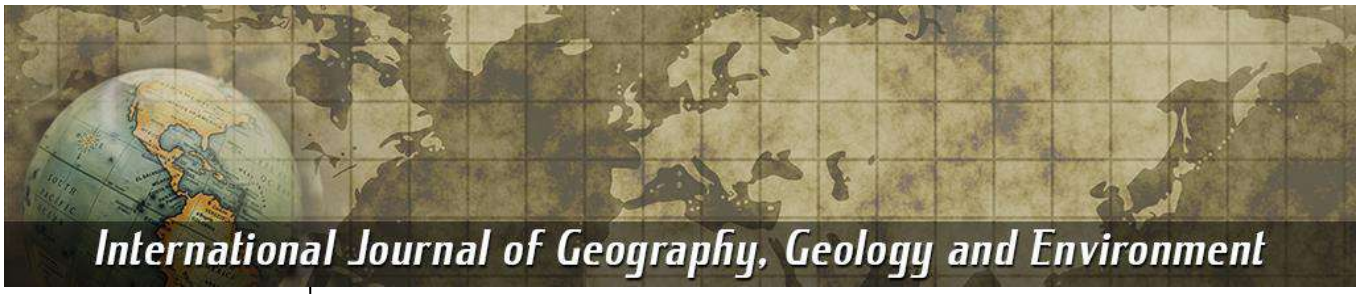
International Journal of Geography, Geology and Environment 2023; 5(1): 205-210



P-ISSN: 2706-7483
E-ISSN: 2706-7491
IJGGE 2023; 5(1): 205-210
Received: 18-02-2023
Accepted: 22-04-2023

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Flood damage scenario: A comparative study of the 2004, 2007 and 2017 floods of Bihar

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Abstract
Floods as a disaster is quite synonymous in the state of Bihar and in that context, a relative assessment of the 2004, 2007 and 2017 floods could be hatched out. The disaster management authority of the state has a regular monitoring and updated climate change goals with respect to flood management. But the 2007 flood was highly intensive with 1287 human deaths with a maximum in Darbhanga district while Araria recorded second highest deaths in 2017. The most affected by crop damage was the district of Samastipur in 2007 among the three years. Data processing through GIS mapping provides inundation damage. In all the year's flow of Gandak, Kosi and Bagmati was very high above danger mark. Though in recent years pre-emptive measures are engaged like early warning systems, riparian buffers, wetland rejuvenation and the like.

Keywords: Flood, Bihar, disaster management, GIS mapping

Introduction
In the list of natural disasters, floods have made a remarkable benchmark from devastation to vulnerability throughout the Indian subcontinent. In India, twenty- three of the thirty-six states and Union Territories in the country are subjected to floods and 40 million hectares of land, roughly one-eighth of the country's geographical area, is prone to floods (NIDM, 2014) [8]. Bihar being situated on the Ganga floodplains streamlined by its various tributaries with a tropical monsoon climate is quite prone to floods. "About 6.9 out of 9.4 million hectares comprising 73.06 per cent of the state is flood affected which accounts for approximately one-sixth (17.2%) of the flood-prone area in India" (Kansal et al., 2017; Sinha, et al., 2012) [4, 11]. This implies that the number of persons hit by flood per unit area in Bihar is quite large and the state incurs a huge loss both financially and infrastructurally every year. The floods in Bihar during the South West Monsoon 2004, 2007 (July to September) and 2017 to a certain extent portray yet another familiar picture of the State's vulnerability to recurrent floods and is a grim reminder of the extensive devastations and disruption caused by floods. The focus of this study is to highlight on the practical problems, dilemmas and challenges and to suggest measures for reducing the loss of life and property due to major floods in a comparative process among the four years.

Literature review
Flood is a state of hydrological extreme of high water level in a stream channel or on bank that results in inundation of land that isn't ordinarily submerged. Generally, it occurs in event of heavy showers and becomes a disaster once it causes loss to lives, livestock and livelihood. In this scenario, the state of Bihar has a recurring series of floods every year. Ironically enough the state faces flood and drought situations equally due to rainfall variability with differences in rainfall distribution spatially as it is situated on the crossroads of wet eastern coastal region and dry continental regions of the western plains. So, the Government has classified the type of floods, int the following:

"**Class I**
Flash floods– floods occurring due to rainfall in Nepal, lead time is short (8 hours), receding of flood waters is fast;

Class II
River floods– lead time 24 hours, receding of flood waters is 1 week or more;

Class III
Drainage congestion in river confluence- lead time more than 24 hours, lasting full monsoon season (i.e., receding of flood water takes 3 months).

Class IV
Permanent water-logged area." (BSDMA, 2023)
The state is divided into three agro-ecological zones: North West Alluvial plains (Zone-I) consisting of 12 districts, the North-East Alluvial Plains (Zone-II) consisting of 9 districts and the South Bihar Alluvial (Zone-III) consisting of 17 districts. Out of the total geographical area the land use is as given below: It has a tropical climate with hot summers and cold winters. The summer temperature shoots up to 45 °C and in winter drops even below 5 °C. Rainfall is largely due to South-West Monsoon in the State. It accounts for about 85 percent of the total rainfall and the remaining 15 percent of rainfall is from winter rain and hot weather rain. The average rainfall is around 1120 mm. The area is divided into seven geo-cultural zones according to the rivers as special purpose areas:

1. Ghaghara- Gandak Zone consisting of East and West Champaran, Gopalganj, Siwan and Saran districts.
2. Gandak- Bagmati Zone consisting of Sheohar, Sitamarhi, Muzaffarpur, Vaishali, Samastipur & Begusarai districts.
3. Bagmati- Kosi Zone consisting of Darbhanga, Madhubani, Supaul, Saharsa & Khagaria districts.
4. Kosi- Mahananda Zone consisting of Madhepura, Araria, Purnia, Kishanganj and Katihar districts.
5. Karmnasa- Sone Zone consisting of Buxar, Kaimur, Bhojpur and Rohtas districts.
6. Sone- Punpun Zone consisting of Patna, Jehanabad, Arwal, Gaya, Nalanda, Aurangabad and Nawada districts.
7. Punpun- Sakri Zone consisting of Sheikpura, Lakhisarai, Jamui, Banka, Munger and Bhagalpur districts.

Flood profile of the state

- Most of the rivers namely, Ghaghara, Gandak, Burhi Gandak, Bagmati, Kamla, Adhwara group of rivers, Kosi and Mahananda have Himalayan origin and have a considerable portion of their catchment in the glacial region falling in Nepal and Tibet.
- The area worst affected by floods in the state is 56% of its total geographical area covering 28 out of 38 districts. In the 15 highly vulnerable to flood districts a population of 4, 69, 18, 520 is at risk.
- Causes differ in different geo-ecological zones, but the end result is the same- Inundation, siltation, water logging and erosion.
- From flood point of view, the vulnerability of Bihar as a state is intense on all five factors: location, poverty, density of threshold population and awareness and preparedness of the people.
- The number of human lives affected ranged from 7.18 lac to 244.42 lac. Livestock affected ranged from 0.1 lac to 86.86 lac. The total area affected ranged from 1.81 lac ha to 19.69 lac. ha out of which agriculture land ranged from 1.6 lac ha. to 14.4 lac ha, and non-agricultural land ranged from 0.39 lac ha. to 9.3 lac ha. The total crop loss ranged from those sown in 0.1 lac ha to 10.6 lac. ha. (2001-2010)

Study area
The state of Bihar is located in the eastern part of the country between 24°20'10" to 27°31'15" North latitude and 82°19'50" to 88°17'40" East longitude with a population of 10,38,04,637 (According to 2011 Census). The total area of the state is 94,163 sq. km out of which 92,251.49 sq. km (97.97%) are rural areas and 1,911.51 sq.km. (2.03%) are urban areas. Surrounded by Uttar Pradesh, West Bengal, Jharkhand and neighbouring country Nepal, Bihar is a completely landlocked state drained by numerous rivers and divided into half by the river Ganga flowing in West to East direction.

Methodology
The data has been taken from the state's disaster management statistics of the year 2004, 2007 and 2017, then simulated. The study area has been extracted from India's shapefile and the attribute table has been laid down after the data computation. Classification evaluation after processing has been shown in 5 classes in terms of severity. Graphical representation of the crop damage and deaths has been produced thereafter.

Results
In the year 2004, flood was spread over 20 districts of North Bihar with an area over 2.772 MH (4.99 MH according to CWC) and affected population of 21.3 million.
The flood of 2007 was more widespread throughout the northern part of the state rather being concentrated to 4 districts like the 2004 floods. Districts like Madhubani and Darbhanga faced high damage in terms of both crop loss and human deaths.

Analysis
This damage analysis shows that the mid Northern plain of the state is the most affected area in floods almost every year as the gradient of the slope dips quite suddenly allowing huge sediment flow but a huge velocity of the stream during a substantial downpour especially during the summer monsoon when there is a sudden release of waters from the upper catchment areas of Nepal and as the sluggishness increases in the downslope the water holding capacity decreases and as many rivers have the channel rerouting tendency like Kosi they overflow through even the embankments. With the anthropogenic influence in the levees the population become more vulnerable. A huge deforestation and poor drainage are also the primary reasons to it.
In 2004, Darbhanga has recorded the greatest number of deaths and after the 2nd maximum number of deaths has been recorded in 2007 floods in Samastipur followed by Araria in 2017 floods. Crop damage is highest in Samastipur in 2007 followed by Muzaffarpur in 2004.
In 2017 southern districts such as Nawada was also inflicted. Gandak, Bagmati and Kosi rivers overflowed every flood season and in 2004 and 2017 along with these Budhi Gandak and Mahananda rivers added. In 2007 there was a swell in the Ganges also causing deaths in Patna as well. Though various mitigation measures can be taken such as revival and maintenance of traditional practices of ahar, pynes and ponds system or reservoirs for diverting and storing flood water and making use of the same for multipurpose activities including irrigation, restoration of water tables etc. Larger involvement of senior citizens from the local areas can be encouraged who have better understanding and knowledge about the system. For this, major river-based GIS mapping would be required. Besides the bed of the rivulets and tributaries would have to be

properly structured and meticulously maintained. It is believed that the Ganges cause erosion on the side of its left bank only and almost all its tributaries excepting Jamune, Karmnasa, Sone, Punpun and Kiul rivers merge in Ganges from its right bank side. In the process a lot of sediments gets deposited on the right side creating narrow streams within the bed. If Large anti-flood sluices across the rivers are built then a controlled release of water in the Ganges will take place, and a considerable level of water would be maintained in the tributaries as well which requires a lot of studies and technical feasibility periods adding to the endowing poverty of the state. The state also incurs huge losses of agricultural crops, inundation of waters to fresh areas, livestock losses and even human deaths. All the 2004, 2007 and 2017 floods were quite devastating in the history of Bihar floods affecting mainly the districts of Madhubani, Darbhanga and Samastipur doubling with the effects of climate change. It is noteworthy that the number of deaths has significantly reduced on the banks of major flood prone rivers like Kosi and Mahananda showing Government's roadmap 2030 is building back better as well as involving local bodies at those districts in the lines of Sendai Framework (BSDMA, 2015) [] of 2015. So, with the adoption of mitigation measures, technical advancements and participation in all levels can help reducing the vulnerabilities faced now.

Conclusion

The state of Bihar faces the perils of intense floods every year mainly during the south west monsoon and mainly the poor sections of the population are most vulnerable who have to displace and face a lack of livelihoods for quite long

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Appendix

Table 1: a) Land use and land cover

Sl. No	Category	Area (ha)
1.	Forest land	6,76,400
2.	Land under misc tree, groves	2,11,709
3.	Current fallow	2, 56,783
4.	Other fallow	6,87,570
5.	Cultivable waste	79,319
6.	Net area under cultivation	56,05,798
7.	Barren land & permanent pasture	5,03,381
8.	Areas under non-agriculture use	13,95,340
	Total	94,16,300

Source: Director of Statistics & Evaluation, GoB.

Table 1: b) Seasonal Rainfall data of 10 years

Year	Winter rain	Summer rain	South-west monsoon	North-west monsoon	Total (Rainfall in mm)
2000	0.40	101.70	994.10	10.00	1106.20
2001	20.90	83.70	908.20	192.20	1208.00
2002	48.90	66.80	896.90	33.20	1045.80
2003	19.20	93.00	767.60	128.90	1008.70
2004	23.70	41.40	906.10	60.10	1031.30
2005	0.10	89.50	777.60	30.20	897.40
2006	0.10	88.97	925.86	27.77	1042.69

2007	28.34	76.40	1360.85	40.49	1506.08
2008	30.61	61.78	1081.27	19.31	1195.97
2009	0.09	98.22	699.17	71.13	868.61
Average	17.23	80.4	932.06	61.33	1091.08

***Source*:** Director of Statistics & evaluation

Fig 1: Flood Zones in Bihar (BSDMA, 2023)

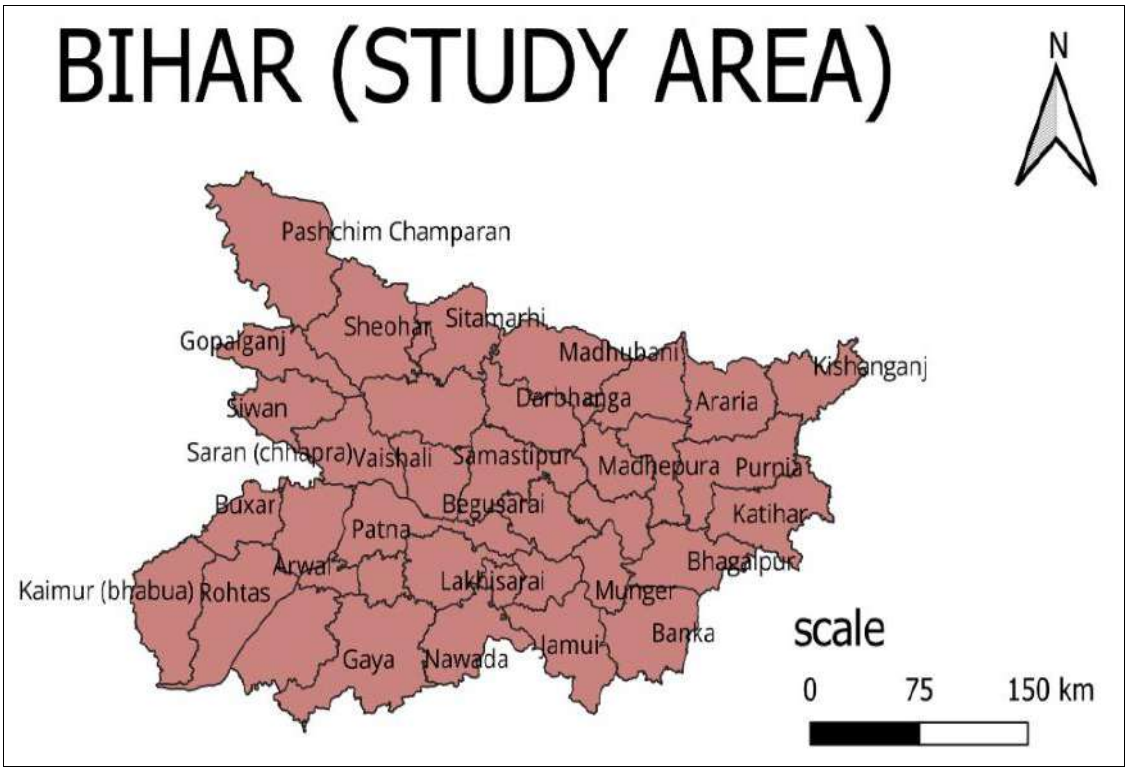

Fig 2: Political Map of Bihar

Table 2: Loss of life and property due to flood

Year	Human lives lost	Livestock lost	Crop Damaged (in Rs Lac)	House Damaged Value (in Rs Lac)	Public Property Damaged (in Rs Lac)	Villages Affected
2004	885	3272	52205.64 (1.4 mha)	75809.5 (929773 nos.)	103049.6	9346
2007	1287	2423	76837.82 (1.06 mha)	83144.52 (784328 nos.)	64241.52	18832
2017	815	472	68587	77879	10887	9197

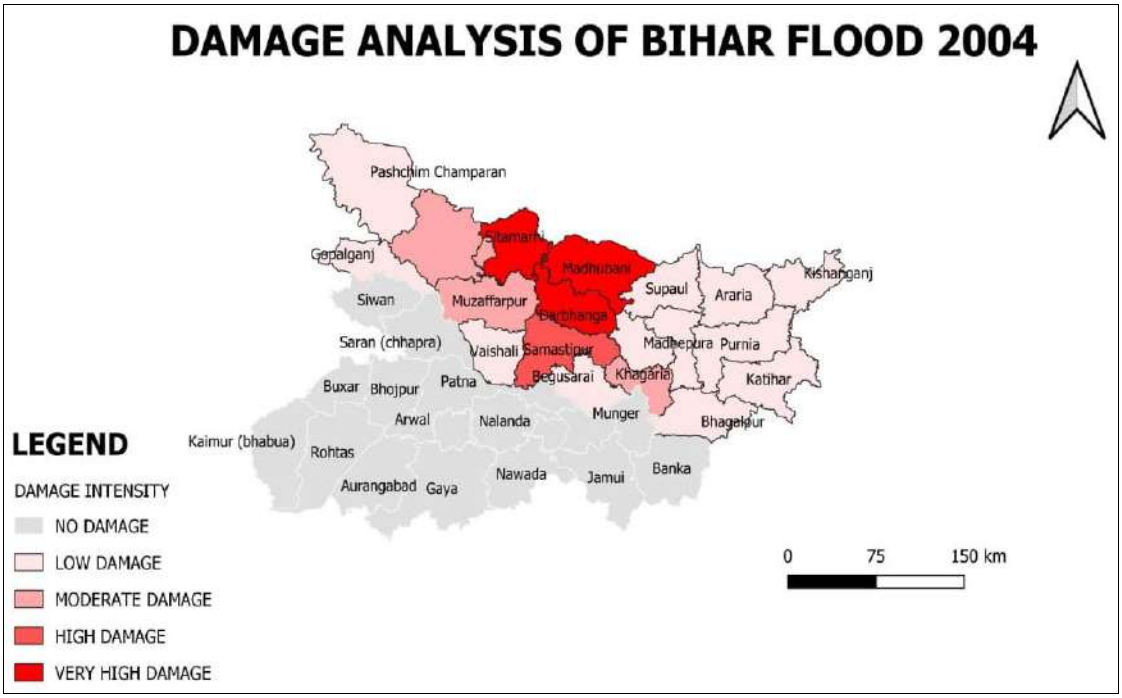

Fig 3: Damage Analysis Map of 2004 Bihar floods

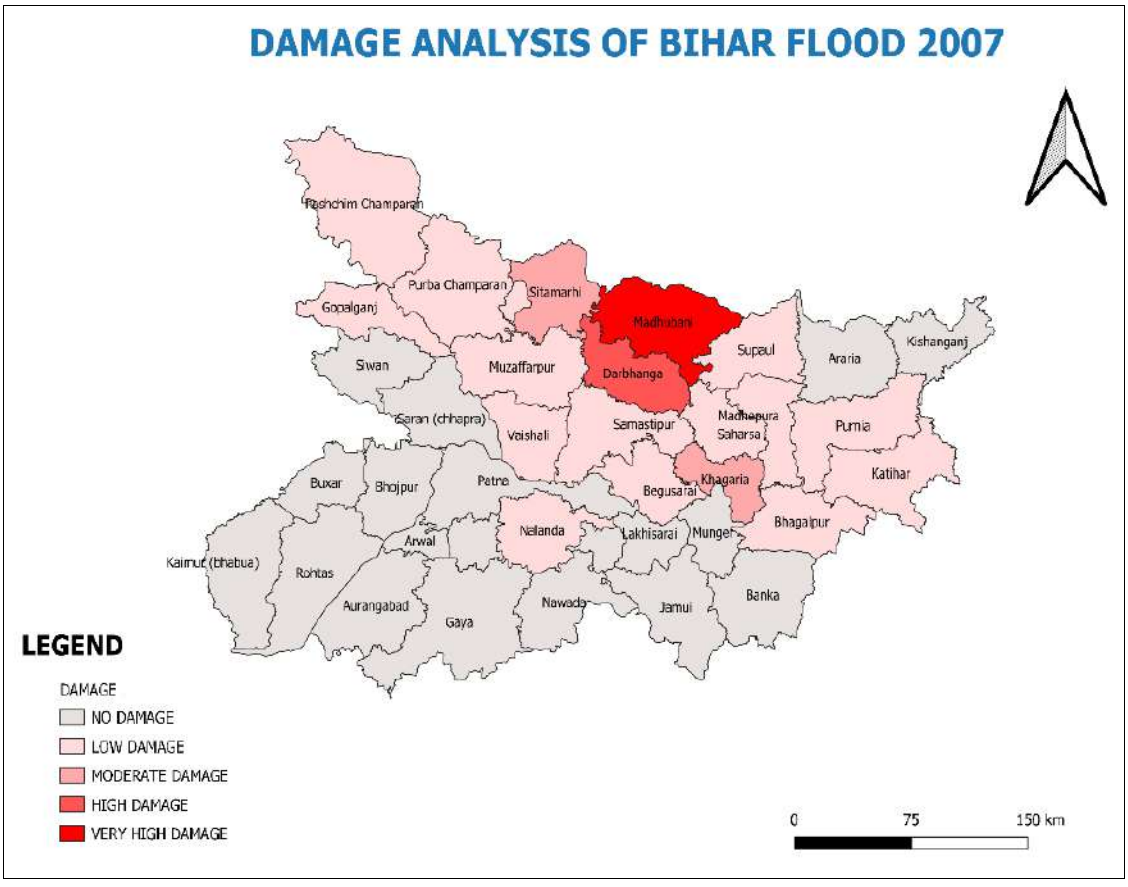

Fig 4: Damage Analysis Map of 2007 Bihar floods

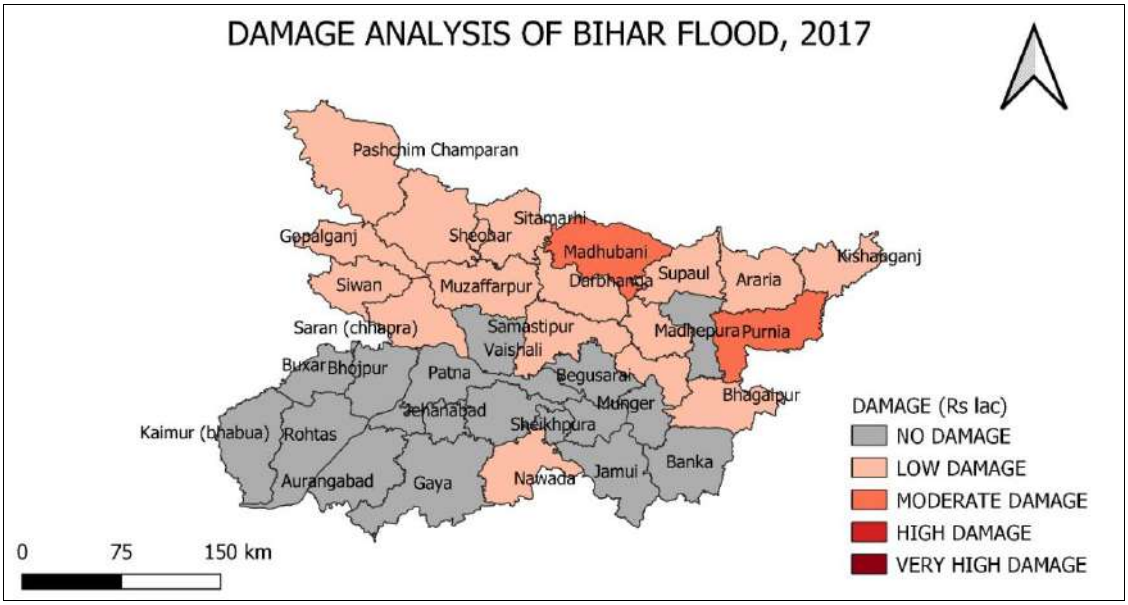

Fig 5: Damage Analysis Map of 2017 Bihar floods

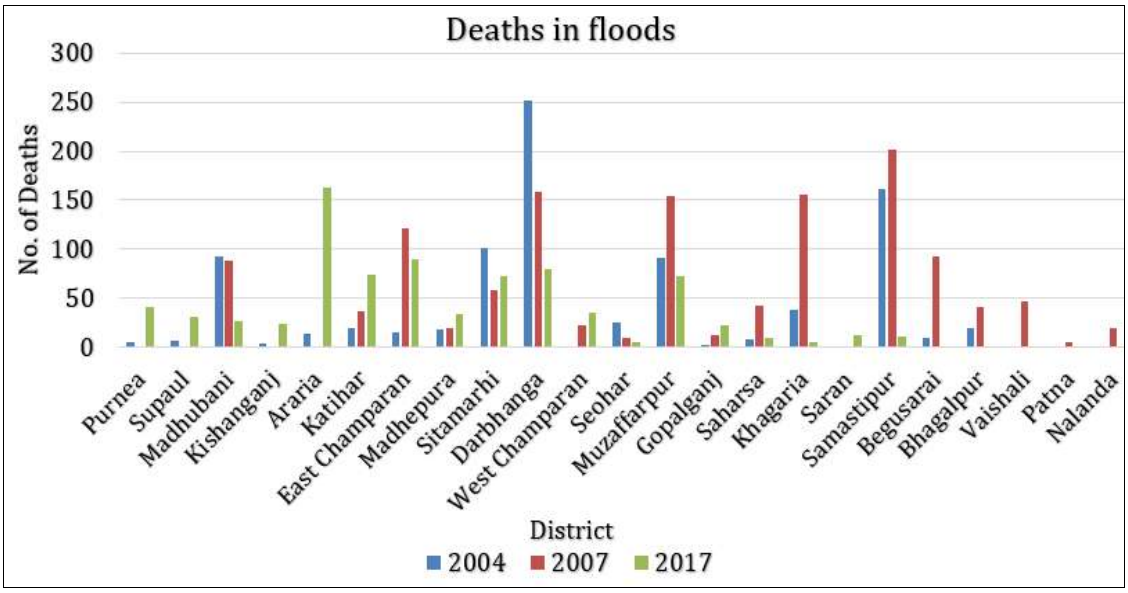

Fig 6: Number of Deaths district wise

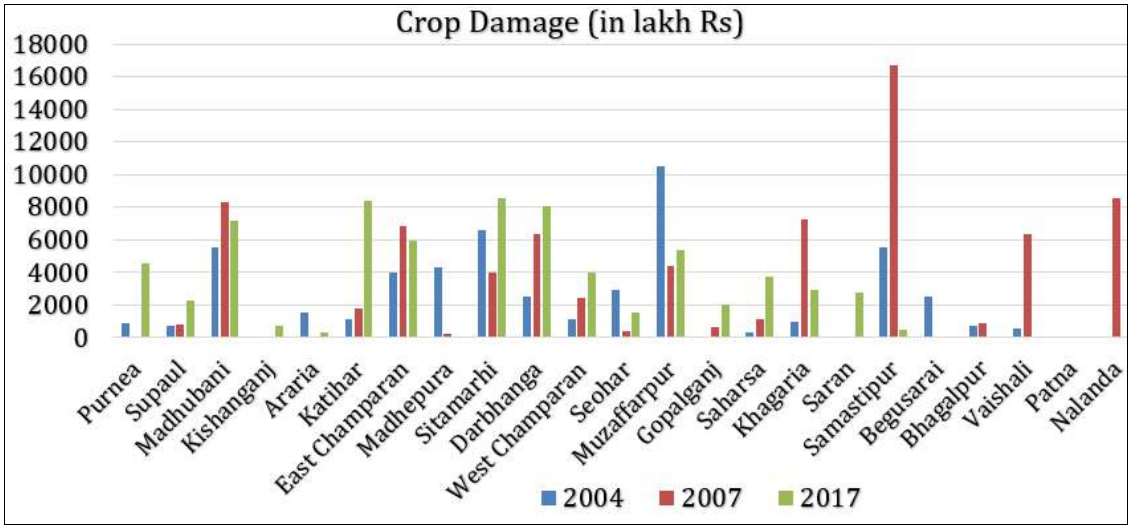

Fig 6: Total crop damage in Rupees