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Dynamics of river Tapti using geo-spatial techniques at the distance between 600-650 km

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Abstract

The dynamics of the river is categorized in three categories viz straight, sinuous and meander. The river dynamics summarized through temporal change in entrenchment ratio and sinuosity. The spatial and temporal flow dynamics of the river is very technically analyzed by successful use of remote sensing and Geographical Information System. River Tapti has higher sinuosity on spatial basis which indicates the highly meandering nature. The flood prone width and bankfull width is increasing the area of river banks, because of landslide, erosion and sedimentation. The MSS 1975 data revealed the river fall under the category of meander while the TM 1989 imaginary reveals that the river seems to be sinuous rather than meander and the ETM 2009 imaginary reveals that again the river is moving towards meandering.

Keywords: Meandering, sinuosity, entrenchment ratio, soil erosion, rural development

Introduction

Many of earlier civilization came into being in the fertile and stable laps of rivers valleys. Civilizations have been prospered in Nile valley in Egypt, along the Tigris and Euphrates river in Mesopotamia, Indus river in India and yellow river in China. As early as 4000 B.C. people built dams across rivers to store water, dug canals for navigation purposes and also for irrigation purposes. These earlier civilization were confronted with the problems of flood control, therefore Chinese had been developed excellent system of dikes for the protection of inhabited areas against flood. More complicated problems are encountered in modern time, with the increase of population more and more rivers are being harnessed for multipurpose use i.e., for flood control, water supply, power generation, irrigation and navigation so the artificial changes are being made in water courses. The rivers and other water courses are running with loose materials which cause the change in river nature. Therefore the flow dynamics of river confuse researcher on temporal basis study [1]. stated that river dynamics involve complex, incompletely understood interactions among flow, sediment transport and channel form. The capacity to predict these interactions is essential for a variety of river management problems, including channel migration, width adjustment and habitat development. World's major rivers flow through many different types of terrain, they are similar in physical and biological functions. Tectonic processes result in the uplift and formation of major mountain chains, while the world's major rivers systems help erode those mountains [2]. Traditionally, the channel pattern of a river has been classified into straight, meandering and braiding types [3]. The channel pattern of a river depends on its plain form geometry and the processes operating within its reach [4]. Practically, a characteristic of water flowing in a definite channel tends to meander or not flow in a straight line because it is affected by a number of causative factors, which makes the river to deviate from the straight-line path. A geomorphologist is interested in fluvial morphology, principally as a tool in explaining the origin of the present form of the surface of earth. According to [5]. Cycle erosion in the primary action is the formation of the earth by the movement of water in the geographical or geomorphological cycle. This gives rise to increased erosive and transporting force of water flowing from land, the water begins to carve the landscape in various forms. As time passes the forms of land surface changes in various type of topography, being characteristics of geographical structure of various length site, with respect to time during which water has been acted. The development of remote sensing (RS) and geographic information system (GIS) have assisted to understand and assess the ease with which the data from different sources can be combined to the river morphology [6]. RS and GIS provide a broad range of tools for determining the area affected by flood due to rise in sea water levels.

RS and GIS provide a broad range of tools for determining the area affected by flood due to rise in sea water levels. For an effective management of flood water in low lying flood prone areas, GIS and RS technology are proving to be a useful and efficient instrument [7, 8, 9]. GIS is a system for storing, retrieving and analyzing geographically referenced spatial and non-spatial data sets. GIS consists many activities *viz.*, data capturing, archival of new survey data, integration of data sets, designing of different data structures, databases, user interfaces and analysis of integrated data sets. The data sets of the required environment can be visually and numerically displayed for exploring relationships among spatial data sets, to identify locations which meet specific criteria, making land use trade off decisions and assessing impact of proposed projects for actions. The information system consists spatial and non-spatial data set can be modeled to obtain information, which can be directly use to implementation for decision support scenario. Others maintain that GIS and modeling are largely separate traditions in computer assisted geographical research that can be integrated [10]. Remotely sensed data are finding acceptability as primary source of information for GIS with the transformation of data to information provided by image interpretation [11]. GIS is now established as a common feature for both in management and research, and some other diverse stream also as: planning urbanization at regional and national level, natural resource inventory, morphological analysis, change in river courses, stream dynamics and natural hazard evaluation. GIS may be the most important technology that resource managers have acquired in recent past [12]. determined many features can be attributed in successfully delineating the existence of palaeochannels on a regional scale using remote sensing information. Satellite images have been successfully used for the delineation of fluvial features of recent and palaeoriver systems. Thus, the activities normally carried out by GIS include the measurement of natural and human made phenomena and it processes from spatial perspective. These measurements emphasize three types of properties commonly associated with these types of systems, i.e. elements, attributes, and relationships. The measured data has been stored in computer database in digital forms. These measurements are linked to the features on a digital map. These features can be of three types i. e., points, lines, or areas (polygons). The data collected or discovered by numerical manipulation and modeling of different data sets, can be depicted through some type of maps, graphs or statistics. The river of the Deccan plateau and central India are totally dependent on monsoon and these rivers dry up in summer and almost all of them are non-perennial rivers. The major rivers of this region are Tapti, Narmada, Mahanadi, Damodar, Godavari, Krishna and Kaveri. The length of Tapti river is 724 km. The total erosion observed between 0 to 724 km is 3113 ha, whereas sedimentation is only 1139 ha. The river originates from Bethool in Madhya Pradesh. The geographical structure of Tapti river is in the form of the land soil formation all along its course. The geology of Tapti River is more or less similar to the geology of Indian peninsula. The geology of Tapti river can be said as old and geologically stable region with an average elevation between 300 and 1,800 meters [13]. The basin of Tapti river have vast fertile patch of land in central India. The entrenchment ratio of the flood-prone width (measured across the valley at an elevation twice the maximum bankfull depth), normalized by the bankfull width. Flood-prone width can be estimated by the ratio of bankfull width and twice of bankfull depth but potentially resulting in large differences in the flood-prone elevation, and even larger differences in the flood-prone width [14]. If the flow dynamics of the river Tapti meanders it will affect the *Canal Culturable Command Area* (CCA). The information regarding the flow dynamics of Tapti river, which is the main source of irrigation in Madhya Pradesh, Maharastra and Gujrat are lacking. The dynamics of river Tapti was undertaken by using different time of satellite data. The study length of the river (between 600-650 km) is studied extensively and graphically. The total movement of the river bank includes north and south site. The objectives of the present study are as follows:

1. To study the flow dynamics of the river Tapti.
2. To study the entrenchment ratio of the river Tapti.
3. To study the sinuosity index of the river Tapti.

2. Materials and Methods

2.1 Study area

The Tapti River is a river of central India. It is one of the major rivers of peninsular India with the length of around 724 km [13]. It is one of three rivers in peninsular India that runs from east to west the others being the Narmada and the Mahi river. The river rises from the eastern Satpura range of southern Madhya Pradesh and flows westward, draining via Madhya Pradesh's Nimar region, Maharashtra's Kandesh and east Vidarbha region in the northwest of the Deccan Plateau and south Gujarat, before emptying into the Gulf of Cambay of the Arabian sea at Surat. The river, along with the northern parallel Narmada river, forms the boundaries between north and south India. The Tapti river basin encompasses an area of 65,145 Sq. km, which is nearly two percent of the total area of India. We studied the Tapti river at the length from 600 km to 650km. The river basin of the river tapti is shown in (Fig../ Plates. 1). The hydrometerological network of the tapti river basin is shown in (Fig. / Plates. 2).

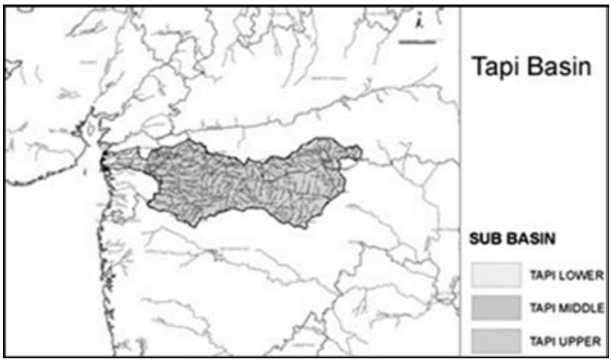

Fig 1: (Plates.) Basin of River Tapti

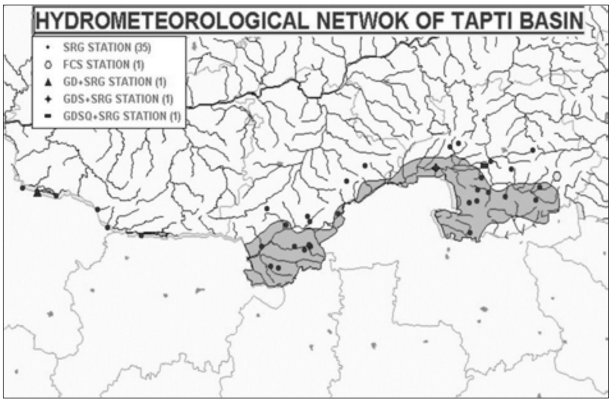

Fig 2: (Plates.) Hydrometeorological network of Tapti basin

2.2 Data used and its processing

Survey of India Toposheets

The top o sheets of the river Tapti has been taken from Survey of India, Dehradun, India of year 1972. The details of Landsat *mobile satellite services* (MSS), remotely sensed data of 1975, details of Landsat *Thematic Mapper* (TM), remotely sensed data of 1989, and details of Landsat Enhanced *Thematic Mapper* (ETM), remotely sensed data of 2009. The toposheets were mosiaced and georeferenced. The mosaiced toposheet covers the study length of the river Tapti. Georeferenced toposheets provides the information about the features prevailing in the area and details of latitude /longitude of study length of Tapti river.

Georeferencing

The toposheets were geo-referenced by using the software program Arc GIS 9.3, at one degree (1^0) polynomial geo-referencing operation. The satellite data were then subsetted with boundary of the study area delineated from the toposheet to get the satellite imagery of the study area.

2.3 Digitization of bank full and central stream line

The 1975, 1989 and 2009 year, Land Sat satellite imageries were mosaic and geo referenced. The different years satellite imagery has been taken as reference map to notice change detection during the period between years 1975 – 2009. The centre line of river flow is digitized by satellite imageries; this helped us to digitized bankfull and centre line, measurements has been taken along latitude and longitude with the help of grid. A grid each of 500 meters square dimension is created for study length of digitized Tapti river. Finally the Grids were superimposed on the digitized vector file of river Tapti and measured from the stream central line to left site and right site.

2.4 Determination of Sinuosity Index

Sinuosity index (SI) is used to separate straight from sinuous and meander channels [15, 16]. The sinuosity index (SI) can be calculated as follow

$$\text{Sinuosity Index} = \frac{\text{Length of Channel}}{\text{Length of meander belt axis}}$$

According to sinuosity index channel can be classified into three classes Sinuosity Index <1.05 straight

Sinousity Index is between 1.05 – 1.50 sinuous Sinousity Index > 1.5 meandering.

The sinuosity index is determined for different years on screen visual interpretation of different year satellite data. Vector files of central stream of the river flow for the three mentioned years were digitized form satellite data by using Arc GIS 9.0 tool, the central stream width, bankfull width and flood prone width. The straight line distance between two points (600 km to 650km) has been measured. Meandering of river of the study area is calculated by sinuosity ratio, which determines whether a channel is straight or meandering (Fig. 3). The sinuosity Index is the distance measured between two points only stream divided by straight line distance.

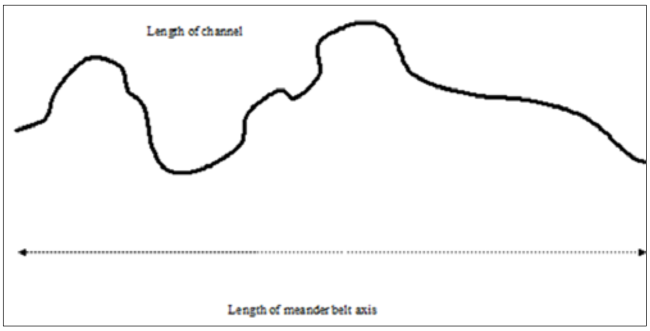

Fig 3: Meandering of river

2.5 Determination of Entrenchment ratio

The Entrenchment ratio is determined by dividing the width of the flood prone area by the bank full width (Fig. 4). The flood prone width (including the channel bank) and bankfull width is defined by screen visual interpretation of different years satellite data [17]. Used the entrenchment ratio of the flood prone width to the bankfull width can be calculated as follows:

$$\text{Entrenchment ratio} = \frac{\text{Flood-prone Width}}{\text{Bankfull width}}$$

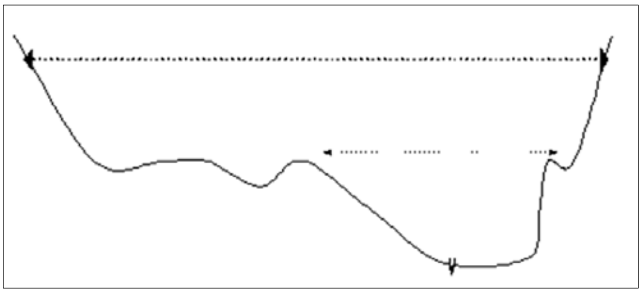

Fig 4: Ratio of flood prone width and bankfull width

3. Results

Meandering of river Tapti of the study area has been calculated by sinuosity ratio, which determines whether a channel is straight or meandering. The sinuosity of the river has been measured and expressed in the form of sinuosity index (SI). The method to estimate the bankfull velocity and discharge in rivers that uses the morphological variables of the river channel, including bankfull width, channel slope, and meander length were developed and tested. Since these variables can be measured remotely from topographic and river alignment information derived from aerial photos and satellite imagery, it is possible that the bankfull state of flow can be estimated for rivers entirely from remotely-sensed information [18].

3.1 Flow dynamics of the river

The flood prone width of the river increases with respect to time, indicates change in slope of the river and deposition of sediment. The mean flood prone width and mean bankfull width has been obtained through MSS, TM and ETM$^+$ along with the central line, the MSS 1975 data revealed that the mean flood prone width of the river is minimum 242.24 m at the distance 615 km and the maximum mean width is 5964.73 m at the distance 648 km from the origin. Whereas TM 1989 data revealed that the minimum mean flood prone width is 398.55 m at 601 km and the maximum mean flood prone width is 5891.32 m at 648 km downstream. As per ETM$^+$ 2009 data the minimum mean width is 232.48 m at 627 km whereas the maximum mean width is 11996.16 m at 605 km downstream Fig. 5. The mean bankfull width of the river according to MSS 1975 minimum mean width is 73.55 m at the distance 633 km and the maximum mean width is 941.26 m at the distance 650 km from the origin. As per TM 1989 the minimum mean bankfull width has been observed 70.30 m at the 633 km downstream from origin and the maximum mean width has been observed 995.23 m at 650 km downstream. As per ETM$^+$ 2009 the minimum mean bankfull width has been observed 67.00 m at the distance 640 km from origin and the maximum mean width has been observed 11331.47 m at the distance of 605 km as shown in Fig. 6 Analysis of data revealed that the change in land surface to water body causes erosion and on the other hand deposition process lead to appear new land for rural development. Erosion by river leads to collapse the river bank which ultimately transported into the deposition sites. Explained about the erosion and sedimentation by using Land sat imagery.

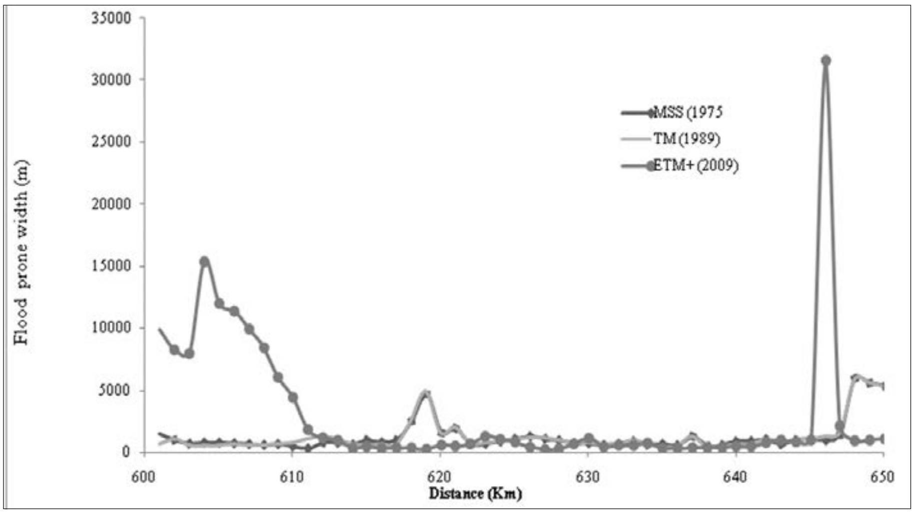

Fig 5: Flood prone mean width of the river from 600 to 650 km downstream

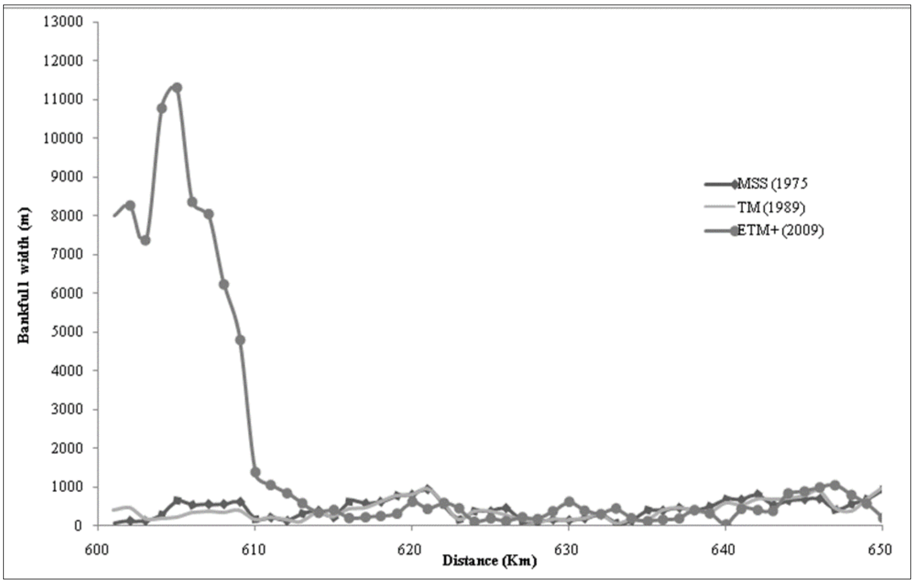

Fig 6: Bankfull mean width of the river from 600 to 650 km downstream

3.2 Entrenchment ratio of the river

Migration of river's course forms new land mass has been detected by year 1975 to 2009 satellite data. Migration of river course is due to deposition and erosion of soil at the river bends. Meandering river shift their courses across the valley bottom by deposition of sediment on the inside of river bends which simultaneously eroding on the concave site of the meander. The mean entrenchment ratio of the river according to MSS 1975 is minimum 1.16 at the distance 619 km and the maximum is 15.8 at the distance 601 km from the origin. As per TM 1989 the minimum mean entrenchment ratio has been observed 1.04 at the downstream of 640 km from origin and the maximum has been observed 15.57 at 648 km downstream. As per ETM$^+$ 2009 the minimum mean entrenchment ratio has been observed 1.00 at the distance 620 km and the maximum has been observed 8.49 at a distance of 624 km downstream. The peaks explain with respect to time the change in the entrenchment ratio of the river is due to the erosion and sedimentation process Fig. 7. We observed that the particular lengths of the river maintain the same entrenchment ratio throughout the study period which explains that these lengths are recommended for any crossover structure to be built over the river in future. Such lengths are found at 610, 615, 618, 622, 632 and 641 km between 600 to 650 km downstream.

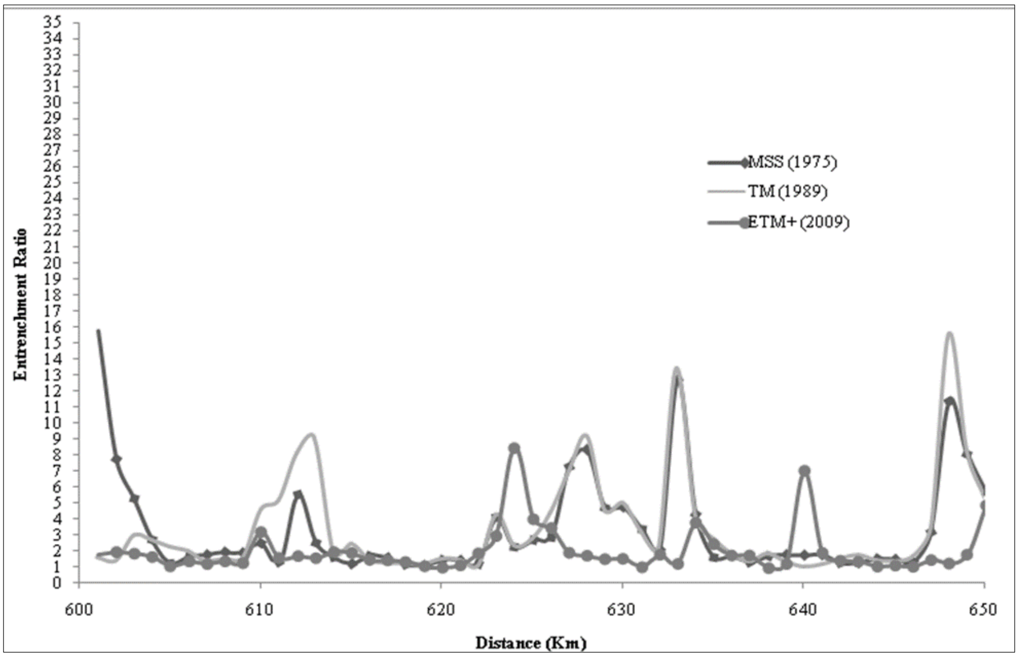

Fig 7: Mean entrenchment ratio of the river from 600 to 650 km downstream

3.3 Sinuosity Index of the river

The river has been classified into three categories namely straight where the sinuosity index is less than 1.05, sinuous where the sinuosity index is between 1.05 to 1.5 and meander where the sinuosity index is more than 1.5 respectively [15, 16].

3.3.1 Identification of the river lengths as straight of the river

It has been observed that throughout the length of the river, the sinuosity index of the river was never found to be less than 1.05, hence all along the course of the river, no length the river site does not fall in this category Fig. 8

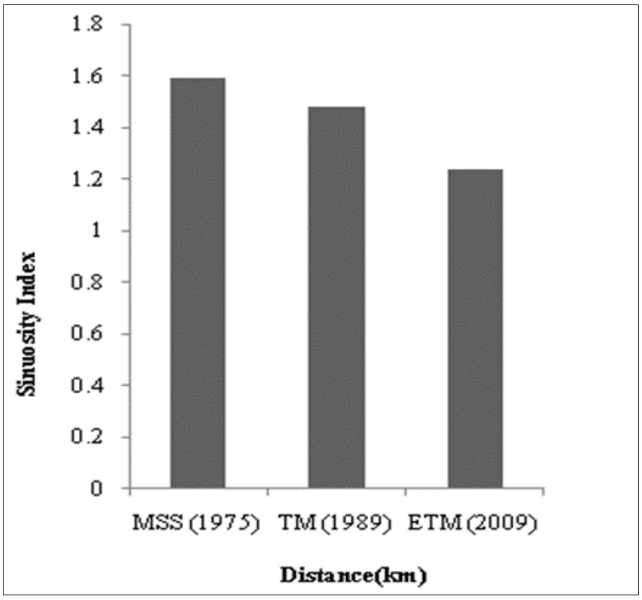

Fig 8: Sinuosity Index of the river from 600 to 650 km downstream

3.3.2 Identification of sinuous length of the river

It has been observed that during the year 1975the nature of river is meander , the river is sinuous in the year 1989 after a time interval of 14 years, and in the year 2009 it has been observed that again the river is meandering downstream. In the past 37 years it has been observed that the river is meander in nature Fig. 8.

3.3.3 Identification of meandering length of the river

The meandering nature of the river Tapti is extremely dynamic and the river changes from meandering to sinuous and vice versa. Meandering of river is determined by using Sinuosity Index. Meandering is the natural geomorphologic feature of rivers, which results gradual migration of the river course and erosion at river banks. Sinuosity Index is used to separate straight from sinuous and meandering channels. The Sinuosity Index can be calculated as length of channel divided by length of meander belt axis. According to the sinuosity Index, channels can be classified into three classes, Straight (SI is less than 1.05), sinuous (SI is between1.05 to 1.5) and meander (SI is greater than 1.5). After the analysis of three different time data it has been observed that meandering took place in different places in different year caused by erosion and sedimentation process of river at different site.

4. Discussion

Minimum temporal change in entrenchment ratio indicates that the river is stable. The curves indicate a very dynamic boundary of the river, represented by sinuosity. The flood prone width and bankfull width, adjacent to the river stream provides extremely important, ecological and geologically related services that not only determined the integrity of specific river stream, but it also influenced downstream stream channel condition. The peaks (fig. 5 and fig. 6) explain that with respect to time the increased width has been observed in the flood prone width and bankfull width of the river, due to the erosion and sedimentation process of the river. The total erosion observed between 600 to 650 km is 28 ha whereas sedimentation is only15 ha. The flood prone width includes dry land from extremes of agricultural lands at river bank. The process of erosion and sedimentation is in a dynamic state along the river. Effects of erosion and sedimentation by river results change in natural waterway. Therefore it has to be recommended at that particular points needs some preventive measures because meandering place of the river Tapti has been observed in our study, to be continued by different time satellite data. Created confusion in our study that not to be stable characteristic of the river Tapti, because same finding has been reported by [19]. The embayment was typically located almost a channel width upstream of the entrance to the meander that undergoes cutoff, and subsequent floods extend the embayment downstream until a chute is formed. Using sequences of historical aerial photos of the Sacramento River in California, USA, they found that embayments formed where channel curvature was greatest, or where the channel most tightly curved away from the downstream flow path. Embayments formed only within those portions of the floodplain that were lightly vegetated by grasses or crops. They developed a simple physical model that describes the environmental conditions that can lead to embayment formation. The model considered the role of floodplain vegetation in preventing chute incision and in part explained why chute cutoff is prevalent along some meandering rivers but not others. Therefore TM 1989 satellite data revealed that the river is seems to be sinuous. We studied he hard rocks of the hilly tract situated in between result in development of entrenched meandering and this tract has suffered minimum bank erosion [20]. We report riparian forest vegetation is widely believed to protect riverbanks from erosion, but few studies have quantified the effect of riparian vegetation removal on rates of river channel migration. [21]. The use of RS and GIS in the estimation of entrenchment ratio is found to be much more superior than estimating entrenchment ratio through field crew measurement. Since RS and GIS techniques is easily estimated the flood prone width, bank full width and central line of the flowing river, therefore we assumed that at the central line of the river the depth should be maximum. To address this need, high resolution numerical models increasingly are being used by river engineers, fluvial geomorphologists and river biologists to explore the complexity of river dynamics and to predict fluvial behaviour [1]. A Geomorphological could approach for restoring incised river for area development.

5. Conclusions

The river dynamics summarized through temporal changes in entrenchment ratio and sinuosity. The spatial and temporal dynamics of the river for the period of 37 years is very technically analyzed. Continuous erosion and sedimentation of river has been observed. We suggest, an improved understanding of the effect of floodplain vegetation on river channel migration will aid efforts to predict future patterns of meander migration for different river management and restoration scenarios [21]. The Geospatial analysis by RS and GIS is a crucial tool for the resource manager to face the new challenges. It helps resource managers to develop, analyze, and display spatially, explicit to deal with larger spatial scales such as regional landscapes. At its most fundamental level, RS provides a mean by which data can be produced and analyzed and then incorporated to design high technology water resources project for rural development. To understand the river problems, proper planning and designing of water resource projects should implement and the morphological behaviour of the river is prerequisites. Morphology can be defined as 'the science of structure of form' and fluvial may be defined, produced by the action of flowing water [22]. The knowledge of the principle of fluvial morphology and geomorphology is necessary for hydrological engineers to understand the problems arise due to the form of streams of the river, brought by transportation and deposition, for further research for area development.

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