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Mapping of Flood Plain And Flood Reach of Rapti River in India using Remote Sensing & GIS Techniques

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ABSTRACT-The Rapti River is one of the most dynamic river of Ganga Plain and is characterized by frequent bank erosion resulting in the shifting of bank line. Today, river dynamics and hydrological behavior are strongly influenced by human activities in both catchment and inland areas. Knowledge of recent and historical fluvial dynamics and related structural and morphological changes on the land surface (e.g. Sedimentation, accumulation, movement of the river bed) is a key factor in assessing the risk of flooding and vulnerability of human resources and structures. The geomorphological approach for the study of sub-catchment of river Rapti in parts of Uttar Pradesh attains significance of in view of dynamic changes in Rapti channel and activation of old channel and there water logging during rainy season and consequent risk to the existing civil engineering projects. Satellite images are permanent pictorial records of the terrain and remote sensing satellite have the ability to provide repetitative coverage of of the same area at a particular interval of time. In this study satellite images of the underlying area of Rapti River make it possible to identify and demarcate the fluvial features and the emergence of newer one switch active and old flood plains of Rapti River. The emergence of new fluvial characteristics and the degradation of the earlier one is attributed to the channel separation or otherwise successive channel migration caused by high discharge or floods. Lateral expansion, translation of meander and cut-offs formation are responsible for altering the planform of the channel. As conclusion, it is shown that the combined analysis of satellite data information will be very useful in the flood application domain, especially with respect to risk assessment and vulnerability mapping.

Keywords: Space-borne Earth Observation, River Dynamics, Flood, Floodplain Structures, Floodplain Management.

I INTRODUCTION

The impact on rivers and floodplains of human activity and water regulation is well known. The more intensive river basins are used by man and the lesser user functions are adapted to the characteristics of the natural river, the greater the damage if a flood crisis occurs. It is not possible to prevent floods of great magnitude, but flood damage can be limited. Studies of the spatial and temporal flood distribution are essential in order to take successful measures. Floodplain management also requires the characterization of floodplain structures and information on the extent and dynamics of the river. Remote sensing and geographical information systems (GIS) are important tools for analyzing and visualizing geographical entities in river systems and for supporting decision - making on management measures.

Fluvial geomorphologists are using remotely sensed satellite images together with GIS to detail and monitor geomorphic processes and resulting landforms at different spatial scales ranging from basin to reach. The alluvial rivers are the most dynamic geomorphic agent of the fluvial landscape. They adjust width, depth, area and hydraulic radius regularly in response to variable discharge and supply of sediments. The multidate satellite images and DEM data are very useful for precisely quantifying these adjustments in a short period of time. The geomorphic effect of flooding is also assessed through the competence of stream to alter the shape and size of landforms and amount of erosion generated during floods (Wolman and Gerson,1978). Sinha et. al. (2005) used sediment yield and stream power data for geomorphic characterization of the Gangetic plain.

The main aim of the research described in this paper is to assess the feasibility of using satellite imagery for the floodplain management. Landsat and LISS 3 data products were used to document the pattern of floodplain inundation, floodplain structures and morphological changes due to flooding (e.g. erosion, break of a meander). Selected sites in the floodplain of the River Rapti were analysed regarding the flood risk estimation and the vulnerability of resources and structures.

II STUDY AREA

The entire Rapti river basin extends from 26° 18' 00" N to 28°33'06" N and 81°33'00 E to 83°45'06" E and covers an area of 25793 km2 out of which 44 % (11401 km2) lies in Nepal and 56% (14392 km2) in Uttar Pradesh. The Rapti River flows in the sub-humid to humid monsoon region of the middle Ganga plain. It is the largest tributary of River Ghaghra, which in tum, is a major constituent of the Ganga. It flows through the districts of Bahraich, Shrawasti, Balrampur, Siddharthnagar, Santkabirnagar, Gorakhpur and Deoria districts of Eastern Uttar Pradesh. The study mainly deals with fluvial process and related aspect of arable land in the lower Rapti floodplain which largely comes under the administrative limits of Gorakhpur district. This district is one of the worst flood affected district of the basin. The Rapti river in this particular stretch is very dynamic and frequently inundates considerable area.This part of the basin is densely populated. Area along the river is extensively cultivated. Therefore, the lower Rapti floodplain is an appropriate area for the study of fluvial processes and impact of these processes on the arable land. Apart from this, other factors such as knowledge of regional dialect, availability of data and conducive working conditions also have played an important role in selecting the area for this study. The general slope of the plain is towards east (Yadav, 1999)*.

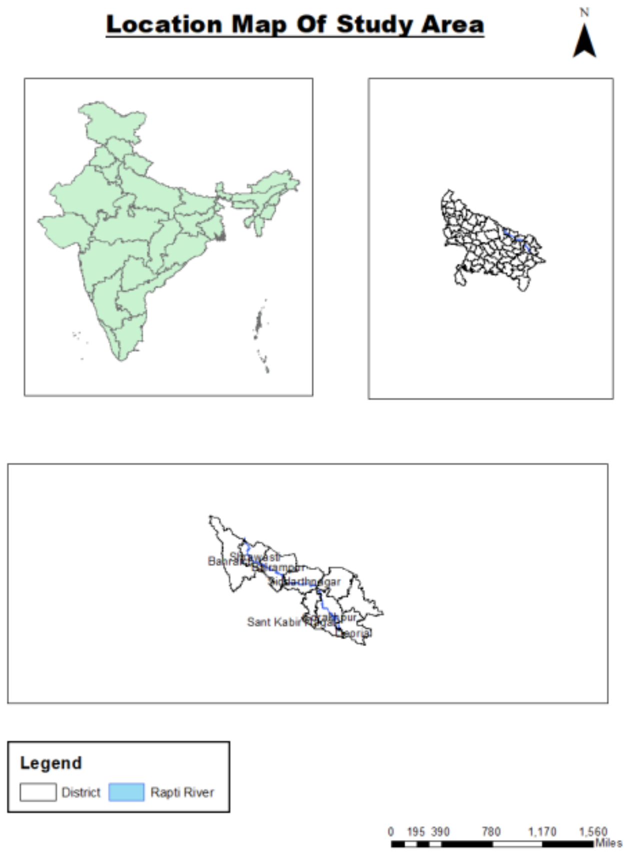


Fig 1. Location Map of Study Area

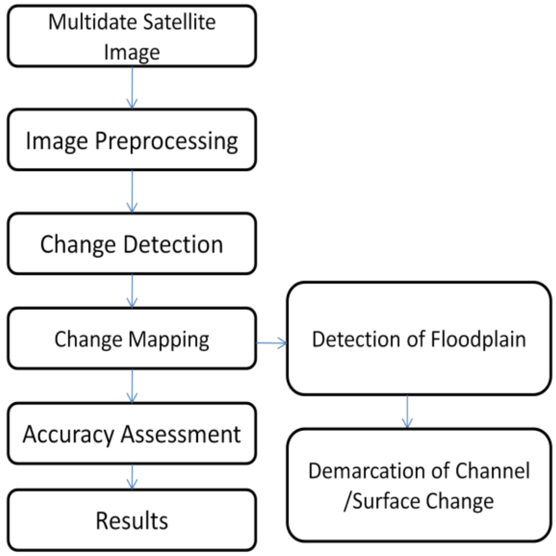
III DATA BASE AND METHOD

3.1. Data

The basic data used in this study are digital satellite images of Indian Remote Sensing LISS-III (Path/Row 100/51,52; 101/51,52; 102/51,52) sensor, comprising of scenes for the years 2008. The other collateral data used in the present study are Survey of India toposheets (63N/6, 63N/2, 63N/1, 63J/13, 63I/12, 63I/16,62H/12) 1:50,000 scale and Landsat 8 images of the year 2018 which are freely downloadable from the web- site www.glcf.umiacs.umd.edu/data/landsat.
ERDAS Imagine 10.15 image processing software has been used for processing the satellite images. ArcMap 10.2 GIS software has been used for analysis of the river bank data.

3.2 Methodology

Satellite images for years 2008 and 2018 have been processed to obtain the required information about the study area. The following section describes the preparation of satellite images for information extraction:



3.3 Multitemporal Approach

The multitemporal image is a system of producing colour imagery that is based upon the additive properties of primary colors. The multitemporal technique uses black and white radar images taken on different dates and adds them to the red, green and blue color channels. The resulting multitemporal image (RGB) reveals change in the Earth's surface by the presence of color in the image. The hue of the color indicates the date of the change and the intensity of the color the degree of change. The reason for change may be the growth of crops, a change in soil moisture, a change in soil structure, or the presence of floodwater in one image where there was none before. In this study, two images from different time intervals can be used in order to distinguish flooded areas from permanent surface water. A multitemporal colour composite with three images taken before, during and after flood, is able to show the flood progress but also morphological changes as accumulation or erosion.

3.3.1 Change detection analysis (e.g. flood evolution monitoring): Changes can either be detected by optical sensors looking for geometric patterns, or by classifying textures. Here, the benefit of the satellite image is the potential of image acquisition under all weather coverage, a typical situation during the flood crisis phase (e.g. monitoring the flood evolution).

3.3.2 Detection of small surface movement: The detection of small surface movements is one of the most challenging applications in this field. It has a special relevance for detecting hazardous phenomena like subsidence, dunes, crustal motion, etc. But also in the flood-disaster monitoring (e.g. damage estimation) it provides useful information. The detection is based on differential image processing.

3.3.3 Generation of Digital Elevation Models
(DEMs): DEM's are important base information for civil engineering activities and environmental planning (e.g. retention areas). For differential processing there is a need of DEM's that remove the terrain height influence. The generation of DEM's from remote sensing is of high importance because of the very limited availability of products for most of the regions on earth.

IV.RESULTS AND DISCUSSION

4.1 Floodplain and Floodline Geomorphology:-

Floodplain structures plays a important role for the potential of flood retention. The detection includes different types of land cover like floodplain forests, herbs and bushes, thin woodland vegetation, meadows and agricultural field as well as other flood plain related features such as rivulets, canals, ditches and different types of former river structures. The hydraulic properties of the section of the river vary with time. It is laborious and expensive to adequately monitor changes with conventional techniques (aerial photographs and field studies) in the floodplains. So, faster, cheaper and more efficient techniques are needed in the future to monitor vegetation and structure in large parts of the river basin. In certain studies, aerobic laser altimetry is used. However, a method involving spatial satellite data also appears to be promising in this context.

Using the derived data as input for water flow models, the constantly changing conditions in flood plains can be monitored quickly and cheaply and the river analyst can ensure sufficient water flow capacity in a dynamic river bed. The valley and the floodplain are characterized by thick deposits of alluvium. The entire canal and active floodplain are partially confined to the valley. The active canal therefore deviates from both the valley and the axis of the floodplain. The average width of the valley and the floodplain is about ~5.4 Km and ~5 Km. The processes involved in floodplain evolution and distribution of sediments are vertical erosion and aggradation coupled with lateral erosion and deposition which are further associated with shifting of meanders across and downstream in the active floodplain (Gregory and Walling, 1973). The CMZ retains complex and episodic side erosion and deposition events due to the meander shift. It covers approximately 38.5% of the area of the active flood plain of the river. Based on Gregory and Walling's classification scheme (1973), the floodplain features are divided into three groups i.e. lateral accretion, intermediate and overbank features. Further, these features cover 23, 12 and 5 per cent of active floodplain area respectively.The present day channel adjustment and active depoisition are restricted to the active flood plain surface.Though some active deposition is also taking place on the old plain surface the sediment on this surface are not deposited by river themselves but by their other subsequent tributaries and minor channel and gullies.older flood plain are cut into old alluvial plain which is evident by it 1m to 2m lower elevation as compared to latter.The active flood plain is develop[ed within the old flood plain and is characterized by narrow and not so continous starch of land running parallel and subparallel to the Rapti river.The suspected point bars developed at the active flood plain of rapti river define the limits of the Active Flood Plain at some places its stretch in balrampur and siddarthnagar districts Active flood plain of rapti and and its tributaries is the youngest geomorphic surface in the study area and are flooded almost every year.

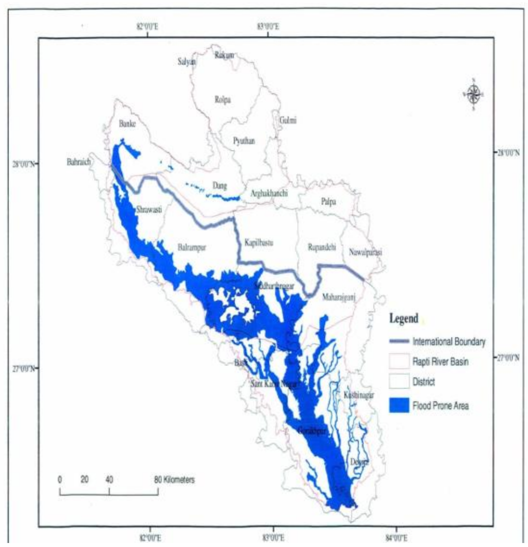


Fig2.Flood Prone Areas in Rapti River Basin

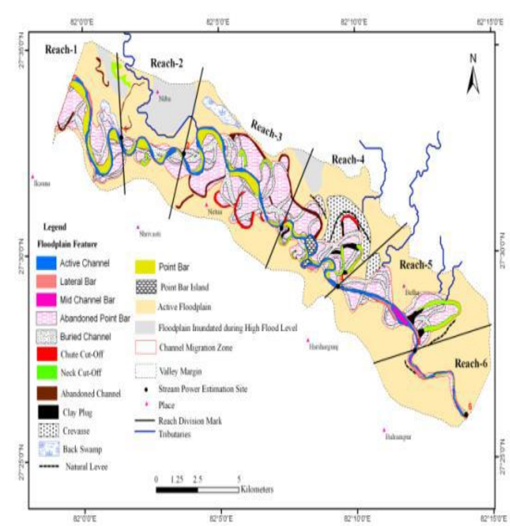


Fig3. Floodplain Morphology of the Study Stretch

4.2 Channel Pattern:

Various relict channel on old flood plain indicate frequent channel migration within this geomorphic surface in the recent part during high floods. Abondened channel of Rapti river are developed within the active and old flood plain. These are in fact cut braided channels of Rapti river which have recently ceased to exist as active channel of the river. However during high flood this may get activated .The paleochannel of Rapti River along with other relict channels such as old meanders and oxbow lakes are conspicuously observed on high resolution satellite data .These paleochannels are developed on the older alluvial plain and old flood plain surfaces and are evidences of old path phase of Rapti river or any other river system.River Rapti is characterized by its meandering behavior throughout its length in Balrampur,Siddharthnagar,Gorakhpur and Deoria districts. However in the upstream area of the Shravasti district the channel is anatomizing and gradually transforms into a meandering channel in downstream.The wide river valley of Rapti River is characterized by old flood plain surface in shravasti and western part of balrampur district and sudden change in its NW-SE course as it enters Gorakhpur district again a broad flood plain in Gorakhpur and deoria districts indicate some kind of tectonic control on the river course.

All alluvial rivers are classified into three categories i.e. meandering, braided and straight (Leopold and Wolman, 1957). The meandering streams have distinct planform with point and mid channel bars. The sinuosity index of 1.5 and above was defined for meandering streams by Leopold and Wolman (1957). However, the straight channels reflect a sinuosity index of less than 1.5. Contrary to these sinuosity values, Schumm (1980) defined the range of sinuosity index between 1.2 and 2 for meandering streams and less than 1.2for a straight stream. Further, he classified alluvial channels into two major categories i.e. stable and unstable channels. A stable channel demonstrates a fixed bed and bank while an unstable channel shows frequent changes in bed as well as bank position. Thus, on the basis of sinuosity index values defined by Schumm (1980), the Rapti river demonstrates a meandering and unstable channel pattern.

In studies of rivers, the sinuosity index is similar but not identical to the general form given above, being given as the difference from the general form happens because the downvalley path is not perfectly straight. The sinuosity index can be explained, then, as the deviations from a path defined by the direction of maximum down slope. For this reason, bedrock streams that flow directly downslope have a sinuosity index of 1, and meandering streams have a sinuosity index that is greater than 1.

It is also possible to distinguish the case where the stream flowing on the line could not physically travel the distance between the ends: in some hydraulic studies, this leads to assign a sinuosity value of 1 for a torrent flowing over rocky bedrock along a horizontal rectilinear projection, even if the slope angle varies.

For rivers, the conventional classes of sinuosity, SI, are:

- SI <1.05: almost straight
- 1.05 ≤ SI <1.25: winding
- 1.25 ≤ SI <1.50: twisty
- 1.50 ≤ SI: meandering

It has been claimed that river shapes are governed by a self-organizing system that causes their average sinuosity (measured in terms of the source-to-mouth distance, not channel length) to be π,[3] but this has not been borne out by later studies, which found an average value less than 2.(Wikipedia(Leopold, Luna B., Wolman, M.G., and Miller)).

4.3 Surface Changes

The point bars on rapti river all along its channel indicates it migratory behavior. This is also evident by presence of paleochannel the oldest geomorphic surface of the study area i.e the older alluvial plain, whereas the abandoned channels are confine d mostly to active and old flood plain. Previous researchers (Thakur and Singh,2014)have termed Rapti river as one of the most migrating river of Ganga Plain and supplemented their view by discussing the high concentration of the point bars channel bars cutoff meanders and paleochannel in the proximity of Rapti River .

During the course of present study a number paleochannels, oxbow lakes, old meanders and meander scars identified through digital enhancements, visual interpretation indicate that these relict channel might have been the ancient pathways of Rapti River and its tributaries. Contarary to the abandoned channels the paleochannel might have ceased to exists as active river channel much before the abandoned channels. Tectonic control of some starches of Rapti Channel and it tributaries streams has also been discussed by some previous researchers(Srivastava et al,1944,Pati et al,2011,Thakur and Singh,2014).Almost parallel and subparallel piedmont streams draining into Rapti on its left bank in parts of Blarampur and Shravasti districts seem to have their incised courses controlled by NE-SW and N-S trending lineaments.

4.4 Vulnerability Mapping

The basic problem concerning floodplains is the conflict between human uses of river environments on the one hand and floodplain resources and natural functions one the other. All natural and cultural resources and functions of floodplains are subjected to threats, the most significant of which are related to human use and development.

The permanent location of settlements, industrial plants, infrastructures as well as agricultural activities within floodplain are the most common infringements in contemporary times and result annually in ever increasing damages, risk for human life, personal inconveniences, and material loss world-wide, when floodwaters reclaim these lands. Natural hazards are having an increased impact on human settlements, probably because of the greater number of settlements and their increased vulnerability due to their uncontrolled extension to high risk areas. The response and policy options to counteract are wise land use and emergency planning to reduce the impacts of floods and other hazards and their interactions with human activities.. The combination of the DEM with flood lines and information about land use and infrastructure will result in vulnerability maps. With this kind of thematic product, the option exists to estimate the flood related risk for the sensitive areas. In addition, vulnerability maps will provide an option to support floodplain-planning activities, especially with view to the installation of retention areas and the reduction of unadapted forms of land use.

5. CONCLUSIONS

Old Flood Plain, Upper and lower Piedmont and Active Flood Plain are the various geomorphic surfaces in the study area. The broad flood plain of Rapti River with numerous relict channel including meandear scars, oxbow lakes, old meanders and palaeochannel when analyzed in conjuction with high sinuosity of Rapti channel and its active flood plain indicated the proneness of the active as well as old plain to frequent fluvial activity. This can be attributed to frequent flooding during rainy season. Hence active as well as old flood plain of rapti river all through the length in Shravasti, Balrampur, Siddarthnagar, Maharajganj, Gorakhpur and Deoria districts should be avoided for colonization and construction of infrastructure facilities other than bridges, barrages and canals. In these districts even the civil engineering structures such as bridges and barrages should be constructed after remote sensing and GIS based detailed studies on channel dynamics since migratory behavior of Rapti River and its tributaries poses a great threat to civil engineer projects across and in close proximity of flood plain and their relict channel(Palaeo channel and old meanders).The significant reduction of the floodplain available for flood extension is affecting the dynamic behavior of the river linked with a rise in the risk of breaks in the embankment. The flood risk can be minimized by a wise use of the landscape, which includes the historical information into the river basin management. Especially the EO-derived DEM's and their indication of the spatial dimension of former areas available for flooding should be taken into account into the planning process. It is not sufficient only to come from a regional, sectional approach towards an international, integrated approach. We also have to include historical information, partially derivable by Satellite Observations.

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