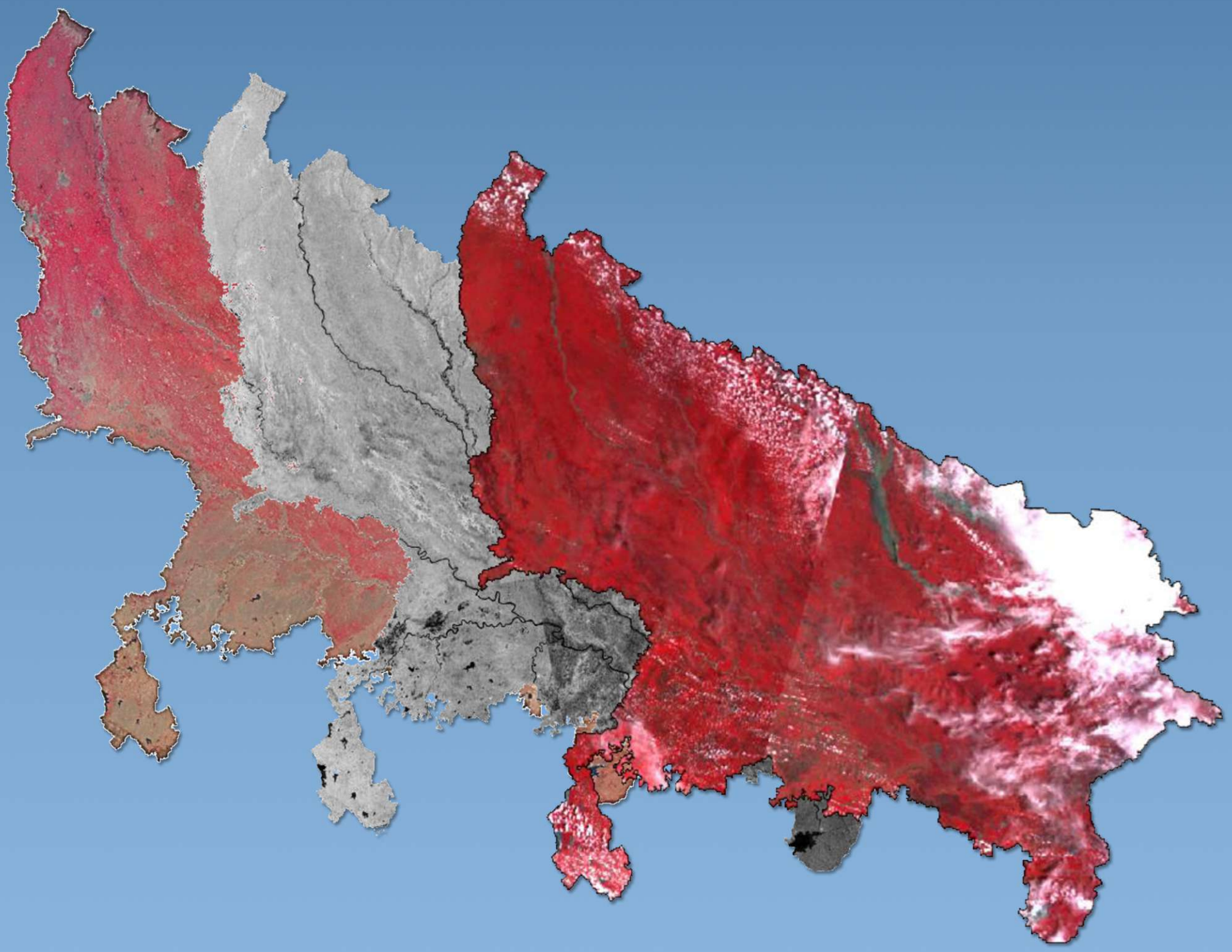
Version - 1 (1998-2020)

Flood Hazard Atlas of Uttar Pradesh

- A Geospatial Approach



Prepared by

National Remote Sensing Centre
Indian Space Research Organisation
Dept. of Space, Govt. of India

In Association with

National Disaster Management Authority
Ministry of Home Affairs, Govt. of India

&

Uttar Pradesh State Disaster Management Authority
Govt. of Uttar Pradesh

April, 2022

Version 1.0

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15.	**Abstract (with Keywords**): Flood hazard zonation is one of the important initiatives in planning sustainable developmental activity in floodplains, construction of relief-rescue & health centrers and identifying areas for flood tolerant cropping. Over a period of time, ISRO has created a repository of large data pertaining to floods and cyclones in the entire country. These historical flood maps generated by NRSC, ISRO can be used to identify the flood hazard areas. In this approach, 23 years (1998-2020) of satellite data from Indian and foreign satellites was used in identifying the flood hazard zones based on frequency of flood inundation due to riverine floods. The flood hazard is categorized into five classes, i.e., Very Low, Low, Moderate, High and Very High based on the frequency of inundation (in Uttar Pradesh State) as per the recommendation of expert committee constituted by NDMA. The atlas is thoroughly validated by Uttar Pradesh State Disaster Management Authority, Govt. of Uttar Pradesh with ground information. This atlas can help in understanding the flood problem in various districts of Uttar Pradesh State and help the decision makers towards sustainable planning and disaster risk reduction. **Keywords** : Flood Hazard, Flood Frequency, Satellite Remote Sensing, Geospatial Approach				

संख्या- 939/एक-11-2021

योगी आदित्यनाथ

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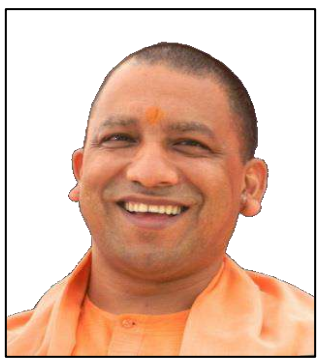

संदेश

मुझे यह जानकर अत्यन्त प्रसन्नता की अनुभूति हो रही है कि राष्ट्रीय सुदूर संवेदन केन्द्र, हैदराबाद द्वारा राष्ट्रीय आपदा प्रबन्धन प्राधिकरण, नई दिल्ली तथा उत्तर प्रदेश सरकार के सहयोग से उत्तर प्रदेश का बाढ़ हैज़र्ड एटलस तैयार किया गया है।

उत्तर प्रदेश देश के अति बाढ़ सम्भावित राज्यों में से एक है। नेपाल राष्ट्र तथा पड़ोसी राज्यों में भीषण वर्षा / बाढ़ की स्थिति के कारण प्रदेश के लगभग 40 जनपद बाढ़ से प्रभावित होते हैं। मुझे विश्वास है कि उत्तर प्रदेश का बाढ़ हैज़र्ड एटलस बाढ़ आपदा की क्षतियों को न्यूनीकृत करने तथा बाढ़ प्रबन्धन योजना तैयार करने में अत्यन्त उपयोगी सिध्द होगा।

बाढ़ हैज़र्ड एटलस को तैयार करने में राष्ट्रीय सुदूर संवेदन केन्द्र, राष्ट्रीय आपदा प्रबन्धन, प्राधिकरण, केन्द्रीय जल आयोग एवं राहत आयुक्त कार्यालय का योगदान सराहनीय रहा है।

उत्तर प्रदेश के बाढ़ हैज़र्ड एटलस के उद्देश्यपरक प्रकाशन हेतु मेरी हार्दिक शुभकामनाएं।

(योगी आदित्यनाथ)

एस. सोमनाथ
S. SOMANATH

सत्यमेव जयते
भारत सरकार
Government of India

अध्यक्ष, अन्तरिक्ष आयोग
व
सचिव, अन्तरिक्ष विभाग

Chairman, Space Commission
&
Secretary, Department of Space

FOREWORD

The State of Uttar Pradesh is one among the major flood affected areas in the country. Identification of the flood-prone areas would enable the decision makers to plan and prioritize focused flood mitigation measures. Satellite Remote Sensing helps to monitor large areas on recurrent basis, towards deciphering the flood inundation & its dynamics in space & time.

Under the Disaster Management Support Programme (DMSP) of Indian Space Research Organisation (ISRO), National Remote Sensing Centre (NRSC) has been monitoring and mapping major flood & cyclonic events in the country using multi-mission satellite data, for more than two decades. The derived information is provided to MHA, NDMA, and the State Disaster Management Departments for supporting effective disaster management & disaster risk reduction measures.

NRSC/ ISRO has been proactively supporting Uttar Pradesh State Government by providing space based inputs and building geospatial database, to support disaster management activities of the State. Further, at the behest of National Disaster Management Authority (NDMA), NRSC has prepared Flood Hazard Atlas of Uttar Pradesh using information derived through satellite data (1998-2020). River water level data of various gauge stations obtained from Central Water Commission (CWC/MoJS) has been integrated in computing flood hazard index of each district. The flood hazard maps are ground validated by Uttar Pradesh State Disaster Management Authority.

I am confident that the information provided in the atlas will be of immense use to the Government of Uttar Pradesh in its efforts for flood preparedness, risk assessment, planning and implementation, towards enabling long-term mitigation measures, in minimizing the damage due to flood disasters in the State.

I compliment the project team from NRSC / ISRO, Government of Uttar Pradesh, and National Disaster Management authority, for bringing out this informative and useful Flood Hazard Atlas, for the benefit of the State of Uttar Pradesh.

Dated: March 29, 2022

सोमनाथ

(सोमनाथ एस. / Somanath S.)

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डॉ. प्रकाश चौहान / Dr. Prakash Chauhan
निदेशक / Director

PREFACE

Indian subcontinent is liable to the floods & cyclones and causing immense damage to the property and life every year. In India, the recent trend has been rather giving concern that the floods have been increasing in intensity and frequency. In an era where non-structural methods are considered as viable options for flood damage mitigation, flood hazard zonation is one of the best non-structural methods for flood damage mitigation.

Indian Space Research Organisation (ISRO), Department of Space (DOS), launched Disaster Management Support Programme (DMSP) with National Remote Sensing Centre (NRSC) as the single window delivery mechanism for providing near-real time products and services using satellite remote sensing and aerial data to support different phases of disasters. NRSC over the last two decades is involved in the preparation of flood inundation maps and in the assessment of associated damages due to floods & cyclones in the country under near real-time inundation mapping and monitoring, thus, enabling creation of reliable and long term geospatial database on flood hazards and associated risks.

Using historical multi-temporal satellite data available during 1998-2020, National Remote Sensing Centre (NRSC), ISRO has prepared the flood hazard maps for Uttar Pradesh State. Flood Hazard Maps are prepared using 139 Indian Remote Sensing (IRS) Satellite and other foreign satellite datasets covering riverine floods spanning over 23 years (1998 to 2020). Spatial extent of flood inundation and the frequency of flooding in a given area are derived from the satellite datasets. The hazard zones are categorized into five classes as per the flood hazard classification schema proposed by Expert Committee on Flood Hazard Zonation constituted by the National Disaster Management Authority. River water level data of various gauge station obtained from Central Water Commission has been integrated in computing flood hazard index of each district.

These hazard maps prepared using satellite remote sensing data has been ratified with ground truth by the respective district administration of Government of Uttar Pradesh to ensure effective acceptance of the information. This will enable all stakeholders in assessing flood prone areas for an effective management and informed decision making. The UP State Flood Hazard Atlas may assist the planning agencies, the state and district administrations and the communities at panchayat levels in raising the level of alertness about the disaster proneness of the identified areas and the need for disaster preparedness and mitigation on a scientific and realistic basis.

I am sure that information on flood hazard derived from space datasets will be useful to Government of Uttar Pradesh for various disaster risk management planning, preparedness and mitigation activities.

Dated: March 28, 2022

(PRAKASH CHAUHAN)

कमल किशोर
सदस्य
Kamal Kishore
Member Secretary I/C

सत्यमेव जयते

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MESSAGE

Action Point No. 5 of Hon’ble Prime Minister's ten point Agenda for disaster risk reduction advocates leveraging technology to enhance the efficiency of disaster risk management efforts.

National Disaster Management Authority (NDMA) has commenced various programs to induct Science & Technology (S&T) in the country with the goal to create a safe and disaster resilient India through an integrated and technology driven approach for disaster risk management.

One such important initiative is to develop upgraded hazard profiles of various natural hazards (for their subsequent use in vulnerability and risk assessment work). Flood is one of the most frequent disasters that adversely affect socio-economic profile of the country. Information of flood hazard profile at a reasonably large scale is not available for planning necessary mitigation measures by concerned State Government.

The Working Committee of Experts formed by NDMA decided to prepare the flood hazard map for the State of Uttar Pradesh on priority, utilizing the scientific inputs from the various stakeholders and the actual satellite based observations on flood inundated areas of Uttar Pradesh accumulated over the past 22 years by the National Remote Sensing Centre (NRSC) as a major step forward in NDMA’s initiative to induct S&T for Disaster Management.

I am sure the updated Flood Hazard Atlas prepared by NRSC, ISRO under the guidance of NDMA using the space based data would deliver the much needed information for the efficacious management of flood hazard and risk reduction in the State of Uttar Pradesh.

(Kamal Kishore)

Place : New Delhi
Dated : April 1, 2022

लेफ़्टिनेंट जनरल रविन्द्र प्रताप साही, एवीएसएम
Lieutenant General Ravindra Pratap Sahi, AVSM
उपाध्यक्ष
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No. 88/UPSDMA/2022-23

Date: 27 April, 2022

MESSAGE

Uttar Pradesh is the 4th largest state in India covering an area of 243,290 square kilometre and a population of approx. 23.50 Crore. Being a large state, Uttar Pradesh is more vulnerable in case of any calamity. Uttar Pradesh is vulnerable to Flood, Drought, earthquakes, Lightning, Thunderstorm, Heat Wave, Cold Wave. Amongst these disasters, flood is one such calamity that is a highly recurring event in the state of Uttar Pradesh.

Flood hazard maps are one of the very important non-structural mitigation methods. Historical flood maps are useful in planning and regulating developmental activities in flood plains. It is a matter of great pleasure that National Remote Sensing Centre (NRSC), ISRO has joined hands with the State Government of Uttar Pradesh along with NDMA to release the Flood Hazard Atlas for Uttar Pradesh State using remote sensing satellite observations.

I hope this flood hazard atlas will be very useful for the Uttar Pradesh State Disaster Management Authority in training the District Authority and related stakeholders in identifying the risk and in taking the mitigation measures even before the onset of floods.

I congratulate the National Remote Sensing Centre, ISRO team for bringing out this hazard atlas.

(Lt. General Ravindra Pratap Sahi)

Place: Lucknow

Dated: April 27, 2022

दुर्गा शंकर मिश्रा, भा.प्र.से.
मुख्य सचिव
Durga Shanker Mishra, I.A.S.
Chief Secretary

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संख्या-136-एक-11-2022
दिनांक : 22 मार्च, 2022

MESSAGE

Uttar Pradesh is a large State with 18 administrative divisions consisting of 75 districts. It has various vulnerable areas exposed to different types of natural calamity. Flood is the most common disaster which occurs almost every year in the State. It mostly affects the Eastern, Central and Tarai regions of the State.

Flood hazard maps are one of the important non-structural mitigation methods. Historical flood maps are useful in planning and regulating developmental activities in flood plains, construction of relief, rescue and health centers.

I hope this Flood Hazard Atlas will be used extensively by the District Authorities and concerned stake holders in identifying the risks and in taking the necessary mitigation measures much before the onset of floods.

I congratulate the National Remote Sensing Centre, ISRO team for bringing out this Hazard Atlas.

(Durga Shanker Mishra)

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D.O. Ref. No. 950/एक-11-2021

MESSAGE

The State of Uttar Pradesh is vulnerable to flood. Every year it disrupts the lives of people and causes large-scale damage to crops, houses, roads, bridges and other public utilities.

It is a matter of great pleasure that National Remote Sensing Centre (NRSC), ISRO has joined hands with the State Government of Uttar Pradesh along with NDMA to release the Flood Hazard Atlas for Uttar Pradesh State using remote sensing satellite observations. It's a well-thought-out effort that will add a new and effective dimension to flood management in the state.

On behalf of the Government of Uttar Pradesh, I thank NRSC for this collaboration. I also appreciate the leadership and the team of scientist at NRSC and the Relief Commissioner and his team for this useful exercise.

Manoj 4.1.22
(Manoj Kumar Singh)

Date: 04 January 2022

Ranvir Prasad, I.A.S.

Secretary Revenue & Relief Commissioner
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MESSAGE

The State of Uttar Pradesh is vulnerable to disasters like Flood, Drought, Earthquakes, Lightning, Thunderstorm, Heat Wave and Cold-Wave. Amongst these disasters, flood is a highly recurring event in the state of Uttar Pradesh that causes human loss, economic loss, and severe damage to infrastructure. Apart from floods, due to excessive rains in the catchment areas of the river basin, the lower Shivalik region and adjoining areas of Nepal trigger floods in the State.

In this context, the present Flood Hazard Atlas prepared by NRSC Hyderabad would empower the stakeholders, policymakers, Districts Magistrates, and field-level officials to judiciously deal with the crisis and in mitigating the adverse effects of the floods. This Atlas will provide a climate picture of the flood-prone areas and help In effective flood management and mitigation activities.

Relief Commissioner's office and District Authorities have provided extensive support to NRSC in bringing out this atlas mainly by ground verification. Efforts of Ms. Aditi Umrao and Chander Kant, Relief Commissioner Office are worthy of special mention.

(Ranvir Prasad)

ACKNOWLEDGEMENTS

The project team would like to place on record our deep sense of gratitude to Shri S Somanath, Chairman, ISRO and Secretary, Department of Space for showing keen interest in DMS programme and for his extensive support and guidance in DMS activities of NRSC.

The project team sincerely thanks Sri Kamal Kishore, Member Secretary, National Disaster Management Authority (NDMA) for his support and encouragement in preparing the State level Flood Hazard Atlases of maximum flood-prone states.

The project team expresses deep sense of gratitude to Dr. Prakash Chauhan, Director, NRSC for his constant encouragement, guidance and for providing necessary support in bringing out this atlas.

The project team conveys earnest thanks to Shri. B. P. Shantanu, Scientific Secretary & Director, EDPO, ISRO Headquarters, Bengaluru for being the torchbearer by providing guidance in disaster management support activities of NRSC.

The project team would also like to express sincere gratitude to Dr Raj Kumar, Former Director, NRSC and Dr. PVN Rao former DD RSA for their constant support and guidance in executing this task.

The project team sincerely thanks Shri Ranvir Prasad, IAS, Secretary, Revenue & Relief Commissioner, Government of Uttar Pradesh and the concerned officals of Uttar Pradesh State Disaster Management Authority (UPSDMA) for extending support towards completing the ground validation of the hazard atlas in a timely manner.

Consistent support provided by Joint Secretary, Mitigation and concerened officers of National Disaster Management Authority, New Delhi is sincerely acknowledged. The project teams sincerely thank Dr John Mathew, AD, EDPO, ISRO for his support and cooperation. The project team sincerely thanks the concerened officers of Central Water Commission and India Meteorological Department for providing inputs in preparing the flood hazard atlas.

Finally, the project team is indebted to Sri G S Rao, Sri C M Bhatt, and Sri Sunil Kumar for their contribution during their tenure in DMSG, NRSC. The team also thanks everyone who contributed directly or indirectly in preparing the atlas.

(PROJECT TEAM)

PROJECT TEAM

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Sri Aakash Mohan	Scientist/Engineer 'SD', DMSG, RSA
Sri Shaikh Rafik Ramjan	Draughtsman, DMSG, RSA
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GOVT OF UTTAR PRADESH

Ms. Aditi Umrao	Project Director (Emergency Operations)
Mr. Chander Kant	Project Expert (Flood Control)
Mr. Prashant Shahi	Programmer

CONTENTS

LIST OF FIGURES

LIST OF TABLES

Executive Summary

Flood hazard maps are one of the very important non-structural methods of flood damage mitigation. These maps are useful in planning and regulating developmental activities in flood plains, construction of relief, rescue, and health centres. Satellites provide synoptic observations of the natural disasters at regular intervals that help in disaster risk reduction in the country. Over a period of time, National Remote Sensing Centre (NRSC), ISRO has created a repository of large data pertaining to the floods & cyclones in different areas of the Country. These historical flood maps, generated by NRSC/ISRO, are useful for identification of flood hazard areas. At the behest of the National Disaster Management Authority (NDMA), NRSC/ISRO has prepared the State level and District wise Flood Hazard Zonation Atlas for Uttar Pradesh State using the available historical satellite datasets spanning over 23 years (1998 to 2020). About 139 Indian Remote Sensing (IRS) satellite and foreign satellite datasets (optical and microwave) during this period were acquired covering different flood magnitudes in Uttar Pradesh State and used in generating the flood hazard maps after its thorough analysis. The flood hazard zones are categorized into five classes ranging from very low hazard zone to very high hazard zone based on the hazard classification schema finalized by the expert committee constituted by NDMA. Peak flood level data from 31 gauge stations of UP State during the period 1998 to 2020 has been obtained from Central Water Commission and integrated in preparing District Level Flood Hazard Index Zoning. Geo-spatial database like village administrative boundaries, roads, rains, water-bodies, point of interest data has been integrated in preparing State level and District level flood hazard maps. Flood inundation extent and frequency of flood occurrence maps are provided along with the list of villages falling in various hazard categories in the Atlas. These flood hazard maps have been validated on ground by the Government of Uttar Pradesh, through its district administration. Suggestions given by them are incorporated in this report. State level and district level flood hazard statistics are provided in the atlas. Inundation observed is mainly due to the South west monsoon induced heavy torrential rains and also due to riverine floods. It is observed that about 26.5 lakh hectares of land in UP State is affected by major floods during 1998 to 2020 as per satellite observations. It is believed the Atlas would serve as a useful resource of information for policy makers, planners and civil society groups and find its value towards flood risk evaluation, sustainable development and flood mitigation efforts in the Uttar Pradesh State. This atlas will be useful in preparing disaster management action plans at state level and in disaster risk reduction in the country.

1.0 INTRODUCTION

1.1. FLOOD AND ITS SEVERITY

Flood is one of the most severe disasters affecting the people across the globe. India, on account of its geographical position, climate and geological setting, is one of the the worst affected centre of disaster in the South-Asian region, making it vulnerable to many natural hazards, particularly to floods. Nearly 75 per cent of the total Indian rainfall is concentrated over a short monsoon season of four months (June-September). As a result, the rivers witness a heavy discharge during these months, leading to widespread floods. About 50 million hectares of land in the country is liable to floods according to 12th five year plan working group on flood and management an average of 18.6 million hectares of land is affected annually. The annual average cropped area affected is approximately 3.7 million hectares. The most flood-prone areas in the country are the Brahmaputra, Ganga and Meghana River basins in the North and North-east India. Table-1 shows the extent of flood damages incurred during 1953-2016 in India. The damages due to flood can be minimized by proper flood mitigation measures. Hence flood hazard zonation will form one of the effective non-structural measures.

There are several causative factors for flooding in the country. Inadequate capacity of the rivers to contain the high flows brought down from the upper catchment due to heavy rainfall, leads to flooding. Areas having poor drainage characteristic gets flooded by accumulation of water from heavy rainfall. Excess irrigation water applied to command area and increase in ground water level due to seepage from canals and irrigated fields accentuate the problem of water logging. Flooding is accentuated by erosion and silting of the riverbeds resulting in reduction of carrying capacity of river channel, leading to changes in river courses & obstructions to flow due to landslides, synchronization of floods in the main and tributary rivers and retardation due to tidal effects. With the increase in population and developmental activity, there has been a tendency to occupy the flood plains, which has resulted in more serious nature of damage over the years. Because of the varying rainfall distribution, many a times, areas which are not traditionally prone to floods also experience severe inundation. Thus flood is the single most frequent disaster faced by the country. Floods have different dimensions, inundation due to spills over the banks, drainage congestion due to poor drainage characteristics, erosion due to change in river course etc.Fig 1 shows the the field photographs of the flood situation at Salori in Prayagraj (Allahabad) district of Uttar Pradesh state.Fig 2 shows total damages to Urban, Rural Infrastructure and Crops.

Fig 1: Field photograph of floods in Prayagraj district, Uttar Pradesh State.(Source: Internet)

Table 1: The extent of flood damages incurred during 1953-2016 in India

Sl.No	Year	Area affected in Mha	Population affected in million	Damage to Crops		Damage to houses		Cattle lost	Human live lost	Damage to Public Utilities in Rs.Crore	Total damages crops, houses and public utilities in Rs.Crores
				Area in Mha	Value in Rs.Crore	Nos.	Value in Rs.Crore	Nos.	Nos.	Nos.	(col6+8+11)
1	2	3	4	5	6	7	8	9	10	11	12
1	1953	2.3	24.3	0.9	42.1	264924	7.4	47034	37	2.9	52.4
2	1954	7.5	12.9	2.6	40.5	199984	6.6	22552	279	10.2	57.2
3	1955	9.4	25.3	5.3	77.8	1666789	20.9	72010	865	4.0	102.7
4	1956	9.2	14.6	1.1	44.4	725776	8.0	16108	462	1.1	53.6
5	1957	4.9	6.8	0.5	14.1	318149	5.0	7433	352	4.3	23.4
6	1958	6.3	11.0	1.4	38.3	382251	3.9	18439	389	1.8	44.0
7	1959	5.8	14.5	1.5	56.8	648821	9.4	72691	619	20.0	86.2
8	1960	7.5	8.4	2.3	42.6	609884	14.3	13908	510	6.3	63.2
9	1961	6.6	9.3	2.0	24.0	533465	0.9	15916	1374	6.4	31.4
10	1962	6.1	15.5	3.4	83.2	513785	10.7	37633	348	1.1	94.9
11	1963	3.5	10.9	2.1	30.2	420554	3.7	4572	432	2.7	36.6
12	1964	4.9	13.8	2.5	56.9	255558	4.6	4956	690	5.1	66.6
13	1965	1.5	3.6	0.3	5.9	112957	0.2	7286	79	1.1	7.1
14	1966	4.7	14.4	2.2	80.2	217269	2.5	9071	180	5.7	88.4
15	1967	7.1	20.5	3.3	133.3	567995	14.3	5827	355	7.9	155.4
16	1968	7.2	21.2	2.6	144.6	682704	41.1	130305	3497	25.4	211.1
17	1969	6.2	33.2	2.9	281.9	1268660	54.4	270328	1408	68.1	404.4
18	1970	8.5	31.8	4.9	162.8	1434030	48.6	19198	1076	76.4	287.8
19	1971	13.3	59.7	6.2	423.1	2428031	80.2	12866	994	129.1	632.5
20	1972	4.1	26.7	2.5	98.6	897301	12.5	58231	544	47.2	158.2
21	1973	11.8	64.1	3.7	428.0	869797	52.5	261016	1349	88.5	569.0
22	1974	6.7	29.5	3.3	411.6	746709	72.4	16846	387	84.9	569.0
23	1975	6.2	31.4	3.9	271.5	803705	34.1	17345	686	166.1	471.6
24	1976	11.9	50.5	6.0	595.0	1745501	92.2	80062	1373	201.5	888.7
25	1977	11.5	49.4	6.8	720.6	1661625	152.3	556326	11316	328.9	1201.8
26	1978	17.5	70.5	10.0	911.1	3507542	167.6	239174	3396	376.1	1454.8
27	1979	4.0	19.5	2.2	170.0	1328712	210.6	618248	3637	233.6	614.2
28	1980	11.5	54.1	5.6	366.4	2533142	170.9	59173	1913	303.3	840.5
29	1981	6.1	32.5	3.3	524.6	912557	159.6	82248	1376	512.3	1196.5
30	1982	8.9	56.0	5.0	589.4	2397365	383.9	246750	1573	671.6	1644.9
31	1983	9.0	61.0	3.3	1285.9	2393722	332.3	153095	2378	873.4	2491.6
32	1984	10.7	54.6	5.2	906.1	1763603	181.3	141314	1661	818.2	1905.6
33	1985	8.4	59.6	4.7	1425.4	2449878	583.9	43008	1804	2050.0	4059.3
34	1986	8.8	55.5	4.6	1231.6	2049277	534.4	60450	1200	1982.5	3748.5
35	1987	8.9	48.3	4.9	1154.6	2919380	464.5	128638	1835	950.6	2569.7
36	1988	16.3	59.6	10.2	2510.9	2276533	741.6	150996	4252	1377.8	4630.3
37	1989	8.1	34.2	3.0	956.7	782340	149.8	75176	1718	1298.8	2405.3
38	1990	9.3	40.3	3.2	695.6	1019930	213.7	134154	1855	455.3	1708.9
39	1991	6.4	33.9	2.7	579.0	1134410	180.4	41090	1187	728.9	1488.3
40	1992	2.6	19.3	1.7	1027.6	687489	306.3	78669	1533	2010.7	3344.5
41	1993	11.4	30.4	3.2	1308.6	1926049	528.3	211193	2864	1445.5	3282.5
42	1994	4.8	27.5	4.0	888.6	914664	165.2	52315	2078	740.8	1794.6
43	1995	5.2	35.9	3.2	1714.8	2001898	1307.9	62438	1814	679.6	3702.3
44	1996	8.0	44.7	3.8	1124.5	726799	176.6	73208	1803	861.4	3005.7
45	1997	4.6	29.7	2.3	692.7	505128	152.5	27754	1402	1985.9	2831.2
46	1998	10.8	47.4	7.5	2594.2	1932874	1108.8	107098	2889	5157.8	8860.7
47	1999	7.8	28.0	1.8	1850.9	1613260	1299.1	91289	745	462.8	3612.8
48	2000	5.4	45.0	3.6	4246.6	2628855	680.9	123252	2606	3937.0	8864.5
49	2001	6.2	26.5	4.0	688.5	716187	816.5	32704	1444	5604.5	7109.4
50	2002	7.1	26.3	2.2	913.1	762492	599.4	21533	1001	1062.1	2574.5
51	2003	6.1	43.2	4.3	7307.2	775379	756.5	15161	2166	3262.2	11325.9
52	2004	5.3	43.7	2.9	778.7	1664388	879.6	134106	1813	1656.1	3314.4
53	2005	12.6	22.9	12.3	2370.9	715749	380.5	119674	1455	4688.2	7439.7
54	2006	1.1	25.2	1.8	2850.7	1497428	3636.8	266945	1431	13303.9	19790.9
55	2007	7.1	41.4	8.8	3121.5	3280233	2113.1	89337	3389	8049.0	13283.7
56	2008	3.4	29.9	3.2	3401.6	1566809	1141.9	101780	2876	5046.5	9589.9

57	2009	3.8	29.5	3.6	4232.6	1235628	10809.8	63383	1513	17509.4	32551.8
58	2010	2.6	18.3	5.0	5887.4	293830	876.0	39706	1582	12757.3	19520.6
59	2011	1.9	16.0	2.7	1393.8	1152518	410.5	35982	1761	6053.6	7857.9
60	2012	2.1	14.7	2.0	1534.1	174526	240.6	31558	933	9170.0	10944.6
61	2013	7.5	25.9	7.5	6378.1	699525	2032.8	163958	2180	38937.8	47348.8
62	2014	12.8	26.5	8.0	7255.2	311325	582.0	60196	1968	7710.9	15548.1
63	2015	4.5	33.2	3.4	17043.9	3959191	8047.0	45597	1420	32200.2	57291.1
64	2016	7.1	26.6	6.7	4052.7	278240	114.7	22367	1420	1507.9	5675.3
	TOTAL	460.3	2040.3	251.0	102273.6	79465079	44390.3	6022676	105472	199730.2	347581.2

(Source: nidm.gov.in/PDF/guidelines/floods.pdf)

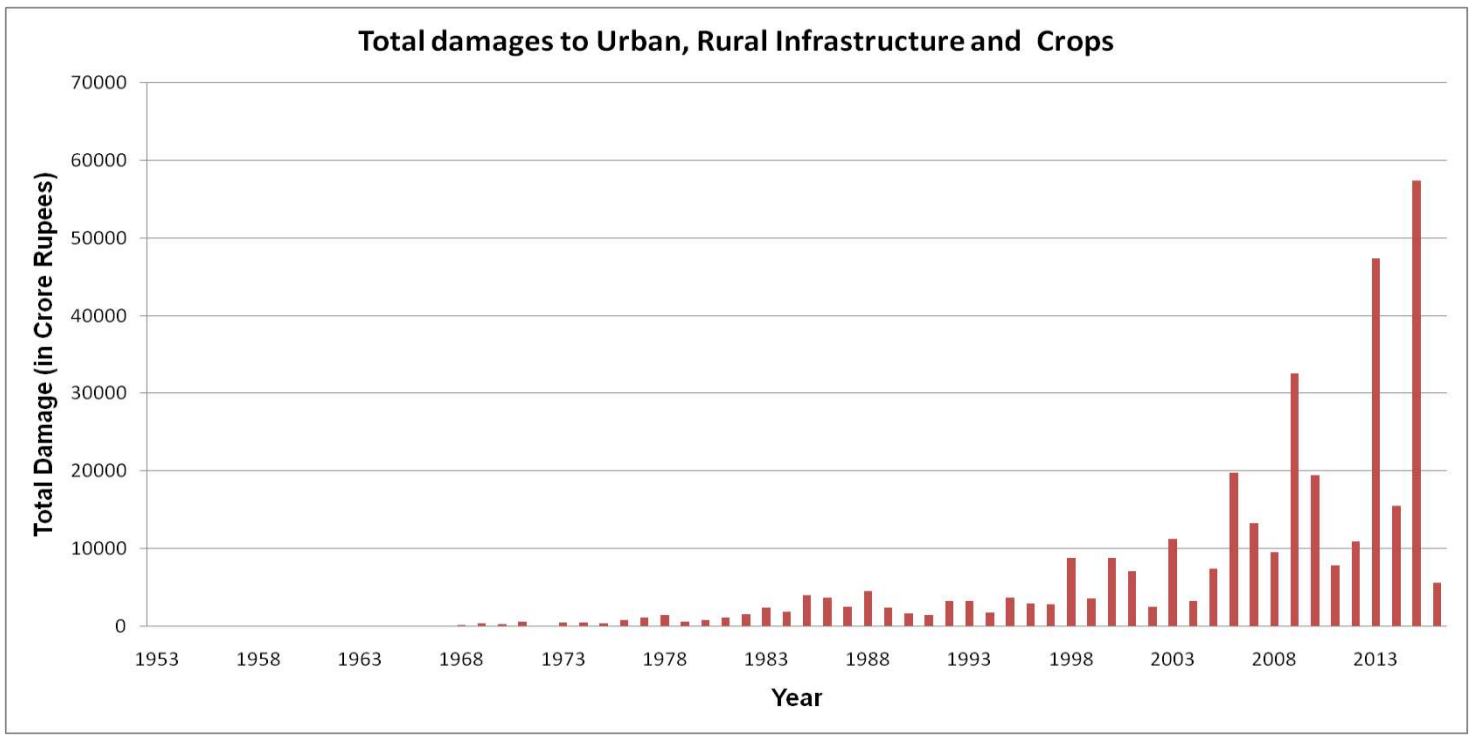


Fig: 2. Total Damages to Urban, Rural Infrastructure and Crops(Source: nidm.gov.in)

1.2 MANAGEMENT OF FLOODS

In order to mitigate the impact of floods, appropriate flood management measures have to be implemented. These measures can be classified into;

1. Structural measures
2. Non-structural measures

Structural Measures : In this approach physical structures are envisaged to prevent the flood waters from reaching potential damage centers. The main structural measures undertaken so far in India are as follows.

1. Embankments, Floodwalls, Flood levees
2. Dams and Reservoirs
3. Natural Detention Basin
4. Channel Improvement
5. Drainage Improvement
6. Diversion of flood water
7. Catchment area treatment/ afforestation
8. Anti-erosion works

In India, systematic planning for flood management commenced with the Five Year Plans, particularly with the launching of National Program of Flood Management in 1954. During the last 48 years, different methods of flood protection structural as well as non-structural have been adopted in different states depending upon the nature of the problem and local conditions.. The various flood management measures undertaken through the successive five year plans are summarized in Table-2.

Table-2 : Flood Management Measures Undertaken during various five year plans

Sl No	Name of States/UT	Area benifitted (Mha)	Length of Embankments (Kms)	Length of Drainage Channels (Kms)	Village Raised/Protected (nos)	Town/Village Protection Works (nos)	Raised Platforms (nos)
1	Andhra Pradesh	1.311	2230	13569	23	72	
2	Arunachal Pradesh	0.055	6.324	4.447	17	0	
3	Assam	1.642	4464.18	850.69	0	694	
4	Bihar	2.949	3430	365	0	47	58
5	Chhattisgarh	0	0	0	0	0	
6	Delhi	0.078	83	453	0	0	
7	Goa	0.003	23.19	32.77	0	2	
8	Gujarat	0.483	104.12	271	30	805	
9	Haryana	2	1144	4385	98	448	
10	Himachal Pradesh	0.012	58	11	0	0	
11	Jammu & Kashmir	0.217	230	14	5	12	
12	Jharkhand	0.001	14	0	5	2	
13	Karnataka	0.005	73.515	10	0	30	
14	Kerala	0.346	205.744	31.1	6	4	
15	Madhya Pradesh	0.004	26	0	0	37	
16	Maharashtra	0.001	44.5	110	0	0	
17	Manipur	0.132	577	166	1	38	
18	Meghalaya	0.001	112	0	2	8	
19	Mizoram	0	0	0	0	0	
20	Nagaland	0.632	10.519	0	0	8	
21	Orissa	0.63	6541	131	14	29	
22	Punjab	3.19	1370	6622	0	3	
23	Rajasthan	0.082	145	197	0	25	
24	Sikkim	0.017	101.81	64.86	0	18	
25	Tamil Nadu	0.122	87	19	4	46	
26	Tripura	0.033	141.74	95.23	0	11	
27	Uttar Pradesh*	1.703	3868.57	60047.3	4511	65	
28	Uttaranchal	0.002	9	0	0	6	
29	West Bengal	2.568	10539	7392.76	0	48	
30	A & N Islands	0	0	0	0	0	
31	Chandigarh	0	0	0	0	0	
32	Dadra & Nagar Haveli	0	0	0	0	0	
33	Daman & Diu	0		0	0	0	
34	Lakshadweep	0	0	0	0	0	
35	Pondicherry	0.004	61	20	0	0	
	Total	**18.222**	**35700.212**	**94862.157**	**4716**	**2458**	**58**

** - Updated as per UP Irrigation Department*

(Source: Ministry of Water Resources: https://mowr.gov.in/writereaddata/linkimages/state9743650818.pdf)

Reservoirs constructed with exclusive flood control storage include Maithon, Panchet, Tilaiya and Konar in Damodar Valley; Chandil dam on Subarnarekha river, Hirakud dam on Mahanadi river and Rengali dam on Brahmani river. In addition, a live storage of 177 billion cubic meters created so far in the various reservoirs for irrigation, hydropower generation, drinking water etc. also help in reducing flood intensity by storing part of the flood waters in them. The flood management measures undertaken so far have provided reasonable degree of protection to an area of 15.81 million hectares throughout the country.

According to Uttar Pradesh State Disaster Management Authority (UPSDMA), out of 240.93 lakh hectares of total geographical area of the state about 73.06 lakh hectares is flood prone. As per the Irrigation Department's estimate only 58.72 lakh hecatres can actually be protected. Up to March 2004, only 16.01 lakh hectares has been protected. The eastern districts as well as those situated in Terai region bordering Nepal are the most affected by floods. About 26.89 lakh hectares is affected annually, and the estimated loss to crops, houses and live stock is to the tune of Rs. 432 crore annually. (*Source: upsdma.up.nic.in/stateprofile.htm*).

The following flood management measures are adopted so far in the Uttar Pradesh State namely:

- Construction of embankments, drainage improvements, building reservoirs, detention basins and afforestation etc.
- Modification of susceptibility to flood damage through flood forecasting and disaster preparedness. And the improvement of river channels to increase their discharge carrying capacity by straightening, widening & deepening.
- The construction of bypass and diversion channels to carry some excess flood water away from the protected areas (as shown in Table 3).

Table 3: Flood Control Works And Extent

S No	Type of Flood Control Works	Extent
1	Total length of Drains	60047.25 Km
2	Total length of Trunk Drains	11856.07 Km
3	Other Drains	48191.18 Km
4	Marginal Embankments on Ghaghgra River	64 Nos
5	Area covered by Embankments(Ghaghra River)	843.265 Km

(Source: Uttar Pradesh Irrigation Department)

Non-Structural Measures

Non-structural measures strive to keep the people away from floodwater. It contemplates use of flood plains judiciously. This technique allows the use of flood plains by reducing the disaster dimension, while retaining its beneficial needs. Following are the main non-structural measures

1. Flood plain Zoning
2. Basin level disaster management plans
3. Flood forecasting and warning
4. Regulation of reservoirs

Presently, there are 226 flood forecasting stations consisting of 166 level forecasting stations and 60 inflow forecasting stations for reservoirs/dams/barrages in the country maintained by Central Water Commission. The Ministry of Water Resources (MoWR) and CWC had circulated the draft bill for floodplain zoning regulations to the state governments for enactment and enforcement. Hence, there is a need for generating flood hazard zonation maps in the country.

1.3 REMOTE SENSING FOR FLOOD HAZARD ZONATION

Flood Hazard Zonation (FHZ) is one of the most important non-structural measures, which facilitates appropriate regulation, and development of floodplains thereby reducing the flood impact. The recurrent flood events at frequent intervals demand the need for identification of flood hazard prone areas for prioritizing appropriate flood control measures. In this context, satellite remote sensing data plays an important role in delineating such flood hazard zones.

Satellite remote sensing technology has made substantial contribution in every aspect of flood disaster management such as preparedness, prevention and relief. Space systems from their vantage position have unambiguously demonstrated their capability in providing vital information and services for flood management. The Earth Observation satellites provide comprehensive, synoptic and multi temporal coverage of large areas in real time at frequent intervals and thus have become valuable for continuous monitoring of floods. In case of persistent cloud cover situation, microwave satellites, which have got all weather capability, can be used for identifying the extent of flood inundation. During last two decades, satellite remote sensing has been operationally used for flood disaster management in India. Figs 3&4 shows the pre-flood and during-flood IRS satellite images over Uttar Pradesh.Table-4 provides list of satellites and sensors used in flood mapping and in preparing flood hazard atlas (1998-2020).

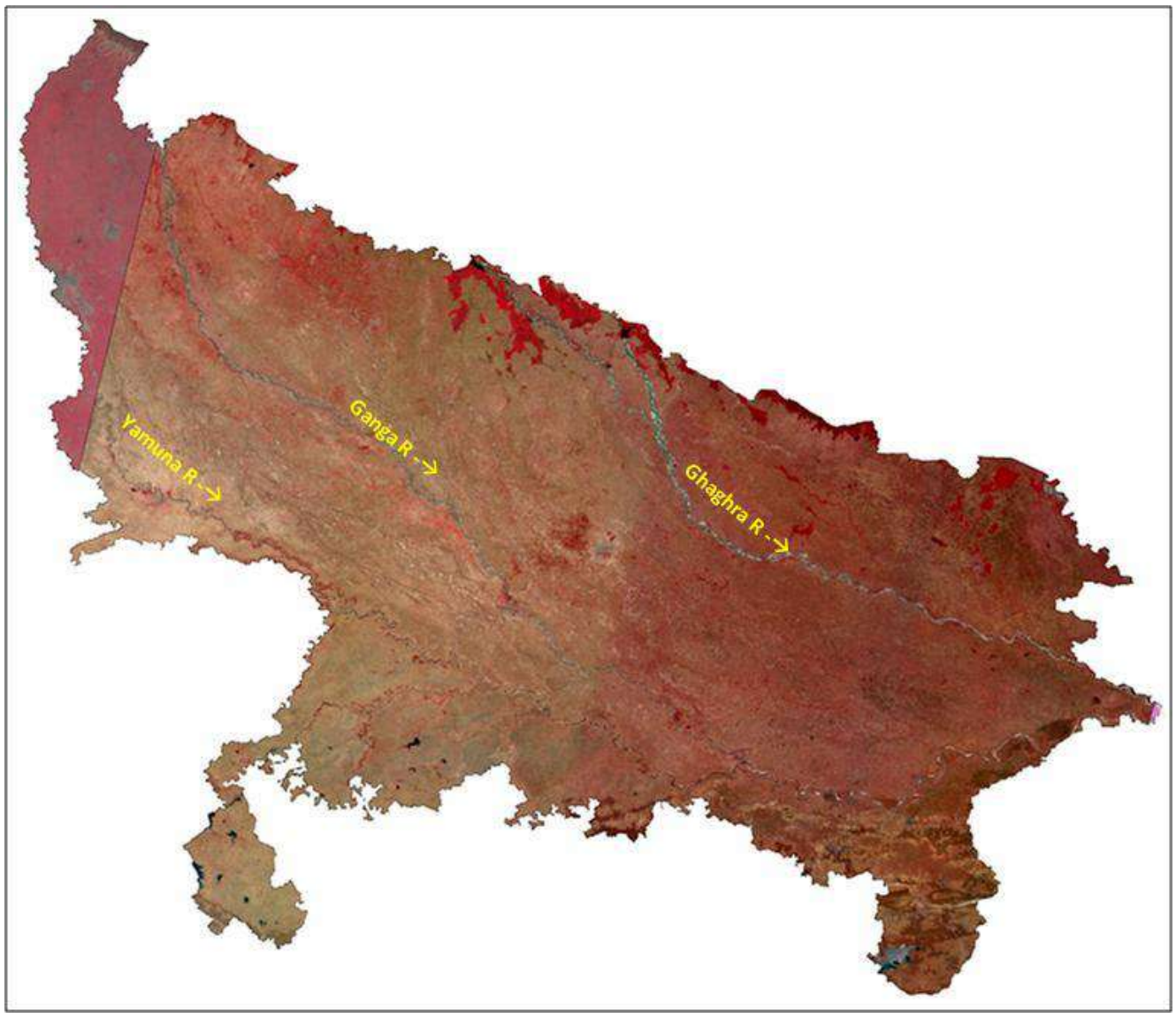


Fig.3: IRS satellite image showing the pre-flood situation in Uttar Pradesh.

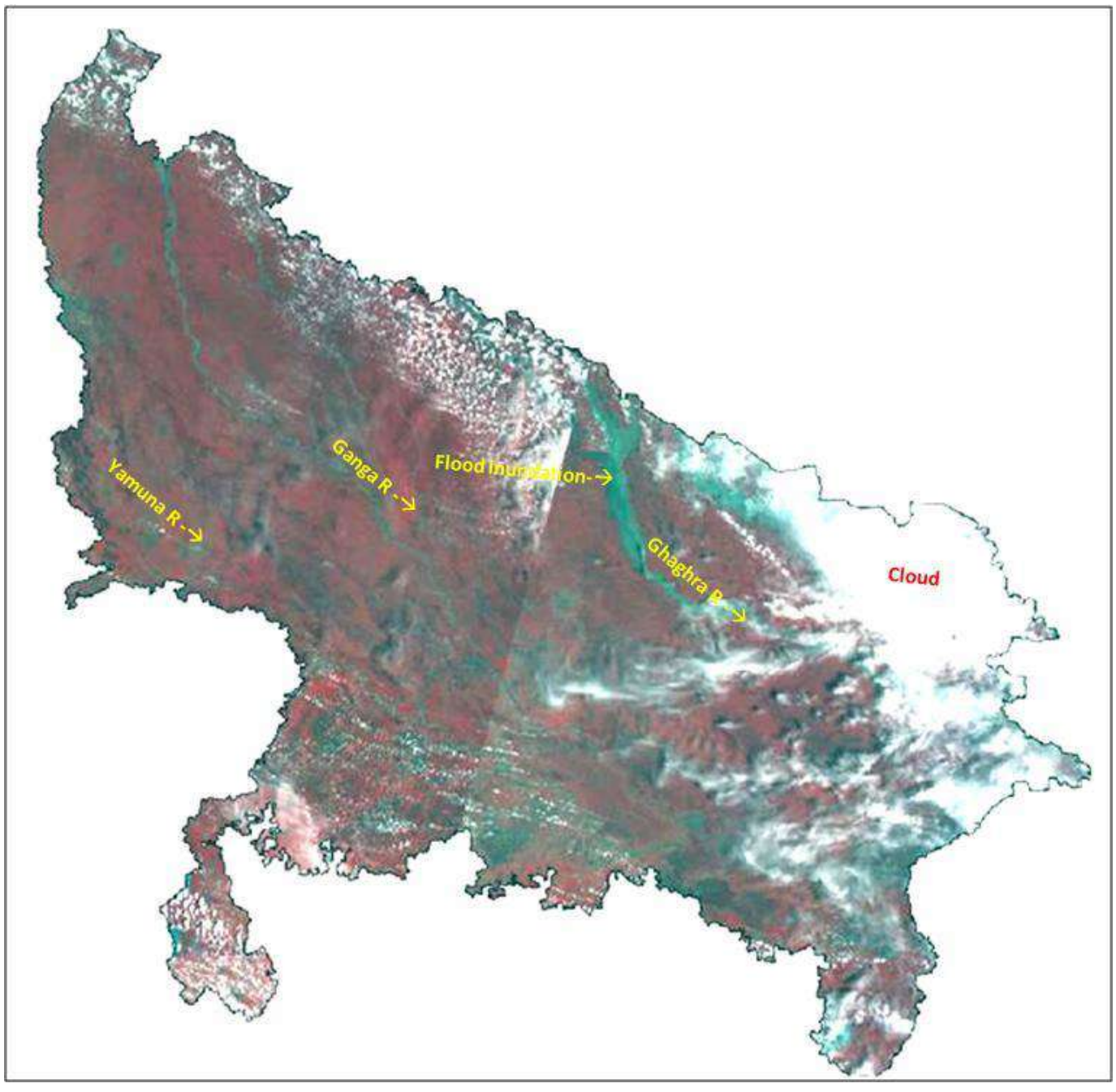


Fig.4: IRS satellite image showing the during-flood situation in Uttar Pradesh.

Table-4 Satellites and sensors for flood mapping (1998-2020)

S No	Satellite	Sensor	Spatial Resolution(in meters)
1	IRS-P6RESOURCESAT-1 & RESOURCESAT-2/2A	AWiFS	56
		LISS-III	23.5
		PAN/L4-MX	5.8
2	IRS-P5 CARTOSAT-1	PAN	2.5
3	CARTOSAT-2/2A/2B/2E/3	PAN	~1.0
4	RADARSAT-1 & 2	SAR	50
5	RISAT-1	SAR	36
6	SENTINEL-1	SAR	10
7	TerraSAR-X	SAR	18.5
8	ALOS-2	PALSAR	10
9	KOMPSAT-5	COSI SAR	1
10	NOVA	SAR	20
11	SAOCOM-1	SAR	30
12	RCM-1/2/3	SAR	30

The potential use of remote sensing technology for flood disaster management can be as follows:

- Flood inundation mapping and monitoring
- Rapid damage assessment
- Monitoring and mapping of flood control works and changes in the river course
- Identification of river bank erosion
- Flood hazard zonation
- Improvement in flood forecasting & warning models

Conventional flood hazard mapping techniques requires historical flood data to map floodplains. In addition to a record of peakflows over a period of years, a detailed survey (cross sections, slopes and close contour maps), maps such as soils, physiography,land use, vegetation, population density, infrastructure, and settlements along with hydraulic roughness estimates are required before determination of the extent of flooding for an expected recurrence interval. Some of the data required for hazard mapping is difficult to obtain from ground measurements and is time consuming. Flood hazard zonation map requires mainly flow information and fine resolution, Digital Elevation Model (DEM). As the fine resolution DEM is not available for most of the floodplains, with these constraints it is difficult to prepare flood hazard zonation maps conventionally. In this context, the Earth Observation satellites provide the extent of flooding for major flood events at regular intervals, which helps in identifying the frequency of the inundated areas. If satellite datasets during flood times are available over a period of time for a flood plain they can be used for flood hazard mapping.

Flood Hazard zonation is useful :

- For controlling the developmental activities.
- For constructing the flood retention structures
- For constructing relief &rescue shelters and establishing mobile health centres in flood plains
- For prioritisation in relief and rescue operations during flood events and aids in effective disaster risk reduction.
- For planning flood tolerent crops in floodplains.

1.4. INITIATIVES OF DEPARTMENT OF SPACE (DOS)

Keeping in view of the demonstrated potential of earth observation and communication satellites, Department of Space (DoS) has launched Disaster Management Support Programme (DMSP) for providing aerospace information for disaster management to the nation.DoS is executing a Disaster Management Support Programme (DMSP) by integrating operationally the space technology inputs and services on a reliable and timely basis for strengthening India towards disaster management.

Disaster Management Support Programme

In order to provide vital inputs and support in the event of a disaster, Department of Space (DoS), Government of India, has been developing techniques and methodology by integrating space based systems and services for disaster management. DoS had executed a Disaster Management Support Programme (DMSP) for integrating operationally the space technology inputs and services on a reliable and timely basis for strengthening India's resolve towards disaster management. DMS Programme addresses five issues mainly (i) creation of digital databases at appropriate scales for facilitating hazard Zonation, damage assessment, etc., in perennially disaster prone areas, (ii) development of appropriate Remote Sensing & Geographical Information System (GIS) based decision support tools and techniques and demonstrations catering to the information needs at different levels, (iii) acquisition of close contour information for priority areas, (iv) strengthening the communications backbone for addressing the real time / near real time information transfer needs and (v) networking of scientific institutions for exchange of data, information and knowledge.

Towards enabling the operational services, a Rapid Reponse Emergency Services (RRES) is established at National Remote Sensing Centre, (NRSC), Hyderabad, as a single window provider, interfacing with the National / State disaster management agencies. The important components of the RRES include satellite/ aerial data acquisition strategy, user required information and formats, output generation, dissemination of information generated to the users through networking, support functions such as digital database, query shells, hazard zonation, etc.

2.0 FLOOD PROBLEM IN UTTAR PRADESH

2.1. ABOUT UTTAR PRADESH

Uttar Pradesh is located between the parallels of 23°52'N and 31°28'N latitudes and meridians of 77°3′E and 84°39'E longitudes. It is bordered by Rajasthan to the West, Haryana, Himachal Pradesh and Delhi to the Northwest, Uttarakhand and an international border with Nepal to the North, Bihar to the East, Madhya Pradesh to the South, and touches the states of Jharkhand and Chhattisgarh to the Southeast.It covers 240,928 km^2 (93,023 sq mi), equal to 7.34% of the total area of India.

The state can be divided into two physiographic regions: the central plains of the Ganges (Ganga) River and its tributaries (part of the Indo-Gangetic Plain) and the Southern Uplands. The vast majority of Uttar Pradesh lies within the Gangetic Plain, which is composed of alluvial deposits brought down from the Himalayas to the North by the vast Ganges network. Most of that area is a featureless, though fertile, plains varying in elevation from about 300m in the Northwest to about 60m in the extreme East. The Southern Uplands form part of the highly dissected and rugged Vindhya Range, which rises generally toward the Southeast. The elevation of that region rarely exceeds 300m.

The climate of Uttar Pradesh is of tropical monsoon type, with year-round warm weather. Average high temperatures in Lucknow range from about low 20 °C in January to over 38 °C in May and June. High temperatures of about 50 °C have been recorded at Gonda, northwest of Ayodhya.

Annual rainfall in the state ranges from 1,000–2,000 mm in the east to 600–1,000 mm in the west. According to IMD, UP, about 90 percent of the rainfall occurs during the southwest monsoon, lasting from about June to September. With most of the rainfall concentrated during that four-month period, floods are a recurring problem and can cause fatalities and heavy damage to crops and property, particularly in the eastern part of the state. Periodic failure of monsoons results in drought conditions. Figure 5 shows the location and physical features of Uttar Pradesh State.

Physical Features	
Latitude of UP	23° 52' to 31° 28' N
Longitude of UP	77°3′ to 84°39'E
Total Area of UP	240,928.00 sq. kms
Height above Sea-Level of UP	60 m to 300 m
Normal Rainfall in UP	1000-2000 mm
Source: https://up.gov.in	

Fig 5: Location map of Uttar PradeshState

2.1.1. Administrative Setup

Uttar Pradesh state is divided into 18 divisions with 75 districts and 821 development blocks. There are 915 cities &towns. Table-5 shows the divisions,head quarters and districts of Uttar Pradesh. Figure-6 shows the district map of Uttar Pradesh state.

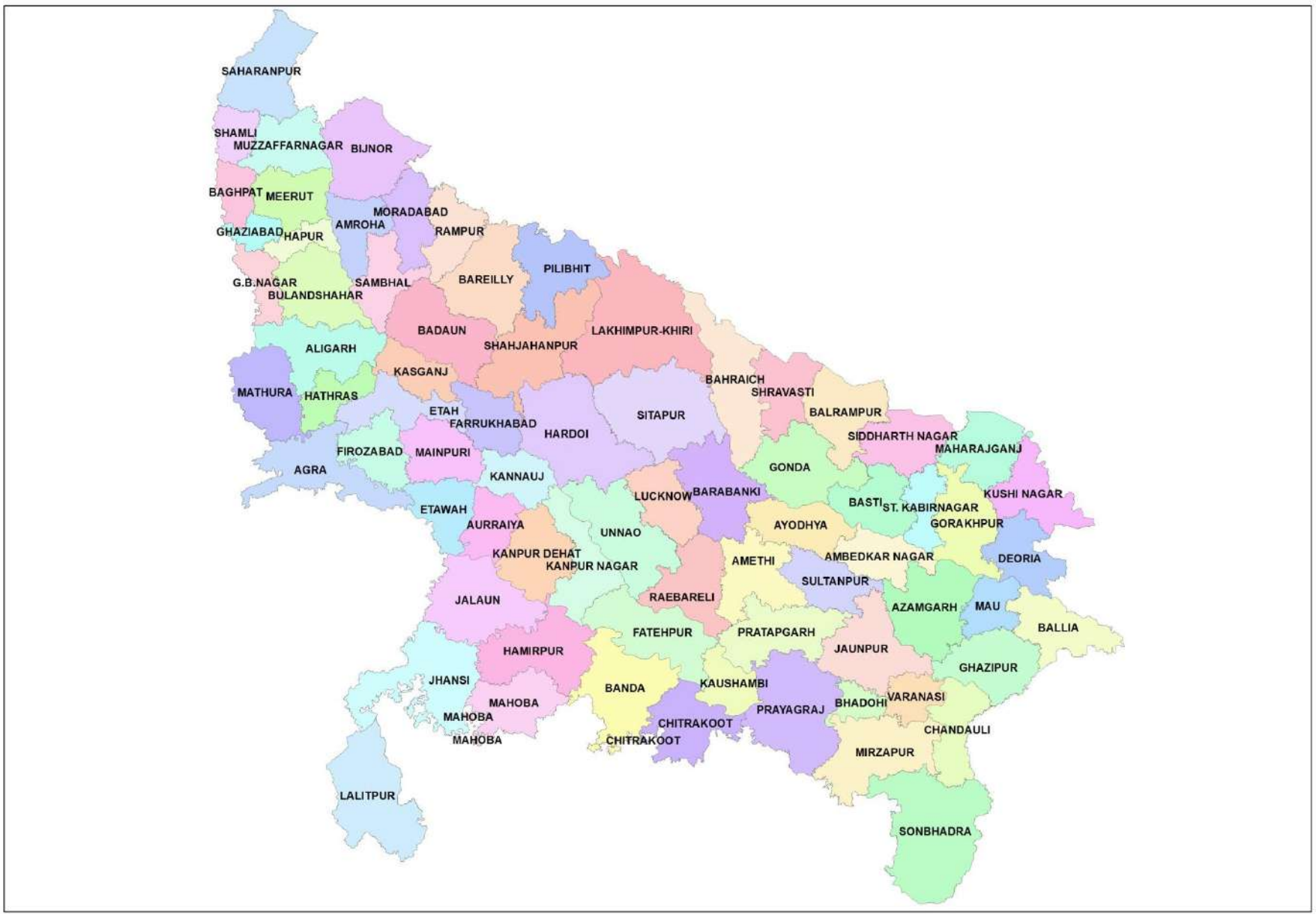


Fig.6: District Map of Uttar Pradesh state (Source: UPSDMA)

Table-5: Divisions and Districts in Uttar Pradesh state

Sl.NO	Division	Headquarters	District
1	Agra	Agra	Agra, Firozbad, Mainpuri, Mathura
2	Sahranpur	Sahranpur	Sahranpur,Shamli, Muzaffurnagar
3	Aligarh	Aligarh	Aligarh,Etah,Hathras,Kasganj
4	Allahabad	Allahabad	Allahabad (Prayagraj),Fatehpur,Kaushambi,Pratapgarh
5	Azamgarh	Azamgarh	Azamgarh,Ballia,Mau
6	Bareilly	Bareilly	Bareilly,Badaun,Pilibihit,Shahjahanpur
7	Basti	Basti	Basti,Siddharthnagar,Santkabirnagar
8	Chitrakoot	Chitrakoot	Banda,Chitrakoot,Hamirpur,Mahoba
9	Devipatan	Gonda	Gonda,Bahraich,Sharavasti,Balarampur
10	Ayodhya	Ayodhya	St.Ambedkarnagar, Amethi,Barabanki,Ayodhya,Sultanpur
11	Gorakhpur	Gorakhpur	Gorakhpur,Kushinagar,Deorria,Maharajganj
12	Jhansi	Jhansi	Jhansi,Jalaun,Lalitpur
13	Kanpur	Kanpur	Etawah,Farukhabad,KanpurDehat, Kanpur Nagar,, Kannauj
14	Lucknow	Lucknow	Lucknow,hardoi,LakhimpurKheri, Raebareli, Sitapur, Unnao
15	Meerut	Meerut	Baghpat, Meerut, Ghaziabad,Hapur, Gautam Buddhnagar,Bulandshahr
16	Mirzapur	Mirzapur	Mirzapur,SantRavidasnagar, Bhadohi,Sonbhadra
17	Moradabad	Moradabad	Moradabad,Bijnor,Rampur,Amroha,Sambhal
18	Varanasi	Varanasi	Varanasi,Chandauli,Ghazipur,Jaunpur

2.1.2. Demography

As per Census 2011, Uttar Pradesh has population of 19.98 Crores, an increase from figure of 16.62 Crore in 2001 census. Total population of Uttar Pradesh as per 2011 census is 199,812,341 of which male and female are 104,480,510 and 95,331,831 respectively. In 2001, total population was 166,197,921 in which males were 87,565,369 while females were 78,632,552. The total population growth in this decade was 20.23 percent while in previous decade it was 25.80 percent. The population of Uttar Pradesh forms 16.50 percent of India in 2011. In 2001, the figure was 16.16 percent. Literacy rate in Uttar Pradesh has seen upward trend and is 67.68 percent as per 2011 population census. Of that, male literacy stands at 77.28 percent while female literacy is at 57.18 percent. In 2001, literacy rate in Uttar Pradesh stood at 56.27 percent of which male and female were 68.82 percent and 42.22 percent literacy respectively. Table-6 shows the district-wise demographic profile of Uttar Pradesh. Figure-7shows the population growth trend.

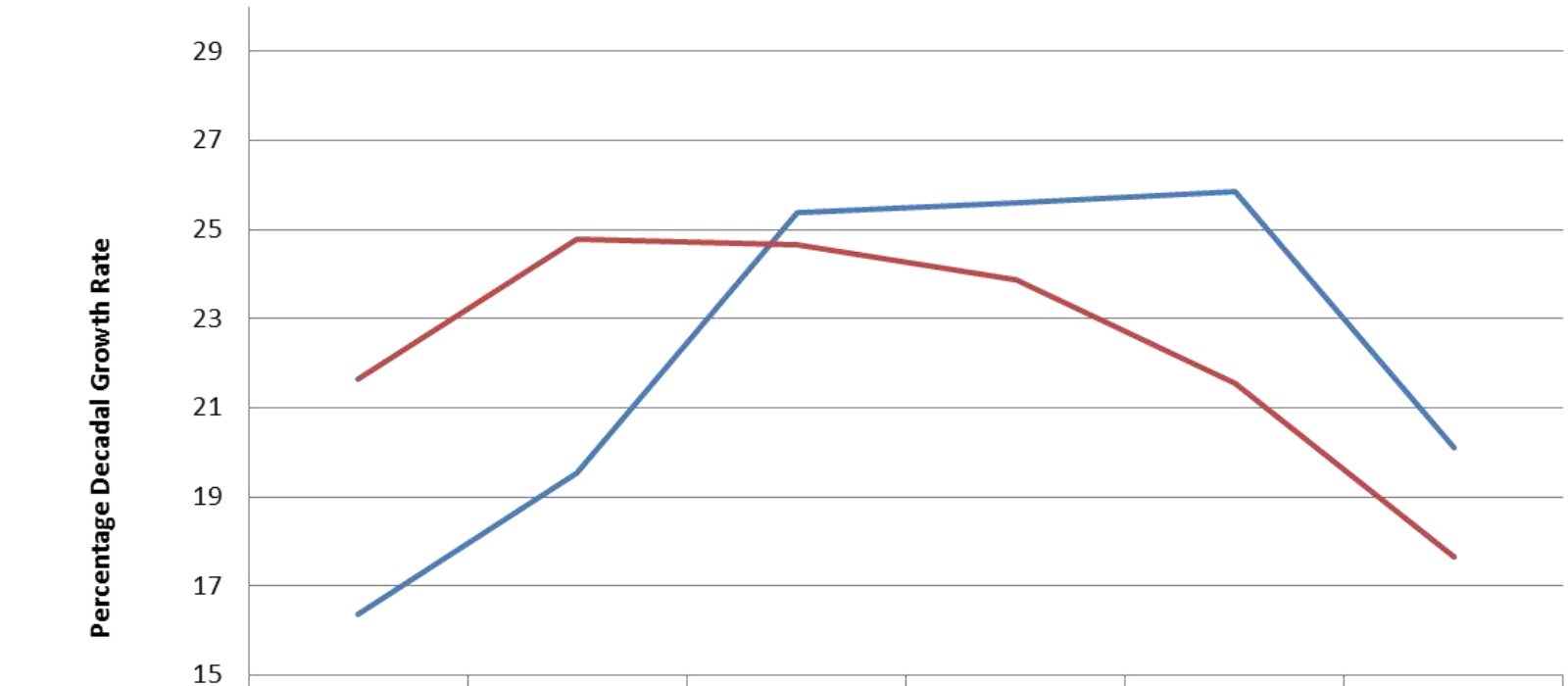
Table-6: District-wise demographic profile of Uttar Pradesh, 2011

Sr.No.	Districts	Population			Sex ratio	Literacy rate		
		Male	Female	Total		Male	Female	Total
1	Agra	2,364,953	2,053,844	4,418,797	868	80.62%	61.18%	71.58%
2	Aligarh	1,951,996	1,721,893	3,673,889	882	77.97%	55.68%	67.51%
3	Allahabad	3,131,807	2,822,584	5,954,391	901	82.55%	60.99%	72.32%
4	Ambedkar Nagar	1,212,410	1,185,478	2,397,888	978	81.66%	62.66%	72.23%
5	Auraiya	740,040	639,505	1,379,545	864	86.11%	70.61%	78.95%
6	Azamgarh	2,285,004	2,328,909	4,613,913	1,019	81.34%	60.91%	70.93%
7	Baghpat	700,070	602,978	1,303,048	861	82.45%	59.95%	72.01%
8	Bahraich	1,843,884	1,643,847	3,487,731	892	58.34%	39.18%	49.36%
9	Ballia	1,672,902	1,566,872	3,239,774	937	81.49%	59.75%	70.94%
10	Balrampur	1,114,721	1,033,944	2,148,665	928	59.73%	38.43%	49.51%
11	Banda	965,876	833,534	1,799,410	863	77.78%	53.67%	66.67%
12	Bara Banki	1,707,073	1,553,626	3,260,699	910	70.27%	52.34%	61.75%
13	Bareilly	2,357,665	2,090,694	4,448,359	887	67.50%	48.30%	58.49%
14	Basti	1,255,272	1,209,192	2,464,464	963	77.88%	56.23%	67.22%
15	Bijnor	1,921,215	1,761,498	3,682,713	917	76.56%	59.72%	68.48%
16	Budaun	1,967,759	1,714,137	3,681,896	871	60.98%	40.09%	51.29%
17	Bulandshahr	1,845,260	1,653,911	3,499,171	896	80.93%	55.57%	68.88%
18	Chandauli	1,017,905	934,851	1,952,756	918	81.72%	60.35%	71.48%
19	Chitrakoot	527,721	464,009	991,730	879	75.80%	52.74%	65.05%
20	Deoria	1,537,436	1,563,510	3,100,946	1,017	83.27%	59.38%	71.13%
21	Etah	947,339	827,141	1,774,480	873	81.28%	58.80%	70.81%
22	Etawah	845,856	735,954	1,581,810	870	86.06%	69.61%	78.41%
23	Ayodhya	1,259,628	1,211,368	2,470,996	962	78.12%	59.03%	68.73%
24	Farrukhabad	1,006,240	878,964	1,885,204	874	77.40%	59.44%	69.04%
25	Fatehpur	1,384,722	1,248,011	2,632,733	901	77.19%	56.58%	67.43%
26	Firozabad	1,332,046	1,166,110	2,498,156	875	80.82%	61.75%	71.92%
27	Gautam Buddha Nagar	890,214	757,901	1,648,115	851	88.06%	70.82%	80.12%
28	Ghaziabad	2,488,834	2,192,811	4,681,645	881	85.42%	69.79%	78.07%
29	Ghazipur	1,855,075	1,765,193	3,620,268	952	82.80%	60.29%	71.78%
30	Gonda	1,787,146	1,646,773	3,433,919	921	69.41%	47.09%	58.71%
31	Gorakhpur	2,277,777	2,163,118	4,440,895	950	81.80%	59.36%	70.83%
32	Hamirpur	593,537	510,748	1,104,285	861	79.76%	55.95%	68.77%

Sr.No.	Districts	Population			Sex ratio	Literacy rate		
		Male	Female	Total		Male	Female	Total
33	Hardoi	2,191,442	1,901,403	4,092,845	868	74.39%	53.19%	64.57%
34	Jalaun	906,092	783,882	1,689,974	865	83.48%	62.46%	73.75%
35	Jaunpur	2,220,465	2,273,739	4,494,204	1,024	83.80%	59.81%	74%
36	Jhansi	1,057,436	941,167	1,998,603	890	85.38%	63.49%	75.05%
37	Jyotiba Phule Nagar	963,449	876,772	1,840,221	910	74.54%	52.10%	63.84%
38	Kannauj	881,776	774,840	1,656,616	879	80.91%	63.33%	72.70%
39	Kanpur Dehat	963,255	832,929	1,796,184	865	83.45%	66.86%	75.78%
40	Kanpur Nagar	2,459,806	2,121,462	4,581,268	862	83.62%	75.05%	79.65%
41	Kanshiramnagar	764,165	672,554	1,436,719	880	71.56%	49.00%	61.02%
42	Kaushambi	838,485	761,111	1,599,596	908	72.78%	48.56%	61.28%
43	Kheri	2,123,187	1,898,056	4,021,243	894	69.57%	50.42%	60.56%
44	Kushinagar	1,818,055	1,746,489	3,564,544	961	77.71%	52.36%	65.25%
45	Lalitpur	641,011	580,581	1,221,592	906	74.98%	50.84%	63.52%
46	Lucknow	2,394,476	2,195,362	4,589,838	917	82.56%	71.54%	77.29%
47	Mahamayanagar	836,127	728,581	1,564,708	871	82.38%	59.23%	71.59%
48	Mahoba	466,358	409,600	875,958	878	75.83%	53.22%	65.27%
49	Maharajganj	1,381,754	1,302,949	2,684,703	943	75.85%	48.92%	62.76%
50	Mainpuri	993,377	875,152	1,868,529	881	84.53%	66.30%	75.99%
51	Mathura	1,367,125	1,180,059	2,547,184	863	81.97%	56.89%	70.36%
52	Mau	1,114,709	1,091,259	2,205,968	979	82.45%	63.63%	73.09%
53	Meerut	1,825,743	1,617,946	3,443,689	886	80.74%	63.98%	72.84%
54	Mirzapur	1,312,302	1,184,668	2,496,970	903	78.97%	56.86%	68.48%
55	Moradabad	2,503,186	2,268,820	4,772,006	906	64.83%	47.86%	56.77%
56	Muzaffurnagar	2,193,434	1,950,078	4,143,512	889	78.44%	58.69%	69.12%
57	Pilibihit	1,072,002	959,005	2,031,007	895	71.70%	50.00%	61.47%
58	Pratapgarh	1,606,085	1,603,056	3,209,141	998	81.88%	58.45%	70.09%
59	Rae Bareli	1,752,542	1,653,017	3,405,559	943	77.63%	56.29%	67.25%
60	Rampur	1,223,889	1,111930	2,335,819	909	61.40%	44.44%	53.34%
61	Sahranpur	1,834,106	1,632,276	3,466,382	890	78.28%	61.74%	70.49%
62	St. Kabir Nagar	869,656	845,527	1,715,183	972	78.39%	54.80%	66.72%
63	St. Ravidas Nagar	807,099	771,114	1,578,213	955	81.47%	56.03%	68.97%
64	Shahjahanpur	1,606,403	1,400,135	3,006,538	872	68.18%	49.57%	59.54%
65	Shrawasti	593,897	523,464	1,117,361	881	57.16%	34.78%	46.74%
66	Siddharthnagar	1,295,095	1,264,202	2,559,297	976	70.92%	47.41%	59.25%
67	Sitapur	2,375,264	2,108,728	4,483,992	888	70.31%	50.67%	61.12%
68	Sonbhadra	971,344	891,215	1,862,559	918	74.92%	52.14%	64.03%
69	Sultanpur	1,914,586	1,882,531	3,797,117	983	80.19%	58.28%	69.27%
70	Unnao	1,630,087	1,478,280	3,108,367	907	75.05%	56.76%	66.37%
71	Varanasi	1,921,857	1,754,984	3,676,841	913	83.78%	66.69%	75.60%
72	Uttar Pradesh	104,480,510	95,331,831	199,812,341	912	77.28%	57.18%	67.68%

(Source: Census of India, 2011)

Note : As per Census 2011, 72 districts only exist in the Uttar pradesh State and the same has been incorporated.



	1951-1961	1961-1971	1971-1981	1981-1991	1991-2001	2001-2011
Uttar Pradesh	16.38	19.54	25.39	25.61	25.85	20.09
India	21.64	24.8	24.66	23.87	21.54	17.64

Figure-7: Population Growth Trend of Uttar Pradesh – 1951 to 2011

(Source: Census of India, 2011)

2.1.3 Physiography of Uttar Pradesh

Morphologically the state of Uttar Pradesh can be broadly divided into three major regions.

1) The Gangetic Plain.
2) Peninsular Region.
3) The Sub-Himalayan Zone.

The Gangetic Plain

The Gangetic Plain covers nearly two-third of Uttar Pradesh and has been built by the Ganga and its tributaries. It comprises of an alluvial tract of Pleistocene and recent deposits of clay and sand. The height of the entire plain area outside the Bhabhar and Terai belts generally ranges between 80 metres and 250 metres. Except for northern part of Saharanpur district at the foot of the Siwalik range, no place in the region is more than 300 metres above the sea-level. The whole area is levelled, except for those portions of Trans-Yamuna, Agra and Mathura districts where several ravines and red-stone hillocks are found on the eastern end of the Arawalli hills. The slope of the plain is from north to south in the western portion and from west-north to south-east in eastern. The plain is watered by the Yamuna, the Ganga and its northern tributaries, the Ram Ganga, the Gomti and the Ghaghra. The whole region is densely populated and immensely vital for the economy of the State. The soil available in this region is mostly alluvial which is very fertile. Generally, two crops Rabi during spring and Kharif during autumn are harvested. The main crops of this region are paddy, wheat, gram, millets and sugarcane.

The Sub-Himalayan Zone

The sub-Himalayan zone is the zone of Terai Bhabar and the foothills of Siwaliks. Geographically, the Siwaliks of the outer Himalayas, immediately below and between the Beas and the upper reaches of Ganga consist of fresh water deposits of middle Miocene to lower Pleistocene age. This belt persists throughout the foothills of the Himalayas and shows a simple type of folding and faulting

Peninsular Region

The southern most part of Uttar Pradesh is the peninsular shield composed of geologically speaking, the most ancient rocks of diversified origins. Its mountains represent the survival of hard masses of rocks which have escaped weathering and removal. The eastern part of this region comprises of Vindhya Mountains, while the western portion consists of a rocky highland plateau with the Vindhya Mountains to the south of it. The Vindhya Range is composed of sedimentary rocks of Vindhyan system i.e. sand stone, lime-stone and shales. The height of the plateau is generally not above 300 metres above the sea-level.

2.1.4 Climate

The State has a tropical monsoon climate with an average temperature varying from a minimum of about 3-4°C in January to 43-44°C in May-June. In the sub-Himalayan belt stretching from Saharanpur to Deoria, the climate is humid. Down below the Gangetic plain usually the temperature in January touching 3-4°C while it shoots upto 43°C in May-June. Generally, the districts of Agra and Jhansi have the highest temperature and Bareilly and Roorkie the lowest.The climatic conditions of the state are also reflected by the three different seasons of the year Winter season from October to February, Summer from March to mid-June and monsoon from mid-June to September. Winters are generally cold during winters. Hailstroms in February and March are not uncommon. The southern hills and plateau are very hot in summers owing to barren and rocky nature of the terrain Characteristics of different agro-climatic zones in Uttar Pradesh are presented in following table 7.

Table-7: Climatic zones and Rainfallin Uttar Pradesh State

Sl.No	Agro Climatic Zones	Soil Type	Average Annual rainfall (mm)	Temperature (^{0}C)	
				Minimum	Maxium
1	Bhabhar and Tarai Zone	Alluvial least to medium phosphorous medium to high potassium and highly carbonised matter	1400	5.5	38.4
2	Western Plain Zone	Alluvial PH value normal to sodic and carbonised matter from least to mdeium	795	1.50	43.3
3	Mid Western Plain Zone	All most alluvial normal to slight sodic and contains medium carbonic matters	1032	4.5	45.4
4	South Western semi arid zone	Alluvial &aravali	662	4.0	47.0
5	Central Plain Zone	Alluvial, PH normal to sodic and containing carbonic matter from least to medium quantity	863	5.5	45.0
6	Bundelkhand zone	Rakar, Parwa,kabar and Maar	867	3.0	47.8
7	North eastern Plain zone	Alluvial, calcarius	1240	4.9	44.2
8	Eastern Plain zone	Alluvial, Sodic and Diarasoil	803	5.7	41.4
9	Vindhyan Zone	Kali, Bhari red granules and alluvial soil in plain are	1134	5.0	45.2

(Source: Department Of Land Development and Water Resources Government of Uttar Pradesh.)

2.1.5 Major Rivers

The State of Uttar Pradesh is enriched with water resources, both the ground water resources and the surface water resources. The major river basins in the State are Ganges, Yamuna, Ghaghra, Gomti, Ramganga,Rapti, Gandak, Son and Sarda river basins which criss-cross the State. The following section briefly describes the various river basins of Uttar Pradesh. Fig 8 shows the major river basins of UP and details are given below.

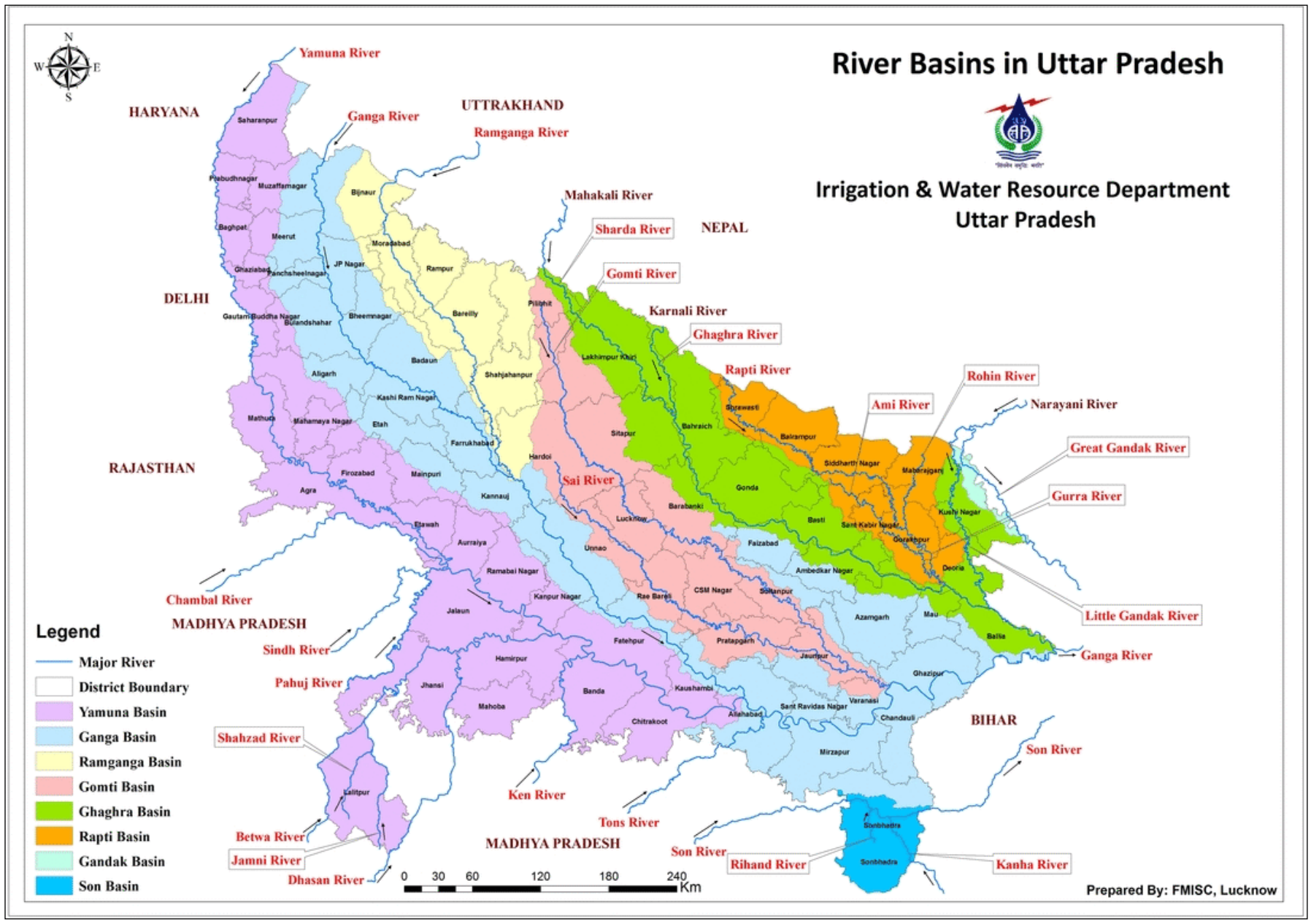


Fig 8 : Major River basins in Uttar Pradesh (Source :Irrigation& Water resource department, UP)

1. Ganga

Ganga is formed by 6 headstreams and 5 of their confluences. Bhagirathi is considered as source of River Ganga which rises at the foot of Gangotri glacier at Gaumukh at an elevation of 3892 mts, though there are many small streams that feed Bhagirathi. The six headstreams are the Alaknanda, Dhauliganga, Nandakini, Pindar, Mandakini, and Bhagirathi rivers. The five confluences, known as the PanchPrayag, are all along the Alaknanda. They are, in downstream order, Vishnuprayag, where the Dhauliganga joins the Alaknanda, Nandprayag, where the Nandakini joins Karnaprayag, where the Pindar joins, Rudraprayag, where the Mandakini joins; and finally, Devprayag, where the Bhagirathi joins the Alaknanda to form the Ganges River proper. It is the longest river of India and also the largest and most fertile basin the country.

2. Bhagirathi

It is considered as the source of river Ganga, rising at the foot of Gangotri glacier. The upper catchment of the river is glaciated and thus continuously feeds the river throughout the year. The river cuts spectacular gorges as it cuts through the granites and crystalline rocks of the middle Himalayas. Its main tributary is Bhilganga which joins it at Tehri, where the Tehri dam has been constructed.

3.Alaknanda

The headwaters of the Alaknanda are formed by snowmelt from such peaks as Badrinath, Kamet, Satopant glaciers in Uttarakhand.It meets the Bhagirathi river at Devprayag. Its main tributaries are Mandakini, Nandakini, and Pindar Rivers. The Alaknanda River drains part of Chamoli, Tehri and Pauri districts. Pilgrimage centre Badrinath and natural spring Tapt Kund lies along the banks of the Alaknanda River.

4. Ramganga

The tributary of Ganga draining through the shivalik ranges and is fed by springs emanating from the reservoirs of underground water. Ramganga flows by the Jim Corbett National Park near Ramnagar of Nainital district from where it descends upon the plains from there it meets Ganges near Kannauj Bareilly city of Uttar Pradesh which is situated on its banks.

5. Gomti

The Gomti river originates from Gomat Taal which is formally known as Fulhaarjheel, near Madho Tanda, Pilibhit, India. It extends 900 km (560 mi) through Uttar Pradesh and meets the Ganges River near Saidpur, Kaithi in Ghazipur. Another major tributary is the Sai River, which joins near Jaunpur. It meets Ganges near Ghazipur.

6. Sai

Tributary of Gomati which joins it in Jaunpur. Towns of Raibareily and Pratapgarh are situated on it.

7. Sarda

Originates from the greater Himalayas at Kalapani at an altitude of 3600 mts. River is known as Kali river in Nepal where temple of goddess Kali is situated in Kalapani, near Lipulekh pass at the border of India and Tibet and after descending into India it is called as Sarda.

8. Ghaghra

It is a perennial river originating near Mansarovar lake, joins sharda river near Brahmaghat in Uttar Pradesh.Ghaghra river joins Ganges at Dariganjbhiar.It is the largest tributary of Ganges in terms of volume. The river flows through Katarniaghat wildlife sanctuary, part of Dudhwa National Park. The upper course of river is famous for gangetic dolphins.

9. Saryu

It is left bank tributary of Ghaghra, it meets Ghaghra in Bahraich district.Ayodhya is situated on the banks of river Saryu.

10.Rapti

Rises south of prominent East-West ridge midway between Dhaulagiri and Mahabharat ranges in Nepal. Fed by springs. City of Gorakhpur lies on its banks and causes frequent floods in the rainy season.

11.Varuna

The Varuna River is a minor tributary of the Ganges River. It is named after the God Varuna. The name Varanasi itself is interpreted to be derived from the name of the river Varuna.

12. Yamuna

Yamuna river originates from Yamunotri glacier in the lower Himalayas, Uttarkashi distict of Uttarakhand. Flows for 1370 kms before it meets Ganges at Allahabad. The river is fed by Tons (in Uttarakhand) and Giri (Himachal P) it forms boundary of Haryana,passes through Delhi along the border of Uttar Pradesh passing through the major cities like Baghpat, Noida, Mathura, Agra, Firozabad, Etawah& Hamirpur. The industrial development all along the course of river is now the major cause of Yamuna being polluted so much.

13. Sirsa

Travels parallel to Yamuna River in South-East direction and passes along the Etawah district.

14. Sengar

Tributary of Sirsa, moves along the bad land and Ravines of Chambal valley.

15. Chambal

The river rises in the Malwa on the northern slopes of Vindhyan near Mhow. The river is part of the confluence of 5 rivers near Etawah district called “Pachnada”(in hindi). The river is famous for the ravines that have been created due to flooding and break of channel by the Chambal River. Most rice and oil seeds are grown along the banks. Chambal is liable to heavy floods due to steep gradient of its bed before it debouches on the alluvial plains. The volume discharge is greater than Yamuna. Clear waters and alligators are common in the river. Hydropower and irrigation projects Gandhi Sagar (MP) and Ranapratap Sagar (Rajasthan) and Kota barrage are built on Chambal River.

16. Kuwari River

A tributary of Chambal, rises from northern border of MP ,northern slopes of Vindhyas, moves in a semicircular tract before meeting Chambal in Auraiya District, though subject to sudden and freshets during rains yet remains an insignificant stream in the hot season.

17. The Ahneya and Puraha

These take rise in a series of lakes, the former near Kakan and the latter near Sauj in the Mainpuri district and little more than the drainage channels for carrying off superfluous rain water. In the hot or cold season they are normally dry but in rains, the Puraha, owing to its sinuous course, injures a considerable amount of land on either bank.

18. Pandu

It is the only stream of the Etawah district which flows into the Ganga. It rises in the extreme North-East of Bidhuna tahsil in a large clay depression forming a lake lying between Sabhad and Nurpur. It flows eastwards into the Farrukhabad district.

19. Betwa

The Betwa rises in the Vindhya Range just North of Hoshangabad in Madhya Pradesh and flows North-East through Madhya Pradesh and flow through Orchha to Uttar Pradesh. Matatila Dam, an undertaking between the states of Madhya Pradesh and Uttar Pradesh, Paricha Dam, Rajghat Dam situated on Betwa river.

20. Dhasan

The Dhasan River is a right bank tributary of the Betwa River.

21. Jawai River

Flows through Bundelkhand region, acts as lifeline of this region due to variability in Monsoon over this region.

22. Ken River

It is one the major rivers of the Bundelkhand region of central India, and flows through two states, Madhya Pradesh and Uttar Pradesh. Rises from Vindhyas. It is a tributary of the Yamuna, The Raneh Falls on the Ken river and Ken Ghariyal Sanctuary are tourist attractions. Gangau Dam has been constructed at the confluence of the Ken and Simri rivers. The Ken River passes through Panna National Park. Banda city is located on banks of River Ken.

23. Baghain River

Also rises from Northern slope of Vindhyas and meets Ken river perpendicular making rectangular drainage.

24. Tons River / Tamsa

The Tamsa River (also known as the Tons River) is a tributary of the Ganges flowing through the Indian states of Madhya Pradesh and Uttar Pradesh. The Tamsa rises in a tank at Tamakund in the Kaimur Range at an elevation of 610 meters. It flows through the fertile districts of Satna and Rewa. The river receives the Belan in UP and joins the Ganges at Sirsa, 300 km from Sangam. The Tamsa River while descending through the Rewa Plateau and draining northwards makes a vertical falls of 70m known as Purwa Falls, Chachai Falls (127m) on the Bihad River, a tributary of the Tamsa, the Keoti Falls (98m) on the Mahana River, a tributary of the Tamsa, and Odda Falls (145m) on the Odda River, a tributary of the Belah River, which is itself a tributary of the Tamsa.

25. Belan River

Tributary of Tons, rising from Kaimur Hills, meets Tons at the boundary of Uttar Pradesh and Madhya Pradesh.

26. Son River

The Son originates near Amarkantak in Madhya Pradesh,just East of the headwaters of the Narmada River. The Son parallels the Kaimur hills, flowing East-Northeast through Uttar Pradesh, Jharkhand and Bihar states to join the Ganges just above Patna. Its chief tributaries are the Rihand and the North Koel. The Bansagar Dam in Madhya Pradesh is made on this river.

27. Rihand River

The Rihand headwaters originate in the Bagelkhand region of Madhya Pradesh State, and flow towards the North into Sonbhadra District of Uttar Pradesh. Here it joins the Son River. The Rihand Dam was built across the river in 1962 for hydropower generation; the reservoir made behind the dam is called Govind Ballabh Pant Sagar.

28. Kanhar River

The Kanhar River is a tributary of the Son River and flows through the Indian states of Chhattisgarh, Jharkhand and Uttar Pradesh. Rises from Chota Nagpur Plateau, flowing through Sonbhadra district in Mirzapur division of Uttar Pradesh. It confluences with the Son River to the North-East of the village of Kota. It has a rocky bed almost throughout its course. A rapid mountain torrent, flowing through forested areas. Sukhdari Falls is 100 feet high. It is located near the meeting point of the borders of Chhattisgarh, Jharkhand and Uttar Pradesh.

29. Gopad River

Gopad River, one of the main tributaries of the Son River, emerges from the hills on the North of radial drainage Baghelkhand plateau.

30. Karmanasa River

It is a tributary of the Ganges. Flows through the Indian states of Uttar Pradesh and Bihar. Along the boundary between Uttar Pradesh and Bihar on the northern face of Kaimur Range . Its tributaries are the Durgavati, the Chandraprabha. Devdari falls, at an edge of the Rohtas Plateau.

2.2. MAJOR FLOODS IN UTTAR PRADESH

Background

The State of Uttar Pradesh accounts for approximately 24 percent of the total flooded area and 23 percent of the total damages in the country during the period 1971-1978, The eastern half of the State is more vulnerable wherein some area gets affected by floods almost every year. Eastern districts of Uttar Pradesh are worst affected by the floods. The rivers which cause damage in this area are the Ghaghara, the Sarda, Gandak, and Rapti, The Ghaghara submerges an area of 7769.97 Sq, Km, and the Rapti about 3107.988 Sq. Km near the confluence of the Ganga and Ram Ganga, The problem of drainage congestion is also found in the Western and North-western districts of Uttar Pradesh.

Records from Central Water Commission say that Ghaghara and Rapti river basin has experienced major floods during 1965, 1969, 1973 & 1998. Flood has occurred 2 times in the Balrampur district. 9 times in Basti district and 21 times in Birdghat (Gorakhpur) between 1987 to 1996. (Nandargi& Dhar D.N., 1998). The severe flood of the year 1998 and losses thereof have necessitated to study the area in detail and develop the methodology for flood risk mapping, silt load assessment and creation of data base for flood management information system for long term flood prone area planning (RSAC, 1998 & 2008).

2.2.1.Floods in 2008

Heavy rains lashed vast areas of Uttar Pradesh during the first week of July. All major rivers in the state were rising steadily with Ghagra in Ayodhya and Sharda at Palikalan crossing the red mark.Subsequently,incessant rainfall continued to play havoc in Uttar Pradesh during the third week of July also as a result large parts of the State remained affected due to flooding during the month of August. In addition, the release of additional 1,45,000 cusecs of water from Narora Barrage added to the already existing grim situation in Kannauj and Farrukhabad districts.During third week of August,unabated rainsled to the submergence of several low-lying areas of Lucknow aslo flooding of several villages in Gorakhpur region brought life to a standstill. During September, the continuous downpour led to severe flood-situation in various districts of the state followed by the continuous rise in the water levels of Ghaghra, Saryu, Sharda, Rapti and Yamuna submerged new areas along the riverbanks inundating several villages in Ayodhya, Bahraich, Lakhimpur and Barabanki districts of the state. During 2008, Floods were mapped 13 times in the state of Uttar Pradesh starting from July- September. During 2008, maximum inundation of about 2,57,829 ha was observed and Gorakhpur district was the worst affected with 40,308 ha of area submerged. Fig 9 shows the pre and post flood inundation in parts of UP.

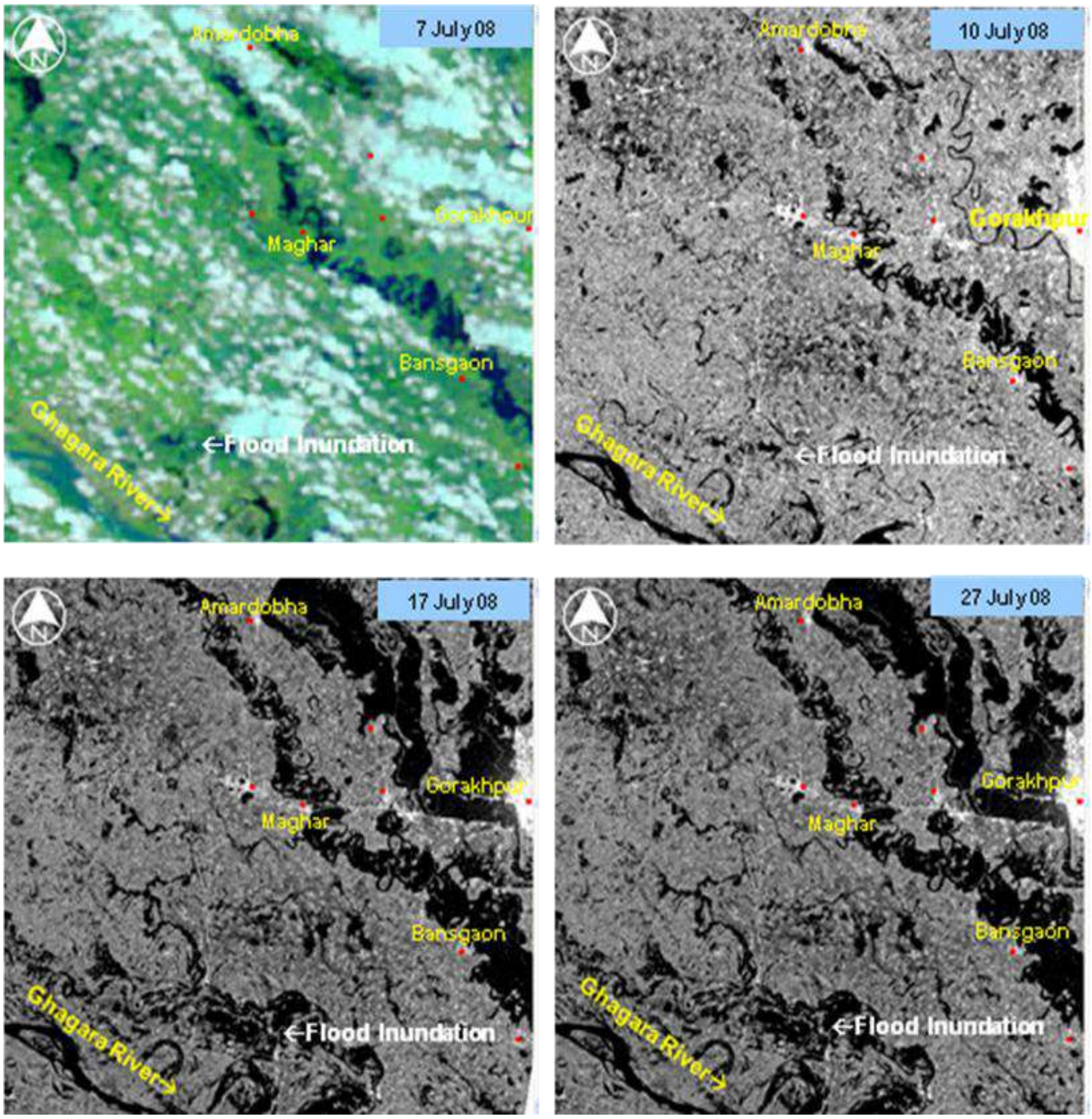


Fig 9 : Satellite Images depicting flood inundation in part of UP during 2008

2.2.2.Floods in 2010

Uttar Pradesh experienced severe floods in 2010, four waves of flood hit the state over a period of four months causing severe flood inundation and damage to property, livelihoods and lives in many parts of the State. Heavy incessant rains followed by the rise in water levels of rivers Ganga, Ghaghra,Yamuna aggravated the floods in Barabanki, Bahraich, Shrawasti, Ayodhya and several villages of Kanpur, Kannauj etc. During September third week, heavy rains followed by discharge of lakhs of cusecs of water from different barrages and dams into the rivers has resulted in worst flood situation in Terai areas and has badly affected the villages falling in the districts of Mathura, Bahraich, Sitapur, Badaun, Basti and Ayodhya districts. Amost 14,29,859 hectares area covering 41 districts of the State was affected by floods.

River Ganga has crossed earlier highest flood level (HFL) at several places, submerging vast stretch of lands in several districts.IRS P6 LISS III on Sept., 29, 2010 captured the unprecedented floods near Fatehgarh in Farrukhabad district, UP.Figs10& 11 shows the satellite images depicting the flood inundated areas in parts of UP.

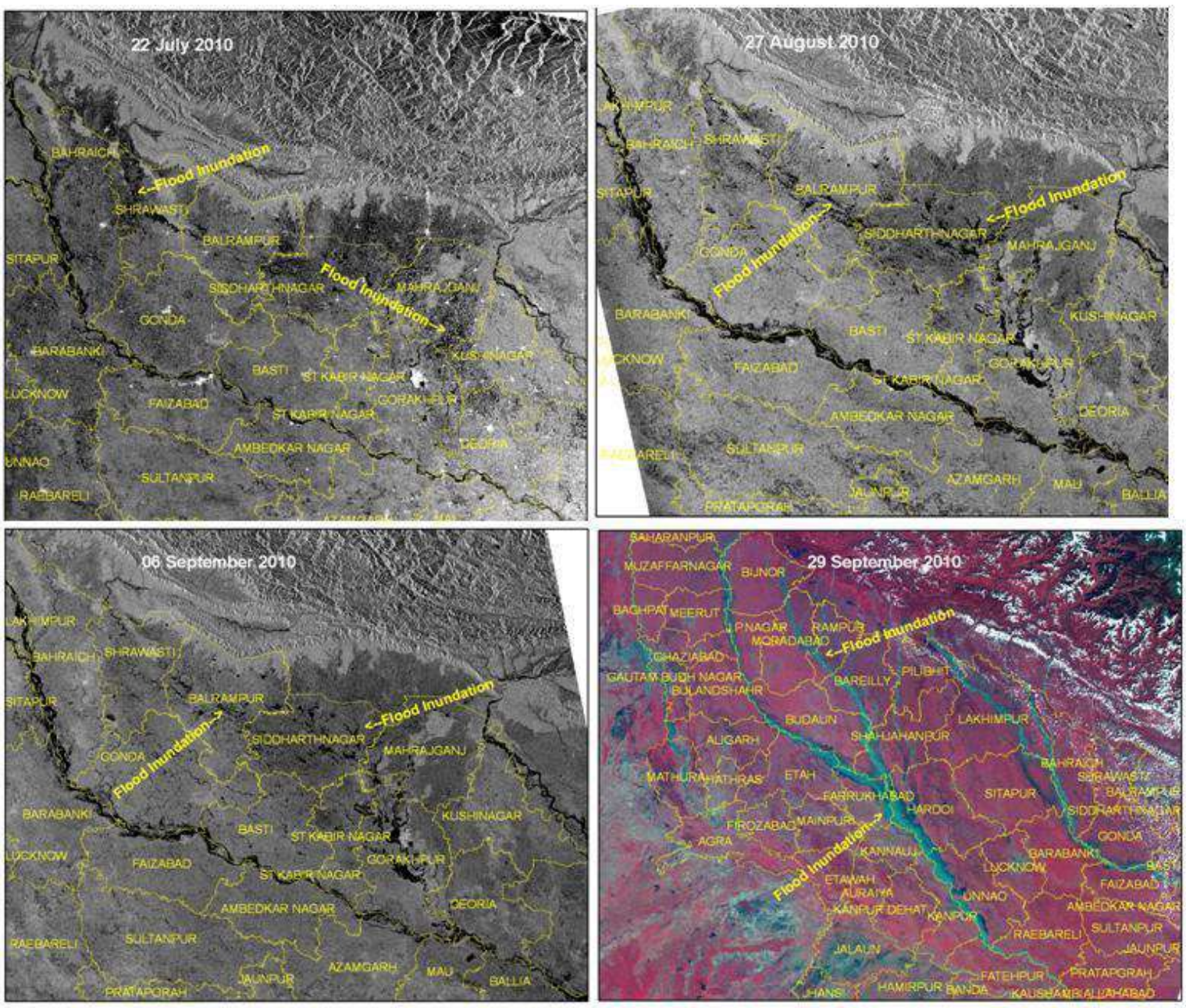


Fig 10 : Satellite Images depicting flood inundation in part of UP during Jul-Sep, 2010

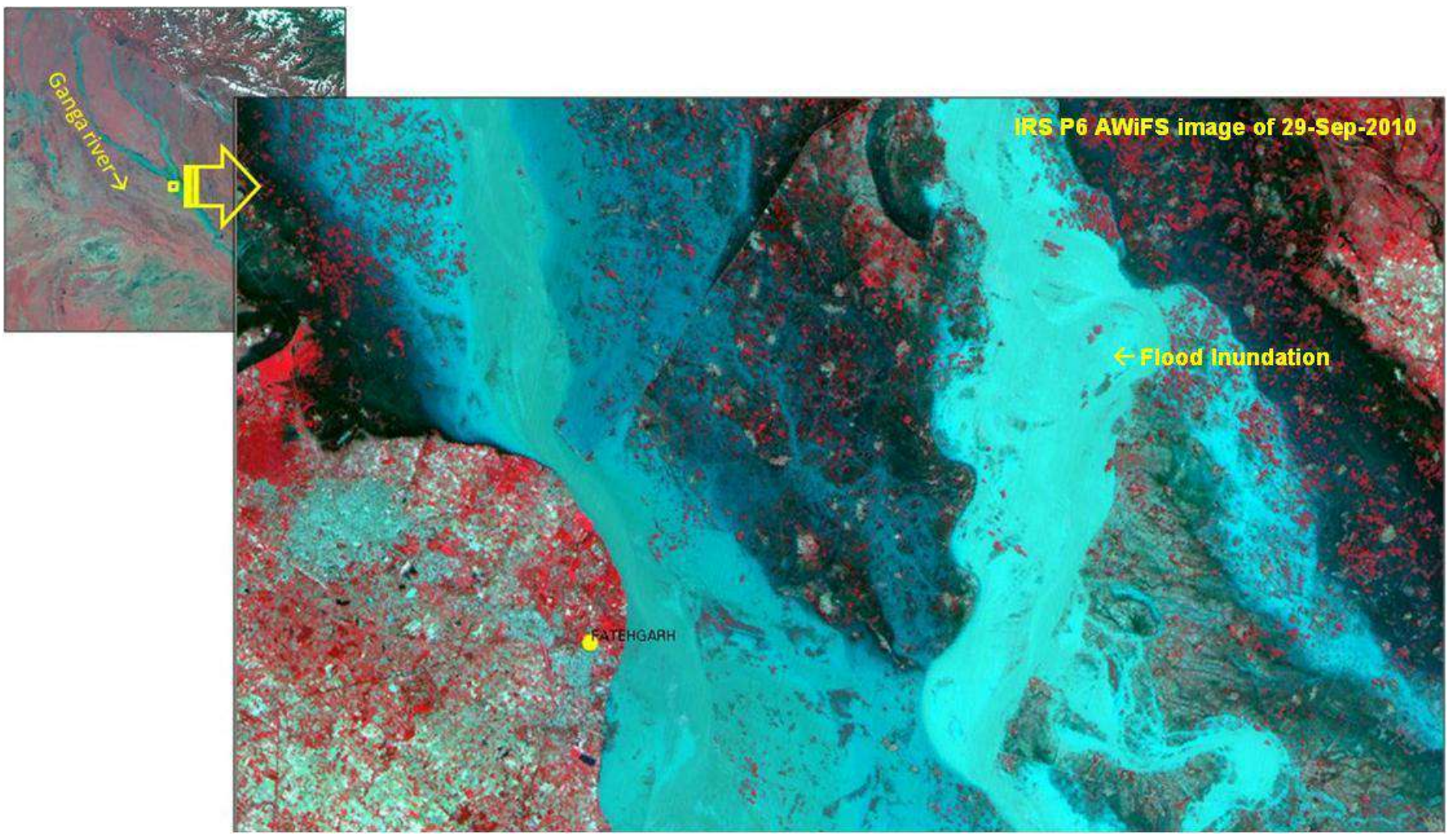


Fig 11: Flood Inundated Areas in part of Farukhabaddist, UP.

2.2.3. Floods in 2011

During 2011, many parts of Uttar Pradesh state experienced severe floods due to incessant rains and rise in water levels in major tributaries of river Ghaghara, Ganga and Ken rivers inundating many districts along their banks. Floods were reported in Barabanki and Gonda districts of Uttar pradesh due to breach in the Elgin-Charsadi embankment of Ghagra river on August 01, 2011 leading to flooding in several villages as shown in Fig 13. During August 2011, due to heavy rainfall in the upper catchments and subsequent release of water from barrages. River Ghaghara was flowing above danger mark at Ayodhya. Several villages were reported to be submerged in flood water.

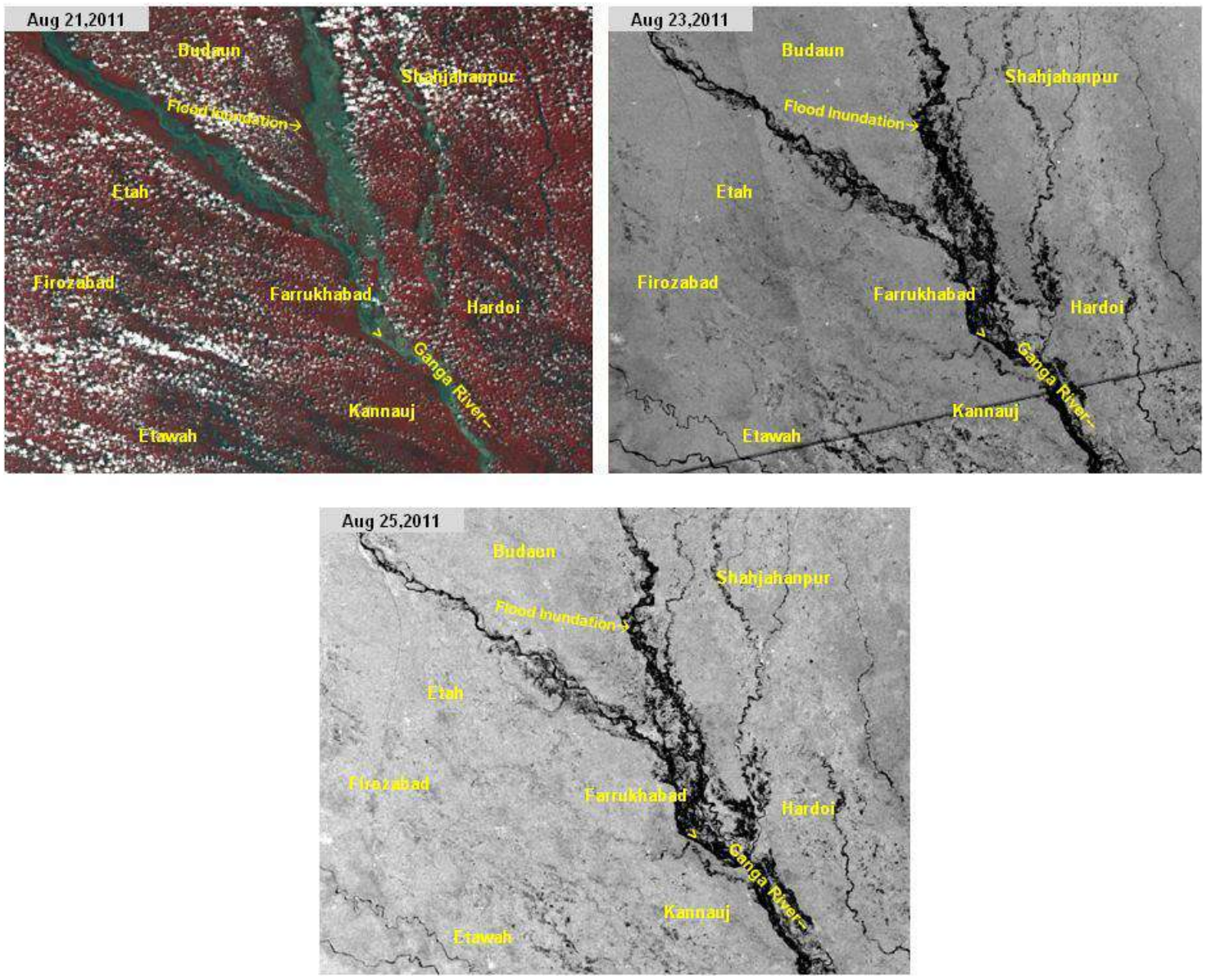


Fig 12: Flood Inundation in part of UP

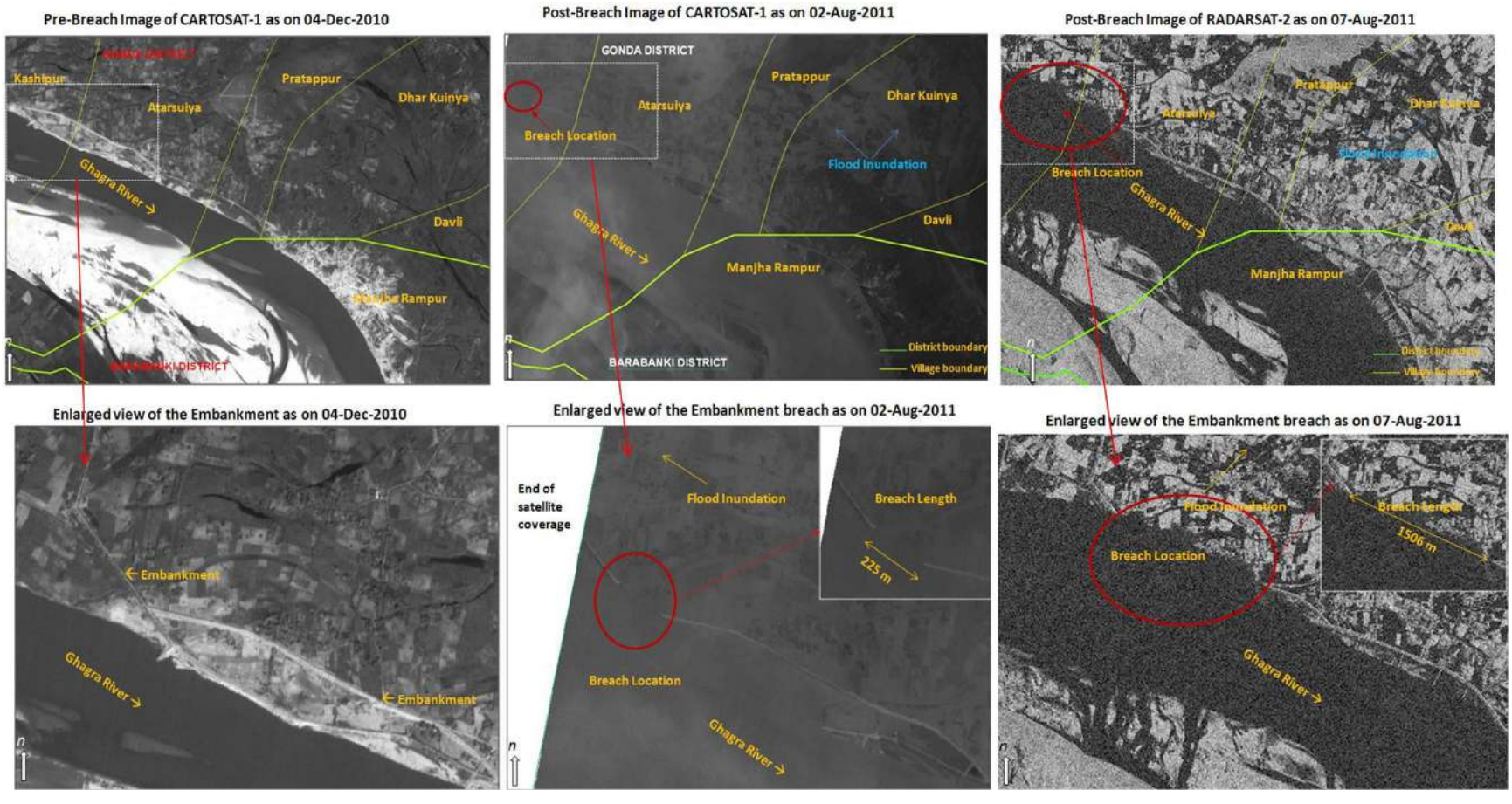


Fig 13: Satellite images showing flood inundation due to breach of embankment in parts of Uttar Pradesh.

2.2.4. Floods in 2013

During 2013, floods were reported in many parts of Uttar pradesh due to heavy incessant rains and rise in water levels of Ganga river and its tributaries. Bijnor, Meerut and JP nagar districts adjoining the river Ganga were affected by flooding. Fig 14 shows the pre and post flood inundated areas in part of UP .

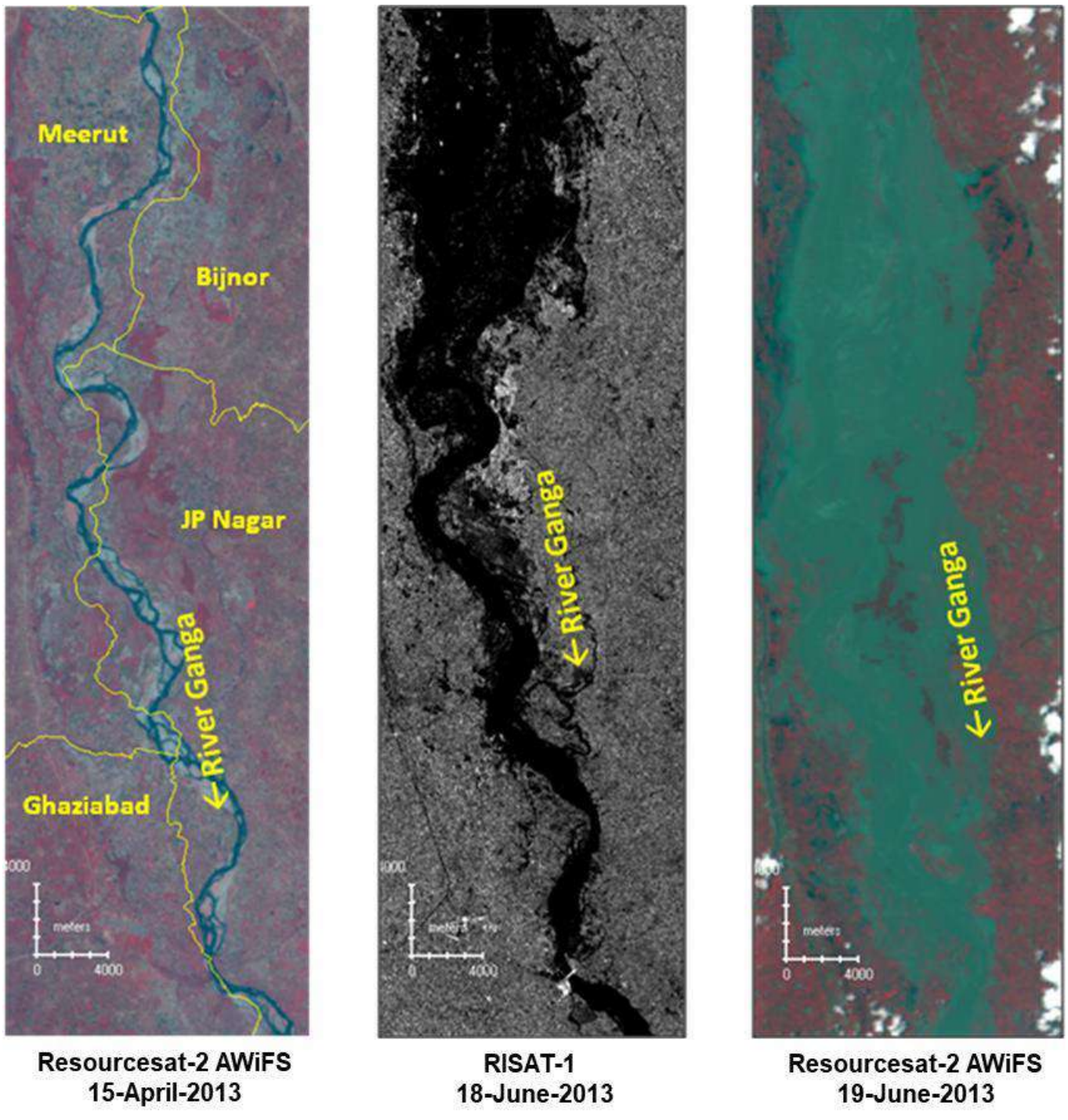


Fig 14: Satellite images floods in parts of Bijnor, Meerut and JP nagar during June, 2013

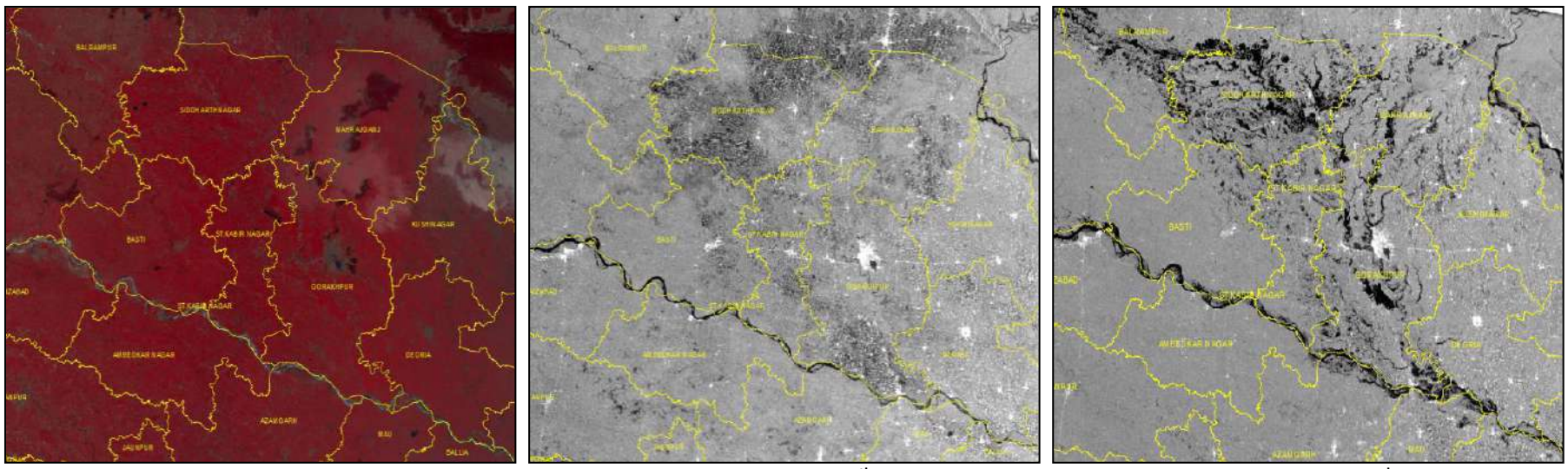
2.2.5. Floods in 2017

Heavy incessant rains in upper catchments of Uttar Pradesh resulted in all the major rivers and their tributaries flowing above danger level for most part of August. River Sharda at Shardanagar and River Ghagra at Elgin Bidge and Ayodhya were in spate during most of August 2017.Floods were mapped in the state of Uttar Pradesh 14 time during July -September.The total area affected by flooding during 2017 in the state was estimated to be about 3,38,931 ha and about 19 districts were found to be affected by flooding. Fig 15 shows the satellite images depicting the flood inundation situation in parts of Uttar pradesh.

ResourceSat-2 AWiFS image of 06th Mar 2017

Radarsat-2 SAR image of 09th July 2017

Radarsat-2 SAR image of 16th Aug 2017



ResourceSat-2 AWiFS image of 24th Aug 2017

Radarsat-2 SAR image of 26th Aug 2017

Radarsat-2 SAR image of 02nd Sep 2017

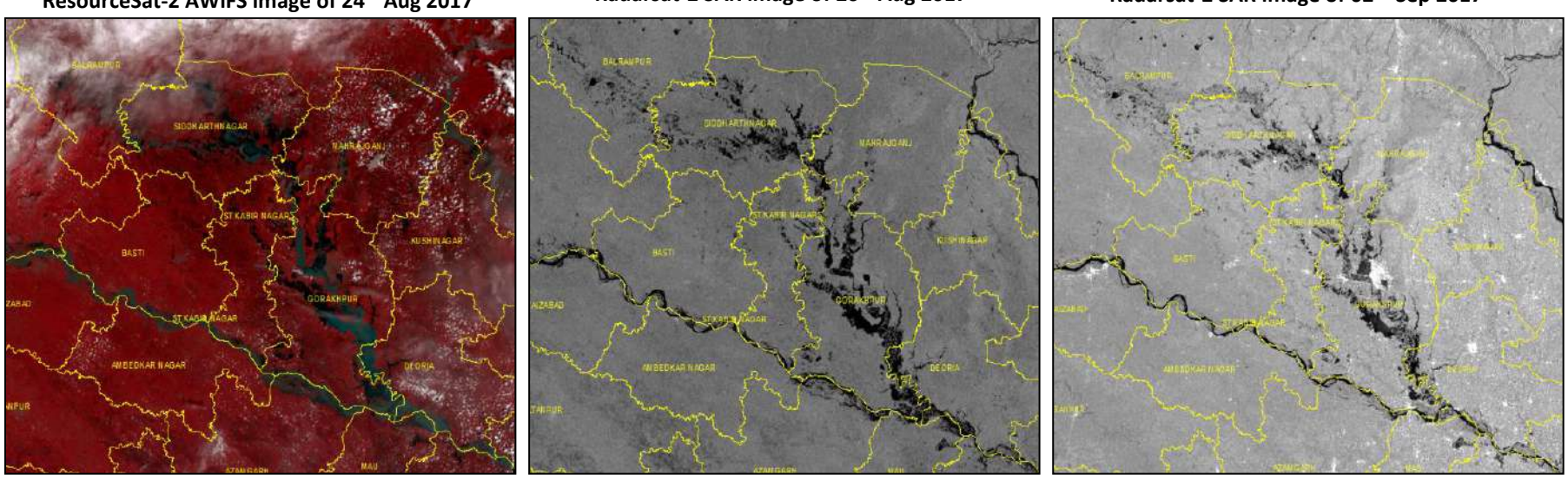


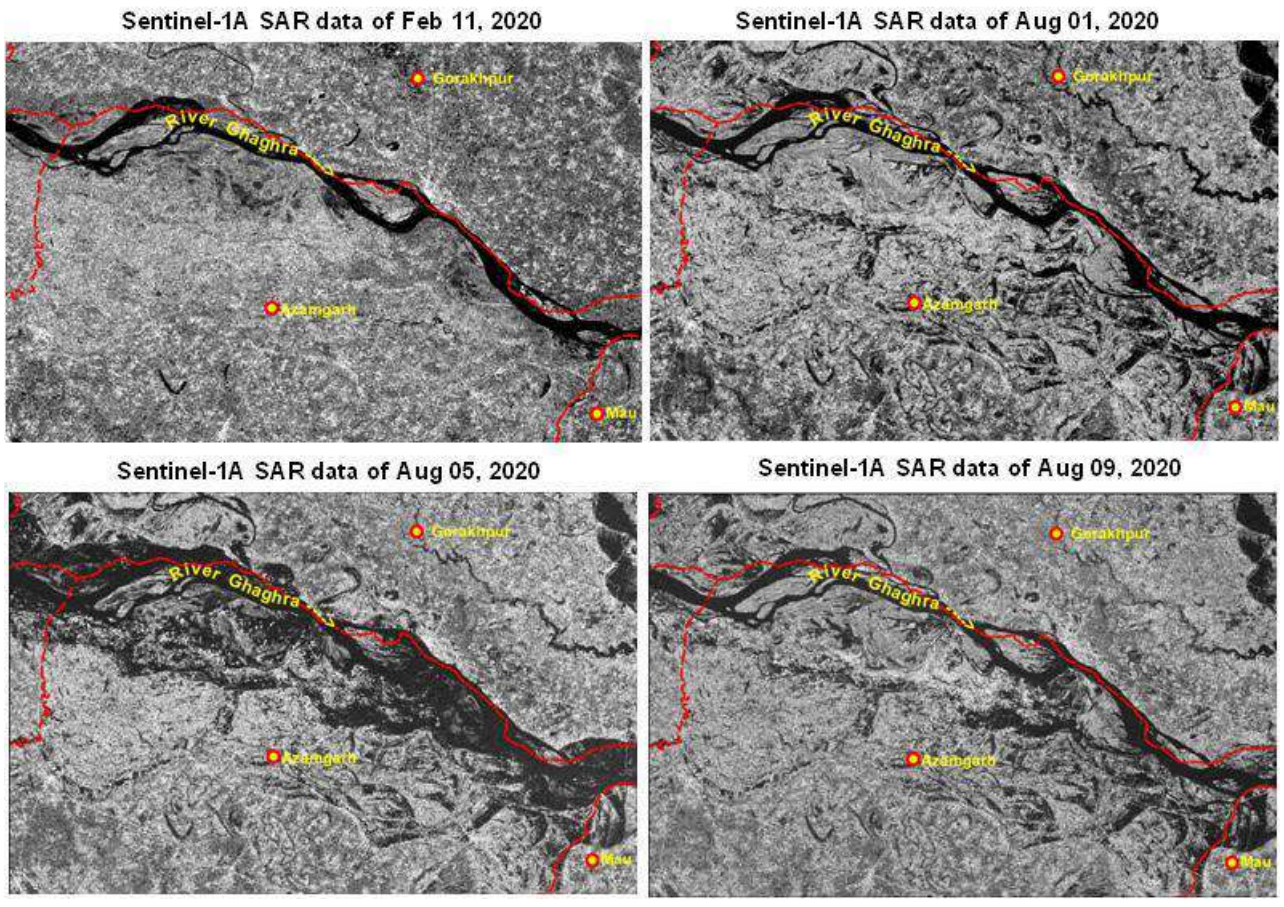
Fig 15: Satellite images showing flood inundation in parts of UP.

2.2.6. Floods in 2020

Uttar Pradesh State witnessed prolonged and devastating floods during 2020. Heavy rains lashed the state of Uttar Pradesh followed by the rise in water levels of River Gandak, Rapti and Ganga during July-September, 2020. Many districts in Eastern Uttar Pradesh were affected. River Gandak and Rapti were flowing in severe flood situation continuously during July and August, 2020. Floods were mapped in the state of Uttar Pradesh 22 times during July - September 2020. About 23 flood maps were prepared using 22 satellite datasets and disseminated to the user departments for carrying out relief and rescue operations. About 27 districts were reported to be affected in the current spell. An estimated area of 6,11,915 hectares spread across 27 districts of the state was affected. Fig 16 shows the flood inundation in parts of UP during 2020.

Sentinel-1A SAR data of Feb 11, 2020

Sentinel-1A SAR data of Aug 01, 2020



Sentinel-1A SAR data of Aug 05, 2020

Sentinel-1A SAR data of Aug 09, 2020

FIg 16 : Satellite images showing flood inundation in parts of UP during 2020

2.3 ROLE OF IMD IN FLOOD MONITORING IN UTTAR PRADESH

Flood Meteorological Offices (FMOs, 14 in all over India) of India Meteorological Department(IMD) provide meteorological support to Flood Forecasting Divisions (FFDs) of Central Water Commission (CWC) to help them issue “Flood warnings/Flood alerts”, since CWC is the nodal agency for issuing Flood Forecast and IMD is the nodal agency for issuing Quantitative Precipitation Forecast (QPF). The meteorological support is provided in terms of ‘Quantitative Precipitation Forecast (QPF)’ through Hydromet Bulletins.

Input comprises in terms of Hydromet Bulletin which contains the following;

i. Synoptic situations
ii. Spatial and temporal distribution of rainfall
iii. River sub-basin-wise QPF(0, 0.1-10, 11-25, 26-50, 51-100 and > 100mm rainfall categories)and Probabilistic QPF for each category for day-1, day-2, day-3, day-4 and day-5
iv. River sub-basin-wise heavy rainfall warnings for day-1, day-2, day-3, day-4 and day-5
v. Outlook for the subsequent two days
vi. Station-wise recorded significant rainfall
vii. Sub-basin-wise past 24 hour realized rainfall

QPF bulletin is issued at 0930hrs IST and Hydromet Bulletin at 1230 hrs IST with further modification by FMOs. Forecast for a lead time of 7-days (forecast for 5 days and outlook for subsequent 2 days) are issued daily during flood season. QPF bulletins are further modified in the evening, if situation demands. QPF bulletins including heavy rainfall warnings are also issued by concerned FMOs during cyclone period or when there is a chance of heavy rainfall which may lead to flood in non-flood season also.

IMD established 14 Flood Meteorological Offices(FMOs) at different parts of flood prone areas of the country which are located at Agra, Ahmedabad, Asansol, Bhubaneswar, Guwahati, Hyderabad, Jalpaiguri, Lucknow, New Delhi, Srinagar, Chennai, Bengaluru and Patna (Fig.-17) in the flood prone areas which caters to the river catchments of Yamuna, Narmada, Tapi, Ajoy, Mayuraksi and Kangasbati, Mahanandi, Brahmani and Subernarekha, Brahmaputra, Dhansiri and Barak, Godavari and Krishna, Cauvery, Teesta, Ganga and Sharada and Sahibi, Kosi, Baghmati, Gandak etc. IMD also provides similar support to Damodar Valley Corporation (DVC) for the river basins Barakar and Damodar. The performance of QPF is verified for the monsoon season annually.

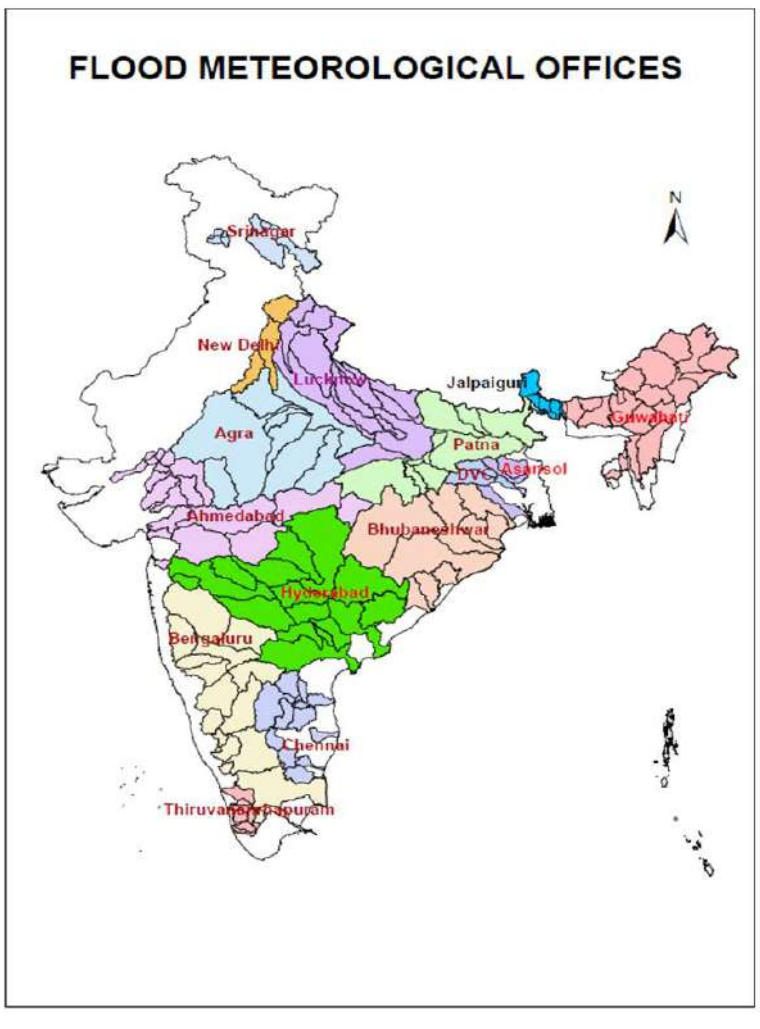


Fig.-17. Flood Meteorological Offices(Source: IMD, UP)

2.3.1.Flood Meteorological Services of IMD for Uttar Pradesh

A Flood Meteorological Office was established in the state at Lucknow in 1974 for providing hydro-meteorological support for flood forecasting activities of CWC. The river sub-basin map under the jurisdiction area of FMO, Lucknow for issuing QPF is shown fig.-18 and detail areas of river sub-basins is given in the table 8.

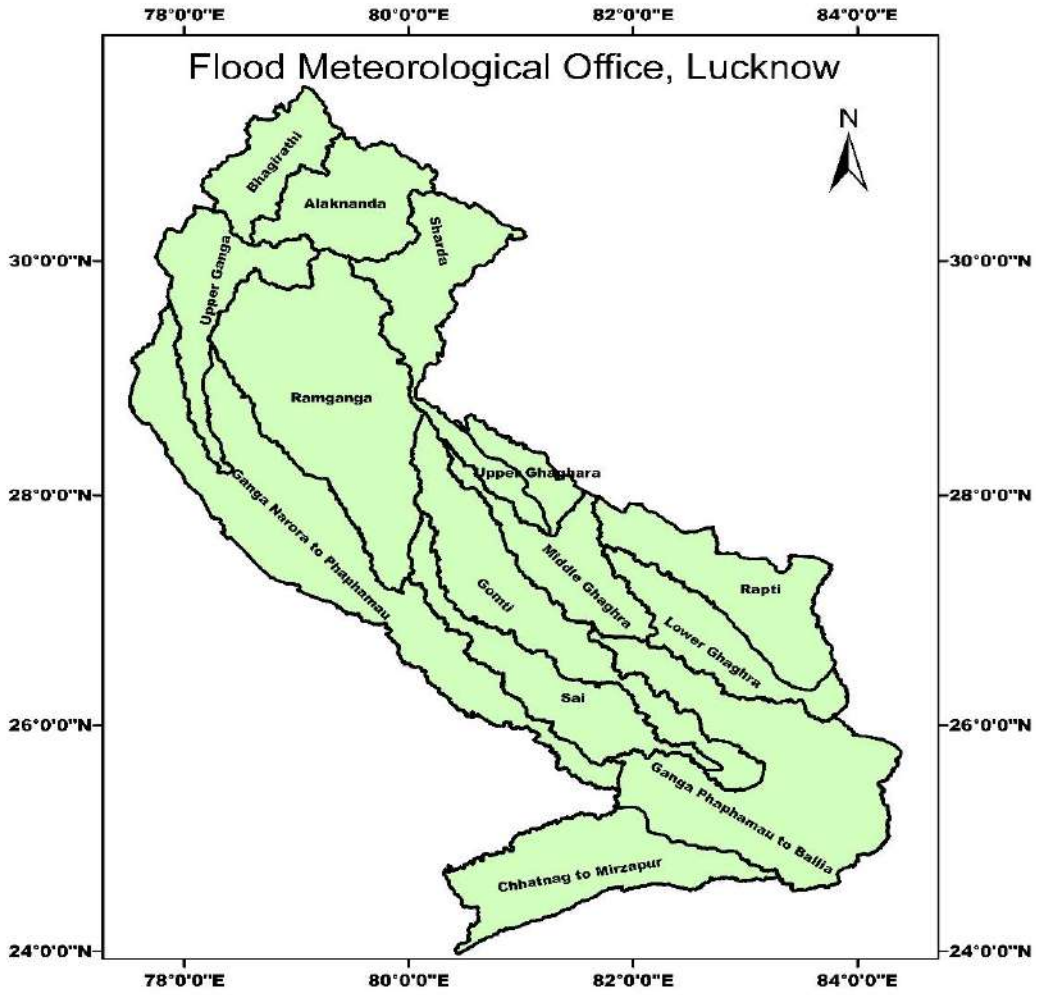


Fig.-18. River sub basin under the jurisdiction of FMO, Lucknow(Source: IMD, UP)

Table-8. River sub-basins and their areas under FMO, Lucknow(Source: IMD, UP)

Sub-Basin	**Area (Km^2)**
Upper Ganga	10604.45
Ganga Narora to Phaphamau	31679.87
Ganga Phaphamau to Ballia	31437.24
Gomti	18317.22
Sai	11943.15
Chhatang to Mirzapur	16871.70
Bhagirathi	7440.94
Alaknanda	10811.73
Ramganga	30728.17
Upper Ghaghra	3397.16
Middle Ghaghra	9705.21
Lower Ghaghra	9766.68
Sharda	13694.38
Rapti	14067.04

Model based Quantitative Precipitation Forecast (QPF) Estimation and Probabilistic QPF

Sub-basin-wise Quantitative Precipitation Forecast Estimation using model WRF ARW (3Km X 3Km) & NCUM-R (4 Km X 4 Km) for day-1 to day-3, GFS (12 Km X 12 Km) and NCUM-G(12 Km X 12 Km) for day-1 to day-7 are uploaded on the IMD's websiteoperationally for 153 river sub-basins across the country and 15 river sub-basins under FMO Lucknow as shown in Fig.- 19.

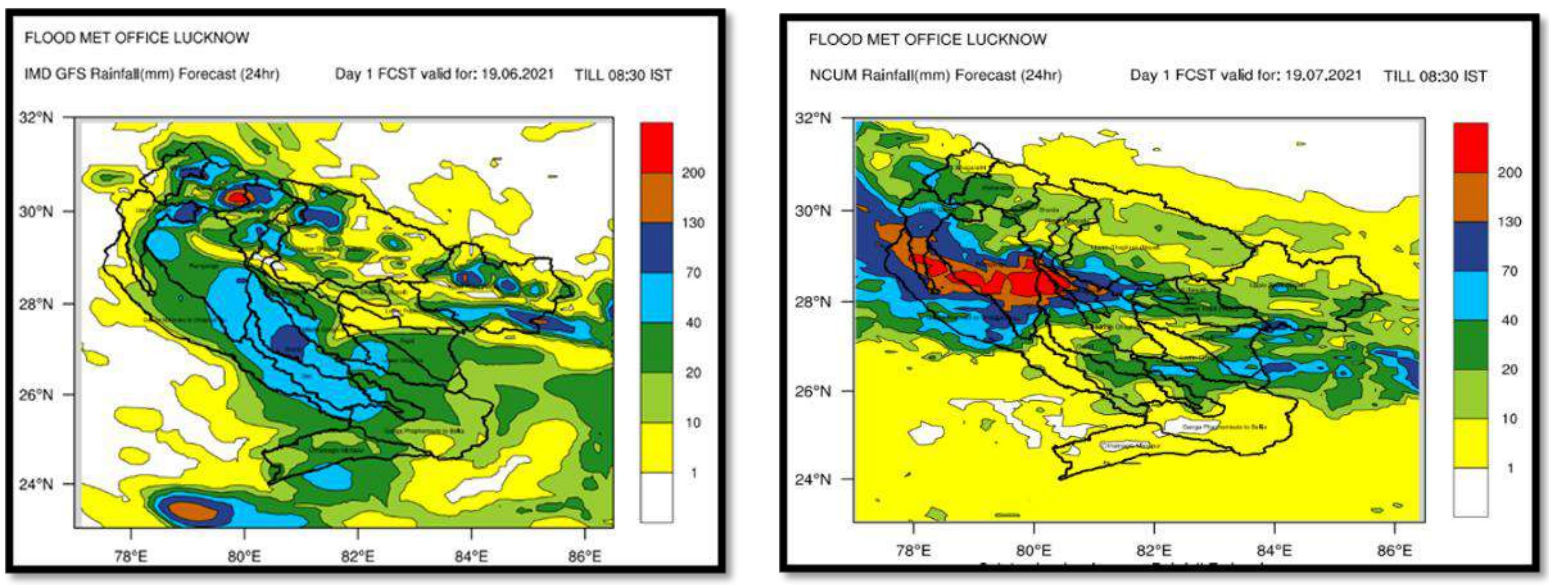
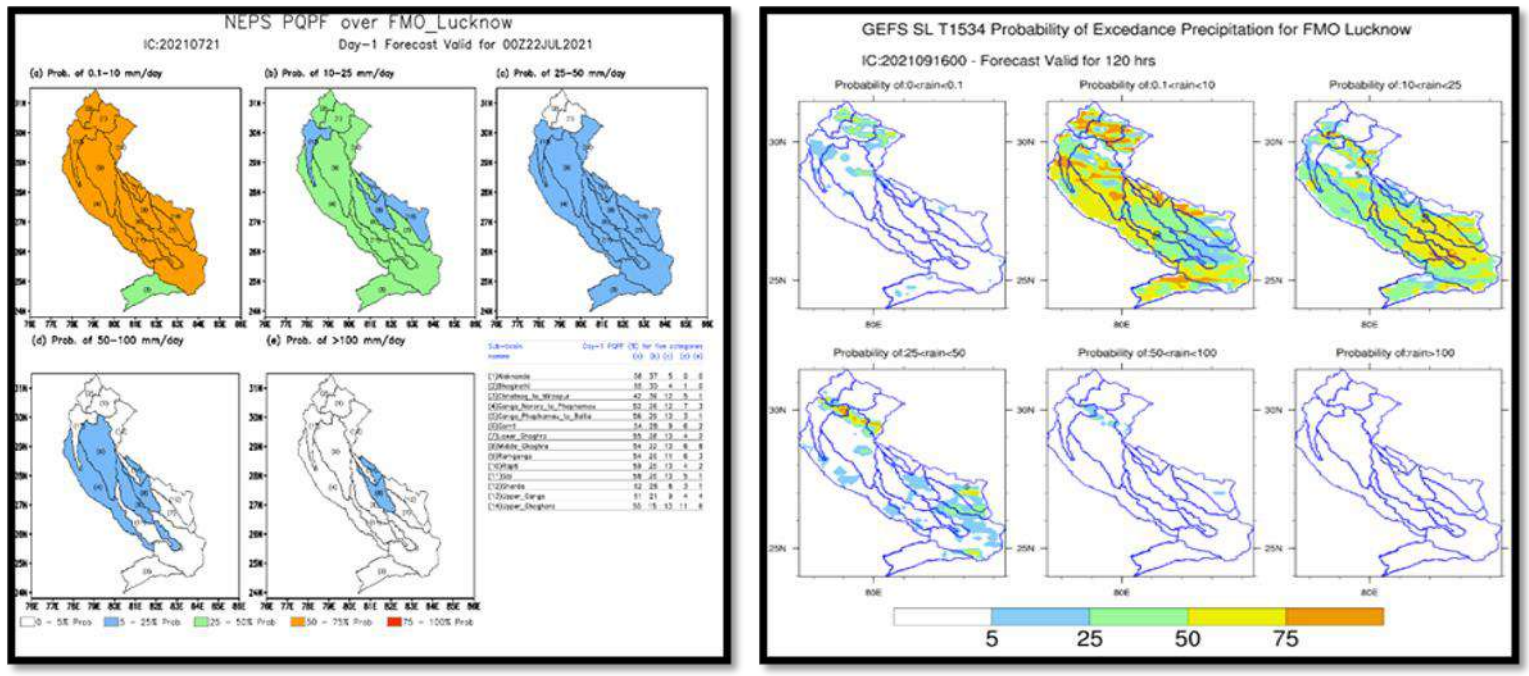


Fig.-19 Dynamical Weather model-based Sub-basin-wise QPF(Source: IMD, UP)



Also, dynamical models viz. GEFS and NEPS based Probabilistic QPF are uploaded in the IMD website operationally(Fig.20).

Fig.-20 Dynamical Weather model-based Sub-basin-wise Probabilistic QPF(Source: IMD, UP)

2.3.2. Analysis of Rainfall over Uttar Pradesh

2.3.2.1.Rain gauge Network: 226 raingauge stations which are shown in the fig.-21 are used for analysis of rainfall for Uttar Pradesh (UP).

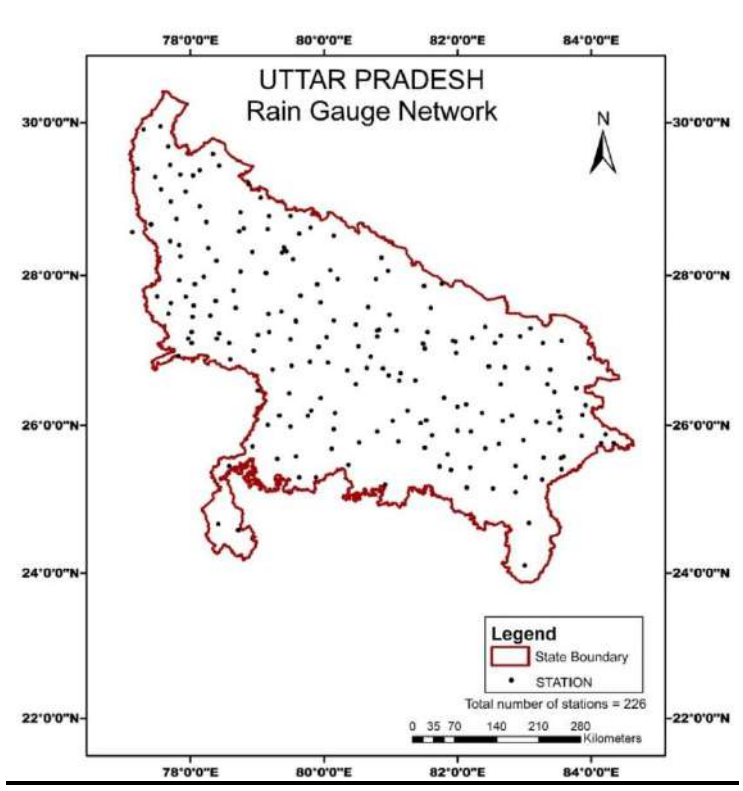


Fig.-21.Raingauge stations used for rainfall Analysis(Source: IMD, UP)

2.3.2.2 Seasonal and Annual normal rainfall:

South-west monsoon season is the principal rainy season in the state. Seasonal and annual Rainfall (based on 1961-2010 rainfall data) over Meteorological Sub-divisions East UP, West UP and for the State Uttar Pradesh are showed in fig. -22.

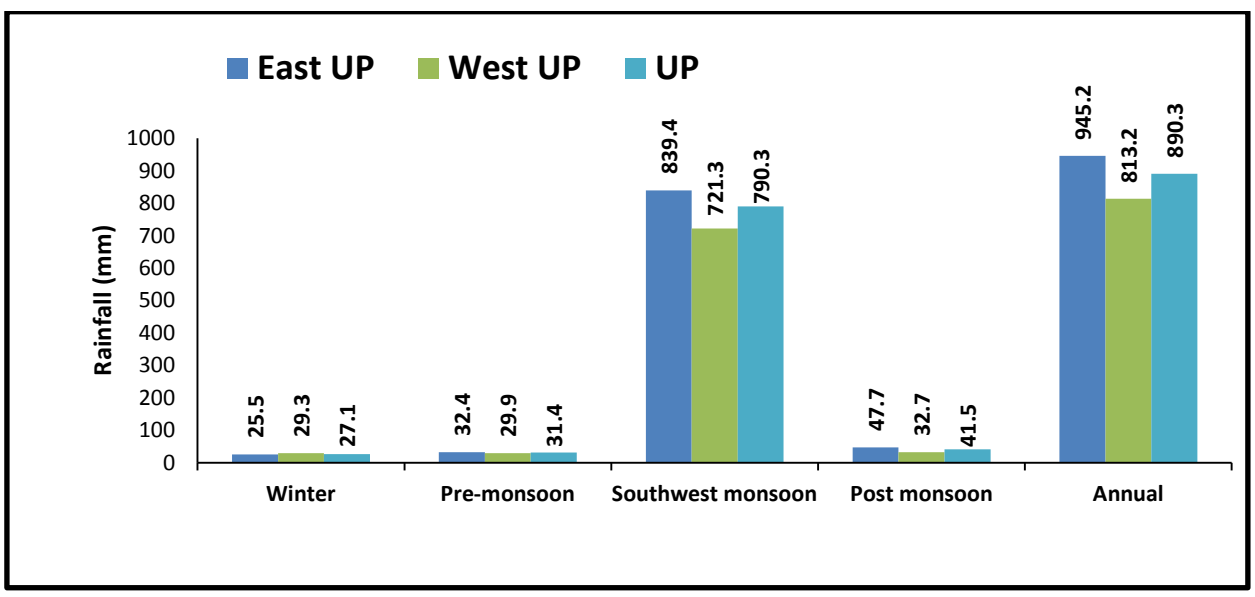


Fig.-22. Seasonal Rainfall over Uttar Pradesh (Source: IMD, UP)

More than 89% of rainfall occurs during South-west monsoon season.The pre-monsoon, post monsoon and winter seasons rainfall contribute 3, 3 and 5% respectively (fig.-23). The spatial normal rainfall distribution during South-west monsoon and annual are shown in fig. 24 and fig. 25 respectively.

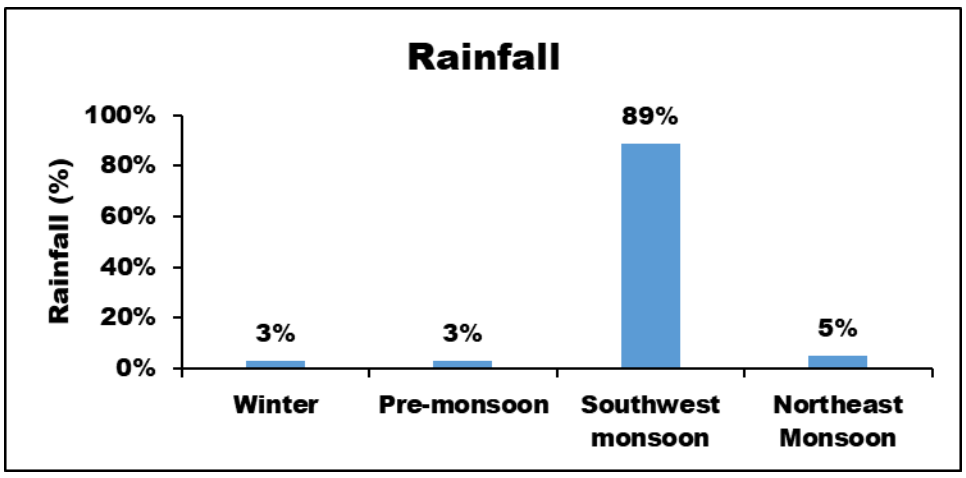


Fig.-23. Seasonal Rainfall (% of annual rainfall) over Uttar Pradesh (Source: IMD, UP)

Normal date of arrival of South-west monsoon in the State is 20 June and it covers whole State generally by 30 June. Normally withdrawal of South-west monsoon commences around 25 September and is completed by 05 October.The rainy season is fairly humid but it gets hot when there is break in the rains for days together.

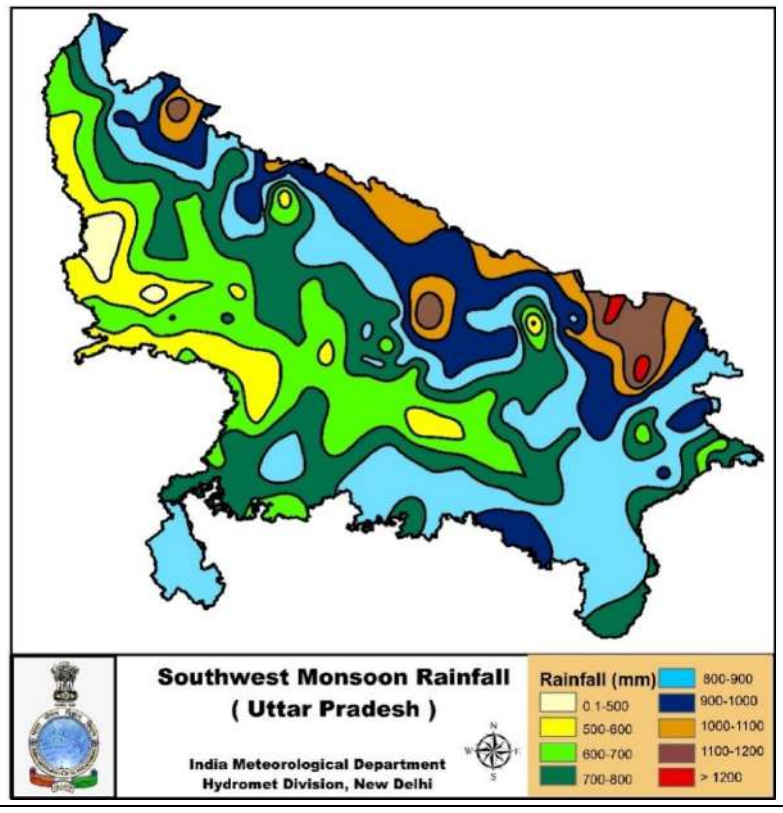


Fig.-24. Normal southwest monsoon rainfall distribution **(Source: IMD, UP)**

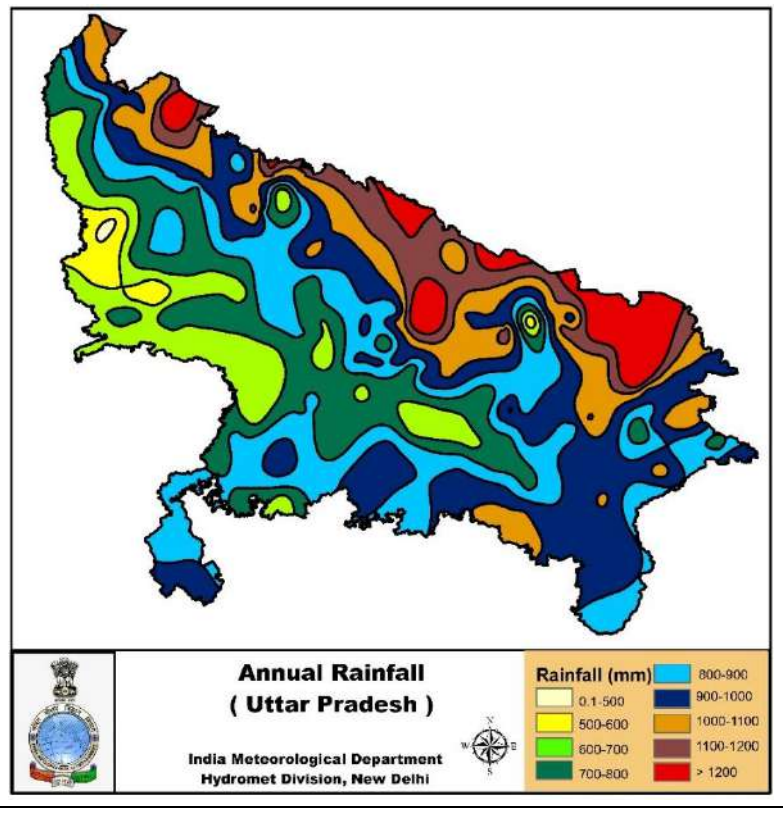


Fig.-25. Annual Normal Rainfall distribution **(Source: IMD, UP)**

2.3.3.Main Synoptic features for Rainfall

Main synoptic features responsible for rainfall over State are as follows;

Monsoon trough- East-west trough at mean sea level during South-west monsoon season and its interaction with other synoptic features like remnant cyclonic circulations of low-pressure systems originating in Bay of Bengal & Arabian Sea, Cyclonic circulations originating due to heat, low and western disturbances is responsible for heavy rainfall over the State. During these interactions, there is moisture feed at lower levels from Bay of Bengal & Arabian Seas and there may be heavy rainfall overeastern,Central & Western UP. North – south movement of monsoon trough leads to shift in areas affected by rainfall and presence of any supporting systems mentioned above enhances the rainfall activity.

i. **Position of monsoon trough –** When monsoon trough shifts northwards from its normal position but is not in break monsoon position, it causes heavy to very heavy rainfall in districts of Terai region of UP (bordering Nepal and Uttarakhand) due to easterly- westerly interaction.

ii. **Low Pressure systems and their remnants**-As the remnants of low-pressure systems originating in Bay of Bengal or inland areas (monsoon lows & depressions and their remnant cyclonic circulations) move northwest wards with moisture incursion from Bay of Bengal and Arabian Seas based on their location. These systems and cyclonic circulations are generally merged with monsoon trough and give rise to high convection over the region.

   a. When these systems are located over South Bihar, West Jharkhand, East and West Madhya Pradesh, they cause heavy rainfall over Southern and Central parts of UP. When these low-pressure systems and their remnants travel in a further Northward trajectory following a path over East and Central UP, they cause heavy rainfall over Northern parts of the state.

   b. When remnants of low-pressure systems and cyclonic circulations in lower troposphere are located further Westwards over West Madhya Pradesh, South east and South west Rajasthan, moisture incursion occurs from Arabian Sea and leads to heavy rainfall over western parts of the State.

iii. **Interaction with Western Disturbances and Easterly systems**- When cyclonic circulations and low-pressure systems are present over Haryana, South Punjab, North Rajasthan, their interaction with cyclonic circulations and troughs at upper and middle troposphere in westerly systems lead to heavy rainfall over Northern parts of West UP. Rainfall pattern generally travels Eastwards and causes heavy rainfall over Northern parts of the state.

2.3.3.1. Seasonal Rainfall Variation

The seasonal and normal rainfall (based on 1961 to 2010 rainfall data) for winter, pre-monsoon, southwest monsoon, post monsoon seasons and annual actual rainfall during the years 1990 to 2020 are shown in figs. 26-30 respectively.

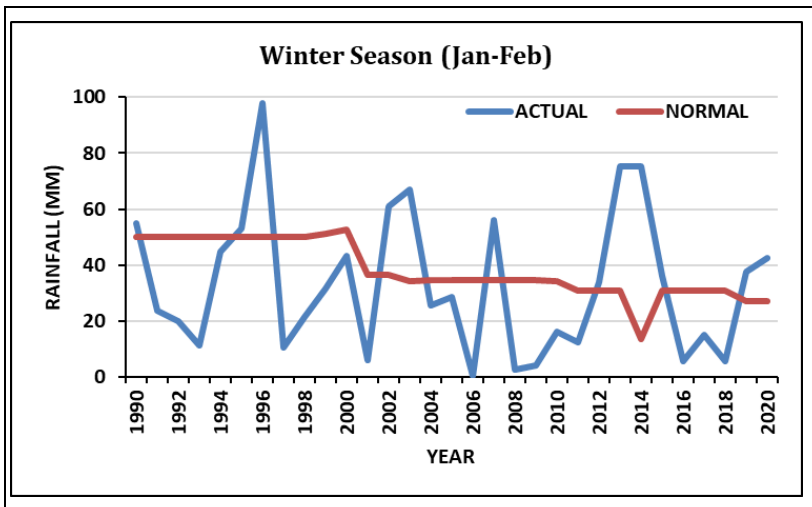


Fig.-26. Actual and Normal rainfall during winter season **(Source: IMD, UP)**

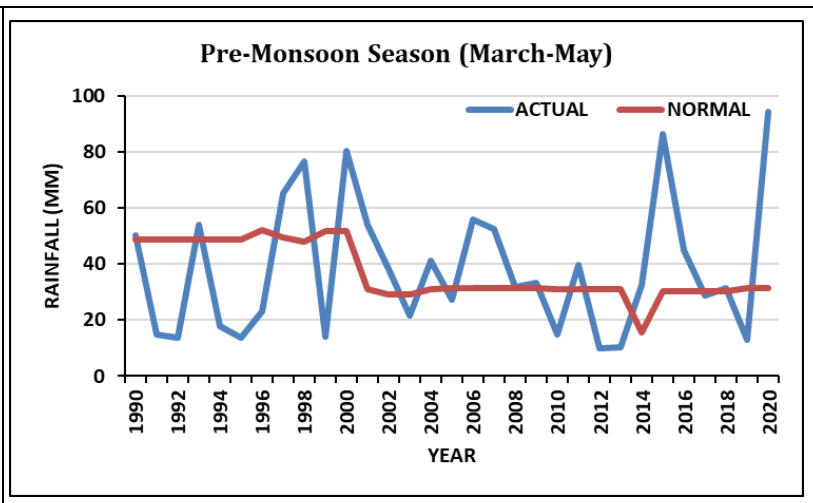


Fig.-27. Actual and Normal rainfall during Pre-monsoon season**(Source: IMD, UP)**

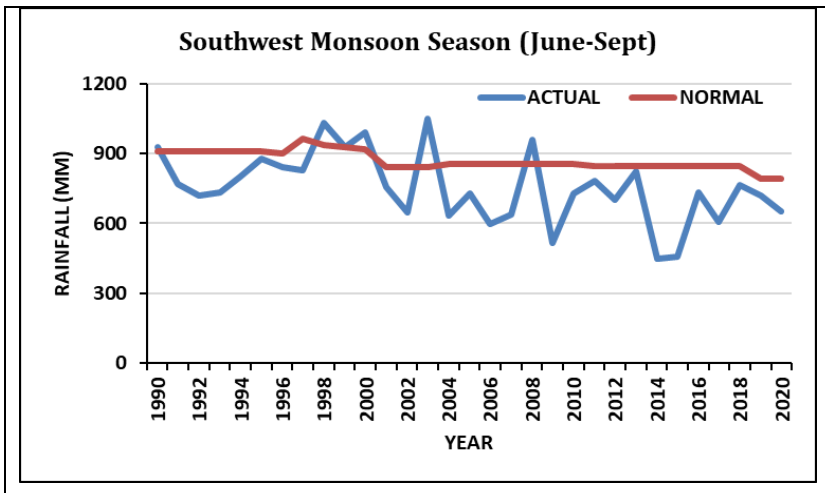


Fig.-28.Actual and Normal rainfall during South-west monsoon season**(Source: IMD, UP)**

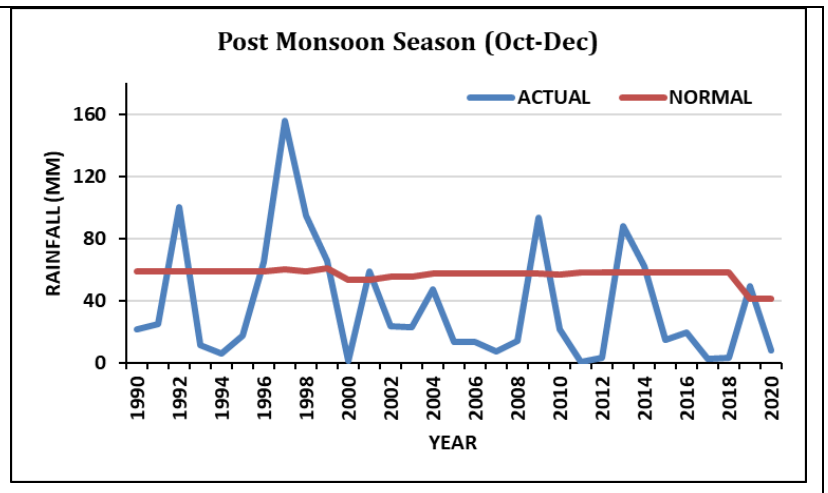


Fig.-29. Actual and Normal rainfall during Post monsoon season**(Source: IMD, UP)**

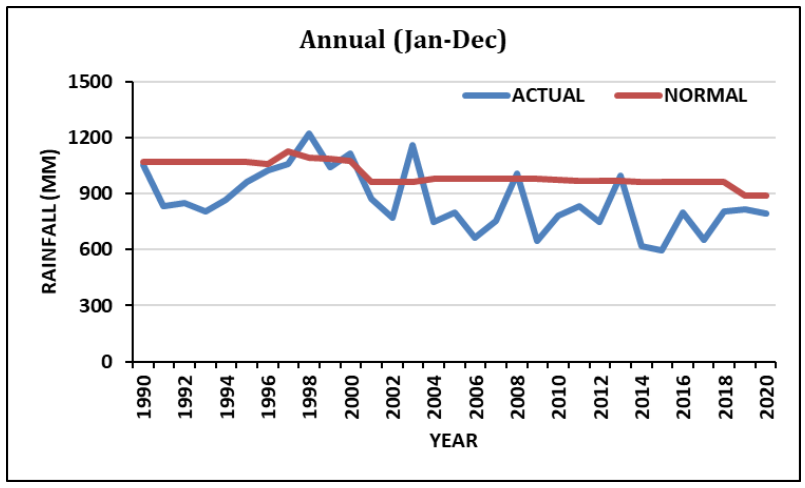


Fig.-30. Annual Actual and Normal rainfall **(Source: IMD, UP)**

It is seen from the figures that annual as well as South-west monsoon rainfall mostly are less than the normal rainfall during the recent 31 years period.

2.3.3.2.South-west monsoonRainfall Departure

The year-wise percentage departure of rainfall for South-west monsoon during the years 1990 to 2020 for the state is shown in fig. 31. During the season, it is found that most of the years for this 31 years period showed negative percentage departure of rainfall except for the year 1990, 1998, 2000, 2003 and 2008 which showed positive rainfall departure.

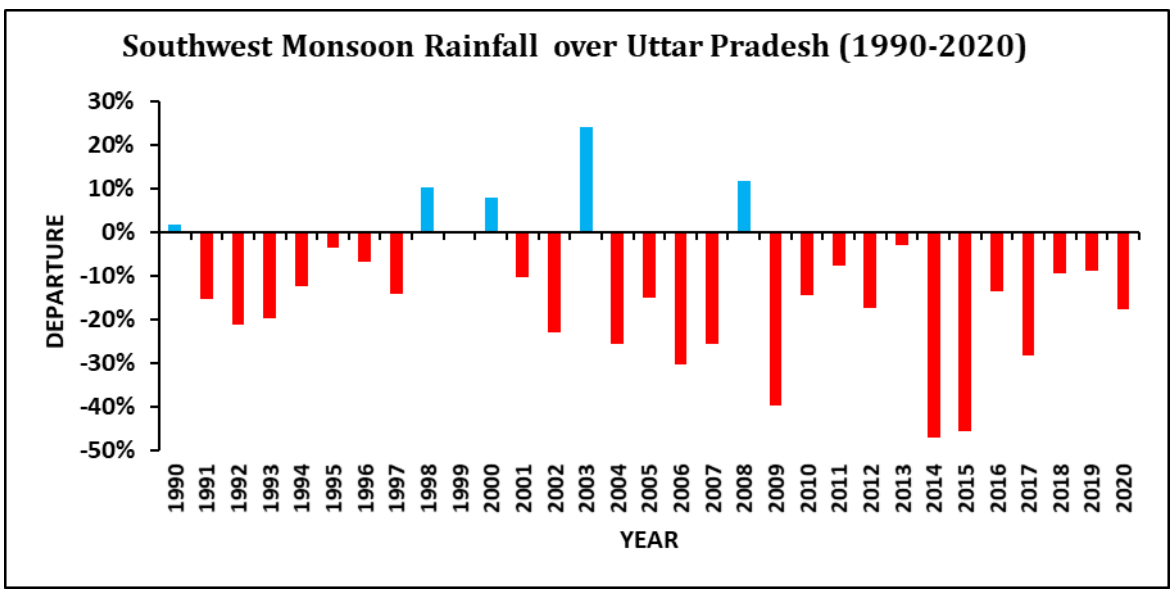


Fig.-31. Southwest monsoon rainfall pattern over UP (Source: IMD, UP)

Note: This chapter is contributed by IMD, New Delhi

2.4 ROLE OF CWC IN FLOOD MONITORING

2.4.1 Flood Monitoring in Uttar Pradesh

Central Water Commission (CWC) is maintaining 44(39 Level and 5 Inflow) Forecast Stations in Uttar Pradesh in the basin of Ganga. The period of flood season extends from 1st June to 31st October for whole state.

CWC is maintaining Hydrological Observation (HO) Stations in almost all the rivers and tributaries within Uttar Pradesh. Since the Northern tributaries of Ganga such as Mahakali, Karnali, Rapti, Narayani, etc originates in Nepal, the hydro-meteorological data of said rivers are also needed for flood forecasting purposes. Currently the hydrological and rainfall data that are uploaded in the website of Govt. Of Nepal (*https://www.hydrology.gov.np/#/?_k=x0c6p3)* on real-time data basis is used for flood forecasting purposes. During the designated flood season, hourly water level observations are taken from the HO Stations maintained by CWC and these are used for formulation of Level Forecast using Statistical correlation techniques.

Central Water Commission (CWC) is providing flood forecast with lead time varying from 6 hours to 30 hours using Statistical models. Statistical model uses correlation diagram which are developed using historical data between upstream (Base Station) and downstream (Forecast Station). The various parameters such as varying travel time, rising and falling limb variations, contribution from tributaries and intervening catchment area rainfall are taken in various quadrants of graph sheet and a comprehensive correlation diagram is drawn. This will be used by the concerned Flood Forecasting centre for real-time flood forecasting.

Inflow Forecasts are formulated by using upstream Stations, Stage vs. Discharge relations and correlating with the inflows coming into the reservoir. Effect of rainfall is added by developing a unit hydrograph (UG) for the intervening catchment rainfall contribution using point rainfall and converting them into areal rainfall as well as area of the intervening catchment to get the ordinates of the UG. The inflow forecasts are used for regulation of water from dams for conservational purposes as well as for storage in times of flood as per rule levels developed for the various projects in their Operational manuals. Besides, based on rainfall-runoff modelling, CWC also issues 5-day advisories for these stations.

After formulation of forecasts in the forecasting centres, these are disseminated to concerned user agencies that have requisitioned flood forecast (i.e. local State Governments/SDMA/DDMA of all districts/ Project Authorities) by the fastest means of communication such as e-mail, Whatsapp Groups etc. These are updated in the CWC's flood forecasting website also immediately and regular hourly trends of water level are also uploaded in the form of Hydrograph in the website for use of General Public. Social Media such as Facebook and Twitter are also being used for dissemination of such alerts from 2018 onwards.

Table-9List of CWC maintained Level Forecast Stations in Uttar Pradesh

Sl.No.	River	Station	District
Flood level Forecasting Stations			
1	Ganga	Kannauj	Kannauj
2	Ganga	Ankinghat	Kanpur
3	Ganga	Kanpur	Kanpur
4	Ganga	Dalmau	Rae-Bareilly
5	Ganga	Phaphamau	Allahabad
6	Ganga	Allahabad Chhatnag	Allahabad
7	Ganga	Mirzapur	Mirzapur
8	Ganga	Varanasi	Varanasi
9	Ganga	Ghazipur	Ghazipur
10	Ganga	Ballia	Ballia
11	Ramganga	Moradabad	Moradabad
12	Ramganga	Bareilly	Bareilly
13	Yamuna	Mawi	Muzzafarnagar
14	Yamuna	Mathura	Mathura
15	Yamuna	Agra	Agra
16	Yamuna	Etawah	Etawah
17	Yamuna	Auraiya	Auraiya
18	Yamuna	Kalpi	Jalaun
19	Yamuna	Hamirpur	Hamirpur
20	Yamuna	Chillaghat	Banda
21	Yamuna	Naini	Allahabad
22	Betwa	Mohana	Jalaun
23	Ken	Banda	Banda

Sl.No.	River	Station	District
24	Gomati	LucknowHanumanSetu	Lucknow
25	Gomati	Jaunpur	Jaunpur
26	SAI	Rae-Bareli	Rae-Bareli
27	Ghaghra	Elgin Bridge	Barabanki
28	Ghaghra	Ayodhya	Ayodhya
29	Ghaghra	Turtipar	Ballia
30	Rapti	Balrampur	Balrampur
31	Rapti	Bansi	Siddarthnagar
32	Rapti	Gorakhpur Birdghat	Gorakhpur
33	Rapti	Kakardhari	Shrawasti
34	Gandak	Khadda	Kushinagar
35	Ganga	Fathegarh	Farukkabad
36	Ganga	Dabri	Shahjahanpur
37	Ganga	Garhmuktheswar	Ghaziabad
38	Ganga	Kachla Bridge	Badaun
39	Betwa	Shahjina	Hamirpur
Inflow Forecasting Stations			
1	Ganga	Narora Barrage (U/S)	Bulandshahar
2	Rihand	Rihand Dam	Sonebhadra
3	Ganga	Dharmanagri Barrage	Bijnor
4	Betwa	Matatilia Dam	Lalitpur
5	Ghaghra	Katerniaghat Dam	Bahraich

Note. This Chapter is contributed by CWC, New Delhi

3.0. FLOOD HAZARD ZONATION USING REMOTE SENSING

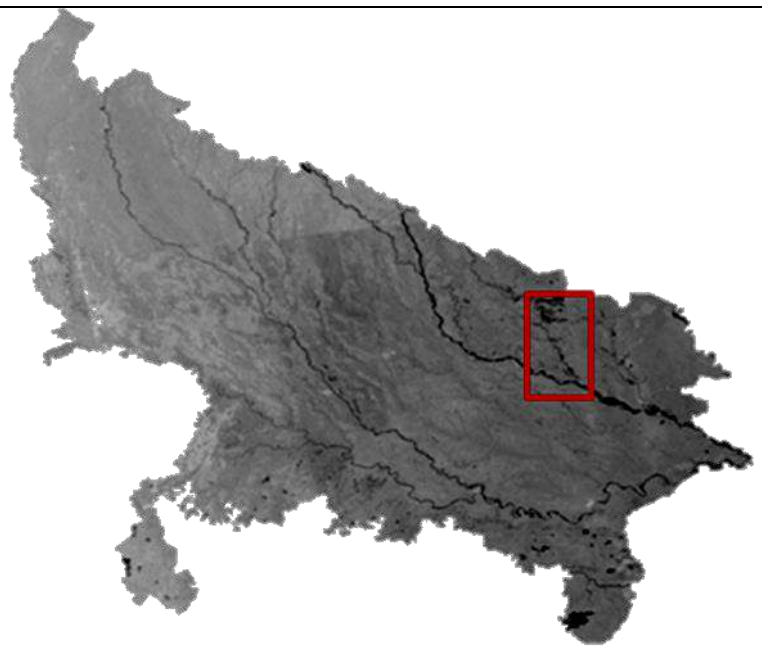
As the flood maps are prepared using long period historic flood layers derived from satellite remote sensing data, flood hazard maps are used to delineate areas of land which are at risk of flooding with different frequencies. Hazard maps show a flood boundary based on different magnitudes of flood with various specific frequencies. These maps can be used to regulate developmental activities within the floodplain, so that damages can be minimized. Flood hazard maps can be used for planning of relief, rescue, and health centres in floodplains. These maps can be used as an input to promote flood tolerant crops in the floodplains. It can be very vital information in basin level disaster management plans and in disaster risk reduction activities.

Satellite remote sensing from their vantage position has unambiguously demonstrated their capability in providing important information and services for flood disaster management. Satellites provide synoptic and frequent coverage of flood affected areas and thus become valuable for monitoring flood disasters. Thus satellite data can be directly used for deriving the flood inundation extent. If satellite data sets during flood times are available over a period of time for a floodplain, they can be conveniently used for hazard zone mapping. In addition, latest land use/land cover, infrastructure, settlements, etc. can also be generated from satellite data.

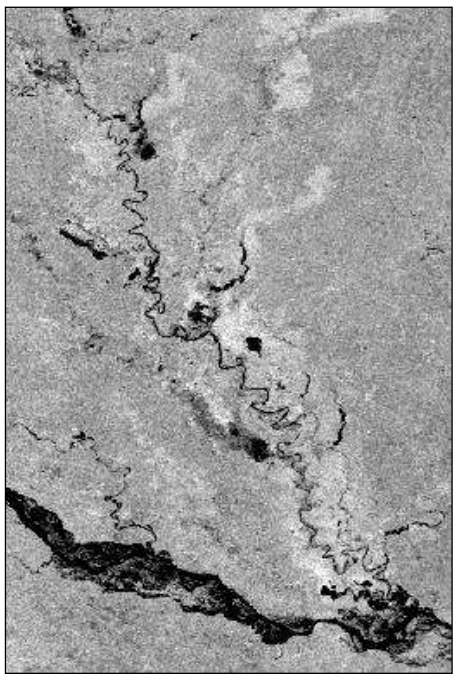
3.1. SATELLITE DATA USED

Satellite datasets (139 in number) acquired during the flood seasons of 1998 and 2020 (23 years) covering flood affected areas in Uttar Pradesh State have been used for preparation of flood hazard zonation map. Optical data from IRS satellites and other space missions of varying resolutions and microwave SAR data of different beam modes from RISAT-1,Radarsat-1/2, RCM -1/2/3& Sentinel-1 satellites are mostly used in flood mapping during various flood events. Sentinel-1 SAR data and data acquired through International Charter during some major disasters were also used in flood mapping. Figure 32 shows satellite images with overview and detailed view of the flood situation during 1998 to 2020. Table-10 shows satellite datasets acquired during the floods of 1998-2020.

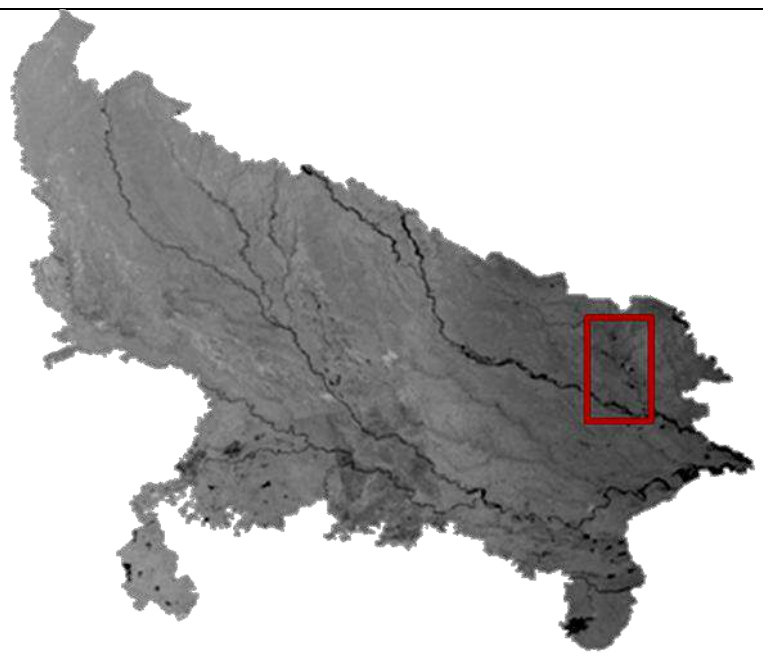
Fig 32 : Satellite images showing Flood Inundation in Uttar Pradesh State during 1998-2020



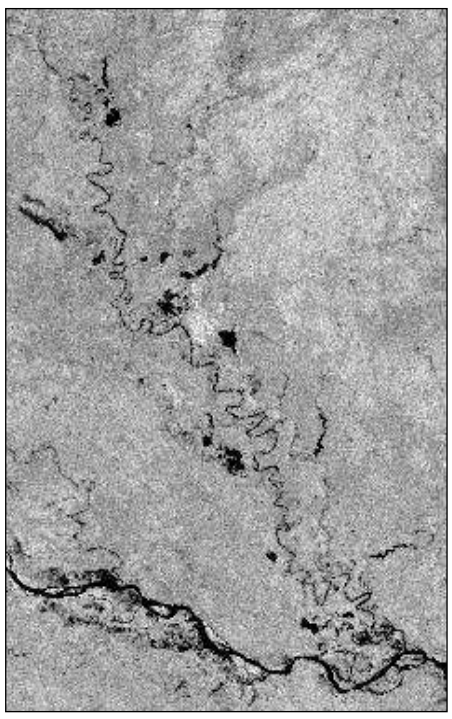
Satellite image showing floods in 2001



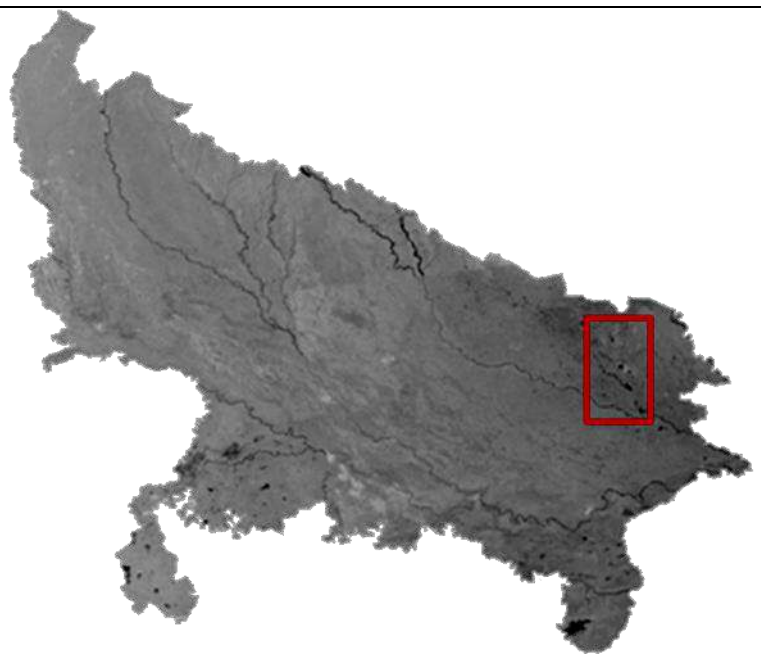
Detailed View



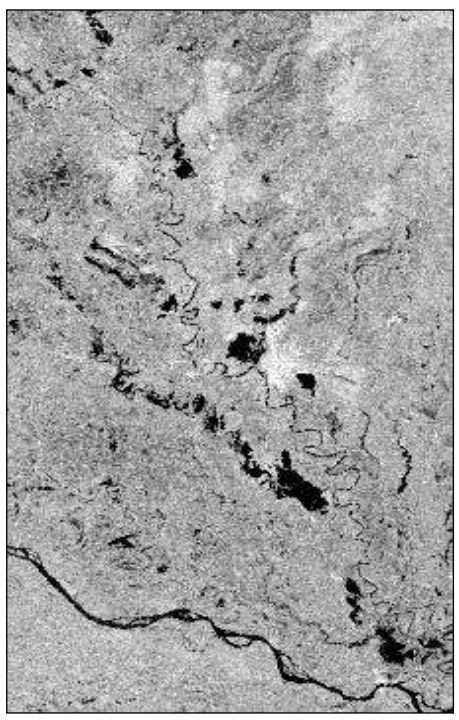
Satellite image showing floods in 2003



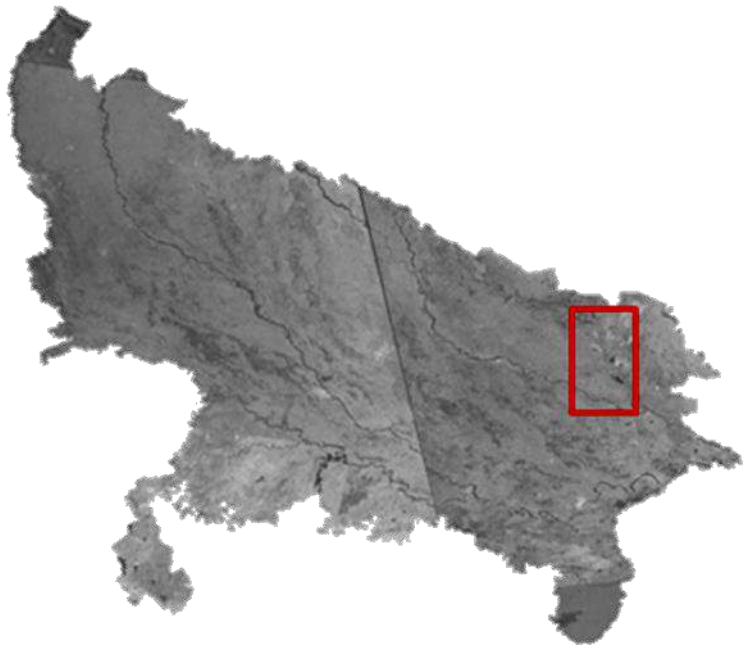
Detailed View



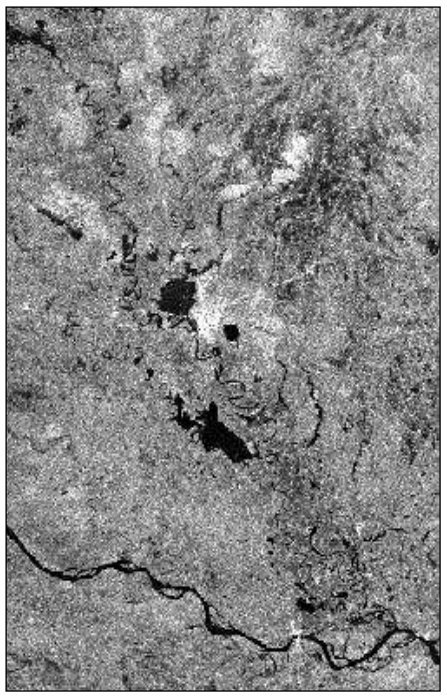
Satellite image showing floods in 2004



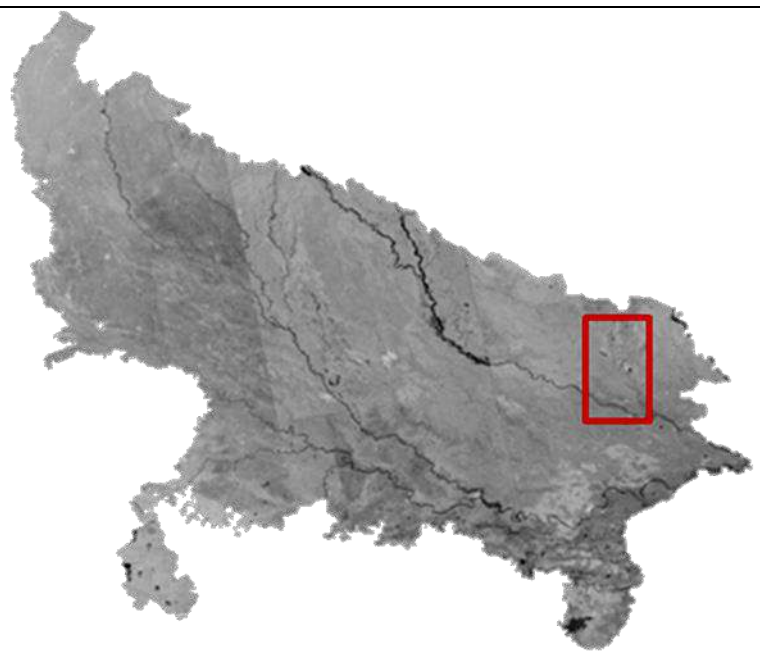
Detailed View



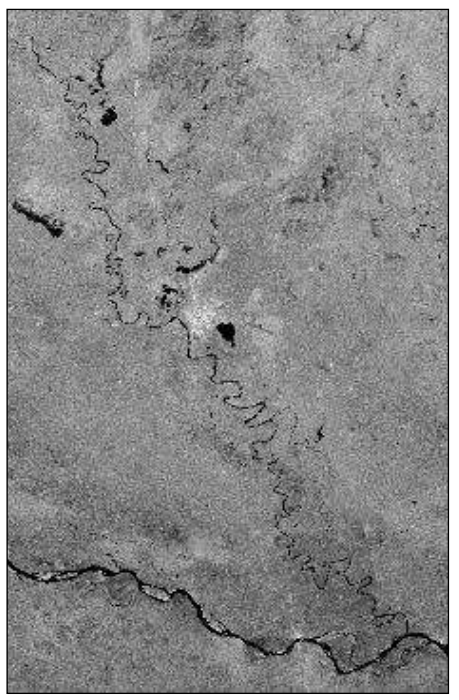
Satellite image showing floods in 2005



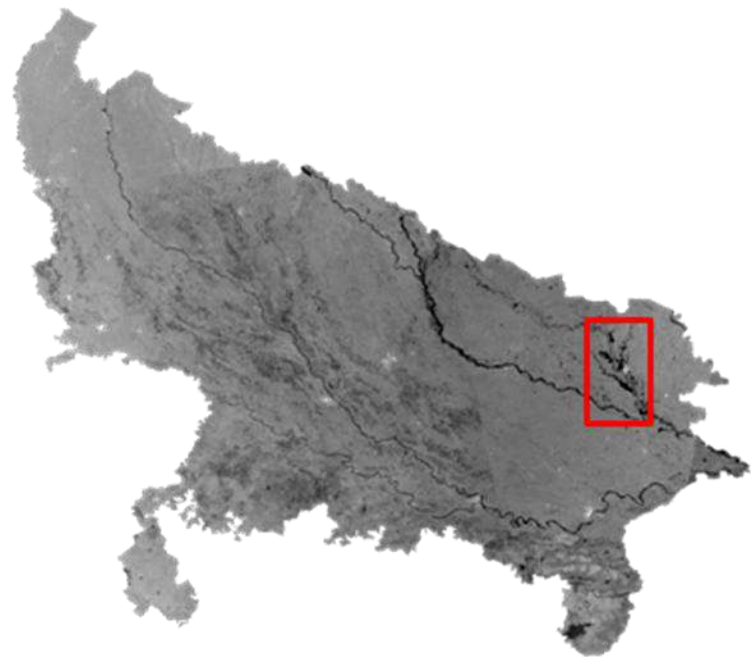
Detailed View



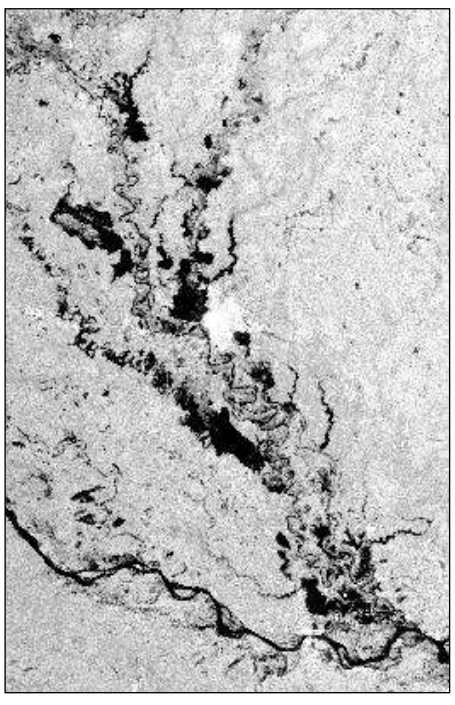
Satellite image showing floods in 2006



Detailed View

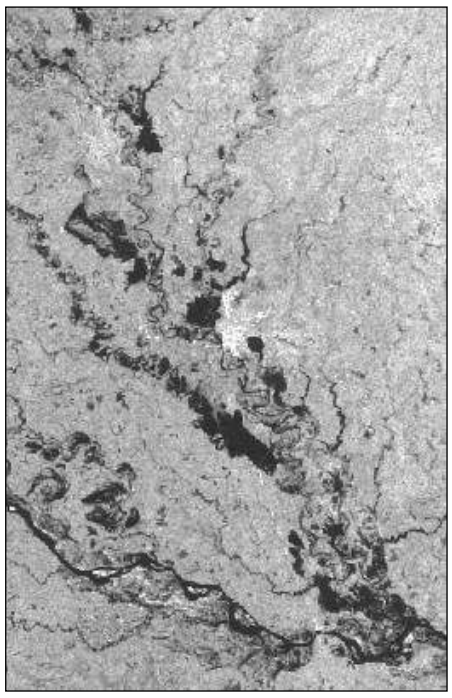


Satellite image showing floods in 2007

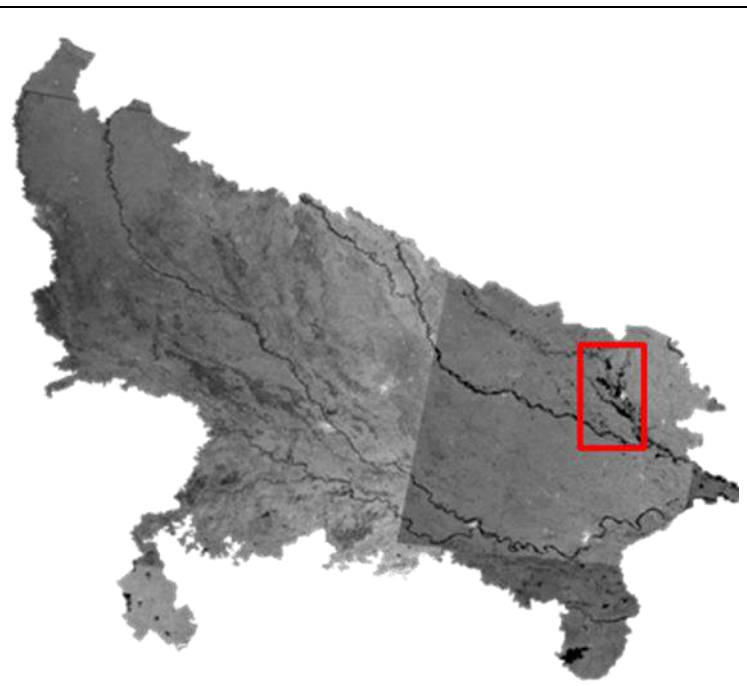


Detailed View

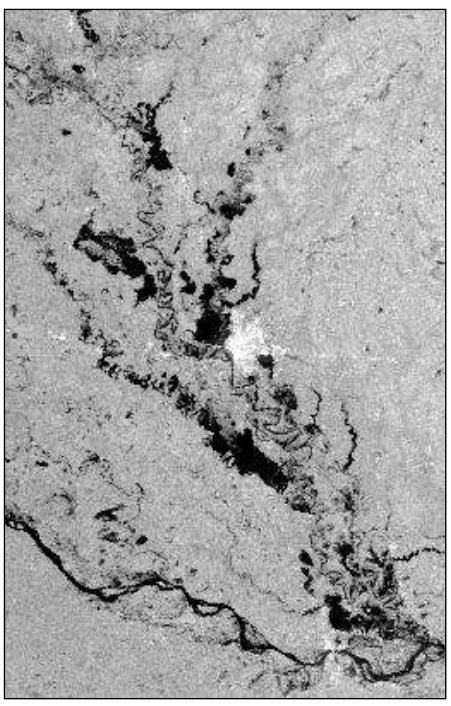
Satellite image showing floods in 2008



Detailed View

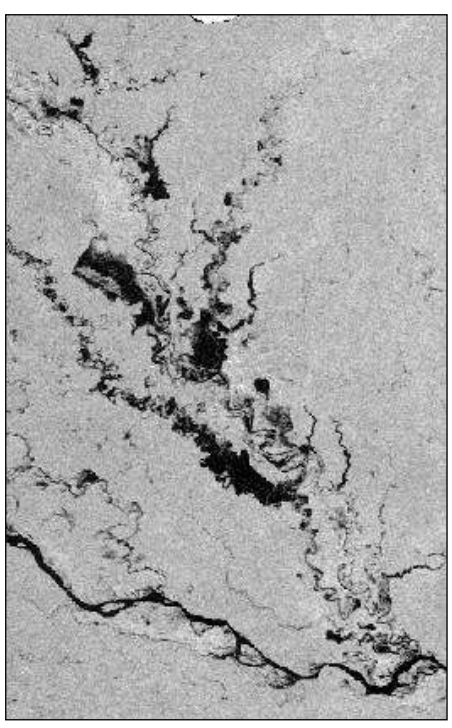


Satellite image showing floods in 2009

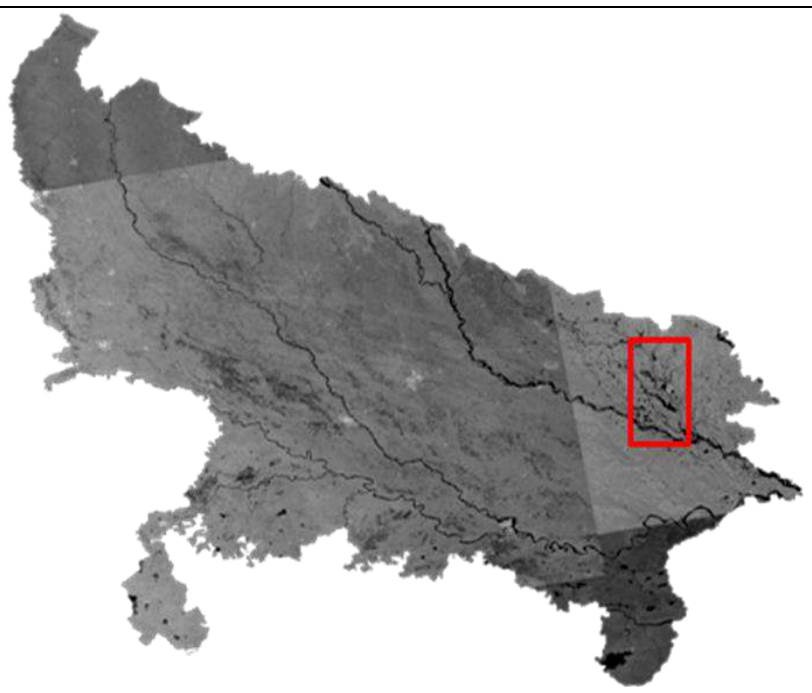


Detailed View

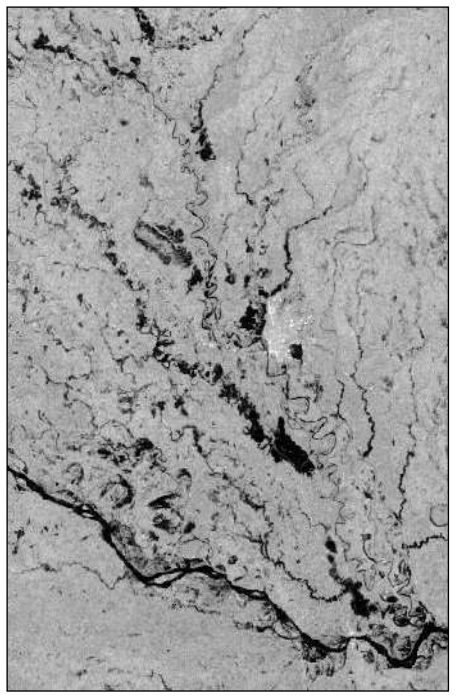
Satellite image showing floods in 2010



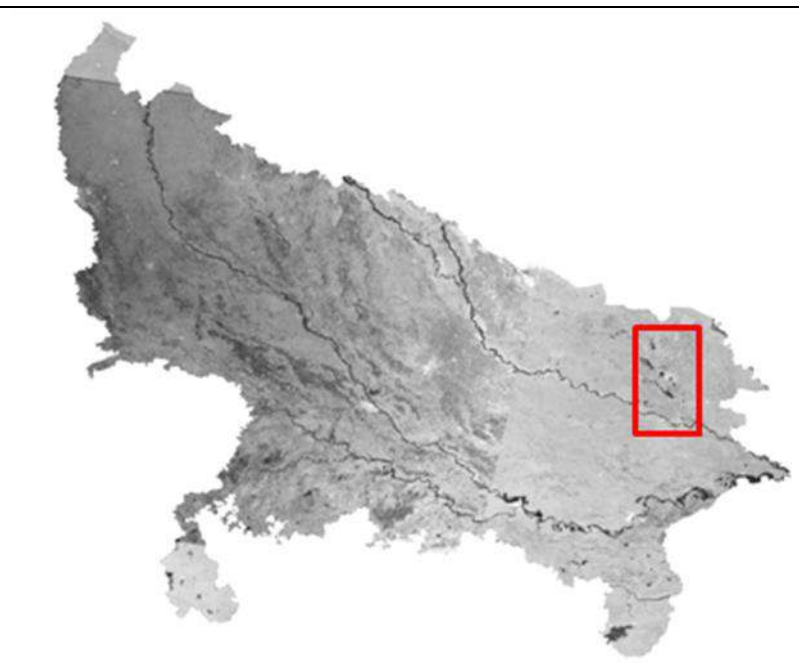
Detailed View



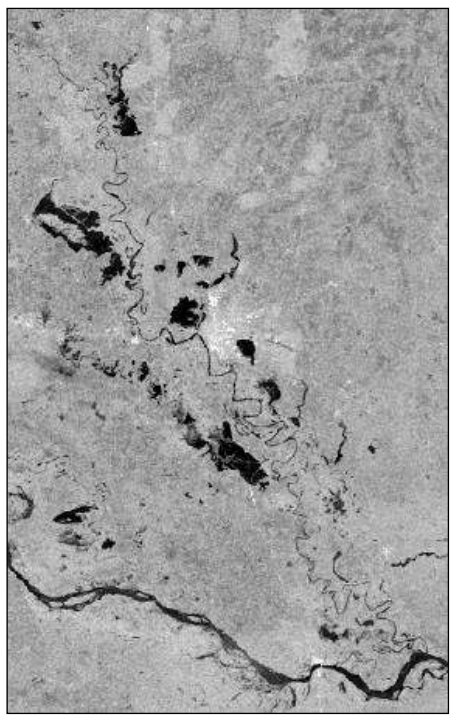
Satellite image showing floods in 2012



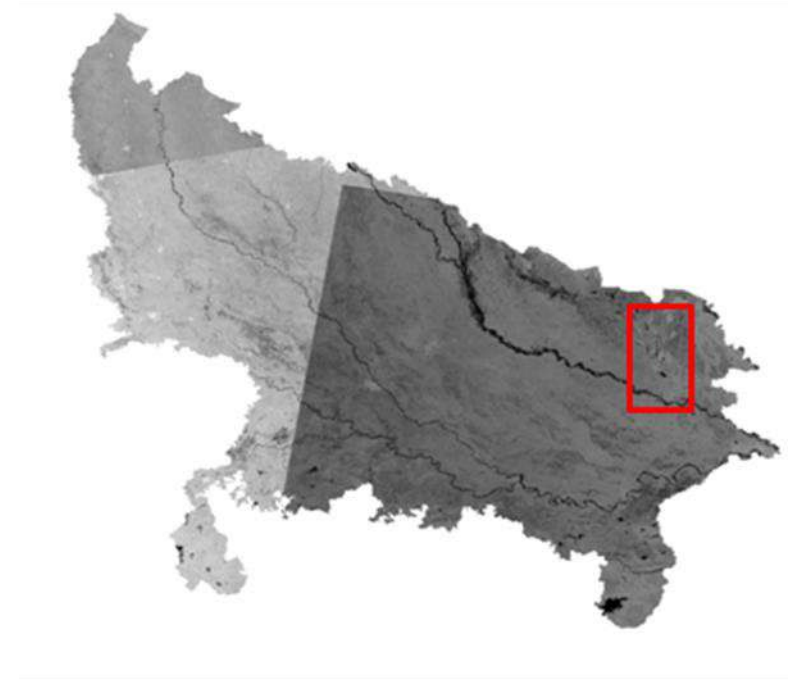
Detailed View



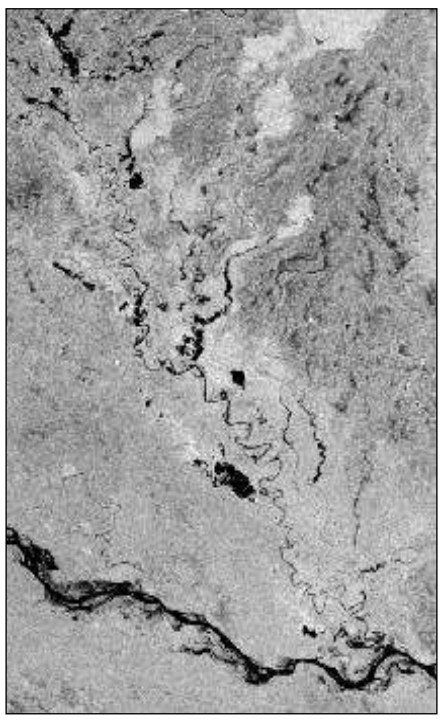
Satellite image showing floods in 2013



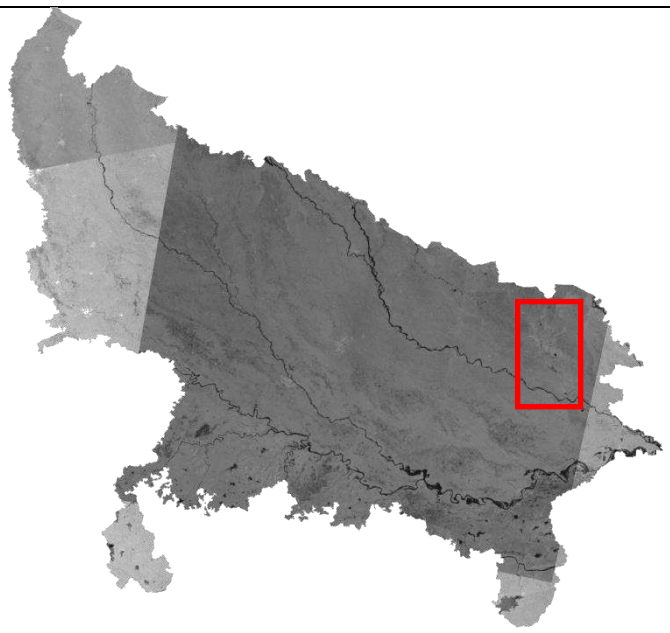
Detailed View



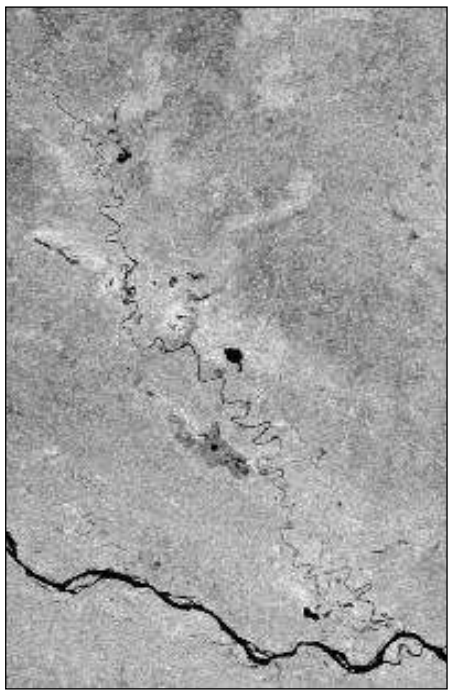
Satellite image showing floods in 2014



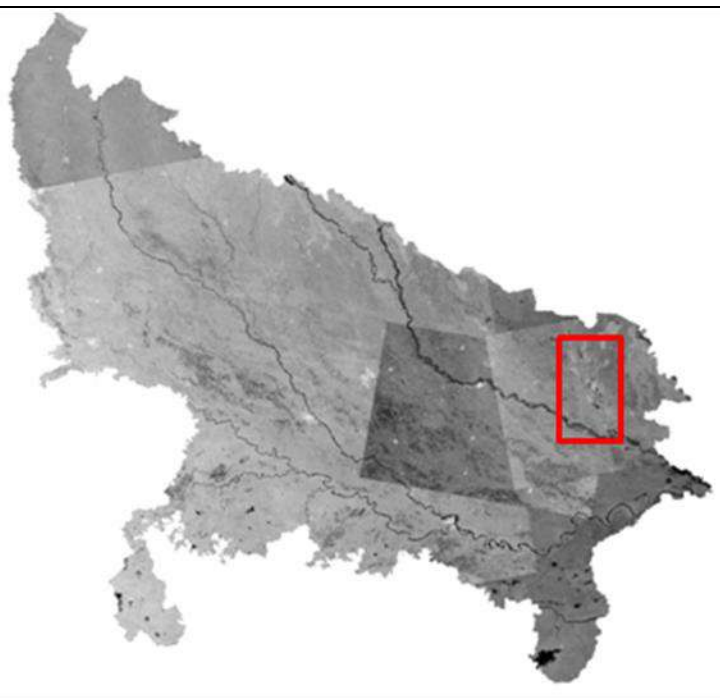
Detailed View



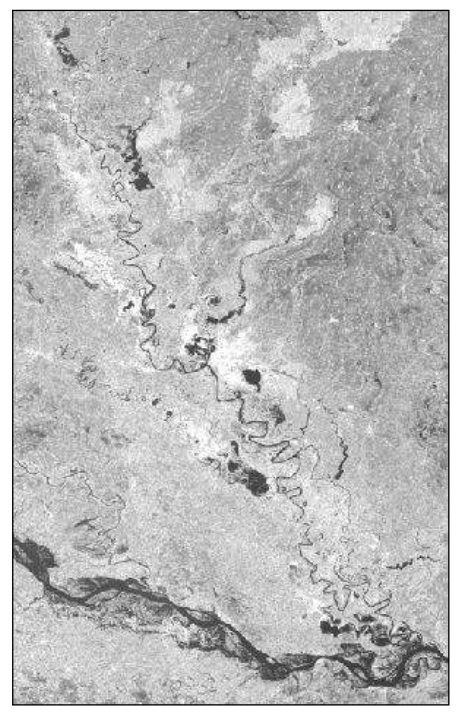
Satellite image showing floods in 2016



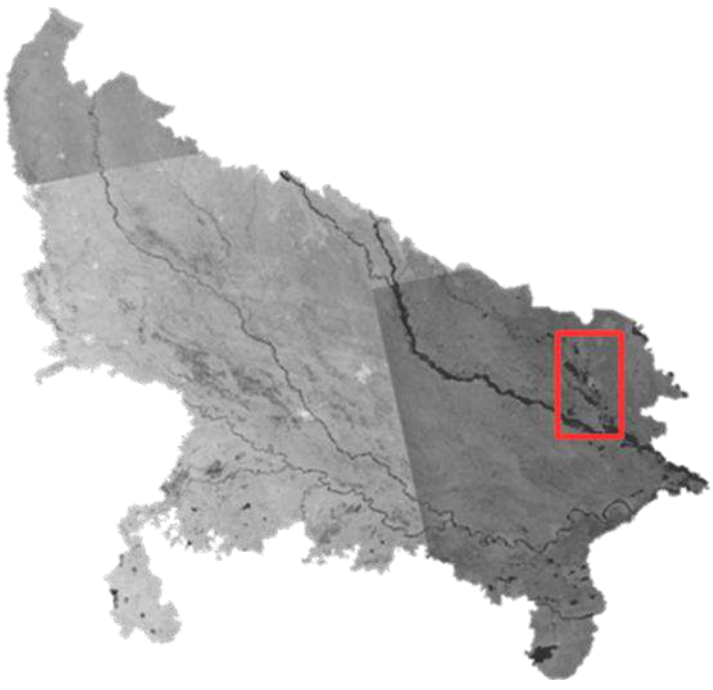
Detailed View



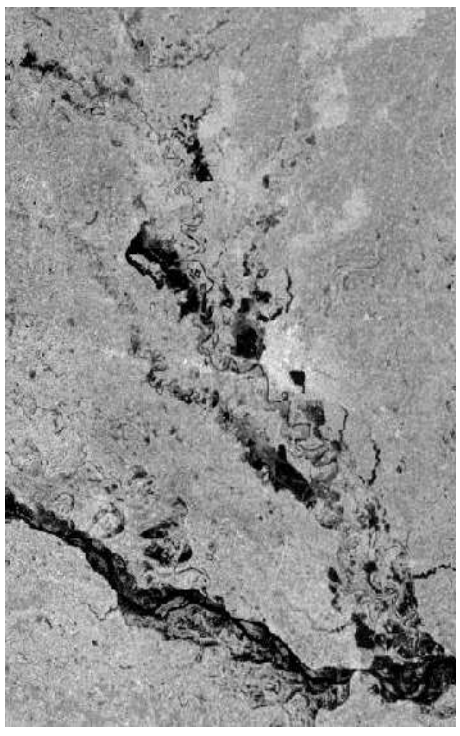
Satellite image showing floods in 2018



Detailed View



Satellite image showing floods in 2020



Detailed View

Table –10: List of Satellite data sets available and utilized for flood hazard zonation of Uttar Pradesh.

S. No	Date	Satellite/ Sensor	S. No	Date	Satellite/ Sensor
1998			34	21-Aug-08	RADARSAT
1	03-Aug-98	RADARSAT	35	23-Aug-08	RADARSAT
2	23-Aug-98	RADARSAT	36	30-Aug-08	RADARSAT
2000			37	06-Sep-08	RADARSAT
3	15-Sep-00	RADARSAT	38	23-Sep-08	RADARSAT
2001			39	25-Sep-08	RADARSAT
4	07-Aug-01	RADARSAT	40	26-Sep-08	RADARSAT
2002			41	04-Oct-08	RADARSAT
5	02-Aug-02	RADARSAT	**2009**		
2003			42	03-Aug-09	RADARSAT
6	04-Jul-03	RADARSAT	43	20-Aug-09	RADARSAT
7	21-Sep-03	RADARSAT	44	22-Aug-09	RADARSAT
2004			45	25-Aug-09	RADARSAT
8	17-Jul-04	RADARSAT	46	27-Aug-09	RADARSAT
9	22-Jul-04	RADARSAT	47	14-Sep-09	RADARSAT
10	29-Jul-04	RADARSAT	48	09-Oct-09	IRS P6 AWiFS
2005			49	12-Oct-09	RADARSAT
11	08-Jul-05	RADARSAT	50	14-Oct-09	IRS P6 AWiFS
12	24-Jul-05	RADARSAT	**2010**		
13	25-Aug-05	RADARSAT	51	22-Jul-10	RADARSAT
14	29-Aug-05	RADARSAT	52	23-Jul-10	RADARSAT
2006			53	20-Aug-10	RADARSAT
15	18-Aug-06	RADARSAT	54	23-Aug-10	RADARSAT
2007			55	27-Aug-10	RADARSAT
16	31-Jul-07	RADARSAT	56	30-Aug-10	RADARSAT
17	02-Aug-07	RADARSAT	57	03-Sep-10	RADARSAT
18	07-Aug-07	RADARSAT	58	06-Sep-10	RADARSAT
19	09-Aug-07	RADARSAT	59	08-Sep-10	RADARSAT
20	17-Aug-07	RADARSAT	60	10-Sep-10	RADARSAT
21	24-Aug-07	RADARSAT	61	18-Sep-10	RADARSAT
22	26-Aug-07	RADARSAT	62	20-Sep-10	RADARSAT
23	31-Aug-07	RADARSAT	63	21-Sep-10	RADARSAT
24	01-Sep-07	RADARSAT	64	23-Sep-10	RADARSAT
2008			65	25-Sepl-10	RADARSAT
25	07-Jul-08	MODIS TERRA	66	03-Oct-10	RADARSAT
26	10-Jul-08	RADARSAT	**2012**		
27	17-Jul-08	RADARSAT	67	26-Jul-12	RADARSAT
28	20-Jul-08	RADARSAT	68	07-Aug-12	RADARSAT
29	27-Jul-08	RADARSAT	69	12-Aug-12	RADARSAT
30	27-Jul-08 28-Jul-08	RADARSAT	70	19-Sep-12	RADARSAT
			2013		
31	01-Aug-08	RADARSAT	71	18-Jun-13	RISAT-1
32	08-Aug-08	RADARSAT-1	72	19-Jun-13	RISAT-1

S. No	Date	Satellite/ Sensor	S. No	Date	Satellite/ Sensor
73	04-Jul-13	RADARSAT	111	02-Sep-17	RADARSAT
74	13-Jul-13	RADARSAT	**2018**		
75	23-Jul-13	RADARSAT	112	04-Aug-18	SENTINEL-1A
76	25-Jul-13	RADARSAT	113	16-Aug-18	RADARSAT
77	28-Jul-13	RADARSAT	114	28-Aug-18	RADARSAT
78	02-Aug-13	RADARSAT	115	31-Aug-18	RADARSAT
79	04-Aug-13	RADARSAT	116	01-Sep-18	SENTINEL-1A
2014			117		
80	18-Aug-14	RADARSAT	118	06-Sep-18	SENTINEL-1A
81	19-Aug-14	RISAT-1 &MODIS TERRA	119	11-Sep-18	RADARSAT
82	20-Aug-14	UK DMSC-2	120	12-Sep-18	RADARSAT
83	21-Aug-14	RADARSAT	121	21-Sep-18	RADARSAT
84	23-Aug-14	RADARSAT	**2019**		
85	23 & 24-Aug-14	RADARSAT& RISAT-1	122	18-Jul-19	RADARSAT
2016			123	20-Aug-19	SENTINEL-1A
86	19-Jul-16	RISAT-1	124	21-Aug-19	RADARSAT
87	20-Jul-16	RISAT-1	125	15-Sep-19	SENTINEL-1B
88	24-Jul-16	RISAT-1	126	15-Sep-19	SENTINEL-1A
89	28-Jul-16	RISAT-1	127	19-Sep-19	RADARSAT
90	02-Aug-16	RISAT-1	128	21-Sep-19	RADARSAT
91	19-Aug-16	RADARSAT	**2020**		
92	21-Aug-16	MODIS TERRA & RESOURCESAT-2 AWiFS	129	21-May-20	RADARSAT
93	24-Aug-16	RADARSAT	130	21-May-20	ALOS2PALSAR
94	25-Aug-16	RISAT-1 & MODIS TERRA	131	22-May-20	SENTINEL-1A
95	26& 27-Aug-16	RISAT-1	132	22-May-20	NOVASAR-1
96	30-Aug-16	RISAT-1	133	24-May-20	RADARSAT
97	07-Sep-16	RADARSAT	134	24-May-20	TERRASAR-X
2017			135	24-May-20	OTHER SOURCE
98	09-Jul-17	RADARSAT	136	25-May-20	RADARSAT
99	06-Aug-17	SENTINEL-1A	137	27-May-20	COSI SAR-X
100	09-Aug-17	RADARSAT	138	26-Aug-20	SENTINEL-1A
101	11-Aug-17	RADARSAT	139	28-Aug-20	SENTINEL-1A
102	14-Aug-17	RADARSAT			
103	16-Aug-17	RADARSAT			
104	19-Aug-17	RADARSAT			
105	21-Aug-17	SENTINEL-1A			
106	23-Aug-17	RADARSAT			
107	24-Aug-17	RESOURCESAT-2 AWiFS			
108	24-Aug-17	RADARSAT			
109	26-Aug-17	RADARSAT			
110	28-Aug-17	SENTINEL-1A			

3.2 APPROACH

In this attempt, a large number of satellite images covering the Uttar Pradesh region during all the flood events that occurred during last 23 years (1998-2020) were used. All satellite datasets were analyzed and flood layers were extracted. The flood layers corresponding to each year are combined and annual flood inundation layer was generated which represents maximum flooded area in that year. The annual flood layers for 23 years were integrated into a flood hazard layer representing the flood inundated areas with different frequencies. The flood hazard has been classified into 5 categories based on the frequency of inundation as finalized by the expert committee constituted by NDMA, New Delhi. The flood hazard area under each category for each district was also estimated. State and district-wise flood hazard maps are composed showing the various flood hazard severity categories. Further, to assess the severity of flood in each district with respect to flood hazard category, hazard area and intra annual variations (the number of flood peaks in a year), a flood hazard index is computed. Major steps involved in preparation of flood hazard zonation is described below.

Satellite data Acquisition: Satellite data acquired from Indian Remote Sensing Satellites (IRS) and other foreign satellites (optical as well as microwave SAR)acquired during the flood season in Uttar Pradesh from 1998-2020 have been used. The water levels observed at different gauge stations were closely monitored during floods and attempts were made to program the satellite data during near peak situations. Satellite data was also programmed and procured during progression and recession of the flood wave for studying the impact of the flood.

Rectification: The acquired satellite datasets were geometrically rectified to a defined projection system for attaining positional accuracy.

Flood inundation layer: Using Digital Image Processing classification algorithms, water layer was classified from the satellite data and integrated with the pre-flood river and water bodies layer to extract flood inundation layer.

Annual Flood Layer: The flood inundation layers generated for different flood waves in a calendar year were integrated to generate the annual cumulative flood inundation extent in that year.

Hazard layer: The annual cumulative flood inundation layers corresponding to 23 years (1998-2020) were integrated for assessing the frequency of inundation and subsequent generation of hazard layer. Hazard map has been classified into five classes as recommended by the expert committee constituted by NDMA, New Delhi.

Database integration: The hazard layer was further integrated with the database consisting of administrative boundaries, landuse/ landcover, infrastructure, etc. for impact assessment and statistics generation.

Map Composition: Flood hazard maps were composed at State and District levels comprising of base details and hazard layer.

Intra Annual Variations: The number of flood waves/peaks for each year has been calculated based on the water level data of 31 gauge stations collected from Central Water Commission. The affected districts for each flood wave in a particular year have been examined by correlating with satellite data observation and annual flood wave index was provided for each district.

Flood Hazard Index: Considering the flood hazard category, hazard area and intra annual variations (the number of flood peaks in a year), a flood hazard index is computed for each district.

The methodology adopted for generation of flood hazard index is shown in Figure 33

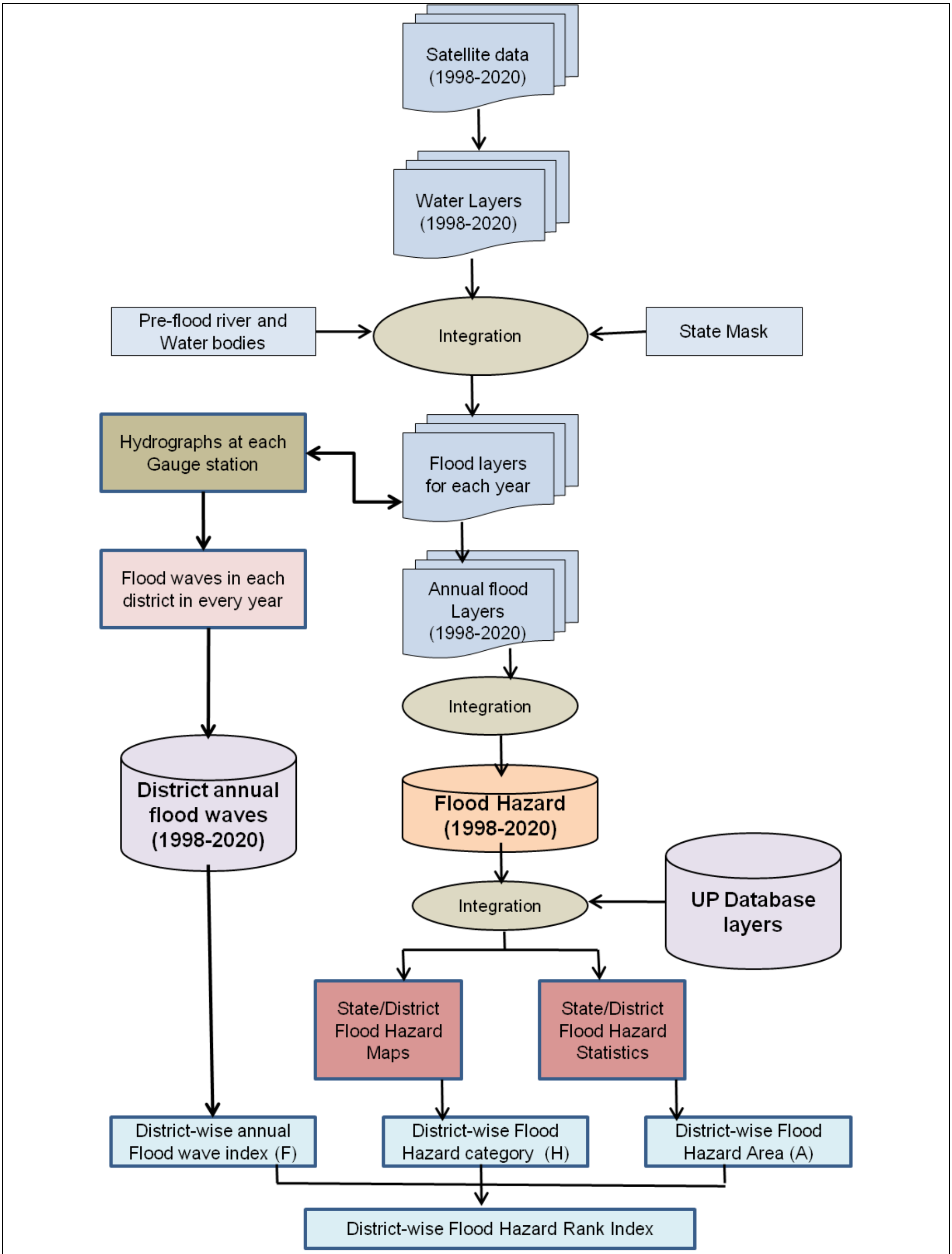


Fig 33 : Broad Methodology adopted for Flood Hazard Zonation for Uttar Pradesh State

3.3. FLOOD HAZARD ZONATION SCHEMA

To normalize Flood Hazard classes at national level, National Disaster Management Authority (NDMA) conducted an expert committee meeting in 2019 to define the classification schema. Based on the suggestions given by the expert committee, flood hazard layer has been classified into 5 classes. Twenty three years of satellite data was used for deriving the flood hazard layer. The hazard layer highlights the frequency of flooding in any area during last 23 years. The flood hazard has been classified into 5 categories based on frequency of inundation. Very Low category indicates the areas, which are inundated once or twice during the 23-year period. Similarly, Low indicates three to five times, Moderate indicates six to nine times, High indicates ten to thirteen times and Very High indicates greater than thirteen times. To facilitate better visualization, colour coding scheme has been adopted for different hazard zones as shown in the table 11.

Table 11: Flood Hazard Zonation Schema

Sl.No	Flood Hazard Classification	Colour coding scheme	Number of times / years the area was subjected to flood inundation during 1998-2019
1	Very Low		1-2 times
2	Low		3-5 times
3	Moderate		6-9 times
4	High		10-13 times
5	Very High		>13 times (almost every year)

3.4 INTRA ANNUAL FLOOD VARIATIONS

The intra annual flood variations have been considered for calculation of final flood hazard index for each district in Uttar Pradesh.The flood variations for each year are estimated based on the number of flood waves in each year. Daily water level data of about 31 gauge stations for the said 23 years has been collected from Central Water Commission and analysed thoroughly. The hydrographs for each river at each gauge station were drawn to calculate the number of flood waves /peaks. The affected districts for each flood wave in a particular year have been examined by correlating with satellite data observation and annual flood wave index was provided for each district. Other collateral information was used to estimate the flood waves where ever hydrographs are not available. Figure 34 shows the hydrograph of Ganga river at Ayodhya from 2001 to 2018 as an example.

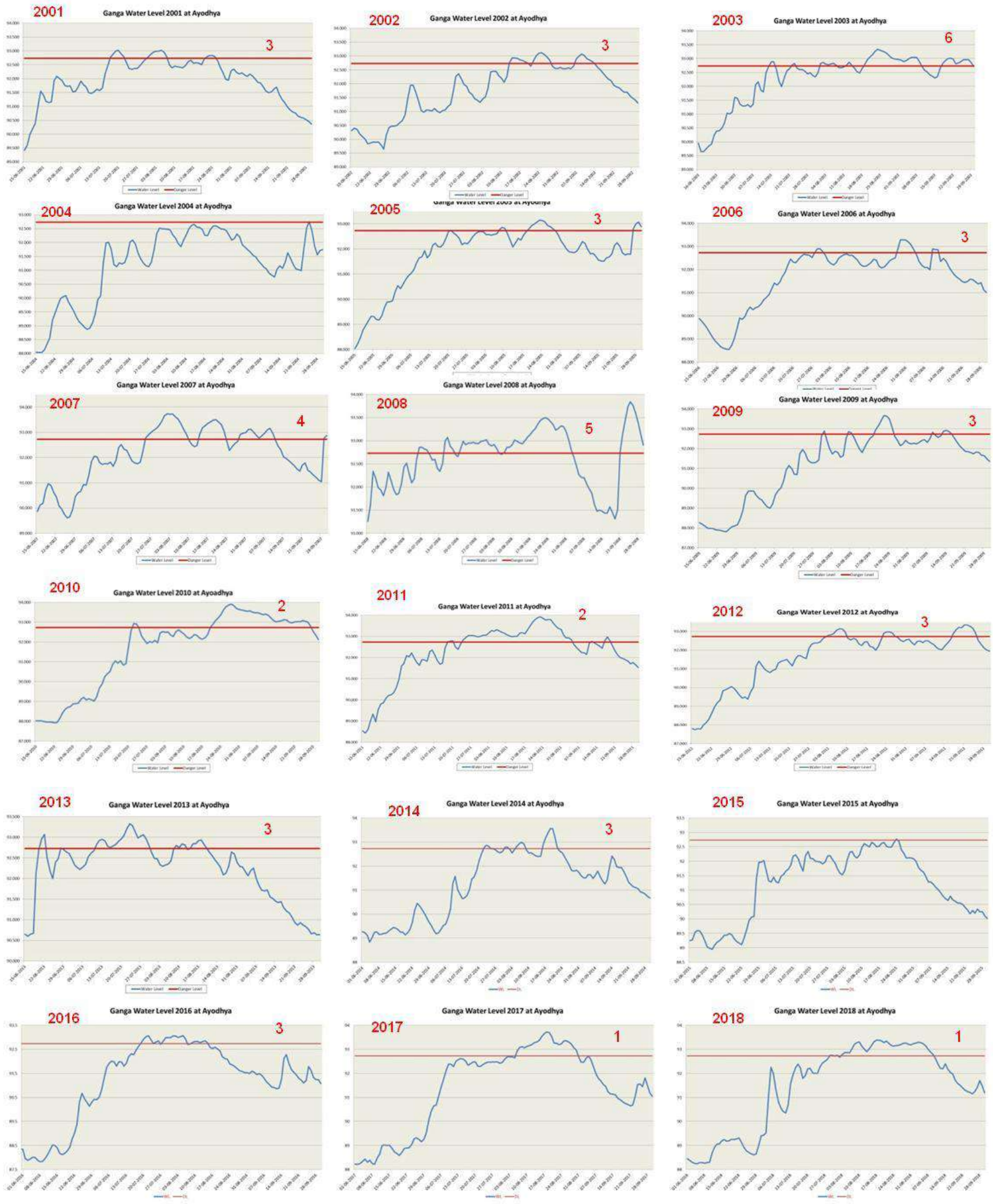


Fig. 34 Hydrograph for Ganga river at Ayodhya from 2001 to 2018.

3.5 FLOOD HAZARD INDEX

Flood hazard index (FHI) for each district is calculated using the following formula

Flood Hazard Index = ∑ (Hazard Category (Hw) X Hazard Area (Aw)) X ∑Intra Annual Variations (IAVw)

- Weightages were given to each category of flood hazard (H) and are shown in Table 12
- Weightages were given as per the percentage of flood hazard area (A) in the district as shown in theTable 13
- Weightages were also given to the number of times a particular district is affected by flood waves (F) annually as shown in the Table 14
- Flood hazard index is derived for each district by using above formula. Further the flood hazard index obtained has been regrouped into five classes (Refer Table 15)

Table 12:Hazard Weightage for Flood Hazard category	
Hazard Zones	**Weightage for Hazard Zones (Hw)**
Very High	5
High	4
Moderate	3
Low	2
Very Low	1

Table 13 : Area Weightage for % Submergence	
Percentage of District Hazard area	**Weightage (Aw)**
0-10 %	1
11-20%	2
21-30%	3
31-40%	4
41-50%	5
51-60%	6
61-70%	7
71-80%	8
81-90%	9
91-100%	10

Table 14: Weightage for Inter Annual Flood Variation	
Intra Annual Variations 1998-2019	**Weightage for Intra Annual Variations (IAVw)**
>25	6
25 to 20	5
19 to 15	4
14 to 10	3
9 to 5	2
<5	1

Table 15: Flood Hazard Index	
Flood Hazard Index (H*A*F)	**Flood Hazard Index**
>95	I (Very High)
46 to 95	II (High)
31 to 45	III (Moderate)
16 to 30	IV (Low)
15	V (Very Low)

3.5.1. Computation of Flood Hazard Index for Ayodhya District

Computation of Flood Hazard Index for Ayodhya district is explained below as an example. Hazard weightages (Hw) are given to each category of flood hazard and are shown in Table 16. Area weightages (Aw) are given as per the percentage of flood hazard area in each category for the district as shown in Table 16.

Table 16: Flood Hazard Index for Ayodhya District

District	Geographical Area (Hectares)	Flood Hazard Zones (H)	Hazard Weightage for each Flood Zones (Hw)	Percentage of Area Submerged (A)	Area Weightage for % submergence (Aw)	Hw*Aw	Total Σ Hw*Aw
Ayodhya	225200	Very High	5	0.03	1	5	**15**
		High	4	0.41	1	4	
		Moderate	3	1.01	1	3	
		Low	2	1.89	1	2	
		Very Low	1	4.35	1	1	

Weightages were also given to the number of times a particular district is affected by flood waves (IAVw) annually as shown in the Table17.

Table 17. Intra Annual Flood waves for Ayodhya District

District	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Toatal Flood waves (Σ IAV)	Annual Flood Wave (Σ IAVw)
Ayodhya	-	-	-	3	3	6	0	3	3	4	5	3	2	2	3	3	3	0	3	1	1	-	-	48	6

Flood hazard index is derived for Ayodhya district by using ($\Sigma(H_W \times A_W) \times \Sigma IAV_W$) =15X6=90. Similar approach is followed for other remaining 68 districts.

3.6 LIMITATIONS OF THE STUDY

The flood hazard zonation was carried out with available satellite data with NRSC. The satellite coverage may not correspond to the peak flooding in all cases. Further, all river gauge stations need not record the peak situation on a single day. For states like Uttar Pradesh where the topography is quite gentle, the flood inundation remains same for few days, even after the peak has passed. Hence, in most of the cases, satellite data acquired even after the peak flood, resembles the peak flood situation. Observed flood inundation may include flooding due to embankment breaches and also due to rain water accumulation in low lying areas. Some flash floods and minor floods that were not covered by satellite data during this period are not represented in the hazard atlas. Hence, actual flood extent may be more than the satellite based assessment.

4.0. OBSERVATIONS

4.1. FLOOD HAZARD ZONES

Based on the analysis of 139 nos. of satellite datasets, acquired during floods of 1998-2020, the flood hazard layer of the Uttar Pradesh State is derived as shown in Fig 35. Table18 shows the flood hazard area computed under various hazard categories. The observations made from the flood hazard analysis are;

- It is observed that about 10.87% (26.50 Lakhs hectares) of land in Uttar Pradesh state is affected by floods during 1998-2020 out of the total state geographical area of 243.92 lakh hecatres.
- Out of total 26.50 lakh hectares of flood affected area, about 2,642 hectares falls in Very High flood hazard zone (greater than 13 times), 22,462 hectares falls under high (inundated 10-13 times) flood hazard categories. Fig 36 shows the percentage distribution of flood hazard area under different categories with respect to total flood hazard area.
- About 82,425 hectares falls in moderate (inundated 6-9 times) flood hazard category, whereas 3.46 lakh hecatres falls under low (inundated 3-5 times) hazard and about 21.96 lakh hecatres falls under Very Low (inundated 1-2 times) flood hazard. Fig 37. shows the Flood Hazard Ranking Index Map.

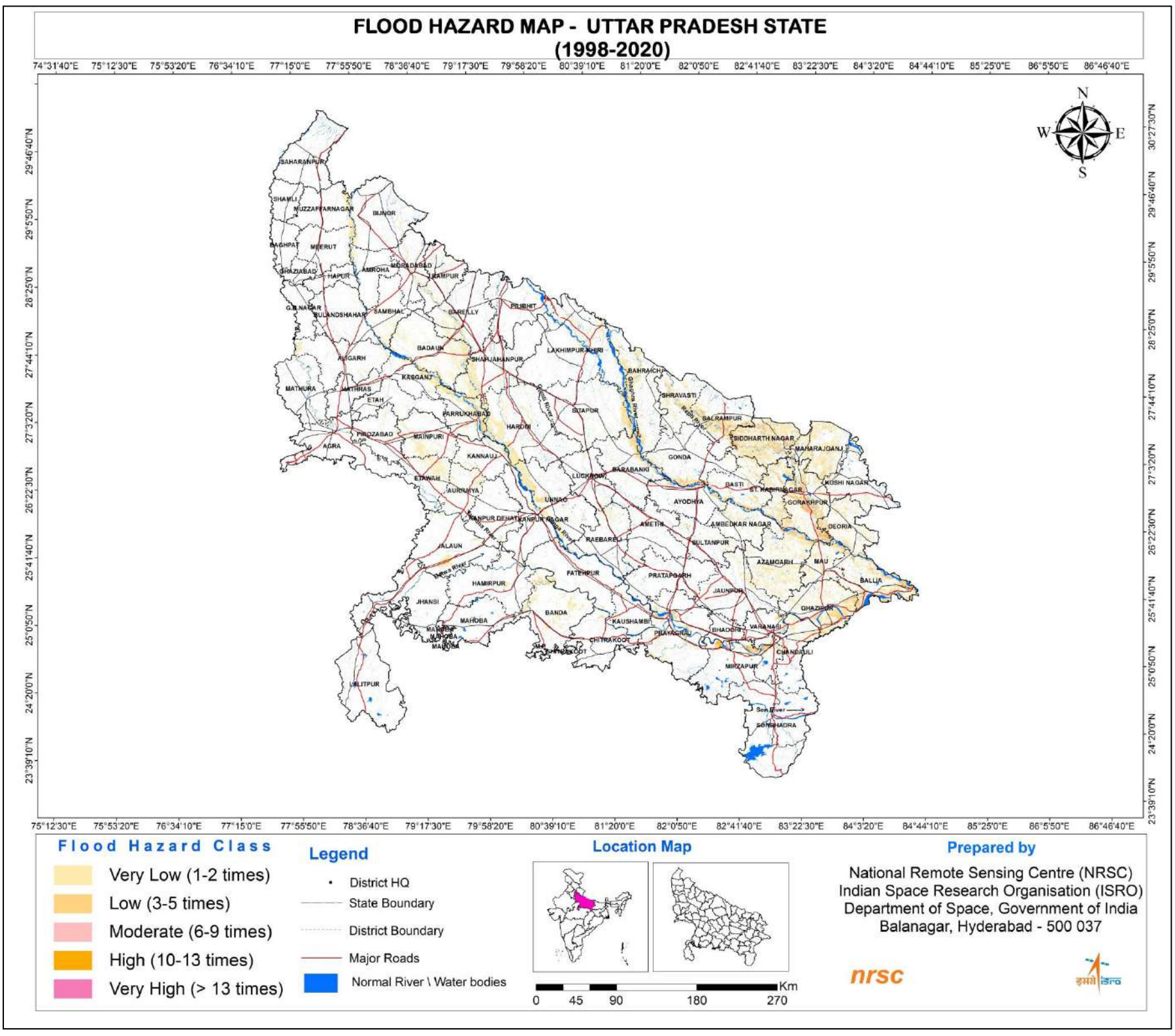


Fig 35 Flood Hazard Map of Uttar Pradesh

Table-18 Flood Hazard Area under Various Categories

Sl. No	Hazard Severity	Flood Hazard Area (ha)	% Flood Hazard (wrt State Geographic Area)	% Flood Hazard (wrt Total Flood Hazard Area)
1	Very High	2642	0.01	0.1
2	High	22462	0.09	0.8
3	Moderate	82425	0.34	3.1
4	Low	346889	1.42	13.1
5	Very Low	2196087	9.00	82.9
	TOTAL	**2650506**	**10.87**	**100**

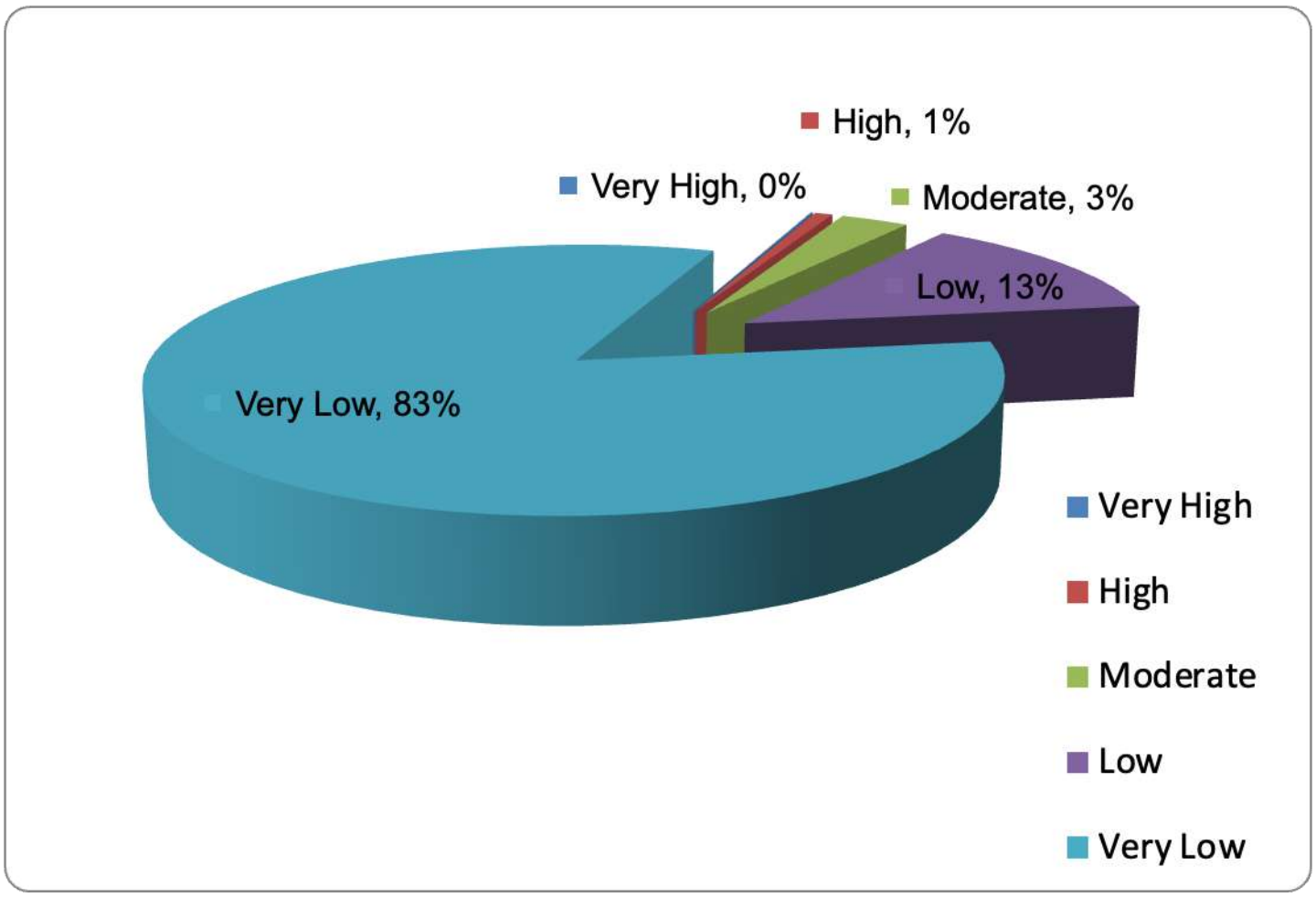


Fig- 36 Percentage of various hazard categories wrt total hazard in the state

Table 19 District-wise Flood Hazard Index

District	District Area (Hectares)	Total Flood Inundated Area (Hectares)	% Flood Hazard Area	Flood Hazard Index FHI= Σ (Hw*Aw) * Σ (IAVw))
Ballia	298100	114548	38	108
Azamgarh	405400	131592	32	102
Maharajganj	295200	118227	40	102
Ghazipur	337700	117697	35	102
Budaun	425954	88762	21	102
Siddhrathnagar	289500	181092	63	100
Bahraich	469680	104590	22	96
Balrampur	334900	91524	27	96
Deoria	254000	74813	29	96
Basti	268800	60233	22	96
Ambedkarnagar	235000	36672	16	96
Gorakhpur	348380	159458	46	95
Sant kabirnagar	164600	72427	44	95
Kasganj	195874	30115	15	90
Lakhimpur-Khiri	768000	70816	9	90
Barabanki	389150	42671	11	90
Gonda	400300	42138	11	90
Ayodhya	252200	19388	8	90
Sambhal	240069	21276	9	90
Amroha	221521	12601	6	90
Etah	248465	6470	3	90
Mau	171300	46673	27	51
Kushinagar	290600	27953	10	45
Aligarh	365000	13078	4	45
Hathras	180010	2857	2	45
Gautambudhanagar	144200	2656	2	45
Chandauli	248470	73420	30	34
Farrukhabad	218100	69540	32	34
Shrawasti	194820	53725	28	34
Hardoi	598900	84910	14	32
Unnao	458800	70513	15	32
Prayagraj	548200	46164	8	30
Mirzapur	452100	33070	7	30
Jalaun	454400	24404	5	30
Hamirpur	412190	10398	3	30
Kanpur nagar	315500	9346	3	30
Varanasi	153500	7953	5	30
Kanpur dehat	302100	7335	2	30
Lucknow	252800	4040	2	30
Banda	440800	55812	13	16
Etawah	231100	37416	16	16
Mainpuri	276000	34889	13	16
Auraiya	201600	24208	12	16
Sitapur	574300	43980	8	15
Shahjahanpur	457500	68050	15	15
Bareilly	412000	38393	9	15
Jaunpur	403800	22082	5	15
Rampur	236700	20887	9	15
Moradabad	227079	14778	7	15
Rae bareli	327289	17269	3	15
Bijnor	404900	15738	4	15
Meerut	259000	15147	6	15
Kannauj	209300	14763	7	15
Fatehpur	415200	14705	4	15
Muzaffurnagar	268633	14677	5	15
Pilibihit	349900	13572	4	15
Mathura	334000	12982	4	15

District	District Area (Hectares)	Total Flood Inundated Area (Hectares)	% Flood Hazard Area	Flood Hazard Index FHI= Σ (Hw*Aw) * Σ (IAVw))
Sultanpur	244271	12969	5	15
Firozabad	236200	7316	3	15
Kaushambi	178000	5732	3	15
Agra	402700	5346	1	15
Chitrakoot	316400	5114	2	15
Bhadohi	101500	4966	5	15
Bulandshahr	435300	4832	1	15
Pratapgarh	373000	2875	1	15
Sahranpur	368900	2248	1	15
Ghaziabad	103400	1545	1	15
Shamli	134188	1505	2	15
Baghpat	132100	1282	1	15
Amethi	332424	390	0	15
Jhansi	502400	106	0	15
Lalitpur	503900	39	0	15

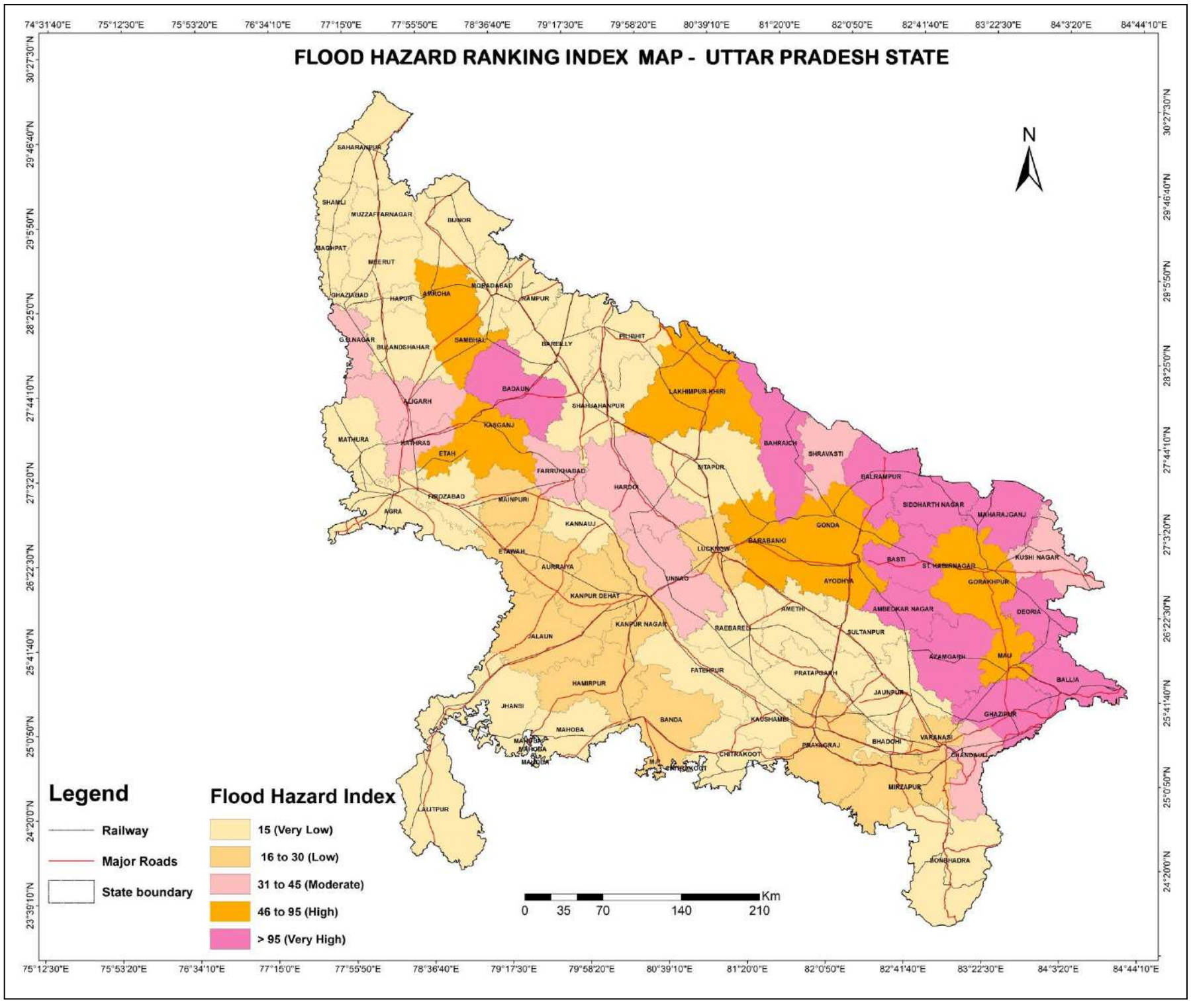


Fig 37 .Flood Hazard Ranking Index Map

4.2CROPPED AREA INUNDATED BY FLOODING

The cropped area (consisting of kharif, rabi, double/triple crop categories) was extracted from the landuse / land cover information (generated under ISRO-NRC project using 2018-19 satellite data) and integrated with the various flood hazard categories. District-wise crop area under each flood hazard category has been computed.From the district-wise cropped area in different flood hazard zones, it can be observed that about 20.08 lakh hectaresof cropped area is under various categories of flood hazard. Out of which about 18,676 hectares of land falls under very high to high flood hazard and 64,019 hectares under the moderate flood hazard category. District-wise details of cropped area in different flood hazard zone are given in Table 20

Table 20 District-wise cropped area (in hectares) in different flood hazard zones

	Very Low	Low	Moderate	High	Very High	Total
AMROHA	4890	29	-	-	-	4919
AMETHI	244	`	-	-	-	244
AGRA	3358	-	-	-	-	3358
ALIGARH	9801	13	-	-	-	9814
ALLAHABAD	21947	5904	94	4	-	27950
AMBEDKARNAGAR	21986	1812	304	17	-	24120
AURAIYA	17446	22	-	-	-	17468
AZAMGARH	93317	5556	2115	243	8	101239
BASTI	33626	8478	1565	132	0	43801
BAGHPAT	547	-	-	-	-	547
BAHRAICH	55616	4120	376	69	-	60182
BALLIA	56271	22940	7065	1152	126	87554
BARABANKI	21687	5167	1765	287	-	28906
BANDA	38264	4205	-	-	-	42469
BALRAMPUR	57632	11947	5610	1628	383	77199
BAREILLY	29582	94	--	-	-	29676
BIJNOR	3979	9	-	-	-	3988
BUDAUN	82731	1855	103	-	-	84689
BULANDSHAHR	2803	-	-	-	-	2803
CHANDAULI	19050	3254	641	206	55	23206
CHITRAKOOT	2840	814	-	-	-	3653
DEORIA	49078	13019	1943	143	0	64184
ETAH	4524	0	0	-	-	4524
ETAWAH	32071	214	-	-	-	32285
AYODHYA	4496	2091	535	128	7	7257
FARRUKHABAD	40459	7973	277	-	-	48710
FATEHPUR	8274	1687	-	-	-	9961
FIROZABAD	6819	-	-	-	-	6819
GAUTAMBUDHANAGAR	1162	-	-	-	-	1162
GHAZIABAD	212	-	-	-	-	212
GHAZIPUR	75272	11711	1224	288	-	88495
GONDA	22978	3336	982	236	20	27551
GORAKHPUR	72700	34489	16092	3902	492	127675
HAMIRPUR	7675	732	275	-	-	8682
HARDOI	65363	2030	-	-	-	67393
HATHRAS	2128	-	-	-	-	2128
JALAUN	20981	541	-	-	-	21522
JAUNPUR	16636	118	-	-	-	16754
JHANSI	93	-	-	-	-	93
KANNAUJ	8793	361	-	-	-	9153
KASGANJ	15261	2238	117	-	-	17616
KANPUR DEHAT	4752	345	-	-	-	5097
KANPUR NAGAR	2993	119	-	-	-	3112
KAUSHAMBI	3639	99	-	-	-	3738
LAKHIMPUR-KHIRI	25612	840	-	-	-	26452
KUSHINAGAR	18552	2337	116	-	-	21005

	Very Low	Low	Moderate	High	Very High	Total
LALITPUR	32	-	-	-	-	32
LUCKNOW	3080	-	-	-	-	3080
MAHARAJGANJ	84073	12968	2412	73	1	99527
MAINPURI	27621	-	-	-	-	27621
MATHURA	10417	-	-	-	-	10417
MAU	32058	4475	546	69	7	37156
MEERUT	6178	760	-	-	-	6939
MIRZAPUR	2495	13168	3869	5168	710	25411
MORADABAD	8346	-	-	-	-	8346
MUZAFFURNAGAR	7766	66	-	-	-	7832
PILIBIHIT	5841	1	-	-	-	5842
PRATAPGARH	1396	0	-	-	-	1396
RAE BARELI	11965	328	-	-	-	12293
RAMPUR	17712	1	-	-	-	17713
SHAMLI	802	-	-	--	-	802
SAMBHAL	14966	79	-	--	-	15045
SAHRANPUR	1471	-	-	--	-	1471
SANT KABIR NAGAR	45911	11077	2993	488	86	60555
SANT RAVI DAS NAGAR	403	48	-	461	-	912
SHAHJAHANPUR	53681	847	106	-	-	54634
SHRAWASTI	38692	5855	638	-	-	45186
SIDDHRATHNAGAR	106779	39228	11966	1560	65	159598
SITAPUR	26162	3914	272	1	-	30349
SULTANPUR	10655	71	-	-	-	10726
UNNAO	55814	5221	-	-	-	61035
VARANASI	1437	3766	18	461	-	5682
Total	**1663895**	**262374**	**64019**	**16715**	**1961**	**2008964**

4.3 GROUND VALIDATION

Ground Validation is a vital process before the product is used by the end user.The flood hazard map, District, Block, Villages under different flood hazard categories were provided to Uttar Pradesh State Disaster Management Authority (UPSDMA) for ground validation.

UPSDMA has done extensive ground validation of the satellite based observations through its concerned Govt officers. Suggestions/modifications provided by Disaster management department officials based on ground report is duly incorporated in the flood hazard atlas and accordingly in the district level maps.

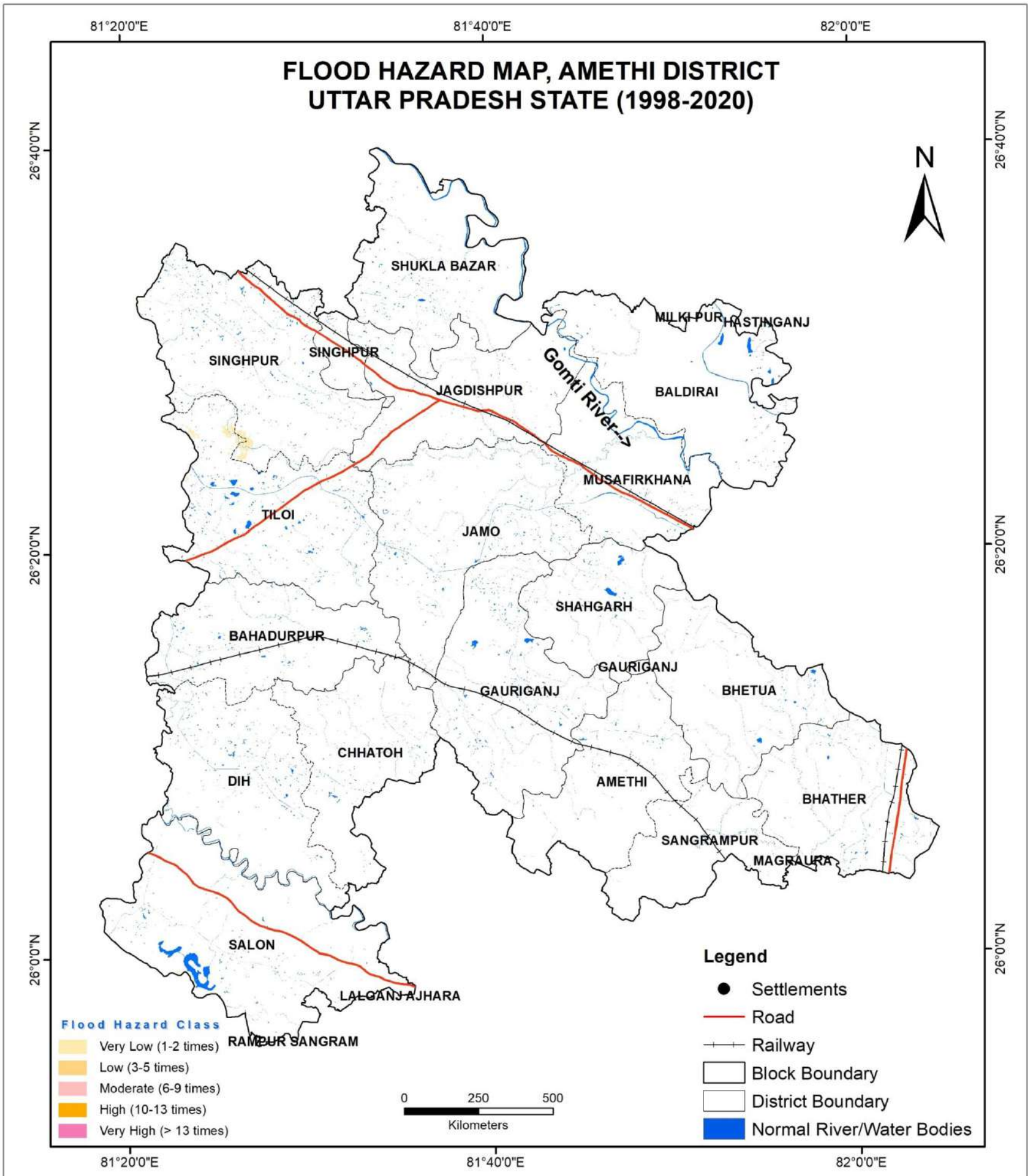
4.4. LIMITATIONS

The flood hazard zonation was carried out with available satellite data at NRSC. Flood layers derived for preparation of flood hazard atlas is dependent of the satellite coverage and pass; hence it may not correspond to peak flooding in all cases. Localized flood and flash floods may not have been captured at times. Observed flood inundation may include flooding due to heavy incessant rainfall and also due to rainwater accumulation in low-lying areas. Hence, actual flood affected area may be more than satellite observed area. Crop area affected by flooding is derived using LULC of 2018-19, since the annual dynamics of LULC have not been considered hence the area affected may be considered an approximation

Annexure- I

DISTRICT WISE FLOOD HAZARD MAPS AND STATISTICS FOR UTTAR PRADESH

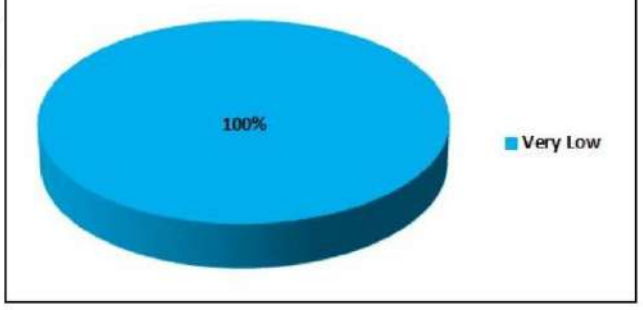
FLOOD HAZARD MAP, AMETHI DISTRICT
UTTAR PRADESH STATE (1998-2020)



Location Map

S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	390
	Total	390

Percentage of Area Affected



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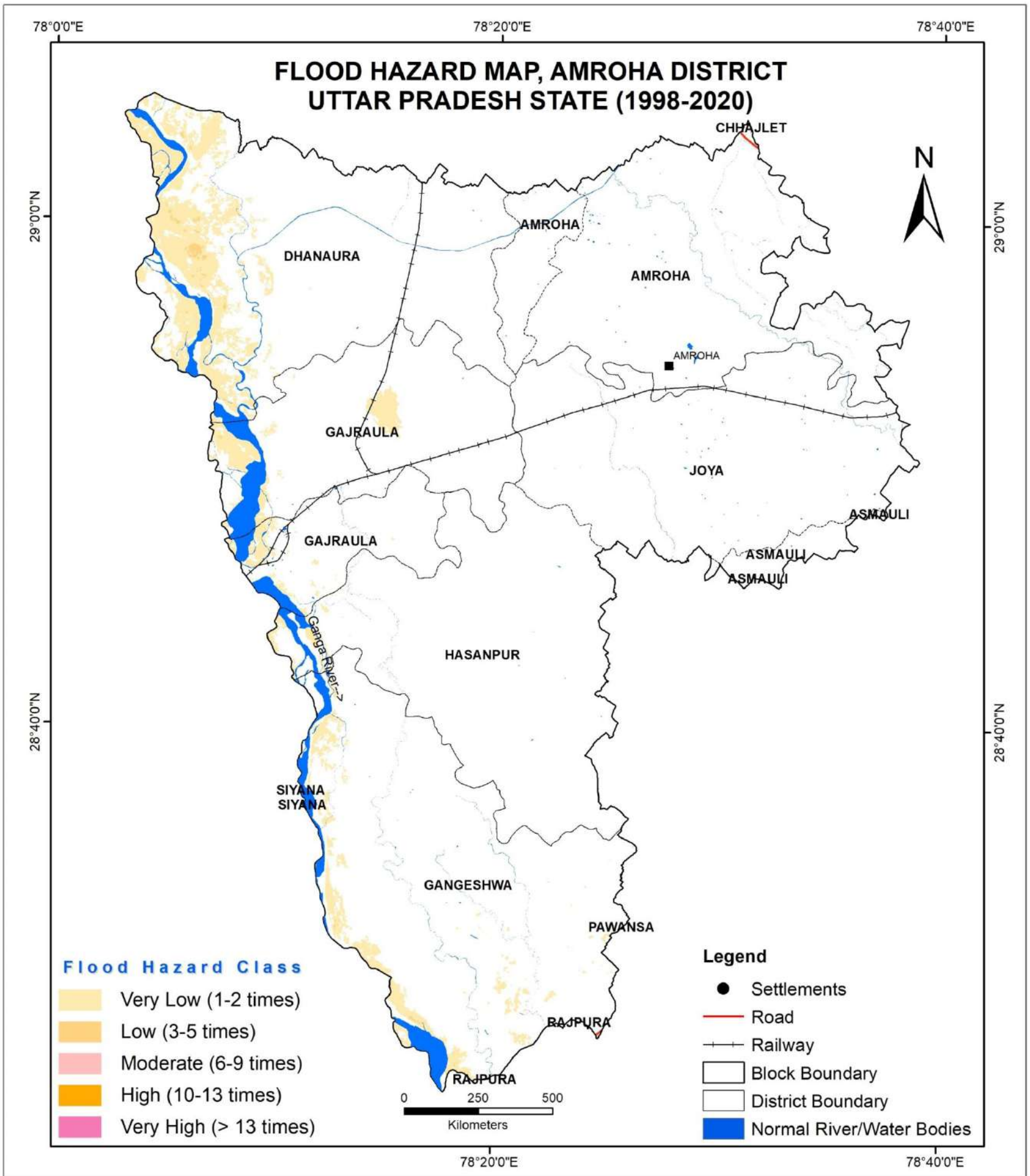
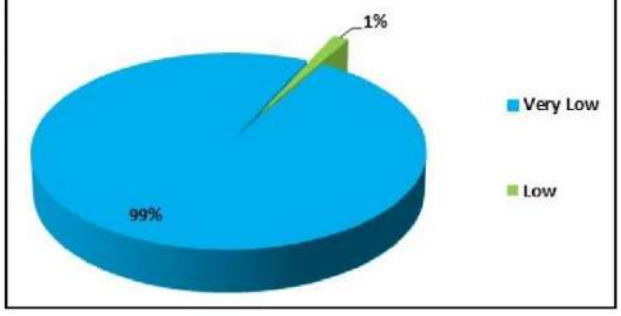
FLOOD HAZARD MAP, AMROHA DISTRICT
UTTAR PRADESH STATE (1998-2020)



Location Map

S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	12414
2	Low	188
	Total	12601

Percentage of Area Affected



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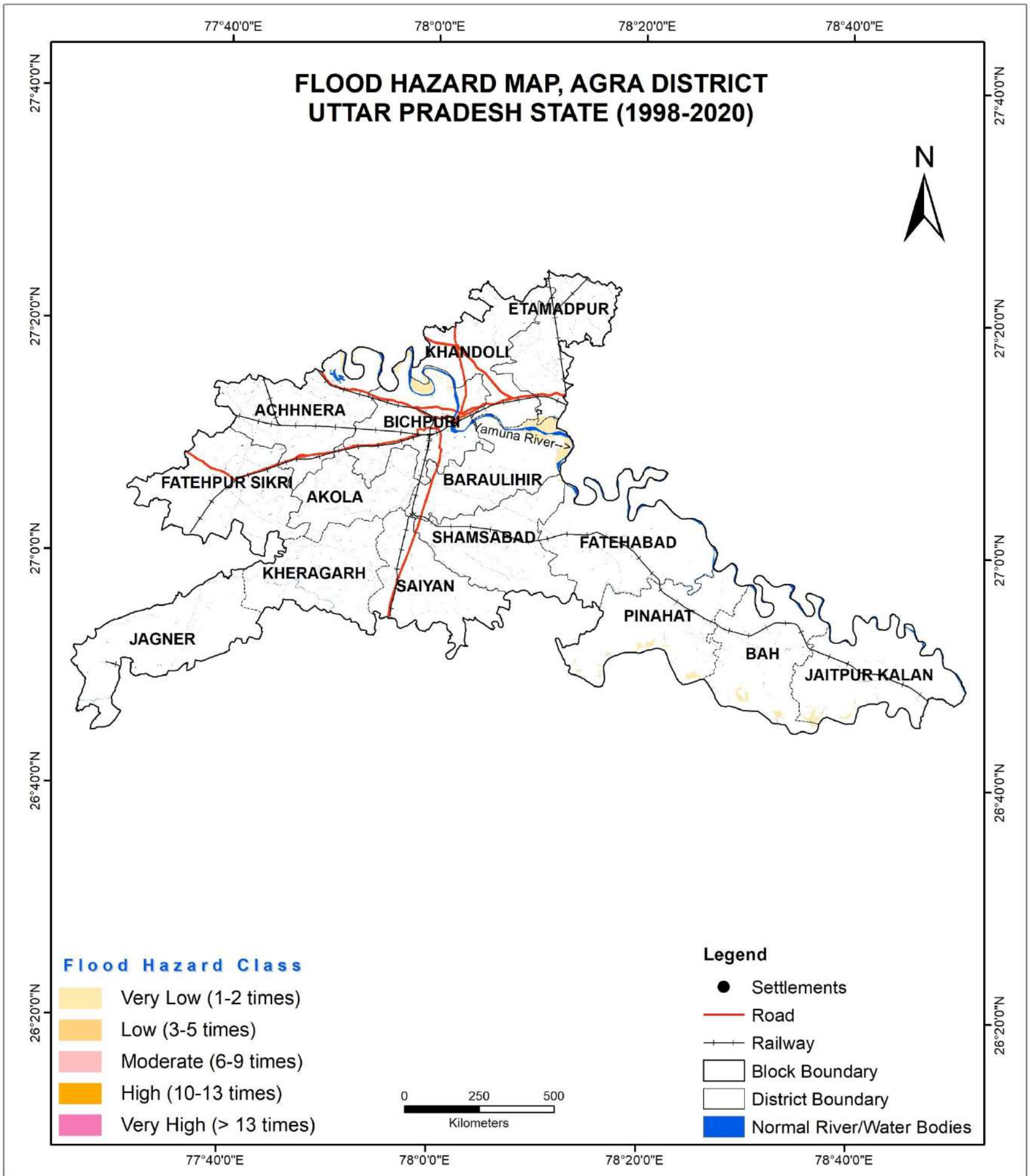
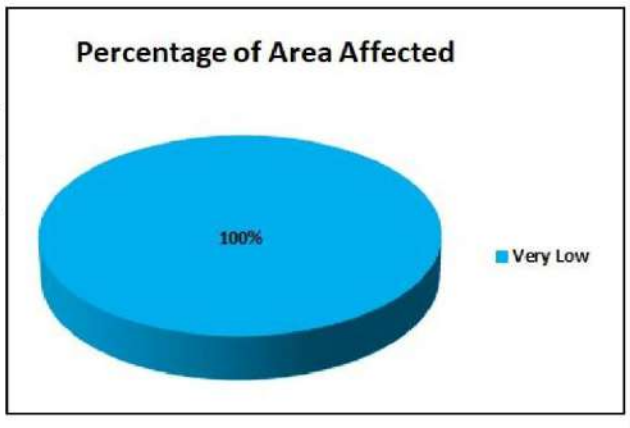
FLOOD HAZARD MAP, AGRA DISTRICT
UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	5346
-	**Total**	**5346**



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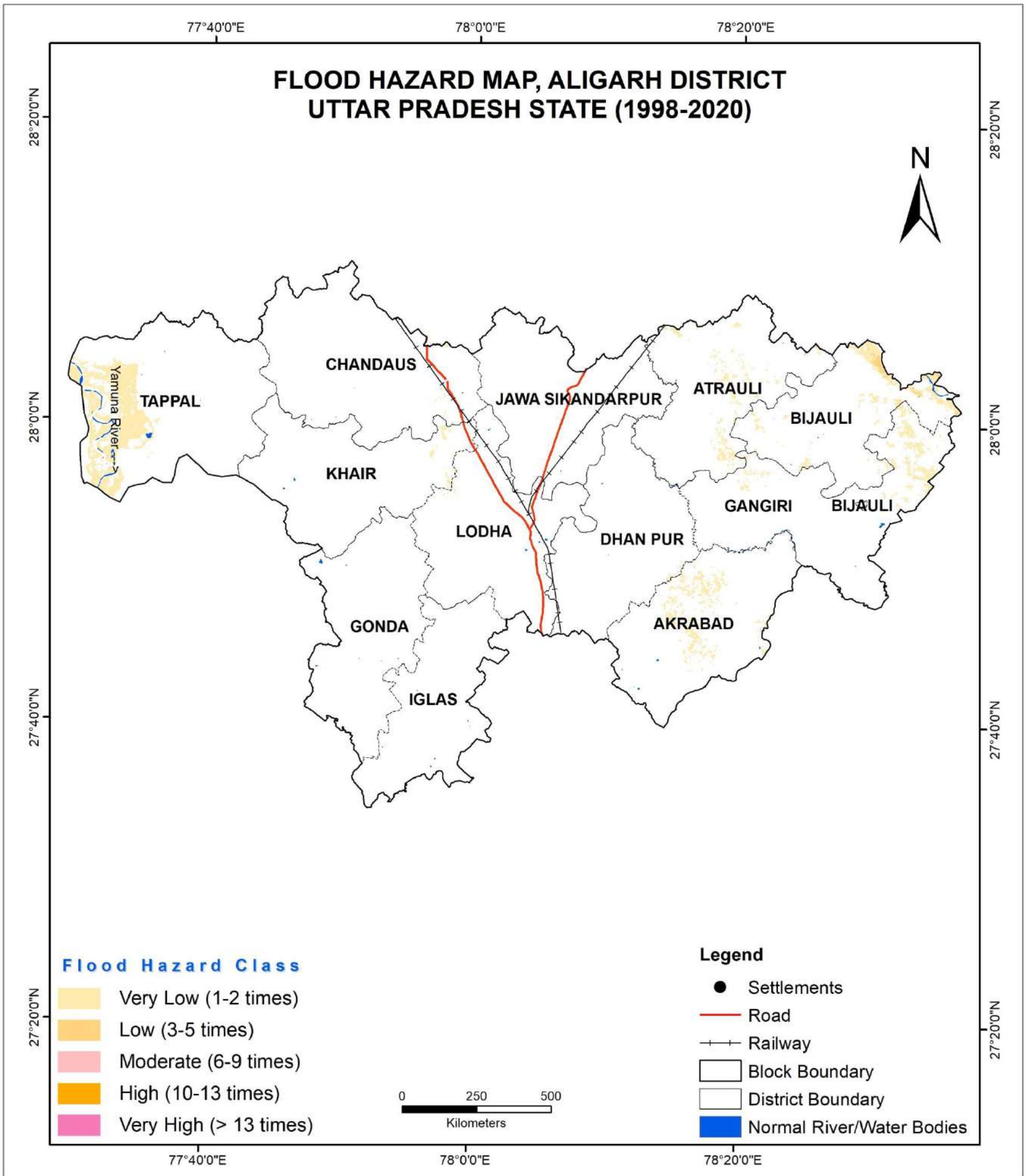
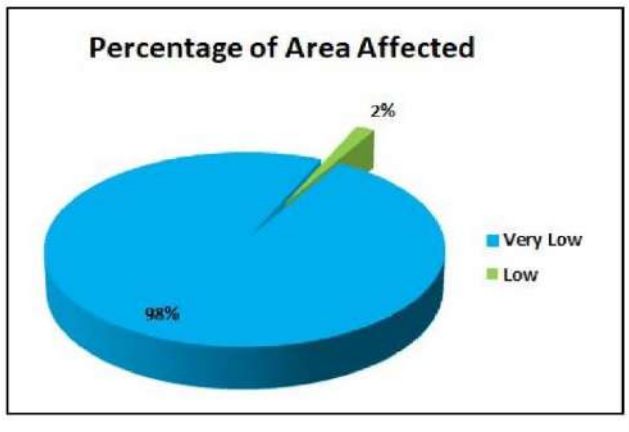
FLOOD HAZARD MAP, ALIGARH DISTRICT
UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	12851
2	Low	227
	Total	**13078**



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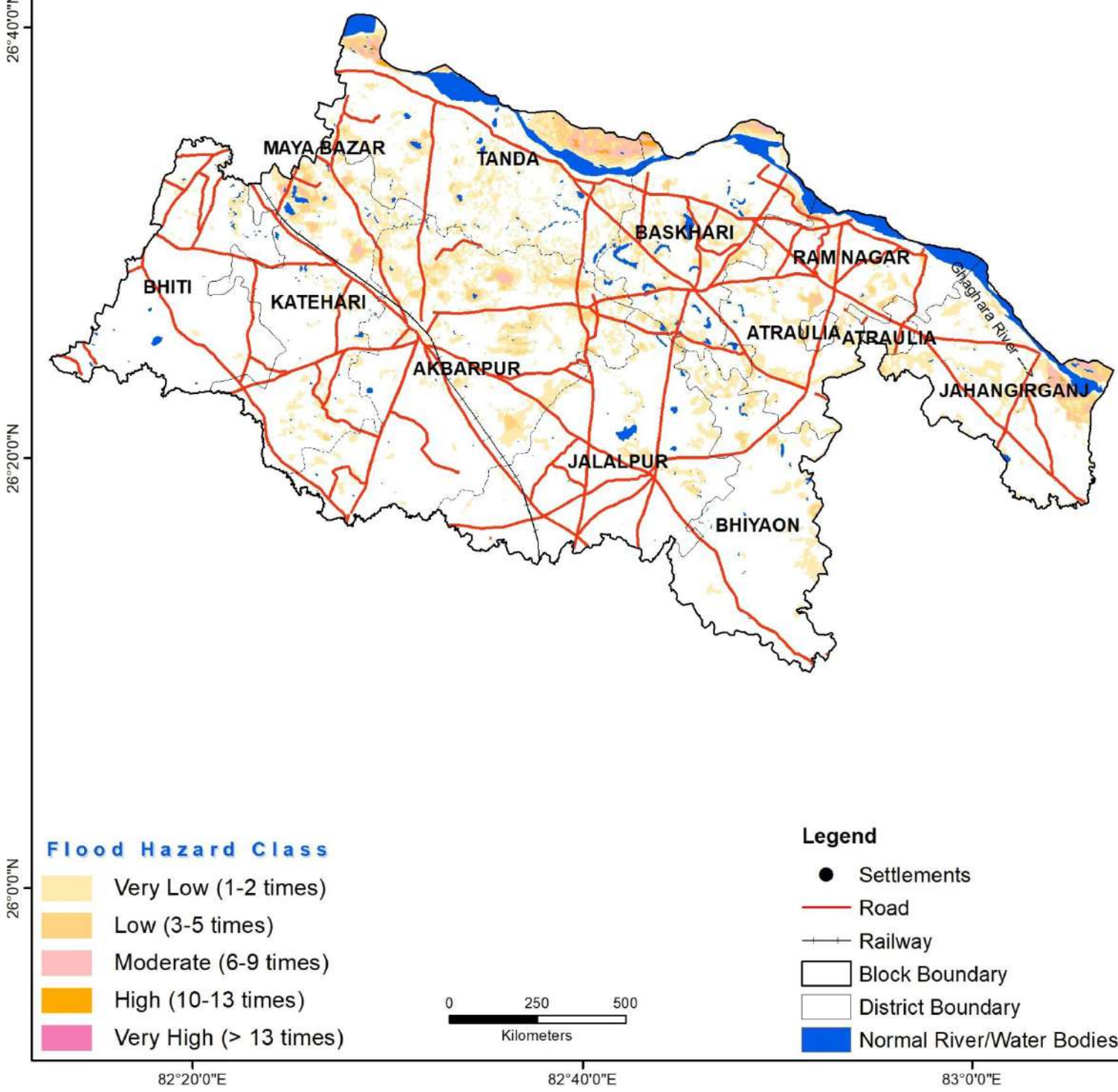
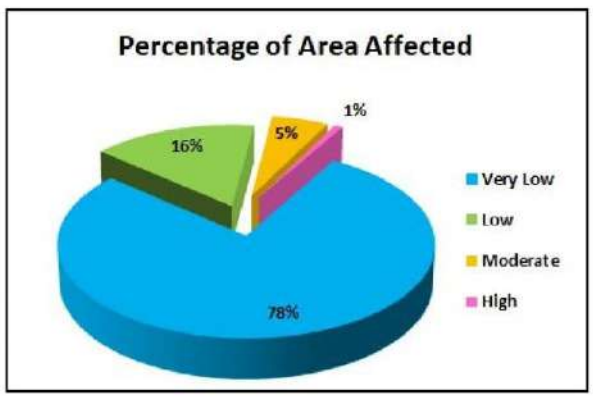
FLOOD HAZARD MAP, AMBEDKARNAGAR DISTRICT
UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	28600
2	Low	5768
3	Moderate	2004
4	High	300
	Total	**36672**



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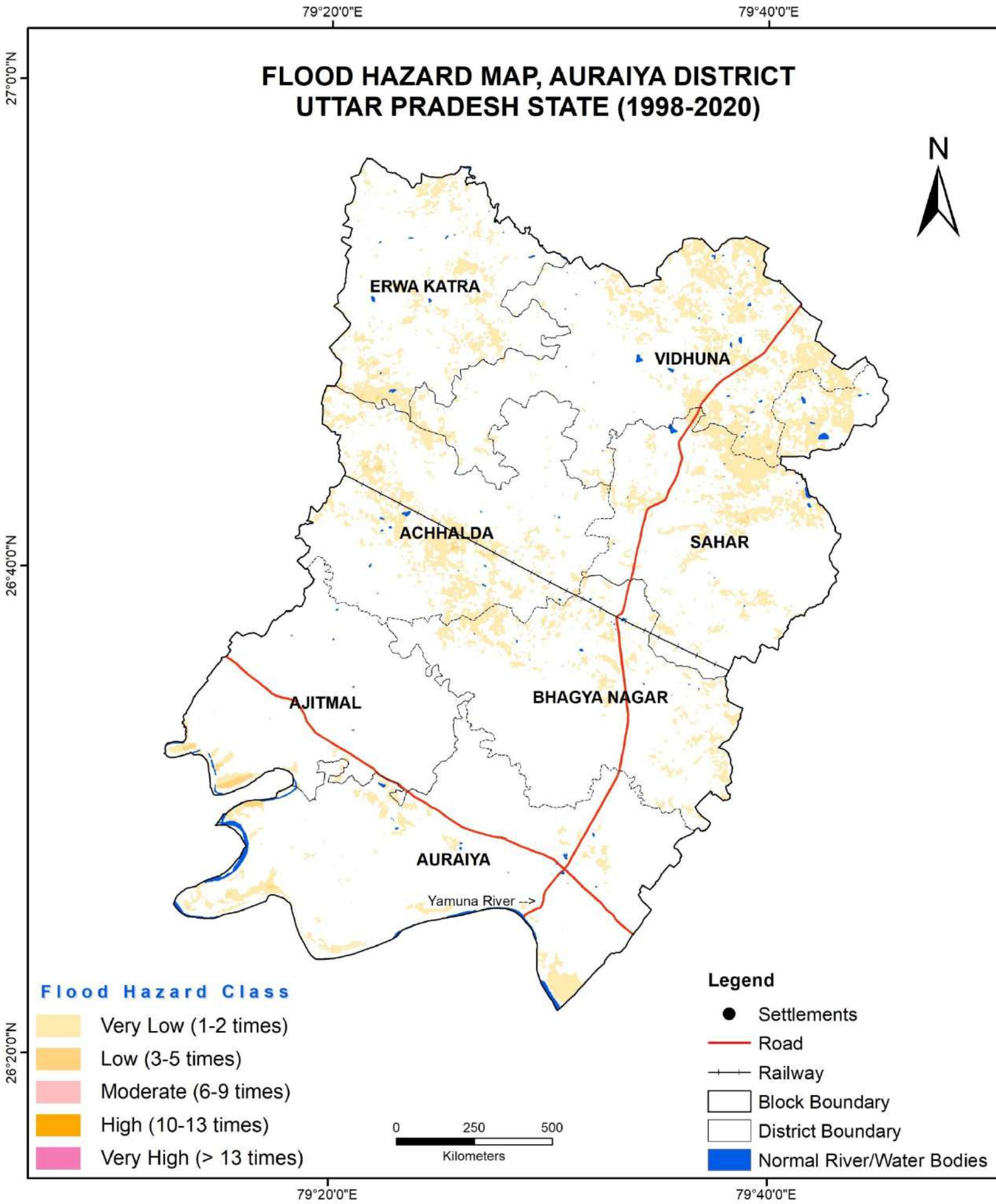
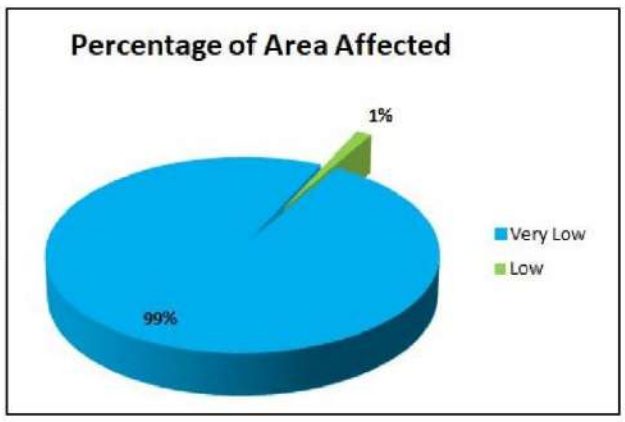
FLOOD HAZARD MAP, AURAIYA DISTRICT UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	23855
2	Low	353
	Total	**24208**



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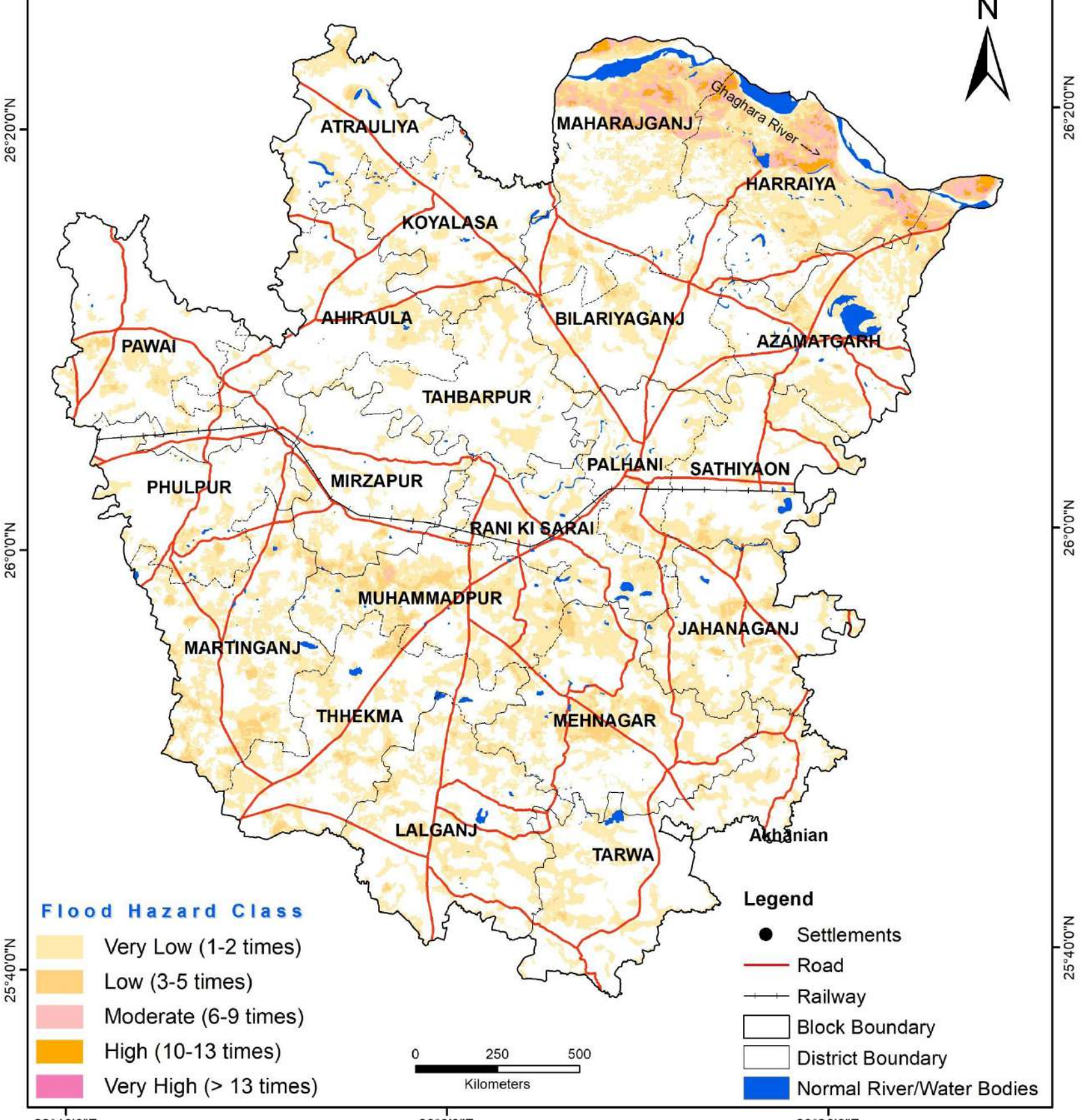
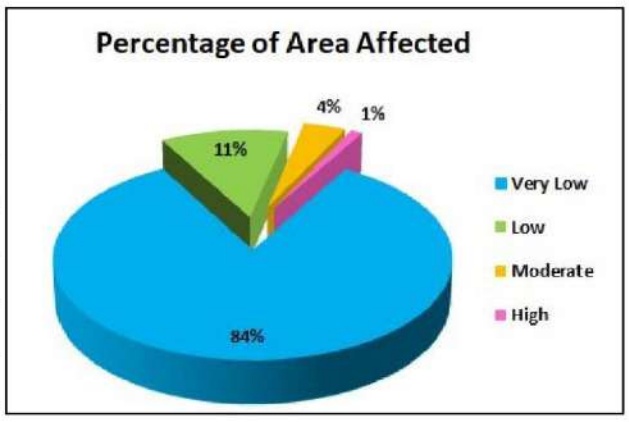
FLOOD HAZARD MAP, AZAMGARH DISTRICT UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	109933
2	Low	15121
3	Moderate	5080
4	High	1414
5	Very High	44
	Total	**131592**



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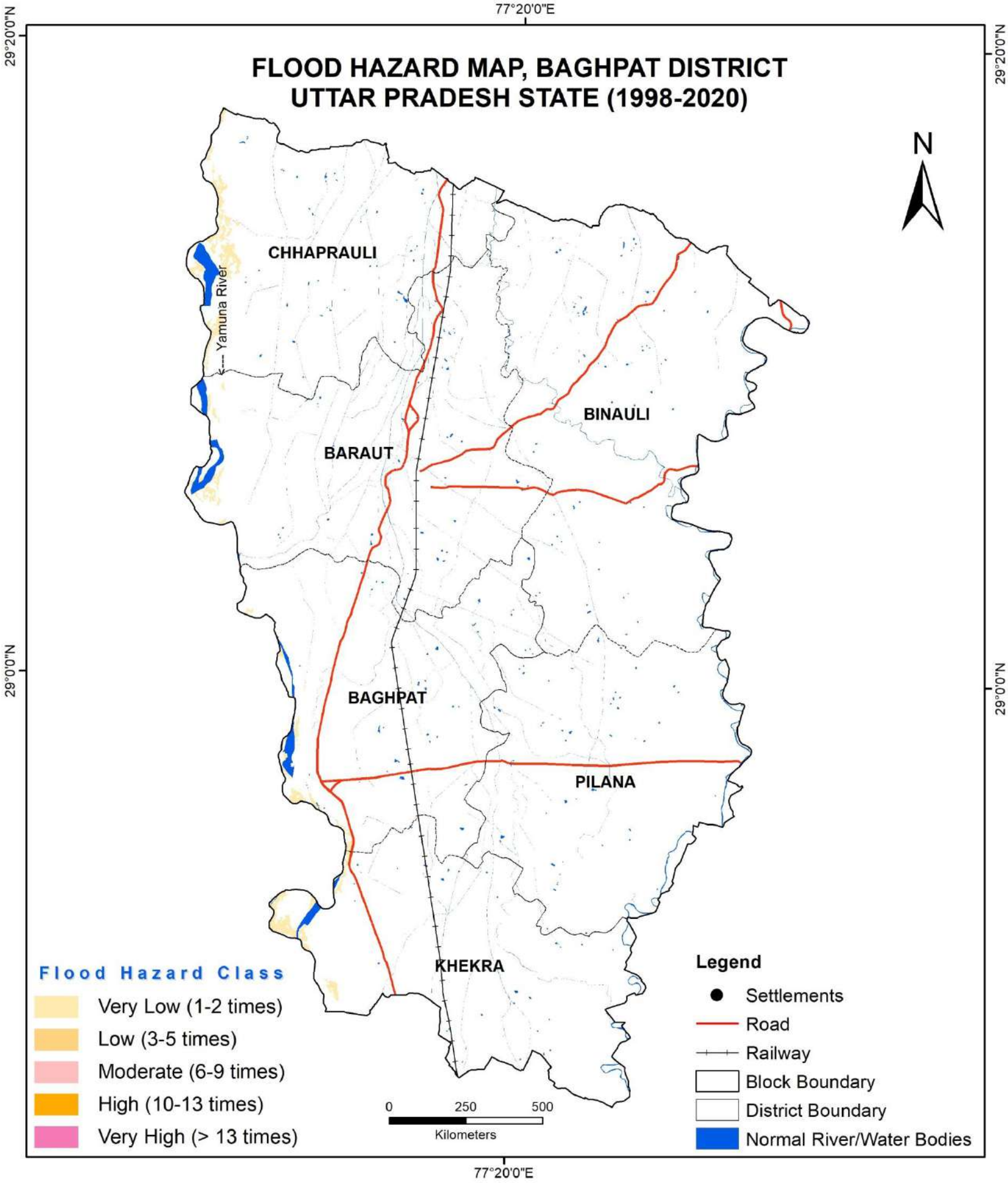
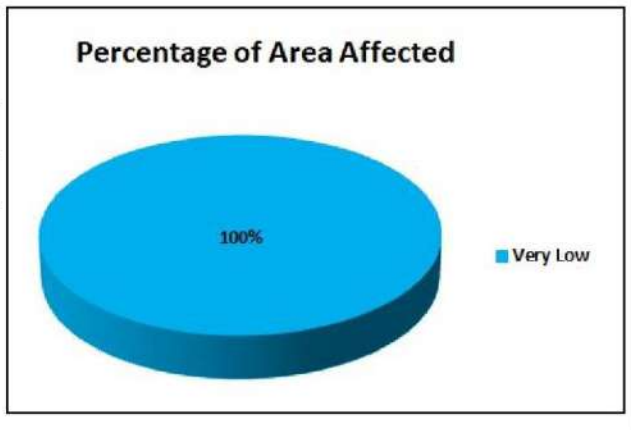
FLOOD HAZARD MAP, BAGHPAT DISTRICT
UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	1282
	Total	**1282**



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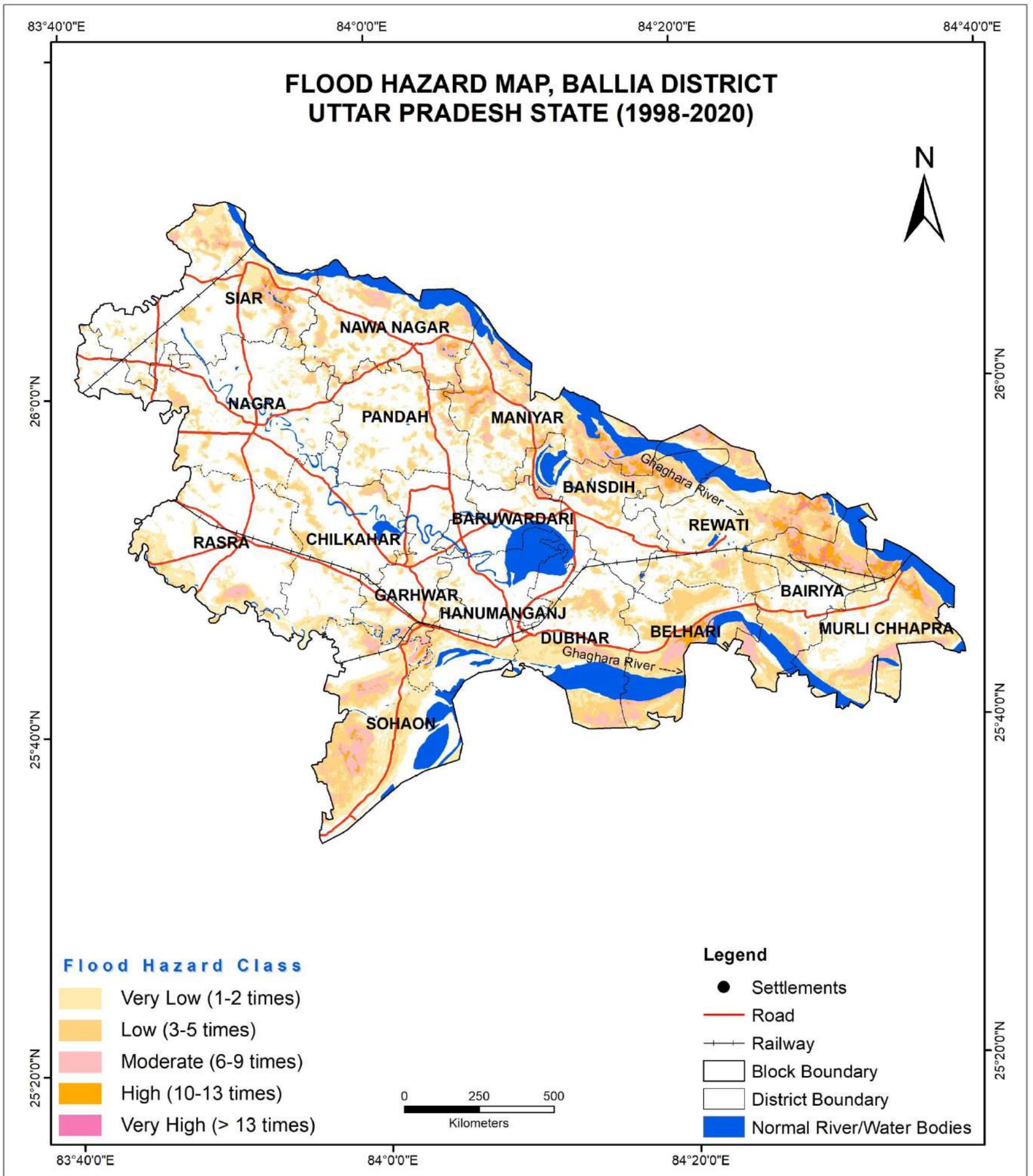
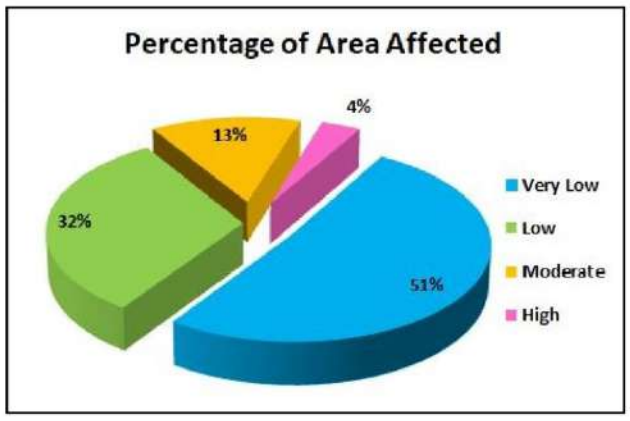
FLOOD HAZARD MAP, BALLIA DISTRICT
UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	58496
2	Low	36105
3	Moderate	15461
4	High	4086
5	Very High	400
	Total	**114548**



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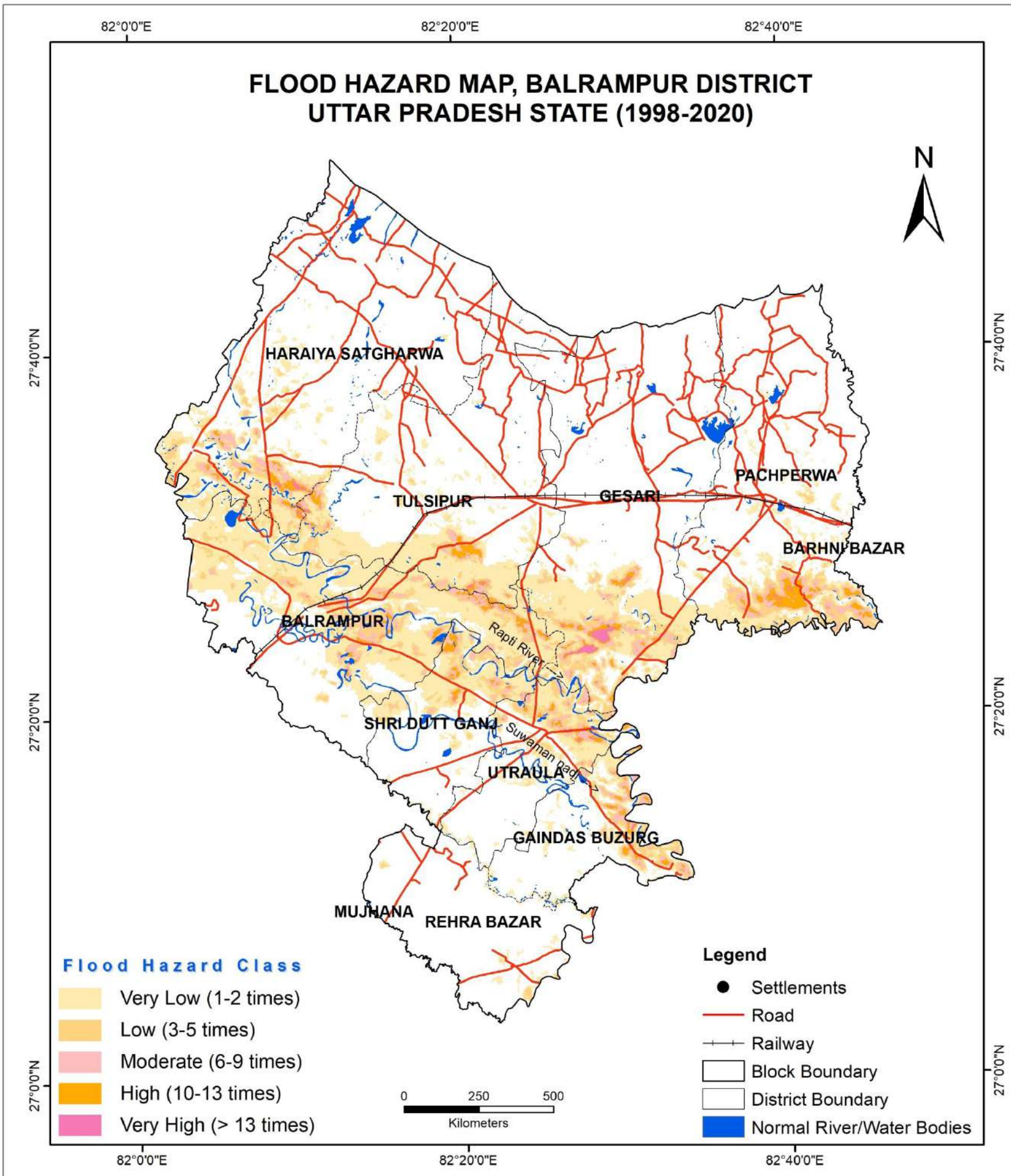
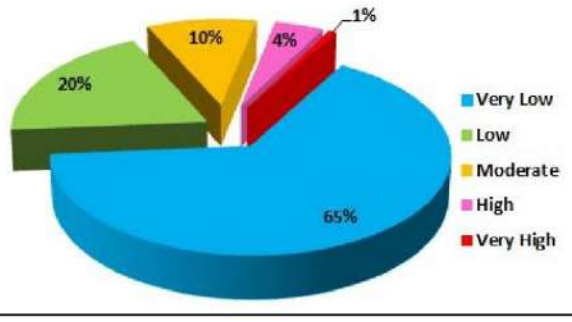
FLOOD HAZARD MAP, BALRAMPUR DISTRICT
UTTAR PRADESH STATE (1998-2020)



Location Map

S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	59806
2	Low	17912
3	Moderate	9100
4	High	4078
5	Very High	628
	Total	**91524**

Percentage of Area Affected



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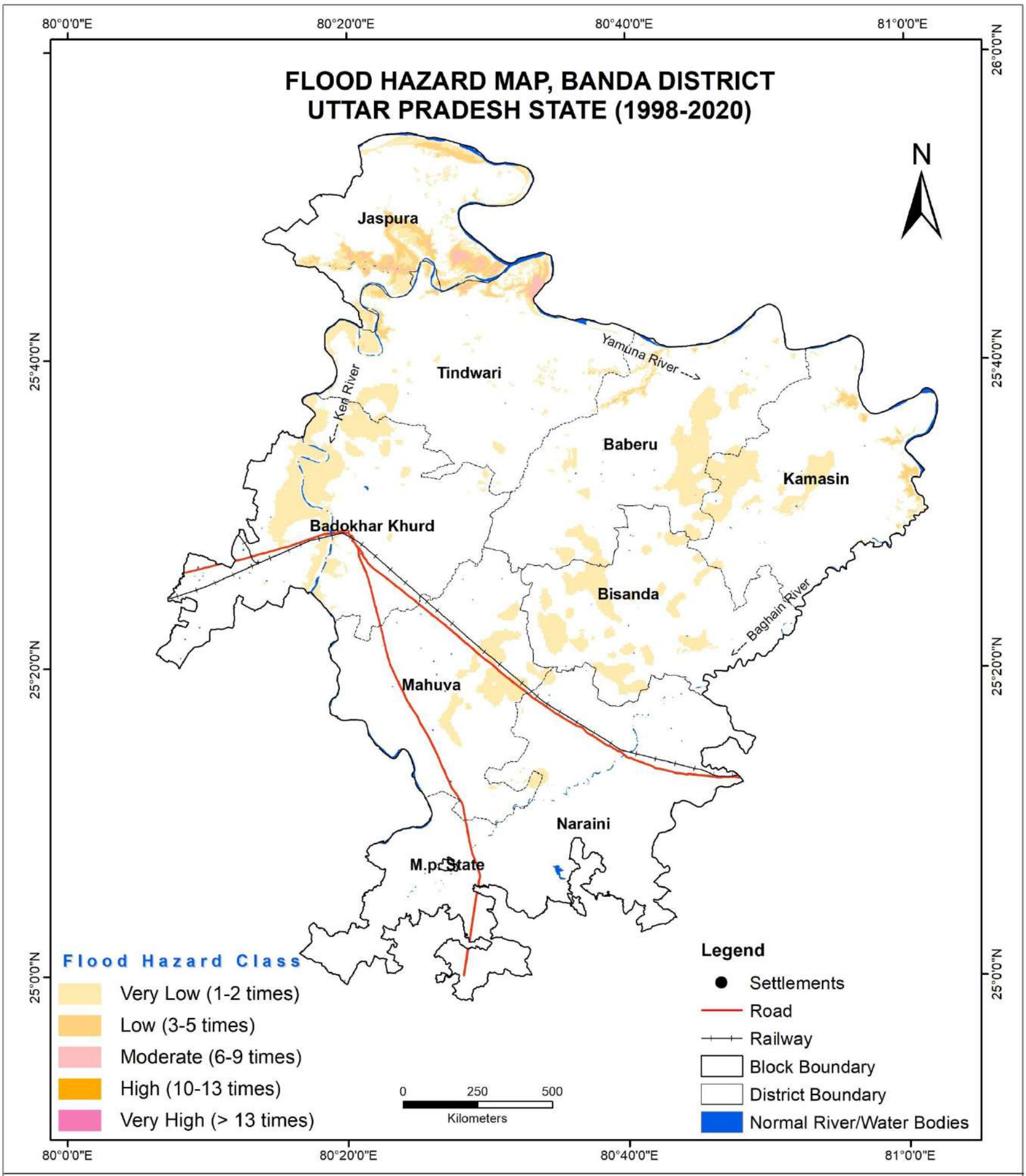
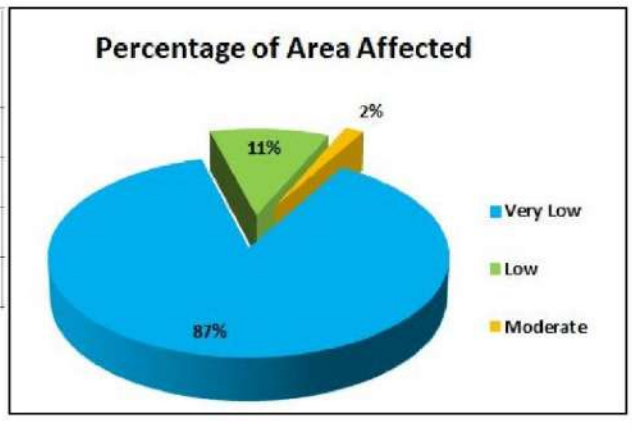
FLOOD HAZARD MAP, BANDA DISTRICT UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	48842
2	Low	5998
3	Moderate	972
	Total	**55812**



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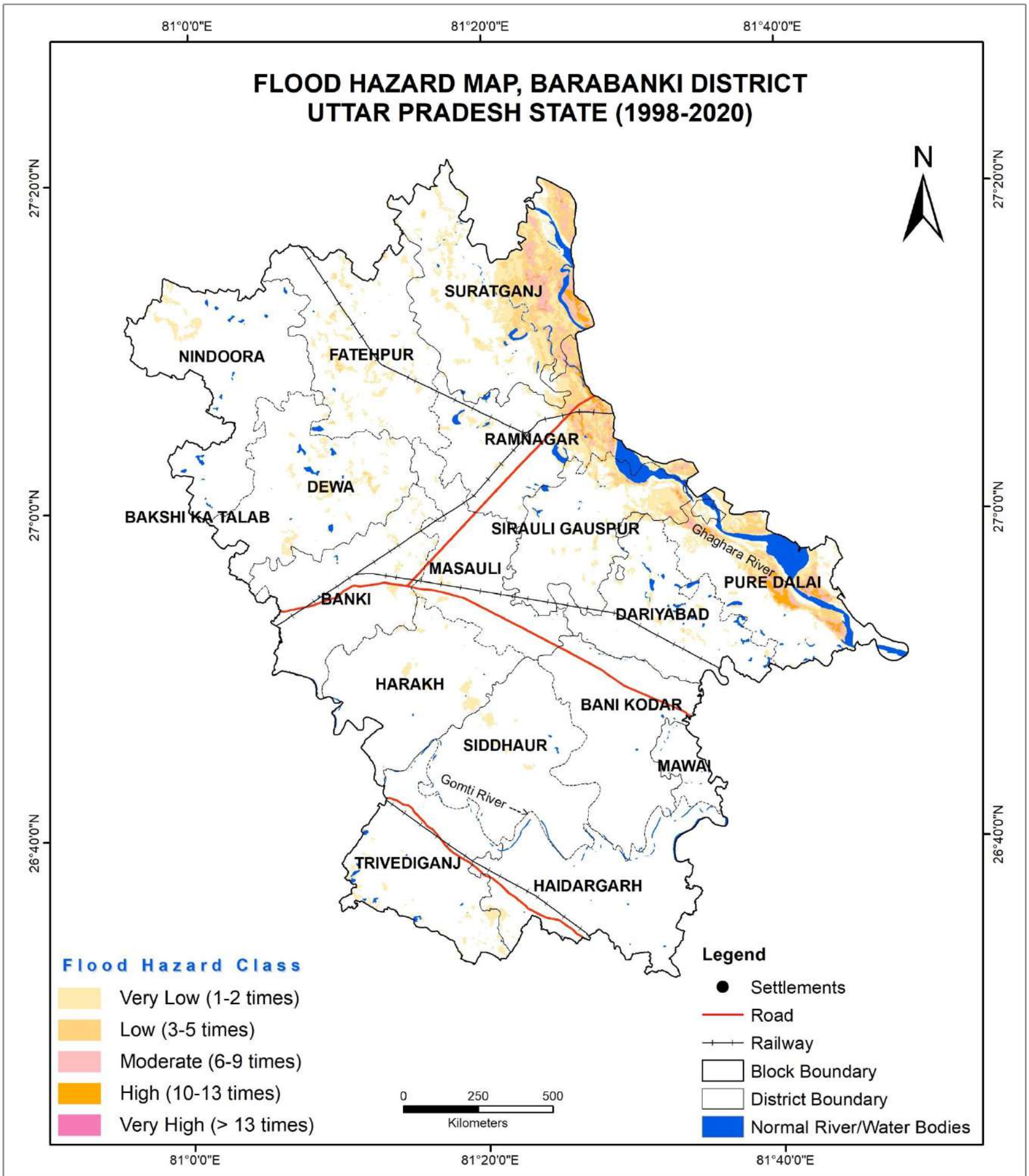
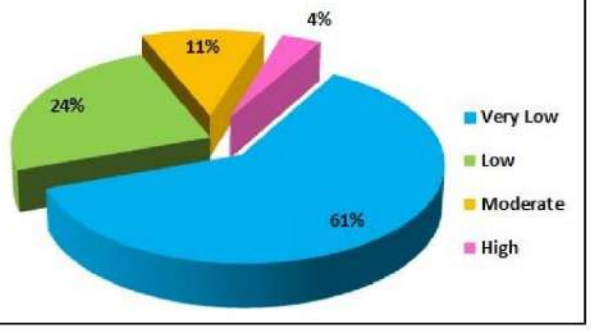
FLOOD HAZARD MAP, BARABANKI DISTRICT
UTTAR PRADESH STATE (1998-2020)



Location Map

S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	26143
2	Low	10332
3	Moderate	4675
4	High	1514
5	Very High	7
	Total	42671

Percentage of Area Affected



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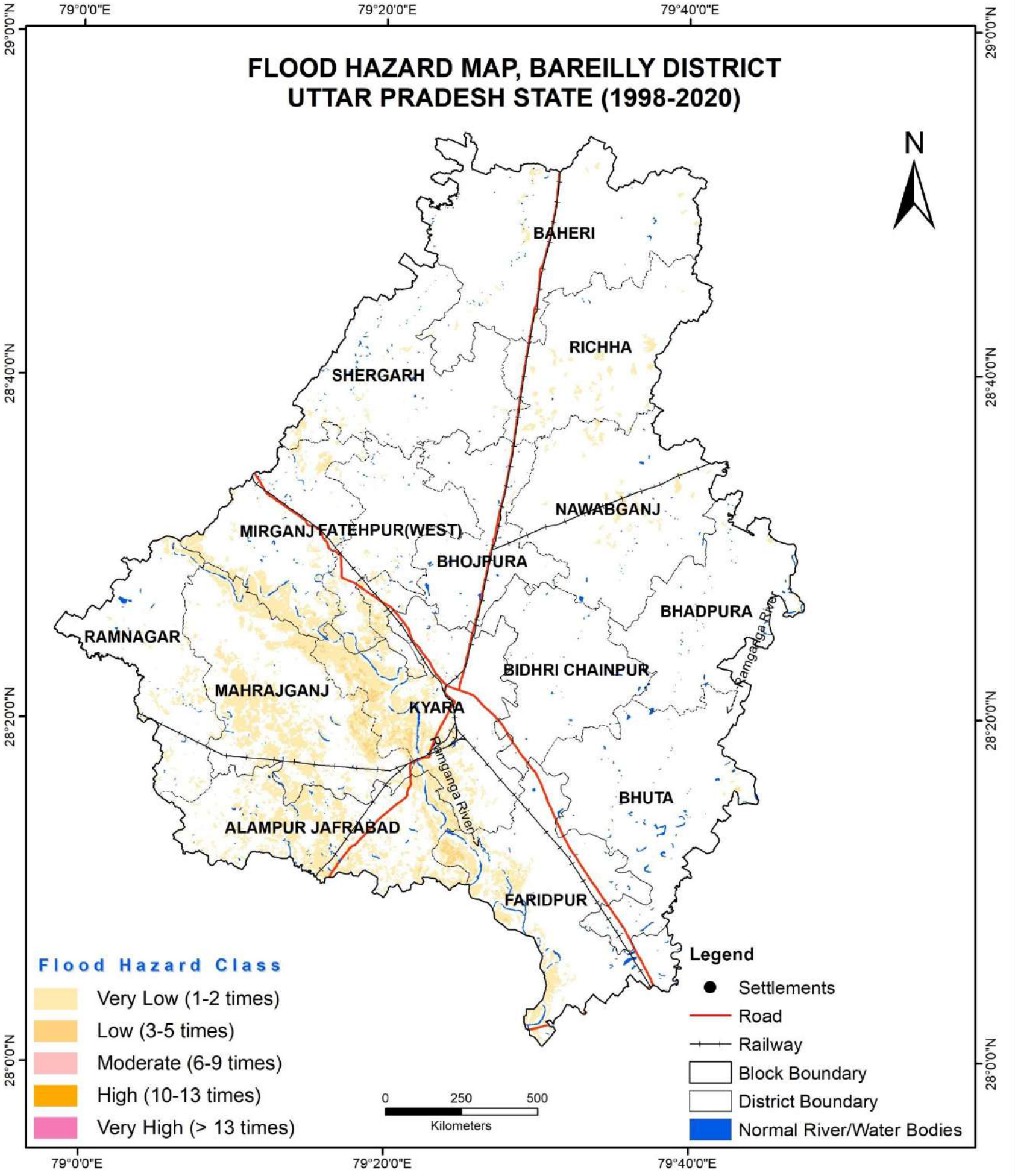
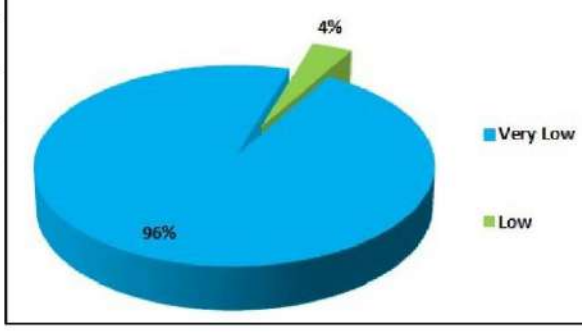
FLOOD HAZARD MAP, BAREILLY DISTRICT
UTTAR PRADESH STATE (1998-2020)



Location Map

S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	36992
2	Low	1401
	Total	**38393**

Percentage of Area Affected



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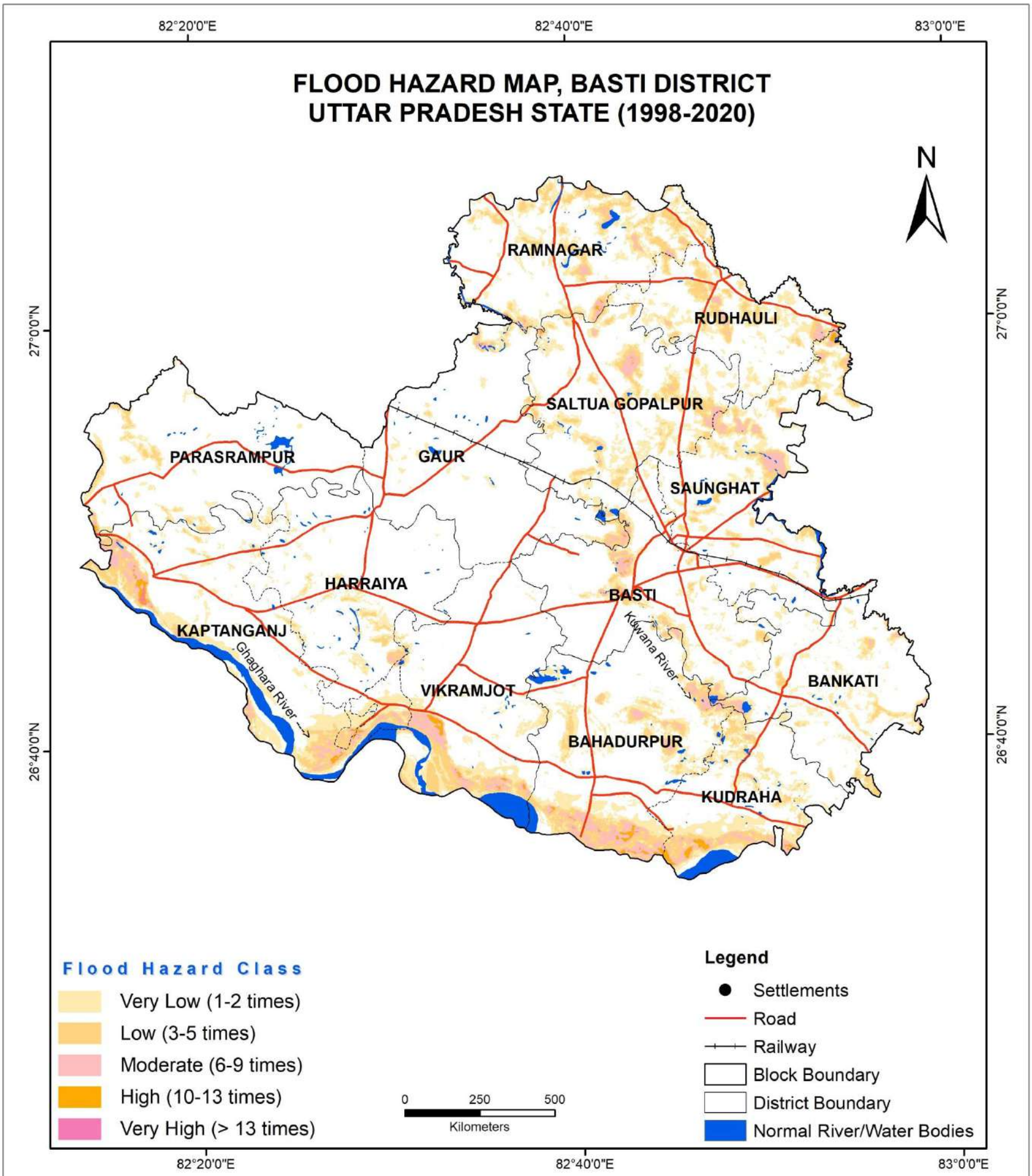
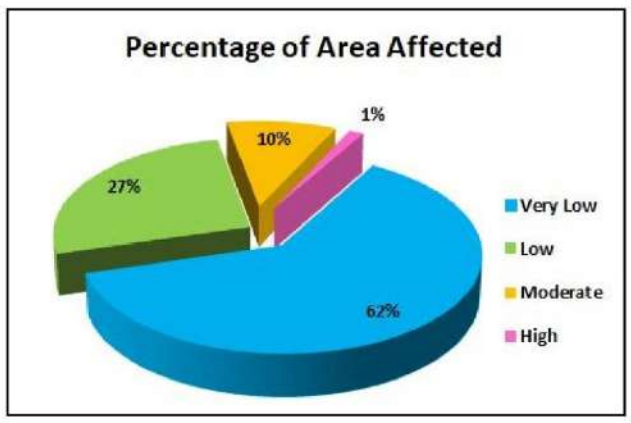
FLOOD HAZARD MAP, BASTI DISTRICT
UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	37455
2	Low	15981
3	Moderate	5980
4	High	784
5	Very High	33
	Total	**60233**



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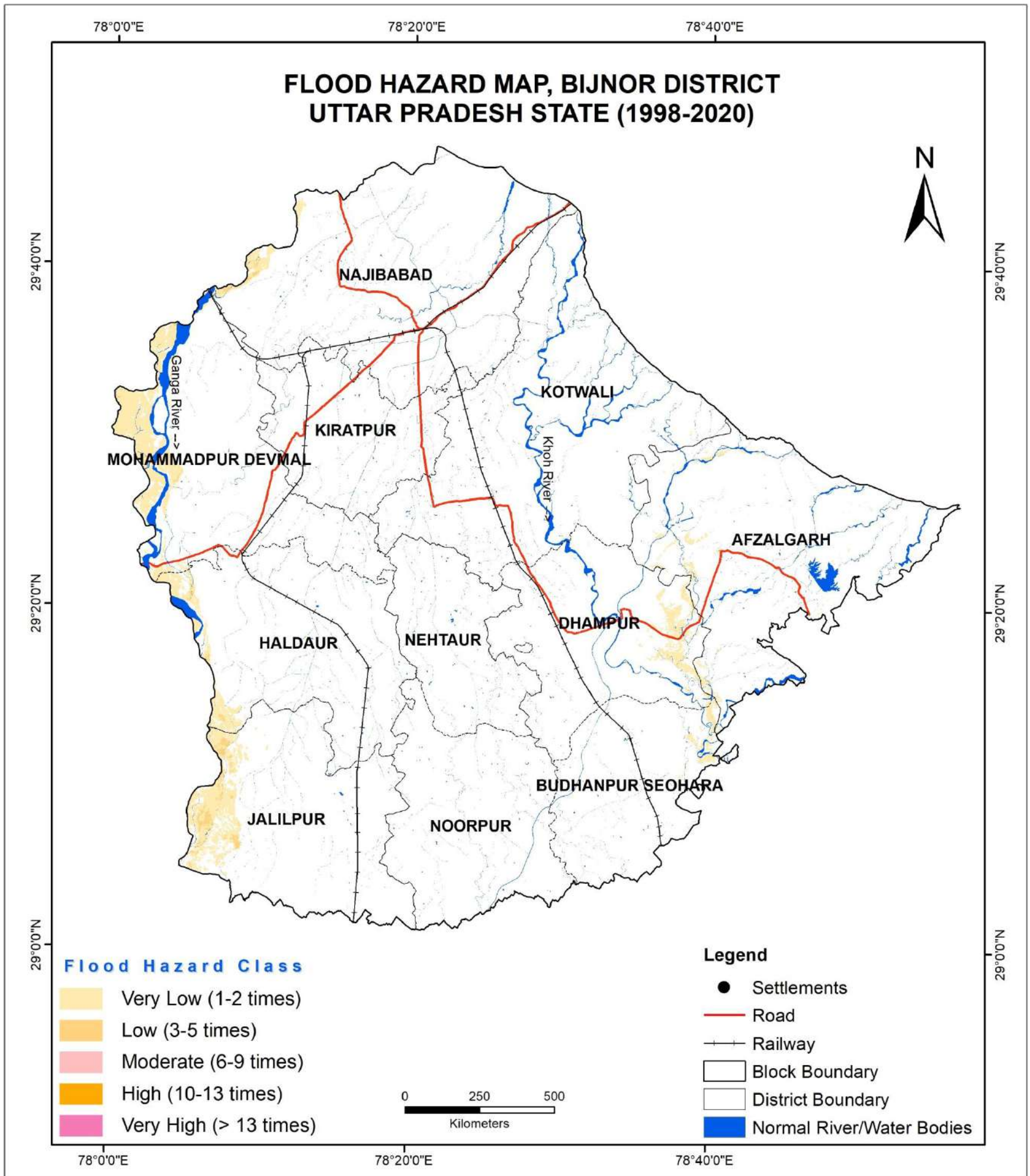
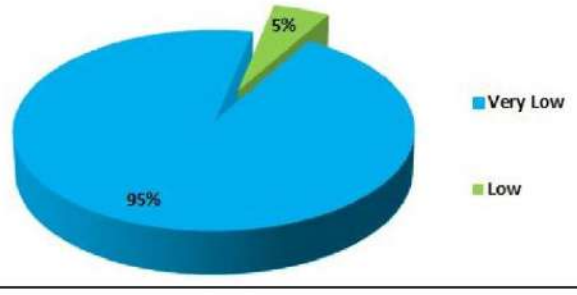
FLOOD HAZARD MAP, BIJNOR DISTRICT UTTAR PRADESH STATE (1998-2020)



Location Map

S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	14936
2	Low	802
	Total	**15738**

Percentage of Area Affected



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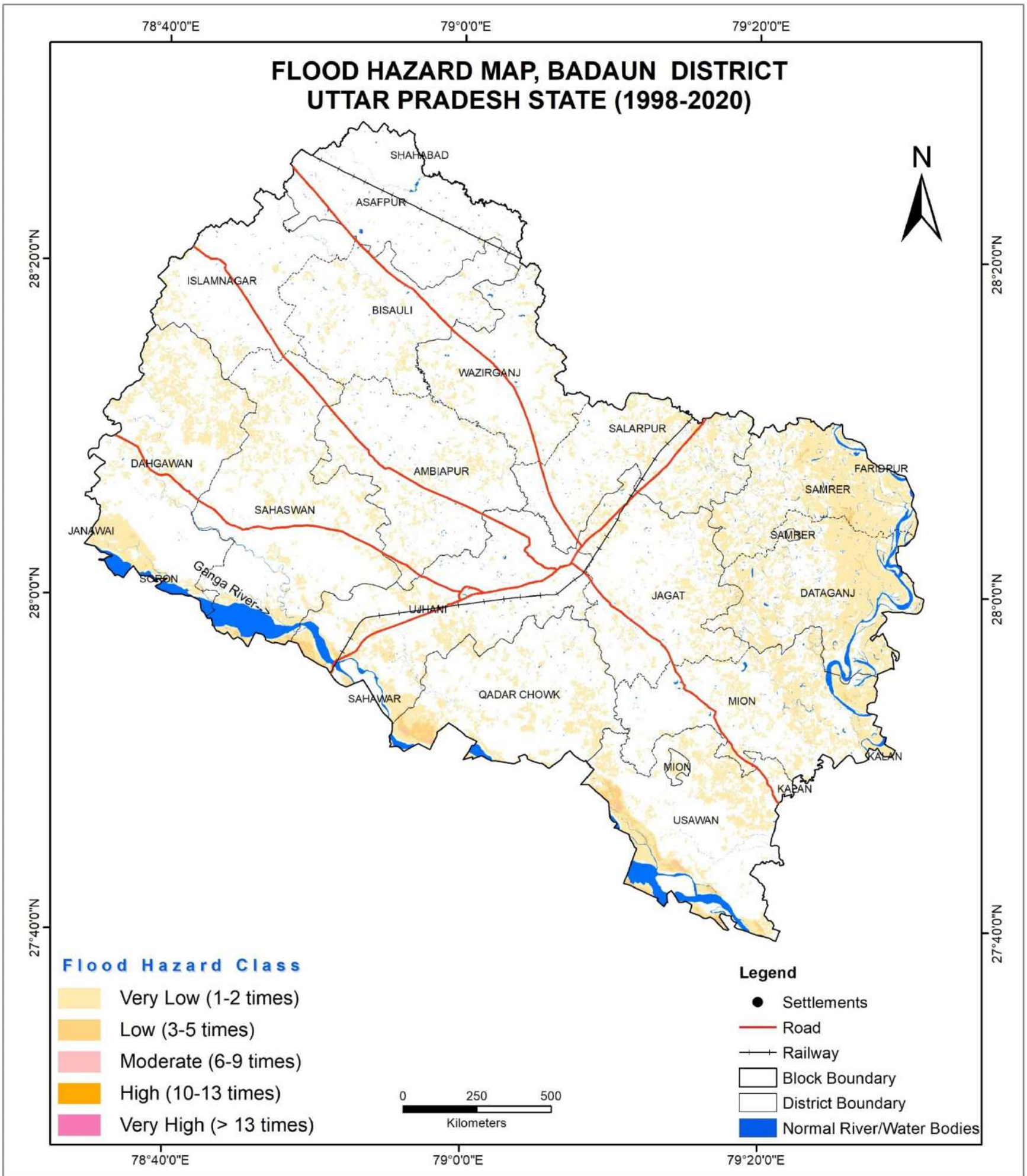
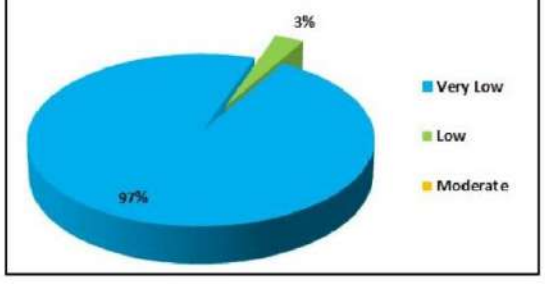
FLOOD HAZARD MAP, BADAUN DISTRICT UTTAR PRADESH STATE (1998-2020)



Location Map

S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	85904
2	Low	2709
3	Moderate	148
	Total	88762

Percentage of Area Affected



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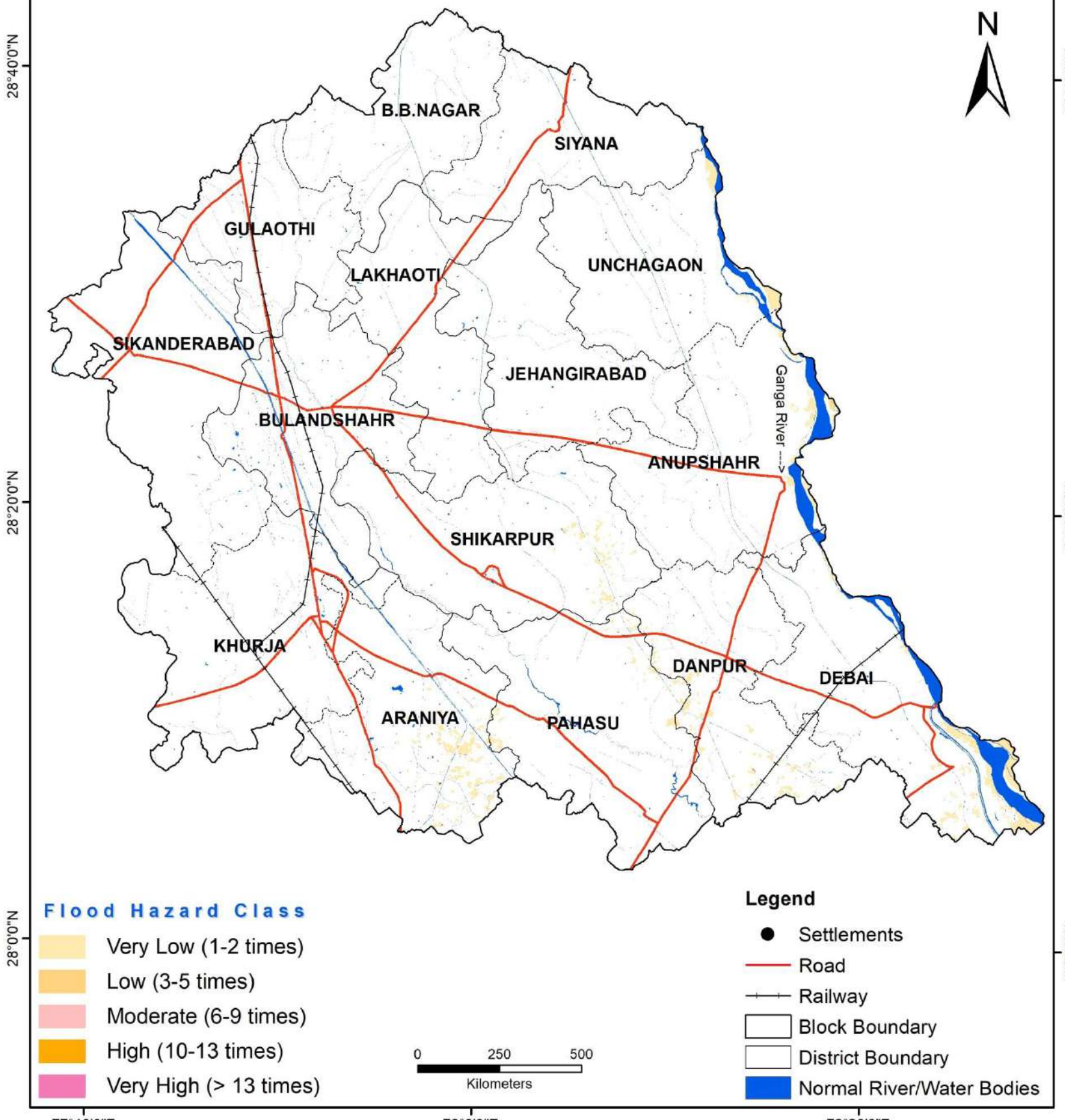
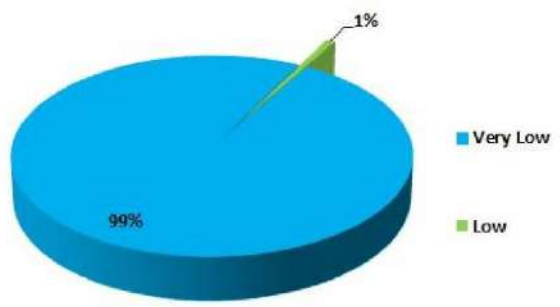
FLOOD HAZARD MAP, BULANDSHAHR DISTRICT
UTTAR PRADESH STATE (1998-2020)



Location Map

S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	4793
2	Low	39
	Total	**4832**

Percentage of Area Affected



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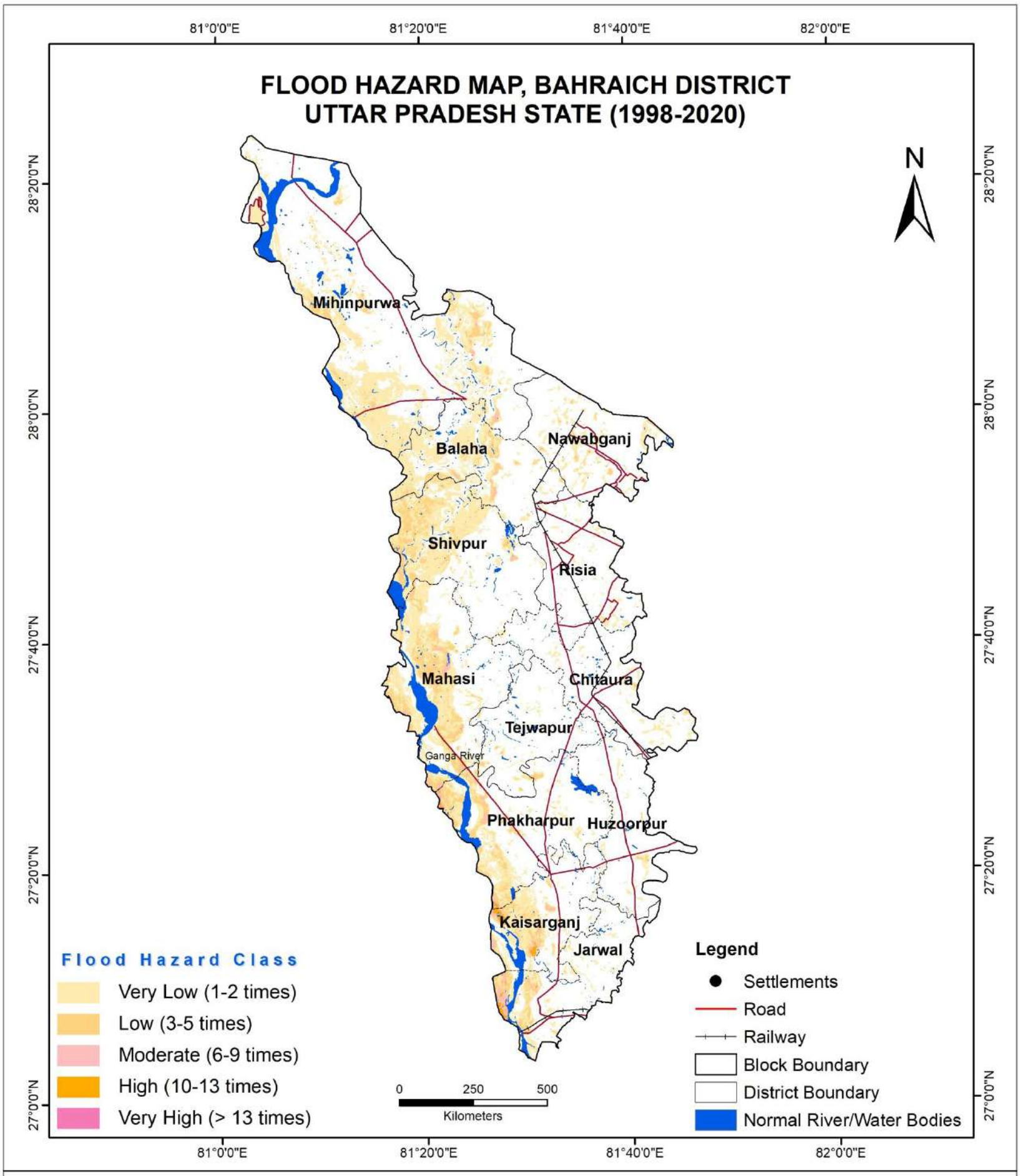
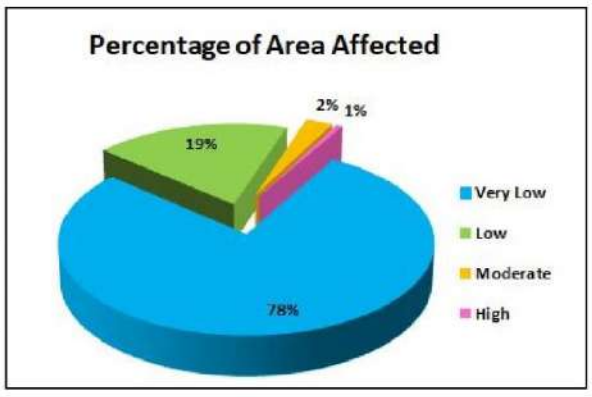
FLOOD HAZARD MAP, BAHRAICH DISTRICT UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	81590
2	Low	19548
3	Moderate	2762
4	High	684
5	Very High	6
	Total	**104590**



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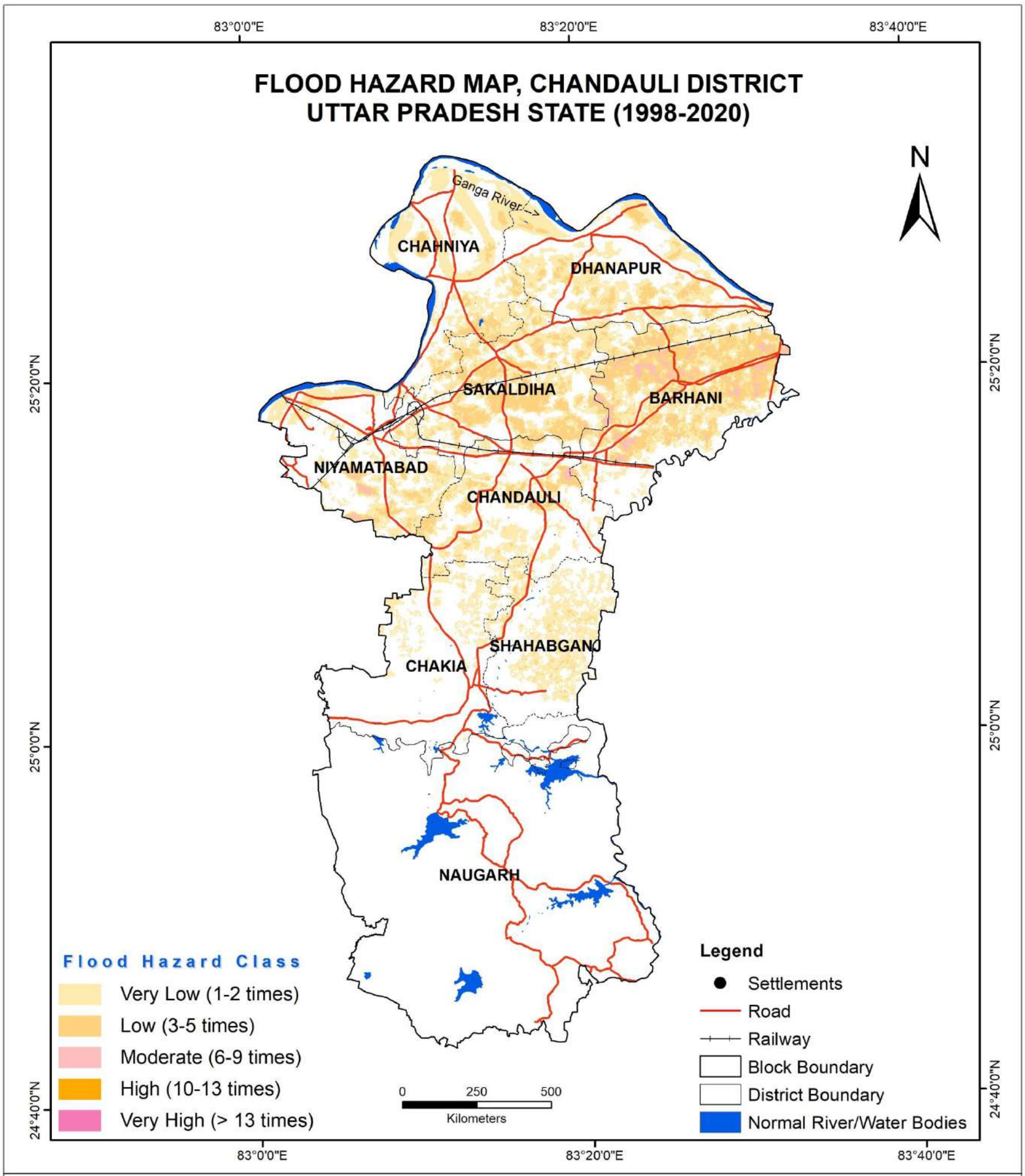
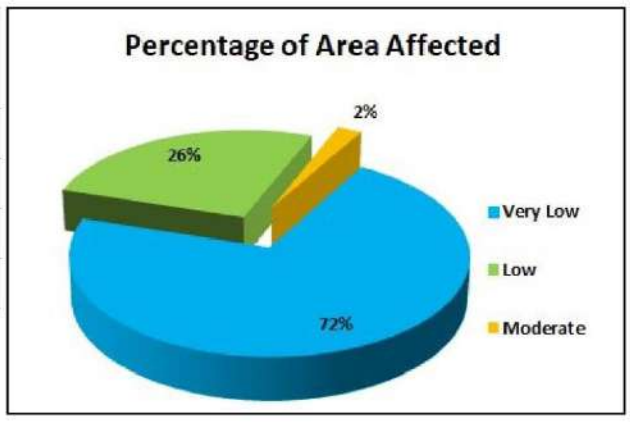
FLOOD HAZARD MAP, CHANDAULI DISTRICT
UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	52476
2	Low	19303
3	Moderate	1641
	Total	**73420**



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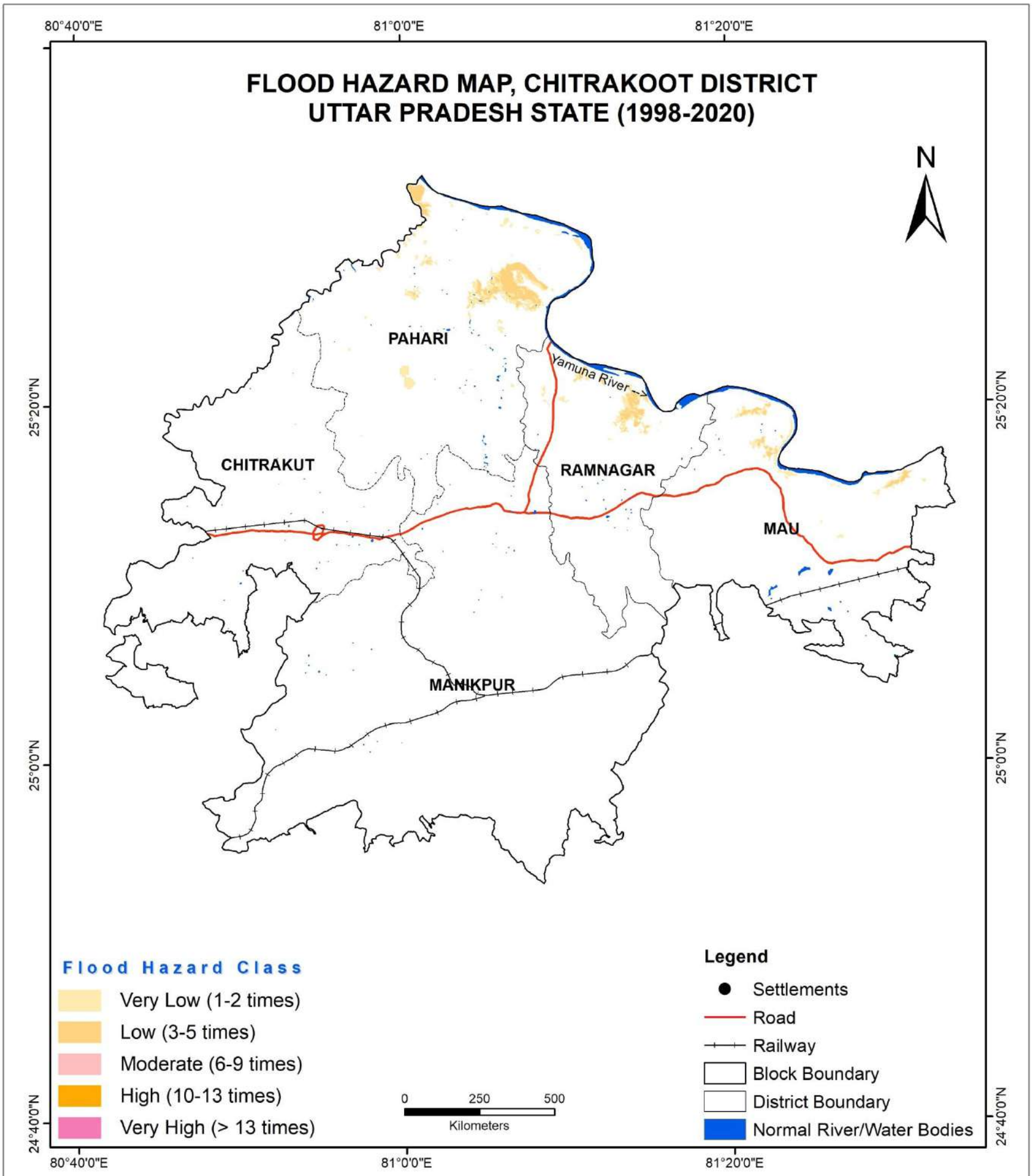
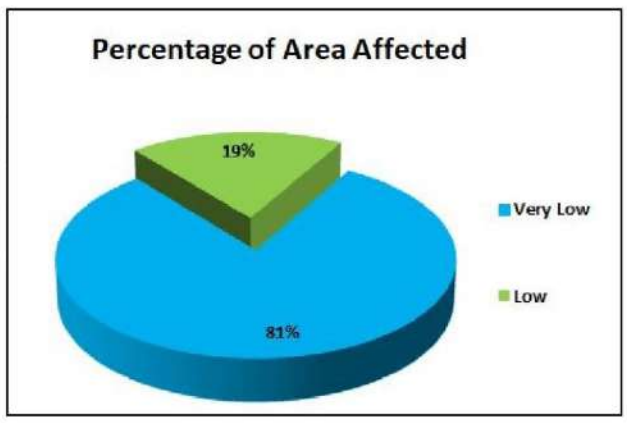
FLOOD HAZARD MAP, CHITRAKOOT DISTRICT UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	4129
2	Low	985
	Total	**5114**



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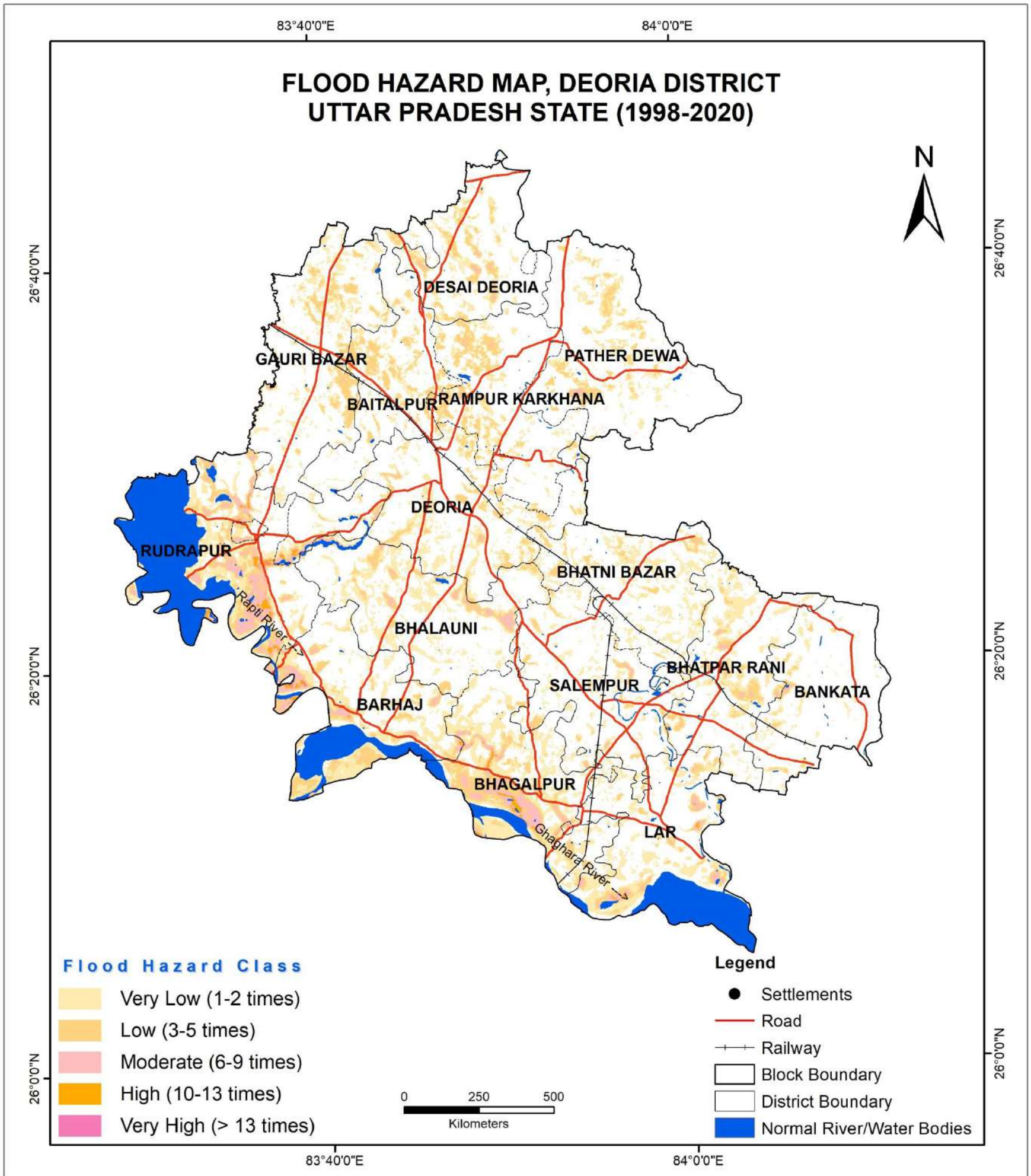
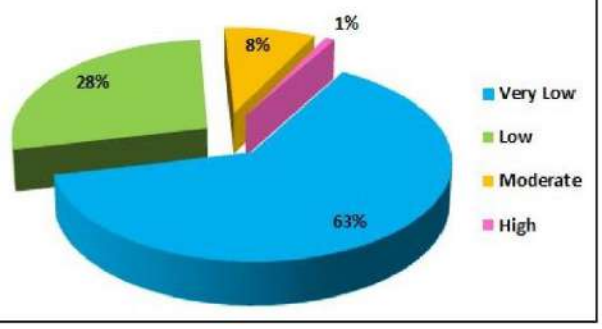
FLOOD HAZARD MAP, DEORIA DISTRICT
UTTAR PRADESH STATE (1998-2020)



Location Map

S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	47204
2	Low	20764
3	Moderate	6171
4	High	645
5	Very High	29
	Total	**74813**

Percentage of Area Affected



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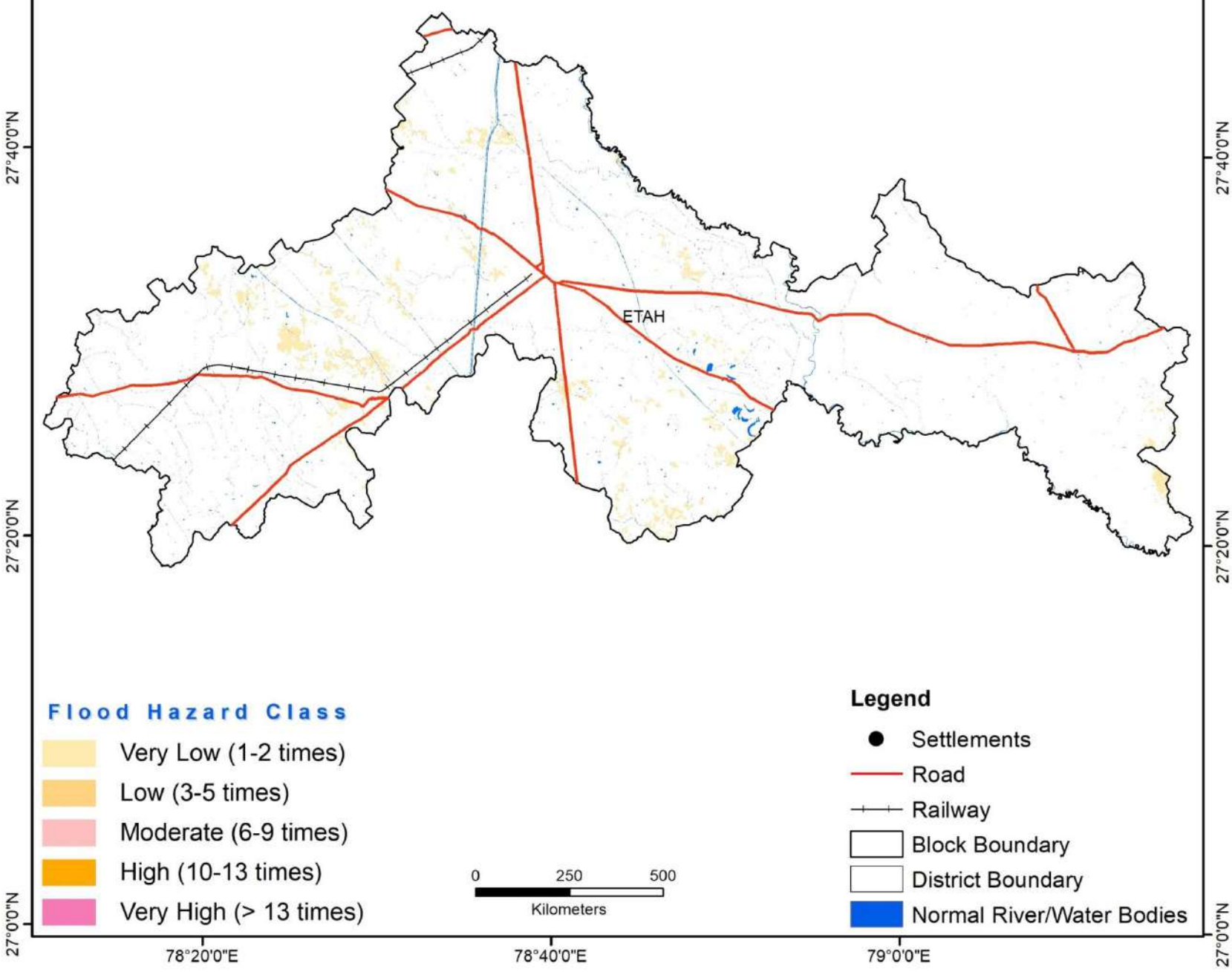
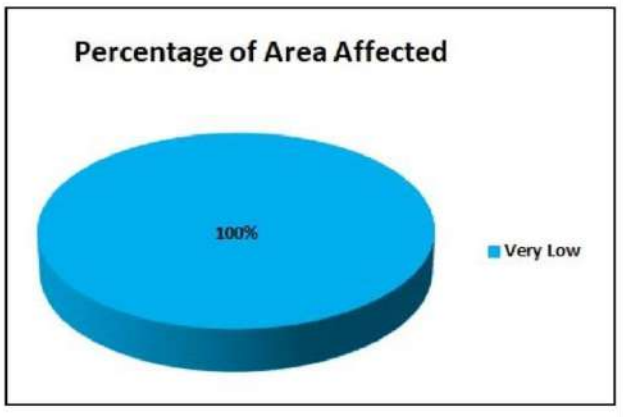
FLOOD HAZARD MAP, ETAH DISTRICT
UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	6470
	Total	6470



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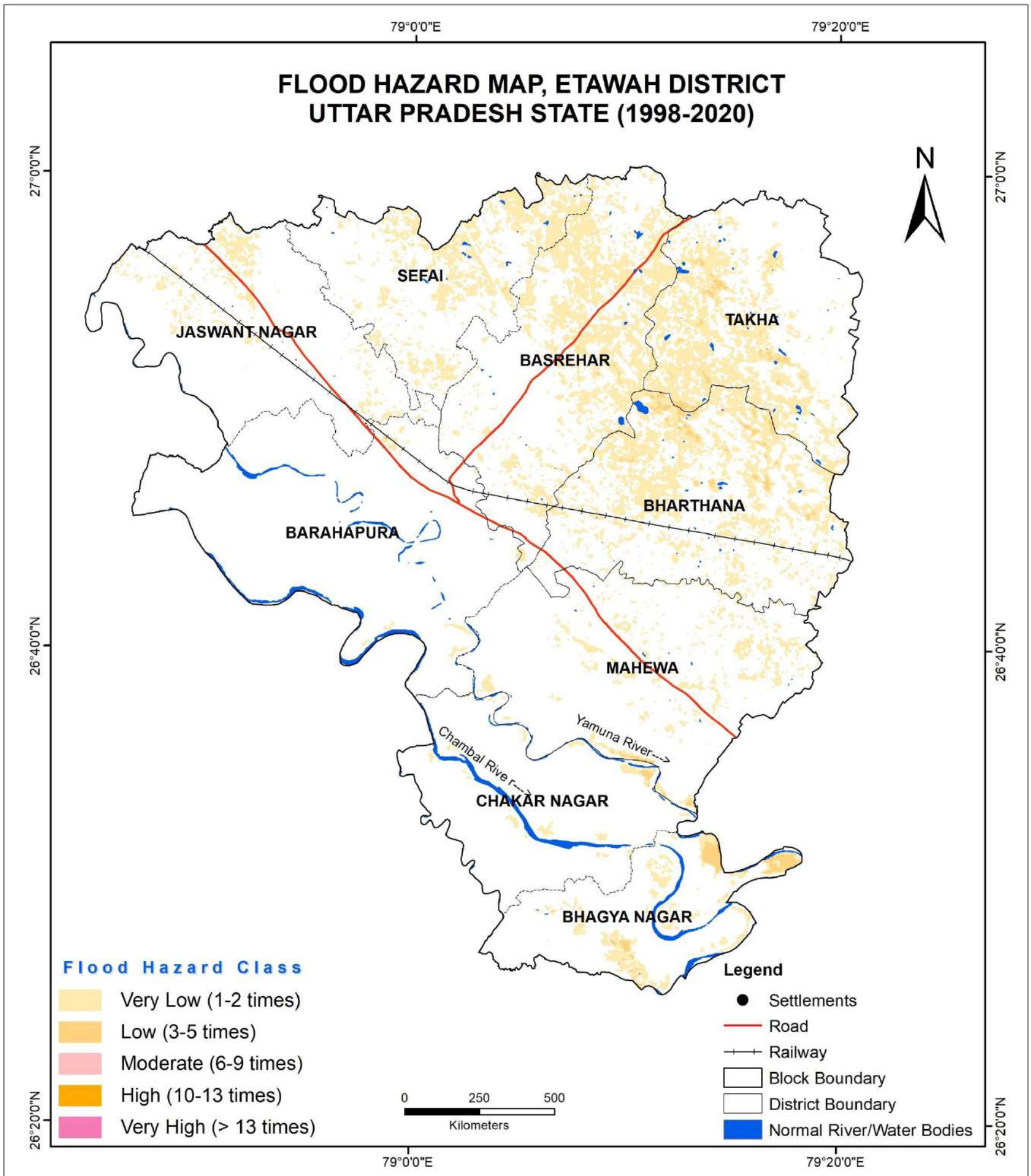
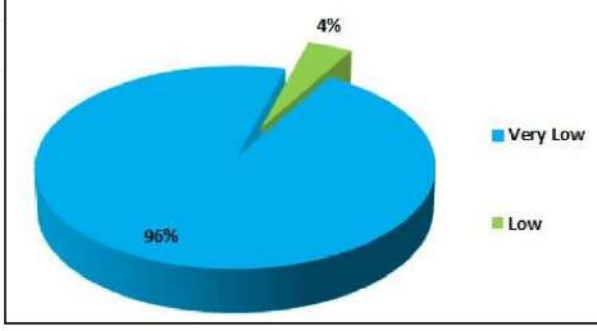


Location Map

S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	35888
2	Low	1528
	Total	**37416**

Percentage of Area Affected



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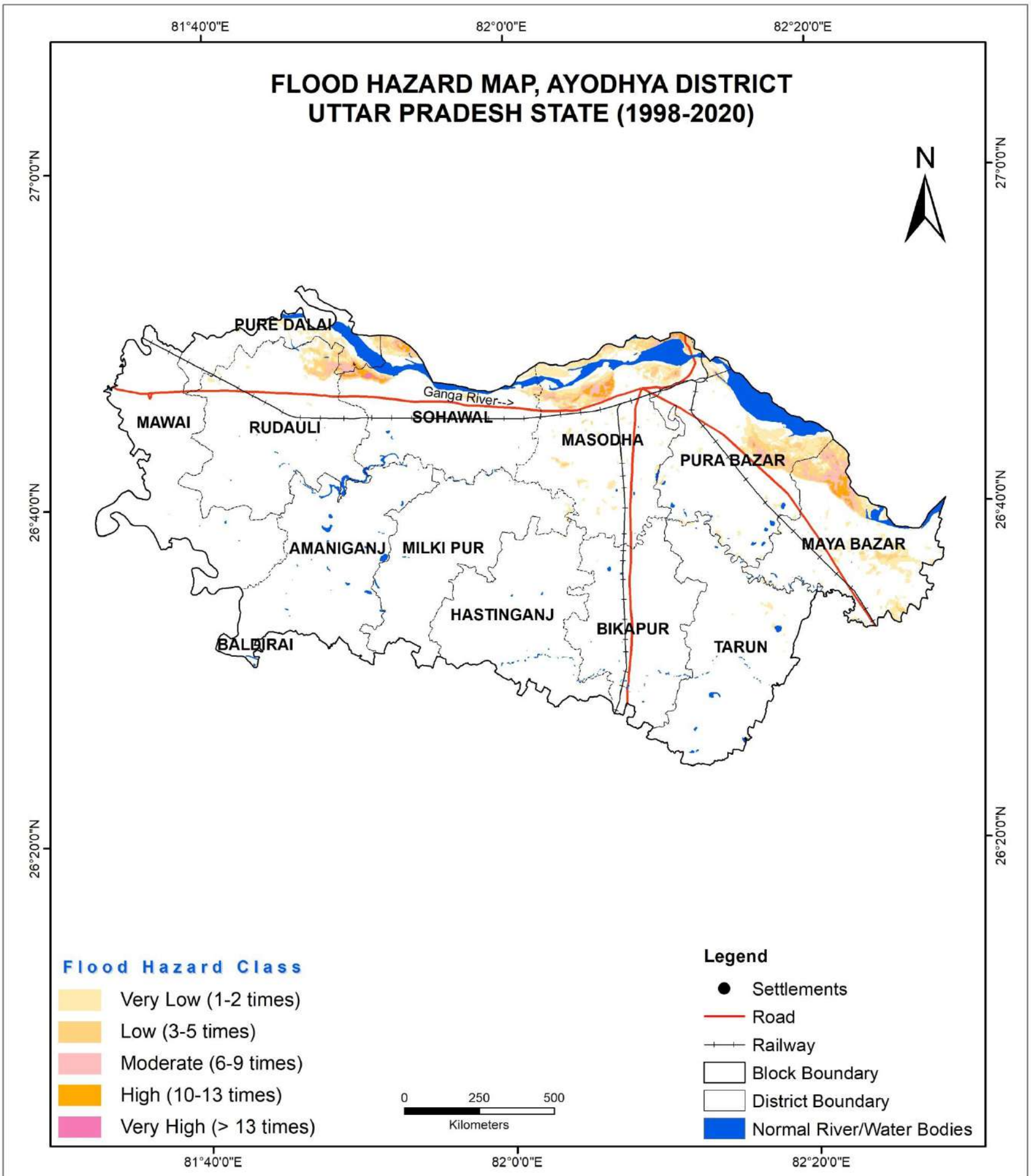
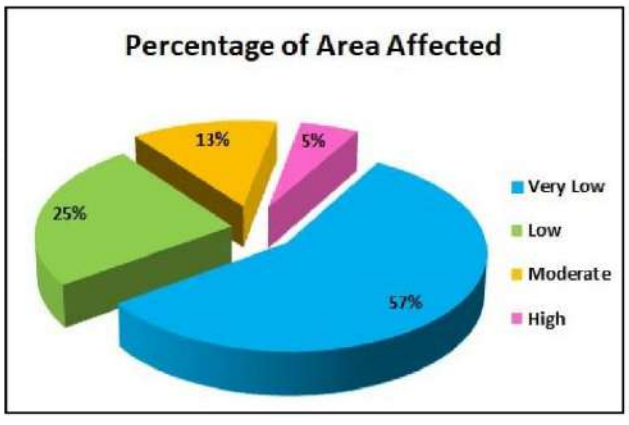
FLOOD HAZARD MAP, AYODHYA DISTRICT
UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	10968
2	Low	4761
3	Moderate	2546
4	High	1033
5	Very High	80
	Total	**19388**



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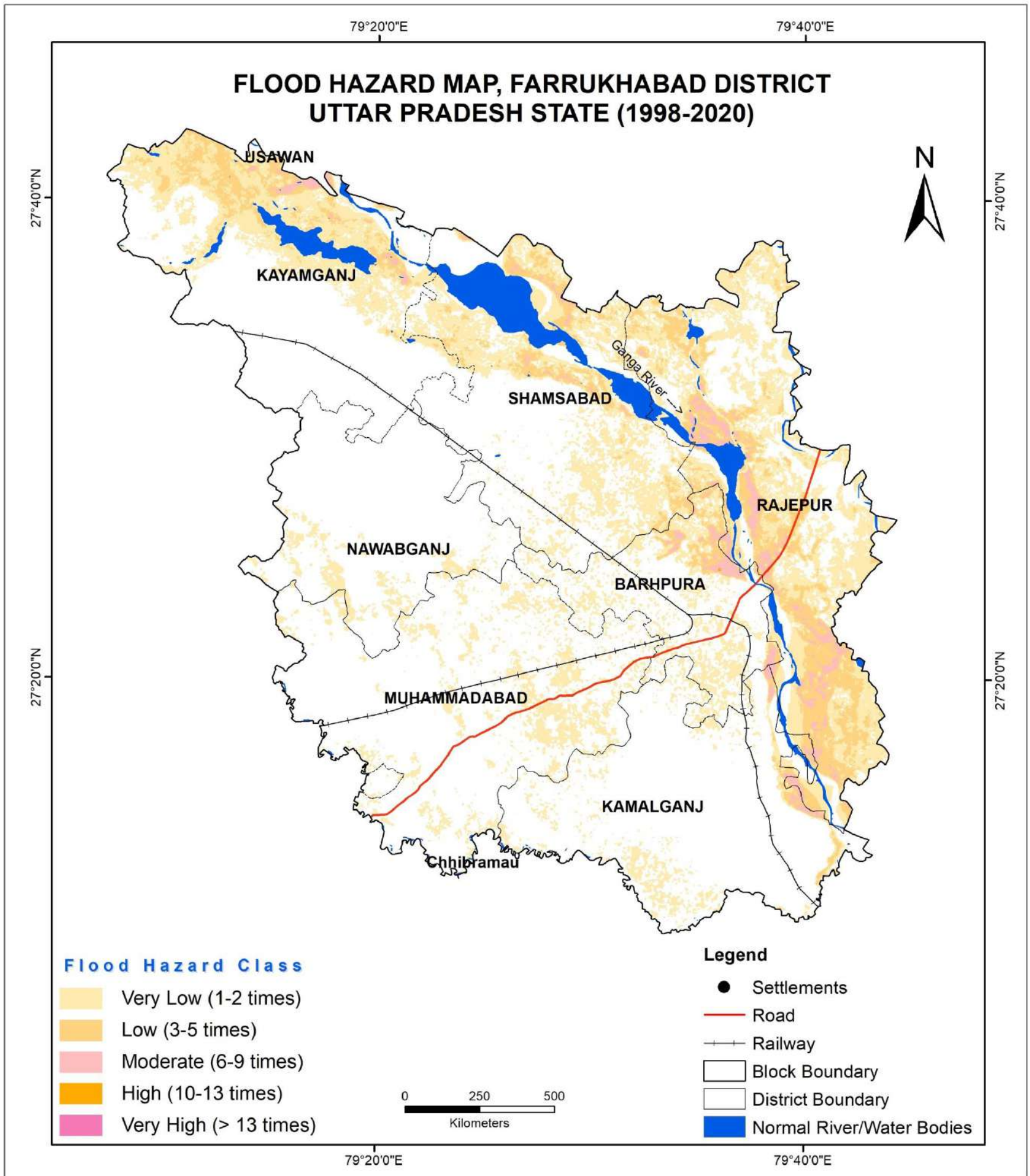
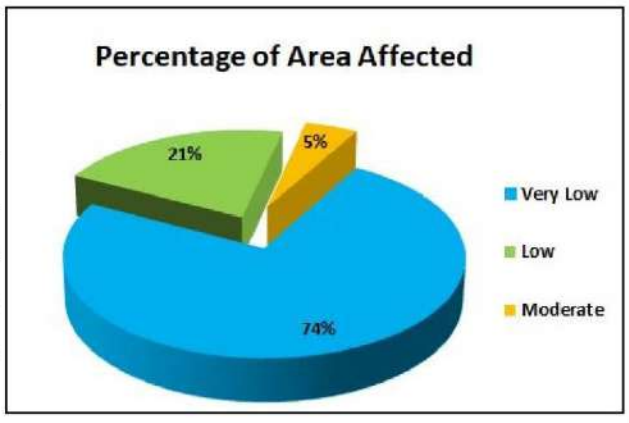
FLOOD HAZARD MAP, FARRUKHABAD DISTRICT
UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	51642
2	Low	14564
3	Moderate	3330
4	High	4
	Total	**69540**



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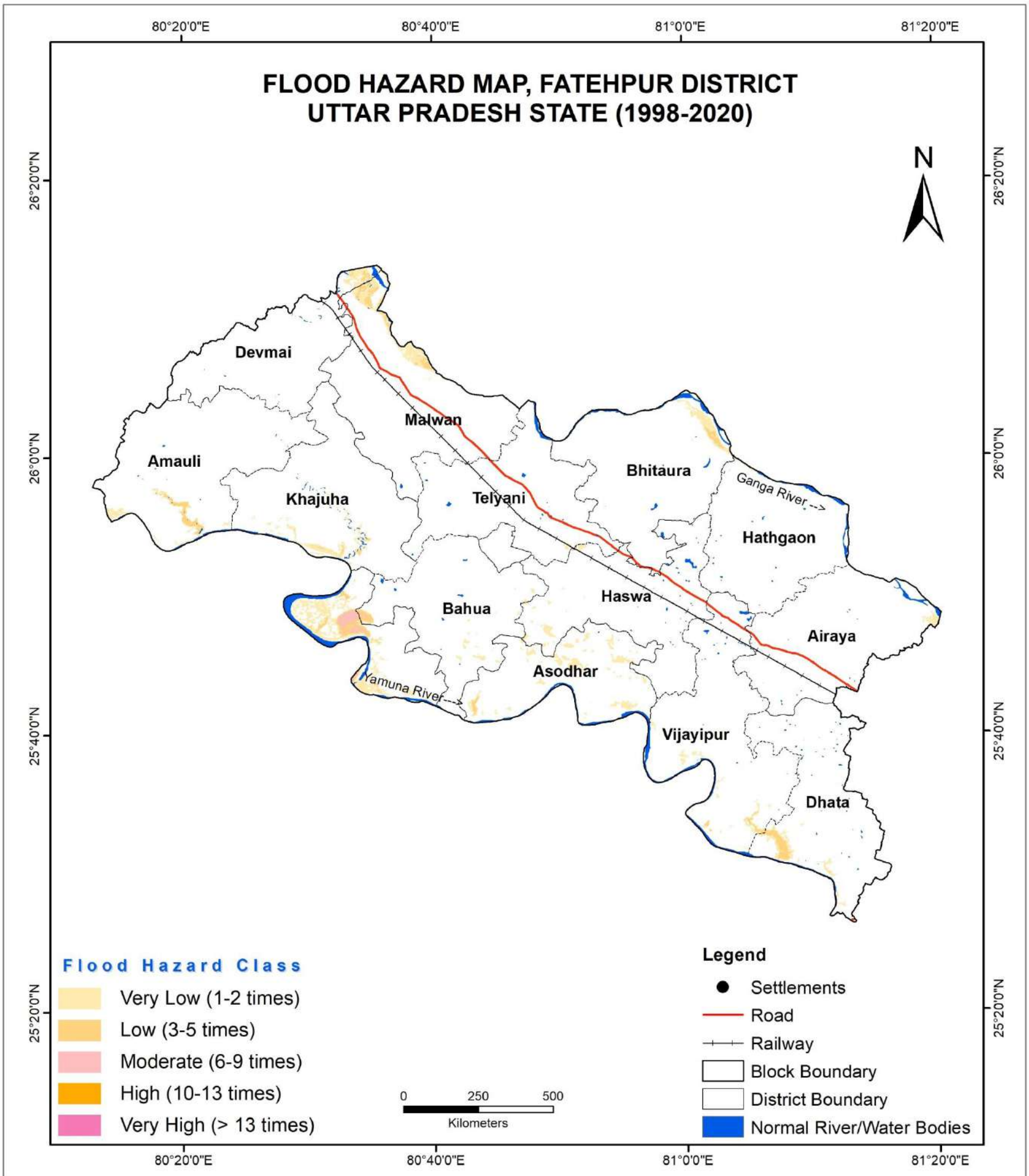
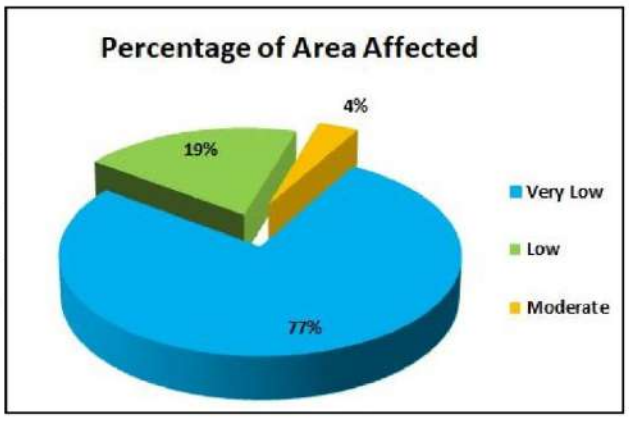
FLOOD HAZARD MAP, FATEHPUR DISTRICT
UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	11293
2	Low	2869
3	Moderate	543
	Total	**14705**



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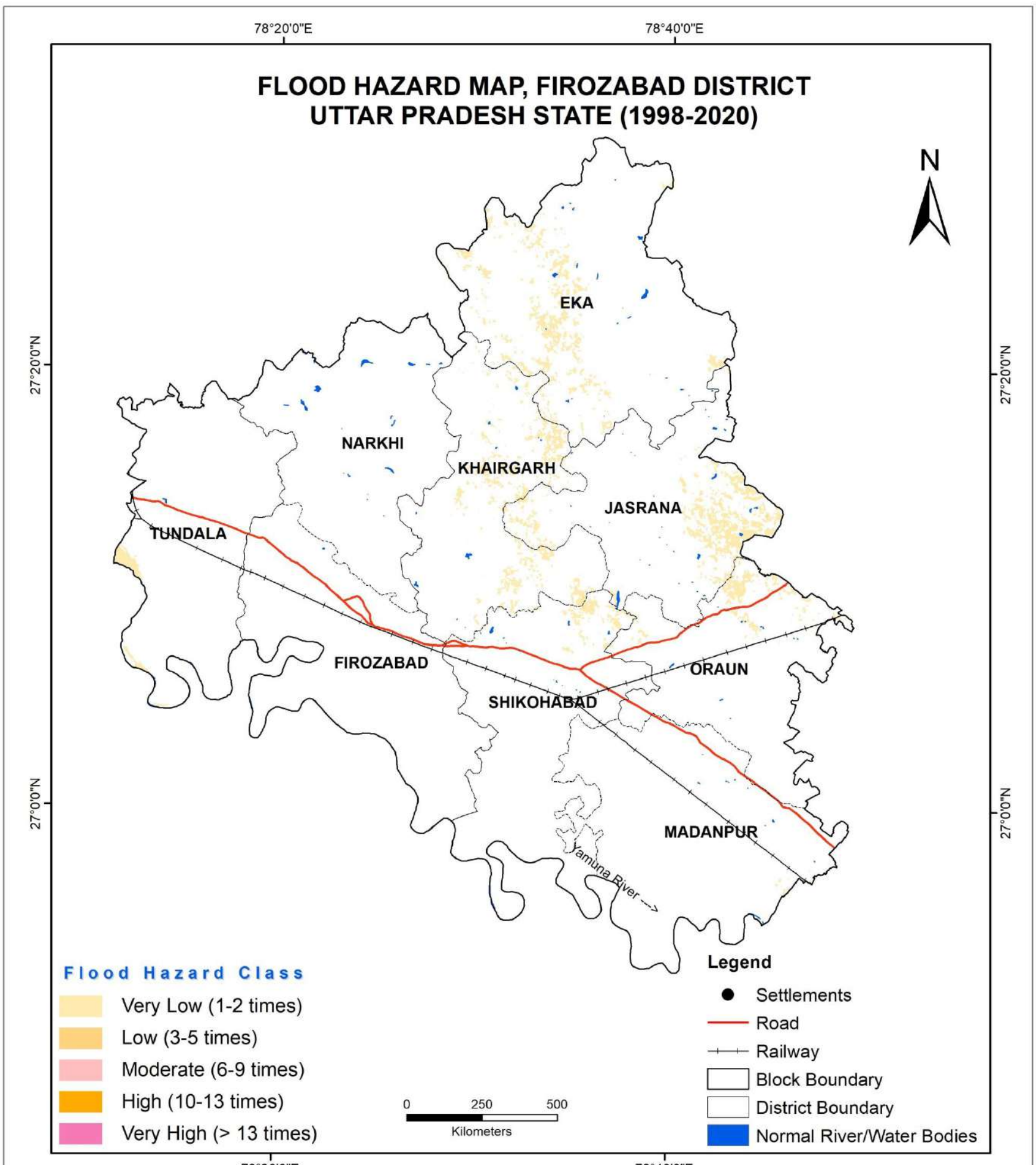
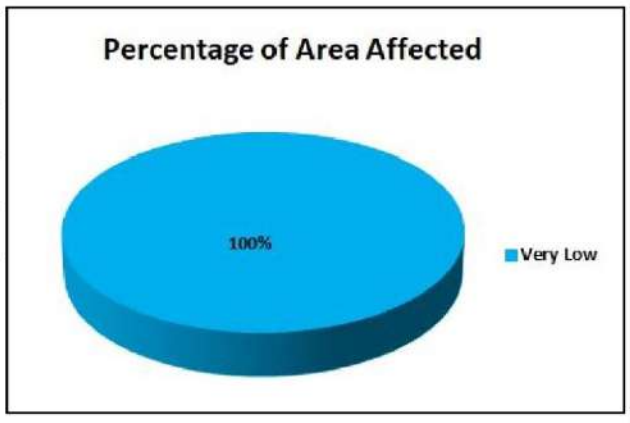
FLOOD HAZARD MAP, FIROZABAD DISTRICT
UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	7316
2	Low	9
	Total	**7325**



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FLOOD HAZARD MAP, GAUTAMBUDHNAGAR DISTRICT UTTAR PRADESH STATE (1998-2020)

77°20'0"E 77°40'0"E
28°40'0"N 28°20'0"N 28°0'0"N

LONI
BISRAKH
DADRI
SIKANDERABAD
DANKAUR
SIKANDRABAD
JEWAR
Yamuna River

N

Flood Hazard Class
- Very Low (1-2 times)
- Low (3-5 times)
- Moderate (6-9 times)
- High (10-13 times)
- Very High (> 13 times)

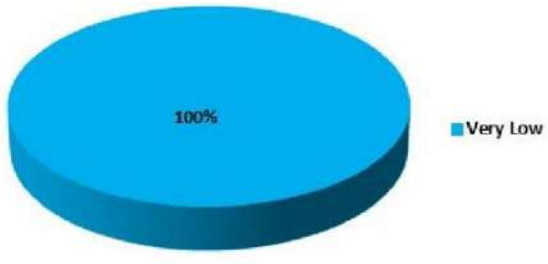
0 250 500
Kilometers

Legend
- Settlements
- Road
- Railway
- Block Boundary
- District Boundary
- Normal River/Water Bodies

Location Map

S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	2656
	Total	**2656**

Percentage of Area Affected



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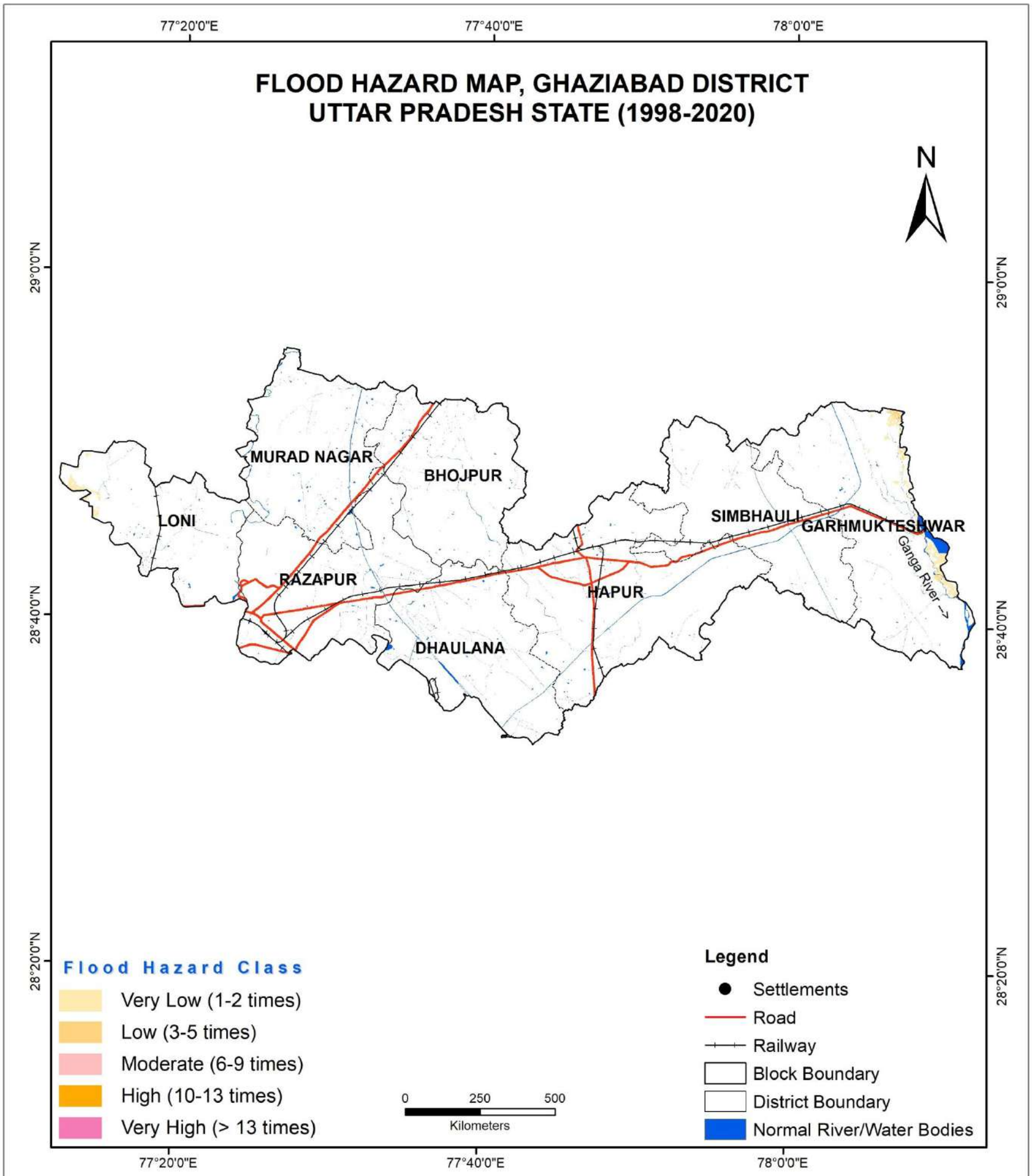
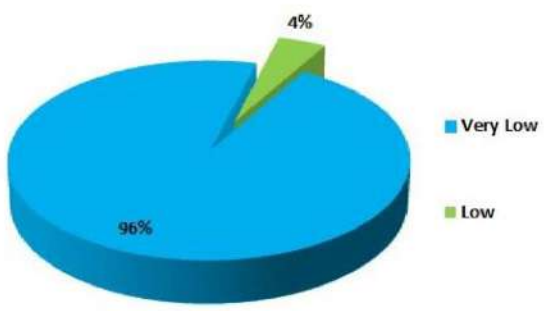
FLOOD HAZARD MAP, GHAZIABAD DISTRICT
UTTAR PRADESH STATE (1998-2020)



Location Map

S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	1478
2	Low	67
	Total	**1545**

Percentage of Area Affected



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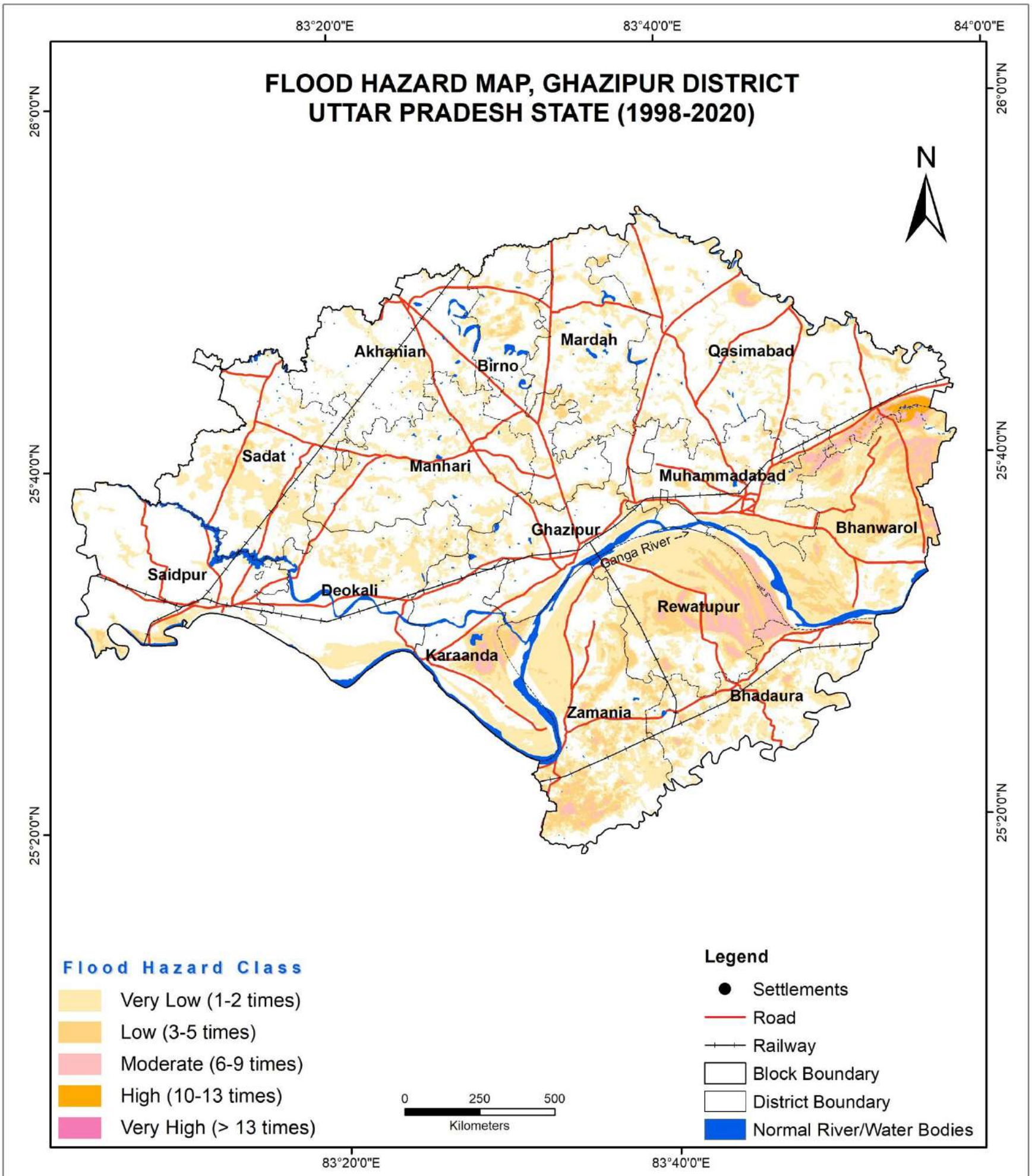
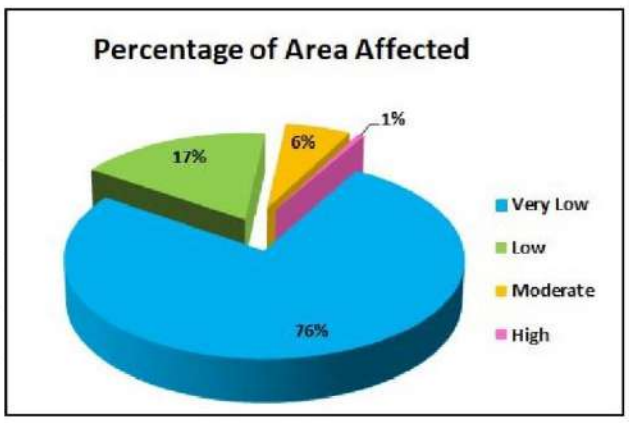
FLOOD HAZARD MAP, GHAZIPUR DISTRICT UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	89586
2	Low	20367
3	Moderate	7038
4	High	706
	Total	**117697**



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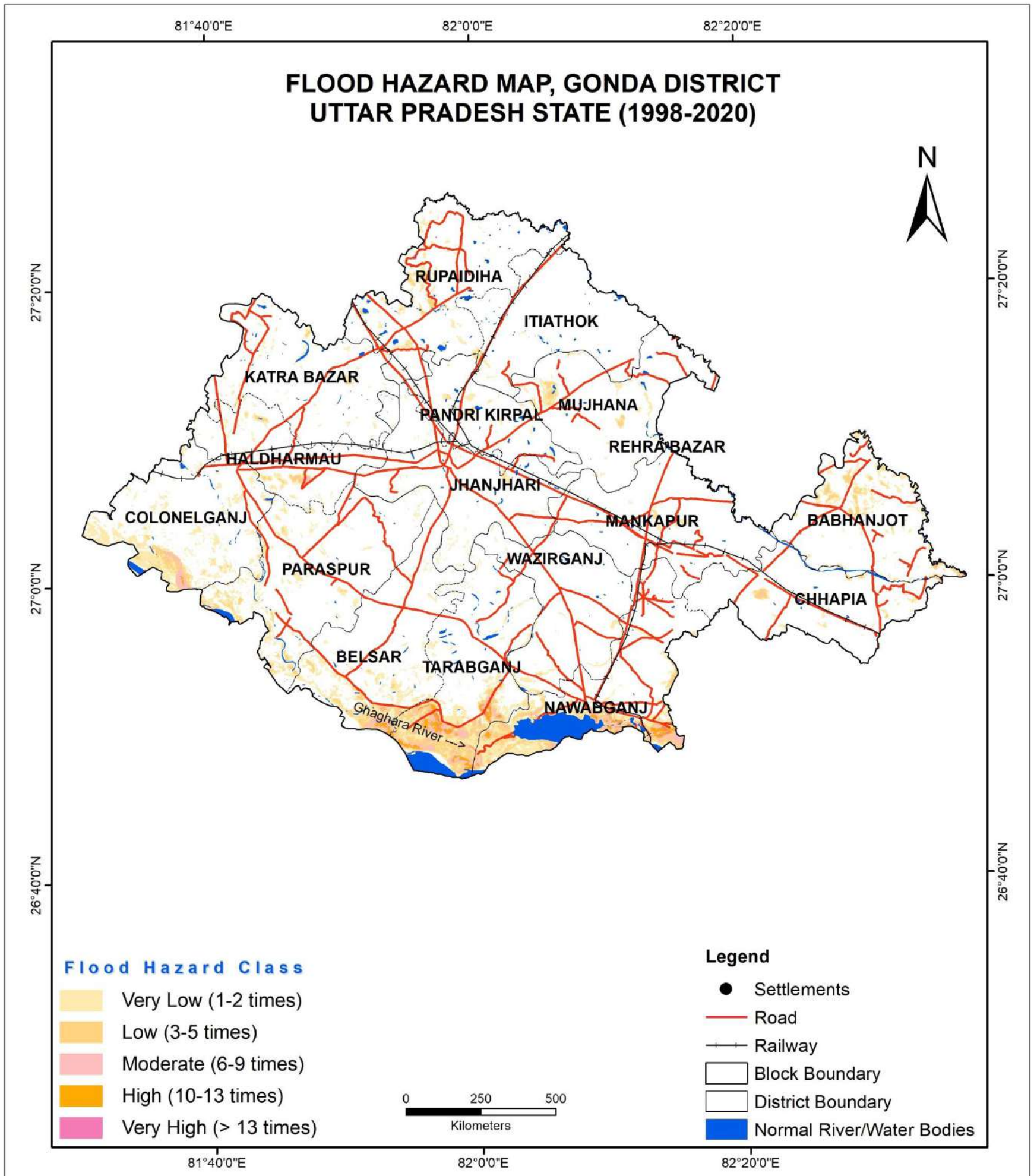
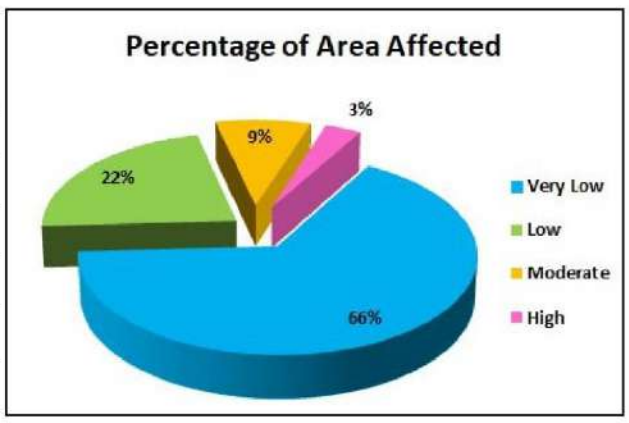
FLOOD HAZARD MAP, GONDA DISTRICT
UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	27650
2	Low	9338
3	Moderate	3630
4	High	1388
5	Very High	132
	Total	**42138**



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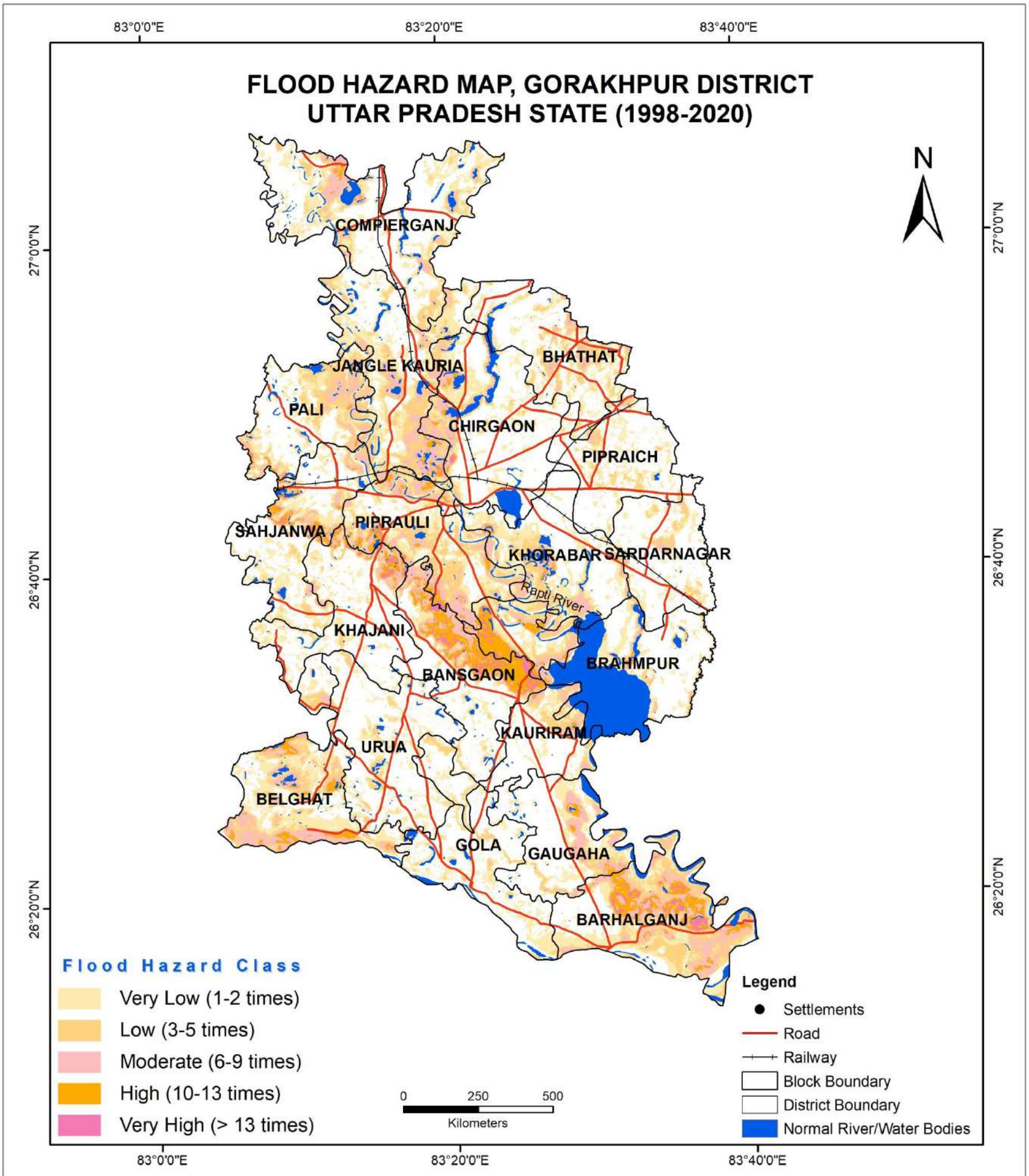
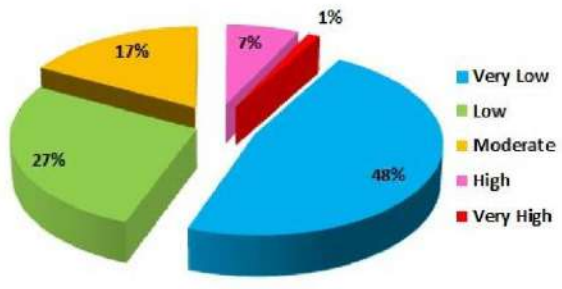
FLOOD HAZARD MAP, GORAKHPUR DISTRICT
UTTAR PRADESH STATE (1998-2020)



Location Map

S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	75397
2	Low	43466
3	Moderate	27533
4	High	11150
5	Very High	1912
	Total	**159458**

Percentage of Area Affected



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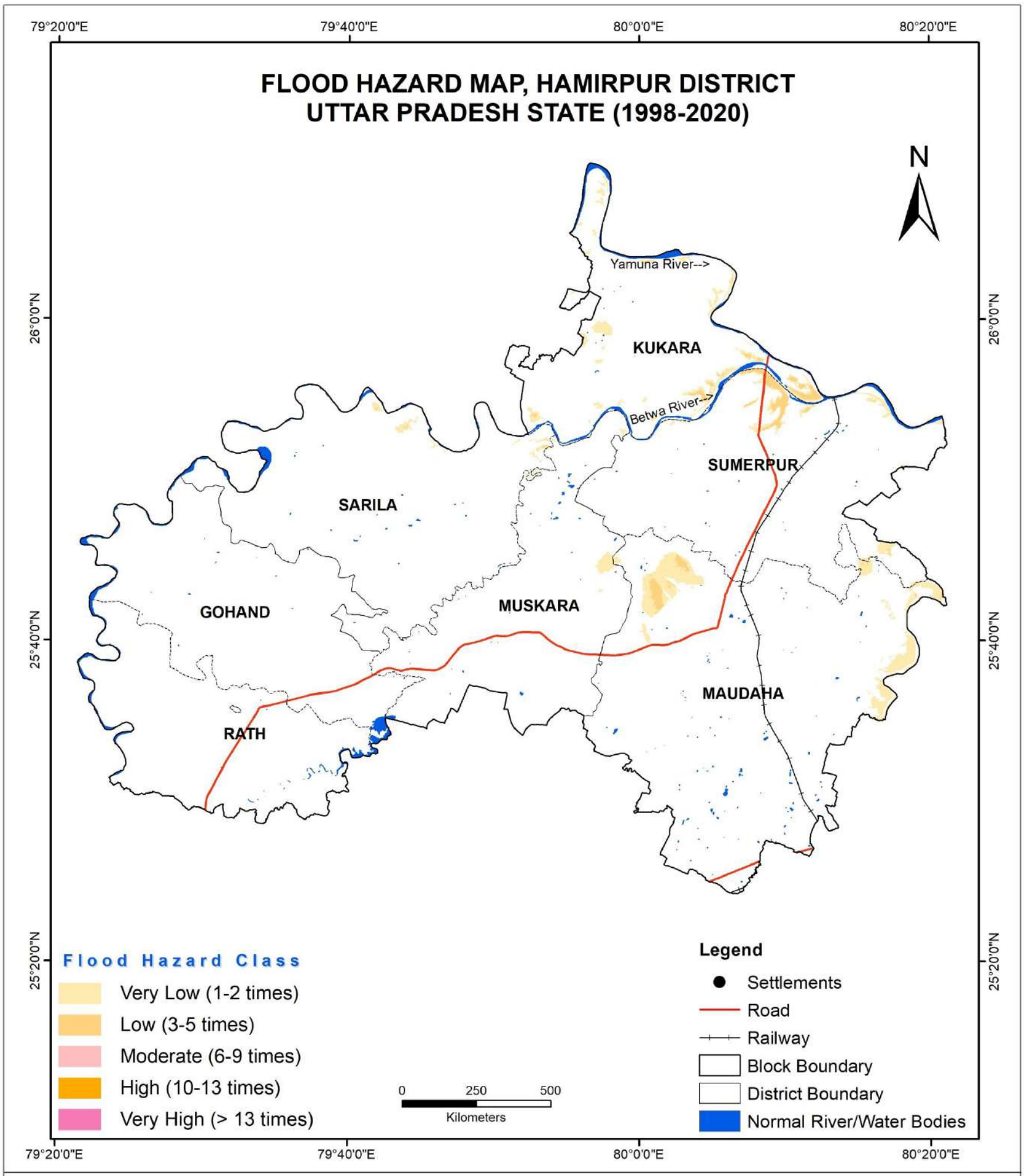
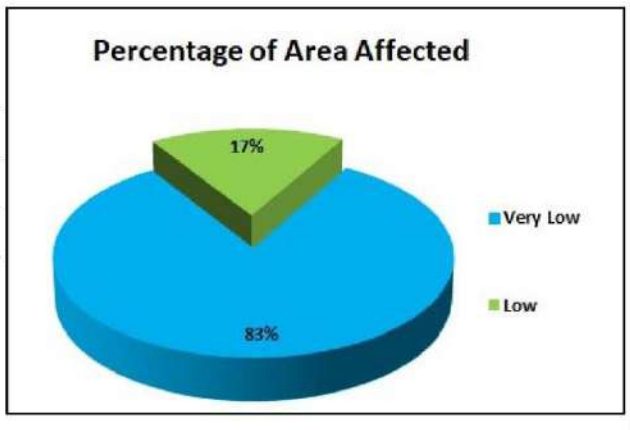
FLOOD HAZARD MAP, HAMIRPUR DISTRICT
UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	8580
2	Low	1818
	Total	**10398**



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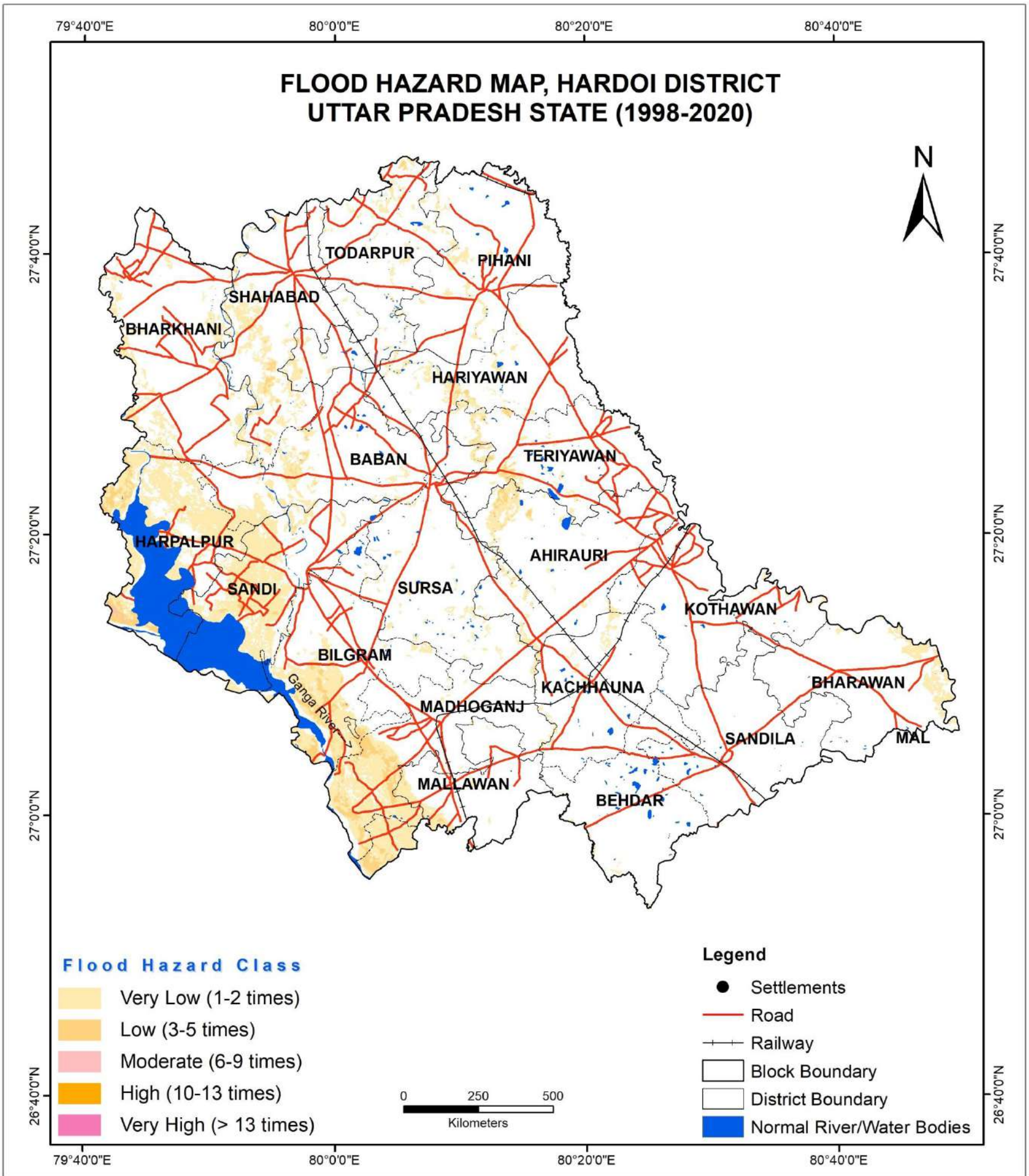
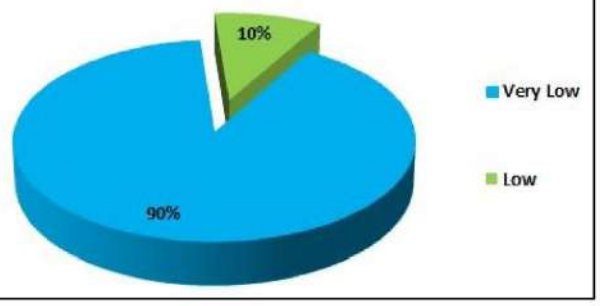
FLOOD HAZARD MAP, HARDOI DISTRICT
UTTAR PRADESH STATE (1998-2020)



Location Map

S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	76647
2	Low	8161
3	Moderate	102
	Total	**84910**

Percentage of Area Affected



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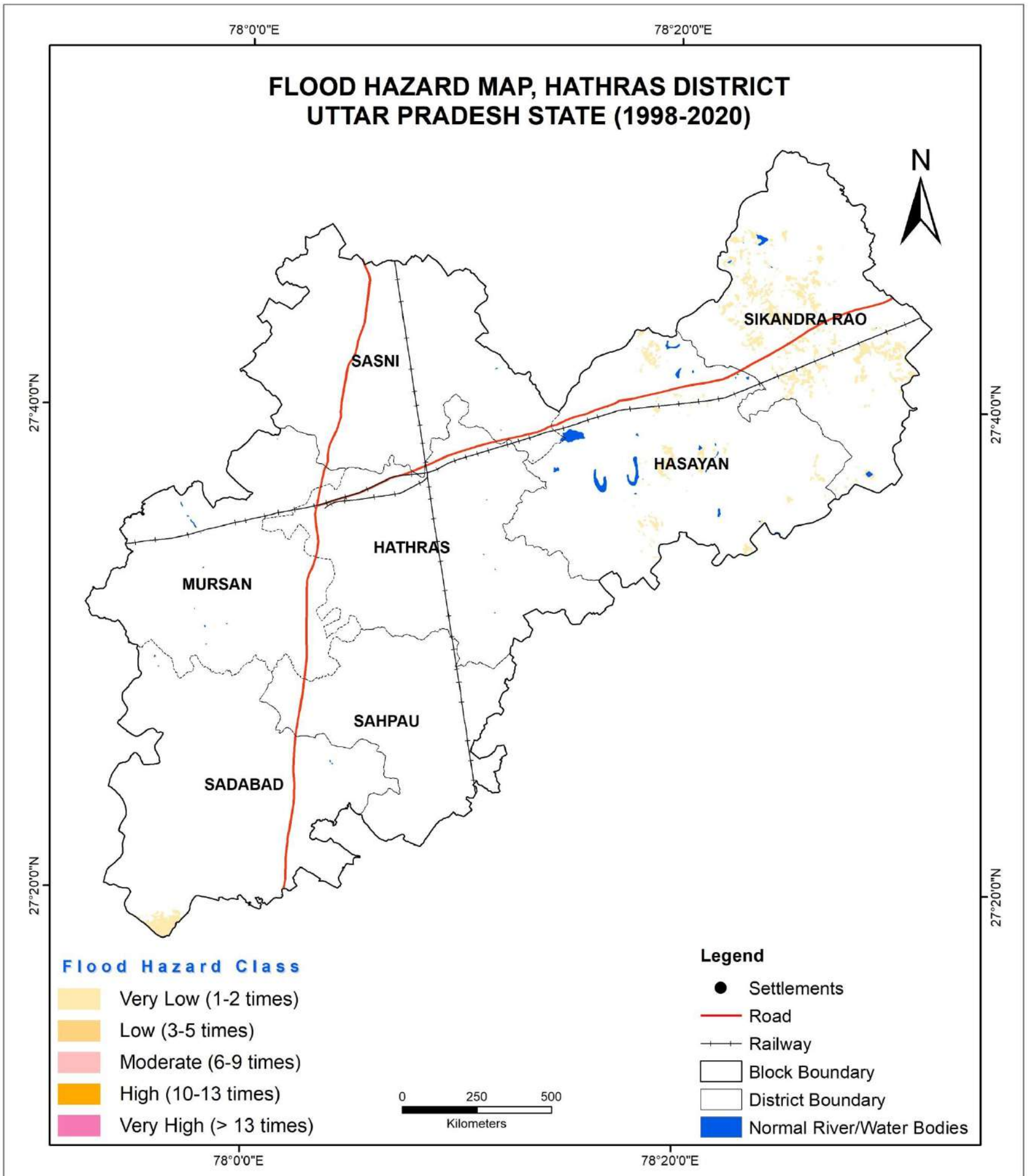
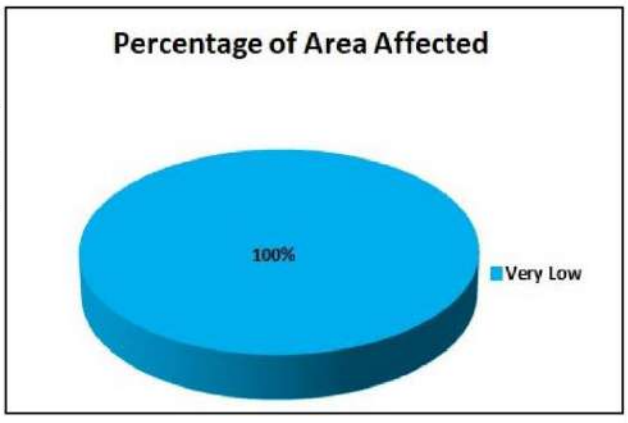
FLOOD HAZARD MAP, HATHRAS DISTRICT
UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	2857
	Total	2857



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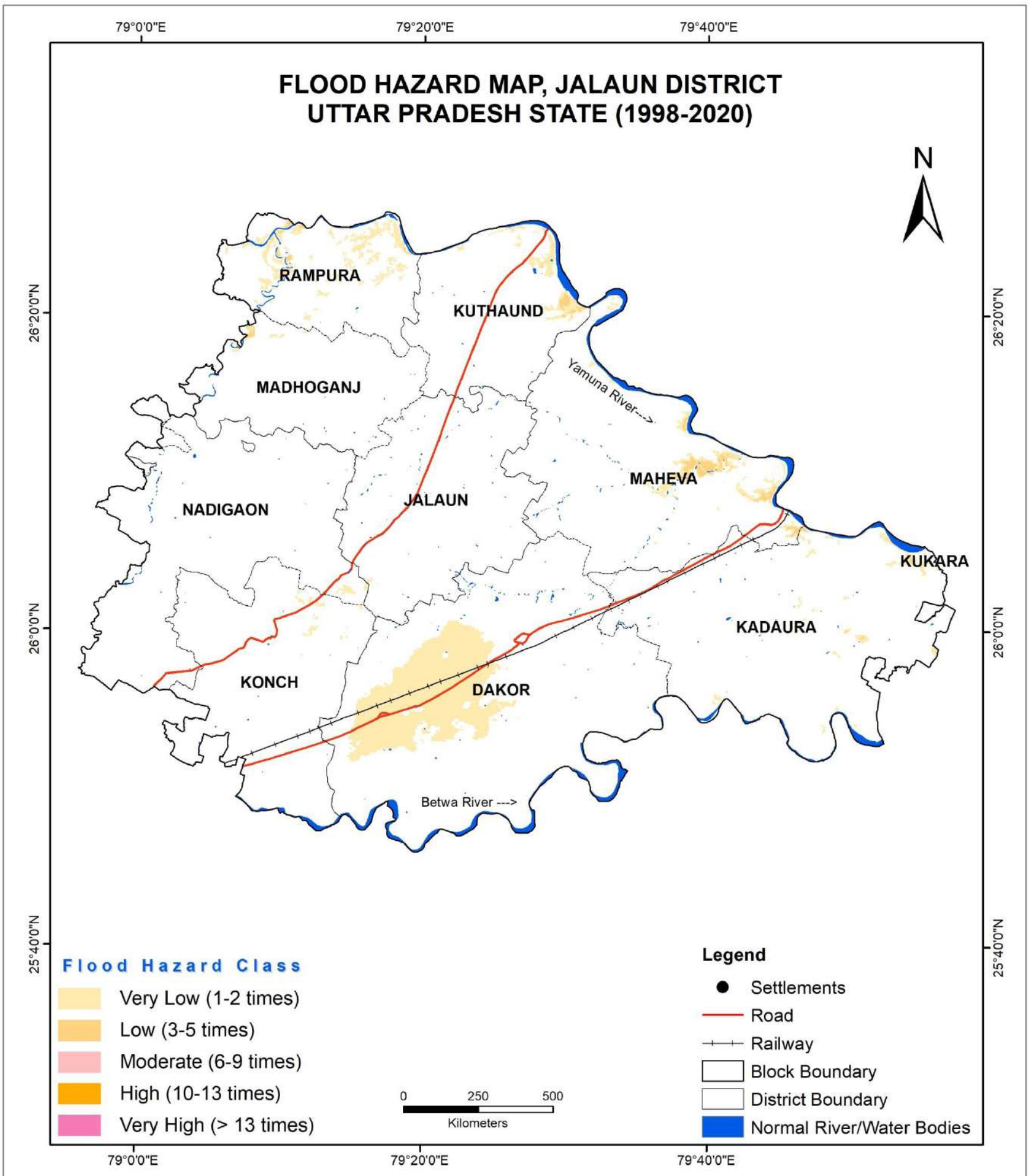
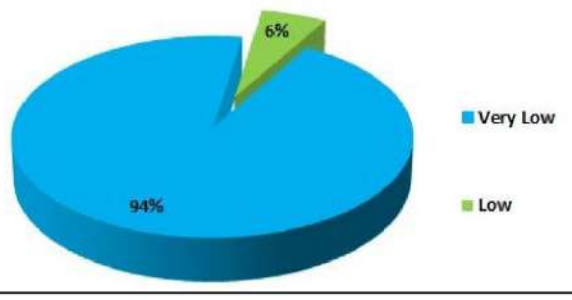
FLOOD HAZARD MAP, JALAUN DISTRICT
UTTAR PRADESH STATE (1998-2020)



Location Map

S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	22967
2	Low	1437
	Total	**24404**

Percentage of Area Affected



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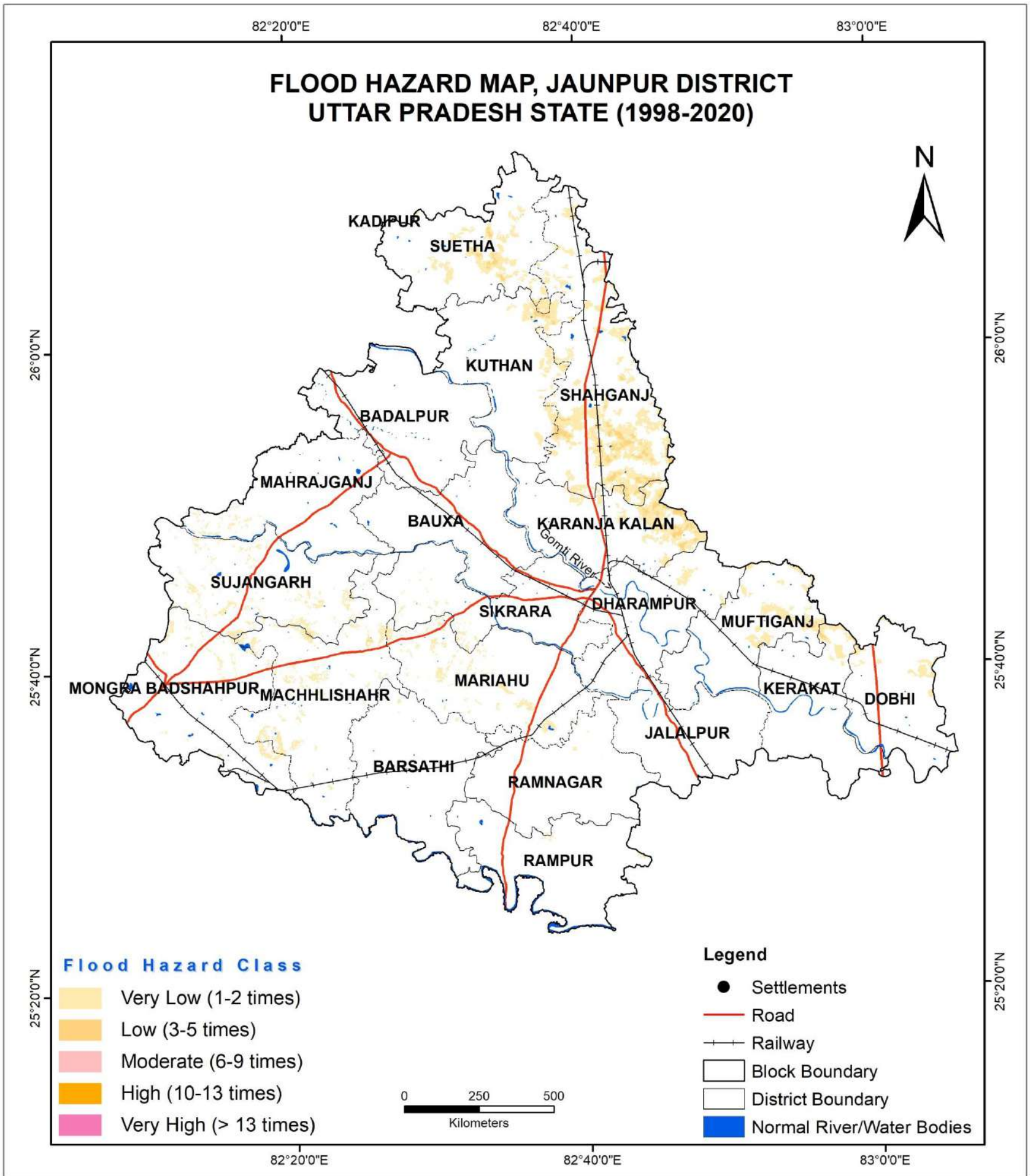
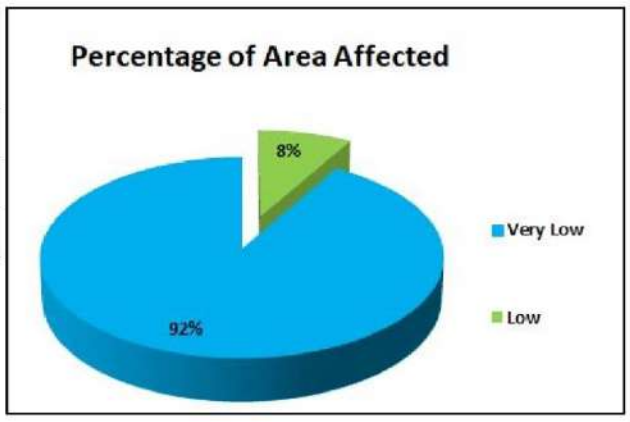
FLOOD HAZARD MAP, JAUNPUR DISTRICT
UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	20225
2	Low	1857
	Total	**22082**



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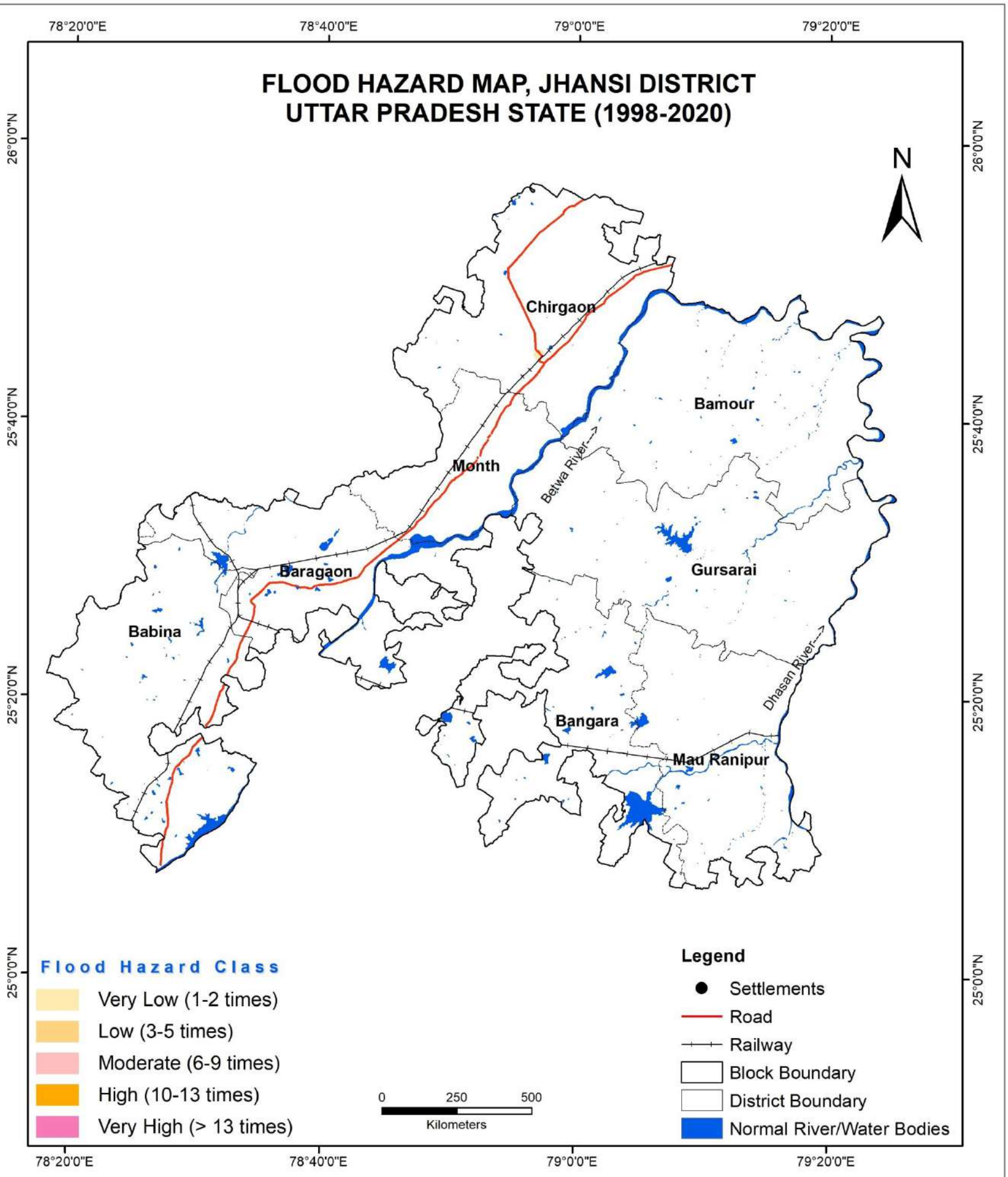
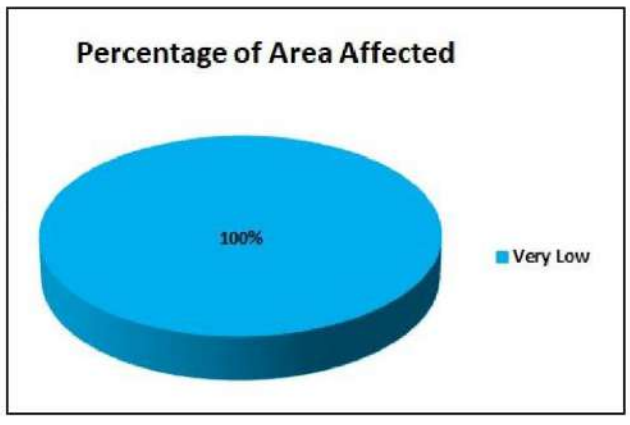
FLOOD HAZARD MAP, JHANSI DISTRICT
UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	106
	Total	**106**



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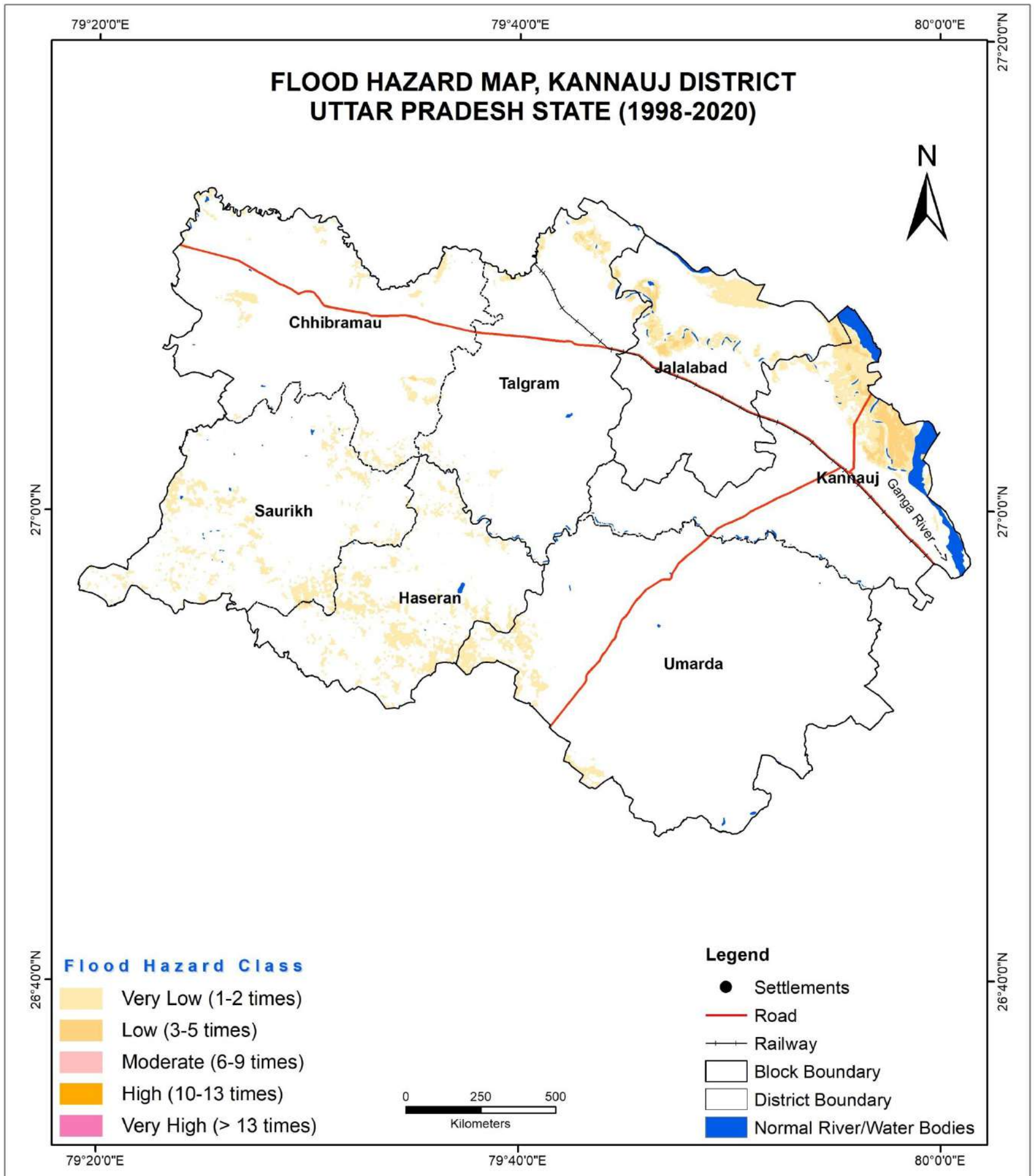
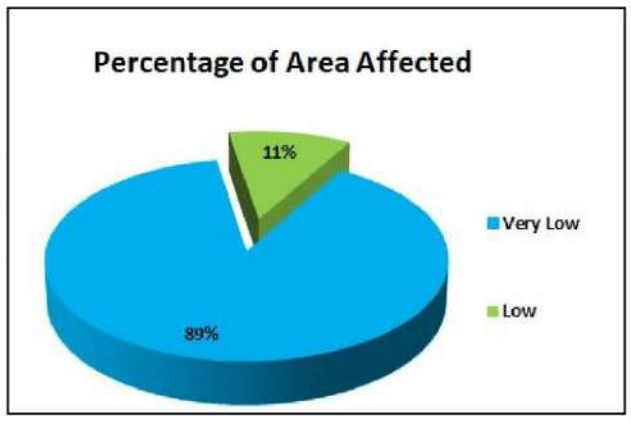
FLOOD HAZARD MAP, KANNAUJ DISTRICT
UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	13143
2	Low	1620
	Total	**14763**



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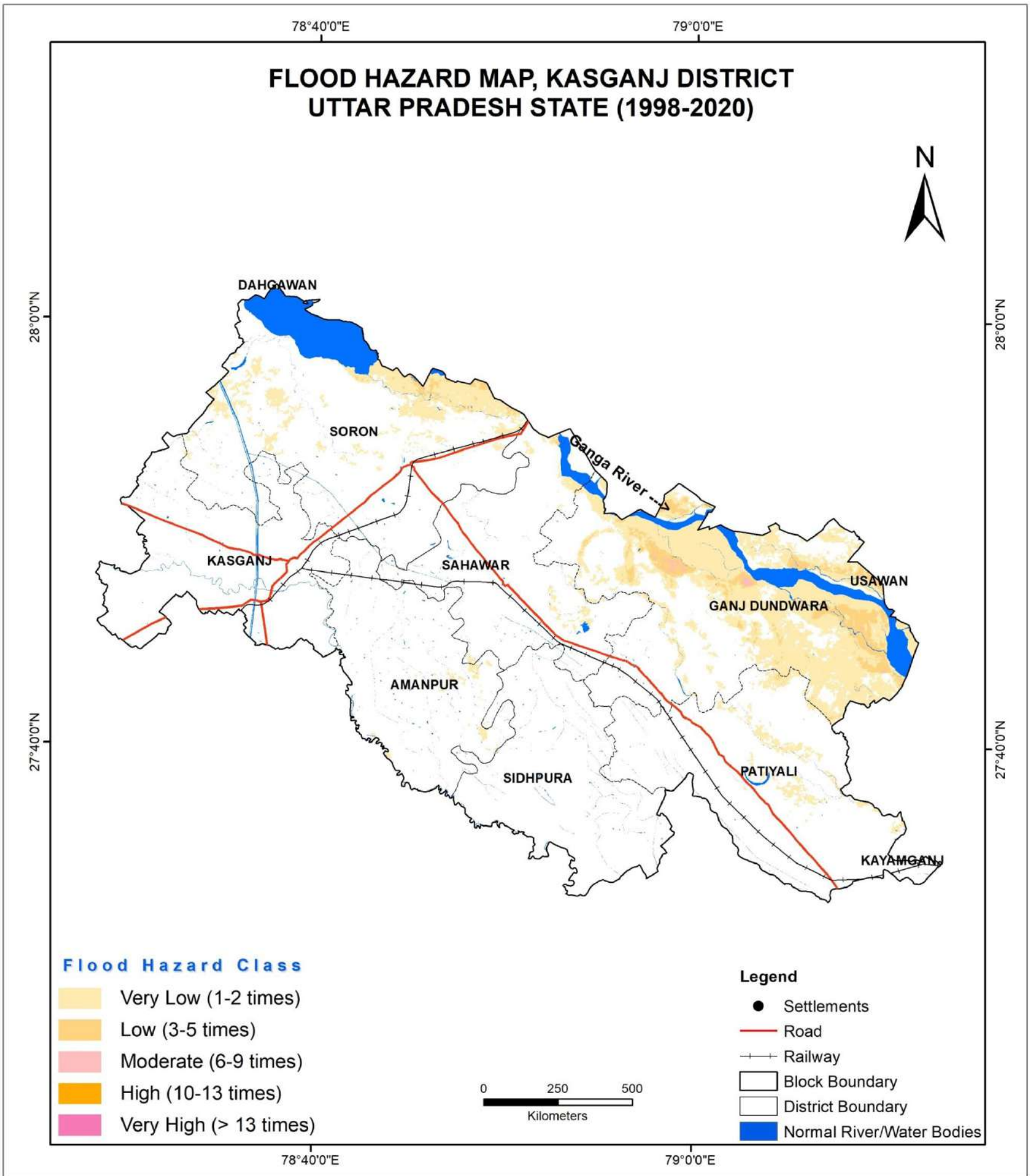
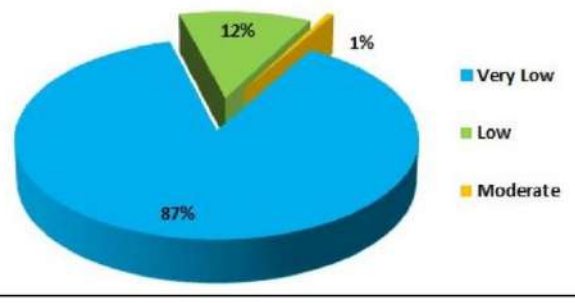
FLOOD HAZARD MAP, KASGANJ DISTRICT
UTTAR PRADESH STATE (1998-2020)



Location Map

S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	26376
2	Low	3563
3	Moderate	176
	Total	30115

Percentage of Area Affected



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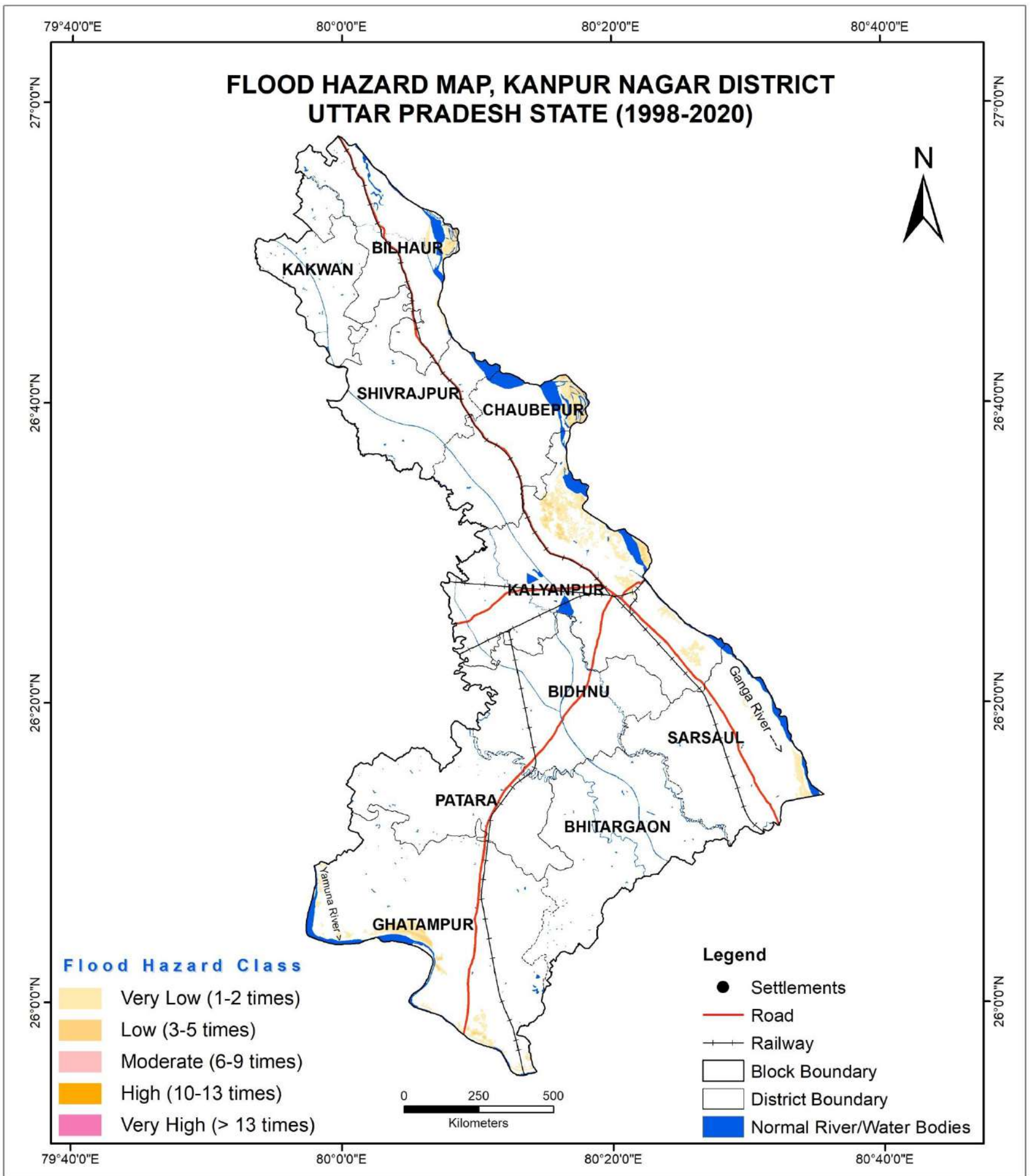
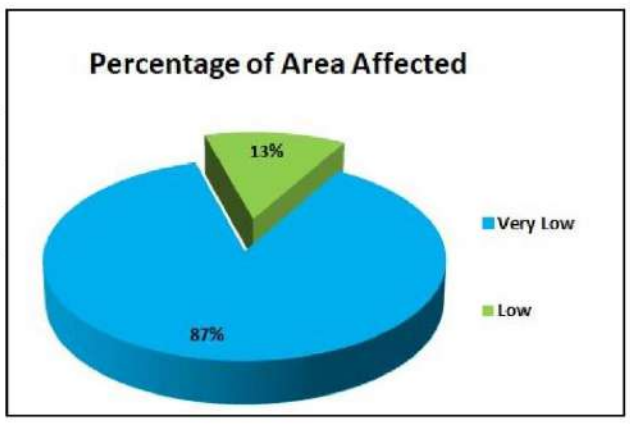
FLOOD HAZARD MAP, KANPUR NAGAR DISTRICT
UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	8164
2	Low	1182
	Total	**9346**



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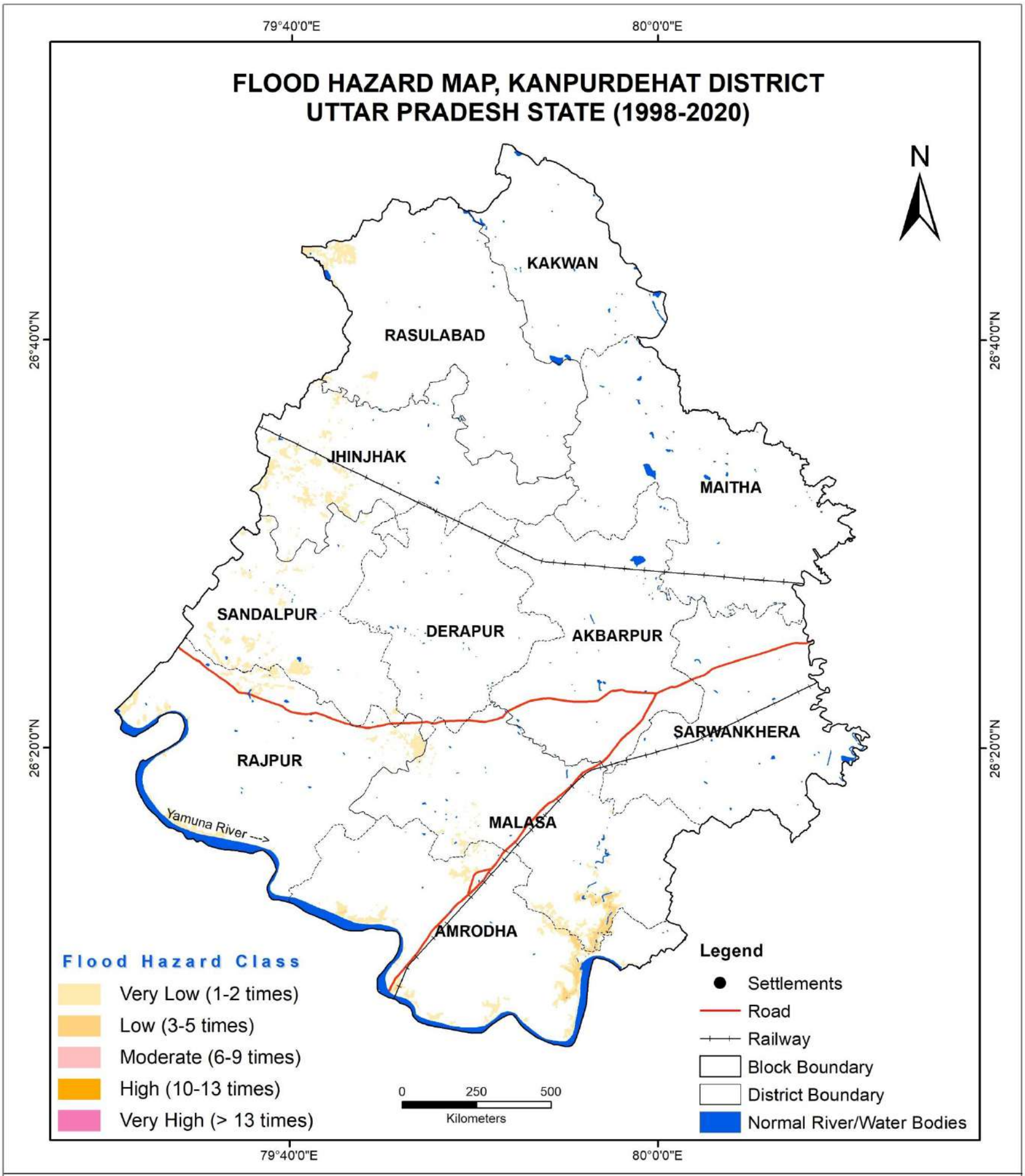
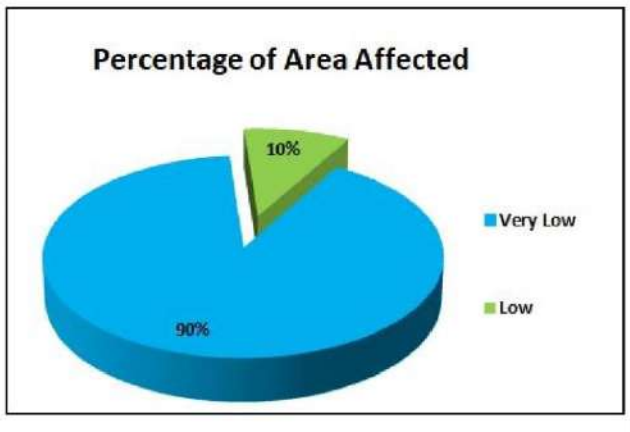
FLOOD HAZARD MAP, KANPURDEHAT DISTRICT UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	6631
2	Low	704
	Total	**7335**



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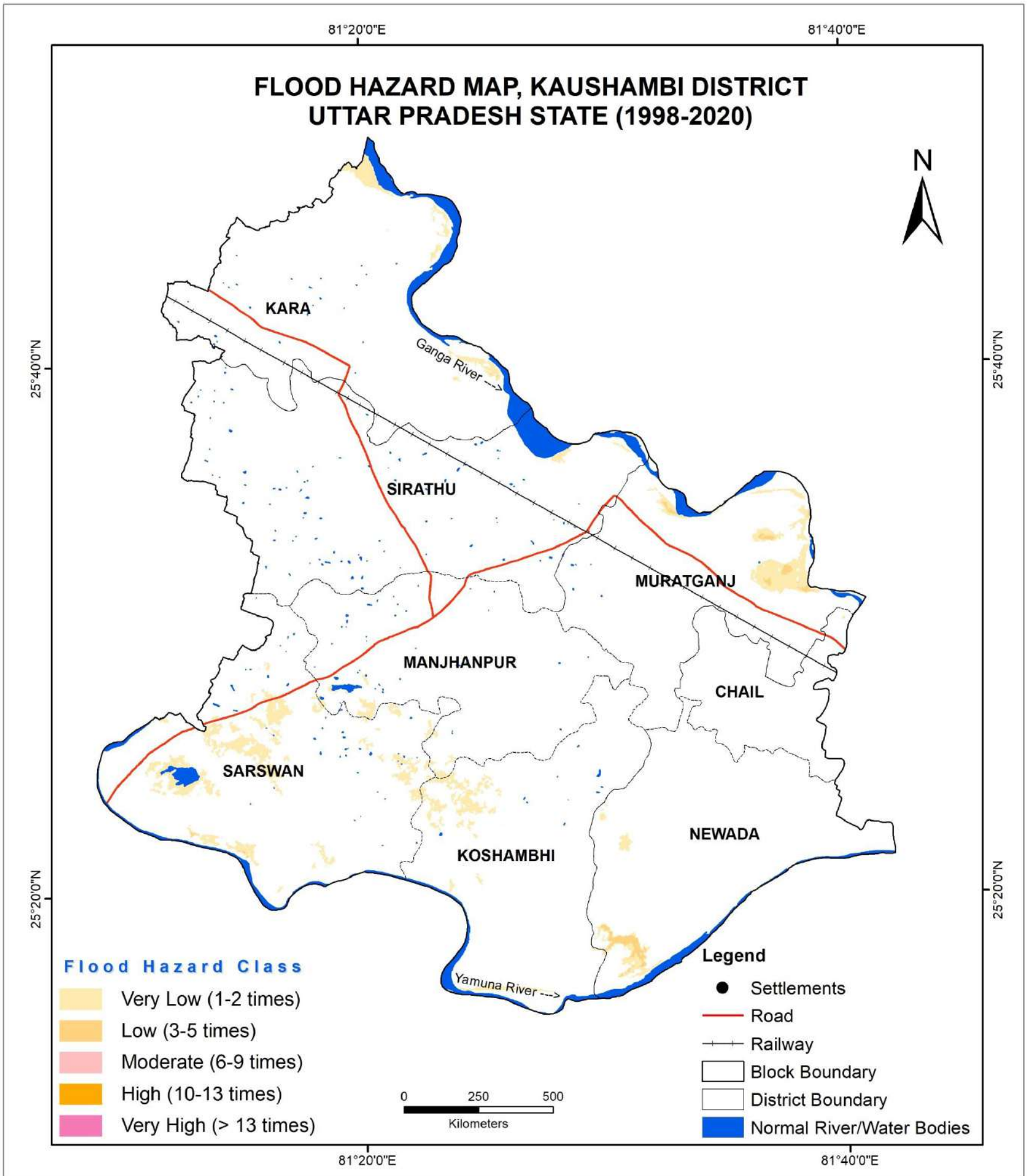
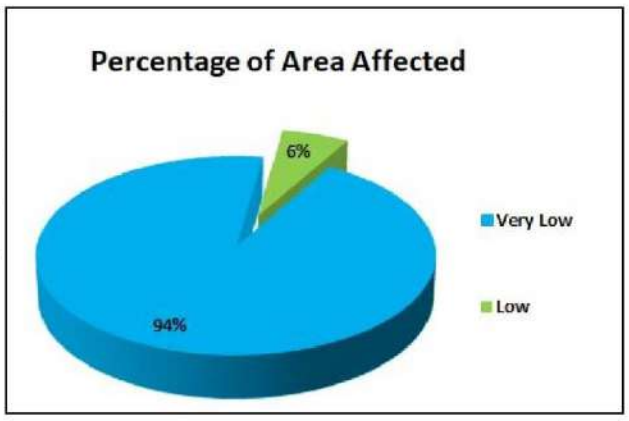
FLOOD HAZARD MAP, KAUSHAMBI DISTRICT
UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	5383
2	Low	349
	Total	**5732**



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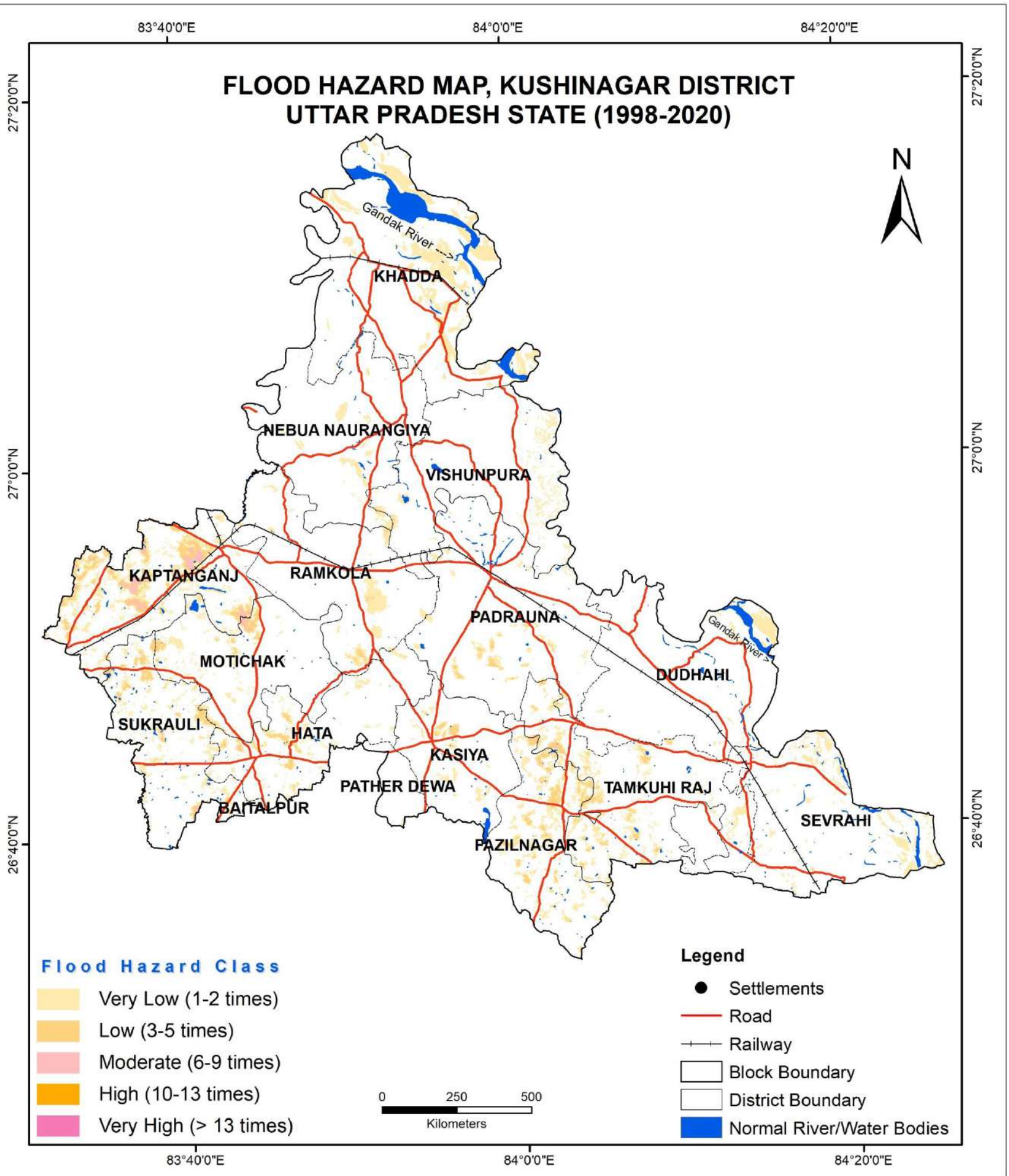
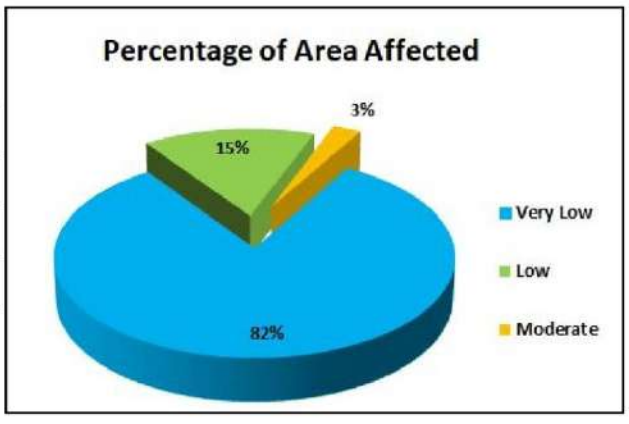
FLOOD HAZARD MAP, KUSHINAGAR DISTRICT
UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	22922
2	Low	4311
3	Moderate	720
	Total	**27953**



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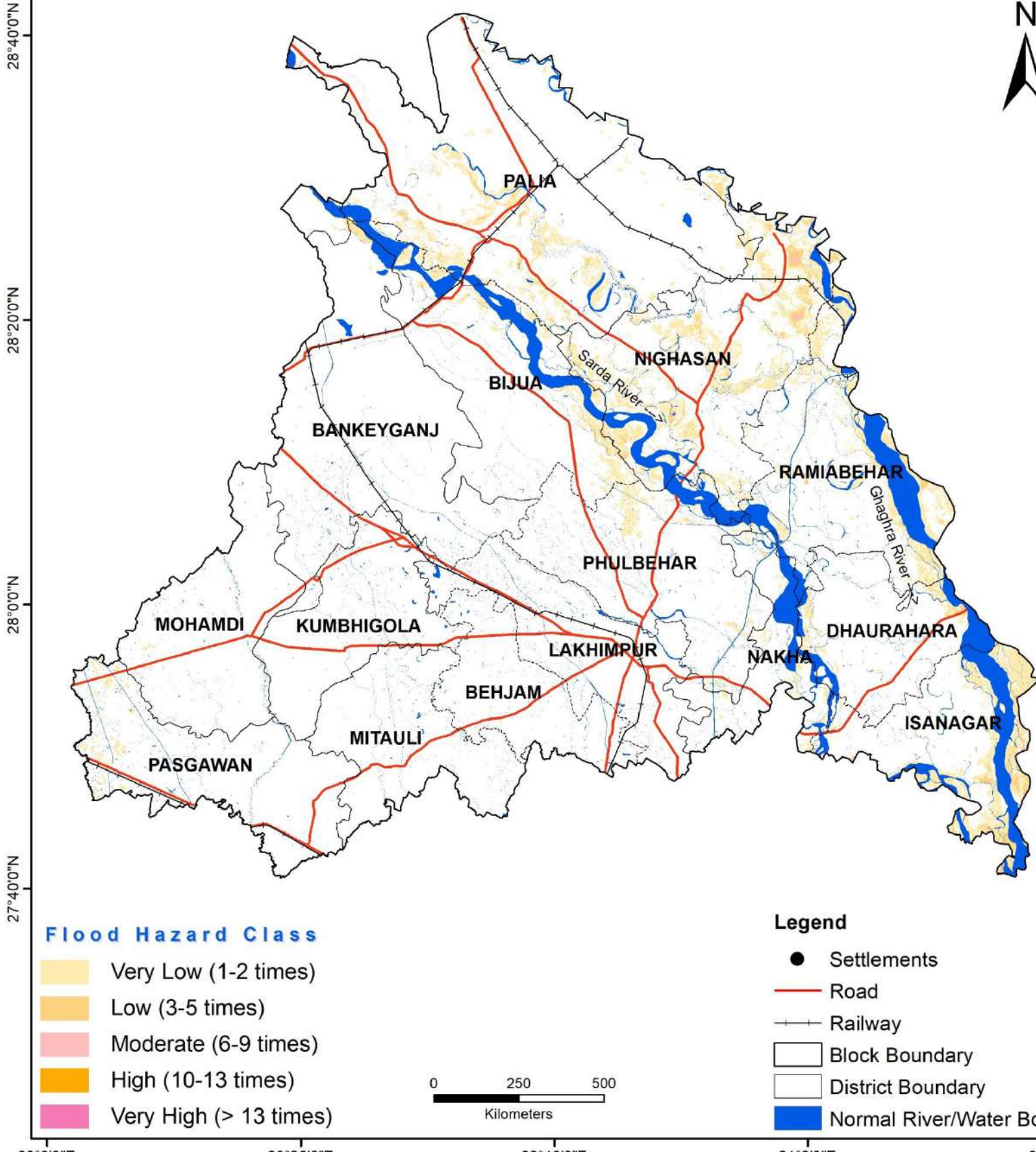
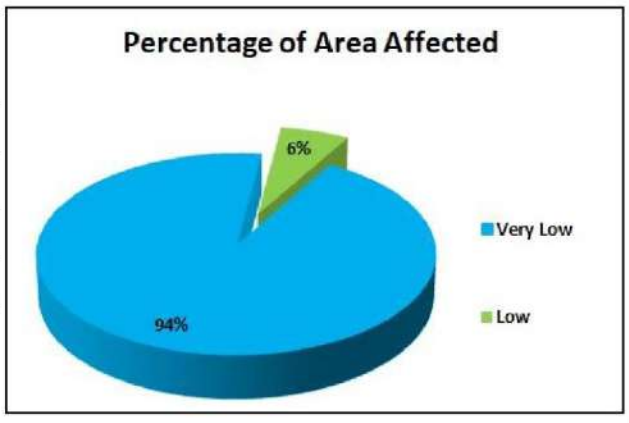
FLOOD HAZARD MAP, LAKHIMPUR-KHIRI DISTRICT
UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	66178
2	Low	4403
3	Moderate	235
	Total	**70816**



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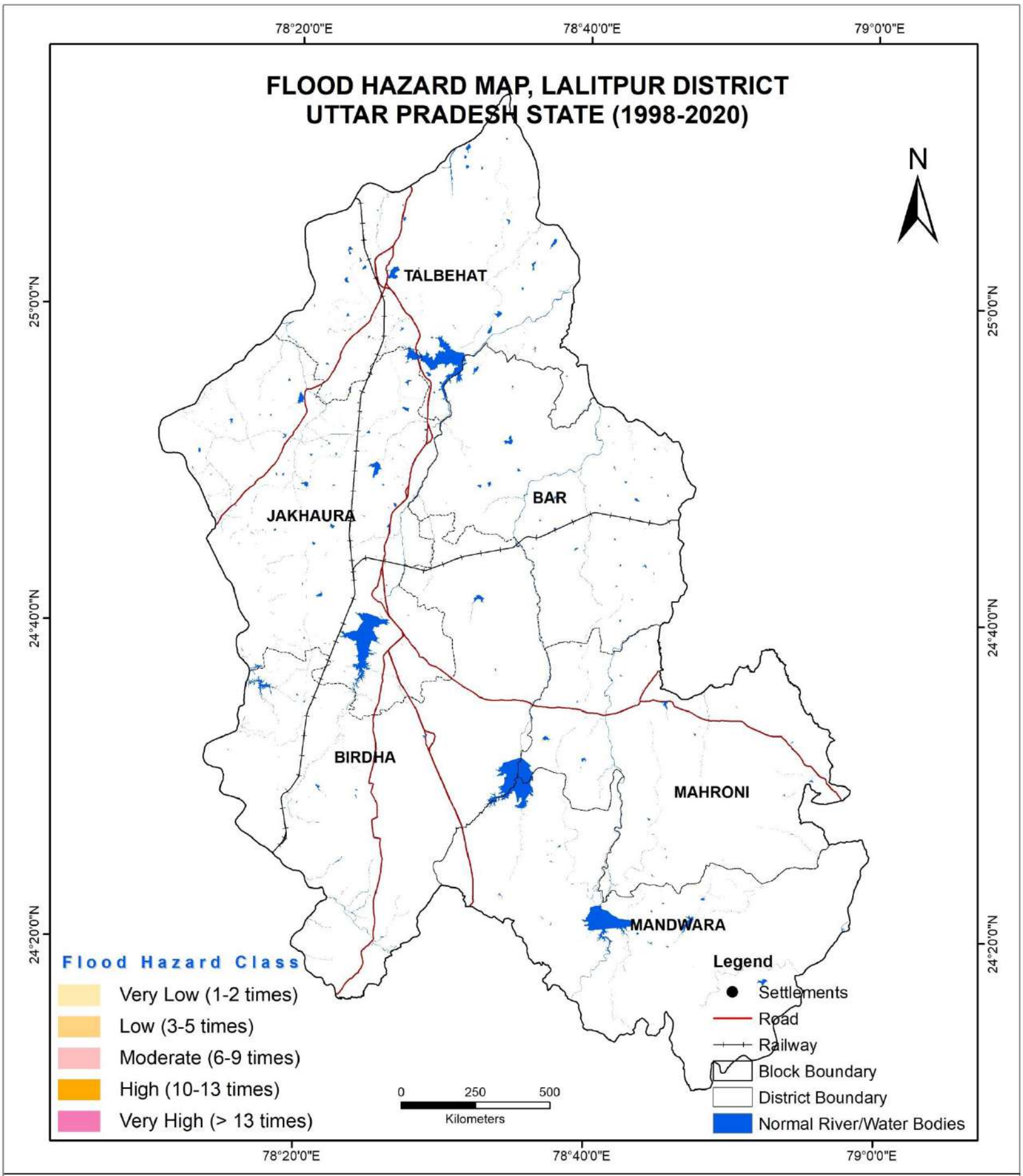
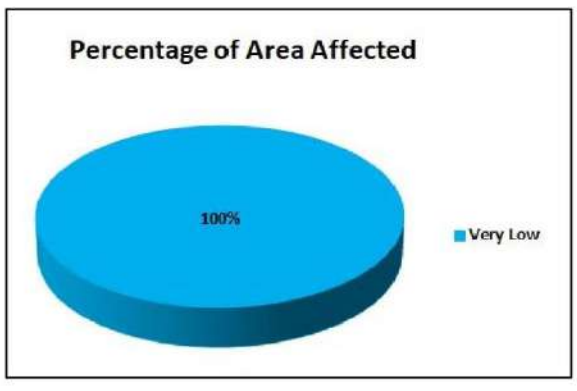
FLOOD HAZARD MAP, LALITPUR DISTRICT
UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	39
	Total	**39**



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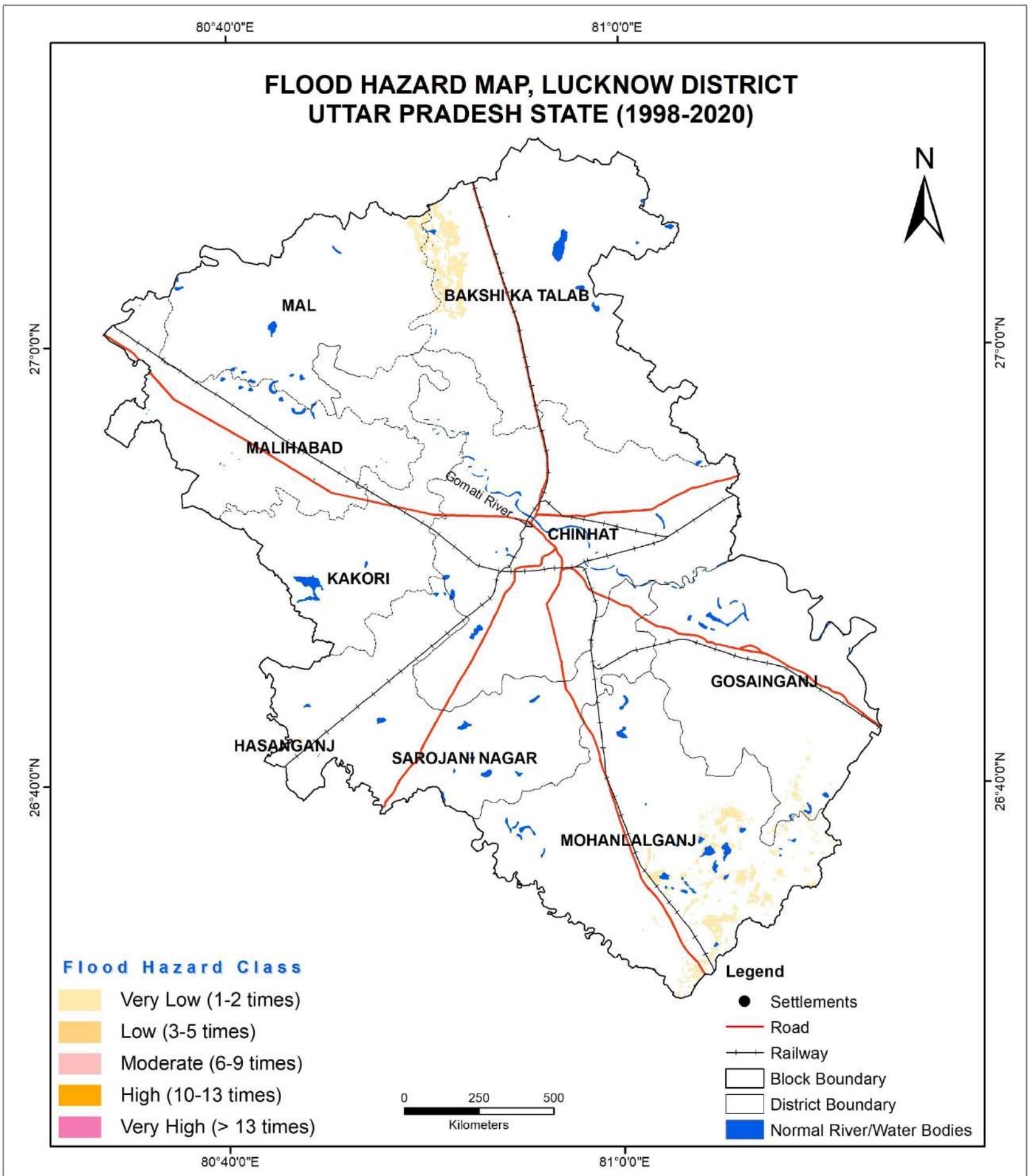
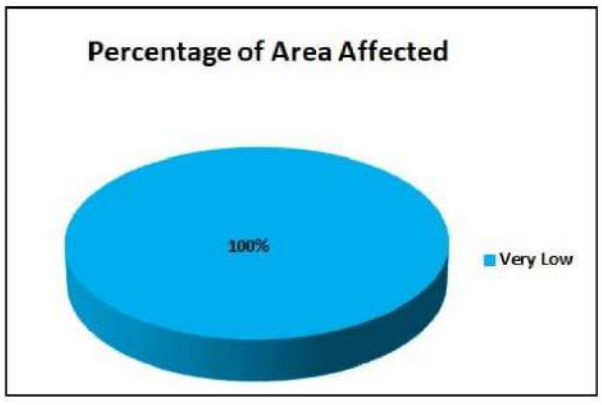
FLOOD HAZARD MAP, LUCKNOW DISTRICT
UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	4037
2	Low	3
	Total	**4040**



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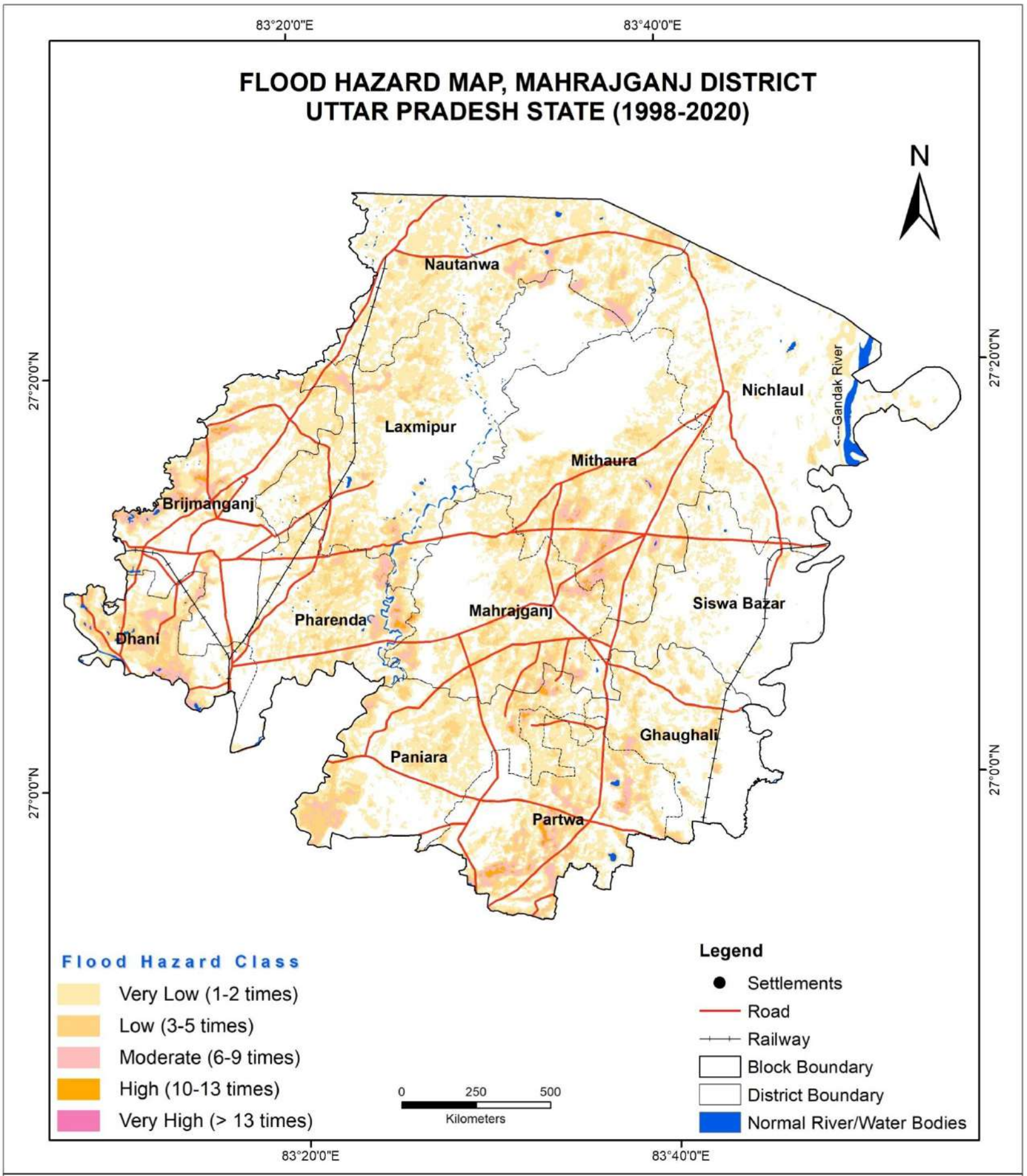
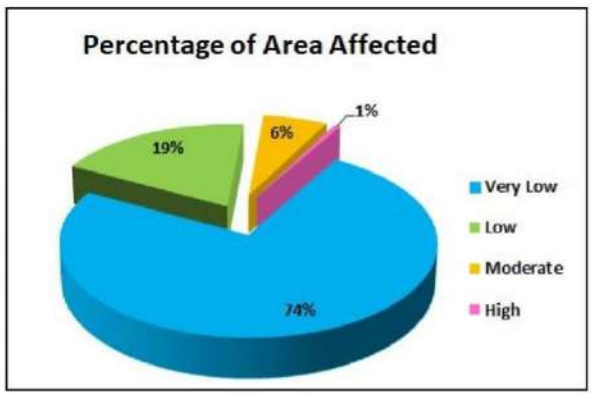
FLOOD HAZARD MAP, MAHRAJGANJ DISTRICT UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	88065
2	Low	22097
3	Moderate	7299
4	High	758
5	Very High	8
	Total	**118227**



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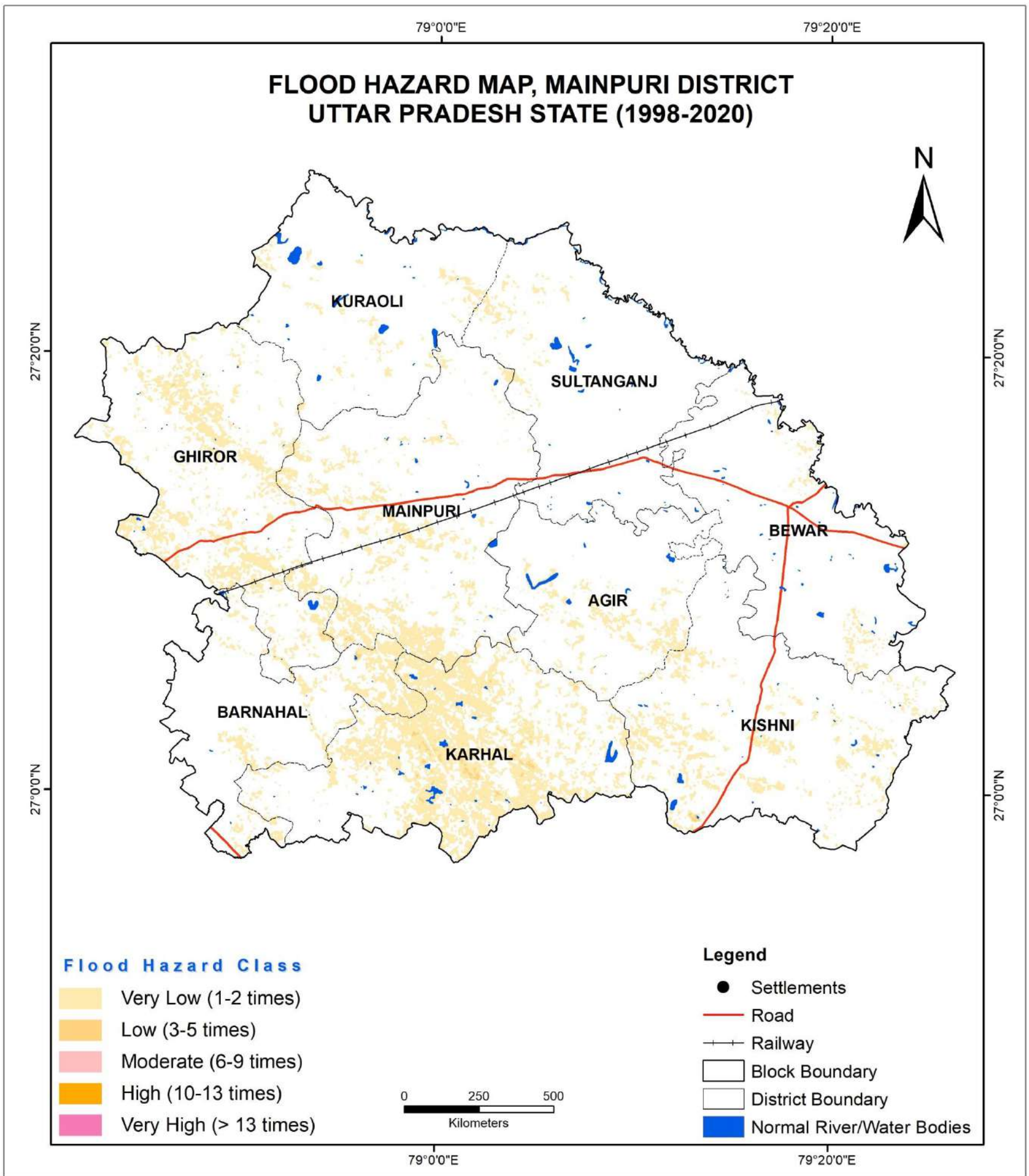
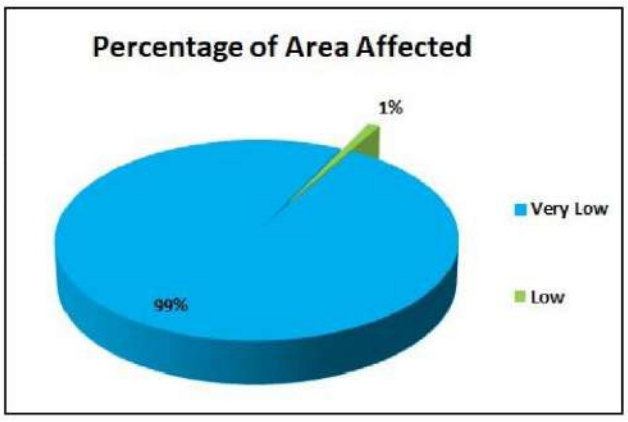
FLOOD HAZARD MAP, MAINPURI DISTRICT
UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	34511
2	Low	378
	Total	**34889**



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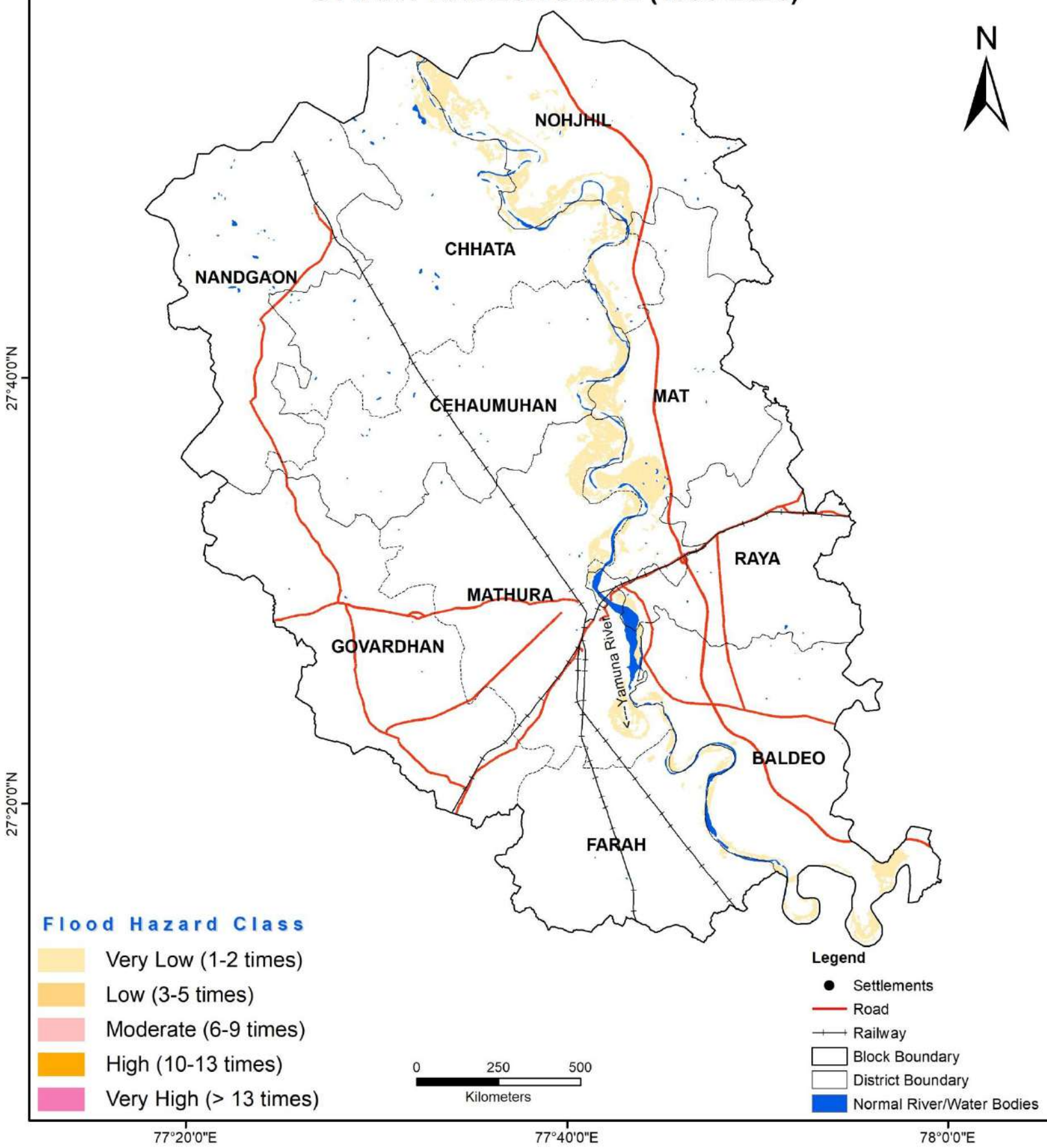
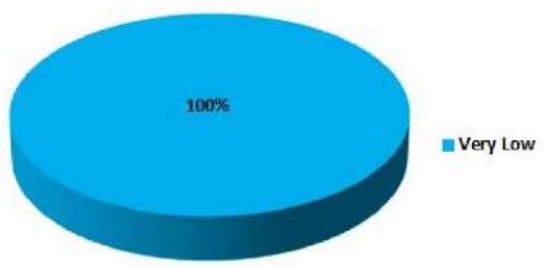
FLOOD HAZARD MAP, MATHURA DISTRICT
UTTAR PRADESH STATE (1998-2020)



Location Map

S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	13125
	Total	**13125**

Percentage of Area Affected



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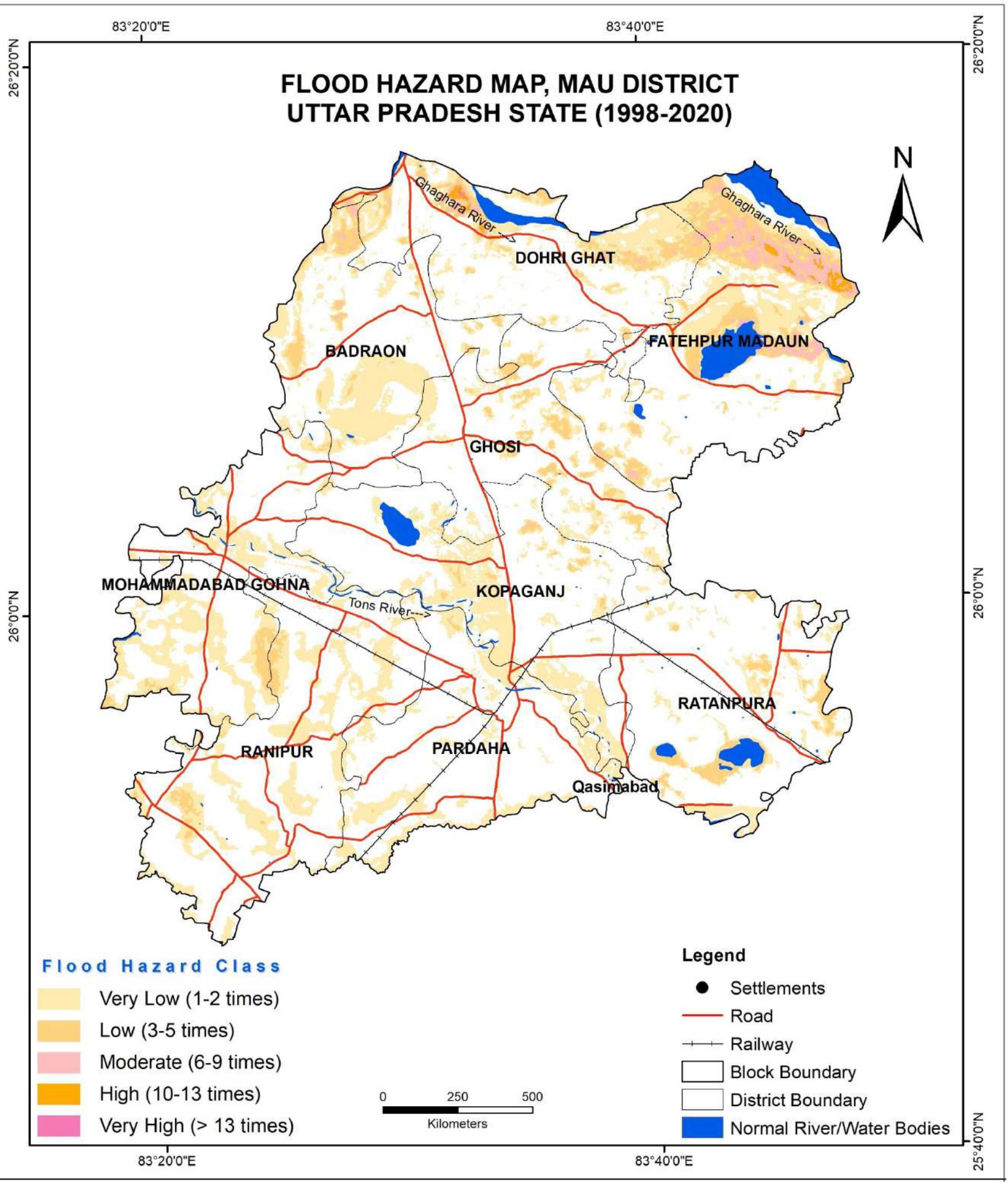
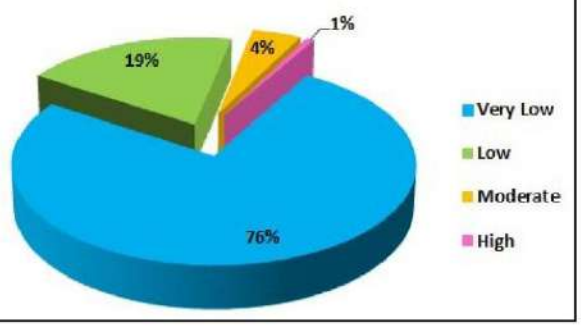
FLOOD HAZARD MAP, MAU DISTRICT
UTTAR PRADESH STATE (1998-2020)



Location Map

S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	35378
2	Low	8885
3	Moderate	2071
4	High	328
5	Very High	11
	Total	**46673**

Percentage of Area Affected



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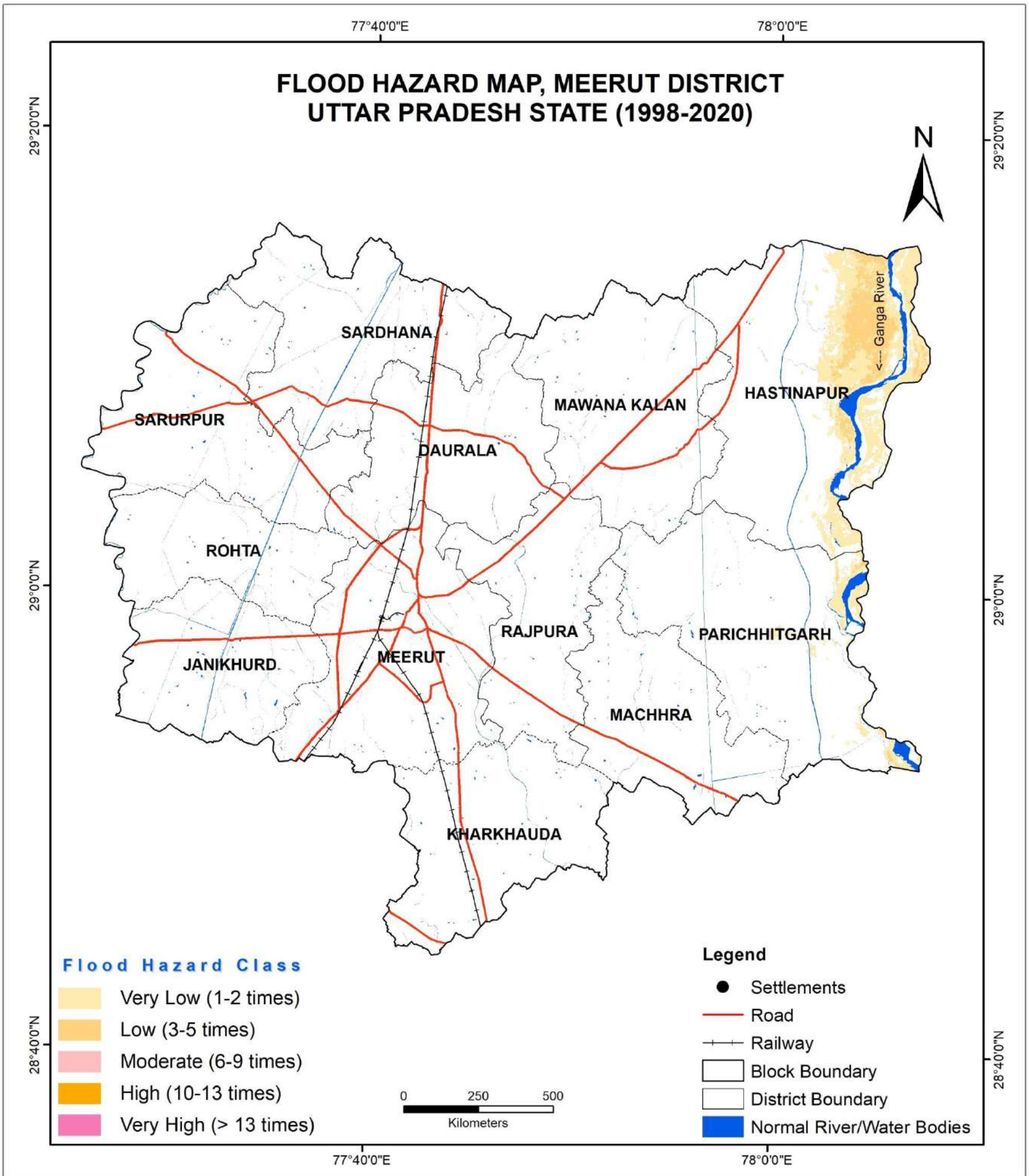
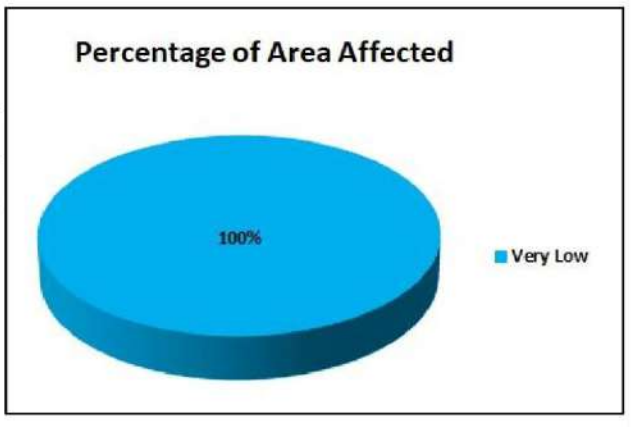
FLOOD HAZARD MAP, MEERUT DISTRICT
UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	5346
	Total	**5346**



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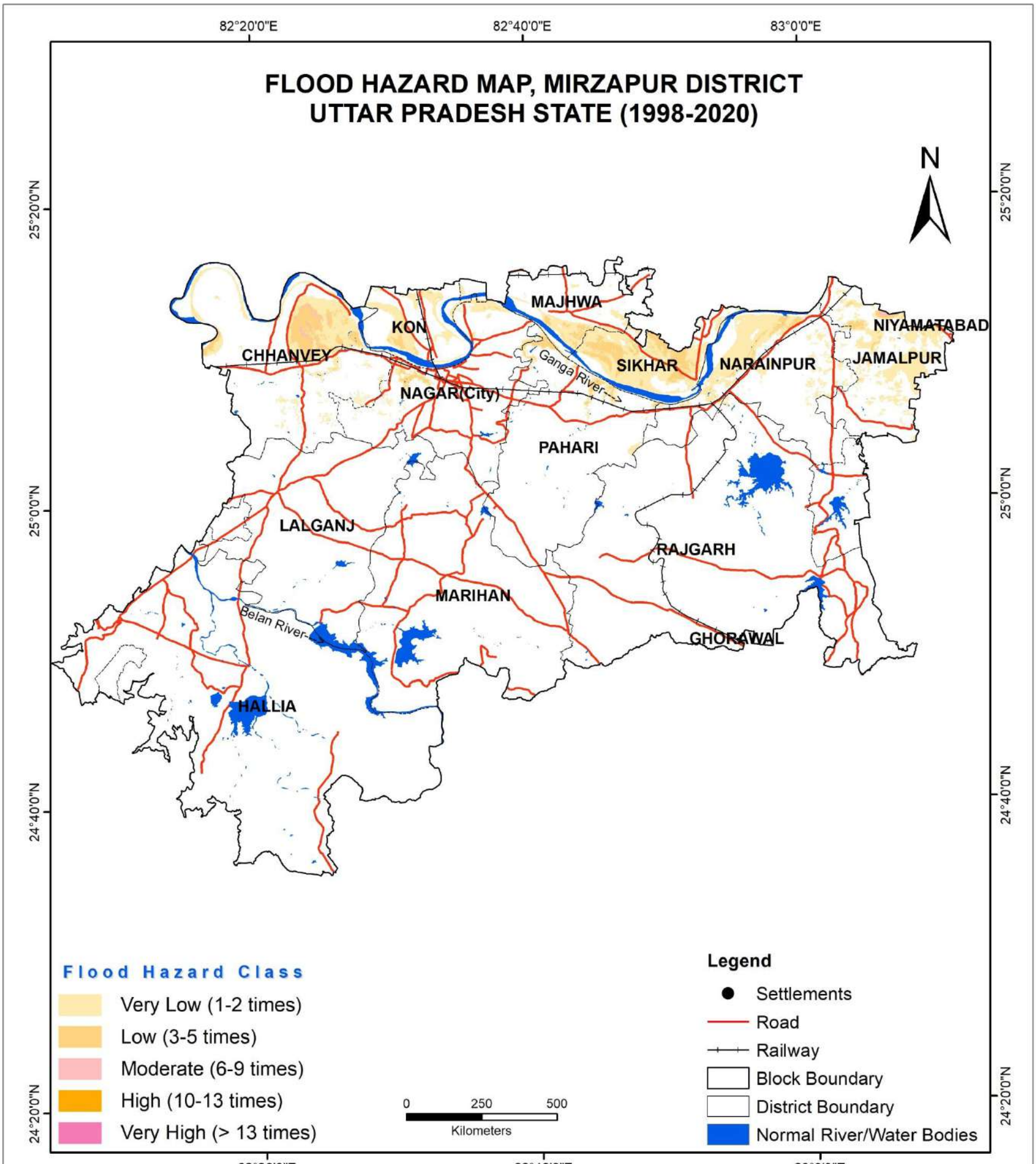
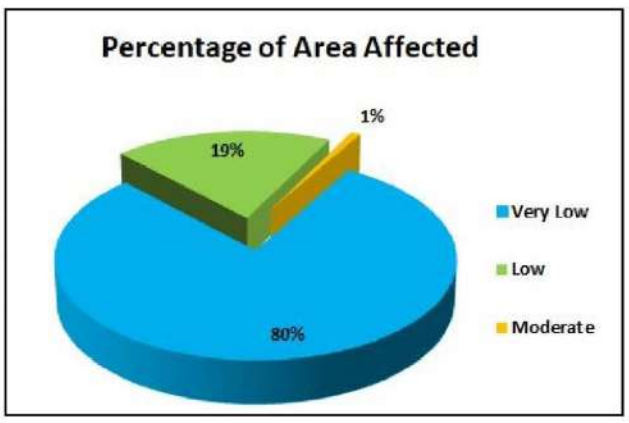
FLOOD HAZARD MAP, MIRZAPUR DISTRICT
UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	26316
2	Low	6467
3	Moderate	287
	Total	**33070**



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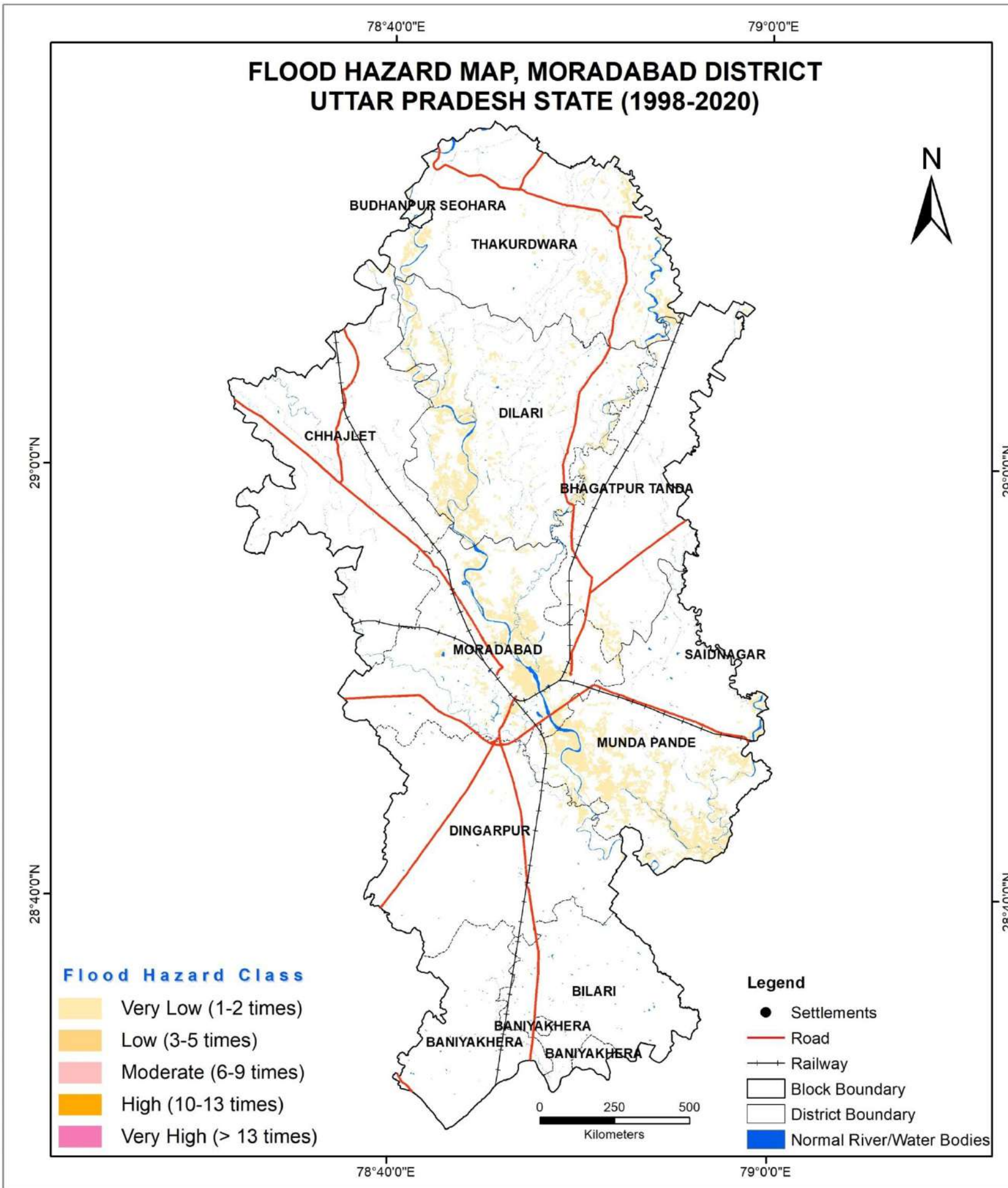
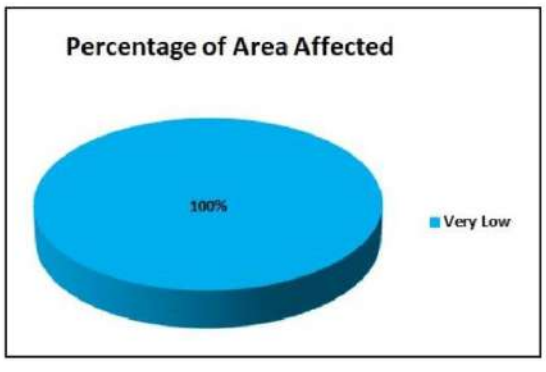
FLOOD HAZARD MAP, MORADABAD DISTRICT
UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	14778
	Total	14778



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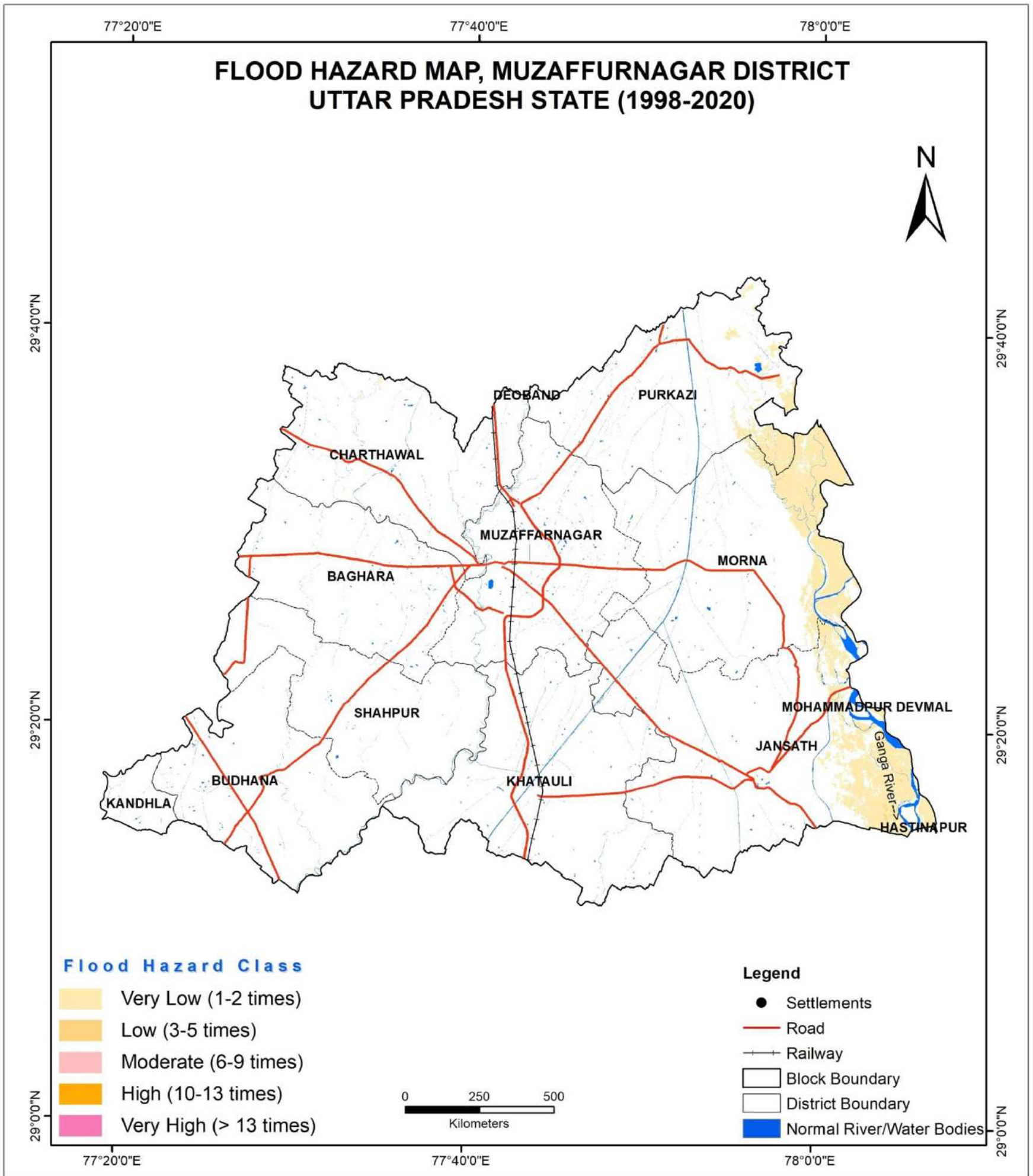
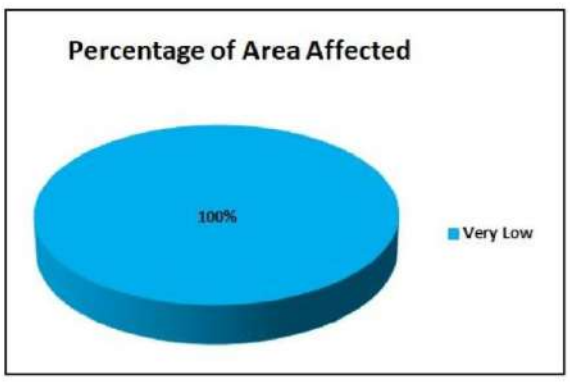
FLOOD HAZARD MAP, MUZAFFURNAGAR DISTRICT UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	14611
2	Low	66
	Total	14677



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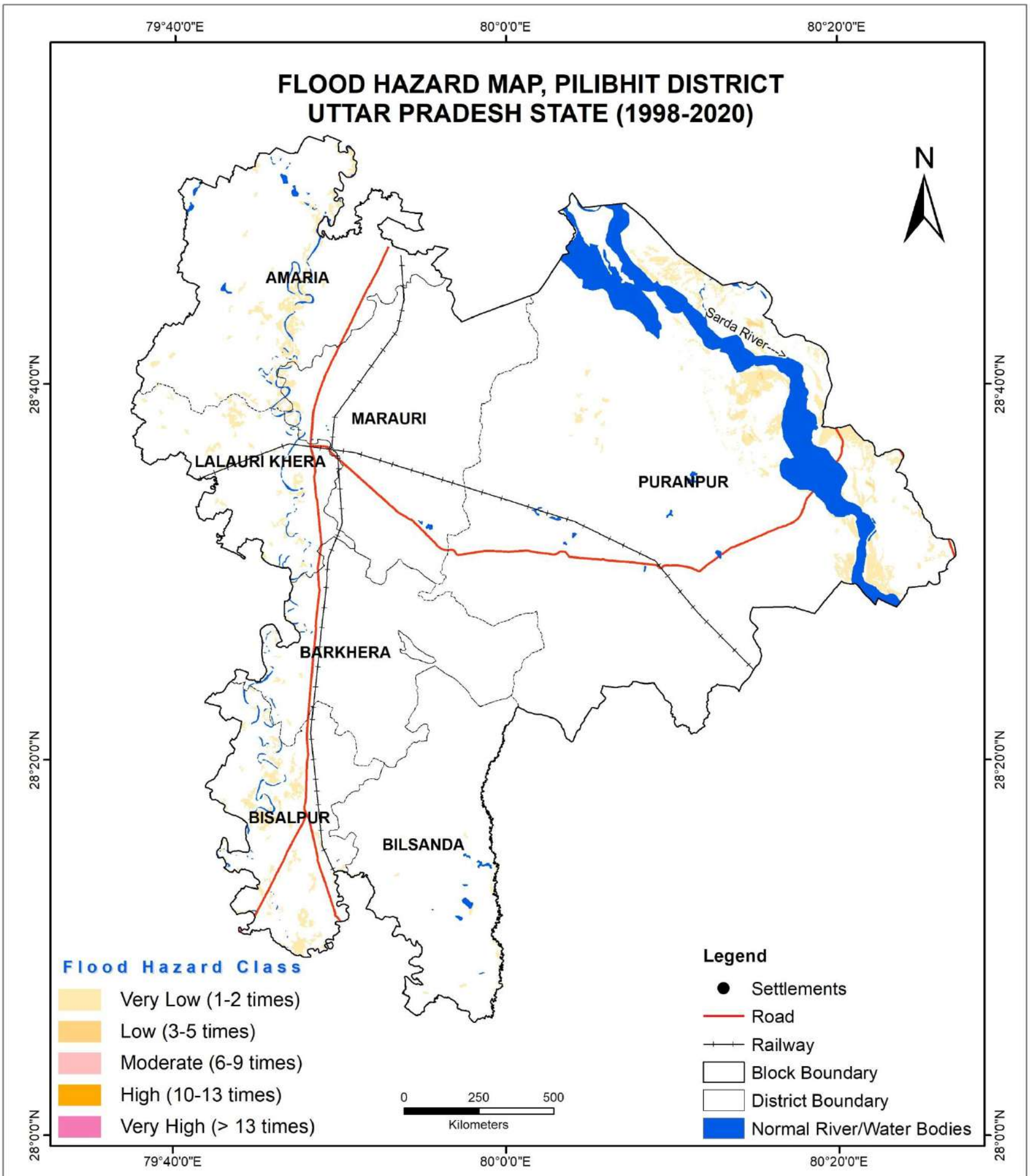
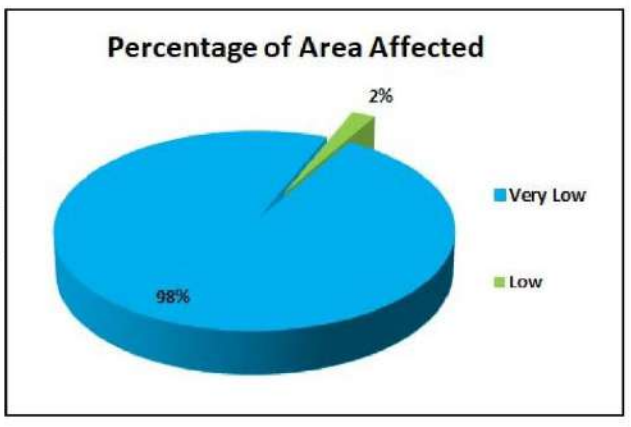
FLOOD HAZARD MAP, PILIBHIT DISTRICT
UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	13283
2	Low	289
	Total	**13572**



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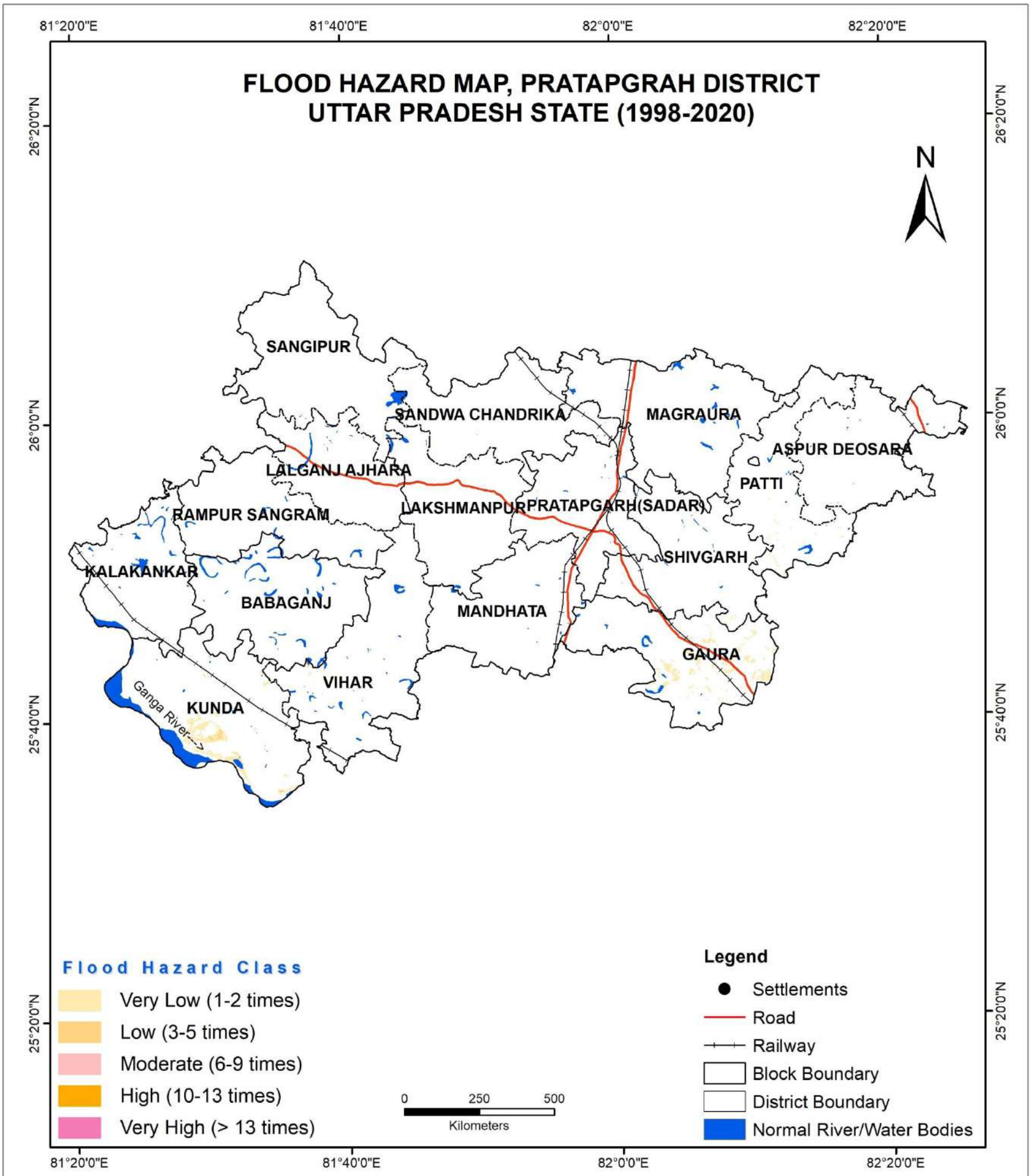
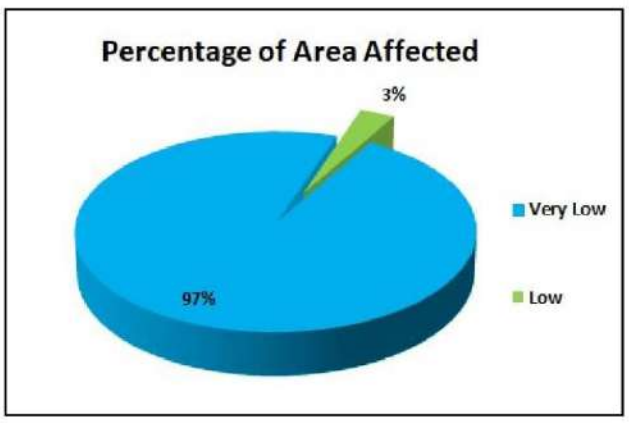
FLOOD HAZARD MAP, PRATAPGRAH DISTRICT UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	2784
2	Low	91
	Total	**2875**



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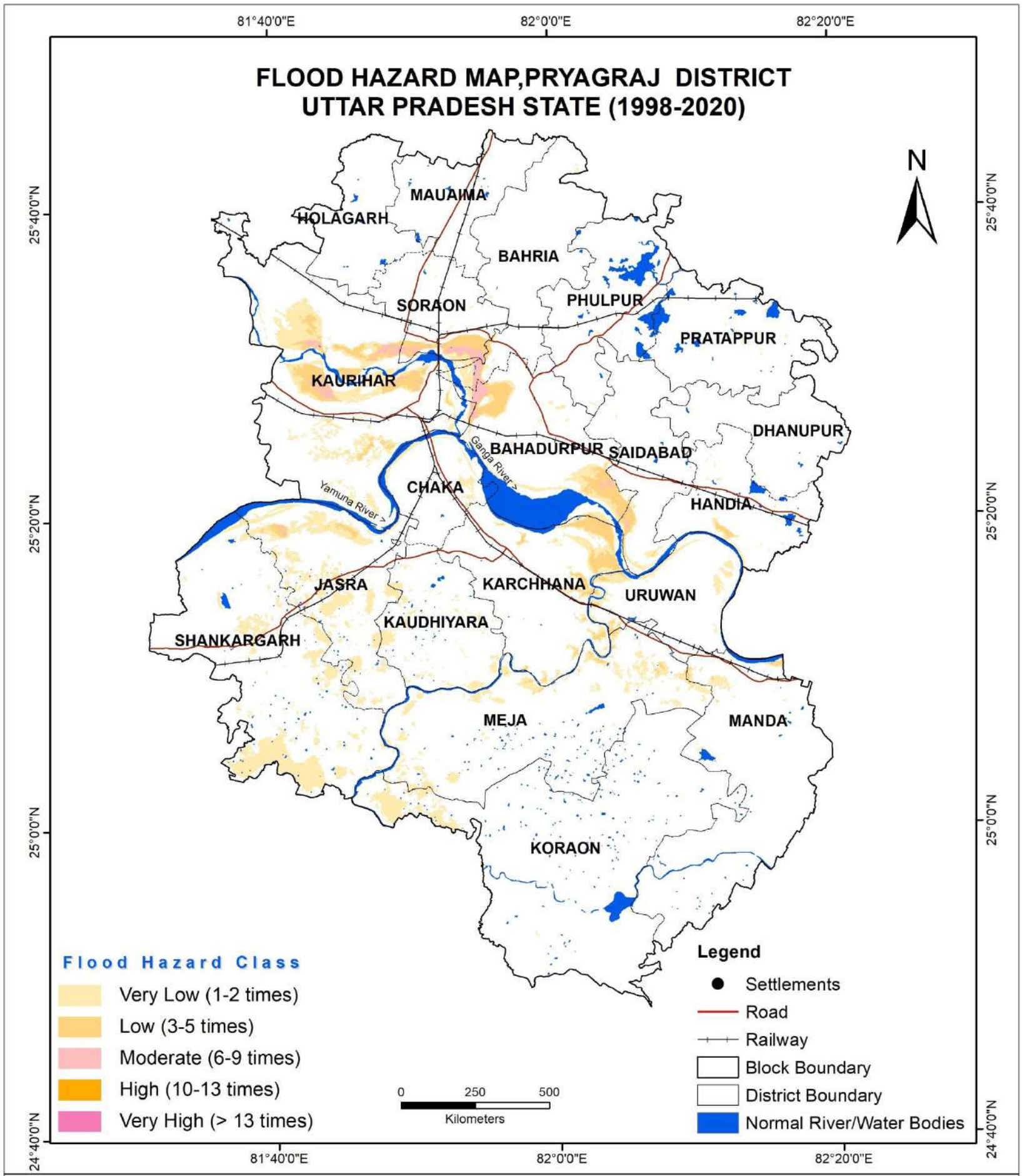
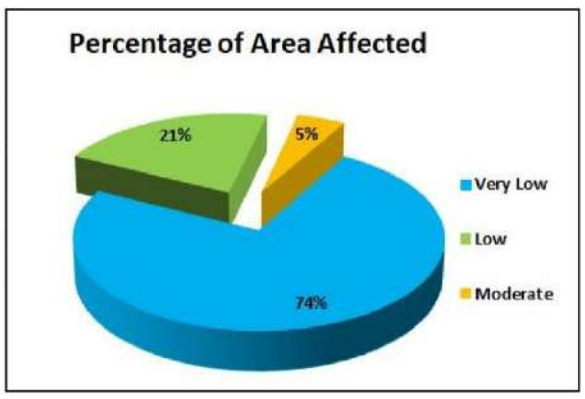
FLOOD HAZARD MAP,PRYAGRAJ DISTRICT UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	34173
2	Low	9801
3	Moderate	2190
	Total	**46164**



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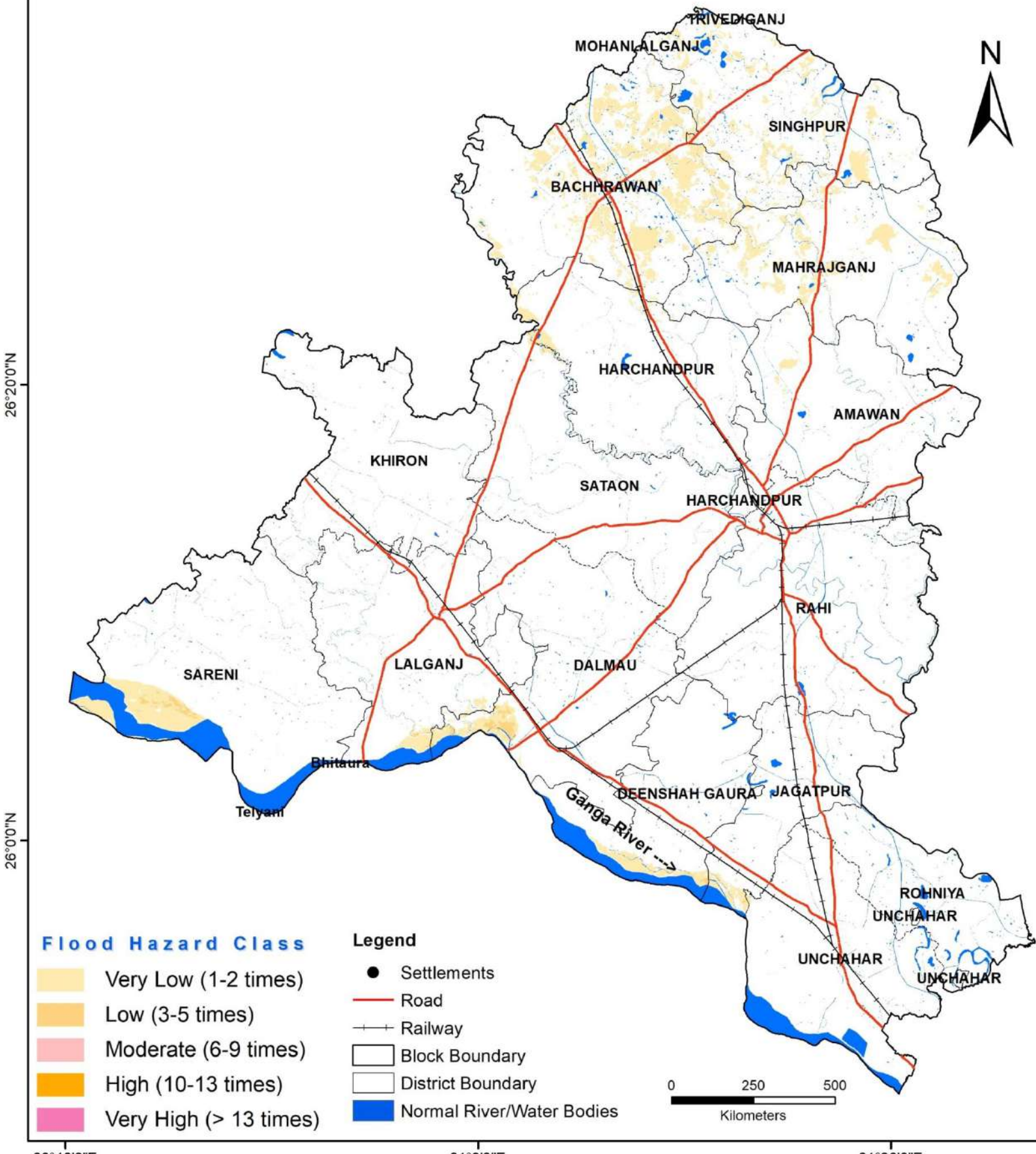
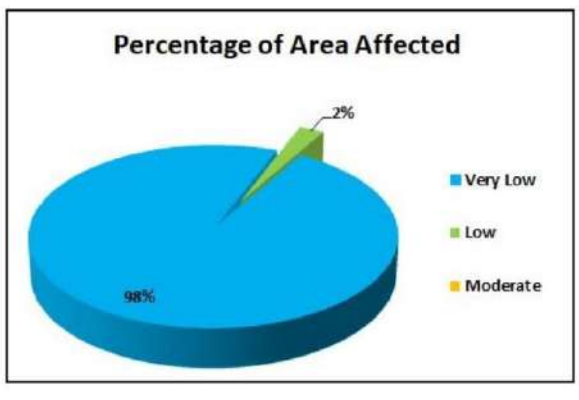
FLOOD HAZARD MAP, RAE BAREILI DISTRICT UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	16848
2	Low	421
	Total	17269



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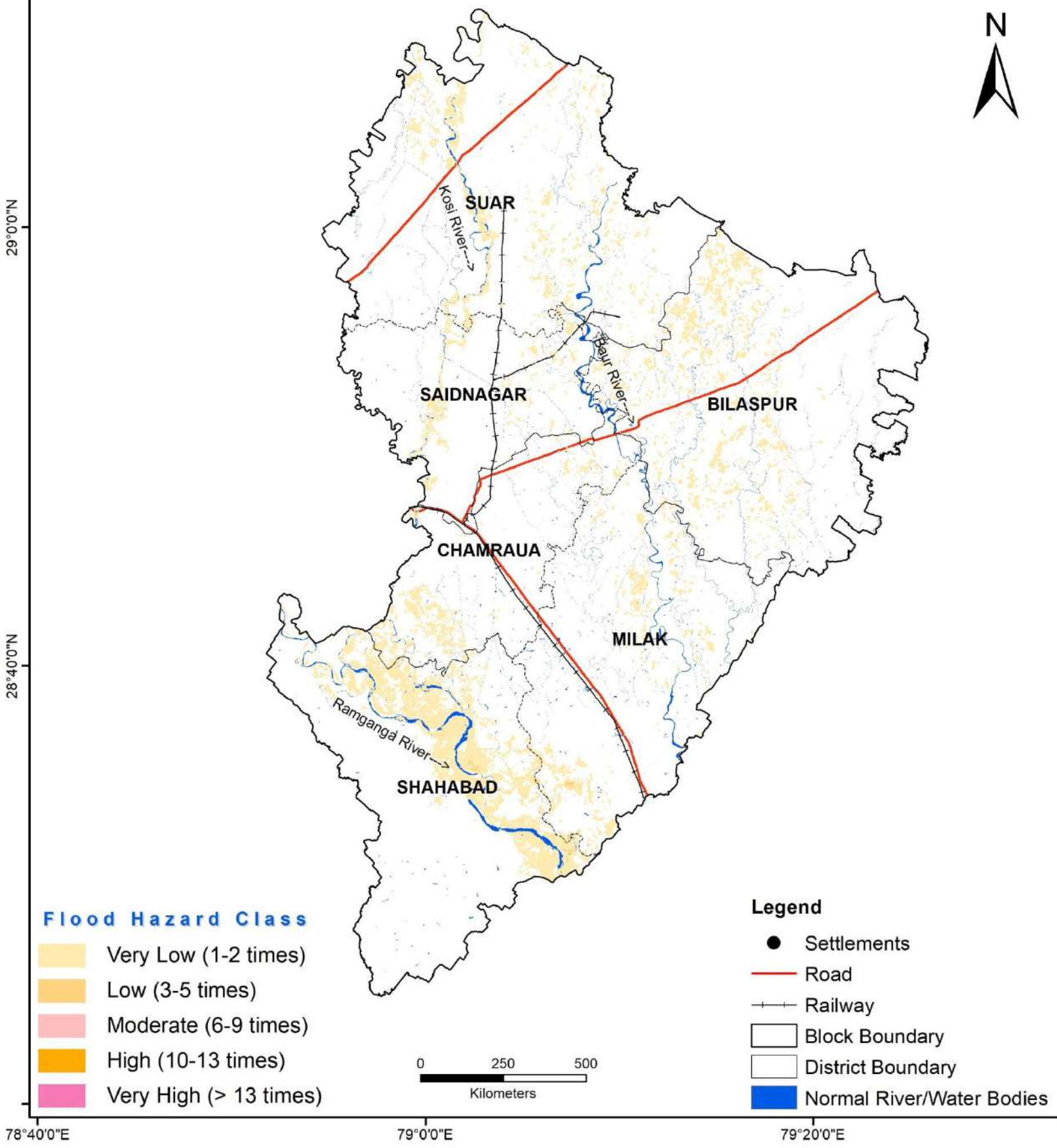
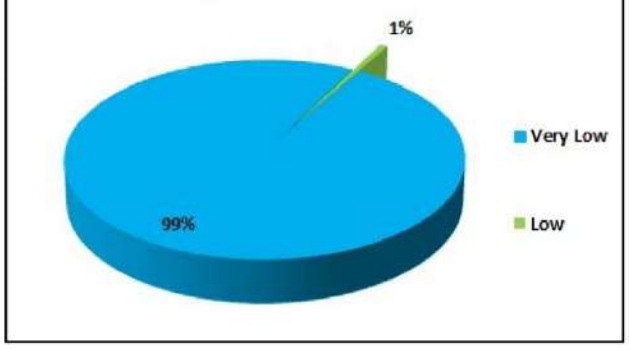
FLOOD HAZARD MAP, RAMPUR DISTRICT
UTTAR PRADESH STATE (1998-2020)



Location Map

S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	20738
2	Low	149
	Total	**20887**

Percentage of Area Affected



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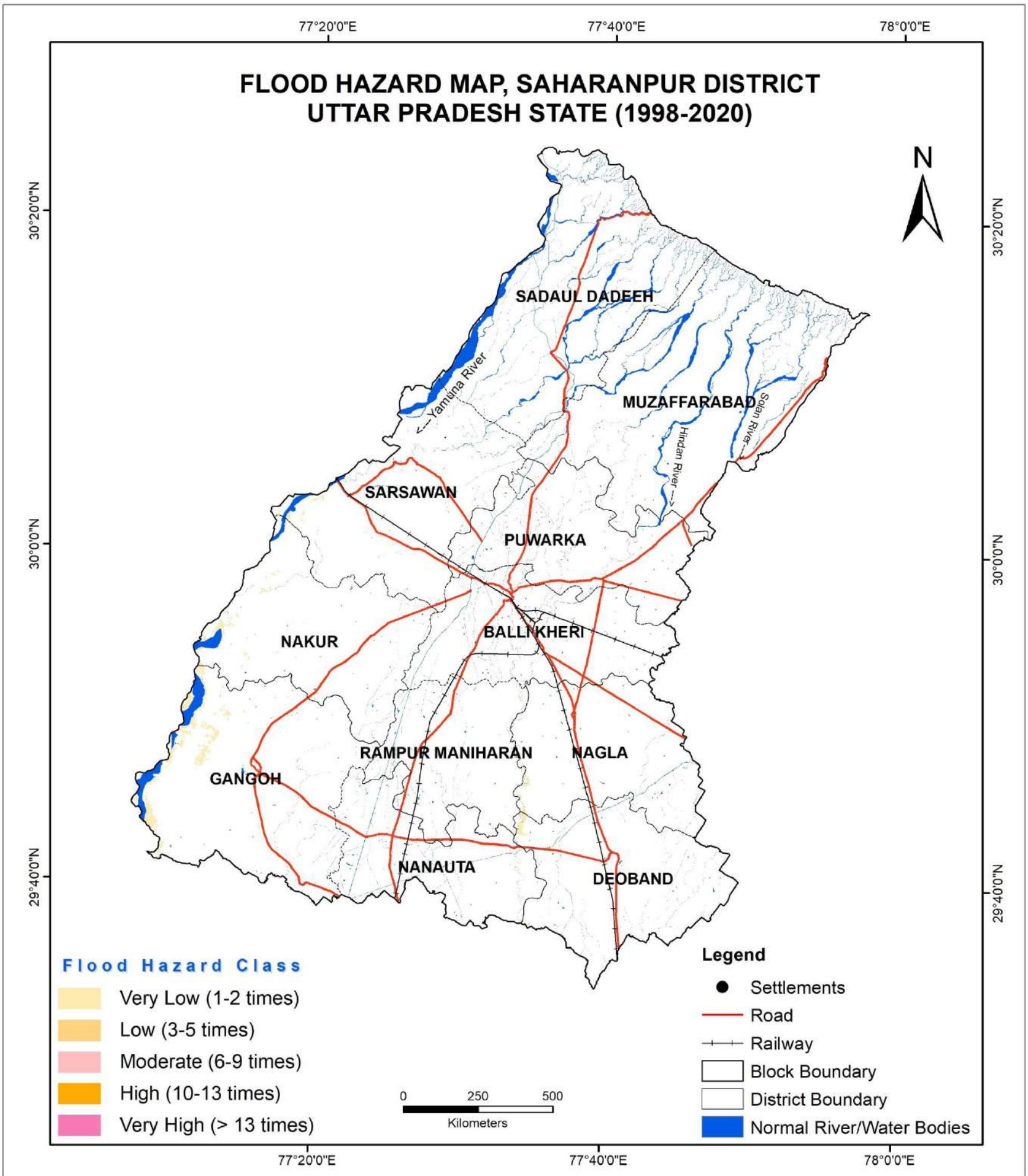
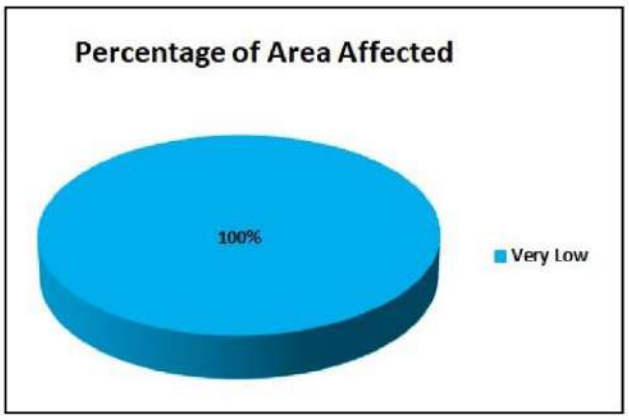
FLOOD HAZARD MAP, SAHARANPUR DISTRICT
UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	2248
	Total	**2248**



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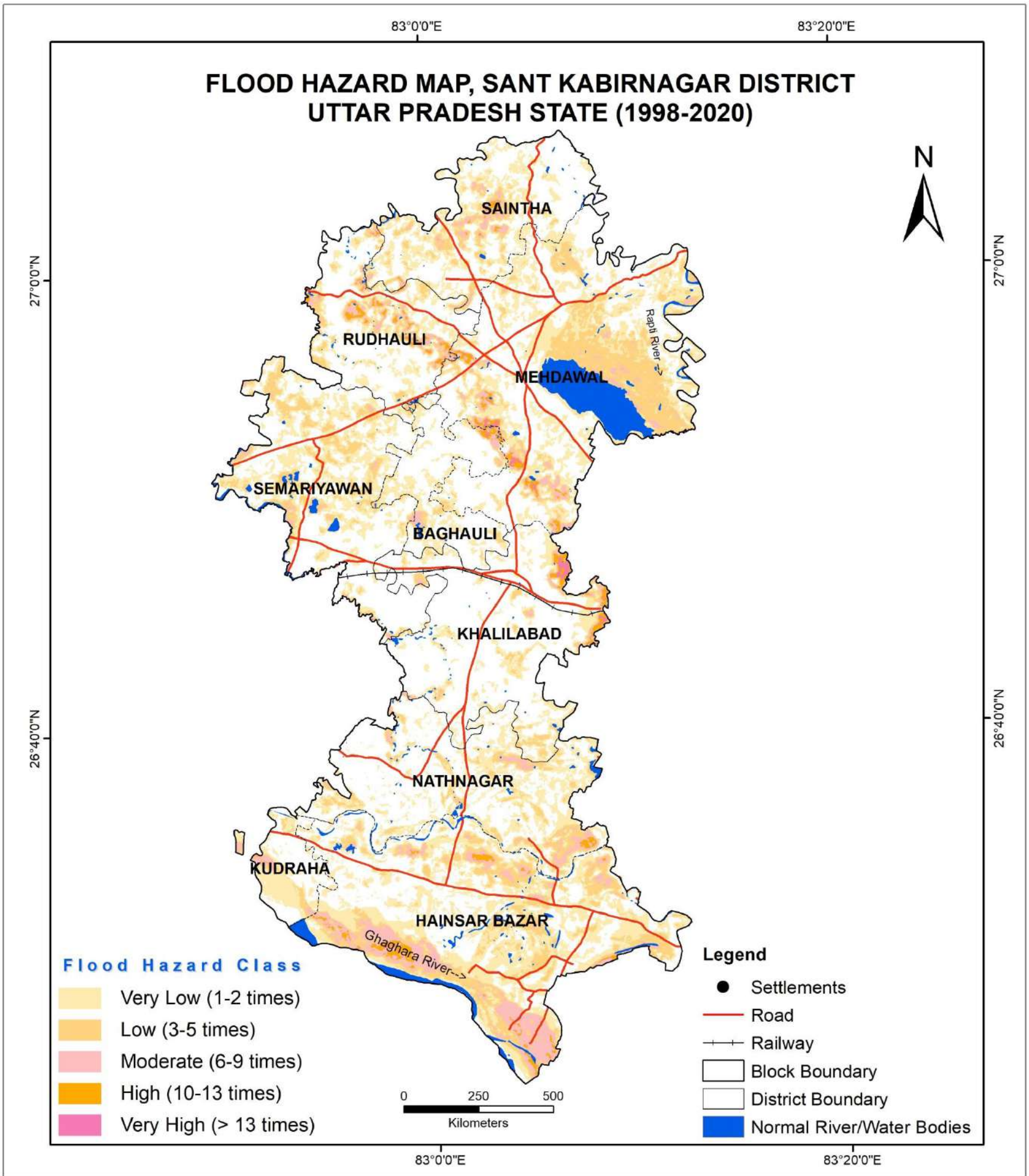
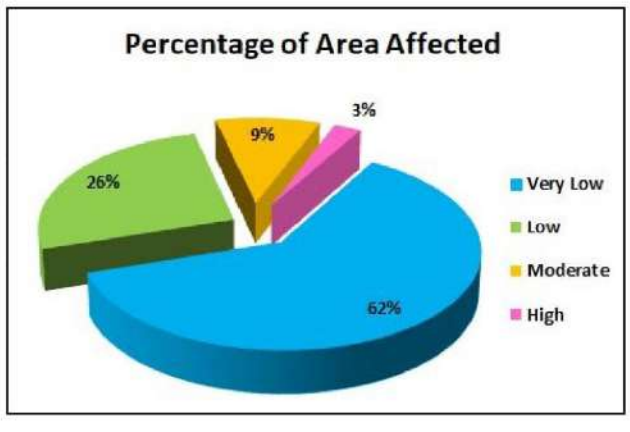
FLOOD HAZARD MAP, SANT KABIRNAGAR DISTRICT UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	44555
2	Low	18992
3	Moderate	6833
4	High	1789
5	Very High	258
	Total	**72427**



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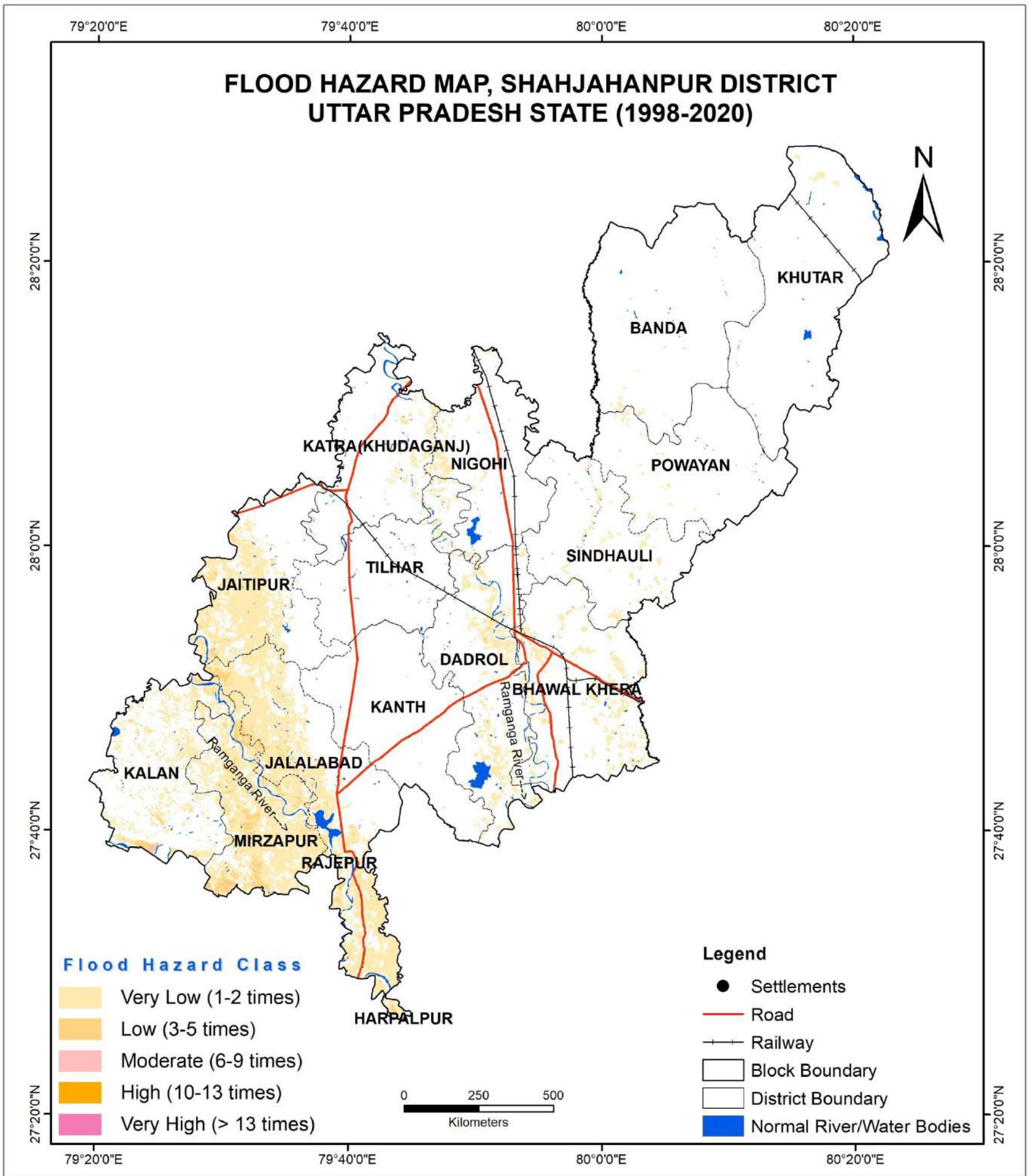
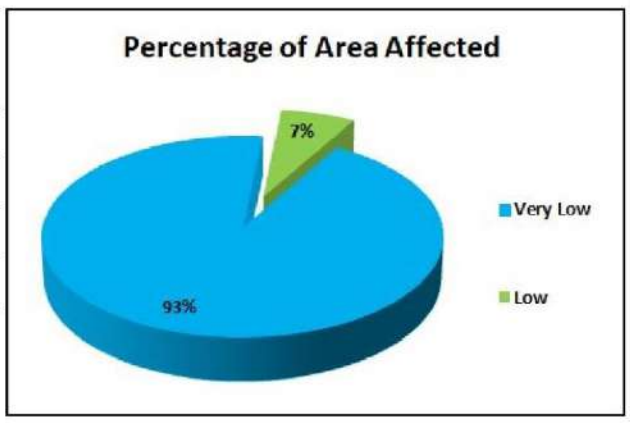
FLOOD HAZARD MAP, SHAHJAHANPUR DISTRICT UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	63366
2	Low	4550
3	Moderate	134
	Total	**68050**



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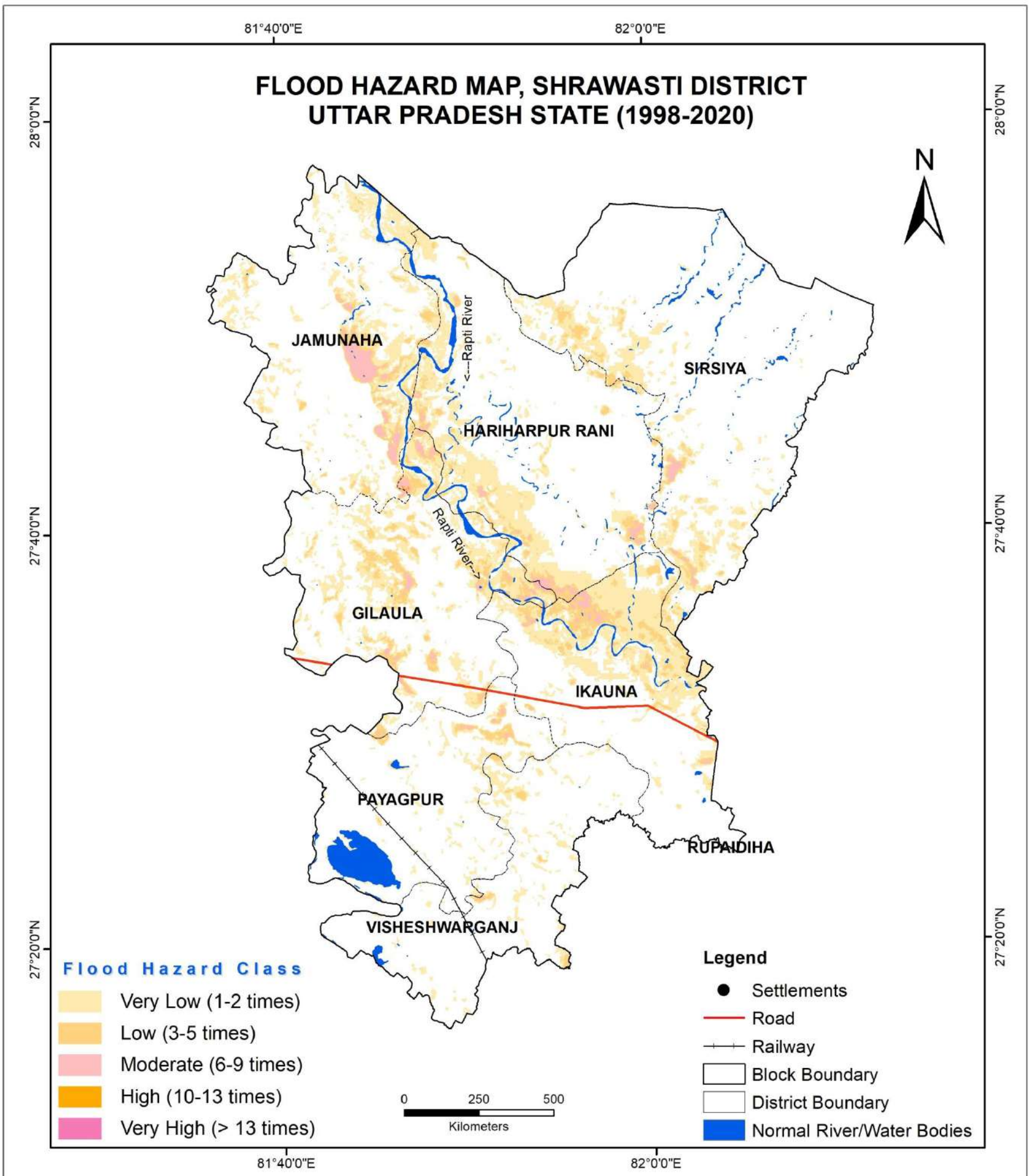
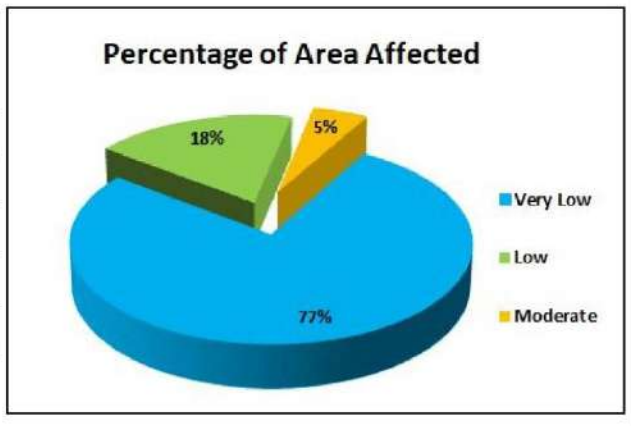
FLOOD HAZARD MAP, SHRAWASTI DISTRICT
UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	41299
2	Low	9713
3	Moderate	2701
4	High	12
	Total	**53725**



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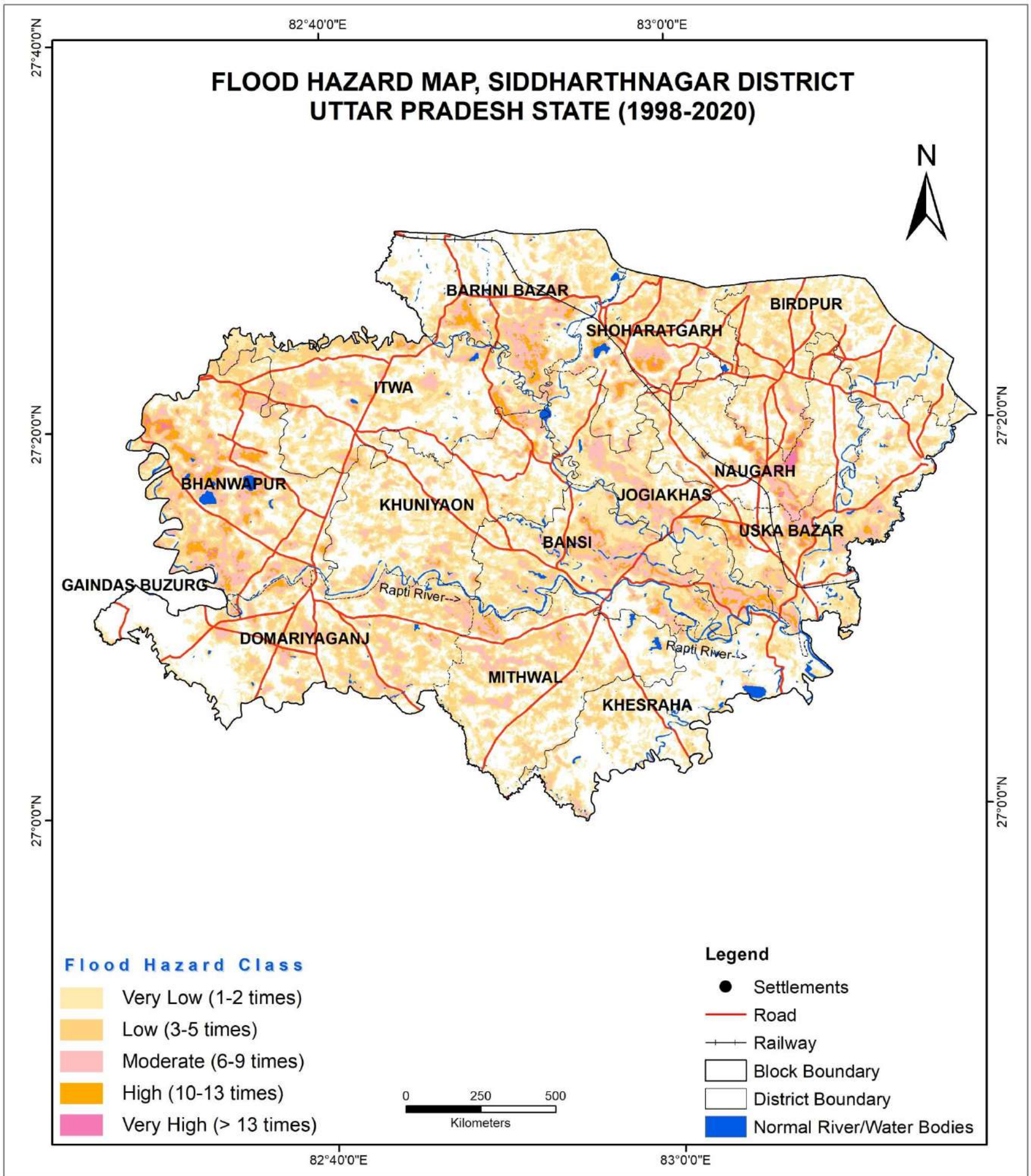
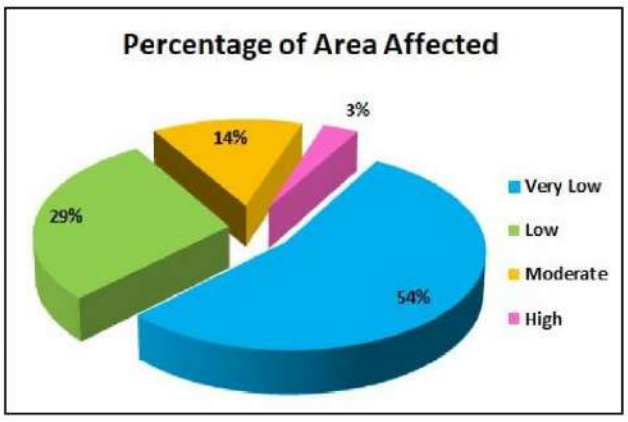
FLOOD HAZARD MAP, SIDDHARTHNAGAR DISTRICT UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	98060
2	Low	51893
3	Moderate	24671
4	High	5829
5	Very High	639
	Total	**181092**



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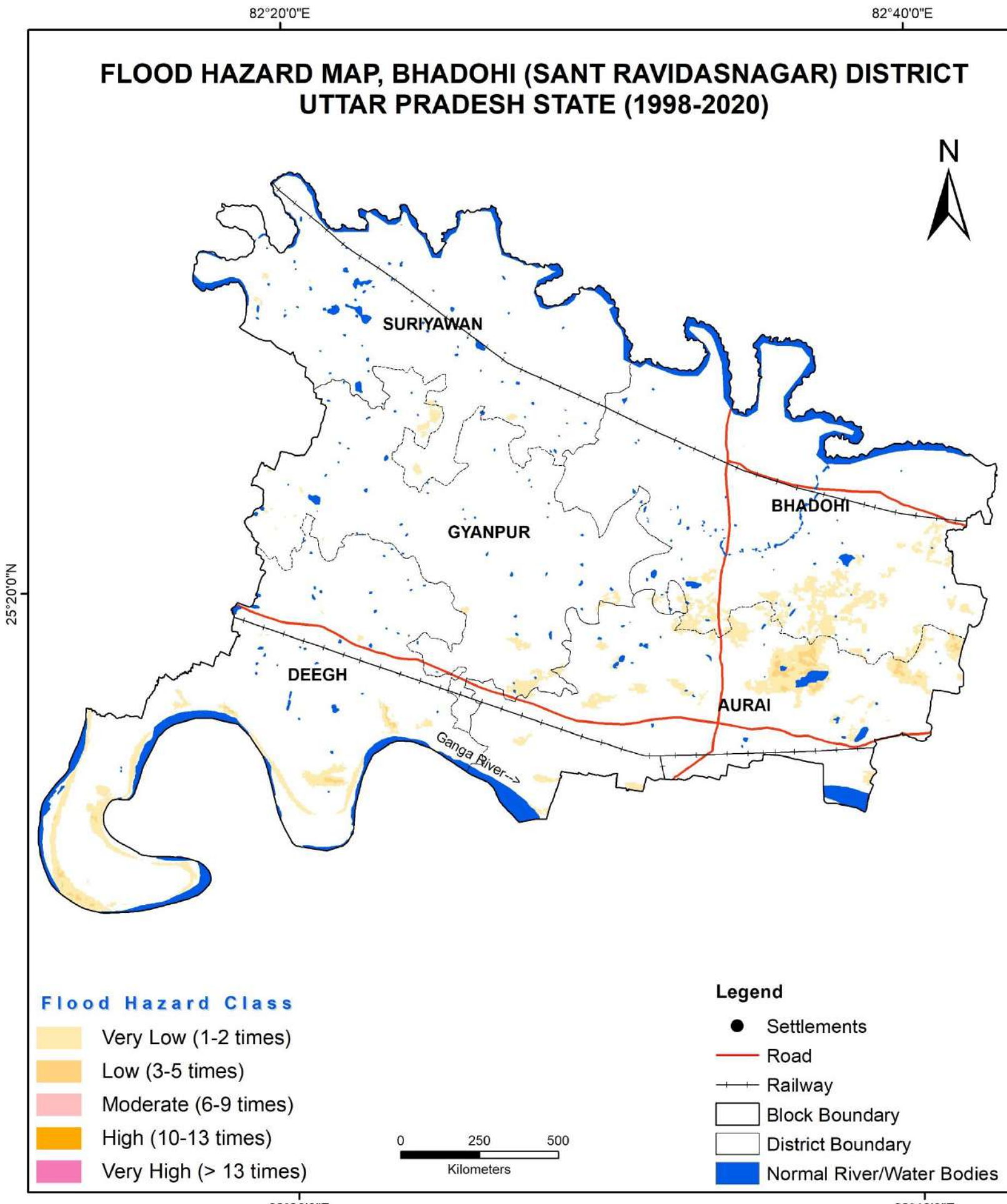
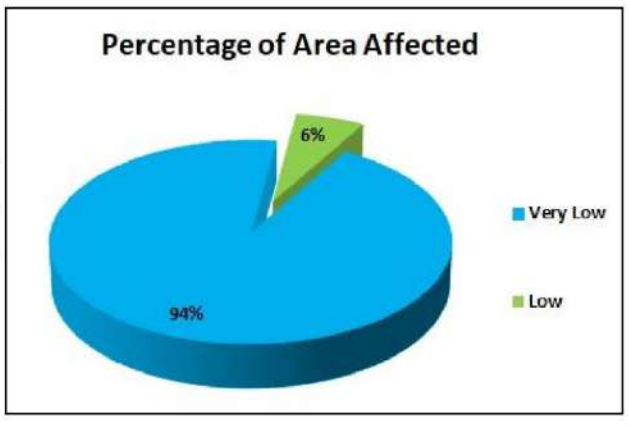
FLOOD HAZARD MAP, BHADOHI (SANT RAVIDASNAGAR) DISTRICT UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	4658
2	Low	308
	Total	**4966**



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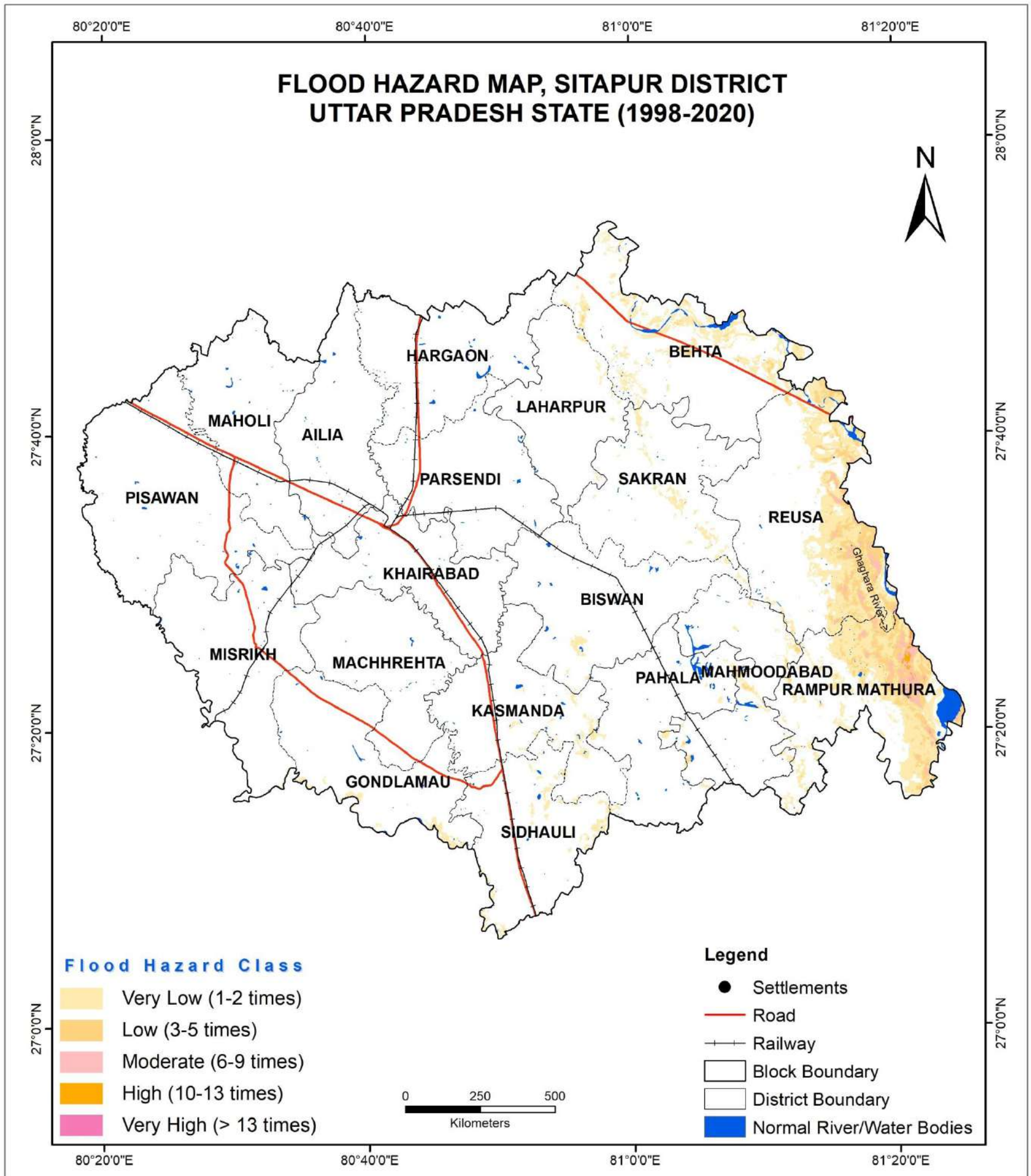
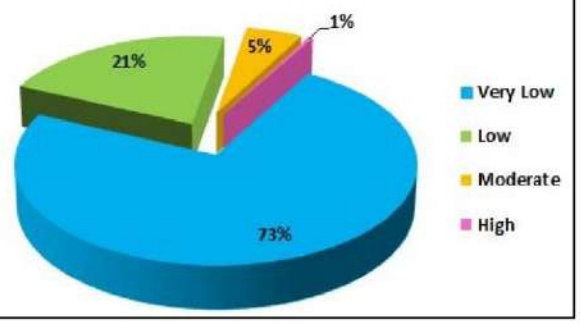
FLOOD HAZARD MAP, SITAPUR DISTRICT
UTTAR PRADESH STATE (1998-2020)



Location Map

S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	32299
2	Low	9256
3	Moderate	2230
4	High	195
	Total	**43980**

Percentage of Area Affected



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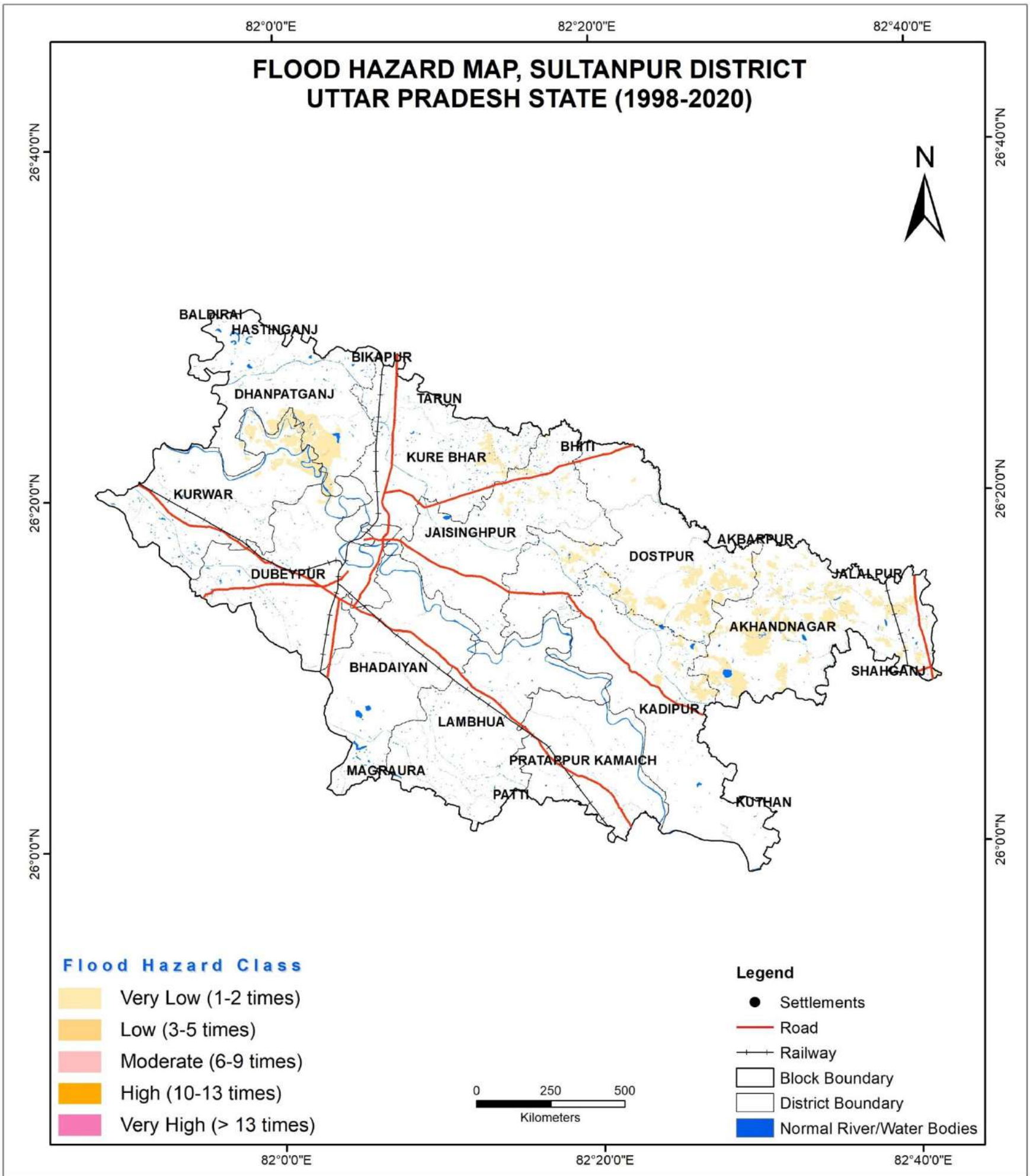
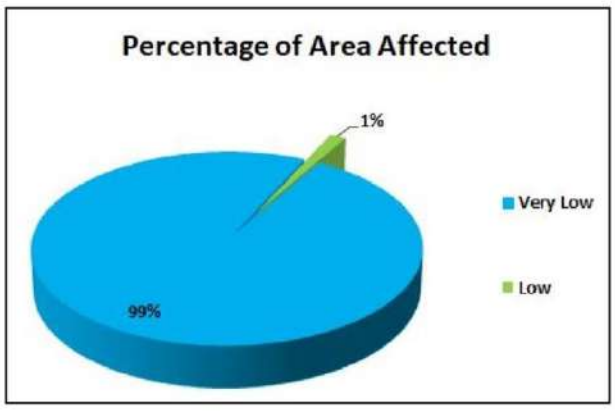
FLOOD HAZARD MAP, SULTANPUR DISTRICT
UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	12890
2	Low	79
	Total	12969



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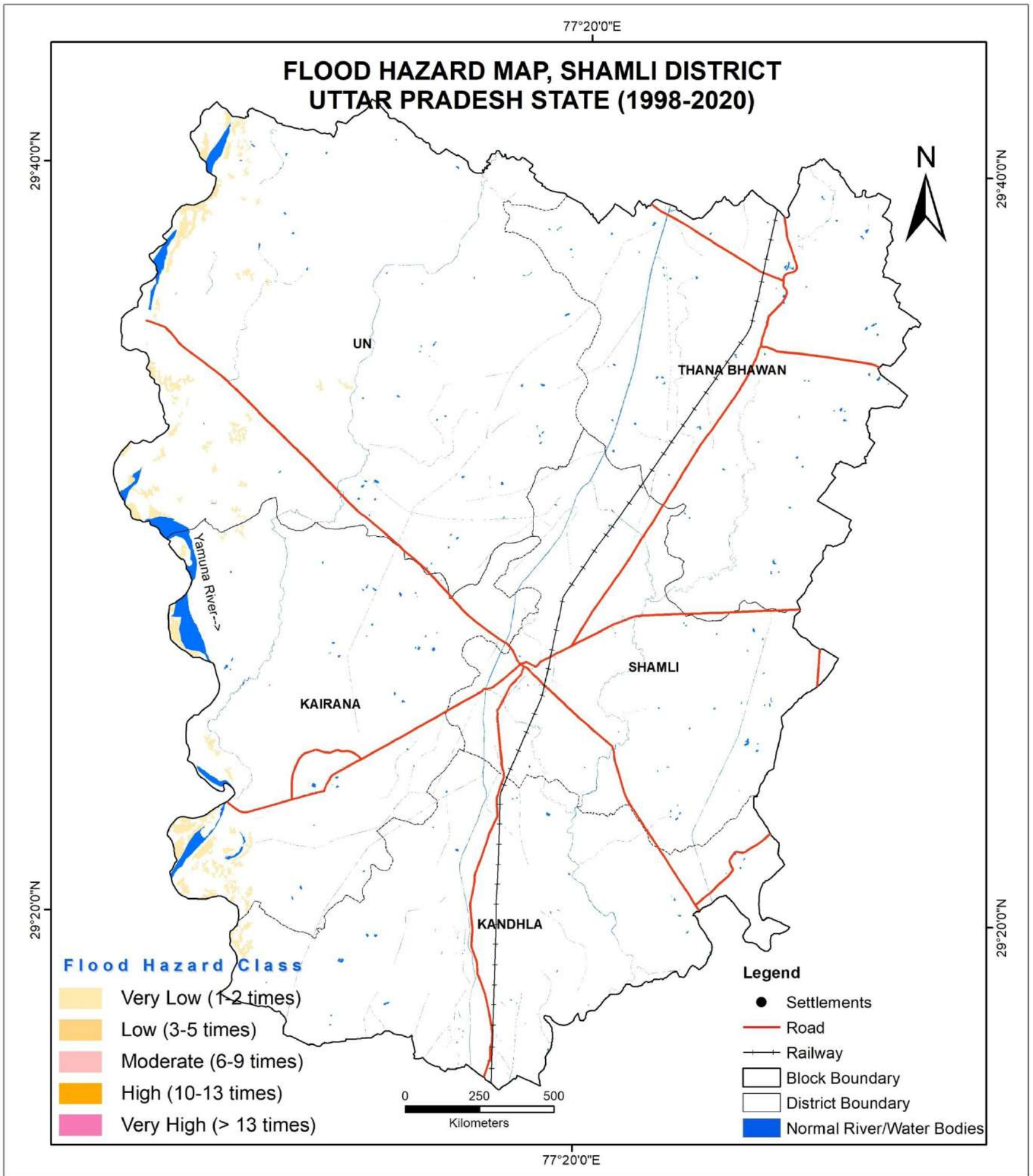
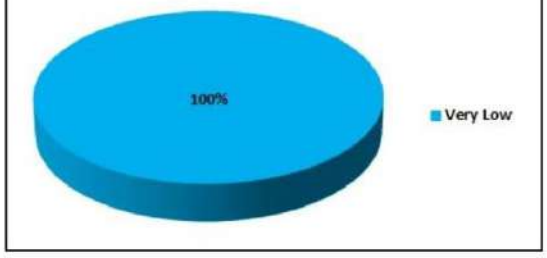
FLOOD HAZARD MAP, SHAMLI DISTRICT
UTTAR PRADESH STATE (1998-2020)



Location Map

S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	1505
	Total	1505

Percentage of Area Affected



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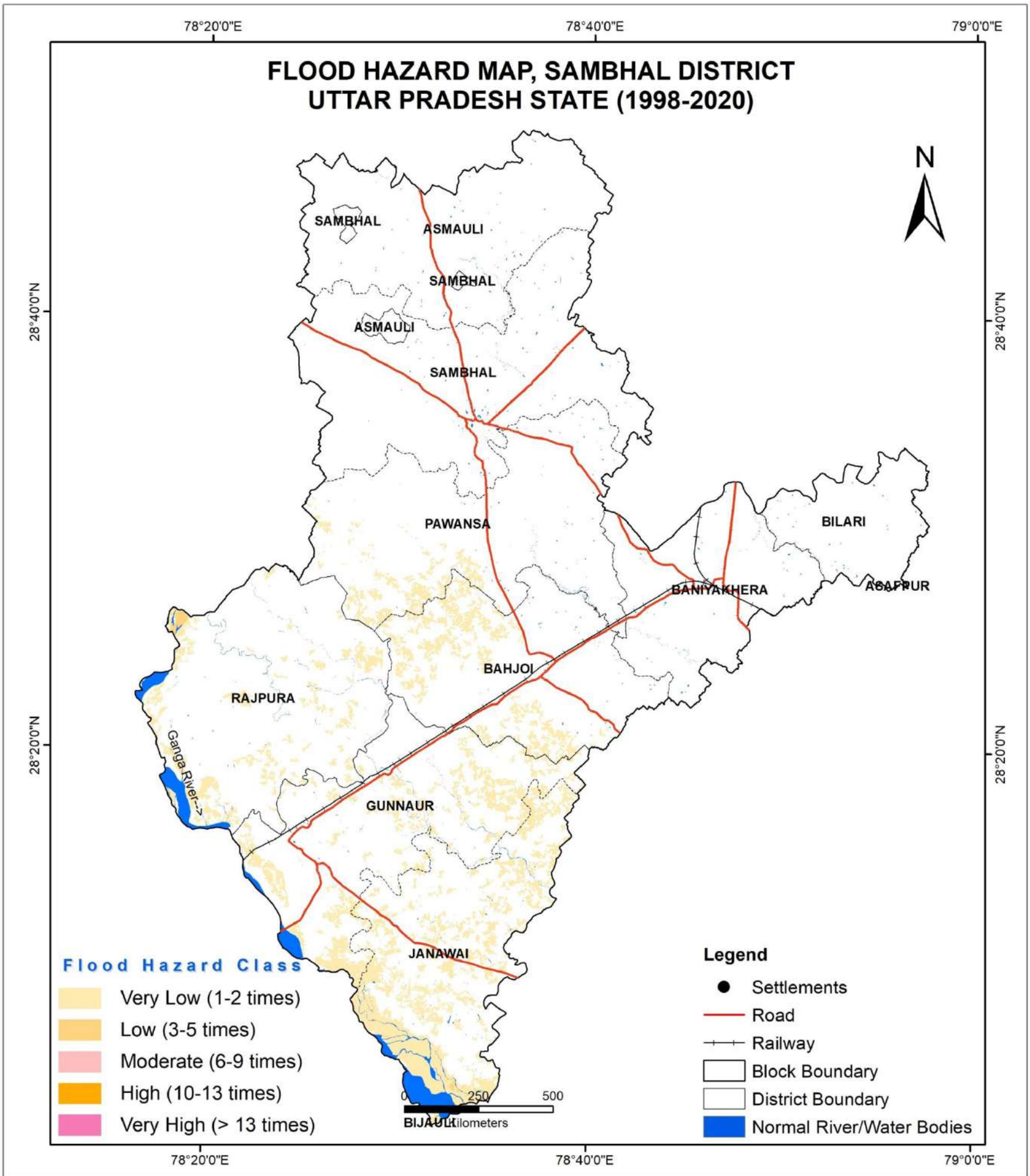
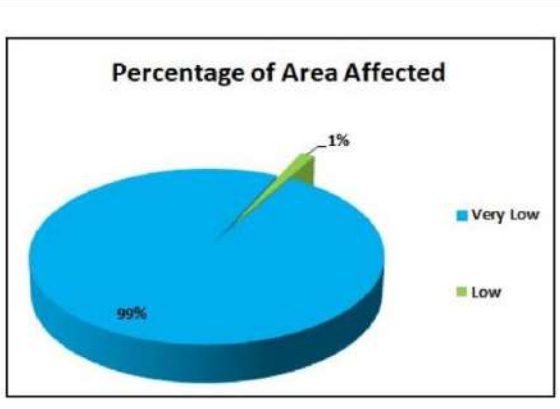
FLOOD HAZARD MAP, SAMBHAL DISTRICT
UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	21081
2	Low	195
	Total	21276



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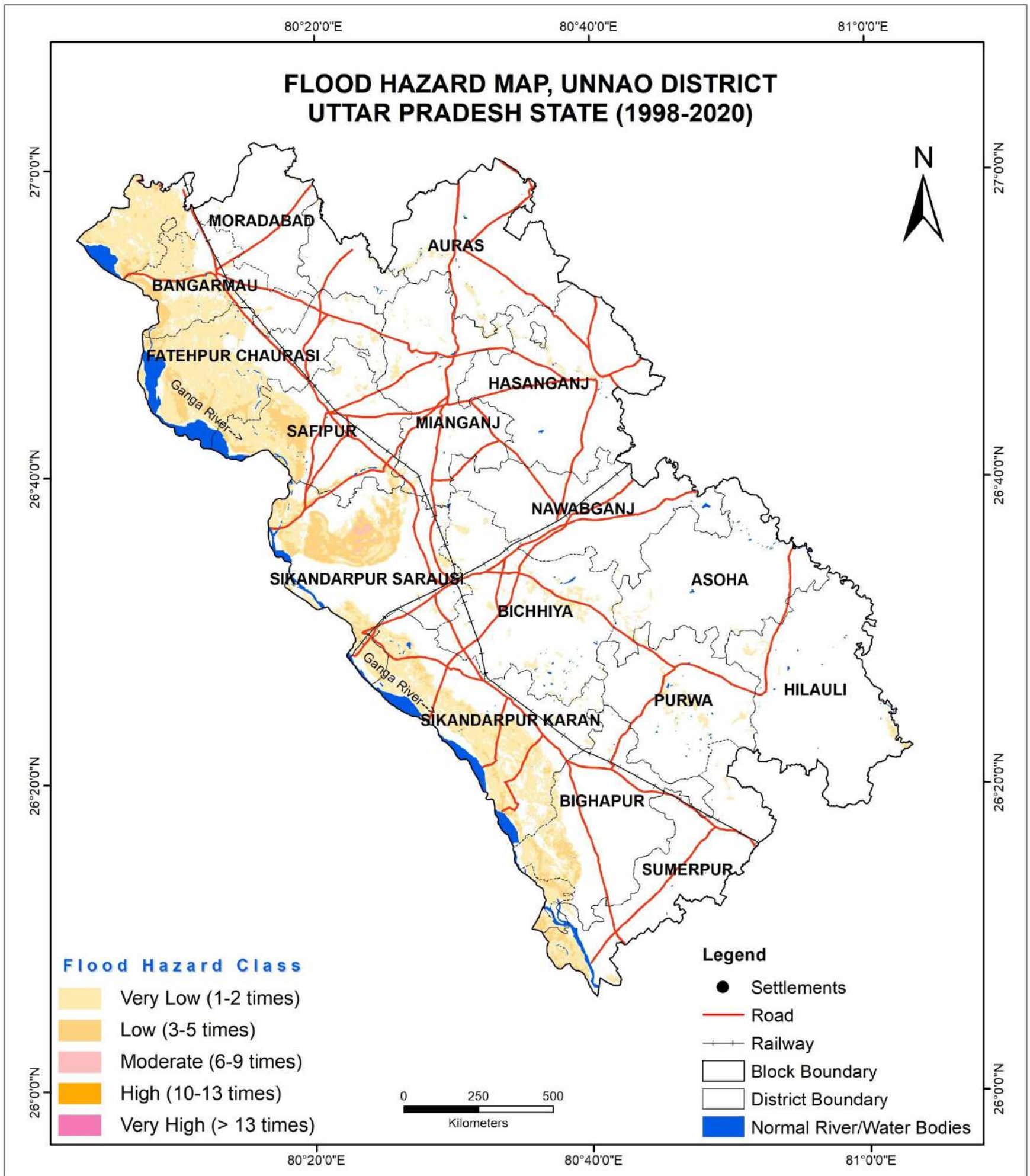
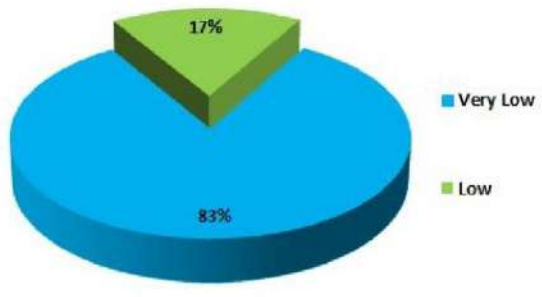
FLOOD HAZARD MAP, UNNAO DISTRICT
UTTAR PRADESH STATE (1998-2020)



Location Map

S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	58191
2	Low	12074
3	Moderate	248
	Total	**70513**

Percentage of Area Affected



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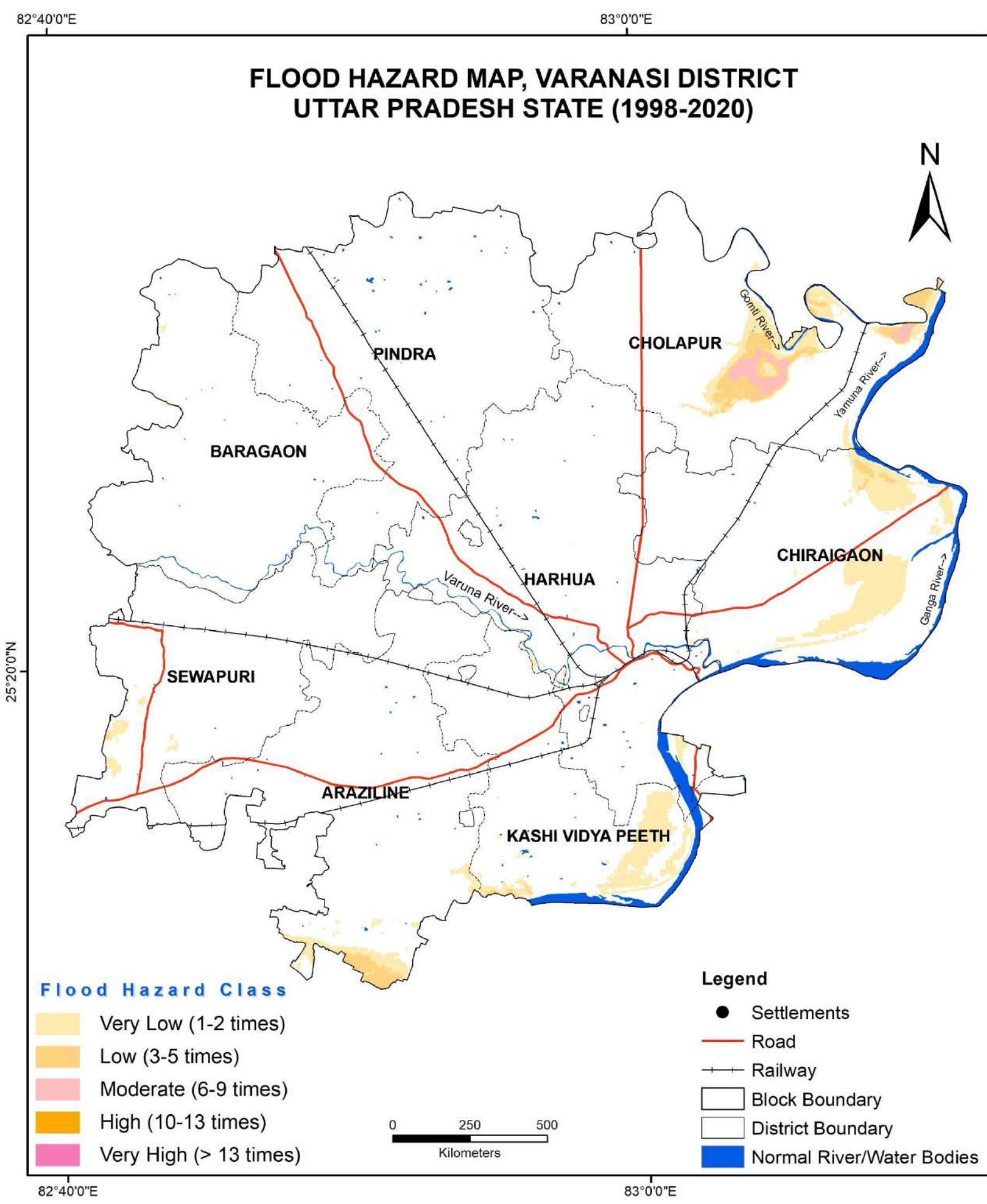
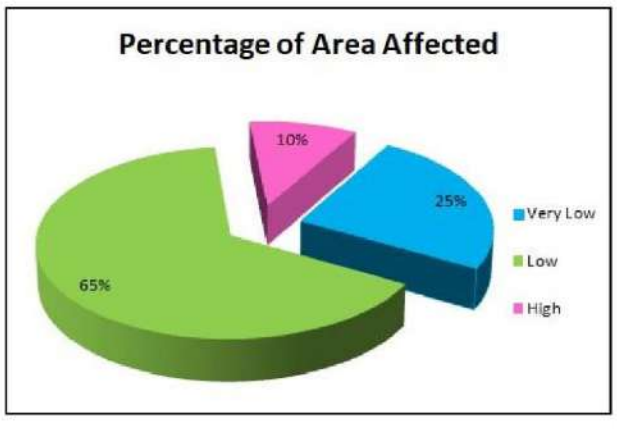
FLOOD HAZARD MAP, VARANASI DISTRICT
UTTAR PRADESH STATE (1998-2020)



S. No.	Hazard Severity	Flood Hazard Area (Ha)
1	Very Low	1972
2	Low	5171
3	Moderate	25
4	High	785
	Total	**7953**



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Annexure- II

District-wise list of villages falling in various hazard categories during 1998-2020

List of District-wise villlages falling in Moderate-Very High Hazard categories in UP state

S.No	DISTRICT	BLOCK	VILLAGE	HAZARD CATEGORY
1	Ambedkar Nagar	Tanda	MajhaAusanpur	Moderate
2	Azamgarh	Sagri	AraziDurgaya Patti	Moderate
3			AraziHathiyagarh	Moderate
4			AraziJhaptiya Mishra	Moderate
5			AraziKazi Amir Ahemad Jot	Moderate
6			AraziKhirujotKazi	Moderate
7			AraziLachhiman Kund	Moderate
8			AraziSemari	Moderate
9			Burhan Patti	Moderate
10			DewaraGirdhari Das	Moderate
11			DewaraHinduroy	High
12			Karim Ganj	Moderate
13			Mukhlis Patti	Moderate
14	Balrampur	Balrampur	Belha	HIGH
15			Dakahi	HIGH
16			Dhondhari	HIGH
17			Kalyanpur	HIGH
18			LalpurPhaguia	HIGH
19			Mirzapur	HIGH
20			TengnahiaMankot	HIGH
21			Adamtara	HIGH
22			Kailash Garh	HIGH
23			Kohar Gaddi Khader	HIGH
24			Lalajot	HIGH
25			Malda	HIGH
26			Tenduwa	HIGH
27			Akbarpur Kalan	MODERATE
28			Allah Nager	MODERATE
29			Bharwalia	MODERATE
30			ChichooriSihania	MODERATE
31			Faguia	MODERATE
32			Khajuria	MODERATE
33			Kundi	MODERATE
34			Lal Nagar	MODERATE
35			Madhwa Nager Khader	MODERATE
36			Majhari Tappa Wak	MODERATE
37			Masjidia	MODERATE
38			Nandouri	MODERATE
39			Odrahia	MODERATE
40			Pachautha	MODERATE
41			Rasoolabad	MODERATE
42			Rustam Nagar	MODERATE
43			Sahdeia	MODERATE
44			Sekhui Kalan	MODERATE
45			Sonhat	MODERATE
46			TilkhiBaraya	MODERATE
47			UtraulaRular	MODERATE
48			Tharuwa	VERY HIGH
49	Ballia	Bairia	Araji Mafi Jharkataha East	Moderate
50			Gobindauli	Moderate
51			Majha	Moderate
52			Man Garah	Moderate
53			Pandeypur Mu. Durjanpur	Moderate
54			Raja Tengaraha	Moderate
55			Shiwal	Moderate

S.No	DISTRICT	BLOCK	VILLAGE	HAZARD CATEGORY
.				
56		Ballia	Araji Mafi Kaithauli	Moderate
57			Badilpur	Moderate
58			Baghoonch	Moderate
59			Balua	Moderate
60			BandhuChak	Moderate
61			BankataPashchim	Moderate
62			Belhari	Moderate
63			Chitbara Gaon (np)	High
64			DhundhChhapra	Moderate
65			Fatehpur	Moderate
66			Kotwari	Moderate
67			Kurchundashinghpur	Moderate
68			Neura	Moderate
69			Parshotampur	Moderate
70			Pirakpur	Moderate
71			Pokhara	Moderate
72			Sateh Ezra	Moderate
73			Shahpur MutlkeAmao	Moderate
74			Tete Dad	Moderate
75			Tikari	Moderate
76		Bansdih	Chandpur	Moderate
77			Durgipur	Moderate
78			Gauri Shahpur	Moderate
79			GosaiPur	Moderate
80			Kamalpur Taluka Kharouli	Moderate
81			MarawattiyaNambari	Moderate
82			MarwattiaNoubrar	Moderate
83			Rampur Noubrar	Moderate
84		Sikanderpur	Chak Habib	Moderate
85	Barabanki	Ramnagar	Ganeshpur	Moderate
86			Puraina	Moderate
87			Ramnagar (np)	Moderate
88			Tapasipah	Moderate
89		Ramsanehighat.	Basant Pur	Moderate
90			Belkhara	High
91			Maila	Moderate
92		SirauliGauspur	Husainpur	Moderate
93	Basti	Basti	Ganawaria Kalan	Moderate
94			Goariya	Moderate
95			Gulawara	Moderate
96			Khorakhar	Moderate
97			RamlaUrfNatheepur	Moderate
98		Harraiya	ArajiDuhiJagwarpur Pure Pali	Moderate
99			ArajiMangla	Moderate
100			Bedpur	Moderate
101			Chakiya	Moderate
102			Chauperwa	Moderate
103			Ekdengwa	Moderate
104			GulauriBujurg	Moderate
105			Laxmanpur	Moderate
106			MajhaDalpatpur	Moderate
107			Mirjapur	High
108			Narwatiya	Moderate
109			Pikaura	Moderate
110			Sahjaura Pathak	Moderate

S.No	DISTRICT	BLOCK	VILLAGE	HAZARD CATEGORY
111			Shivpur	Moderate
112	Chandauli	Chakia	Keraogaon	Very High
113			Lewa Chittari	Very High
114			Patna	High
115		Chandauli	Bahadurpur	Moderate
116			Baradeeh	Moderate
117			Budhawar	Moderate
118			Chauhata	High
119			Dadi	Moderate
120			Jalilpur	High
121			Katesar	High
122			Kunda Kala	Moderate
123			Kunda_khurd	Moderate
124			Larawa	Moderate
125			Madiya	High
126			Mawai Kala	Moderate
127			Ratanpur	Moderate
128			Sahjaur	Moderate
129			Semara	High
130	Deoria	Barhaj	Sisawania	Moderate
131		Rudrapur	Baraipar	Moderate
132			Bishunpur	Moderate
133			Dala	Moderate
134			Jamira	Moderate
135			Malpatti	Moderate
136			NauwaBahbaj	Moderate
137			Sabdalpur	Moderate
138			Sikariya	Moderate
139			Sonbah	Moderate
140	Ayodhya	Ayodhya	Abboo Sarai	Moderate
141			DalpatpurManjha	Moderate
142		Sohawal	BhikhanPur	Moderate
143			Dostpur Raghu Manjha	Moderate
144			HazipurManjha	Moderate
145			ManjhaMaholi	High
146	Ghazipur	Mohammadabad	Chak Ahmad Khurd	Moderate
147			Chak Habib	High
148			Chak Ramji Pandit	Moderate
149			ChampapurChakDoyam	Moderate
150			ChampapurShikohabad	Moderate
151			ChampapurTafeUgarsen	Moderate
152			KakarGhatta	High
153			Karimuddinpur	Moderate
154			Khempur	Moderate
155			KothiaKodartal	Moderate
156			Lathudih	Moderate
157			Mustfabad	High
158			Narsinghpur	Moderate
159			Nizampur	Moderate
160			PawpattiSome	Moderate
161			Raipur M.lauwadih	Moderate
162			Rampur Bisambhar Rai	High
163			Rampur Hirday Rai	Moderate
164			Sonwarsa	Moderate
165			Sultanpur	Moderate
166			Tal Bandial	High
167			Talgondoor	Moderate

S.No	DISTRICT	BLOCK	VILLAGE	HAZARD CATEGORY
168	Gonda	Gonda	Durga Ganj	MODERATE
169			Gabhora	MODERATE
170			Deipur	HIGH
171			Lolpur	HIGH
172	Gorakhpur	Gola	Alavlpur	Moderate
173			Bachhepar	Moderate
174			Baghi	Moderate
175			Bairia Khas	Moderate
176			Barhalganj (np)	High
177			BarhyaTikar	Moderate
178			BelawaDakhili	Moderate
179			Belsari	Moderate
180			Besahani	High
181			Bharhupur	Moderate
182			Bheridih	Moderate
183			Bihula	High
184			Dhudhuri	Moderate
185			Gyankol	Moderate
186			Hinguhar	High
187			Jagadishpur	High
188			Kabitapur	High
189			Katha Dari	Moderate
190			Kharesari	Moderate
191			Kohara Bhawar	Moderate
192			Koili Khal	Moderate
193			Kol Khas	Moderate
194			Kolhua	High
195			Korar Tiwari	Moderate
196			Lakhnaura	High
197			Lakhnauri	High
198			Lal Bhagana	Moderate
199			Maibhara	High
200			Markari	Moderate
201			Marwatia	Moderate
202			MohalJalkar	Moderate
203			Murera Beni Prasad	Moderate
204			Nachana	Moderate
205			Paratapipur	Moderate
206			Pharsar	Moderate
207			Pirahani	High
208			Sahrauli	Moderate
209			Son Gadaha	Moderate
210			Subedar Nagar	High
211			Tharuadih	Moderate
212		Gorakhpur	Bargo	Moderate
213			Bhagraranee	Moderate
214			Bhatehari	Moderate
215			Bishunpur Khurd	Moderate
216			Chhinuteejam	Moderate
217			Chiutaha	Moderate
218			JangalNandlal Singh	Moderate
219			JangalRamgarhwa	Moderate
220			Jharwa	Moderate
221			Kasthaiya	Moderate
222			Kharkatwa	Moderate
223			Kolua	Moderate
224			KoraraUrfDefara	Moderate

S.No	DISTRICT	BLOCK	VILLAGE	HAZARD CATEGORY
225			Lalpur Murli	Moderate
226			Manjharia	Moderate
227			Mohmmadpur Mafi	Moderate
228			Siuria	Moderate
229			Sonbarsa	Moderate
230			Telia Deeh	High
231			Thakurpur No.1	Moderate
232		Sahjanwa	BansipurUrfKachha	Moderate
233			BarparyaKaji	Moderate
234			BaryabharUrfNakaha	Moderate
235			Basahi	Moderate
236			Basiyakhor	Moderate
237			Beili Kund	Moderate
238			Beldar	Moderate
239			BenipurUrfBishunpur	Moderate
240			Bhaluan	Moderate
241			Bharauli	Moderate
242			Bharvalia	Moderate
243			BhulanChak	Moderate
244			Bishambhra	Moderate
245			Chatai	Moderate
246			Chaudia Masan	Moderate
247			ChihariUrf Kachhi	Very High
248			Dadauna	Moderate
249			Dhanaipur	High
250			Dhubaha	Moderate
251			Gathuakhore	High
252			Gherya	Moderate
253			Goda	Moderate
254			Gorsaira	Moderate
255			Govraur	Moderate
256			Jagarnathpur	Moderate
257			JamauliBujurg	High
258			Jamauli Khurd	Moderate
259			JaminBishunpura	Moderate
260			JaminGovraur	Moderate
261			KasbaSangrampur	Moderate
262			Katauta	Moderate
263			Katwar	Moderate
264			KotiyaBishuni	Moderate
265			Lamati	Moderate
266			Madhopur	Moderate
267			Mahuadan	Moderate
268			MajhaKamhariaJadid	Moderate
269			Majhadip	Moderate
270			Majhili	Moderate
271			Miura Kharagrampur	Moderate
272			Miuri	Moderate
273			Nahar Dewa	Moderate
274			Nakauri	Moderate
275			Parsauni	Moderate
276			Pharasadan	High
277			Raksababu	Moderate
278			Raksanara	Moderate
279			RasulpurMisra	Moderate
280			Ratsahi	Moderate
281			Rohua	Moderate

S.No	DISTRICT	BLOCK	VILLAGE	HAZARD CATEGORY
282			Sahidabad	Moderate
283			Saryachandpar	Moderate
284			Sema	Moderate
285			Sohara	Moderate
286			Thathur	Moderate
287	Hamirpur	Hamirpur	Hamirpur (mb)	Moderate
288	Maharajganj	Maharajganj	Mohanapur	Moderate
289			ParasaBuzurg	Moderate
290			Piparia	Moderate
291		Pharenda	Tal Berha	Moderate
292	Mau	Ghosi	Burhawar	Moderate
293			Tikari Khurd	Moderate
294		Madhuban	ChakkiMusadohi	Moderate
295	Mirzapur	Chunar	Ajijganj	Moderate
296			Araji Line Sultanpur	High
297			ArajiMisirpur	Moderate
298			Araji Saraiya Sikandarpur	Moderate
299			ArajiSonbarsa 753	Moderate
300			Bagahi	Moderate
301			Baghera	High
302			Basaratpur	Moderate
303			Bhawanipur	High
304			Bhelampur	Moderate
305			Bidapur	Moderate
306			Bisunpur	Moderate
307			Bisunpur	Moderate
308			Bitthalpur	Moderate
309			ChakBadh	Moderate
310			ChakBasaratpur	Moderate
311			ChakGanghar	Moderate
312			ChakGhariyari	Moderate
313			ChakKhajua	Moderate
314			ChakMilki	Moderate
315			ChakPipri	Moderate
316			ChakTisaha	Moderate
317			Chanchalia	Moderate
318			Chandapur	High
319			Chaudharipur	High
320			Churamanpur	High
321			Darra	Moderate
322			DeenanathpurUrfRatanpur	Moderate
323			Dhanaita	High
324			Dharammerpur	High
325			DheerpurUrfPiprahi	High
326			Dugari	Moderate
327			Gangpur	High
328			GobindpurUrfDhannupur	High
329			Goraiya	Moderate
330			Gorakhi	Moderate
331			Govindpur	Moderate
332			Ishwarpatti	High
333			Jagdishpur	Moderate
334			Jamalpur Milki	High
335			Kashipur	Moderate
336			KataduhiKhaira	Moderate
337			KataduhiPaho	Moderate
338			Keshavpur	High

S.No	DISTRICT	BLOCK	VILLAGE	HAZARD CATEGORY
339			Khaira	Moderate
340			Khanpur	Moderate
341			Lamawa	Moderate
342			Larchhut	Moderate
343			Lorhawa	Moderate
344			Madara	Moderate
345			Maharachh	High
346			Majhara Kalan	High
347			Majhara Khurd	High
348			MajhawaTaras	High
349			Marhia	High
350			Mawaiya	High
351			Meghupur	Moderate
352			Meria	High
353			Misirpur	Moderate
354			Muinuddinpur	High
355			Muzahidpur	High
356			Nakahara	Moderate
357			Niyamatpur Kalan	High
358			Niyamatpur Khurd	High
359			Pasiyahi	Moderate
360			Phulahan	Moderate
361			Premapur Khurd	High
362			Ram Rai Pur	High
363			Ramdaspur	Moderate
364			Ramgarh Kalan	High
365			Rudauli	High
366			Saidpur	Moderate
367			Sajhauli	Moderate
368			Shahpur Mafi	Moderate
369			Shilpi	Moderate
370			Shivpur	High
371			Sonbarsa	Moderate
372			Tal Bisai Mut. Adalpura	Moderate
373			Adampur	Moderate
374			Adhwar	High
375			Ajabpur	High
376			Akabarpatti	Very High
377			Akorhi	Very High
378			Akorhi	High
379			AnurudhpurPashchami Patti	Moderate
380			AnurudhpurPurab Patti	Moderate
381			Arjunpur	Moderate
382			Arjunpur	Moderate
383		Mirzapur	Babhani Mu. Parawa	High
384			Babu Patali	Moderate
385			Babura	Very High
386			Baisukhia	High
387			Bajaha	Moderate
388			Balapur	Moderate
389			BalliParwa	High
390			Bari	Moderate
391			Basewara Kalan	High
392			Basewara Khurd	High
393			Bhaidpur	High
394			Bhatewara	High

S.No	DISTRICT	BLOCK	VILLAGE	HAZARD CATEGORY
395			Bhatewara	Moderate
396			Bhogaon	High
397			Bihari	High
398			Birohi	High
399			Bishunpur	High
400			ChakMahraura	Moderate
401			ChakMajhali Patti	Moderate
402			Chehara	Moderate
403			Churaman Patti	High
404			Dalapatti	High
405			Danghar	Moderate
406			Datti Patti	High
407			Dev Parwa	High
408			Devipur	Moderate
409			Dhanikpur	High
410			Dharam Dhar Pur	High
411			Dharamdas Patti	High
412			Dhaurahara	Moderate
413			Digur Patti	High
414			Dubey Patti	High
415			Dugauli Kantit	High
416			Gahira	High
417			GauraMahraura	High
418			Godari	High
419			Gogaon	High
420			Jagadishpur	High
421			Jalalpur	High
422			Jopa	High
423			Kachhawan	Moderate
424			Kanaura	Moderate
425			Kathinai	Moderate
426			Khoja Patti	High
427			Kholua	High
428			KhutahaMaunas	High
429			Kohalai	High
430			Kurauthi Sagar	Moderate
431			Lakhanpur	High
432			Mahdeva	High
433			Mahraura	Moderate
434			Majhara	Very High
435			Maladharpur	High
436			Mallepur	Very High
437			Mawaiya	High
438			Mishra Dhap	Moderate
439			Mujehara Kalan	Very High
440			Mujehara Khurd	Very High
441			Naugaon	Moderate
442			Newadiya Ghat	High
443			NibiGaharwar	Moderate
444			Nifara	High
445			Pakhwaiya	Moderate
446			Parasuram Patti	High
447			Parwa	High
448			ParwaRajdhar	High
449			PatariJhor	High
450			Patari Tiwari	Moderate
451			Pathan Chak	Moderate

S.No	DISTRICT	BLOCK	VILLAGE	HAZARD CATEGORY
452			Patkhauli	High
453			Raipuri	High
454			Ram Chandarpur	High
455			Rama Chak	Moderate
456			Rampur	High
457			Rampur	Moderate
458			Ranichak	High
459			Saraiya Kamarghata	Moderate
460			Seer	High
461			Semara	High
462			SemaraBelauha	High
463			Shree Patti	High
464			Sinhar Kalan	High
465			Sukhnai	Moderate
466			Supantha	High
467			Thani Patti	High
468			Tilai Chauhan	High
469			TilaiMauwar	High
470			Tilthi	Moderate
471			Trilokpur	Moderate
472			Unchdih	High
473			Vishnu Patti	Moderate
474	Prayagraj	Phulpur	IbrahimpurKacharGair Abad	Moderate
475			RasulpurKacharGair Abad	Moderate
476			RasulpurUperharGair Abad	Moderate
477			SihoriKacharGair Abad	Moderate
478	Sant Ravidas Nagar Badhohi	Ghanghata	AgapurUrfGulariha	Moderate
479			Bahra Dandi	Moderate
480			Chakdaha	Moderate
481			Gai Ghat	Moderate
482			Gunwatia	Moderate
483			Kanchanpur	Moderate
484			KathhaKhairGarha	Moderate
485			Kharagpur	Moderate
486			Kotia	Moderate
487			Loukiha	Moderate
488			Madhaupur	Moderate
489			Musadiha	Moderate
490			Niranjanpur	Moderate
491			Sarraiya	Moderate
492			Sear Jot Bihari	Moderate
493			Suarha	Moderate
494		Khalilabad	Badhua	High
495			Banauli	Moderate
496			ChakPihai	High
497			Chhadna	Moderate
498			Gaura	Moderate
499			Jagdishpur	Moderate
500			Jaggujot	High
501			Karsari	Moderate
502			Kopimaphi	Moderate
503			Nazirjot	Moderate
504			Pipra	High
505			Raksha	Moderate
506			Samda	Moderate
507			Sikohara	Moderate

S.No	DISTRICT	BLOCK	VILLAGE	HAZARD CATEGORY
508		Mehdawal	Belhar Kalan	Moderate
509			BelwaThakurai	Moderate
510			Bhat Purwa	High
511			Bhatauli	Moderate
512			KaramaiHakhas	Moderate
513			PipraAual	Moderate
514			Sahsraw	Moderate
515			Sarbas Dani	Moderate
516		Gyanpur	Anripur	High
517			Arai Tari N. Baripur	High
518			Atibalshah Tari	High
519			Bahadurpur	High
520			Bahapura Tari	High
521			Bankar Tari N. Baripur	High
522			Bejavan	High
523			BerwaPaharpur Tari	High
524			BhatpurwaN.bejawa	High
525			Chakia Tari	High
526			Chhechhua Tari	High
527			Deegh Tari	High
528			Dhan Tulsi Tari	High
529			Duguna Tari	High
530			Fulwariyatari	High
531			Gajadharpur Tari N. Ojhapur	High
532			Gopalpur Tari	High
533			Hari Rampur Tari	High
534			Itahara Tari	High
535			Jagdishpur Tari	High
536			KalikMavaiya Tari	High
537			Kalinjar Tari	High
538			Karbadhiya Tari	High
539			Khemapur N. Diha Tari	High
540			Kundi Kala Tari	High
541			Kundi Khurd Tari	High
542			Kuthawatari	High
543			LakhanpurBhadraun Tari	High
544			Mavaiya Than Singh Tari	High
545			Nagardah Tari	High
546			Parasani Tari	High
547			Poore Purwa Tari	High
548			Sajhara Tari	High
549			Sherpur Tari	High
550			Terhi Tari	High
551			Tulsi Kala Tari	High
552	Shahjahanpur	Shahjahanpur	Shahjahanpur (mb+og)	Moderate
553	Shrawasti	Bhinga	Bahorwa	Moderate
554			HariharpurMahraj Nagar	Moderate
555	Sidharthnagar	Bansi	Bangawan	Moderate
556			KatsaraiBuzurg	Moderate
557			Koiridiha	Moderate
558			Madhwapur	Moderate
559			Talcorai	Moderate
560			BharawaniyaAhatmli	Moderate
561		Domariyaganj	BharawaniyaAhatmli	Moderate
562			BharwniyaMustacum	Moderate
563			Bilriya	Moderate

S.No	DISTRICT	BLOCK	VILLAGE	HAZARD CATEGORY
564			BisunpurAwrangabad	Moderate
565			BudihyaTayar	Moderate
566			Chaura	Moderate
567			Dokara	Moderate
568			Durga Joot	Moderate
569			Jeruia	Moderate
570			Junayaniya	Moderate
571			Lewartal	Moderate
572			Lohrauli	Moderate
573			Maadrha	Moderate
574			MachiyaMustacum	Moderate
575			MahwwaBujurg	Moderate
576			Mubrakpur	Moderate
577			Ramwapur Raut	Moderate
578			Tatari	Moderate
579			VeerpurJootfata Mohmad	Moderate
580		Itwa	Arjunpur	Moderate
581			Dakhinahwa	Moderate
582			Gangapur	Moderate
583			Mohamadpur	Moderate
584			Parsohiya Tiwari	High
585			Pat KhauliMaufi	Moderate
586			Sohana	Moderate
587			Urwaliya	Moderate
588		Naugarh	BairawaNankar	Moderate
589			Bangawa	Moderate
590			Basauna	High
591			Fulawariya	Moderate
592			Gaura	Moderate
593			Gayaghat	Moderate
594			HaraniBuzurg	Moderate
595			Khajuriya	Moderate
596			Khakhara Khurd	Moderate
597			Kolhua	Moderate
598			Laukhai	Moderate
599			Madar Hana	Moderate
600			Mahadeya	Moderate
601			Parsa Shah Alam	Moderate
602			Pipara Nayak	High
603			Pipari	High
604			PithaniBuzurg	Very High
605			PokharBhitawa	Moderate
606			Raje Dera	Moderate
607			Rehara	Moderate
608			RiwaNankar	Moderate
609			Sahila	Moderate
610			SemaraMisir	Moderate
611			Siyarapar	High
612			Tal Bagahiya	Moderate
613		Shohratgarh	Agaya	Moderate
614			Akheraiya	Moderate
615			Chhatahra	Moderate
616			Dafaranankar	Moderate
617			Deorawa	Moderate
618			Gujarauliya	Moderate
619			Khar Ganar	Moderate
620			Lausa	Moderate

S.No	DISTRICT	BLOCK	VILLAGE	HAZARD CATEGORY
621			Mahamudawa Grant	Moderate
622			MatiyarUrfBhutahwa	Moderate
623			Parasiya	High
624			Pipari	Moderate
625			Rekahat	Moderate
626			Sekhuiya	Moderate
627			SemariUrfGulargajawa	Moderate
628			SisawaUrf Shiv Bhari	Moderate
629			SiswaBuzurg	Moderate
630			Taulihawa	Moderate
631	Varanasi	Pindra	Dhaurhara	High
632			Handiyadih	High
633			Kaithi	High
634			Raipura	High
635			Rauna Kala	High
636			Tekuri	High
637		Varanasi	Amwa	High
638			Bahadurpur	High
639			Bhagawanpur	High
640			Naipur Kala	High
641			Naipura Khurd	High
642			Pisaur	High

Note: In this atlas, flood affected areas falling in very high, high, and moderate classes are only mentioned. However, details of all flood affected villages of all categories are provided digital version.

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