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Research Paper

Decadal Change In River Dynamics and Land Use – Land Cover Pattern In Kaligandaki River Valley From 1988 - 2017

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ABSTRACT

The Kaligandaki basin is a snow-fed river system. It encompasses Trans-Himalayan to the Gangetic plain through Higher Himalayan, and Lesser Himalayan zones and Siwalik. This region is exposed to extensive landslides and flood hazards and are susceptible to massive land use and land cover changes every year. The present study deals with land use land cover (LULC) changes and river dynamics of the Kaligandaki river valley from Jomsom to Kusma between the years 1988-2017 using GIS as a tool. The study further focuses on change in river courses with depositional and erosional areas that further causes fluctuations to the sediment area. Decadal LANDSAT images of 30m resolution were considered for the study over 3 decades divided into five stages 1988, 1995, 2000, 2008, 2017. Radiometric correction for those images were done using QGIS, Supervised Maximum Likelihood (SML) classification into six classes viz., water bodies, forest, shrubland, agriculture and grassland, settlement, sediment and bare land, snow were applied. Analysis shows that the Kaligandaki river is a sinuous river. The bankline shift is highest (84.7109m) from 1995-2000 in the upper part of Jomsom and Lete where the width tends to fluctuate the most due to the wide floodplains and the lowest (0.20836m) from 2000 to 2008 in the lower sections where the river is more narrow. In almost three decades , water bodies in the study area has an overall decrease of 1% (15.76 km²); Forest and shrub land decreased by 5% (80.31 km²); Agriculture and grassland increased by 1% (16.22 km²); Settlement increased by 4% (67.23 km²); Sediment and bare land increased by 2% (29.42 km²) and snow cover decreased by 1% (16.81 km²).

1. Introduction

Rivers are dynamic equilibrium systems which balance water flow and sediment transport. Whenever the river channels are disturbed or altered under dynamic hydrologic conditions, the river reaches its former equilibrium with respect to its dimension, profile, and pattern (Couture, 2008). In the source area of rivers, it erodes downwards, creating a steep V-shaped valley. In the middle reaches, it erodes not only downwards, but also sideways and laterally. In the low reaches, it erodes laterally, creating meanders (Das et al., 2014). River dynamics deals with river flow and sediment problems, such as turbulent flow in alluvial channels, sediment settling, transport, deposition, and erosion. River dynamics also incorporates the study of fluvial processes, including river pattern classification, channel evolution laws, and regime theory (Weiming , 2007).

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The study of river dynamics is important to understand the morphology of the river and predict the channel deformation and its related impacts. With time, morphological features of rivers may change due to human or natural disturbances. Shrestha (2010), measured morphological parameters such as channel length (L), sinuosity (K), meander belt width (Wblt), meander wavelength (Lm) and radius of curvature (Rc) of river from 1992 and 2009 using aerial photographs, satellite images, and GIS. It shows that the morphological parameters deviated from normal due to a reduction in stream power and increase in sinuosity.

Some of the anthropogenic activities like deforestation, gravel mining, construction of dams and bridges, bank revetment, land use alterations change the morphology and natural dynamics of rivers (Kondolf, 1997). River dynamics may also affect the land use and land cover patterns. Hazarika et al., (2015) assessed the effects of river dynamics on the land use change in the upper reaches of Brahmaputra river. The agricultural land was mostly affected by erosion-deposition and river migration. This being the case, the Kaligandaki river, one of the longest river in Nepal modifies the floodplains frequently. The change in river dynamics results into long-term changes in the floodplain, river morphology, floodplain vegetation and changes of the landscape in the catchment area. Land Use Land Cover change analysis is important to provide knowledge to aid in effective management of the floodplains in future.

The study aims are to analyze the land cover change of Kaligandaki river valley and analyze dynamics of Kaligandaki river. The Kali Gandaki basin is a snow-fed river system. It is one of the major basins in the Ganges system (Pandey, 2016). The snow-fed river usually has increased runoff which leads to increase in flooding, rock avalanches from slopes and affect the water resources and causes great impact on vegetation cover, agriculture, livelihood, and temperature pattern. It often results in the incidence of drought conditions (Dixit et.al., 2007).

2. Materials

The acquired raw images were processed in QGIS. In order to be fully comparable, imagery that were acquired on different dates and by different sensors has to be converted to surface reflectance products through radiometric corrections (Padró et al., 2017). After the completion of radiometric corrections, False Color Composite (FCC) was employed for better visualization of the image. For each of the LANDSAT sensors, FCC was obtained through combination of different bands. Training samples selection for six land classes; Water, Forest and shrub land, Agriculture and grassland, Settlement, Sediment and bare land, and Snow and a signature file was created. Using the signature file, supervised maximum likelihood classification was performed and the image was classified into the above six land classes throught digitization and band composition.

After the classification, 3x3 Majority Filter tool was used in ArcMap .This tool replaces cells in raster based on majority of their adjoining neighboring cells. It determines the new value of the cell based on the most popular values within the filter window.

3. Research Methodology

3.1 Area Calculation

The area of each land class was calculated in excel and also expressed as a percentage. The following formula was used to determine the area.

$$\textbf{Area (m}^2\textbf{) = Count*900}$$

The LULC classes were converted to percentage of the total study area, and then difference in the percentage was calculated for different time periods, hence being able to observe the change over time.

Extraction of river shape was done by digitizing river. A new polyline shape file was created named the river polygon and then digitization was done along the river banks of the image. The raster river shape was then exported. With the help of conversion tools, the obtained river raster was converted to polygon. Manual editing was done to enhance the river features.

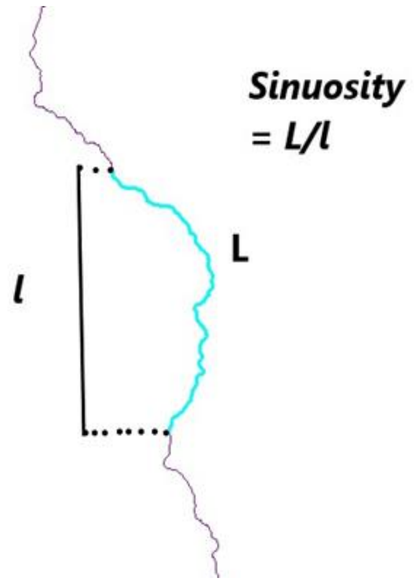

Fig. 1 Sinuosity measurement of a stretch of river

Finally, the river polygon was converted into polylines, and hence bank lines were delineated. With the help of the obtained banklines, channel centerline was generated through the centerline ArcGIS tool. The river channel was divided into 10 segments. Analysis was carried out in those segments.

The extent to which a river channel departs from a straight line is known as river sinuosity (Ebisemiju, 1994). It is calculated as:

$$\textbf{Sinuosity } (S) = L/l$$

Where,

L= Distance measured along stream channel between the two points

l= Straight line distance between the two points

3.2 Accuracy Assesment

The confusion matrix is used to provide a site-specific assessment of the correspondence between the image classification and ground conditions (Foody,2002). Ground truth data is required to conduct an accuracy assessment. It can be obtained in field by GPS or imagery with higher resolution than the classified image (Congalton, 1991). Points were taken from Google Earth to act as ground truth points for the classified image of 2017. The resolution of the imagery was 15m. The overall accuracy was calculated by the sum of the diagonals (correctly classified pixels) divided by the total. Producer's Accuracy is the map accuracy from the point of view of the map maker and was calculated as the ratio of the number of reference sites classified accurately to the total number of reference sites for that class. This statistic indicated the probability of a reference pixel being correctly classified. The User's Accuracy is the accuracy from the point of view of a map user and was calculated as the ratio of total number of correct classifications for a particular class to the row total. It is the probability that a pixel classified on the map actually represents that category on the ground. The Kappa coefficient reflects the difference between actual agreement and the agreement expected by chance and was calculated using the above formula.

4. Results and Discussion

The river was divided into 10 sections, sinuosity of centerline in each section was obtained. Section 1 refers to the uppermost part of the river channel in the study area and section 10 is the downstream part. The sinuosity of Kaligandaki river is generally classified as sinuous but is straight at some points. It generally decreases as one goes downstream but the highest sinuosity is in Section 8, which is around Mangalghat, Beni, of Year 2008 (1.456) ,characterized between sinuous and meandering. The lowest sinuosity is in Section 5, near Dana ,of Year 2000 (1.012) which is characterized as straight. Sinuosity can be affected by erosion and deposition which can affect velocity, width and depth. (Leopold et al.,1960).

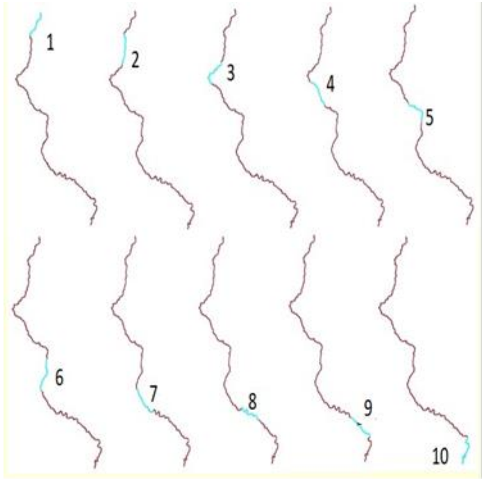

Fig. 2 The Sections of river

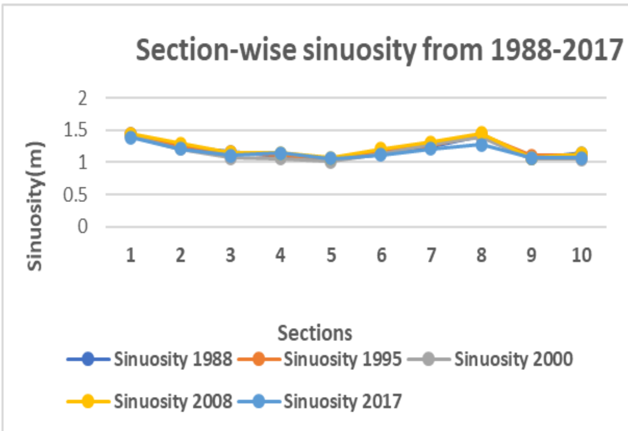

Fig. 3 Section wise sinuosity of Kaligandaki from 1988 to 2017

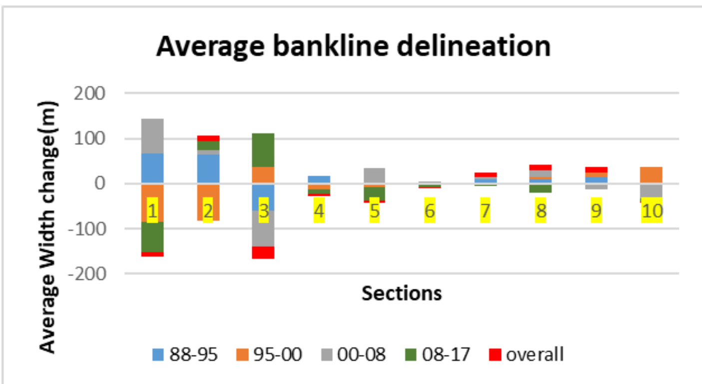

Fig. 4 Average bankline delineation

The highest average bank width is in Section 2 of year 1995 (253.5829m). This section contains the area Lete, where the highest deposition of the sediment takes place. The lowest average bank width is in Section 6, near Tatopani, of the year 2017 (59.39398m) where more erosion takes place.

A research conducted by Chaplin and Brabyn (2013), showed that there has been an overall decrease by 8% of forest cover in the Annapurna Conservation Area from 1999 to 2011 from tourism activities but this change is variable, as there is an increase in forest cover in the northern part and decrease in forest cover in the southern part.

The snow-fed river usually has increased runoff which leads to increase in flooding, rock avalanches from slopes and affect the water resources and causes great impact on vegetation cover, agriculture, livelihood, and temperature pattern. The study area is prone to frequent landslides and erosion, resulting in constant erosion and deposition processes. Important remains of major landslide events are still preserved in the present landforms and, with time, they directly influence the nature and current rates of erosion (Fort, 2000). It often results in the incidence of drought conditions (Dixit et.al., 2007). Urbanization is one of the most widespread anthropogenic causes of the loss of cultivable land (Lopez, 2001), habitat destruction (Alphan, 2003), and the decline in natural vegetation cover.

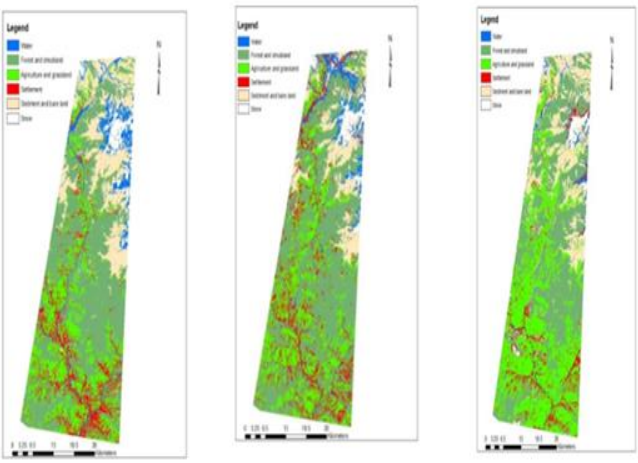

Fig. 5 LULC Map from 1988 to 2000

The change in water bodies over the years is fairly constant but overall, it has decreased by 1% from 1988 to 2017. There is a general decrease in the % of forests over the years. There is highest decrease of forest area from the year 1988-1995(-6%). From then, the forest decreases at a lower rate until it finally starts to increase in the period 2008-2017. There is an overall decrease of 5% in forest area from 1988-2017. There was also a widespread deforestation and forest degradation across the country during the 1960s through 1980s.

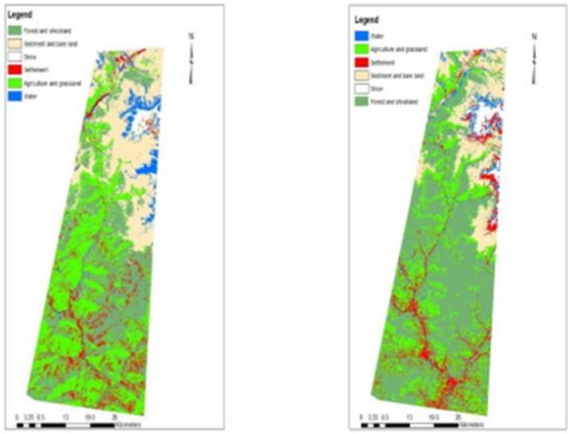

Fig. 6 LULC until 2017

Forest survey done from 1987 to 1998 showed 39.6% of forest area in the country while Forest Resource Assessment conducted from 2010-2014 showed an increase in the % of forested areas in Nepal to 40.36% (F.R.A.,2015) so an increase was seen in the % of forested area from 2008-2018. Agricultural land and grasslands is increasing till 2000, then it starts to decrease from 2008- 2017. This may be attributed to the increase in forested areas. There is an overall increase of 1% from 1988 to 2017. The settlement generally increases with time due to population growth. There is an overall increase of 4% from 1988 to 2017. There is a slight decrease in the period 1995-2000 which may be attributed to some landslide events like the 1998 Tatopani landslide. The snow cover is usually constant, except for the year 1988 where it is higher than the other years. There is an overall decrease of 1% in snow cover from 1988 to 2017. This may be attributed to the changing climate as suggested by a research done by Manadhar et al., (2012) where Climate variability indices revealed warming trends at Jomsom station, where most of the snow cover in our study area is located.

The overall accuracy is 88.2% while the Kappa accuracy is 0.858 or 85.8%. The Kappa accuracy is considered more accurate than the overall accuracy since the overall accuracy is a summary of the average and doesn’t show how the errors are distributed (Congalton,1991). The Kappa accuracy can range from -1 to 1. A value close to 1 indicates that the classification is significantly better than random classification. The producer’s accuracy is 87% for water which means approximately 87% of the water ground truth pixels also appear as water pixels in the classified image. The user's accuracy is 93% which means that approximately 93% of all the water land' pixels in the classified image actually represent water on the ground. Similarly, both the producer's and user's accuracy for agriculture and grassland is 80%. For settlement, the producer's accuracy is 100% and the user's accuracy is 75%. For sediment and bare land, the producer's accuracy is 73% while the user's accuracy is 92%. For snow, the producer's accuracy is 90% and the user's accuracy is 100%. For forest and shrub land, both the producer's and user's accuracy is 100%.

5. Conclusions

Land use and land cover change of Kaligandaki river valley is affected by various erosion and depositional processes of the river. The river is seen to be as generally sinuous, with sinuosity values the highest in the year 2008. The width of the river bank is highest in the upper sections of the valley, including Jomsom and Lete, where higher deposition takes place. The bankline delineation in different years also varies more in the upper sections of the river, where the floodplain is wider, hence more prone to variations. Various erosion and deposition process of the river may be changing the river width and hence the sediment amount. 21.4% of the change in sediment is influenced by change in width of the rivers. The correlation calculated between the two terms is 0.463, which is moderately strong positive correlation.

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