The failure of Kosi River (Bihar, India) embankments and its effect on land use and land cover: a Remote sensing and GIS based approach

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Abstract

The kosi is an important river system in the north Bihar of India. The kosi is important in terms of its Geological settings, Basin characteristics, Flow characteristics, and its dynamic characteristics. The large upper catchment area, the high number of first and second order stream, large Himalayan glaciers makes the river high flood prone. Kosi originates from upper Himalayas and flows through the shiwaliks, Nepal foothills where river makes large alluvial fan, and finally it joins ganga in plain where large bending are seen. In august, 2008, kosi experience its embankment's change and devastating flood. The main idea of the paper is to analyzed the morphometric, geological, and anthropogenic causes of such river embankment's failure with the use of Dem and satellite imagery, how this changes have effect local landuse and land cover characteristics.
Key words: River system, Geological settings, Basin characteristics, Alluvial fan, Embankment, Morphometric characteristics.

Introduction

The eastern state of Bihar in India is a flood-prone fluvial plain, with maximum havoc being caused by the Kosi River and its feeder channels. The recent floods of the Kosi basin by abrupt migration of the master stream eastwards by 110 kilometers have impacted upon the geography of this densely inhabited region. Migratory trends of the Kosi indicate that neotectonism and local isostatic adjustments are active in the heavily faulted river basin. Annual precipitation receipts also contribute to channel over –spillage, and current glacial recession due to global warming in the source regions of the Kosi impact upon the stream's discharge. The channel has shown a marked affinity of following lineaments and faults. It now coincides with the Bhawanipur Fault, while an eastern branch of the river trends towards the Malda Fault. This study seeks to explain changes in the river's morphology in the light of regional landuse and. The methodology adopted includes interpretation of satellite imageries

Land use and land cover change has impacts on the functioning of socioeconomic and environmental systems. Remote sensing images and Geographical Information Systems (GIS) are being used to identify and analyze land use and land cover changes. The present study is carried out to identify and quantify spatio-temporal changes due to river course diversion in part of Kosi river basin, Bihar, India, using multitemporal satellite datasets of Landsat MSS (1976), Landsat TM (1990) and ETM (2000), and TM (2010) AND SRTM(DEM)2012. It was ascertained through remote sensing and time series analysis that there has been a major land cover changes were taking place in the proximity of river course. During 1976 to 1990 a shift of 5 km is found in north western part and 3 km in central and north eastern part of study area. During 1990 to 2004, also Kosi River shows a significant shift of 3.5 km in north western part, followed by central and north eastern parts of river with 2.5 km shift.

Land is very important natural resource, which provides basis of life to terrestrial and aquatic flora and fauna in one way or the other. Land-cover refers to the physical characteristics of earth's surface, captured in the distribution of vegetation, water, soil and other physical features of the land, including those created solely by human activities e.g., settlements. Land-use refers to the way in which land has been used by humans and their habitat, usually with accent on the functional role of land for economic activities (Louisa and Antonio, 2001). Water is the most powerful agent in shaping the earth's surface through the processes of rivers, glaciers, ground water, weathering, mass movement and oceans (Mirza, 2004).

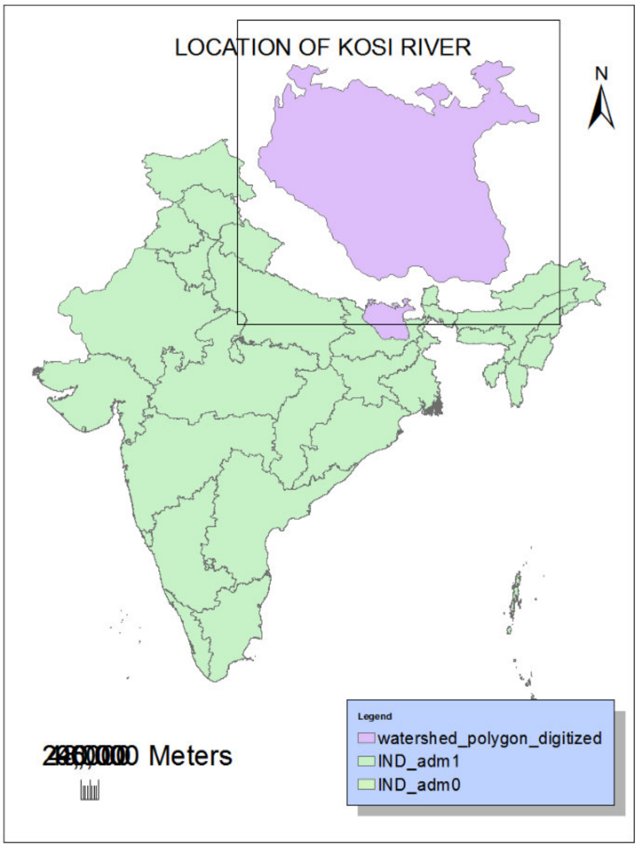
Objectives and hypothesis:

Dynamics of the Kosi River was initially reported by Shilling field (1893) and followed by several workers who focused on the westward movement of the Kosi River in north Bihar plains. Shilling field (1893) suggested that the progressive westward movement of the Kosi River would be followed by the eastward movement in one great sweep. Leopold and Maddock (1954) attributed the lateral shift of Kosi River to the tendency of a braided stream, which depends on the rate of sedimentation. Mukherjee (1961) first mapped the position of Kosi river channel at different times in the past Gole and Chitale (1966) reported that the Kosi has shifted by about 150 km in the last 200 years and related the shifting process with the cone (megafan) building activity. However, Wells and Dorr (1987) didn't find any correlation between any major changes in Kosi and major earthquakes in the region

Earlier hypothesis that the ongoing changes in the surface water configurations, as evinced through remote sensing imageries within a span of twenty years. The ongoing changes in surface water causes river channel shift the shifting of river courses changes the lulc types of the region.

The major objectives of the study are Evaluate the geological background of the river system. The morphometric characteristics of river. The possible causes of change of river channel. The impact of shifting of river channel on lulc types. Measures the vulnerability of the regions.

Study area: The kosi basin lies on the Himalayan foothills of India and Nepal, the upper courses lies on Nepal and lower in India



The Kosi River (The Sorrow of Bihar) is well-known in India for rapid and frequent avulsions of its course and the extensive flood damages it causes almost every year. The Kosi is one of the major tributaries of the Ganga River and rises in the Nepal Himalayas. After traversing through the Nepal Himalayas, it enters India near Bhimnagar. Thereafter, it flows through the plains of north Bihar and joins the Ganga River near Kursela, after traversing for 320 km from Chatra. The river has been causing a lot of destruction by lateral movement and extensive flooding. As its waters carry heavy silt load and the river has a steep gradient, the river has a tendency to move sideways. To check the lateral movement as well as for flood control, embankments on both sides of the river were constructed, five to sixteen km apart. Although this has confined the lateral shift of the river within the embankments, but the problem of flooding is still a challenge in this area (Ghosh et al., 2004). There must be a realization that minimizing the risk and damage from floods may be more rational way of flood management rather than formulating structural measures along the dynamic rivers such as the Kosi

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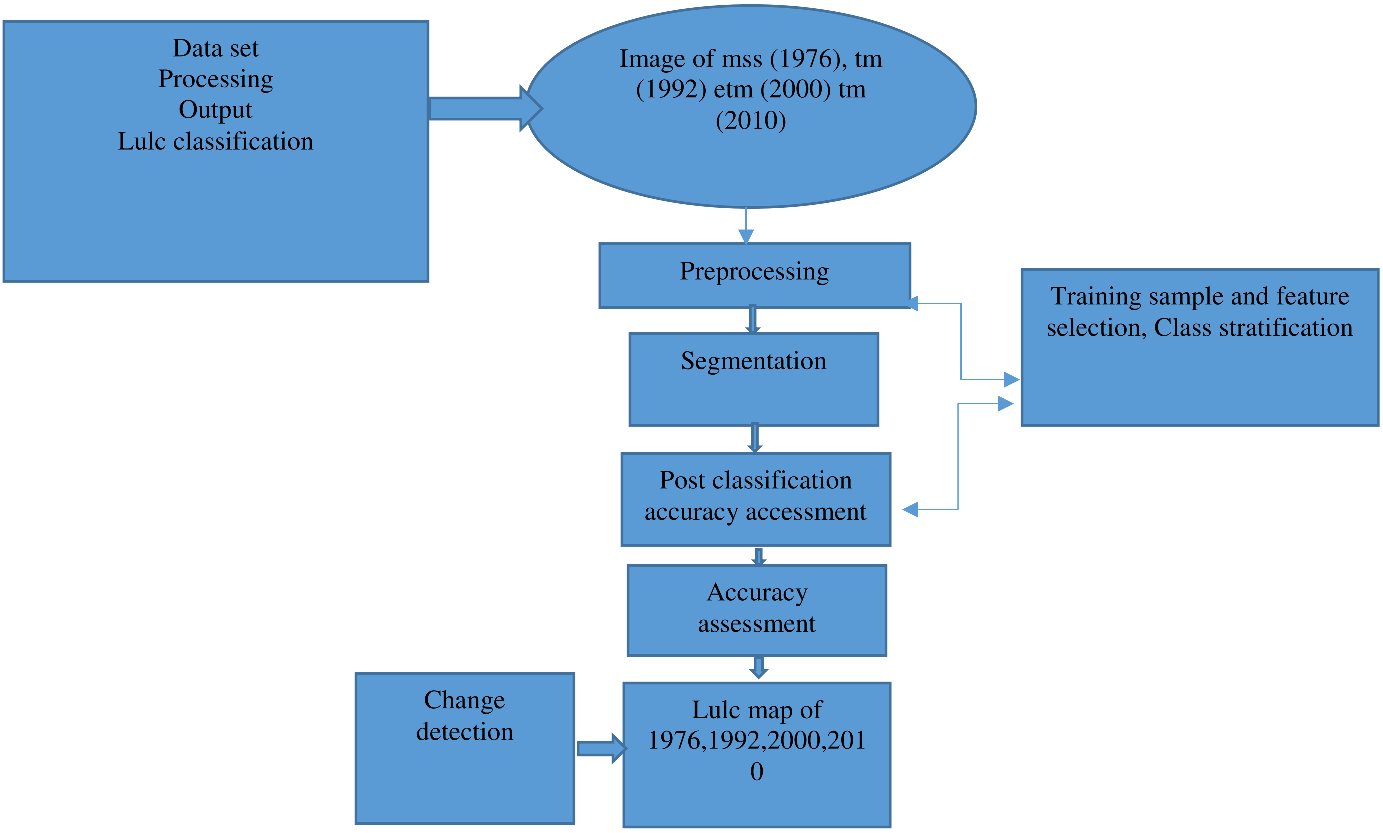
Fig: The location of kosi Basin

Materials and methods:

The methodology adopted includes interpretation of satellite imageries of srtm Dem 90m. , geological reports, followed by GIS analysis of the spatial shift of the Kosi river. This occurrence supports our earlier hypothesis that the ongoing changes in the surface water configurations, as evinced through remote sensing imageries within a span of twenty years, are due to active neotectonism and current climate change in the entire Kosi Fan Belt area. It is also indicative of heightened seismicity of northern Bihar Plains. To fulfill this objective we use dem data for river morphometric analysis, followed by longitudinal profile, the shifting characteristics is evolved through analysis.

The methodology adopted includes interpretation of satellite imageries of srtm dem 90m. , geological reports, followed by GIS analysis of the spatial shift of the Kosi river. Because this allowed us to obtain detailed change information and to handle the intense intra-annual dynamics of agricultural land use in the area. This method was complemented by landscape metrics and focused on the identification of agricultural expansion, vegetation and wetland loss, and habitat fragmentation. A detailed methodological flow diagram is presented in Figure 2.

Data sets: The main data set used in this research consisted of multi-temporal Landsat MSS,TM and ETM images for the four years of interest (1976, 1992,2000 and 2010), covering the main period of agricultural expansion in this region. We selected the images based on (1) availability of cloud-free images, (2) availability of anniversary date images (or images from the same period of the year), and (3) ability to distinguish the targets of interest. Because of the persistent cloud cover during the rainy season in this region, images from the dry period (June to September) were used as base images for the segmentation process. However, because of the intense dynamics of agricultural land use in the area, these images showed some limitation in identifying the targets of interest during the classification process. Therefore, additional images from different dates or sensors were used according to their pertinence and availability.



Pre-processing

Prior to image processing, the Landsat temporal series was geometrically corrected in order to remove spatial distortions before superimposition. The images were registered in an image-to-image procedure using the Landsat Geocode data set as reference. The time series was geometrically corrected using 30 control points per image, nearest-neighbor resampling, and a second-order polynomial warp function. The root mean square error (RMSE) for each image was ≤0.5 pixel. As indicated in the literature (Jensen 2005), the images were not corrected for atmospheric differences because they were classified independently (for each date) and training data were collected from each of the images to be classified (same relative scale).

Image classification

The land-cover maps were produced independently for each year selected, using a supervised, object-based classification approach that involved three main steps: segmentation, feature selection/classification, and accuracy assessment. Definiteness Professional erdas14.0 software (Definiteness 2006) was used to carry out the classification.

Classification scheme

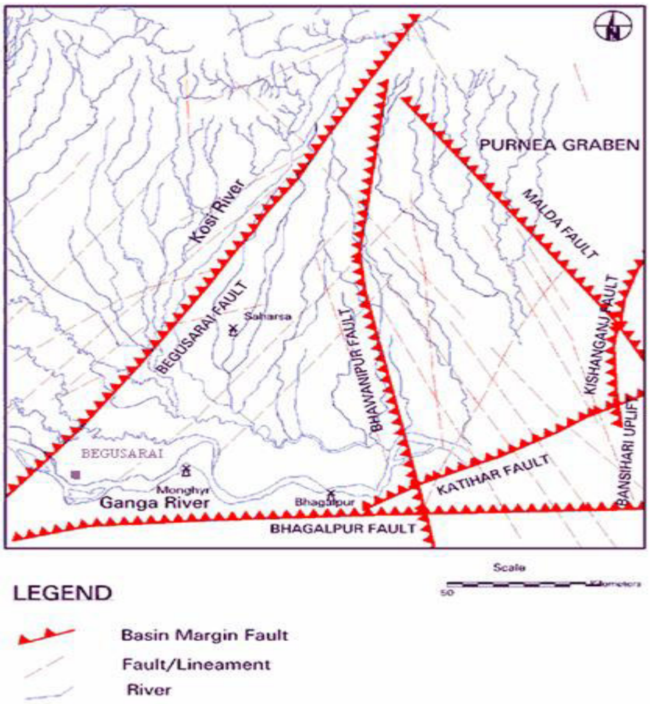
The selected classification scheme (see Table 2) was based on the objective of this research, which was to quantify the conversion of natural vegetation to agricultural lands (crops and pasture), and on a priori knowledge (fieldwork and previously published mapping) of land-cover types occurring in the study area. Our final map legend included the identification of annual crops and pasture, which represents potential differences in soil protection and management and is important for future applications such as soil loss modelling. A more generalized level was also used to report the final results. Moreover, wetlands

Classification method

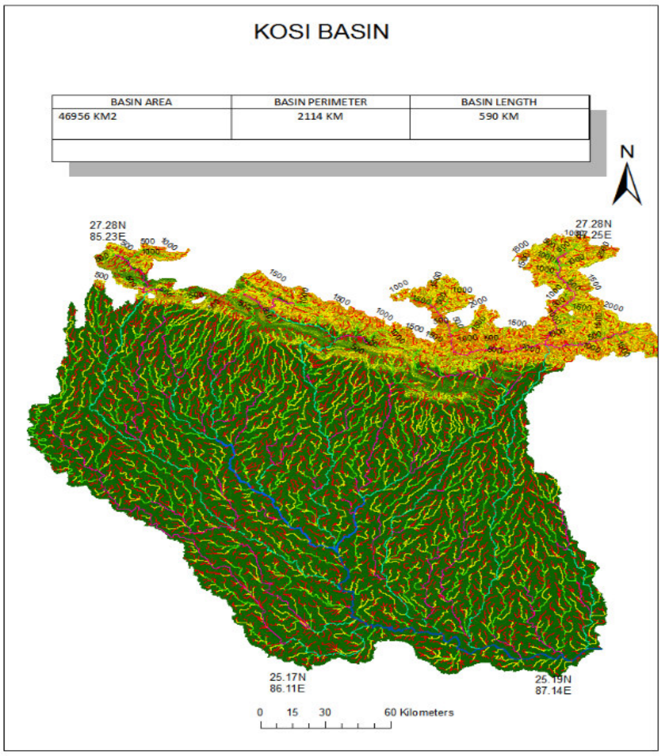
3.3.2.2. Object-based classification. To classify image objects, we used the nearest neighbor (NN) classifier of Erdas. Since NN is a non-parametric algorithm, it does not require that remote-sensing data follow a normal distribution and does not assume that the forms of the probability densities are known (Jensen 2005). The algorithm classifies image objects within a given feature space, based on recorded training samples, and searches the closest sample in the feature space for each object. Several iterations of sample selection and classification are recommended for improving the final Results. The main advantages reported for using the NN classifier within Erdas are (1) it operates in a multi-dimensional feature space, which increases separability in cases of overlapping classes (Ivies and Koch 2002); (2) it is simple to adapt it to other areas and can be applied to any number of classes using any original, composite, transformed, or customized bands (Myint et al. 2008); and (3) it is less time consuming compared with that of decision tree approaches (Laliberte et al. 2006). The classification process involved definition of class hierarchy, selection of training samples, selection of suitable variables for composing the feature space, and revision of results. Training samples (spectrally homogeneous polygons) were selected for alland-cover types, guided by fieldwork samples and available thematic data. Class categories were hierarchically subdivided into subclasses in order to account for all spectral classes resulting from the dynamics of agricultural land use and different vegetation types, later being combined to produce the final thematic maps with the classes of interest.

Geological Background

The Kosi river system is the only Indian River whose hydrology is deeply influenced both by the regional geological complexities and inputs of annual precipitation and Himalayan glacier melts. This antecedent drainage system is notorious for its migratory trends, resultant flooding, and a huge detrital load of boulders and sand. Entire Kosi fan belt is etched with palaeo-channels that demarcate the east-to-west and back swing of the river from the Epic Age onwards. The recent flooding caused by a breach in the Kosi embankment in Nepal has highlighted the increasing role of geological processes like plate motions, geotectonic , and local isostatic equilibrium in the Himalayan region and the adjacent Ganga basin. Presently, the Kosi has abandoned its westward curving channel for an almost direct north-south flow from the Himalayan base up to its confluence with the Ganga.



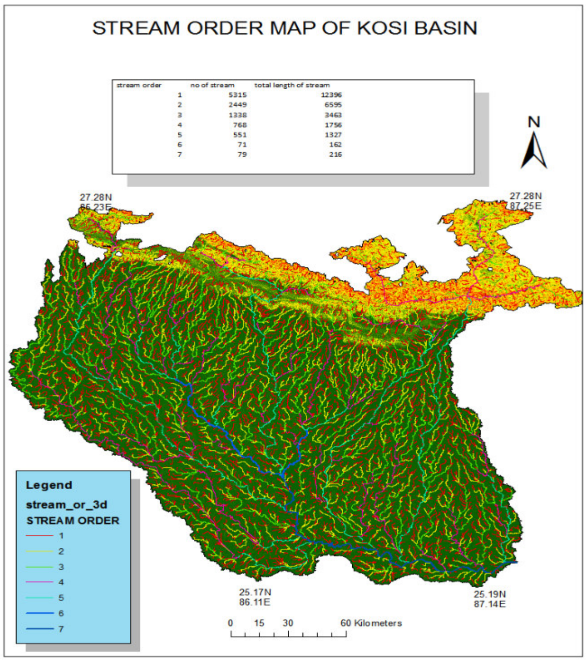
Morphometric Characteristics



The morphometric analysis of a drainage basin and channel network play a significant role in understanding the hydrogeological behavior of the basin and expresses the prevailing climate, geology, geomorphology and structure, etc. The relationship between various drainage parameters and the above factors are now almost well established (Horton, 1945; Strahler, 1957; Melton, 1958; Pakhmode, 2003; Gangalakunta, 2004). The present study mainly aims to analyze the morphometric attributes of the Kosi River. As yet, no detailed work on the morphometric of the area has so far been carried out; and pollution of Yamuna River due to urbanization is studied by Singh (2001). Physiographical kosi is divided into five distinct regions. Geologically the area forms a part of the Indo-Gangetic plain and characterized by alluvium which is an admixture of gravel, sand, silt and clay in various proportions deposited during the Quaternary period

Fig: the general characteristics of kosi basin

Stream order: The first step in drainage basin analysis is designated to stream order, following a system introduced by "strahler" (7, p. 1122) .assuming that one has available a channel- network map including all internment and permanent flow lines located in clearly defined valleys. The smallest fingertips tributaries are designated as no1. Usefulness of the stream order system depends on the premise that, on the average, if a sufficiently large sample is treated, order no is directly proportional to the size of contributing watershed, to channel dimensions, and to stream discharge at that place in the system.



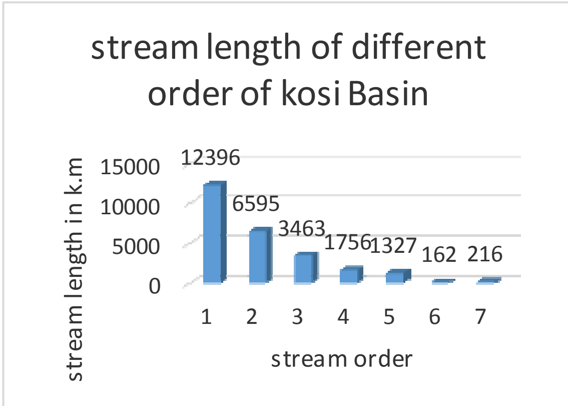


Fig: stream order characteristics of kosi basin

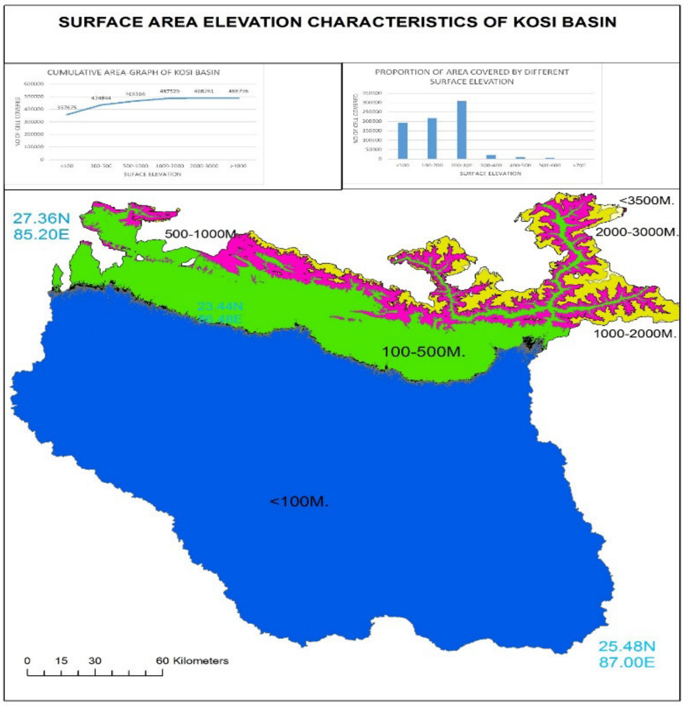


Fig: the surface area elevation characteristics of kosi basin

Because order no. is dimensionless, two drainage network differing greatly in in linear scale can be compared with respect to the corresponding point in the geometry through use of drainage order no. after the drainage network element have been assignment the further linear morphometric calculation has been derived.

Surface area elevation characteristics:

The surface and elevation characteristics of kosi basin shows the different from the other basin areas. It Shows that the large proportion of area is under the <100m. It is the plain region of Himalayan foot hill region as compared the area covered by the high relief as high as >3000m. Is less the area covered by the region. Which is the heighten peaks of Himalayas.

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Drainage density: An important element of the linear scale of landform elements in stream eroded topography is drainage density D, introduced in the American hydrological literature by Horton.

Dd= ∑Lu/Au, where, Lu= length of stream, Au=Basin area.

Thus is the ratio of total channel segment lengths cumulated for all orders with in a basin to the basin area. Drainage density varies with a wide dimension of geologic and climatic environments. In general the low drainage density is favored in the regions of highly permeable subsoil materials, under dance vegetation covered and where relief is low.

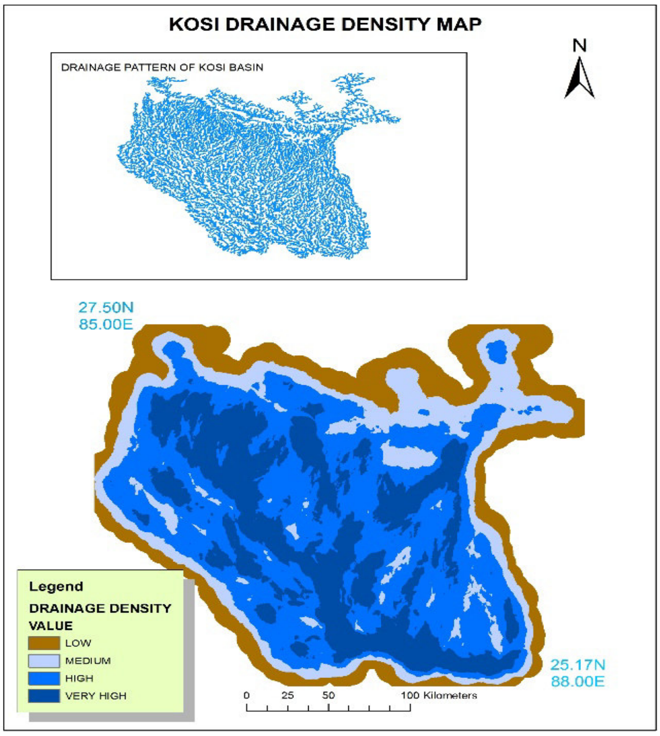


Fig: kosi Basin Drainage Density map

Channel Sinuosity: The shape in the open links in terms of geometric structure of drainage line involves the calculation of derivation of observed path (Ol) from the expected path line (El) of a river from the source of mouth. In fact no river in practice shows straight path. In terms of open link as many causative factors because the drainage line deviate from the straight path of the river. This factor may be geological and hydrological in nature. , deep angle, slope, absolute and relative relief in nature. Thus sinuosity of a river denotes the deviation of the river in its actual path to it's expected from expected theoretical straight path. The degree of sinuosity gives the vivid idea about the stage of basin development as well as the landform evaluation.

Channel sinuosity= Ol/El, where, Ol= observed path of stream, El= expected path of stream.

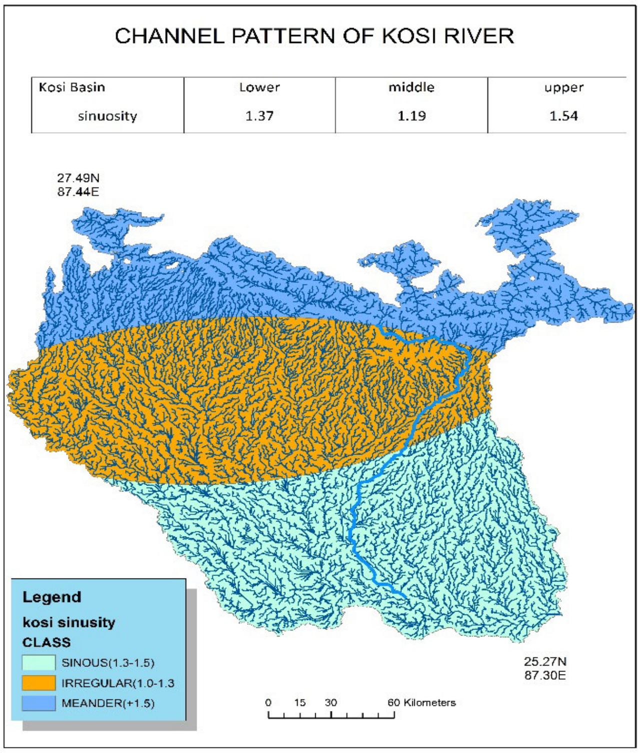
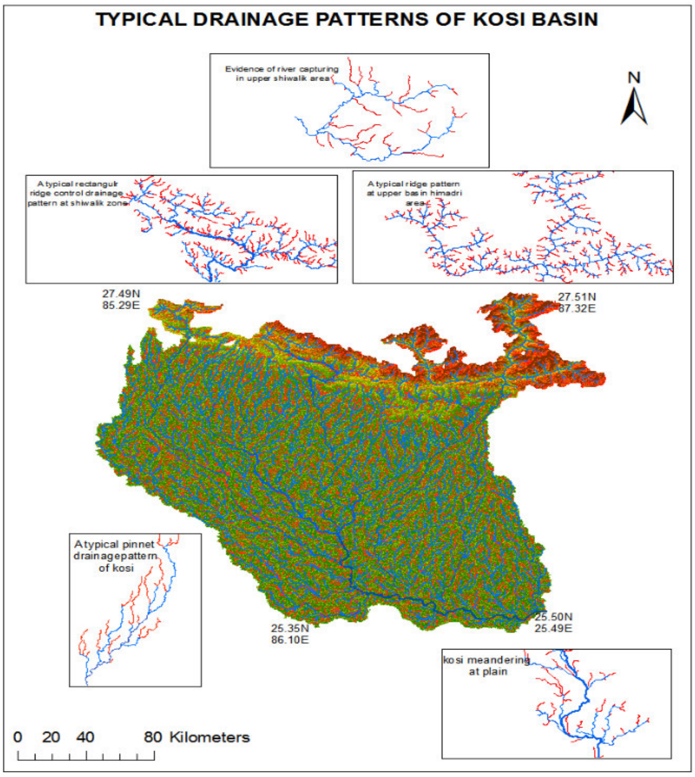


Fig: channel pattern of Kosi River

Drainage pattern: The drainage pattern means the form of the drainage system and spatial arrangements of streams in a particular locality or regions. The location, direction, forms and trends of the drainage patterns depends on the nature of slope, structural controls, lithological characteristics, tectonic factors, climatic condition, and vegetal characteristics etc. since there are much variation in environmental condition in deferent regions and hence there difference in drainage patterns also. Though the drainage pattern of some region may be similar but not the same. But there are some common characteristics which enables us to distinguish different drainage patterns.



The longitudinal profile of Kosi River: The longitudinal profile of a drainage can be shown graphically by plotting the altitude as a function of horizontal distance. Altitude is commonly stated as the meter from the sea level datum; distance in mile or kilometers from stream head, stream mouth or some other convenient reference point. For streams of large discharge and hence order, a considerable factor of vertical exaggeration is used,

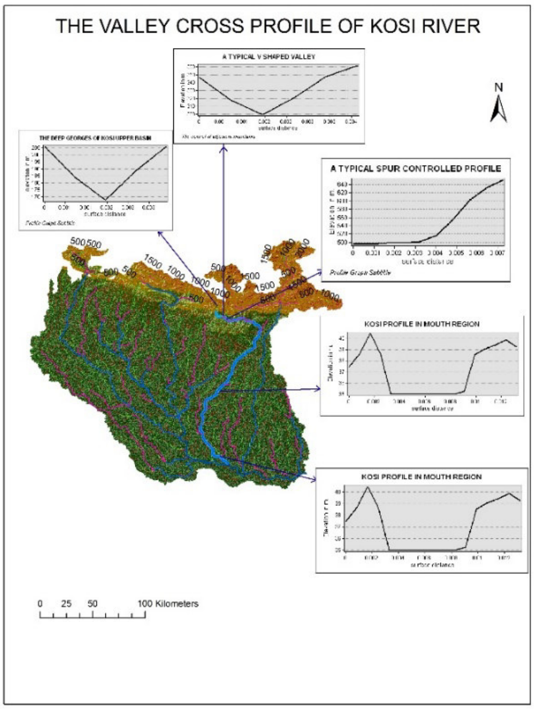


Fig: the channel gradient of Kosi River.

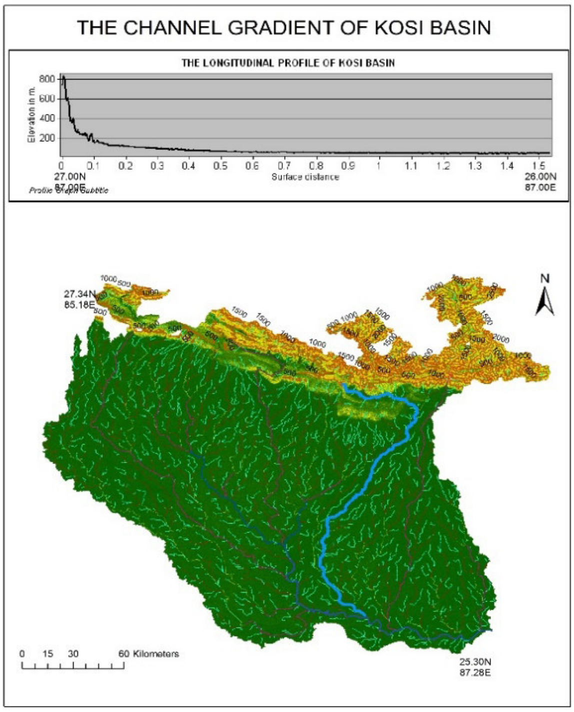


Fig: the valley cross profile of Kosi River.

The hypsometric characteristics of kosi basin: The general hypsometric curve of kosi basin shows the different views from the other basin. The large proportion of the area is covered by the high elevated contour. The general convexity of the curve shows that the region is more prone to potentiality of erosion. As kosi flows through the newly evolved Himalayan region the regional slope and relative relief is very high which leads the river to more erosion, the general rugged nature and general submittal convexity makes the curve to more rigorous to erosion. And also the river characteristics of the region shows the area is highly prone to erosional work. As the total Himalayan mountain region is active in nature. Which gives the river more potentiality to erosion. From the hypsometric curve of the region it is depicted that the region is youth in nature.

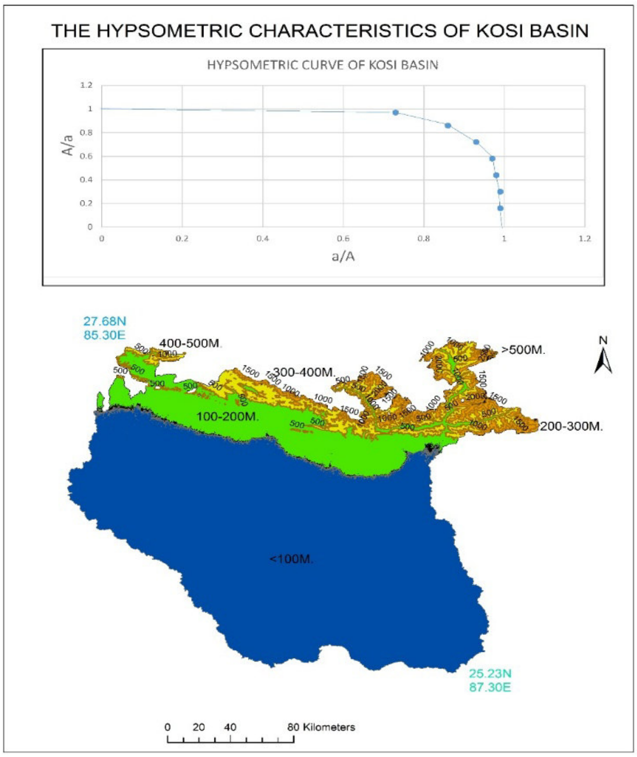


Fig: Hypsometric characteristics of kosi basin

Shifting of kosi belt: The channel movements of the Kosi River have been described as 'avulsive' shifts. Before focusing on the dynamics of the Kosi River in particular, it is imperative to discuss the basic mechanism and anatomy of avulsion. As mentioned before, avulsion involves a sudden movement around a nodal point (divergence point) and occurs when an event of sufficient magnitude (usually a flood) occurs along a river that is at or near avulsion threshold (Fig. 3). Avulsion threshold (Jones and Schumm, 1999) is defined by the changing channel instability through time represented by line the slope, curvature and shape of which vary from river to river. The vertical lines on this figure represent floods of different magnitude. It is obvious from this figure that avulsion may not always be triggered by the largest flood in a given river, and that even a small flood can trigger an avulsion if the river is close to avulsion threshold. One of the most common mechanisms of avulsion is 'channel reoccupation' (rapid) when the new channel occupies a pre-existing channel in the vicinity. On the other hand, 'crevasse splaying' involves a gradual process of breaching through the banks and development of a new channel through time.

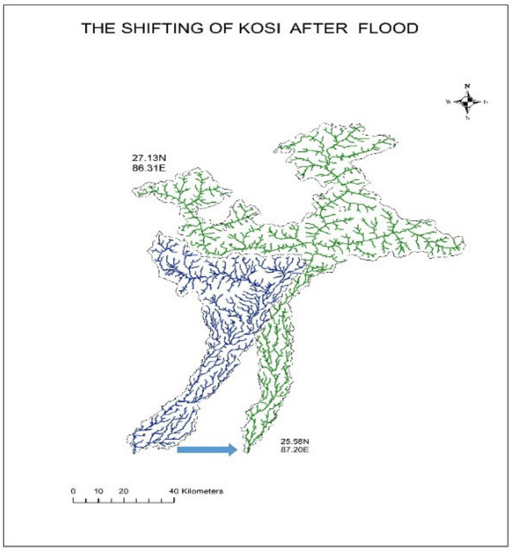


Fig: the shifting of kosi belt

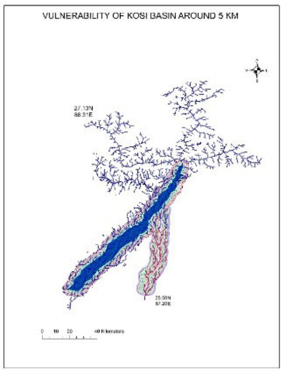


fig: the vulnerable zone of kosi

Land use and land cover changes in kosi Basin:

The Koshi or Kosi River drains the northern slopes of the Himalayas in the Tibet Autonomous Region and the southern slopes in Nepal. From a major confluence of tributaries north of the Chatra Gorge onwards, the Koshi River is also known as Saptakoshi for its seven upper tributaries. Include the Tamur Koshi originating from the Kanchenjunga area in the east, Arun River from Tibet and Sun Koshi from the Gosainthan area farther west. The Sun Koshi's tributaries from east to west are Dudh Koshi, Bhote Koshi, Tamba Koshi and Indravati Koshi. The Saptakoshi crosses into northern Bihar where it branches into distributaries before joining the Ganges near Kursela in Katihar district.

The Saptakoshi is 720 km (450 mi) long and drains an area of about 61,000 km2 (24,000 sq. mi) in Tibet, Nepal and Bihar. In the past, several authors proposed that the river has shifted its course for more than 133 km (83 mi) from east to west during the last 200 years. But a review of 28 historical maps dating 1760 to 1960 revealed a slight eastward shift for a long duration, and that the shifting was random and oscillating in nature.

Land Use and Land Cover Changes Methodology: The present study is an attempt to find out the land use and land cover changes as a reflection of river course shift in surface water bodies. The study is carried out using multitemporal satellite data of Landsat MSS, 13th DECEMBER, 1976 (path/row: 150/42,150/41,151/42,151/41), Landsat TM, DECEMBER 1992 (path/row: 139/42,139/41,140/41.140/42) and LANDSAT ETM (path/row: 139/42,139/41,140/41.140/42) 2000 .And, Landsat TM, DECEMBER 1992 (path/row: 139/42,139/41,140/41.140/42),2010. Ancillary data like Survey of India topographical maps on 1: 50,000 scale and ground truth information are also used. Erdas Imagine 14 software was used for geometric correction and digital image processing. The image to image registration of data is carried out using orthorectified Landsat ETM + data, which was obtained from Anonymous (2004). For registration Ground Control Points (GCPs) are well distributed throughout the scene. The first order polynomial transformation with nearest neighbor resampling technique has been adopted and a registration error (root mean square error) of the transformation 0.28 was obtained (<1 pixel error). Landsat MSS, Landsat TM and Landsat ETM satellite datasets were resampled to 57 m to maintain similar spatial resolution as like Landsat MSS. After0 the registration of digital images, the training samples for each land use and land cover classes have been collected from image. The multispectral classification was carried out using supervised classification techniques with maximum likelihood classifier. Prior to this, homogenous sites in the image were located in each land use class. These are called training sites. Then multivariate statistical parameter viz. mean, standard deviation, covariance matrices, correlation matrices etc., were extracted for each training site. Every pixel both within and outside these training sites is then evaluated and assigned to class by using maximum likelihood classifier. Classification was performed separately for multitemporal image datasets. Spatio-temporal change analysis was determined by comparing multi-temporal images.

LAND USE TYPE	2010	2000	1992	1976
MAIN RIVER	412	797	995	1044
RIVER VALLEY	3557	1423	930	1341
ALLUVIAL FAN	872	720	1753	1322
SETTLEMENT	2352	2987	2780	1661
DENCE FOREST	3130	3396	4247	6644
OPEN FOREST	557	1596	2000	1877
CULTURABLE LAND	3978	3412	2100	612

Table: The major land use and land cover area of Kosi Basin (km2)

The land use and land cover map of kosi Basin of different year: The general lulc changes are following

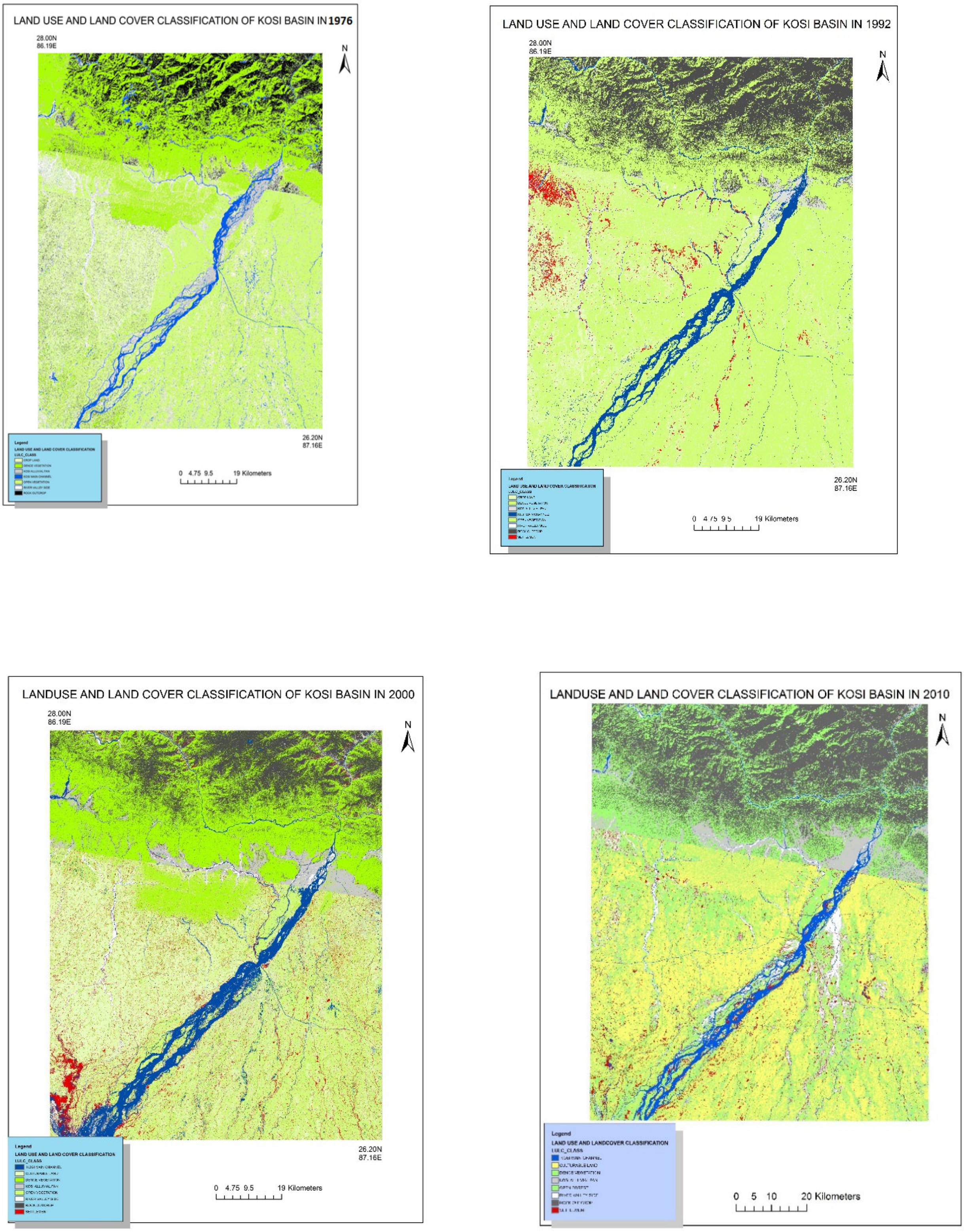


Fig: the landuse and land cover map of kosi basin in distinctive four year (1976, 1992, 2000, and 2010).

Conclusions

Remote sensing is a reliable tool for understanding the historical transformations that have taken place in recent decades in the AOI, especially for unveiling the 'long-term' pattern, rates, and trends of LULC changes in an area that is representative of many other agricultural landscapes undergoing heavy changes within this very important biome. The changes detected point towards increasing loss and fragmentation of natural vegetation. Between 1985 and 2005, Due to the river channel shifting the alluvial fan expand more .Also shows that the intense pressure of landuse causes forest cover change. Which indicates the intense pressure of agricultural expansion on the natural vegetation resource. The trends of changes were 'from' natural resources 'to' annual crops. High annual rates of crop expansion predominated, especially from 1985 to 1995. From 1995 to 2005, the rate was moderated somewhat; however, during this latter period, agriculture advanced into more fragile lands. Thus, our study provides the foundation for further analysis towards linking these massive LULC changes to other environmental changes, as for example, changes in erosion risks, water quality, and biological diversity, among others**.**

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