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Study of River Channel Migration and Identification of Potential Sugarcane Cultivation Area: A Case Study on Tulsipur Sub-Metropolitan City

Prajwol KC [1], Amit Tiwari [1], Ashish Dutta [1], Pradeep Gywali[2*], Kutubuddin Ansari[3]

[1]Department of Geomatics Engineering, Kathmandu University, Dhulikhel, Nepal
[2]Survey Officer, Tulsipur Submetropolitan city, Dang, Nepal
[3]Integrated Geoinformation (IntGeo) Solution Private Limited, New Delhi, 110025, India
*Corresponding author: pradeep2gywali@gmail.com

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Abstract: River channel migration involves the lateral migration of an alluvial river channel across its floodplain which is mainly driven either by bank erosion or point bar deposition over time. It is the study of major rivers of Tulipa Sub-Metropolitan City using remote sensing images over the span of 11 years (2010-2020). The river channel migration directly affects the land use, and it has also direct effect on the settlements lying on the plain area near the river side. Cultivating sugarcane in the sand area is one of the mitigating measures to control floods and prevent erosion of banks. This paper presents an enhanced change detection method of river channel migration using remote sensing images and identification of sand area using classification and interpretation technique.

Keywords: GIS, LULC, UTM, Supervised Classification, LANDSAT, River Channel Migration,

1. Introduction

Nepal is a geographical and topographical complex country. Flood and landslides are natural disasters that occur yearly in various parts of Nepal. Flood plains are considered as one of the most endangered areas worldwide as they are facing degradation by river regulations and enhanced land-use pressure (Hazarika et al., 2015). Migration of river channels within flood plain regions and the bank erosion due to lateral shifting is a natural process (Leopold, 1994) but due to rapid and unsegregated human intervention on natural processes, most of the natural process now becomes semi-natural.

Land use refers to the purpose the land serves. It shows how people use the landscape-whether for development, conservation or mixed uses. Land cover refers to the surface cover on the ground, whether vegetation, urban infrastructure, water, bare soil or other. Identifying, delineating and mapping land cover is important for global monitoring studies, resource management, and planning activities. Land cover can be determined by analyzing satellite and aerial imagery whereas land use cannot be determined through satellite imagery (Ocean Facts, 2020). There are different land cover types like forests, agricultural lands, water lands, settlement areas and other lands. It represents how much of a region is covered by mentioned land cover types. Land use and land cover change impact the annual water balance by decreasing annual evaporation and increasing stream flow and base flow (Schilling et al, 2008). As we already mentioned, Nepal is geographical and topographical complexity country. It has very rough topography. Natural disasters such as flood and landslides are the most frequent occurring hazards in the country. The Terai areas of Nepal experience relatively higher rainfall intensity which results to higher soil erosion in the slopes of the Churia hills. The rivers that originate from the Churia hills bring a lot of sediment thereby eroding the hill slopes as well as riverbanks (Adhikari, 2013). Erosion deposition-induced channel migration in alluvial meandering rivers pose a serious threat to the adjacent community living in the floodplain areas. The river eats up its outer edges, widening its course. The deposition of the sediments forces the river to change its course. Most of the river changes its course when it enters the lower part of region i.e., Terai region.

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Yearly, about hundreds of hectares of agricultural areas of Terai region are lost to riverbank erosion in the alluvial plains of Nepal which is the major food production region of the country. So, the study of channel which migration helps to determine the flow of river over time behavior is necessary (Ansari et al, 2008; Karki, 2019).

Image classification is the process of categorizing and labelling groups of pixels or vectors within an image based on specific rules (Gavali and Banu, 2019). It refers to the task of extracting information classes from a multiband raster image. The image classification accepts the given input images and produces output classification for identifying various features. Digital image classification uses the spectral information represented by the digital numbers in one or more spectral bands and attempts to classify each individual pixel based on this spectral information. This type of classification is termed spectral pattern recognition. In either case, the objective is to assign all pixels in the image to particular classes or themes (e.g., water, coniferous forest, deciduous forest, corn, wheat, etc.). The resulting classified image is comprised of a mosaic of pixels, each of which belong to a particular theme, and is essentially a thematic "map" of the original image (Image Interpretation and Analysis, 2013). Depending on the interaction between the analyst and the computer during classification, there are two types of classification. They are supervised classification and unsupervised classification. Unsupervised classification finds spectral classes/clusters in a multiband image without the analyst's intervention. The image classification toolbar aids in unsupervised classification by providing access to the tools to create the clusters, capability to analyze the quality of the clusters and access to classification tools. In unsupervised classification, an algorithm is chosen that will take a remotely sensed data set and find a pre-specified number of statistical clusters in multispectral or hyper spectral space (Hasmadi et al, 2009). Supervised classification uses multispectral or hyper spectral data from the pixels in the sample area or spectral signatures from spectral library, to train a classification algorithm. The algorithm can then be applied to the entire image and a final classification image is obtained Hasmadi et al, 2009). With the assistance of the image classification toolbar, training samples are created to represent the classes. Suitable number of land use classes like forests, rivers, water, barren land, vegetation and others can be defined from the satellite image. The quality of the training samples is analyzed using the training sample evaluation tools in Training Sample Manager. From image classification toolbar and training sample manager, training samples for representative area are determined.

The river channel migration is the geomorphological process that involves the lateral migration of an alluvial river channel across its floodplain. This process is mainly driven by the combination of bank erosion of and point bar deposition over time. When referring to river channel migration, it is typically in reference to meandering streams. In braided streams, channel change is driven by sediment transport (Gyawali and Neupane, 2018). Migration of river channel is organized within a corridor or region (Richard et al, 2005). It creates problems to those who are living in this region. Sometimes, many people have lost their homes agricultural land, infrastructure, their livelihoods due to the river channel migration and erosion (Islam and Rashid, 2011). This study includes the determination of River channel migration of five major rivers of Tulsipur Sub-Metropolitan City between last 10 years. Along with this, the area of sand cover will be determined which could be potential for sugarcane cultivation. For the purpose of determination of channel migration of river across various years, this work will contribute to fulfill the scope of the project. Also, this project helps in determining the land use and land cover maps.

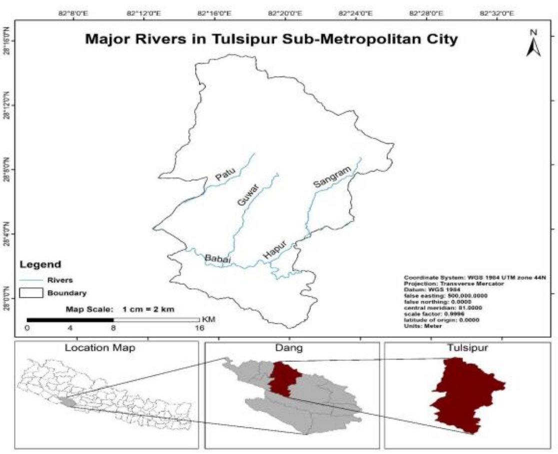

Fig. 1: Study Area (Major Rivers of Tulsipur Sub-Metropolitan City)

2. Study Area

Tulsipur is a Sub-Metropolitan City in Dang District of Nepal and lies in Lumbini Pradesh. It is also the headquarter of Rapti Zone (Fig. 1). It covers an area of 384.63 square kilometer. According to the data, 2015 the total population of Tulsipur is 149,647 comprising 73,143male and 76,504 females residing in 34,987 households. The average family size is 4.4. The city lies between Mahabharat Hills and Chure Hills.

Geographically the city spreads from 82° 12' E to 84° 26' E longitude and 27° 57' N to 28° 15' N latitude. This city is rich with its geographic, biologic, social, economic, religious, and cultural diversity and has abundant potential of tourism. The city has average length of 22 km and average width of 29 km. (CBS, 2012) It lies in the mid of Dang district and it has 19 wards. On the eastern side it has Ghorahi Sub-Metropolitan City, Shantinagar and Dangisharan VDC on western side, Lamahi Municipality on southern side and Kapurkot, Tribeni VDC of Salyan district on northern side. The major rivers like Patu, Guwar, Babai, Hapur and Sangram arise from the Mahabharat and Chure Hills gaining most of their dry season flow from springs. These rivers are composed of very fragile sediments. The city is known for its landscape and a slightly milder climate. The elevation value ranges from 529-2020m. It is the second most populated city after Ghorahi City in Dang District.

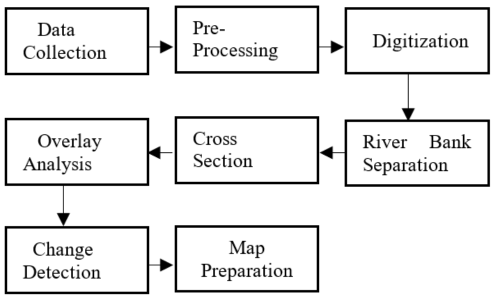

Fig. 2: Workflow Diagram to determine River Channel Migration.

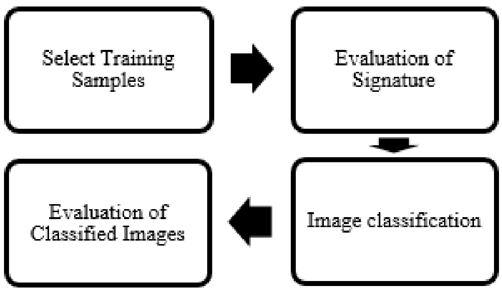

Fig. 3: Working of Supervised classification

3. Methodology

The first stage of any work is image acquisition. Before image acquisition, the study area was downloaded from Google earth in KML format. The KML file is then imported, and the images were downloaded from official USGS database which is freely available to use. The LANDSAT images of years 2010, 2012, 2014, 2016, 2018 and 2020 were downloaded. The criteria while downloading images was below 10% cloud cover. We used Landsat 7 images for 2010 and 2012 which contains 7 bands and remaining images for year 2014,2016,2018,2020 were taken from Landsat 8 which contains 12 bands. The pixel of those images were 30 meters which means that each pixel represents an area of 900 square meters. The land cover classification group includes forests, rivers, sand, clouds, barren land, settlements and vegetation. The primary objective is to identify the sand area in the rivers, so we used suitable classes. Different training sites were selected for land cover from the satellite images. After selecting the different training sites, classification signature of each land cover classes was generated using Image Classification toolbar in ArcGIS. Spectral signatures were simultaneously extracted for each land use classes for each training site within each class using the signature editor module in ArcGIS. Among various methods, we used supervised classification technique as it has more advantages over the unsupervised classification. Supervised classification we can distinct the useful information and after that their spectral reparability is examined. In unsupervised classification, software detects spectrally separable class automatically. With the assistance of the image classification toolbar, training samples were created to represent the classes. Total seven number of land use classes like forests, sand, rivers, cloud, barren land, settlements and vegetation are defined using satellite images for years 2010, 2012, 2014, 2016, 2018 and 2020. The quality of the training samples was analyzed using the training sample evaluation tools in Training Sample Manager. From image classification toolbar and training sample manager, training samples for representative area were determined. And then, maximum likelihood classification was performed from the toolbar. Accuracy assessment of a remote sensing output is a most important step in classification of remotely sensed data. Without accuracy assessment, the quality of the output produced would be lesser value to the end users. The accuracy assessment is the comparison of a classification with region of interest. It represents how well the classification represents the real world. This is produced in a matrix table showing four different types of accuracies. It requires an adequate number of samples per map class to be gathered when the classified results are compared with actual ground conditions. We took the sample from base map as field verification was not possible and the accuracy, we obtained was 82%. The sand area in rivers of Tulsipur sub-metropolitan city is taken as the potential area for sugarcane cultivation area. It increases sugarcane production in one hand and also protects the flooding in another hand. Total sand area of year 2010, 2012, 2014, 2016, 2018 and 2020 was calculated along with total sand area in each river for respective year of study.

The conventional analogue and digital data of rivers in Tulsipur are used for the study. Google Maps were extracted from the Google Earth Engines from where we obtained the KML layer of mitigation point. After that, KML layer was converted into shape file using ArcGIS. There are five major rivers in Tulsipur Sub-Metropolitan City. They are Babai River, Sangram River, Guwar River, Patu River and Hapur River. All the river polygon and center line were digitized manually. The river of years 2010, 2012, 2014, 2016, 2018 and 2020 were analyzed for river channel migration. The detailed diagram for the analysis is shown in Fig. 3. The satellite images which were used for sand cover area detection was also used for river channel migration detection. Landsat images were downloaded from the USGS Explorer. The downloaded satellite images were clipped for our required study area i.e., Tulsipur Sub-Metropolitan city. After clipping, the satellite images were transformed into WGS 1984 UTM Zone 44N.The main rivers of Tulsipur Sub-Metropolitan City i.e., Babai River, Sangram River, Guwar River, Patu River and Hapur River are digitized. Five polygons of river for year 2010-2020 are created maintaining 2 years interval. The center line of the rivers was also digitized. For center line, separate shape file was created for different years. After creating river polygon, polygon to line tool was used to separate the river right and left bank. Separate shape file is created for both right and left bank. The diagram of above all methodology has been shown in Fig. 2.

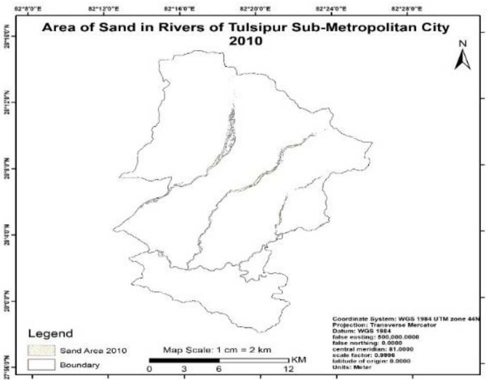

Fig.4: Sand Cover Map of Tulsipur Sub-Metropolitan City, Nepal for the year 2010.

Using River Bathymetric Toolbox (RBT), cross section was generated for each river polygon at the interval of 500m by taking the reference of year 2020. This toolbox is available in Arc Map. The intersection points for each river were generated using Intersect tools by intersecting cross-section lines with Riverbanks. The intersection points of all the rivers for year 2010, 2012, 2014, 2016, 2018 and 2020 was generated as an output so that they can be analyzed for lateral shift. Landsat 8 OLI and Landsat 7 ETM+ were used, which are freely available in USGS official site. Using these satellite images, the spatial and temporal patterns of the five rivers, Babai River, Sangram River, Guwar River, Patu River and Hapur River are described. Finally, the sand area cover was identified which can be used for sugarcane growth. After that, maximum likelihood classification is performed from the toolbar. The steps of the image classification workflow are illustrated in Fig. 3.

4. Result and Discussion

The sand area in Tulsipur Sub-Metropolitan City is identified where they can be undertaken as potential area for sugarcane cultivation, and it might reduce future flooding's and reduce riverbank erosion. Total sand area of each year was calculated along with total sand area in each river for year 2010, 2012, 2014, 2016, 2018 and 2020. The sand cover map for all those years were also generated (Fig. 4). The case study shows that sand area has significantly changed during the interval of 2012-2014 to an increase of 5.17%. In the beginning of the years the sand area has decreased and similarly the sand area has also decreased for year 2016 and 2018.

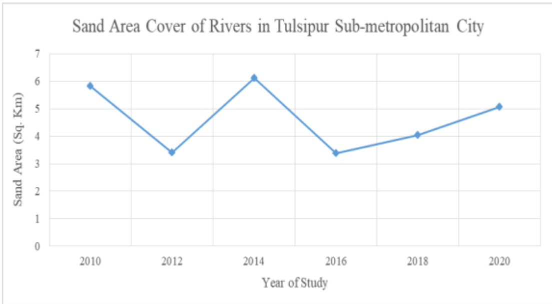

Fig. 5: Sand Area Cover of Tulsipur Sub-Metropolitan City River over year 2010-2020

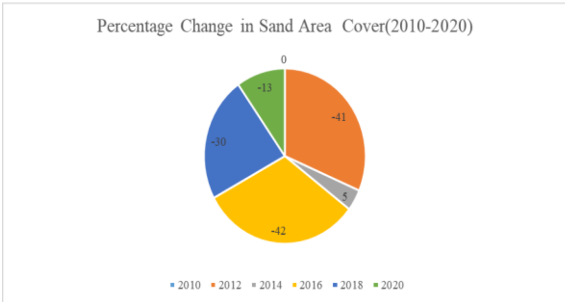

Fig. 6: Percentage change in Sand Area Cover (2010-2020).

Table 1: Total Sand Area Cover and Percentage Change

Year	Sand Area Cover (Sq.Km)	Area Covered (%)	Percentage Change
2010	5.815	1.51	0
2012	3.406	0.89	-41.42
2014	6.115	1.59	5.17
2016	3.384	0.88	-41.80
2018	4.042	1.05	-30.48
2020	5.065	1.32	-12.89

Finally, the sand area has increased than the previous year by 1.32%. The total sand area change by river with percentage is listed in Table 1. The plotted graph in Fig. 5, shows the variation of sand cover area with the time 2010-2020. Here, the highest sand cover was observed in year 2014 and the lowest sand cover was observed in 2016. From 2016, it is seen that the sand cover area is increasing gradually. We also studied the sand cover area for each river within the time of 2010-2020. Similarly, the percentage change in sand area for Year 2010-2020 was also plotted in pie-chart and is given in Fig. 6. Linear regression model of sand cover change is shown in Fig. 7. We also calculated River wise Sand Area for Each Year from 2010-2020 (Table 2). Change in sand cover is directly related to rainfall pattern in the area with the highest sand cover in the year 2014 and lowest in 2012. Guwar and Patu River are identified as the most suitable areas to cultivate sugarcane as they have high amount of sand, and it will reduce the bank erosion and mitigate the effects of floods (Fig. 8 & 9).

Table 2: River wise sand area for each year from 2010-2020. All the areas are in square kilometer

River/Year	2010	2012	2014	2016	2018	2020
Babai	0.999	0.258	1.714	0.877	0.912	0.958
Guwar	2.094	1.553	2.200	1.150	1.664	2.064
Hapur	0.418	0.413	0.539	0.329	0.193	0.179
Patu	1.962	1.030	1.487	0.935	1.186	1.707
Sangram	0.342	0.152	0.176	0.090	0.087	0.158

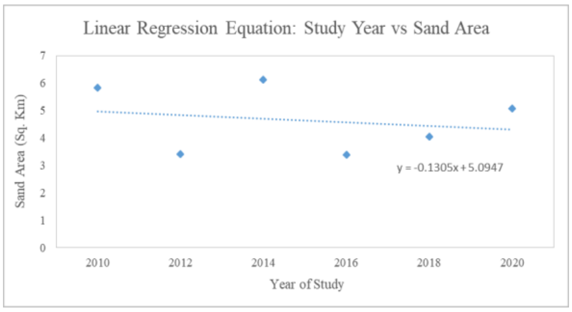

Fig.7: Regression model of sand area change across 2010-2020

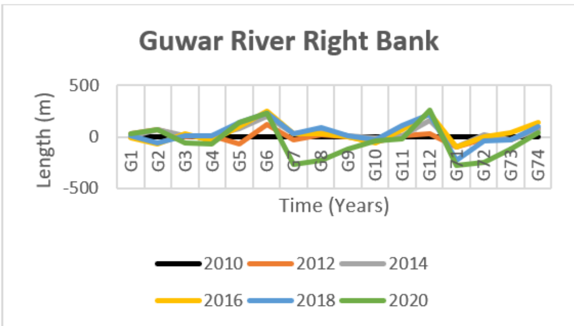

Fig. 8: Shift of right bank of Guwar River.

We analyzed the pattern of river shifting for the year 2010-2020 within an interval of 2 years (Table 3). After analyzing the data, we found that in 2012 there was reclaim of 2387599 sq. meter due to mitigation work. In 2014, we found that there was land erosion of 2458791 sq. meter. In 2016, there was reclaim of 340965 sq. meter and mitigation has really worked in this year whereas in 2018 there was land erosion of 1746780 sq. meter. In 2020, there was also land erosion of 8646254 sq. meters.

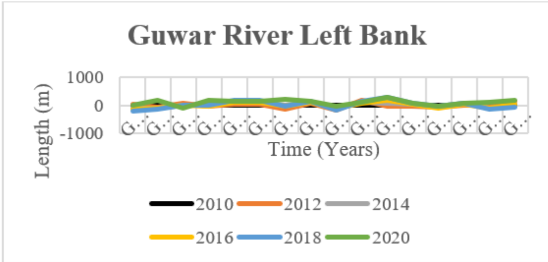

Fig. 9: Shift of left bank of Guwar River

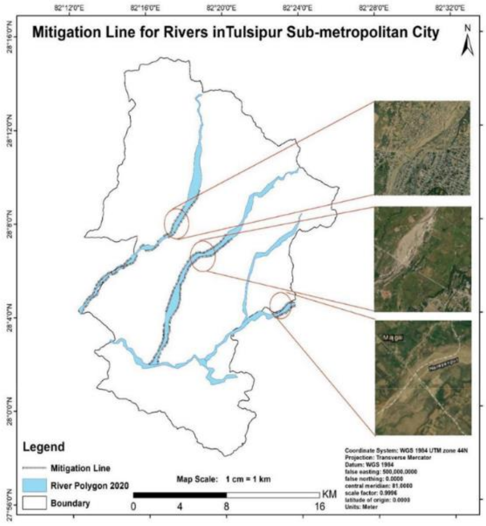

Fig. 10: Mitigation Line for Rivers.

Table 3: River shifting calculation.

	River Channel Migration									
	Right Bank					Left Bank				
SN	2012	2014	2016	2018	2020	2012	2014	2016	2018	2020
G1	34.25	4.93	-13.69	9.46	33.74	31.87	-108.88	-131.97	-177.35	22.02
G5	-74.13	80.70	101.88	143.04	136.94	51.10	121.38	120.50	136.67	164.27
G9	-3.66	7.62	2.96	8.31	-117.54	-165.17	-109.72	-112.89	-46.91	-36.06
B13	15.24	140.10	36.19	127.01	236.93	29.74	-126.41	-107.43	-72.27	-142.42
B17	26.88	85.92	113.93	98.78	112.73	135.75	39.00	67.43	17.73	58.90
B21	13.67	41.06	-10.51	-84.20	-58.49	28.32	-207.46	-237.11	-215.90	-230.09
B25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B29	12.19	128.22	186.17	71.34	340.41	32.78	-63.03	-122.57	-3.42	-36.69
B33	-27.76	-25.11	-64.32	-91.03	-22.90	48.22	-20.62	-515.76	-74.82	-256.77
S37	21.88	19.13	24.81	-35.05	-171.56	14.00	-18.22	22.70	148.83	147.18
S41	-4.50	240.52	230.04	210.55	154.35	78.34	123.67	262.33	123.39	287.75
H45	-9.27	-52.34	1.56	-111.21	-210.14	-31.40	-18.10	7.65	-4.48	-74.47
H49	5.79	9.21	-20.30	9.69	-5.11	-3.36	22.65	-34.97	80.45	180.29
P53	-39.28	-33.04	-9.01	-144.83	-80.20	-27.17	82.00	74.74	91.76	102.68
P57	-104.79	-57.43	-48.12	-30.69	-57.24	-170.98	125.83	-66.67	-13.61	-5.89
P61	-3.86	-10.32	39.71	-4.87	10.33	-136.55	-60.91	29.06	-14.56	-35.49
P65	-23.40	-42.55	-13.13	19.77	-28.49	-60.30	-71.52	-38.45	-40.45	-51.32
G71	-95.90	-97.91	-97.85	-228.61	-281.52	-56.94	-45.70	-88.44	-37.39	-36.67

This analysis suggests that continuous erosion has been occurring year by year. From this study, we found that riverbanks were really conserved in the places where mitigation has been carried out. We also found that banks were eroded completely where there was not mitigation work. Mitigation can be done in fruitful way by cultivating sugarcane in sand areas as sugarcane helps in erosion and prevents flooding. We can also generate income from sugarcane cultivation as sugarcane growths well in sand places. In the case study, it has become clear that remote sensing data plays a vital role in giving accuracy to the work. Shift of riverbank of Guwar, one of the rivers of the Tulsipur Sub-Metropolitan City is shown in the graph below. The fluctuations can be seen inside and outside for the years 2010 to 2020. Here is the image showing mitigation line for different rivers which is cross checked with Google earth (Fig. 10).

5. Conclusions

The case study is objected to find out how much the river has shifted and also to find out the potential sugarcane cultivation area in Tulsipur Sub-Metropolitan City. The sand area is found to be changing disproportionately. Also, change in sand cover is directly related to rainfall pattern in the area with the highest sand cover in the year 2014 and lowest in 2012. Guwar and Patu River are identified as the most suitable areas to cultivate sugarcane as they have high amount of sand, and it will reduce the bank erosion and mitigate the effects of floods. Also, this study is aimed to focus for the mitigation so that erosion could be controlled. River changes its path due to various natural and manmade phenomenon and similarly sand also changes either naturally or physically due to deposition of soil or mud. Remote Sensing digital data gave better results than the conventional methods. The channel of various rivers shifted to both bank side, which results obtained by super imposing of topographical maps and Google maps. Highest shift in River channel is seen in Babai River where the channel has shifted to as high as about 300 meters from the original path.

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