

# Geomorphic Features and Flood Susceptibility Zones: A Study For Allahabad District, Uttar Pradesh, India, Using Remote Sensing and GIS Technique

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## Abstract

*The paper using satellite imagery and GIS attempts to associate geomorphology in defining flood susceptibility zones in Allahabad district, Uttar Pradesh, India. Varied landforms found in the district are the result of the processes of erosion and deposition that were operated in the past and are still continuing. Flood plain and associated features in the northern part of the district got formed during the Quaternary period whereas numerous landform features in the southern part were defined by the development of Vindhyan plateau during Pre-Cambrian to Recent periods.*

**Keywords:** *Geomorphic features, Flood susceptibility, Satellite imagery.*

## Introduction

Geospatial information technologies especially remote sensing and geographic information science now provide a new dimension of time saving and cost effective as well as interactive approaches to geographic researches (Mishra, 2006). Satellite imagery is helpful in demarcating the geomorphic features of a large area. The temporal, spectral and spatial resolutions of remotely sensed data are valuable for analyzing geomorphic dynamics and mapping of relief and landforms. The geomorphic mapping using remotely sensed data has received great impetus in regional surveys during the recent time at macro, meso and micro scales (Hazra, and Bhowmik, 2000). The present exercise attempts to map out the distribution of landforms and its lead in defining flood – prone areas for Allahabad district, Uttar Pradesh using remotely- sensed data and GIS.

## Study Area

Allahabad District (24° 45'N to 25° 45'N) and (81° 30'E to 82° 30'E) lies in the south eastern part of Uttar Pradesh, India at the confluence of holy rivers Ganga, Yamuna and invisible Saraswati, popularly known as Triveni Sangam. Allahabad district occupies an area of 5246.0 sq.km with a population of 59, 54,391 persons (2011). Geologically it exhibits more complex nature and broadly be categorized into Recent alluviums in the north and Vindhyan system in the south. (Fig.1).

## Data and Methodology

Topo-sheets of survey of India at the scale of 1:250,000 (No. 63G, H, K and L) alongwith remote sensing data of IRS P6 and LISS-III both in digital format and hard copy (Path 101 and Row 54) were consulted

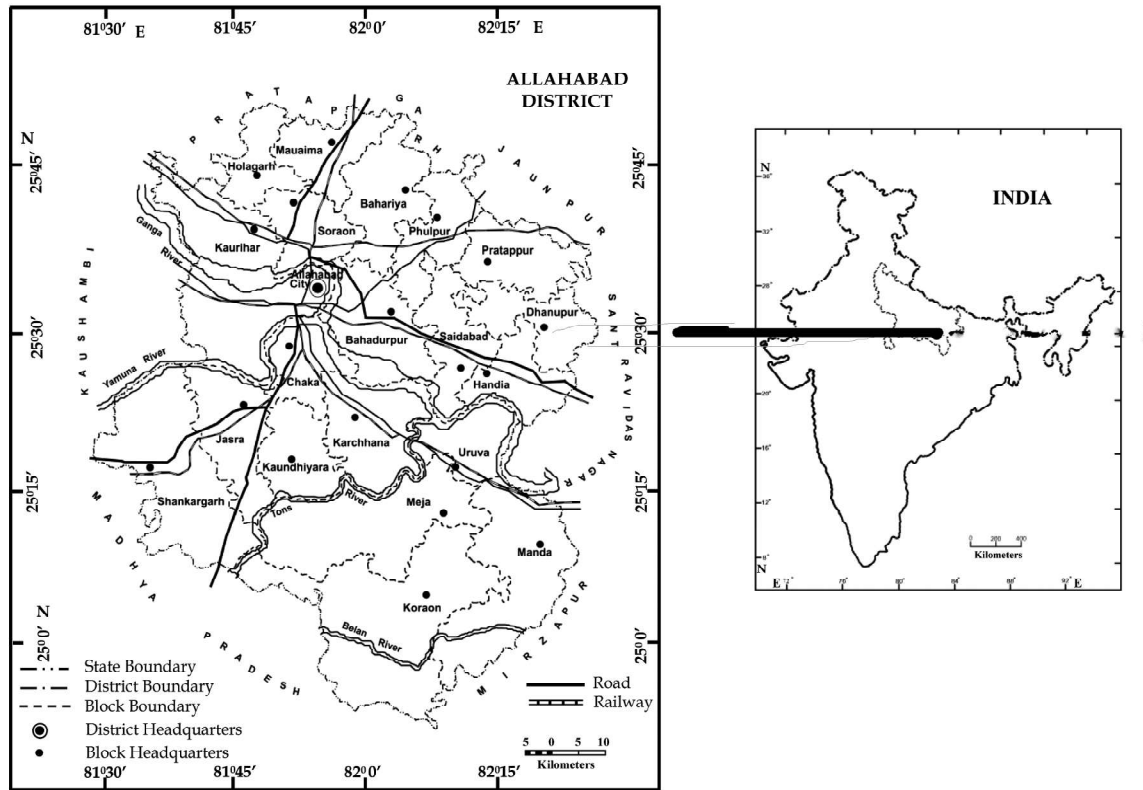


Fig. 1 : Location Map

for demarcating and mapping of landform features and flood susceptibility zones in the following sequences:

First, the base map was prepared based on topo-sheet by adopting different steps of geo-referencing, mosaicing and subset creations. Second, pre-field satellite image interpretation for identification, demarcation and mapping of geomorphological units and flood susceptibility zones were attempted by using visual image processing techniques. Third, the interpreted image-based information was transferred on base map by selecting numerous control points and using ERDAS software. Fourth, selective field checks were done to assess the validity of the pre-field image interpretation. Finally, incorporating the necessary corrections,

image-based maps were completed by using Arc View.

### Geomorphic Processes and Features

The area under study appears to be the result of complex geologic and geomorphic processes. In the northern alluvial plain, river Ganga with its tributary, Yamuna, have been playing a dominant role in shaping and reshaping the landforms with their frequent changes in courses. On the other hand, the southern part covered under Vindhyan plateau is flown by rivers Tons and Belan. The Ganga flood plain features include, new flood plain, old flood plain, paleo channel, channel bar, point bar and ox-bow lakes etc. while Vindhyan upland includes the features like buried pediment, pediment

with vegetation, pediment with stony surface and denudational hill etc (Fig. 2 & Table1). The geomorphic features of the study area are largely governed by the geomorphic processes, geologic structures and stages of development. For example, the area of recent alluvium, i.e., Ganga flood plain bears more landform features developed by erosional and depositional actions with less variation in gradient while the Vindhyan upland on the other hand, characterizes with undulating surface caused by complex geomorphic processes.

### **Geomorphic Features in Ganga Flood Plain**

The flood plain surface can geomorphologically be defined as landform composed primarily of unconsolidated depositional materials derived from sediment being transported by the related stream (Schmudde, 1968). The flood plain features of the study area are created by sedimentation of alluvial materials brought down by the Ganga and its tributaries. It is characterized by various geomorphic features as discussed below:

**New Flood Plain:** New flood plain locally known as 'Khadar', represents the tracts of newer alluvium formed by the floods of streams. It is generally considered as an integral part of the streams where deposition of sediments occurs during each flood. The soil of this zone is extremely fertile. On the imagery, such landforms are characterized by dark red tone, smooth texture, and irregular shape. The new flood plain zones are more prominent along the banks of the river Ganga especially at its confluence zones with Yamuna and Tons such as near the city of Allahabad, Sirsa town and villages of Usmanpur, Pansa, Laktha etc.

**Old Flood Plain:** Old flood plain (OFP) locally known as 'Bangar' represents older alluvium of higher ground located far from the channels. This older or outer flood plain has been generally observed on satellite imagery with varying characteristics in photo elements which are used in dividing it into OFP type-I (light to dark red tones), OFP type-II (light red mixed with gray tones) and OFP type-III (red mixed with white tones).

**Point bar, Channel Bar and Island:** Point bars are formed on the convex side of meanders and grow by individual increments outwards into the meander curve (Thornbury, 1969). One of the prominent bars may be observed in the southern bank of river Ganga near Allahabad city. Numerous point bars may be identified near the villages of Muhammadpur, Amod Chail, Lawain Kalan, Mungari, Laktaha, Usmanpur and Paranipur. Point bar formation by river Yamuna is limited at a few locations because of its restricted course governed by Vindhyan formations.

The channel bars are formed by the deposition of huge amount of sediments in the course of a stream with an elongated shape (Mishra and Chaubey, 1999). Formation of channel bars takes place within the streams, creating islands that split the stream into several channels (Schmudde, 1968). Sizeable channel bars may be marked at many places in the river Ganga especially towards north and north-west of Allahabad city and they are easily marked by very light tone on satellite imagery. Island is a tract of land in the river surrounded by water of a stream. In due course of time, the island may become the part of the flood plain when any one side of the channels becomes dry and is filled with sediments. A well-developed island is located in the river Ganga near

Dubawal village of Bahadurpur block, about 20 km to the east of Allahabad city.

**Natural Levee:** Natural levees are narrow belt of higher relief that is formed by the accumulation of sediments brought by the rivers during floods when water overflows its banks and spreads over the adjacent flood plains. On satellite imagery, these features can be marked by light to grey tones on lands higher to the surrounding areas. Some of stabilized natural levees are noted to be the good sites for location of old cities / towns like Allahabad, Phaphamau, Jhansi (older name Pratisthanpur), Naini, Sirsa etc. Generally, the natural levees are supported by back swamps in their countryside (back region) but in reference to Allahabad district, these features are either merged with new flood plain zone or not visible due to human interference.

**Ox-bow Lake and Palaeo channels:** An oxbow lake is a crescent-shaped often ephemeral body of standing water situated on the abandoned channel (oxbow) where the stream -neck is cut-off and later filled up with silted materials such as in the Gangapar region (Phulpur, Saidabad and Dhanupur areas). Palaeo channel may be preserved as abandoned surface channels on flood plains or might have been unfilled by fluvial or other sediment and are exposed as isolated sediment section (Thomas and Andrew 2002). The satellite images provide a clear vision of palaeo channels because of their specific terrain characteristics, underlying materials and land use. The earlier river courses bear their distinct appearance with dark tone, irregular pattern and crescent-shape on satellite imagery.

## **Geomorphic Features on Vindhyan Upland**

The Vindhyan upland is composed mainly of fluvio - marine deposits of probably the Cambrian age, which might have got uplifted and peneplained several times (Pichamuthu, 1980). A great variety of geological and lithologic phenomena existed in the area influenced the remarkable formations of landforms. Weathering played a vital role in dissecting several blocks of the rocks. Landforms identified on Vindhyan Uplands by image interpretation may be noted as pediment with stony surface (Type I), pediment covered with vegetation (Type II), shallow buried pediment, deep buried pediment and denudational hill (Fig 2 & Table1).

**Pediment:** A pediment is a gently inclined erosional surface carved in bedrock, thinly veneered with gravel, and developed at the base of mountains. The term pediment is used to designate the open rock – surfaces created by complex geomorphic processes including weathering and erosion. They are mostly surfaces of flat to very low slope and sometimes, attached with denuded hills. The pediment is the characteristics feature of Vindhyan Upland. There are two types of pediments identified on the basis of image interpretation. Pediments type I generally visualized by light to very light tones (whitish) due to higher reflectance caused by open rock surfaces uncovered with vegetation such as in Shankargarh, Koraon, Meja and Manda blocks of the district. Along the road from Shankargarh to Nari Bari one may see a characteristic pediment formation showing extensive bare rocks and dissection in the upper parts. To the south of Meja town, such pediments of low gradient

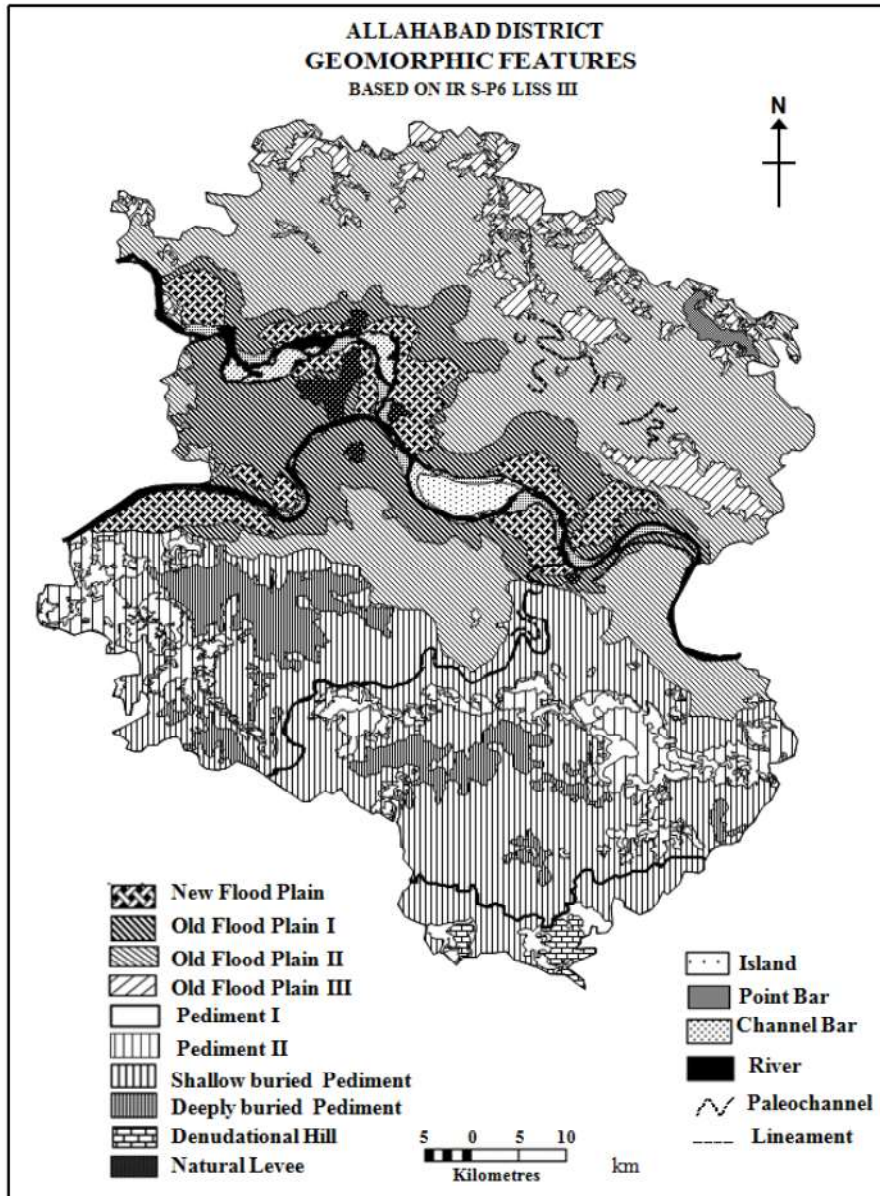


Fig.2

are found rising from the southern margin of Ganga flood plain. Denudational hills are absent in this region, and it may be due to the gradual reduction of the mountain mass (Bloom, 2002) to a flat and rolling surface. Pediment type II are those rock cut surfaces that are covered with veneer of soils mixed with stony waste materials and sparse vegetation or bushes. These features

are found in Yamunapar region. Pediment with Vegetation is very clearly marked on imagery by light to moderate gray tones. Such features may be noted in a narrow strip starting from Shankargarh in the west to Manda in the east. From Koraon to Meja, the pediment type II is marked with scattered trees (Palas) of poor quality.

Table 1 : Image Characteristics of Geomorphic Features in Allahabad District  
(Based on IRS P 6 LISS III)

Geomorphic Features	Tone	Texture	Shape	Size
<b>Ganga Flood Plain</b>				
New Flood Plain	Dark red	Smooth	Irregular	Large
Old Flood Plain- Type I	Light to dark red	Coarse	Irregular	Large
Type II	Red mixed with white	Coarse	Irregular	Large
Type III	Light red mixed with gray	Coarse	Irregular	Large
Channel Bar	Very Light	Coarse	Elongated	Small
Point Bar	Very Light	Coarse	Crescentic	Small
Paleo channel	Dark red			
<b>Vindhyan Upland</b>		smooth	Crescentic	Small
Pediment- Type I	Light to very light	Coarse	Irregular	Large
Type II	Light to moderate gray	Coarse	Irregular	Large
Shallow Buried Pediment	Light to dark red mixed	Coarse	Irregular	Large
Deep Buried Pediment	Dark red to grey mix	Coarse	Irregular	Small
Denudational Hill	Light grey to whitish	Uneven	Irregular	Small

**Buried Pediment:** Buried pediments are those flat surfaces of the plateau area which have thin to thick unconsolidated materials, mainly soil, gravel or weathered rock over them. The buried pediments are very clearly marked on imagery by dark red to mixed tones. They are well-developed in southern part of the district covering Shankargarh, Jasra, Meja, Koraon and Manda blocks. Buried pediments are sub- grouped in two types- shallow buried and deeply buried pediments on the basis of their surface cover and depth of soil. Shallow buried pediments are those where rock beds are found at the depth of one to three metres whereas in deeply buried pediment areas, these beds are found at more than three metres depth. The later type is characterized with good

to very good cultivation in addition to grown up trees and gardens. During field investigation, it was reported by the villagers of Rigwa, Shivrajpur, Hadai (Shankargarh block) that during well digging, they come across rocks at a depth of about 12 -14 m. In Shankargarh area, some quarrying works were going on by private owners for getting the rock fragments to convert into silica sand in the near by workshops.

**Denudational Hill:** Denudational hills are of low relief (356m – 363 m) mostly covered with vegetation. The denudational hills with flat top surfaces are seen at two locations in Yamunapar region (Koraon block) at southeast corner of the district. They are generally surrounded by rocky surfaces partly buried by debris.

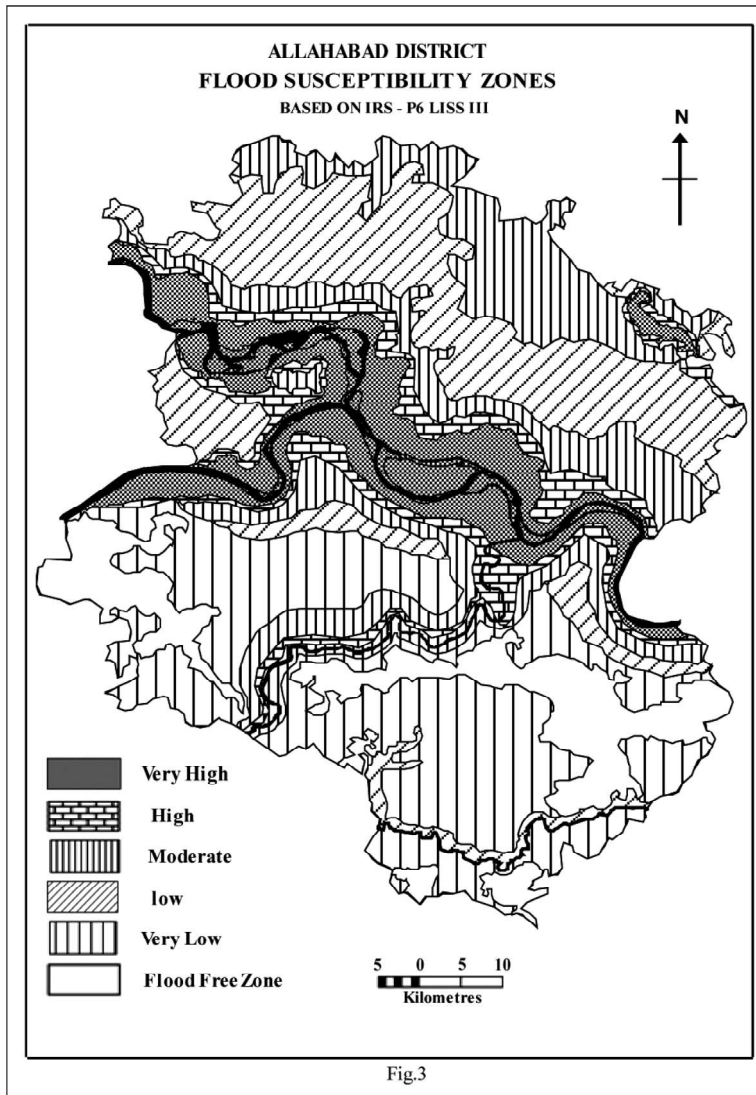
## **Flood Susceptibility Zones**

Flood inundation mappings as well as flood plain zoning are the most essential facts for the country's economic development and environmental management (Kar and Goswami, 1995). Floods are the short-term geomorphic hazards that may affect geomorphic stability of a landform to adversity of living things (Chorley, 1984). The purpose of flood susceptibility map is to map out the areal extent and characters of past floods as well as to predict and assess the damages of future floods of various magnitudes (Cochrane, 1981). Considerable work has been done in Japan to develop the concept of flood susceptibility while in India, the pace of research in this area of vital human concern is rather slow. In mapping the flood susceptibility, emphasis is laid upon, the distributional pattern of the areas of flooding, the duration and depth of inundation, the direction of the current, possible changes in the river course and erosion and deposition due to flooding (Verstappen, 1983). Such information is necessary to adopt the precautionary measures like constructing structures like Bandh for reducing the loss of life and property.

The use of satellite-based remote sensing techniques has significantly improved the quality and coverage of flood susceptibility mapping in the country in recent years. In fact, the delineation of flooded areas may clearly be marked by infrared part of EM spectrum. The important aspects that may be taken into consideration for flood susceptibility survey are micro relief, geomorphological units of the plain and their inherent property with respect to flooding, the deposition of the sediment, bank erosion and other characteristics of the channel bed (Verstappen, 1983).

In present investigation, the mapping of flood susceptibility zones of Allahabad district was attempted by using IRS LISS P6 imagery and selective field visits. The fluvial process is the main geomorphic process in the Gangetic plain. Landforms of the Gangatic flood plain provide a clue for mapping the extent of past floods that are prominently inferred from the high soil moisture content, water logging and marshy lands in the flood affected areas. Geomorphic features and micro-relief (spot height) along with the image elements, and nature of cultural set-up such as roads, settlement, electric transmission line, railway line, height of the bridge and scattered or negligible appearance of trees etc. are considered in mapping of flood susceptibility. The identified zones are classed as very high, high, moderate, low, very low and flood free zone (Fig 3).

**Very High Flood Susceptibility Zones:** The area is located along the rivers Ganga and Yamuna, where water of the rivers easily reaches in the form of flood. Geomorphologically such areas are confined under new flood plain zones and paleo-channels. The average height of these zones is less than 88 m above mean sea level (AMSL). The very high flood susceptibility zones are more remarkable and wider along the trunk river of Ganga especially in the south of Saidabad and at the western margin of Kaurihar block. Generally, these areas are situated under the earlier courses of river Ganga locally known as Kiryat. The very high flood susceptibility zone along river Yamuna is confined in a narrow strip except in the north and north - west of Jasra station where the river takes U turn causing major flood belt. A very small strip of this zone can be marked in the north eastern part of



the district which is affected by the flood water of river Barna. During field check, the villagers reported at Barna market that much of the areas of Mallhan, Birbhanpur and Sarai Kutbuddin villages get inundated during rainy seasons. The main causes of the flood in this zone are the leveled terrain and the poor carrying capacity of river Barna during heavy rains. The terrain configurations of the low land plains and the distributional pattern of gravel, sand, silt and clay deposition resulted from fluvial action in the past by the same

river may be accounted as responsible for the future floods.

**High Flood Susceptibility Zones:** These zones are confined along the very high flood susceptibility zones marked with average heights of 88m – 91m AMSL. They may represent older courses of the rivers. Some of the historical towns like Saidabad, Handia, Hanumanganj and Jasra are located here. They are considered as high flood susceptibility one party because of its location adjacent to the very high one.

**Moderate Flood Susceptibility Zones:** Such areas are confined in between the high and low flood susceptibility zones located in northern and southern parts of the district. They are characterized with dark grey to white tones in patches on imagery because

of reflectance variation caused by marshy and saline (usar) surfaces, and they are prominently seen in Mauaima, Bahariya, Phulpur, Handia and Pratappur blocks situated in the northern parts of the district. A narrow strip of this zone occurs in the north of river Ganga following the high flood zones, stretching from west border of the district to Handia town in the east. This belt is well-known for guava and mango garden which are marked by dark grey linear tone on satellite imagery. The field visit indicated that this zone lies along the older route of

the Ganga. Soraon is the famous market of this belt. Moderate flood susceptibility zones in the Yamunapar region are located in Karchhana, Chaka and Kaundhiyara blocks and are identified on imagery with tonal variations, spot heights ranging from 90m – 94 m AMSL and local nalas.

**Low Flood Susceptibility Zones:** These areas are identified by red to mixed tones on satellite imagery. A very large portion of the district in northern Ganga flood plain stretching from east to west is marked by low flood susceptibility zones. The average height is noticed between 94 m – 97 m AMSL with some local variations. Along the Allahabad – Faizabad road from Soraon to Mauaima, potato and wheat are the main crops. In Yamunapar region, the low flood susceptibility zones are seen in the narrow strips drained by Yamuna, Tons and Belen.

**Very Low Flood Susceptibility Zones:** Very low flood susceptibility zones were identified on satellite imagery by light grey to dark grey tones mainly confined to southern part of the district covering Shankargarh, Meja, Manda, Jasra and some portion of the Karachhana, and Kaundhiyara blocks of Vindhyan Upland. The average height of these zones is 97 m – 100 m AMSL. Geomorphologically, these areas are characterized by buried pediment where flood may occur only when rain is heavy or upstream dams or embankments located on Belen river at Baraundha, Sirsi and Meja and a number of reservoirs situated in Mirzapur district, get burst during heavy rains. With canal networks of Belen, this zone is the one with intensive cultivation. Paddy in Kharif and wheat and massor in Rabi seasons are the prominent crops.

**Flood Free Zones:** Such areas on satellite imagery can easily be identified and marked

by white tones. Flood free zones are mainly found in Shankargarh, Meja and Manda blocks. Geomorphologically, these areas come under pediment and denudational hills where the possibility of flooding is very low because of their higher level of surfaces on Vindhyan Upland. They are characterized with sparse vegetation or forest in patches but mostly accounted as rocky waste lands.

## **Conclusion**

The results of the present study indicate that the remote sensing and GIS are very convenient tools for mapping geomorphic features and flood susceptibility zones of Allahabad district. The remotely sensed data of IRS-P6-LISS III with 23 m resolution is proved to be very suitable for delineating the spatial extent of regional geomorphic features like new flood plain, old flood plain, oxbow lake, natural levee, channel bar, point bar, island, paleo channel, pediment, and denudational hill. These landform features largely help in delineating flood susceptibility zones. New flood plain, paleochannels, channel bars and point bars form the very high flood susceptibility zones. Old flood plain and natural levees, depending on their spatial location, pediments type – II and buried pediments are characterized by moderate to low flood susceptibility zones while pediment type- I and denudational hills are marked with flood free zones .

Allahabad district located at the confluence zone of two major rivers of the country, i.e., rivers Ganga and Yamuna, undoubtedly faces the hazards like flood and hence mapping of flood susceptibility zones appears to be helpful for disaster management of flooding. Some of the settlements are located in the very high flood susceptibility zones as there were no

major flood during the last a few decades and here the authorities should be vigilant enough. The high and moderate flood susceptibility zones although do not bear the flood problem at present but the peoples living here should be aware of the facts that if any damages are caused on the reservoirs and dams constructed on the upper course of the rivers Ganga, Yamuna and Tons / Belen may bring down a havoc. Low flood susceptibility zones and flood free zones are the safe areas that may be considered for planning rehabilitations of flood victims.

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