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Flood Risk Assessment: A case study of Kosi River in Bihar

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Abstract— Asian countries are most frequently affected by high intensity floods, in particular by river floods; Although the number of lives lost has decreased in terms of economic losses, its impact on the population, agriculture and infrastructure has increased significantly. Evaluating flood risk zoning and flood vulnerability of the landscape are key aspects of flood risk management. Landsat 8 OLI and Aster DEM data were used to assess landscape vulnerability to flood inundation and flood risk of Kosi River in Supaul district. The Flood Inundation map was prepared based on the water area and Non water in the images before and during the flood event. The flood risk map was prepared using an equal separation interval based on altitude and flood area. Overlaid on land use and land cover map before monsoon to produce landscape vulnerability to flood. The flood risk map of district shows that temporary river island, sand bank along the Kosi River courses lie in low flood plan and were consider under high risk zone. Flood risk is low in area which are away from the rivers the study suggest that effort should be to remove the sediment for increasing the depth of river spurs and bed bars should be constructed to avoid great loss of agriculture land, property and loss of lives.

Index Terms— Flood risk assessment; Landscape vulnerability; Land use/ Land Cover; Landsat 8 OLI; Digital Elevation Model (DEM); Normalized Difference Water Index (NDWI); Supaul District, Remote Sensing and GIS.

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1 INTRODUCTION

Floods are part of the earth's natural hydrological cycle and have occurred for centuries. Of all-natural disasters, floods are the most repeated natural disasters that occur in one part or another of the world every year. Over time, floods slowly become a flood hazard, mainly due to the occupation of incompatible anthropogenic activities in the flood plains. Otherwise, floods rejuvenate ground water aquifers and help maintain fertile floodplains by depositing rich silt on land adjacent to rivers / streams [1].
Floods are the most frequent type of natural catastrophe and occur when an overflow or water submerges a generally dry soil. Floods are caused by heavy rain, rapid thaw or tropical cyclone storms or tsunamis in coastal areas. Floods can cause widespread destruction, resulting in suffering of life and damage to personal infrastructure and critical to public health (World Health Organization) [2].

More than 2 billion people have been affected by floods living in non-resilient buildings or lacking an alarm system and awareness of flood risk is the most vulnerable to flooding.

According to the European Commission (2007), a flood can be defined as "a natural phenomenon that causes the temporary immersion of a land with water that does not occur in normal conditions"[3]. They are the natural event and therefore cannot be prevented and can have serious consequences, such as the movement of people and damage to the environment [4].
"Flood Risk" is the definition of risk as a product of "Hazard", i.e. the physical and statistical aspects of actual flooding (e.g. flood return period, extent and depth flood) and "vulnerability", i.e. the exposure of people and property to floods and the susceptibility of elements at risk of flood damage[5].

$$R = P \times L \quad (1)$$

When performing risk analysis, risk (R) is considered to be a product of probability (P) and loss (L), " (1) ".
In case study of the Susan River, Ghana. The Land cover data obtained from classified ASTER image, the Contour generated DEM the geometric data extracted from the DEM, topographic map and field measurement collection. HEC-RAS model used as main model to calculate flood plain elevation and determine flood way encroachments the geometric data coalesced with the topographic map to generate the flood hazard maps that covers an approximately 2.93 sq.km indicating flood depth of 4.02m was obtained as the maximum water level and high water depth occurred along the main channel and spread

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gradually to the flood plain. Therefore, recent high-resolution satellite images are needed to create an effective terrain model, as the accuracy of any hydrological model strongly depends on the accuracy of the terrain model is being used [6].

GIS tool with the help of Web-GIS as a decision support tools in relation to the flood risk assessment. Digital Elevation model has been used to produce the hydro graphic network and the hydrological basin layer the morphologic characteristics such as area mean slope mean elevation and total relief were calculated for each basin [7].

The term "flood", flood hazard and flood risk cover a broad range of phenomena the term such as "flood risk" and flood loses are essentially our interpretation of the negative economic losses and social consequences of natural events. Flood risk may increase due to human activity and may decrease by appropriate flood management and planning [8].

2 STUDY AREA

The Study for the analysis includes the part of the Kosi river basin in Supaul District. It is covered between the longitude 86°46'17.66"E to 86°51'18.48"E and latitudes 26°04'40.13"N to 26°17'39.07"N. It includes 11 blocks. Its show the location of kosi river in Supaul district.

The Kosi River or Kosi also known as Saptakosi known for its seven Himalayan tributaries, is a trans-boundary river flowing through Nepal and India. The name 'Kosi' came from 'Kausiki' after the name of a legendry ascetic who was a low cast woman [9].

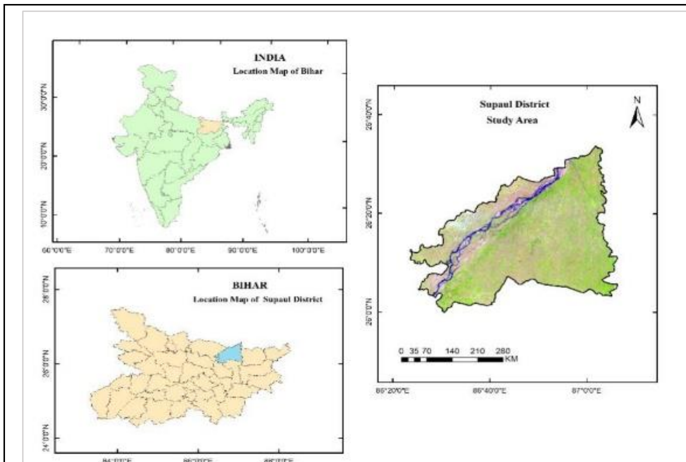

Fig. 1. Locational Map of Study Area

3 DATABASE AND METHODOLODY

The Remote Sensing and GIS are important tools of flood risk assessment which give reliable and accurate information of inundation area, risk etc. For this information we need better resolution of satellite data which give maximum accuracy for flood study. The methodology of Flood risk assessment for district level requires more attention in comparison to the village and block level study. Spectral data collected from the Satellite are extensively used for flood risk assessment around the globe. For Flood risk assessment of Supaul District uses NDWI and Visual Image Classification technique. Landsat 8 OLI data of Pre monsoon (17 April 2017) and Post monsoon (17 September 2017) were used for Land use and Land cover mapping and Aster DEM data was used to assess the flood risk in Supaul District. The study area was taken from Survey of India (SOI) Topographical Sheets (R.F 1: 50,000). The methodology adopted for flood Risk Zonation are presented in fig. 2. basically, we are using NDWI for the showing of water index and highlighted the water pixel area which are helpful analyze flood area. NDWI model of water indices and Visual Image classification is the method of land use and land cover classification on the basis of Ground truth The Statistical data of Supaul district is used for the purpose for analysis of the flood risk by Remote Sensing and surveyed Statistical Data.

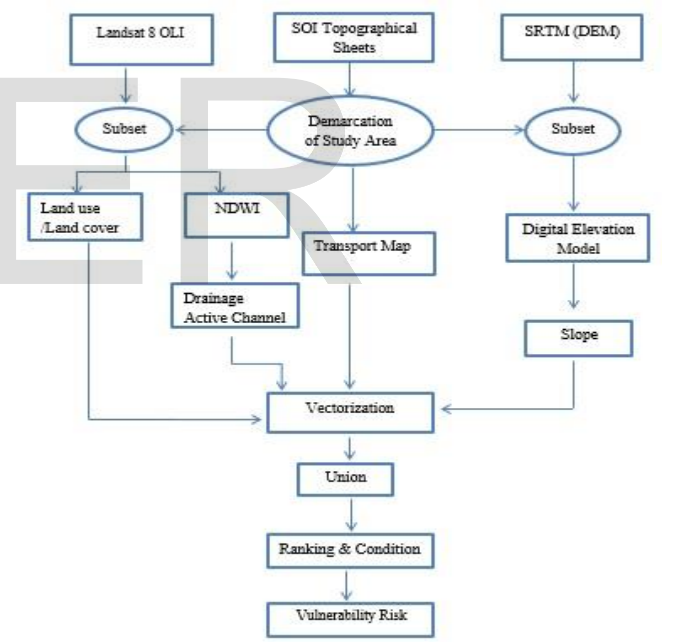

Fig. 2. Flowchart of Methodology

3.1 Land use and Land cover map

Land use and Land cover maps of study area (2017) were generated by Visual classification with the help of Landsat 8 OLI (Operational Land imager). We were using visual classification method and prepare the vector layers of all feature and create land use and land cover. In which shows how much part of land is covered by what type of natural phenomena or how it is used by humans. LULC is prerequisite in lots of projects related to Remote sensing and

GIS because it gives us broad idea of what type of activities is running in that region or if we took LULC map of different year we can easily identify what changes has occurred in certain period of time.

3.2 Normalized Difference Water Index

The Normalized Difference Water Index (NDWI) was obtained to identify water related surface. The main advantage of NDWI is that near infrared (NIR) is highly sensitive to moisture content in the soil and canopy of vegetation. The Normalized Difference Water Index (NDWI) was used to achieve the goal of isolating the characteristics of water and those not related to water features.

$$NDWI = Green- NIR / Green+ NIR \qquad (2)$$

Where NIR is the reflectance or brightness in a near infrared band (0.85-0.88 µm OLI and 0.76-0.90 µm for TM) and Green is the reflectance or brightness in a visible channel (0.53-0.60 µm OLI and 0.52-0.60 µm TM, ″ (2) ″.

3.3 Drainage Active channel

River channel largely of size and shape in cross section, but generally delimited by defined banks that separate the channel from the flood plain. The bank full dimension of a channel combines with the velocity of the flow to determine the discharge it can convey. Discharge increases with increasing catchment area and width or depth of the channel and velocity of the Water also increases downstream.

3.4 Flood mapping

Water versus non-water areas were delineated on Landsat image before, and after flood events and were compared to determine flooded areas. Then identifying water and non-water areas on both images (first image was using after the flood event and the another during the flood) using the above criteria, determination of areas that were flooded was made. The area is identified as dry or non-water on the April (pre-monsoon) image was classified as water on the August (monsoon) image and considered to be flooded. The area identified as dry on both April and December images was considered non-flooded.

3.5 Flood risk Zonation

Flow Risk is categorized based on the level of difficulties in daily life and damage to properties. Flood risk assessment is the estimation of overall effect of flooding. It depends on many parameters such as flow direction, duration of flooding, flood wave velocity and rate of water level. In the present study Flood Risk assessment classified in to five categories: very high risk, high risk, moderate risk, low risk and non-flooded area using equal interval of separation based on elevation which are very useful for defining and assessment of flood risk zone.

3.6 Flood Inundation Mapping

Flood mapping during the flooding and flood plain mapping after the flood recedes is essential. One of the important information required is the nature and extent of the damage caused by floods in the flood prone areas. Satellite remote sensing provides synoptic view of the flood affected areas at frequent interval for assessing the progression and recession of the flood inundation in short span of time which can be used for planning and organizing the relief operation effectively. Remote Sensing can be used for effective mapping and assessing flood damaged areas. For mapping purposes, pre flood scene and peak flood image was compared to delineate the inundated areas.

3.7 Site Suitability for non-flood area using Boolean Approach

Site suitability analysis is used to find out suitable place or location for something. The approach behind site suitability is rule based mapping in which we define certain condition of If and then if they will meet, we have result of most suitable site. In site suitability analysis, we can have result based on Boolean logic. It gives output in the form of 0 and 1, same factors are responsible for site suitability of Active river and canal but here analyst doesn't need to each factor, output can be generated by query operation such as river distance in meter and name = barren field=1 and road distance in meter. Result is generated as we can see in the map suitable site for safe zone in form of polygon.

4 RESULT AND DISCUSSION

4.1 Pre-Monsoon Land use and Land cover

With the help of using Landsat 8 OLI of Pre flood time period (17 April 2017) and Post flood time period (17 September 2017) prepare the visual image classification for showing the land use/ land cover area of Supaul district. Pre-Monsoon land use/ land cover area of Supaul district is represented in fig. 3 And Post Monsoon LULC is showing in fig. 4.

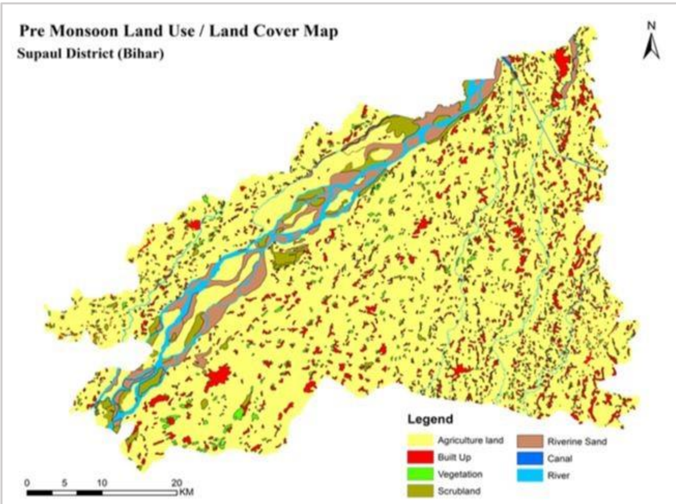

Fig. 3. Pre-Monsoon Land Use/ land Cover Map of Supaul District

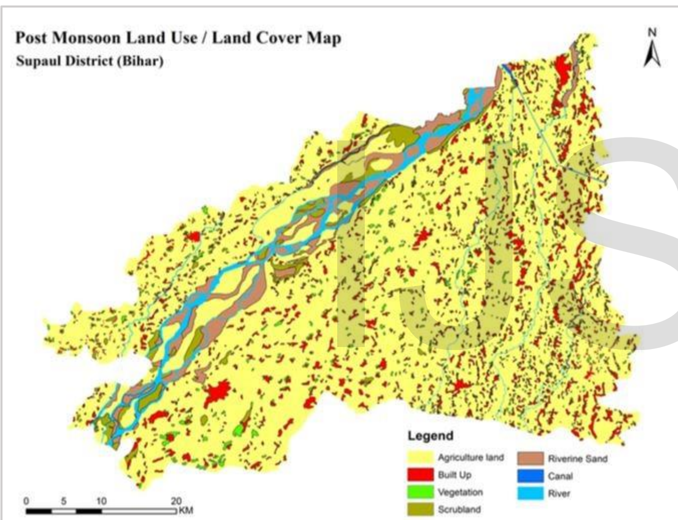

Fig. 4. Post Monsoon Land Use / Land Cover Map of Supaul District

Areas under various land use categories are presented in Table 1 Seven land use categories were identified viz. Built-up, Riverine sand, Agriculture, Vegetation, Scrubland, Canal and River in the study area. Table 1 revealed that agriculture occupied the largest area (1908 sq.km) followed by built up area. Mostly people are engaged in primary activities due to the alluvial soil availability highly production are grown in these areas. Built up covered (173 sq.km) area. In this area people are feel unsecure because its region coming in flood prone area and every year people faces the problem of flood which has causes of damage lives. (58.40 sq.km) area under vegetation which has been profitable for overcome the rate of flood but in this area vegetation are medium. Soil quality is also depending upon the rate of vegetation while Scrubland (63 sq.km) are found highly near the river because in sandy area is not suitable for growing vegetation and Shrubs has been grown naturally. Riverine sand also covers (112 sq.km) areas mostly find its coast region of Kosi river due to the flood debris every area in times of flood and River Covers (67.19 sq.km) area which has been determines condition of overall area and (2.4 sq.km) covers by Canal.

Table 2 represent the area after flood in which analyze the few classes are highly affected from flood other than not much affected like we have seen agriculture area has been (1902 sq.km), Built up (172.06 sq.km.), Vegetation (57.05 sq.km), Scrubland(58.05 sq.km) all these areas has been decreased due to flood. While Riverine Sand (120.87 sq.km) and River (71.66 sq.km) both increased because various areas like agriculture, scrubland has been changed in to riverine sand after the flood.

TABLE 1
Pre flood Land Use / Land Cover area in Supaul District

Area	(Sq.km.)
Agriculture	1908
Built-Up	173.04
Vegetation	58.40
Scrubland	63
Riverine Sand	112
River	67.19
Canal	2.4

TABLE 2
Post flood Land Use / Land Cover area in Supaul District

Area	(Sq. km)
Agriculture	1902
Built-Up	172.06
Vegetation	57.35
Scrubland	58.05
Riverine Sand	120.87
River	71.66
Canal	2.4

4.2 Changes between Pre & Post Monsoon Area

There result shows addition of new sandy Riverine class which is estimated at (122.94 sq.km) and river has been changed (70.12 sq.km) which was (67.19 sq.km) and depicted in table 3.3. Scrubland were reduced which were (62.14 sq.km) before flood and it has been left 57.05 after flood because it has been changed in to river and Riverine sand. Near coastal Built up area has been affected by flood because its make kachha house which has flow in monsoon time so (0.06 sq.km) few built up area has been converting in to Riverine sand. Crops has been destroyed due to flood which are directly impact on social and economic aspect of Humans like showing the agriculture area which were (1908.69 sq.km) before monsoon period while it has been left after flood (1902.04 sq.km) area. Vegetation area were also affected by flood which was (58.40 sq.km) while post monsoon its left (57.35 sq.km).

TABLE 3
Change Matrix between Pre and Post flood area

Post Monsoon	Agriculture Land	Built Up	Canal	River	Riverine Sand	Scrubland	Vegetation	Total
Pre-Monsoon	Area in Sq.km.							
Agriculture Land	1902.04	-	-	1.50	5.15	-	-	1908.69
Built up	-	172.33	-	-	0.95	-	-	173.28
Canal	-	-	2.46	-	-	-	-	2.46
River	-	-	-	67.19	-	-	-	67.19
Riverine Sand	-	0.06	-	0.63	111.54	-	-	112.34
Scrubland	-	-	-	0.80	4.30	57.05	-	62.14
Vegetation	-	-	-	-	1.05	-	57.35	58.40
Total	1902.04	172.39	2.46	70.12	122.94	57.05	57.35	2384.39

Due to flood mostly all infrastructure facilities have been destroyed. Small and marginal farmers, their present and future is under dark. Standing crops like paddy, madua, patua or parsan have been completely destroyed. Major population of livestock has also been affected from floods. Not only is the immediate future scary. Locals are aware that the water inundating their land is not going to recede. Due to the breach of the embankment, Kosi river mostly changed its course, those result lands are lost. Some of the flood affected areas in Supaul district followed by several interactions with the affected populations; the present scenario comes across as extremely grim. There are high chances of the situations deteriorating at a fast pace. Mostly areas affected from floods and cut from the mainland.

4.3 Normalised Difference Water Index

The mean value of NDWI during flood was 0.3 for the flood areas and 0 for the non-flood areas. The NDWI values <0 indicate non-flood areas and values between 0 and 0.3 indicate moist soil while values > 0.3 indicate water on the map fig. 5. This area very moist due to flood effected every year Therefore availability of water is high which the bad impact on this area. Total area of the district, 67 % area was affected by flood. North-western part has been highly affected by the flood in comparatively the eastern part of the district. Every year this area was affected from flood because in this region various streams has been jointed in Kosi and overflow water.

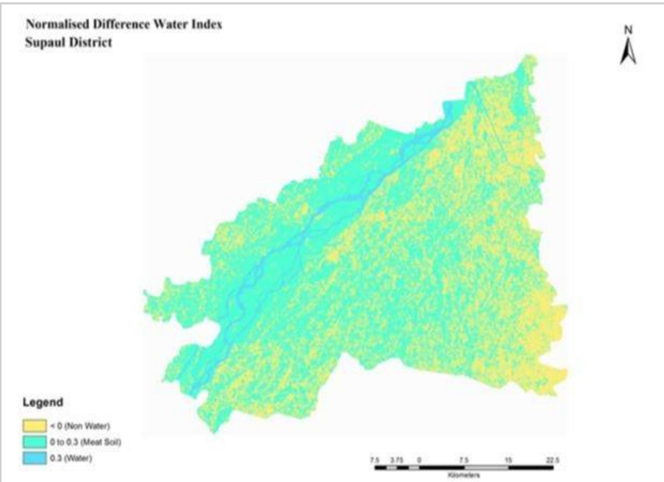

Fig. 5. NDWI (Monsoon), 2017

4.4 Active River Channel

Active channel is the main passage for the flow of river water. Apart from the main channel of the Kosi River, there are numerous palaeo channels on the Kosimagafan surface.
These channels are long and meandering in pattern as they are flowing over low gradients and have easily erodible banks. During flooding, dam break or embankment breach, they become the passage for flood water and sediments which causes the loss of life and property as well as damage to the natural environmental conditions.
The Kosi river channel and Stream fig. 6 were considered for generating this thematic layer. These channels have been buffered by considering the distance up to which damage to life and property can be significant fig. 9. This will also help to locate the distances from active channel for the safe evacuation of the people at risk. After buffering, the values were divided into four classes with respect to hazard assessment namely, very high (0-500 m), high (500-1500 m), moderate (1500-3000 m), and low (>3000 m) based on our general experience. Based on the above classes, distance to active channel buffer map shows that the blocks downstream of the river Kosi in Supaul District's blocks are to be more affected by flooding by the active channels. Several of these channels have been blocked due to human interventions, which have resulted in severe water logging in these areas, thereby making the area unfit for cultivation and settlement. With the help of NDWI in highlighted area of water pixel (Either 1 or 0 otherwise) define the active river channel.

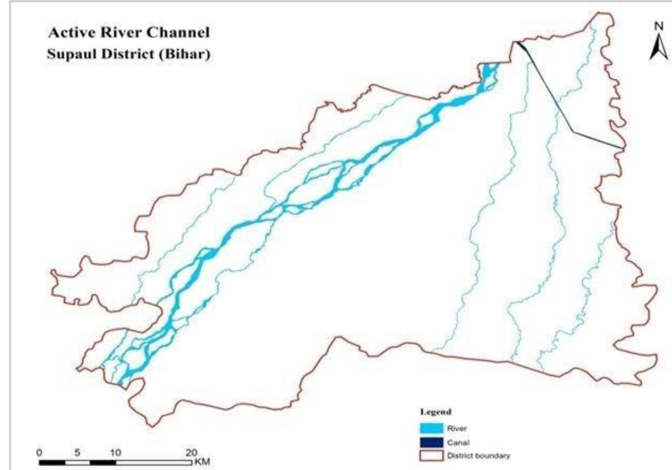

Fig. 6. Active River Channel in Supaul district

4.5 Transportation Map

Road transport is considered as an integral part of a nation infrastructure and often termed as its 'socio-economic lifeline' since it is used to promote social and economic activities more than any other transportation. Transport infrastructure are vulnerable to weather extreme because of the associated risk for flooding and erosion. Several major events where extreme weather damaged roads and railways in disastrous ways.

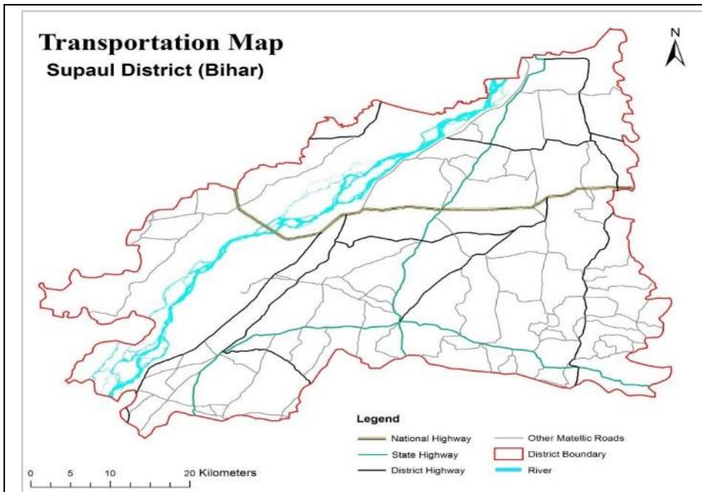

Fig. 7. Transport Map of Supaul District

4.6 Landscape vulnerability to flood inundation

Of the total agricultural area 78% nearly 14% area under paddy was vulnerable to flood thus affecting the crop production in the district. About 3% vegetation cover was flooded resulting in the degradation of ecosystem and 7% built up area was exposed to flood rending many people homeless. The high and moderate risk areas were lying between flood plain areas and low slope gradients along the Kosi river.

Table 2 shows the area of each land use/land cover class affected by flood. It revealed that about 1902 km hectares of agriculture, 173 hectares of built up, 58 hectares of vegetation cover area, 58 km of scrubland, 120 km of riverine Sand 70 km of river and 59 km by Canal of their respective total areas was affected during the flood in the district. Patches of flooded areas in north west and south west of the images were identified mainly in southern river bed, fallow land and cultivated land.

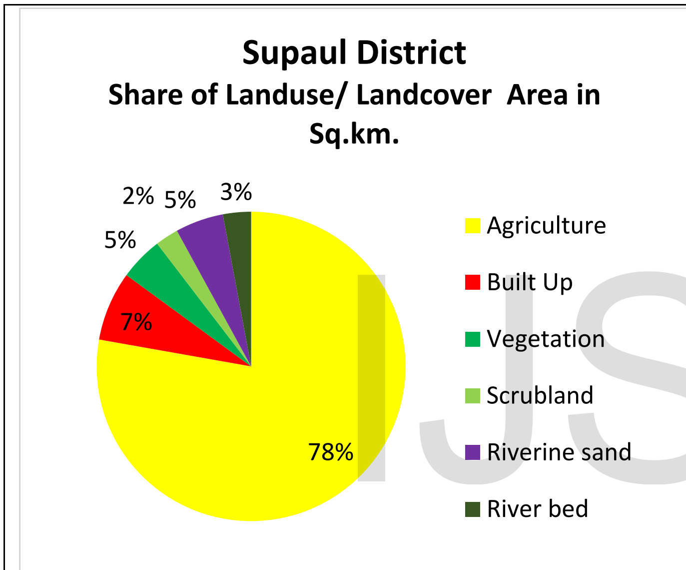

Fig. 8. Landscape Vulnerable area of Supaul District

These three categories were mostly affected by the flood in terms of size and percentage of the total flooded area in Supaul District. It should be noted that most of the relatively higher elevated areas were not affected from flood.

4.7 Flood risk Zonation

There are five flood risk zones (Very high, high, medium, low and non-flooded) were delineated in the district fig.9. The stabilized river islands occupied by vegetation and agricultural crops were clearly identified with the help of remote sensing satellite data.

TABLE 4
Flood Risk Zonation Areas

Risk Zonation	Area in Sq. Km.	Area in %
Very High Risk	19	1
High Risk	500	11
Moderate Risk	420	16
Low Risk	358	21
No Risk Zone	1087	51

These islands are located in low floodplain and have been considered under high risk area. Sand banks and temporary river island are flooded every year during the rainy season. The flood plains alongside minor stream drainage in north eastern and in between them fall under low and middle level floods plains and were identified as medium risk zones. The Low and middle level flood plains get submerged each and every year during monsoon season. Flood risk is low in areas which are away from the rivers. Non-flooded area is identified in the eastern region which was safe for human beings and due to this these areas found more populated.

4.8 Boolean Logic Method

Boolean logic is an alternative way to find risk zone. It's very easiest and best-known type of GIS model which is based on Boolean Operation. The Boolean model consist of AND and OR operators. Based on set theory, the AND operators yield the logical intersection of two data set, and the OR operators obtain the logical union of the two data sets, " (3) ". The query data is analyzed based on Boolean logic and entered in the raster calculator (from spatial analyst) According to the existing thematic layers as following:

[Slope output] 1.0-1.5 & [Distance to River] >1500 km & Built up, Agriculture land, vegetation, Scrub, Riverine

= Means equal, means OR means AND (3)

The result is a Boolean true or false map for the locations which meet or do not meet the given criteria. The results of Boolean query for identifying the risk zone in Supaul district.

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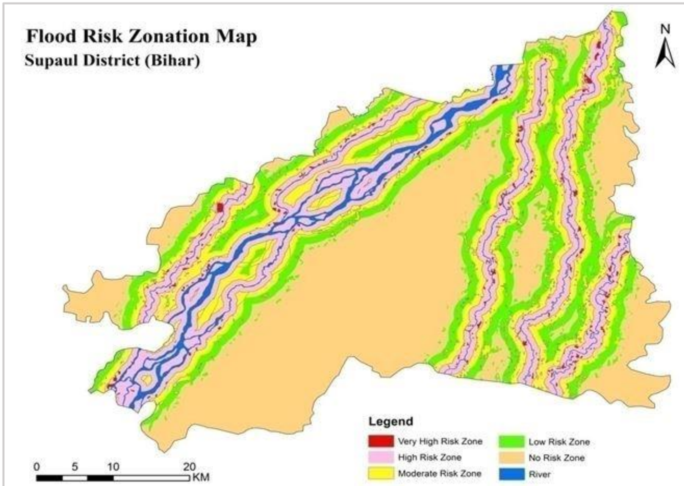

Fig. 9. Flood Risk Zonation Map

The high risks areas in the plain correspond well with the areas that experienced a high flood level and were submerged during flood of August due to monsoon rainfall. The very low and low risk areas also coincide well with the non-flooded areas shown in flood inundation maps. The main anthropogenic intervention within stream beds that affect flooding are encroachment, especially when the stream passes through urban areas. The narrowing is being caused by the banking up of the beds, performed for the extension of the riverside land, covering of streams, construction of building into the channel bed and adequate technical works, such as bridges and ducts, for maximum discharge channeling. The existence of a well-shaped trapezoidal cross section, with an adequate bottom width to reach maximum capacity often lacks due to human activities that alter stream bed geometry. This can be handled with appropriate technical work for caisson of the beds.

5 CONCLUSIONS

A Geographic information system is used to analyses information in this paper. GIS as a computer system perform the tasks including capturing information, storing information and analyze it. Risk analysis conducted in this paper is based on an efficient methodology with an objective to delineate the flood hazard areas, flood vulnerability area, and finally produced the combined risk areas in the Supaul Kosi River. This analysis has finally focused on the identification of the factors that controls the flood hazard and vulnerability in the study area. It is accomplished by the Boolean technique with the GIS based overlay analysis. The application of this methodology is not restricted to Kosi River but can be applied to any river reach

The decision factors identified are rainfall, population Density, distance to active channel, land use land cover, slope of the area, geomorphic features. Thematic maps were prepared using several image processing techniques and GIS operation at different scale. Each of the thematic layers (Classified data sets) was brought to same scale.

Buffer zones are created for the river and houses distance of site from the road; river and houses were some important factors. River buffer of 700m, 1500m and 2500m and 3500m were made river buffer for showing flood risk is done near the river and so the distance is less as if it done away from the river less of the flood Risk.

Basically, our study observes that the patterns with which we develop and used the landscape have important implications when establishing flood resilient communities. Planners and decision makers should factor in the local pattern of LULC when designing flood reduction programmed and be more strategic when deciding where future development should take place.

The role of Remote sensing and GIS is very important in our paper because the collection, storage, analysis and display of the geospatial information was done using Remote sensing and GIS together with the query; and finally, we obtained the excepted output and were able to fulfil the objective. This information may be applicable on the ground because we used accurate data and information for preparing the results considering Supaul topography and climate. We have also discussed the flood risk vulnerability and assessed risk.

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