and future LULC are projected in decadal scale (2020 to 2050. From those studies, the monthly peak and lean minimum discharge have been changed by +5% and -6% per decade respectively due to changes in the runoff characteristics by the urbanization process. Simultaneously, in that period, the built-up area has been increased by the 6% per decade in the basin. These variations in runoff and corresponding LULC are used in the analysis. From the analysis of the data generated from the sediment regression model, the average rate of sediment transport rate is increased in the river reach by 13% in 30 years period. The rate of peak sediment discharge will be increased by 18% in three decades. Similarly, in that period and minimum flow condition, sediment flow will be reduced by the 8% rate due to decreased river flow conditions as per Fig. 8. From the simulated data, in the future, the rate of increased sediment transport capacity from the basin degrades the watershed area as well as the natural channel of the drainage system.

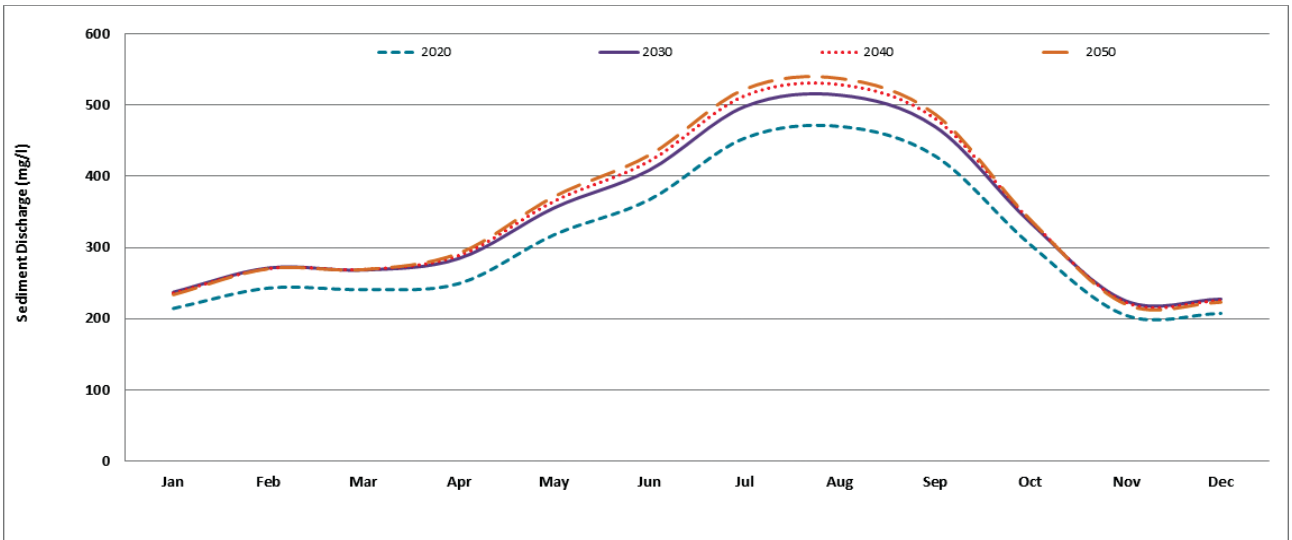

Figure 8 Generated sediment decadal data

3.5 Discussion

The historical and future LULC change creates the basin is more impervious and the ground surface is hardening. It means that the runoff volume is increased due to a rise in a built-up area and runoff coefficients. The rises in runoff volume tend to raise the sediment transport capacity in the channel. In general, the sediment inflow in the river channel is coming from over land and stream bank erosion but in the case of urban areas especially for Kathmandu valley all the top surface of the ground is concreted hence the top surface of the ground cannot be supported to provide the extra sediment in the drainage reach, it has a tendency to reduce the sediment from the watershed. And as well as, the small drainage network is also artificially hardened on its side hence the channel system getting impervious and cannot support increased sediment concentration.

Runoff characteristics and volume in the basin area have been increased due to urbanization, more water is runoff, and less recharge in the groundwater. That creates an increasing trend in the flood (wet) period and a decreasing trend in the lean (dry) period. In the past series, there was high open land which creates less runoff as well as high sediment concentration in the channel. In that period, it is assumed that the channel equilibrium condition is achieved. When the urbanization process was accelerated through the increase in impervious surface. It creates to increase the runoff volume in the basin or river reach. But this process retards the sediment erosion capacity of the basin due to the rise in urban concrete. When the runoff water (less sediment) is reaching the natural drainage network and they tend to take extra sediment for maintaining the sediment equilibrium state. In that condition channel has two options, one is increase in the erosion in the channel either bank or bed. And the other is aggraded the river channel as per Lane's equilibrium Eq. 1. Due to excess of discharge, less sediment concentration, and its corresponding high velocity cannot support the river channel in aggradation. Then, the rise in stream flow tendency increases the bank and bed erosion for maintaining the equilibrium condition. High land price and low space the banks of channels are mostly protracted, so in that case bed erosion is mostly occurred in the river channel.

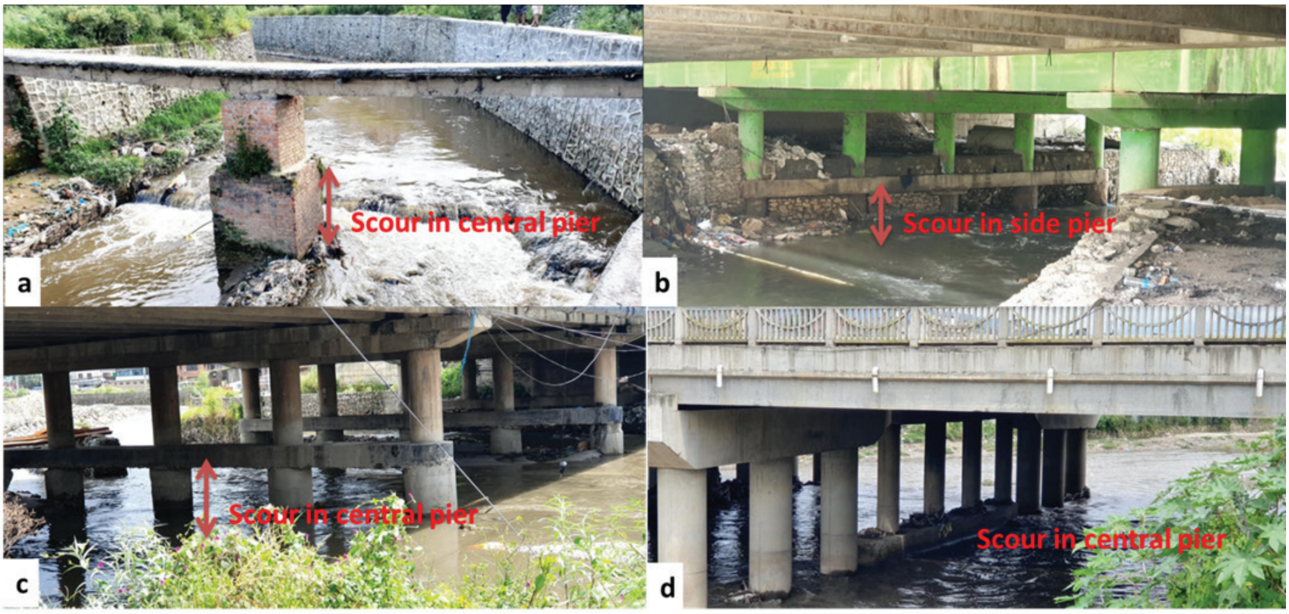

Figure 9:- Drawdown of bridge piers due to bed scour in a) Balkhu Khola at Tinthana [27⁰41'09"(N); 85⁰16'21"(E)] b) Dhobi Khola bridge at Bijuli Bazar [27⁰41'26"(N); 85⁰19'21"(E)] c) Bagmati River at Tinkune [27⁰41'11"(N); 85⁰20'37"(E)] d) Bagmati River at Balkhu Chowk [27⁰41'05"(N); 85⁰18'00"(E)]

The same consequence also occurred in the Kathmandu valley Bagmati River network system. The past urbanization effects on the river reach, the bed erosion of the channel was distinctly visible in the down of bridge piers in the river and also sensed through Fig. 9. Decreases in riverbed level due to bed erosion are seen in the figure by the variation of initial bed level and exiting bed level of river system. Similarly, Due to heavy rainfall in 4th September 2014 the central pier of the Bagmati Bridge at Sinamangal Kathmandu was collapsed by excess of bed erosion. The pier was partially tilted, and the cracks were formed in the bridge slab. Such type of events may be occurred in the future upcoming day due to excess of bed and bank erosion.

Figure 10:- Collapse of Bagmati Bridge at Sinamangal due to settlement of Central pier [27⁰41'56" (N); 85⁰20'48" (E)]

The study by Lamichhane & Shakya, (2019b, 2019a)LULC and integrated change considering both factors, with KV watershed in central Nepal as a case study. Historical LULC data were extracted from satellite image and future LULC are projected in decadal scale (2020 to 2050, if the urbanization process is in the same manner and the rise in the peak river discharge in the future, the bed level of the basin channel has been decreased day by day. So, the urbanized river basin is normally a degraded type. It indicated that the river structures like the bridge, culvers, and river training structures are more vulnerable due to excess of bed erosion. So, the future design of small structures in the urbanized river basin system such type of simple analysis is more fruitful during the design. The conscience of the rises in the built-up area within the basin is not overlooked during the analysis of the basin hydrology and the other river structures.

4. Conclusion

The past and future urbanization patterns of the Kathmandu Valley alter the hydrological and sediment balance of the basin. Hydrological and sediment study is done simultaneously in the river basin for future analysis. For easy understanding of the dynamics of sediment with corresponding river discharge, the rating curve is an effective and easy technique to generate or measure sediment data. Similarly, the simple regression model also simulates the future sediment scenario of the basin with influencing factors of urbanization or LULC change context. The generated rating curve and the historical sediment flow pattern indicate that the annual flow of the sediment in the basin has an increasing trend due to the rise in the built-up area. In seasonal analysis, except in the summer, the sediment discharge rate declines due to less groundwater contribution or minimum flow in the river reach but in summer the increasing gradient of trend is very high even decreasing the precipitation and river discharge. That indicates that the LULC change rate has significant impact on the basin sediment transport capacity. Finding the future consequences in the basin simple sediment regression model was developed through the empirical analysis between discharge, precipitation, and LULC change pattern. The developed models were calibrated and validated through the statistical indicators (NSE, PBIAS, and R^2) and the obtained values represent better performance and reliable outputs through it. The generated simple regression equation is more useful for the future analysis of the sediment flow and concentration characteristics. The average 6% increase in built-up area induced the monthly peak and lean minimum discharge by +5% and -6% per decade respectively. From the sediment regression model, the future sediment transport capacity of the channel is changed by average monthly, maximum, and minimum flow conditions by +4.33%, +6.00%, and -2.66% respectively per decade. The rising quantity of the basin sediment in the river reach is generated through the bed erosion of the channel, which may cause the degradation of the channel bed and it is easily seen through the river structures. So, such a simple sediment model and analysis of the urbanized river basin system is more useful and the LULC change in the basin should not overlook for future analysis.

Conflict of interest

Not declared by the author(s).

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