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Research Article

THE HYDROLOGICAL RESPONSE OF VISHWAMITRI RIVER WATERSHED: A SPATIO-TEMPORAL ANALYSIS OF THE IMPACT OF LAND USE CHANGE ON PLANFORM

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ABSTRACT
Urbanisation creates various changes in the natural environment through altering and also replacing natural systems. The process of urbanization thus has the potential to affect stream courses by altering watershed hydrology and geomorphic processes. As a result, studies regarding the impacts of urbanisation on the hydrological and geomorphic processes within urban catchments are becoming important. It would be of significance to know the linkage of plan form to anthropogenic changes viz. land use change. The hydro-geomorphic dynamics of river and other external factors directly distort its course from earlier path and it is well measured by sinuosity index.
The present study focuses on Vishwamitri River, which falls in the semi-arid region of the Gujarat alluvial plain, a major tributary of the Dhadhar River. Using toposheets, satellite images and Geographic Information System (GIS), temporal pattern of river plan-form have been measured (1976 – 2016) with the help of Sinuosity Indexes to unfold the magnitude of river instability, contributing factors of sinuosity. The analysis reveals the change in plan form of the river course with time and space which signals to impact of anthropogenic influence of development. The study measures the various shift of selected longitudinal segments of the river with associated peripheral land use.

Keywords: *Plan-form, Sinuosity Index, Land Use, Vishwamitri River, Vadodara*

INTRODUCTION
Hydro-geomorphologically, the study of river meandering provides information on the tendency of rivers to reach and form a state of equilibrium. The process of meander changes is important to identify the environment-related causes that occur naturally or vice versa. Rivers in a natural state are free to adjust their form and features to both system-scale drivers and local conditions their ability to transport water and sediment produced by the watershed in such a manner that they maintain their dimension, pattern and profile in the present climate. (Malcolm, 2002). The pattern (Planform) of a river can be considered at vastly different scales, depending upon both the size of the river and the part of the fluvial system that is under consideration. (Schumm, 1985).
Anthropogenic activity has long been recognized as a controlling influence on stream morphology and bed material distribution by both geomorphologists and ecologists (Wolman, 1967; Leopold, 1968; Allan, 2004; Kang and Marsten, 2006; Poff et al., 2006; Urban, 2006, Levell and Chang, 2008). Stream morphology and ecology are an integration of geology, climate, habitat and disturbance regime over a range of spatial and temporal scales; hence identifying specific watershed responses to human action continues to be a challenge (Montgomery, 1999; Allan, 2004). We must strive to understand stream response within the context of the landscape processes, both natural and anthropogenic, on a continuum of spatial scales from stream reach to watershed to the wider physiographic region. Most meandering streams show significant change of sinuosity through time and hence the planforms reflect not only the geomorphic history but the geological controls such as active tectonics, tributary contributions and other factors affecting valley slopes (Burnett and Schumm 1983).

Land use/land cover (LULC) and climate changes, are a key limiting factor in highly vulnerable ecosystems in arid and semi-arid regions (Jing yin *et al.*, 2017). Managing land use in a watershed is vital to protecting drinking-water supplies, recreational opportunities, and stream ecosystem health. However, the effect of land use and management practices on streams is difficult to assess and often unmeasured (USGS, 2002). The perception of the human role in changing river channels varies with culture as well as varying over time should enhance application of design for river channel landscapes.

Urbanization, a human activity that modifies (directly and indirectly) components of the landscape that can alter flow and sediment discharge into streams. In the 1956 classic volume, Man's Role in Changing the Face of the Earth, Strahler (1956) and Leopold (1956) both recognized the links between watershed scale changes and stream response. Urbanization can affect river systems in unexpected ways (Kang & Marston, 2006). The primary measure of urbanization in a watershed is the area under impervious cover (May *et al.*, 2002). The Land use of the study area have undergone significant changes over time (Bhatt et al, 2006)

Considering the significance of change in LULC on of planform, present work attempts to relate the condition of those changes.

Objective:

a) To quantify the Spatio-temporal plan-form changes.

b) To identify the impact of land use change on planform.

Study area:

The present paper is focused on the study of Vishwamitri River, a major tributary of the Dhadhar River flowing in the semi-arid region of Gujarat alluvial plain. As per a part of Dhadhar river basin It extends over an area of 3423 sq km. Located in eastern part of Gujarat, river originates from Pavagadh hill at about 22º28´ N latitude and 73 º45´ E longitude at elevation of more than 600 m. The study proposed for area between Pavagadh (origin and upper catchment) to Jambuva Confluence (where it leaves Vadodara City) covering length of 92 km and area of about 601 sq.km. Vishwamitri catchment comprises of 102 villages with more than 12 lakhs population of Vadodara district (Savali, Waghodia and Vadodara taluka) and Panchmahal District (Halol taluka).

The Vishwamitri watershed is in the center of the golden corridor is witnessing rapid industrialization, urbanization and shift from primary to secondary economic activity. The adjoining area of the river channels has therefore witnessed gradual land use land cover change as a part of development and urbanization. The increased anthropogenic pressure can result in the imbalance in the carrying capacity of the region, owing to the finite land and water resources.

MATERIALS AND METHODS

Data Set:

Data	**Scale/Resolution**	**Year**	**Source**
SOI Topographical sheet	1:50000	1976	Survey of India
Landsat 3 MSS	79	1981	USGS
Landsat 5 TM	30	1991	USGS
Landsat 7 ETM+	30	(2001, 2011)	USGS
Landsat 8 OLI & TIRS	30	2016	USGS

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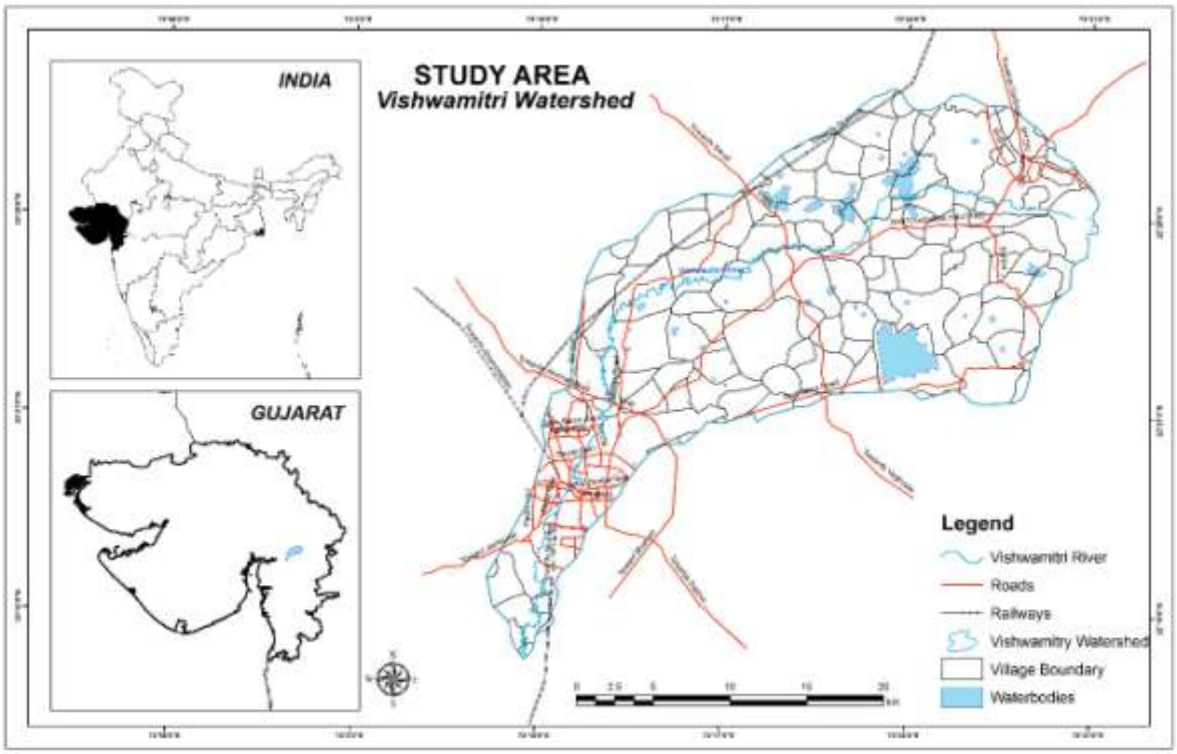

Figure 1: Location Map of Study Area

Methodology

To achieve the objectives of the studyfollowing technique are implemented.

1. Calculating Sinuosity Index to detect the changes in planform.
2. Changes in Land use land cover adjacent to the study area withindistance of 500 m and 1000m from river to recognize impacts of land use changes.
3. Overlapping the sinuosity and LULC to sortout the associated changes due to anthropogenic influence

Sinuosity Index:

The study was carried on Geographical Information System (GIS) Platform. All the data such as topographic maps, Satellite image ancillary maps were geo-referenced and brought to common projection system. The main alignments of the River course for the temporal period were digitized and river was subdivided into 9 segments (Figure 2), and the changes were identified based on sinuosity index. Sinuosity Index is the measure of deviation of the river from its ideal path of movement between two points. The study of the sinuosity index of a drainage line helps us in evaluating the effect of terrain over river course and vice-versa (Panda and Bora, 1992).

The method of calculating the sinuosity indexes as suggested by Schumm's Model (1963), mathematically it is calculated by the following formula:

$\boldsymbol{Channel\ Sinuosity = OL \div EL}$Where, OL refers to Observed Path length and EL is Expected Path length.

Sinuosity index is calculated using Schumm's method, and the river course is classified into four classes as on the basis of the SSI.

1. Sinuous (SSI=< 1.3),
2. Slightly meandering (SSI = 1.3 - 1.5),
3. Meandering (SSI = 1.5- 2.0)
4. Highly meandering (SSI = > 2.0)

According to Schumm, more than 2.0 sinuosity index isdefined as braided channel but for this study area as the river doesn't reach to braidingstage and thus value of,SSI > 2 is referred as highly meandering sinuosity class.

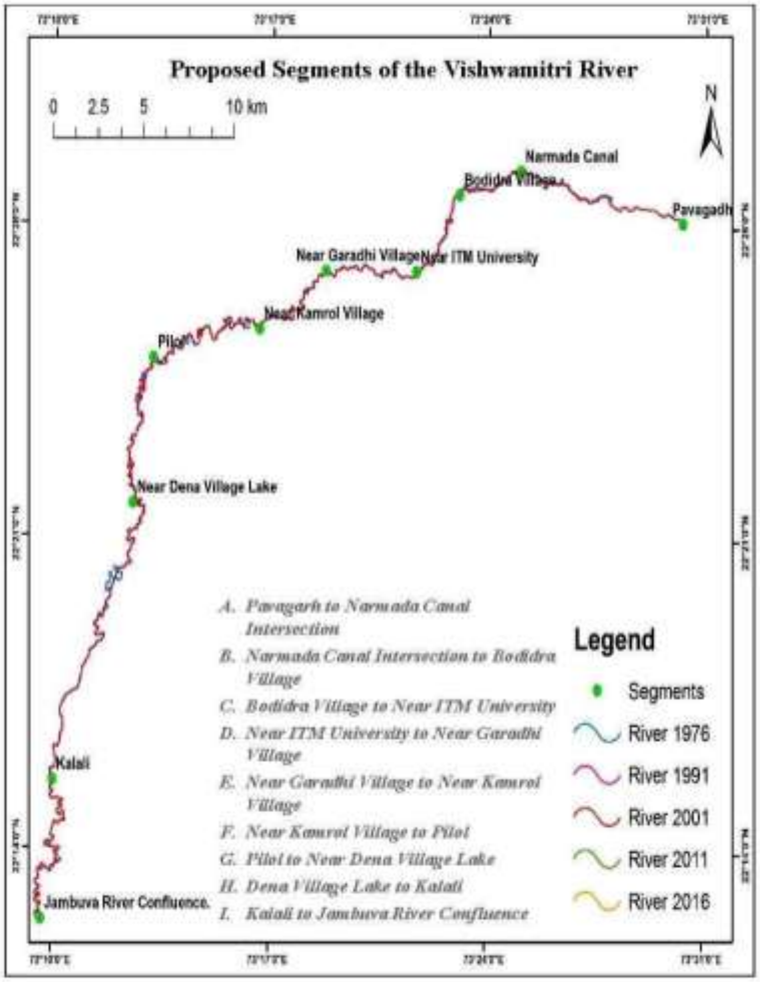

Figure 2: Proposed Segment of the Vishwamitri River.

Table 1: Observed Path length (OL) and Expected Path length (EL) of segments of Vishwamitri River.

Years	***1976***		***1990***		***2001***		***2011***		***2016***	
Segment code	***OL***	***EL***	***OL***	***EL***	***OL***	***EL***	***OL***	***EL***	***OL***	***EL***
A	11.77	9.12	11.13	9.13	11.01	9.16	12.09	9.23	11.86	9.23
B	4.77	3.65	4.42	3.61	4.13	3.51	4.47	3.52	4.42	3.52
C	5.32	4.03	5.67	4.13	5.23	4.16	5.61	4.02	5.34	4.03
D	6.73	5.01	6.75	4.98	6.43	4.92	6.83	5.01	6.79	5.00
E	7.12	4.41	7.18	4.41	6.97	4.45	7.35	4.41	7.26	4.38
F	14.12	5.98	12.17	5.98	12.02	5.93	12.79	5.96	12.38	6.00
G	12.65	6.11	11.70	6.07	11.82	6.12	12.22	6.09	11.91	6.10
H	21.14	12.26	18.82	12.35	18.59	12.28	18.24	12.31	18.54	12.29
I	14.74	5.81	13.98	5.73	14.30	5.78	14.18	5.78	14.24	5.78

Table 2: Sinuosity Index of Vishwamitri River.

Segment code	1976	1990	2001	2011	2016
A	1.29	1.22	1.20	1.31	1.29
B	1.31	1.23	1.18	1.27	1.26
C	1.32	1.37	1.26	1.39	1.32
D	1.34	1.36	1.31	1.36	1.36
E	1.62	1.63	1.57	1.67	1.66
F	2.36	2.03	2.02	2.15	2.06
G	2.07	1.93	1.93	2.01	1.95
H	1.72	1.52	1.51	1.48	1.51
I	2.54	2.44	2.47	2.45	2.46

The analysis shows that, the sinuosity index is varying. The upper course of the river segments ‘A’ of Pavagadh to Narmada canal intersection, there is littlechange. While, in the ‘B’ segment from 1980 to 2016 river sinuosity index have decreased, it was 1.31 in 1981and 1.18 in 2001. It shows that sinuosity of river have decreased in the last 30 years in the upper reach.

It is found that in ‘G’, ‘H’ and ‘I’ segments which are in the Vadodara city area sinuosity have reduced which can be attributed to anthropogenic activity like stream straightening.

From the SOI maps it is found thatin ‘G’ segment sinuosity was 2.07 in 1981 which is 1.95 in 2016.Similarly, in ‘H’ segments from Dena village lake to Kalali it was 1.72.in 1981 whereas 1.51 in 2016. From Kalali to Jambuva river confluence as segments ‘I’ the sinuosity in 1981 and 2016 is 2.54 and 2.46 respectively.

Thus, the change in SSI, in upper catchment and in urban stretch shows marked differences owing to the differing usage of the riverfront along the river. In the upper catchment the agricultural, vegetated land cover along with the river gradient prevents the increase in the sinuous condition. The River in the city has seen artificial straightening activity due to which meanders are cut off forming ox bow lakes. As seen in H segment.

Land Use- Land Cover Changes

Land use and Land cover changes can either be natural for example a mud flow or human induced (increase in paved surfaces), and their impact on the environment can range from a short period after which the environment recovers, to recovery periods that are decades to centuries long. The human reshaping of the earth has reached a truly global scale, is unprecedented in its magnitude and rate (Meyer and Turner II, 1992).

Change detection, as defined is the temporal effects as variation in spectral response involves situations where the spectral characteristics of the land cover type in a given location change over time. LULC changes along to Vishwamitri river course have been identified to understand the impact of anthropogenic interference, which may contribute to direct or indirect impact on river channel or meanders.Thus, land use/land cover were classified into major six classes using satellite data i.e. Landsat Images of 1981, 1991, 2001 & 2011 and 2016. Later, these classified areas were delineated along river with a buffer for 500 m and 1km. Following figure 3 shows the land use land cover area calculation along buffer.

Figure 3 and Figure 4 shows the variations in LULC over the last 4 decades along the sides of the river at 500 meter buffer and 1000 meter Buffer respectively. The dominant land use types are cropland which encompass a total of >50 % of the area. However, the important changes were found in built up land which was nearly 1% which has increased to 12.30% within buffer of 500m in 2016. Similarly, built up increased from 1981 to 2016 it is 1.18% to 10.90 % respectively in 1 km buffer. This shows that the river proximity had been an attraction for the development and it has impacted the natural river landscapes. By large a straightening of the river stretch, in H segment was one of the changes which have reduced the sinuosity index of the stretch.

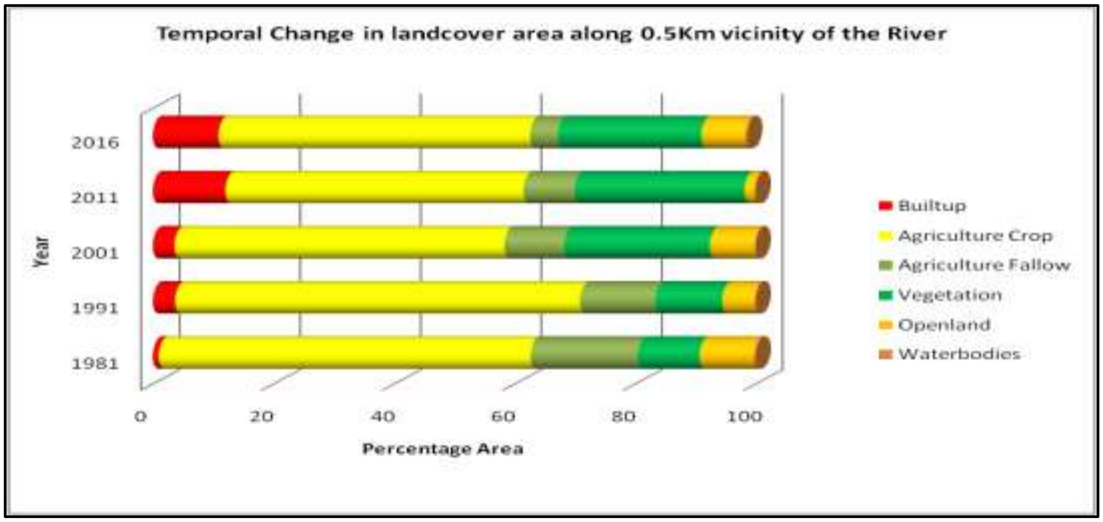

Figure 3: Temporal Change in land cover along 500 meter buffer of longitudinal section of ViswamitriRiver

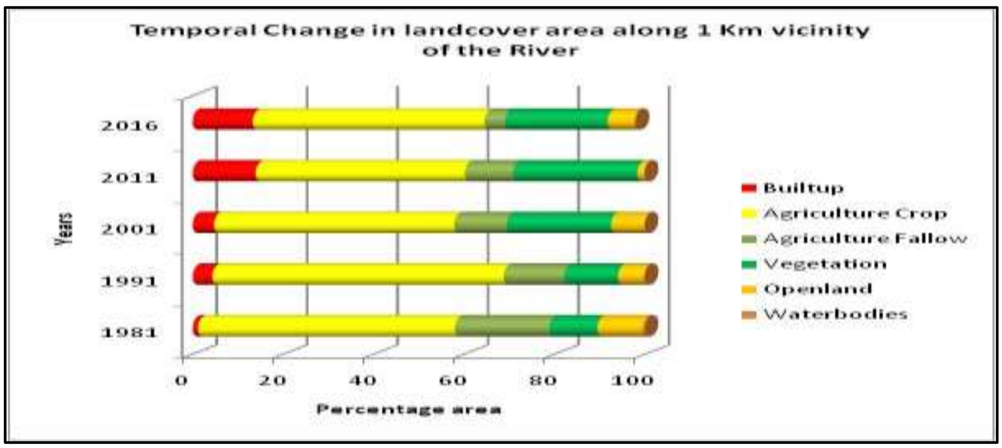

Figure 4: Temporal Change in land cover along 1Kilometer buffer of longitudinal section of ViswamitriRiver

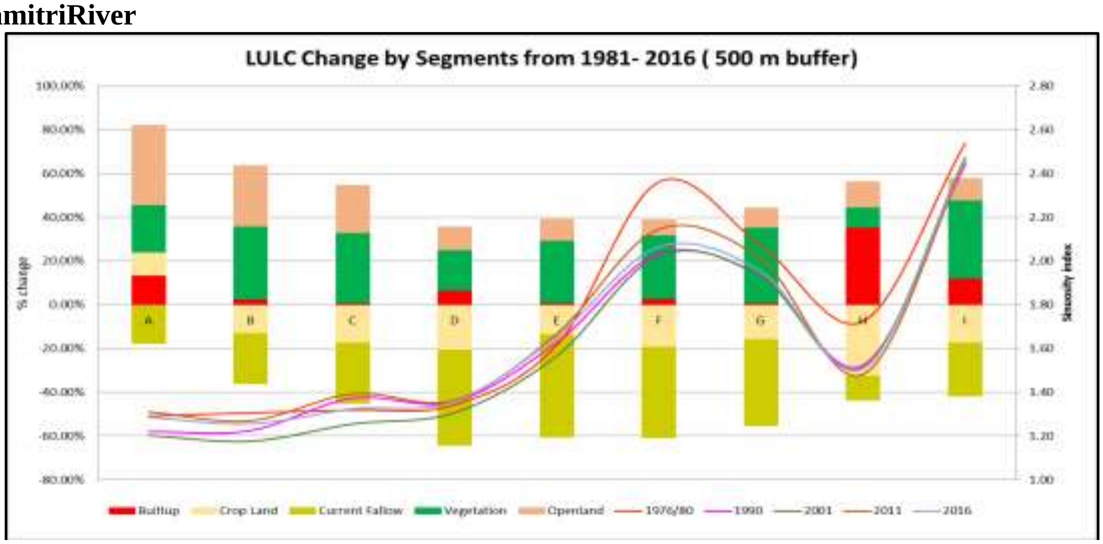

Figure 5: Areal Change in land cover along 500 meter buffer of longitudinal section of Viswamitri River

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The river segments show the dynamic interaction of the land use as apparent from the figure 5. In the headwater segment sinuosity remains nearer to the 1.2 showing slight meandering under the influence of gentle gradient and alluvial plains. The river taking its natural course in the agricultural dominated landscapes. With consistent coverage of the vegetation the erosion of the banks and ephemeral characteristics of the river had resulted in the reduced erosion as evident from slight differences in the sinuosity change in the segment from A to F. whereas the anthropogenic evidences of the reduction of the Sinuosity in F, G and H segment owes to straightening of the segments in the center of the Vadodara city.

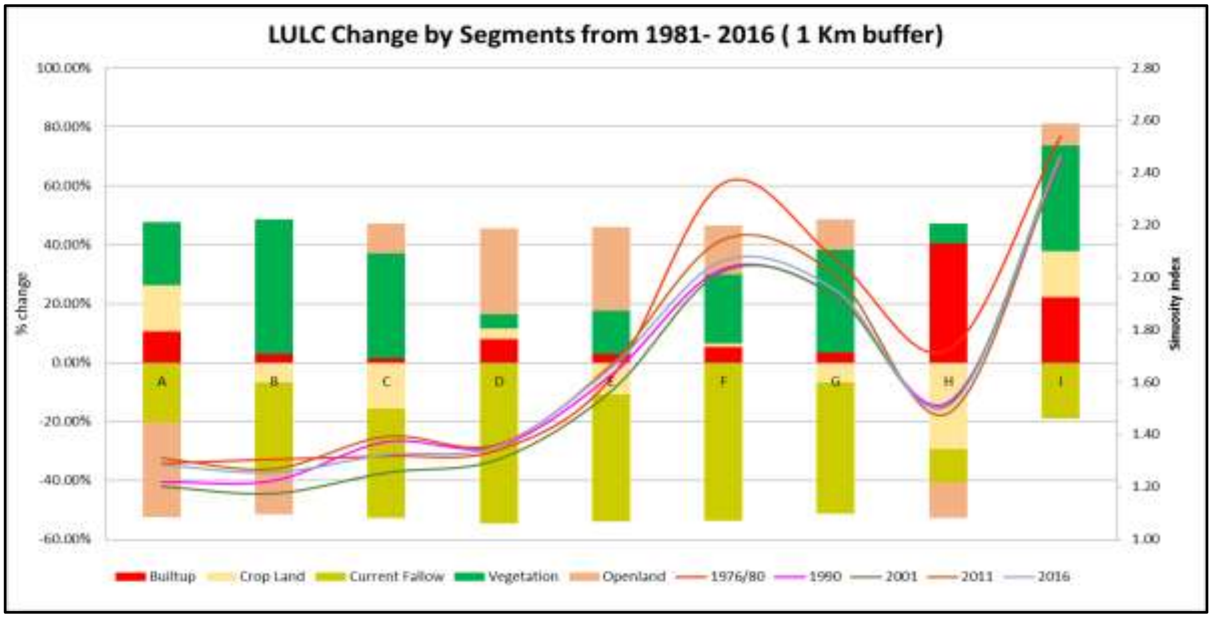

Figure 6: Areal Change in land cover along 1 kilometer buffer of longitudinal section of Viswamitri River

RESULTS

Based on the channel plan form change and land use classification, results of the study can be summarized that, streams are affected by watershed land use. These effects are evident in the amount of stream flow during storms, in the number of constituents in a stream, (USGS, 2002) and Sinuosity. The maps shown suffer a limitation of the scale of publication due to which changes are not apparent from the Map.

LULC is a dominant factor in influencing the heterogeneity of ecosystem services on the landscape (Bennett *et al.*, 2009). Hence, the study reveals that increase in built up land use has impact along the Vishwamitririver. VishwamitriRiver hasmade meanders along its course. The changes in land use land cover have impact on Vishwamitri River, mainly due to the industrialization and urbanization (Joshi and Bhatt, 2011).

Figure 7 shows the sinuosity index overlay on the LULC area. In 1976 the sinuosity index varies from head to mouth of the river. The upper stage of the river in A, B, and C segments, sinuosity is found < 1.3 it's almost into the sinuous category. From the segment F up tosegments G sinuosity is > 2.0, whereas in city area as segment H is range between 1.5 – 2.0 sinuosity indexes in meander class.

In figure 7 shows the insignificant changes in sinuosity in C segments, it changed from < 1.3 in previous decade to 1.3-1.5 in 1991(refer Table 2)whereas in G segments sinuosity index changed from >2.0 to 1.5 -2.0 as in this segments most of the open land is converted into agriculture land as seen in 500m and 1km buffer region.

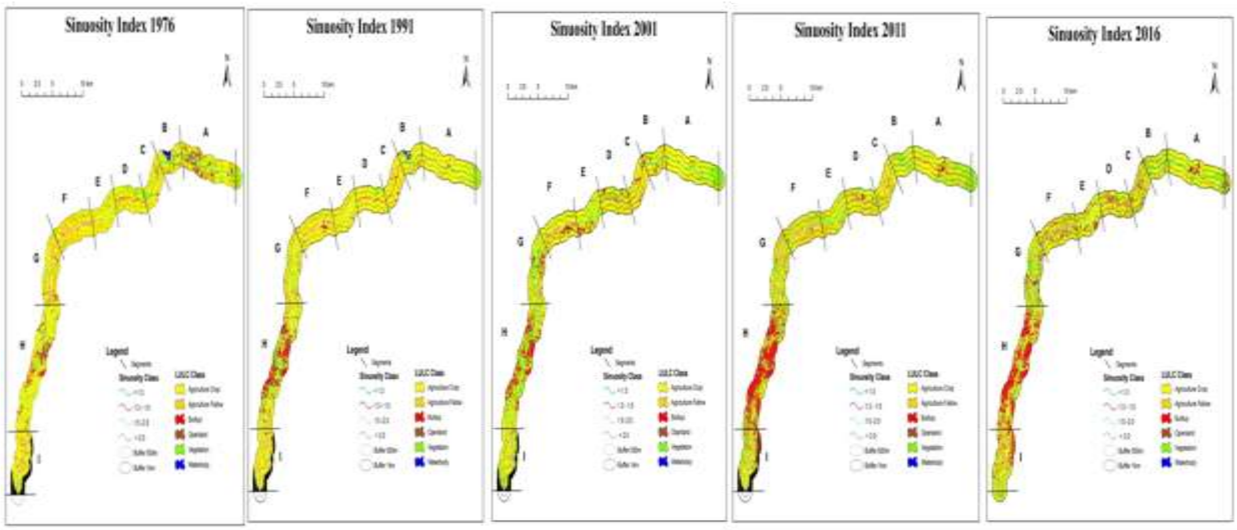

Figure 7: Sinuosity Index and LULC for the year 1976, 1991, 2001,2011,2016

In 2001, increasing urbanization has impacton sinuosity of the river. Figure6 shows the major changes in the segments H in 1991 value of sinuosity was 1.5-2.0 in which decreased to 1.3-1.5. Here, change in value means menders to slightly meander class. Whereas in segment A the change is from sinuous to slightly meanders.

DISCUSSION

Overall impact of decreasing a stream's sinuosityin urban areas could be increase in the stream velocity and the erosive energy. This transforms into erosion of the stream banks, increased rate of sedimentation, or the process of sediment being deposited into the stream channel. Another effect of decreased sinuosity is an increase in flood potential. If the length of the channel is decreased, and the flow of water remains the same, the depth must increase. When coupled with the decreased storage capacity of the floodplain, owing to less contact between the stream and its surrounding riparian wetland, it becomes evident why many stretches of channelized streams are equipped with levees that are built higher and higher with each successive flood (1998, Watershed assessment guide for citizen monitors). This is frequently experienced in Vadodara city. The progressive development of the Vadodara city also possesses a threat to the vegetation cover on the flood banks as they were planned for the beautification of the river bank also use as recreational spots. For which concretization of the banks will not be the feasible in this ephemeral stream. Also, the plantation has to be dense and such that it retard the velocity of the peak flow and conserves the soil else the erosion will be escalated in the downstream.

CONCLUSION

Present study has proved the utility and application of remote sensing and GIS technology and provided a detailed assessment of spatial and temporal changes in river channel processes and impact of LULCin the study area. The past and present data analyses indicate that the changes in sinuosity of channel. Also, there are significant changes in Land use which have impact on river as whole. When we are planning for sustainable development, maintaining ecological services such approaches can give better understanding of the regional setup. Therefore, it is necessary to plan and to mitigate the hazards specially floods that are frequent phenomena in the study area especially in urban stretch and to minimize human intervention to the natural flow of the river and ensuring the growth of riparian vegetation so that the ecological and biological diversity of the flood plan area will be more prosperous and healthy than before. Combining the GIS method and SSI analyses, this study supports the analysis of the impact of land use conversion on the watershed structure and can be applied to other cases. Because urbanization is expected, studies that assess and protect the watershed must be continued with developing the interlinkage of the environmental factor for the futuristic climate resilient development.

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REFERENCES

Allan JD (2004). Landscapes and Rivers capes: The Influence of Land Use on Stream Ecosystems.” *Annual Review of Ecology, Evolution, and Systematics* **35** 257–284.

B Ajay Kumar, G Gopinath and MS Shylesh Chandran (2013). River sinuosity in a humid tropical river basin, south westcoast of India. *Saudi Society for Geosciences* **7** 1763–1772.

Bennett EM, Peterson GD and Gordon LJ (2009). Understanding relationships among multiple ecosystem services. *Ecology Letters* **12** 1394–1404.

Bhatt B, Gupta AK and Gogoi G (2006). Application of Remote Sensing and GIS for Detecting Land Use Changes: A Case Study of Vadodara. GIS Development. India

Bunte K and Abt SR (2001). Sampling Surface and Subsurface Particle-Size Distribution in Wadable Gravel- And Cobble-Bed Streams for Analysis in Sediment Transport, Hydraulics, and Streambed Monitoring. *General Technical Reports* RMRS-GTR-74. USDA Forest Service Rocky Mountain Research Station: Fort Collins, CO.

Joshi JP and B Bhatt (2011). Quantifying Urban Sprawl: A case study of Vadodara Taluka Geo-Science research 2 (1), 34-37

Jing Yin, Fan He, Yu Jiu Xiong and Guo Yu Qiu, (2017). Effects of land use/land cover and climate changes on surface runoff in a semi-humid and semi-arid transition zone in northwest China. *Hydrology and Earth System Sciences* **21** 183–196.

Keen-Zebert A (2007). Channel Responses to Urbanization: Scull and Mud Creeks in Fayetteville, AR. *Physical Geography* **28** 249–260.

Leopold LB, Wolman MG and Miller JP (1992). Fluvial Processes in Geomorphology. Dover Publications, Inc. New York, 522.

Leopold LB (1968). Hydrology for Urban Land Planning – A Guidebook On The Hydrologic Effects Of Urban Land Use. *US Geological Survey Circular* **55** 21.

Levell AP and Chang H (2008). Monitoring the Channel Process of a Stream Restoration Project in an Urbanizing Watershed: A Case Study of Kelley Creek, Oregon, USA. *River Research and Applications* **24** 169–182.

Malcolm D Newson (2002). Geomorphological Concepts and Tools for Sustainable River Ecosystem Management. Aquatic Conservation Marine and Freshwater Ecosystems. *Aquatic Conservation: Marine and Freshwater Ecosystems* **12** 365–379.

Montgomery DR and Buffington JM (1997). Channel-Reach Morphology in Mountain Drainage Basins. *Bulletin of the Geological Society of America* **109** 596–601.

Montgomery DR., (1999). Process Domains and the River Continuum. *Journal of the American Water Resources Association* 35 397–410.

Panda PC and Bora HN (1992). A Study of Sinuosity Index of Siang River and It’s Major Tributaries: Arunachal Pradesh. *Environmental Management* **1** 97-101.

Poff NL, Bledsoe BP and Cuhaciyan CO (2006). Hydrologic Variation with Land Use across the Contiguous United States: Geomorphic and Ecological Consequences for Stream Ecosystems. *Geomorphology* **79** 264–285.

Kang RS and Marston RA (2006). Geomorphic effects of rural-to-urban land use conversion on three streams in the Central Redbed Plains of Oklahoma. *Geomorphology* **79** 488–506.
Schumm SA (1985). Patterns of Alluvial Rivers. *Annual Review Earth Planetary Sciences* **13** 5-27.
Urban MC, Skelly DK, Burchsted D, Price W and Lowry S (2006). Stream Communities across a Rural-Urban Landscape Gradient. *Diversity and Distributions* **12** 337–350.
USGS (2002). Does land use affect our streams? A watershed example from Gwinnett County, Georgia.
Wolman MG (1967). A Cycle of Sedimentation and Erosion in Urban River Channels. *Physical Geography* **49** 385–395.
Wubishet T, Stephanie W, William C and Constance W (2015). Assessing the Impact of Land-UseLand-Cover Change on Stream Waterand Sediment Yields at a Watershed Level Using SWAT. *Open Journal of Modern Hydrology* **5** 68-85.