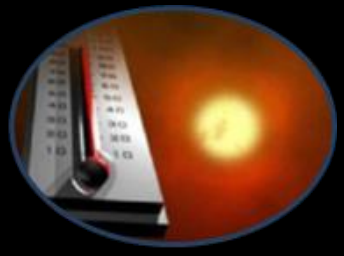

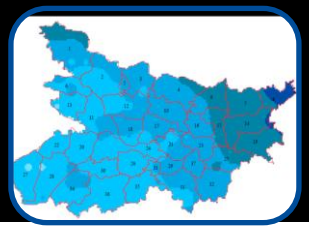

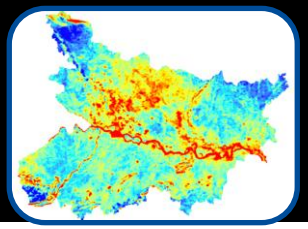

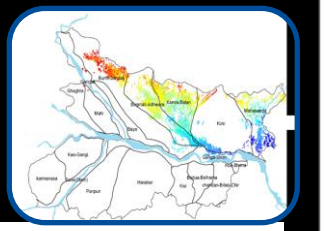

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Schematic Natural Hazard Zonation of Bihar using Geoinformatics

Tuhin Ghosh[a] and Anirban Mukhopadhyay[b]

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Working Paper
June 2013

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United Kingdom

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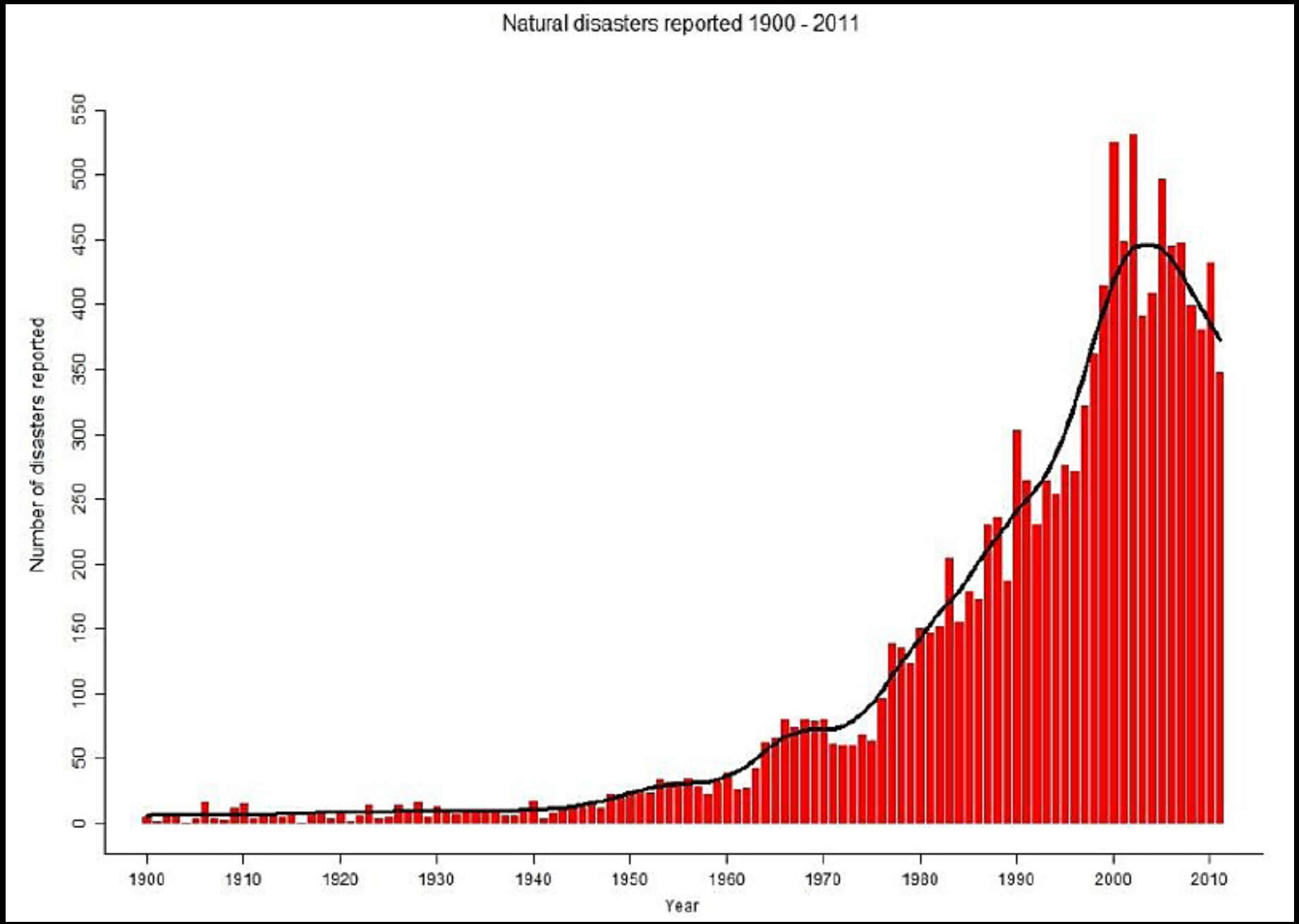
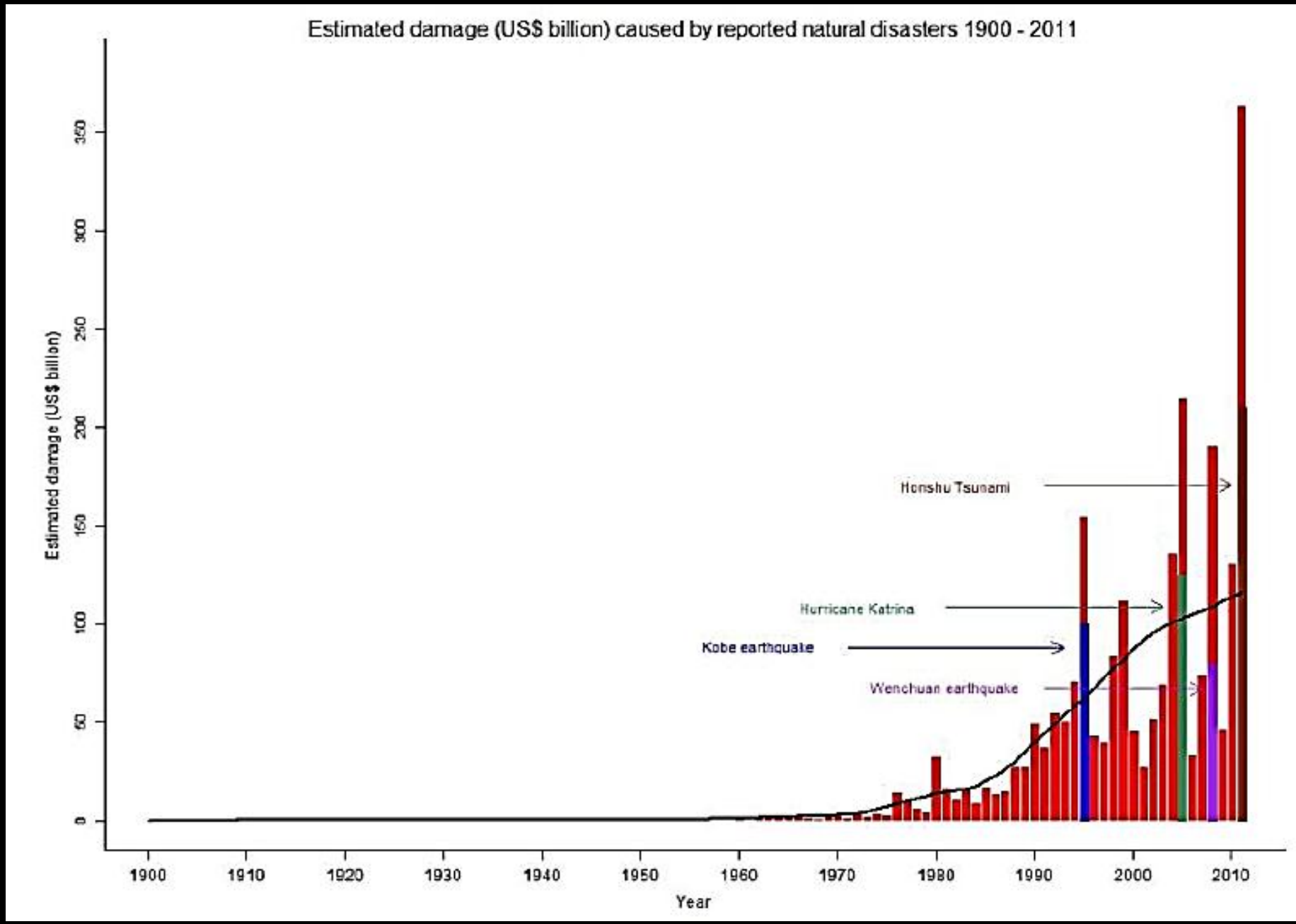
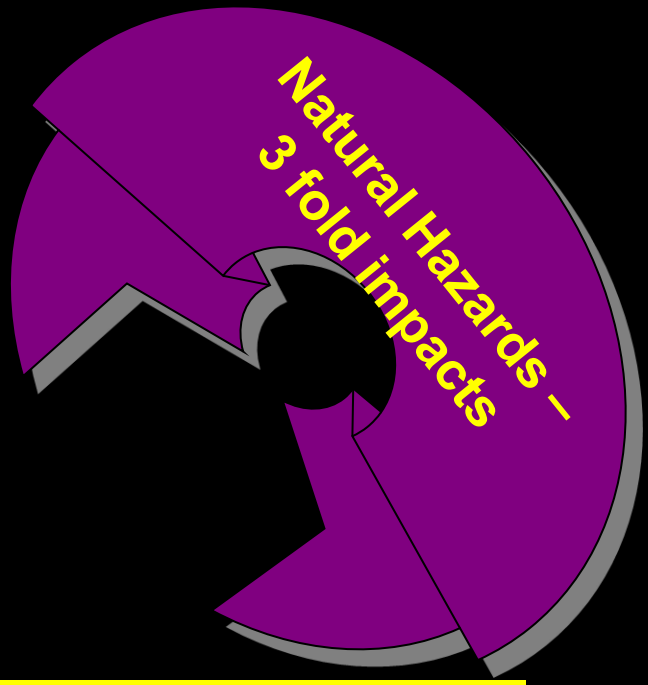

Natural disasters reported 1900 - 2011
Number of disasters reported
0
50
100
150
200
250
300
350
400
450
500
550
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Year


Estimated damage (US$ billion) caused by reported natural disasters 1900 - 2011
Estimated damage (US$ billion)
0
50
100
150
200
250
300
350
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Year
Honshu Tsunami
Hurricane Katrina
Kobe earthquake
Wenchuan earthquake



Affect all the primary resources e.g. -

- Land
- Water
- Biomass
- Air

Cause damage to -

- Agriculture / Fisheries, etc.
- Population – Gender and Age specific
- Property

Negatively affect -

- Poverty alleviation
- Economy
- Education
- Infrastructure
- Health & Sanitation
- Employment

As a consequence of such Natural Hazard, all developmental processes get impeded

Impacts of Natural Hazards on the people of Bihar from different activity and background

- Housing
- Health
- Education,
- Culture and Sports

→ Social Sectors

- Transport
- Communication
- Energy
- Water and Sewage

→ Infrastructure & Services

- Agriculture
- Industry
- Services
- Tourism, etc.

→ Productive Sectors

- Land, Biomass, Water & Air
- Gender & Social conditions
- Employment and Poverty

→ Environment

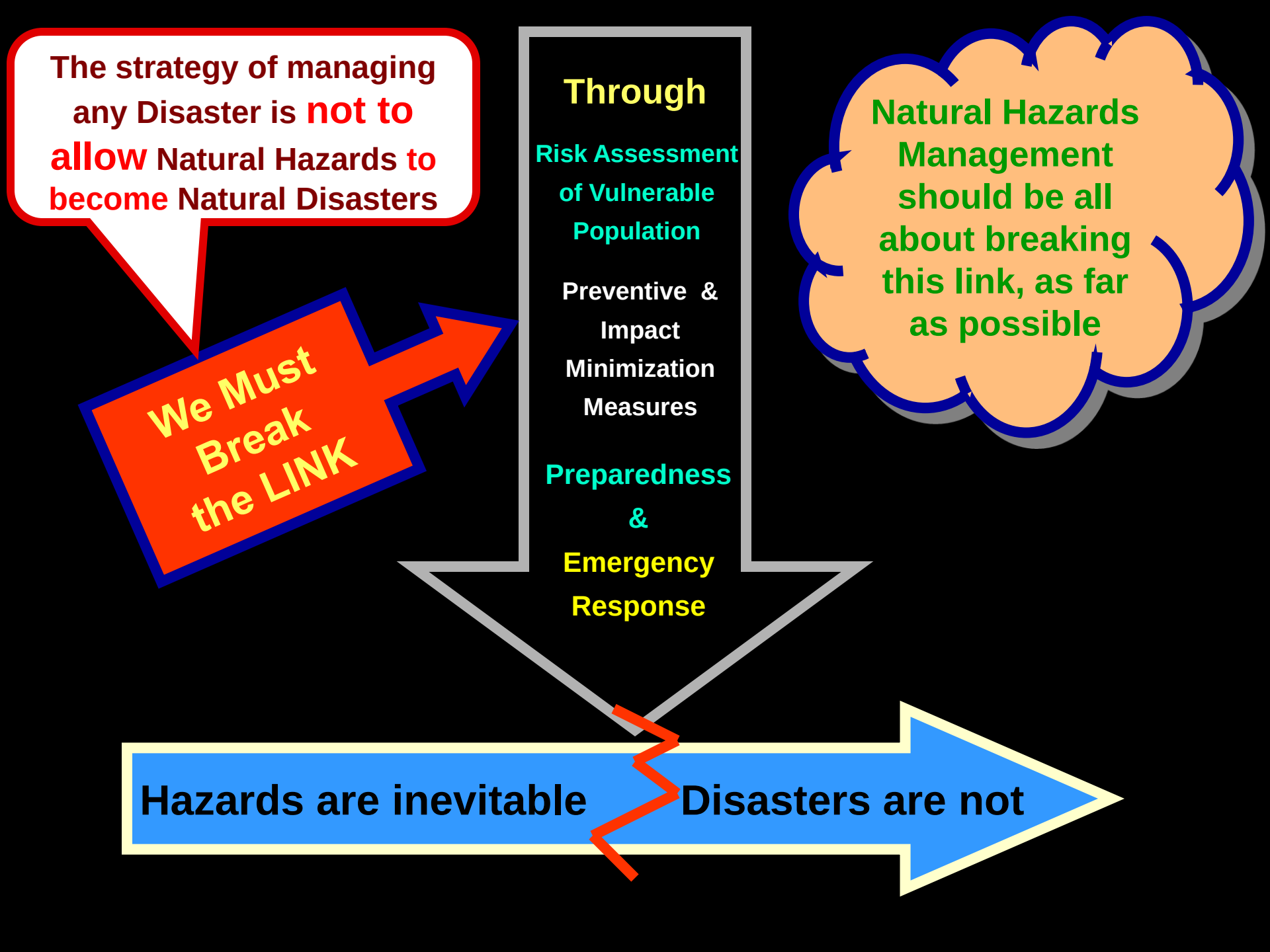
The Natural Hazards, the People of Bihar face,
and
The range of sectors in which the impacts are felt

Flood | Drought | Earthquake | Urban Heat Islands | Climate Change (?)

After understanding the possible direct or indirect impacts of Natural Hazards, now the question arises –

- **How do we manage the natural hazards in terms of preventing or minimizing its impact to Society and Environment?**

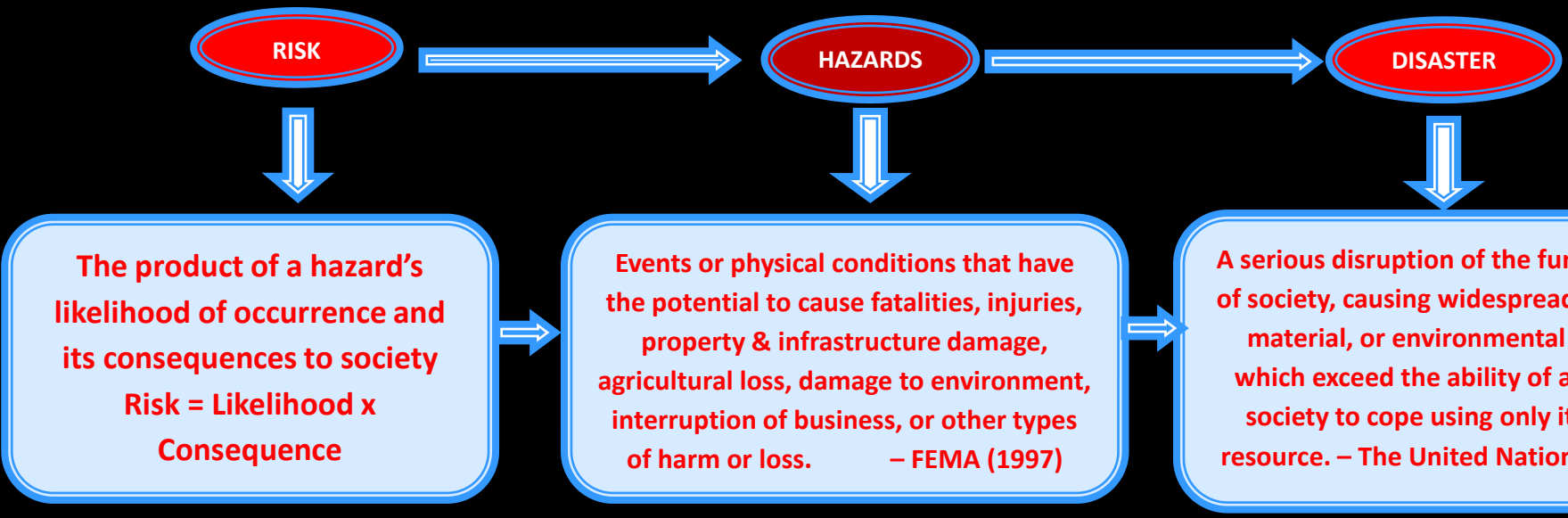
- **And how do we keep away the impacts of natural hazards from the pace of development and growth?**


The strategy of managing any Disaster is not to allow Natural Hazards to become Natural Disasters
We Must Break the LINK
Through
Risk Assessment of Vulnerable Population
Preventive & Impact Minimization Measures
Preparedness & Emergency Response
Natural Hazards Management should be all about breaking this link, as far as possible
Hazards are inevitable
Disasters are not

The link up between Natural Hazards, Vulnerability & Disaster

Vulnerable
People,
Society,
Environment
& Economy

Disaster
=
Vulnerability
+
Hazard



Impact of Natural Disasters

Affect all the primary resources - Land, Biomass, Water, Air

Cause damage to Agriculture Fisheries, Population - both gender and age specific, Property and infrastructure

Negatively impact -

- Development programmes including poverty alleviation
- Economy & Education
- Services & Infrastructure
- Health & Sanitation
- Employment

Strategies and interventions to minimize loss and cope with the worst scenario

Growth Potential:

Agriculture - Crop Yields, Irrigation Demand, Food Processing

Fisheries – Productivity, Marketing

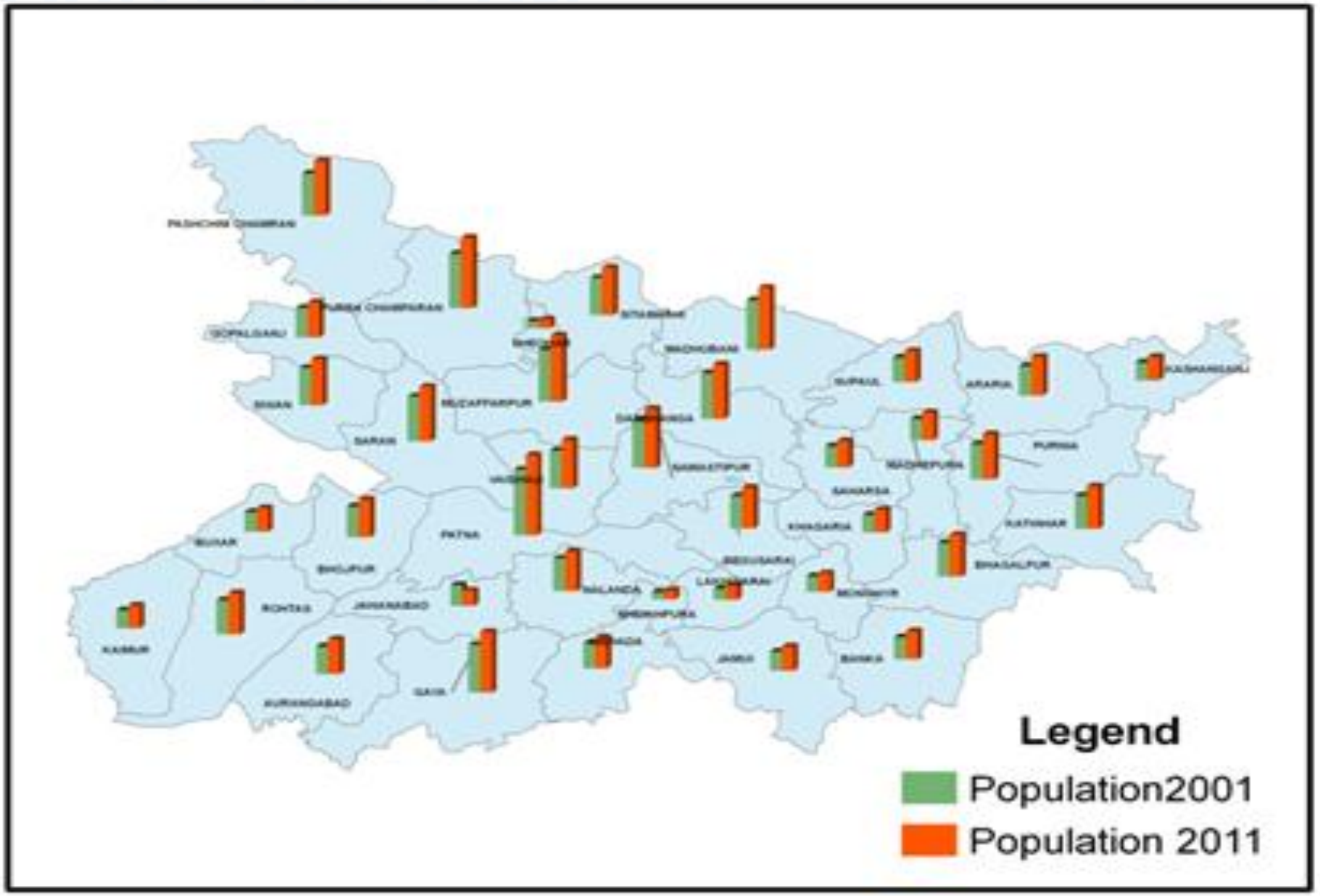
Forestry - Forest Composition, Geographic Range of Forests, Health and Productivity

Water Resources - Water Supply, Water Quality

Energy - Hydroelectricity generation

Biodiversity - Species and Natural Areas, Gain of Habitat and Species

OUR CONCERN


PASHCHIM CHAMPARAN
PURBA CHAMPARAN
GOPALGANJ
SIWAN
SARAN
MUZAFFARPUR
SITAMARHI
MADHUBANI
SUPAUL
ARARIA
KISHANGANJ
PURNIA
MADHEPURA
SAHARSA
KHAGARIA
KATIHAR
BHAGALPUR
BANKA
JAMUI
BEGUSARAI
MUNGER
LAKHISARAI
SHEIKHPURA
NALANDA
PATNA
BHOJPUR
BUXAR
ROHTAS
KAIMUR
JAHANABAD
GAYA
AURANGABAD
Legend
Population2001
Population 2011

Assessment Of Flood

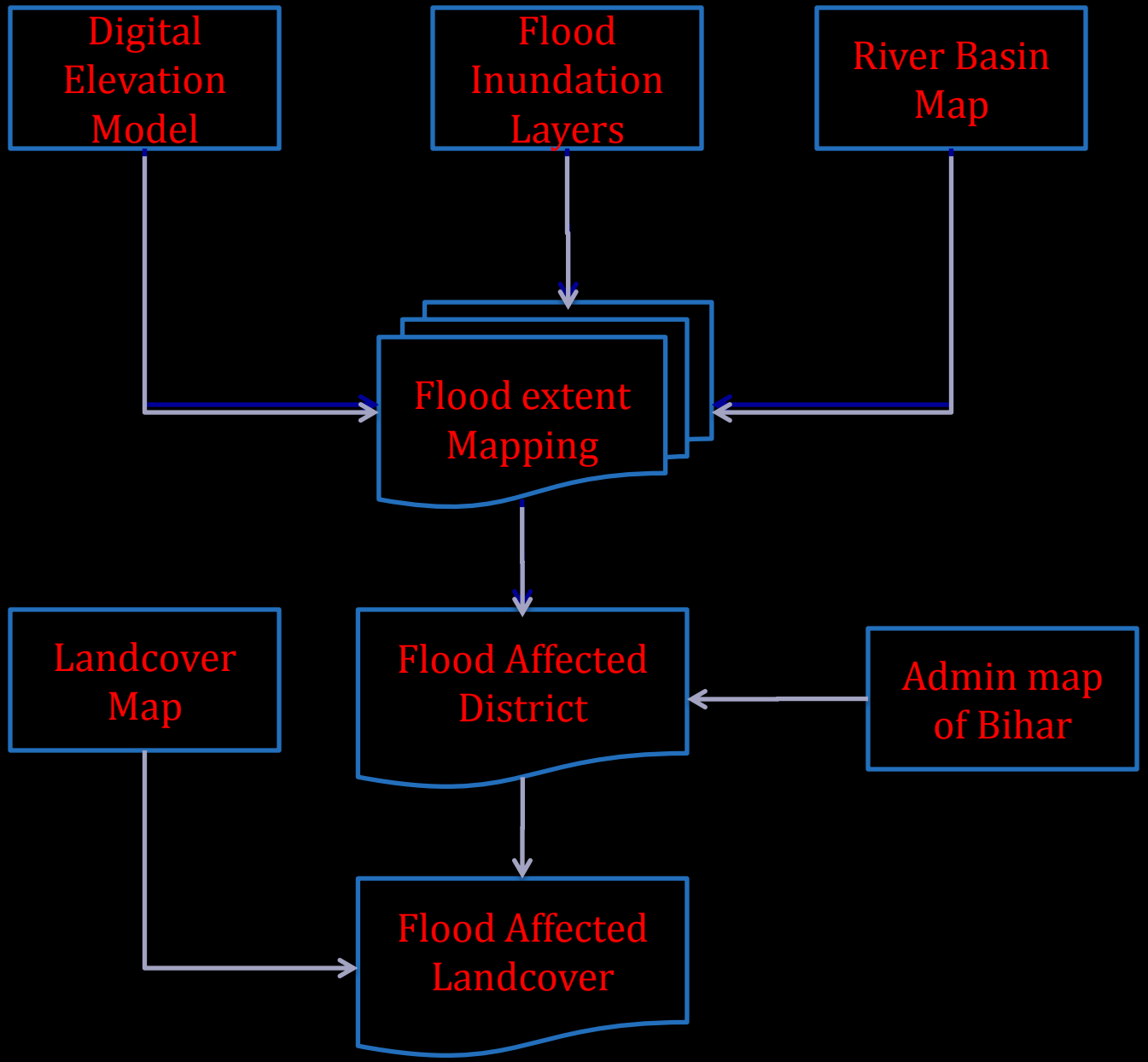
Assessment Of Drought

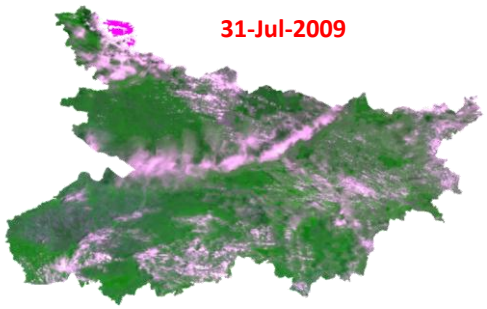
Assessment Of Earthquake

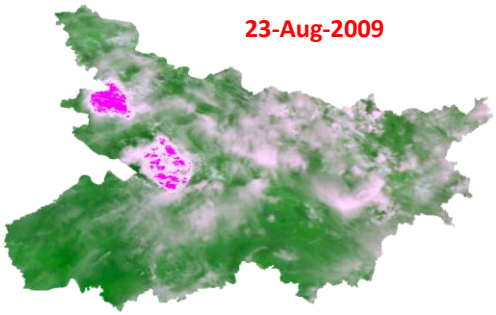
Assessment Of Thermal Heat island

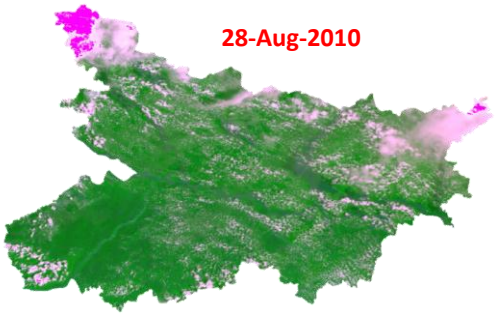
Framework of the Project

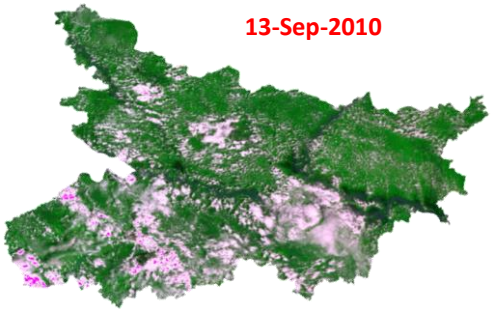
Flood

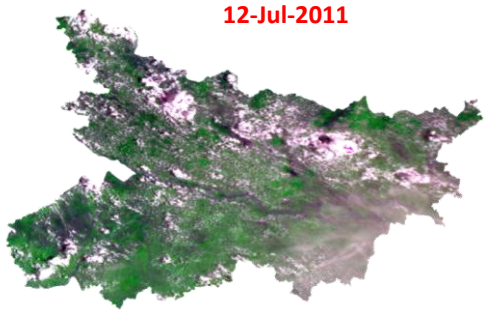

Digital Elevation Model
Flood Inundation Layers
River Basin Map
Flood extent Mapping
Landcover Map
Flood Affected District
Admin map of Bihar
Flood Affected Landcover

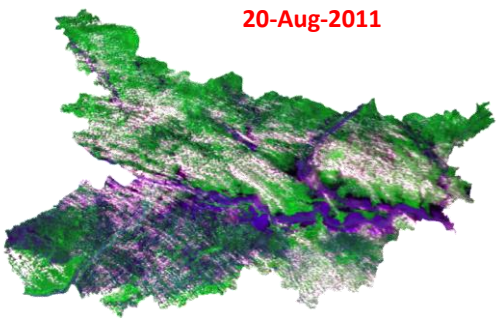


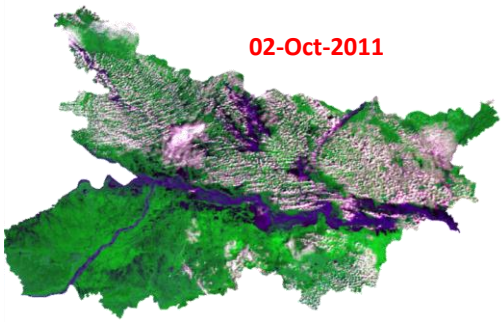


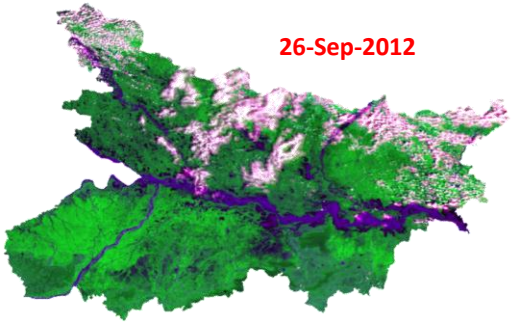








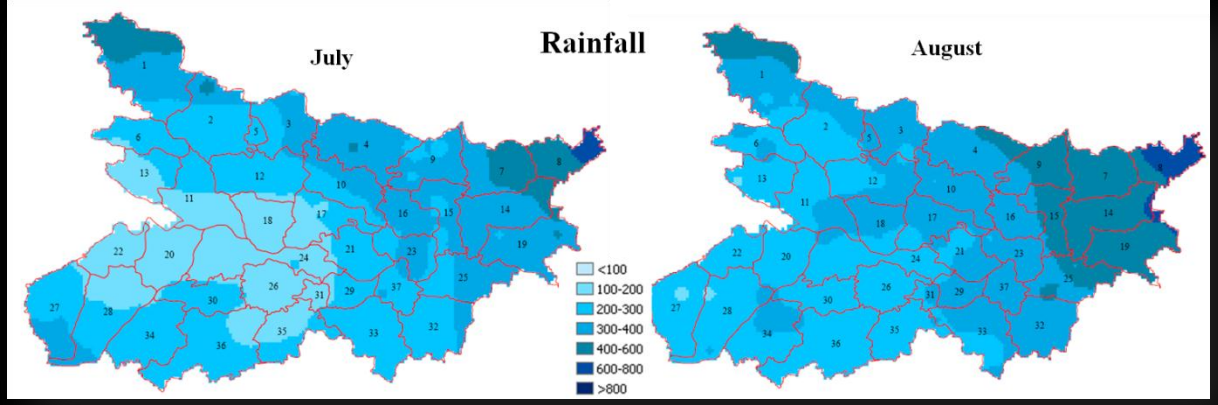


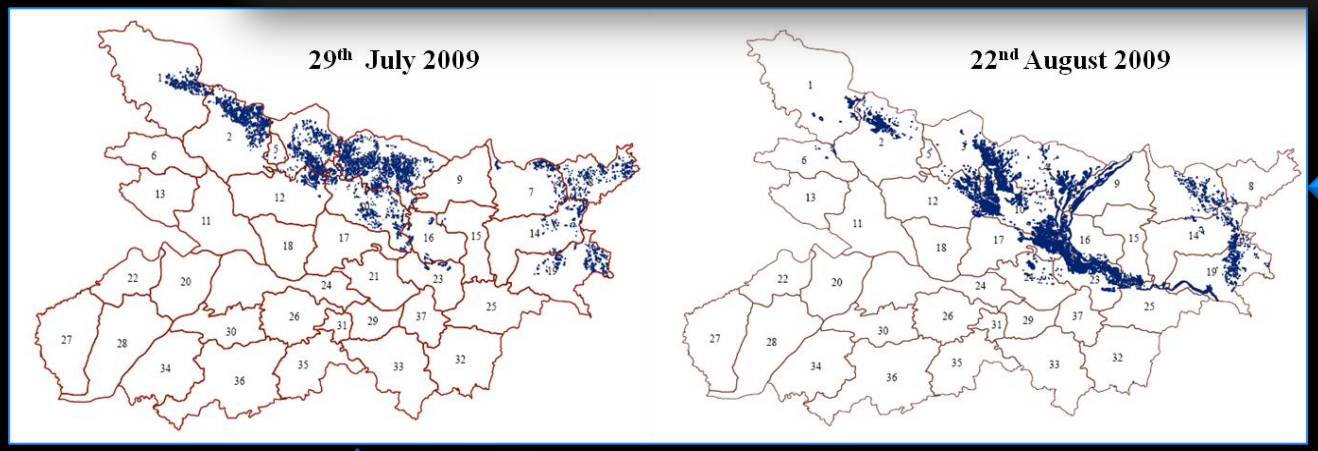


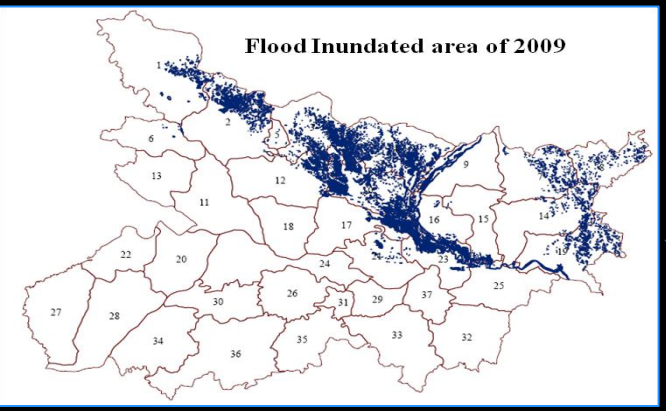
Flood Plains of Bihar

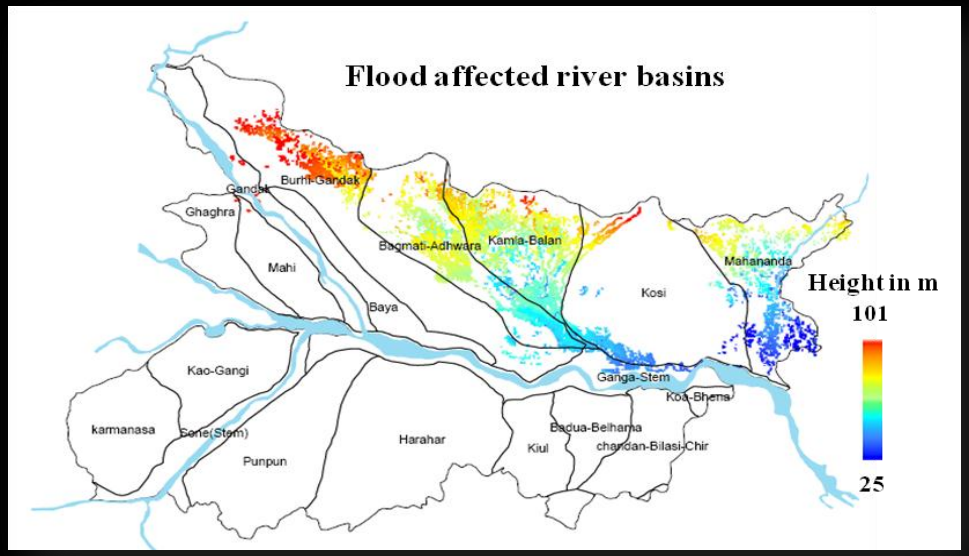
MODIS optical imagery during the flood period of 2009 to 2012 . The flood inundation is seen in the imagery.

2009 Flood


Rainfall
July
August
<100
100-200
200-300
300-400
400-600
600-800
>800


29th July 2009
22nd August 2009

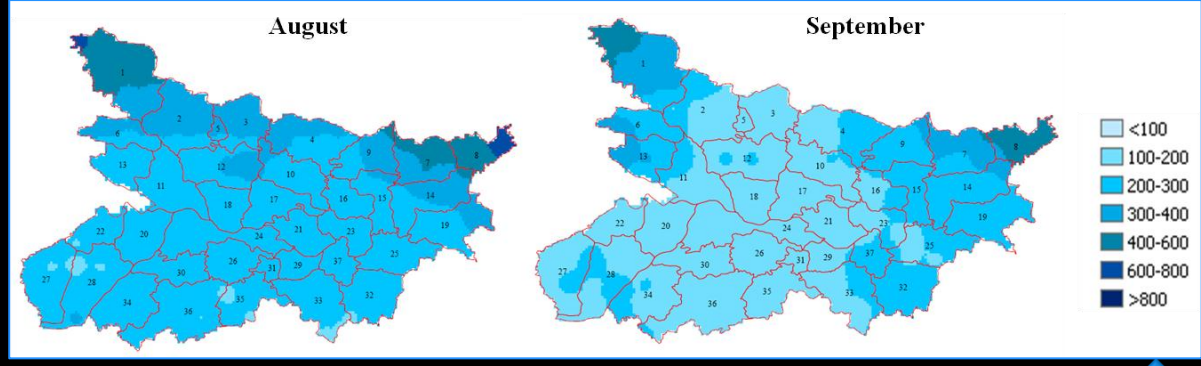

Flood Inundated area of 2009

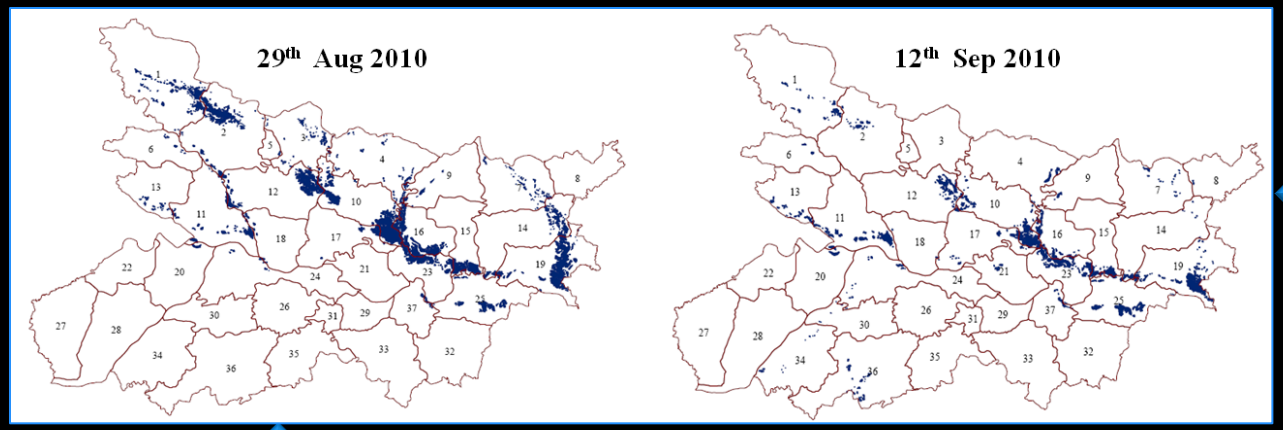

Flood affected river basins
Ganga
Burhi-Gandak
Ghaghra
Bagmati-Adhwara
Kamla-Balan
Mahananda
Mahi
Kosi
Baya
Height in m
101
Kao-Gangi
Ganga-Stem
Koa-Bhena
karmanasa
Bane(Stem)
Harahar
Badua-Belhama
Punpun
Kiul
chandan-Bilasi-Chir
25

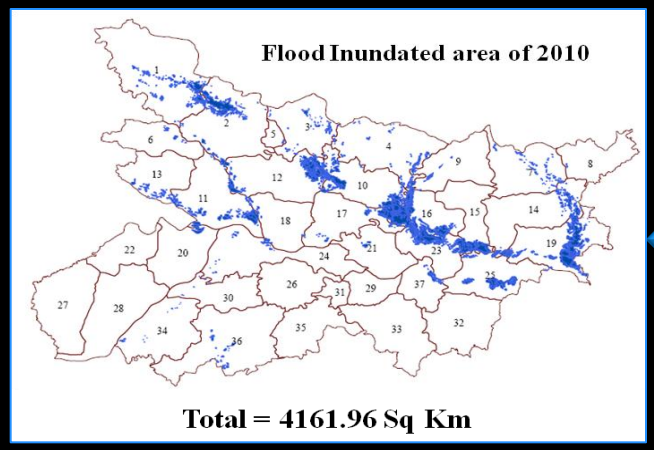
Flood 2009

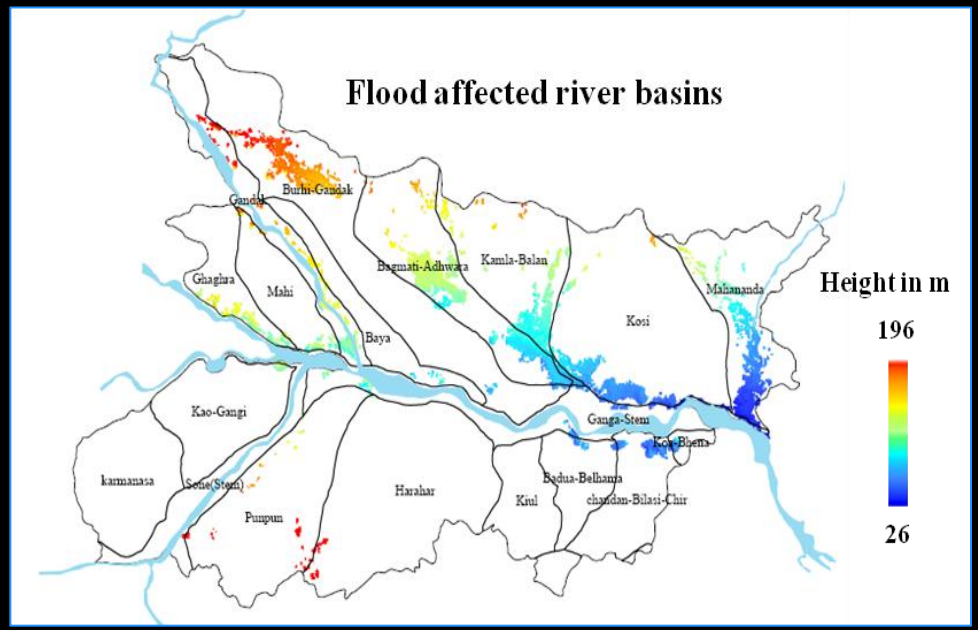
- The prime reason for floods was heavy rainfall in the catchment area of Kosi in Nepal
- Floods also occurred in Bagmati, Mahananda, Kosi, Kamala Balan, Burhi-Gandak, and Adhwara river basins
- Northern part of Bihar was highly affected by floods

2010 Flood


August
September
<100
100-200
200-300
300-400
400-600
600-800
>800


29th Aug 2010
12th Sep 2010

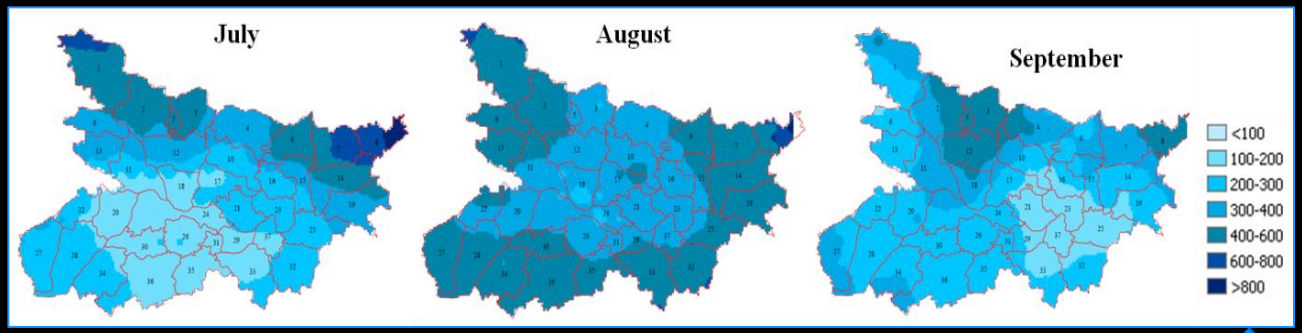

Flood Inundated area of 2010
Total = 4161.96 Sq Km

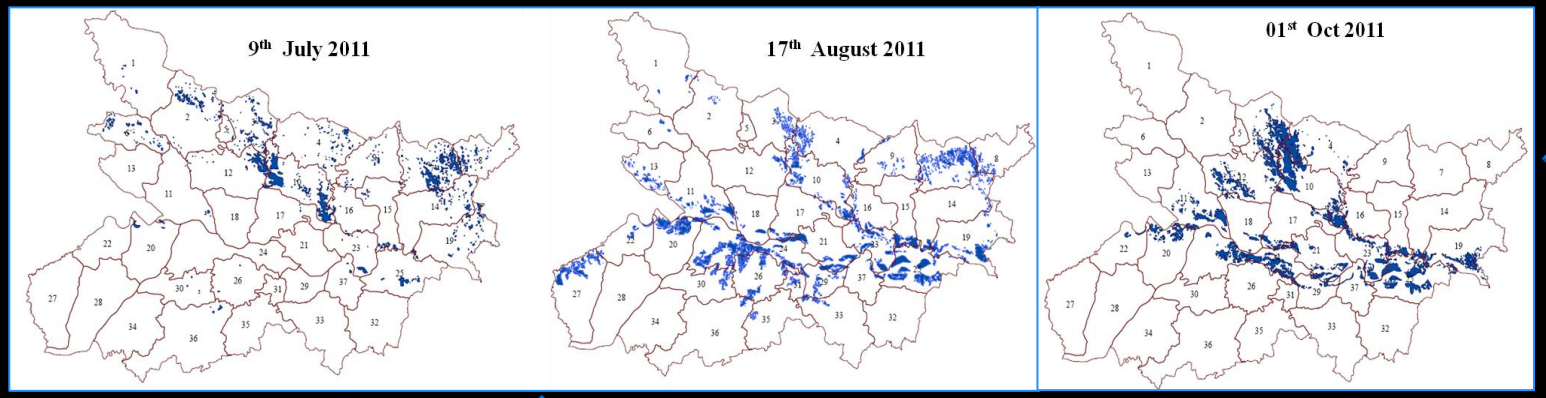

Flood affected river basins
Burhi-Gandak
Gandak
Bagmati-Adhwara
Kamla-Balan
Ghaghra
Mahi
Mahananda
Kosi
Baya
Kao-Gangi
Ganga-Stem
Kol-Bhera
karmanasa
Sone(Stem)
Harahar
Badua-Belhama
Kiul
chandan-Bilasi-Chir
Pumpum
Height in m
196
26

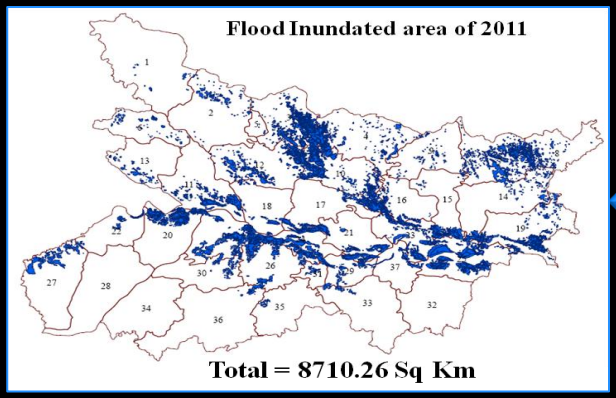
Flood 2010

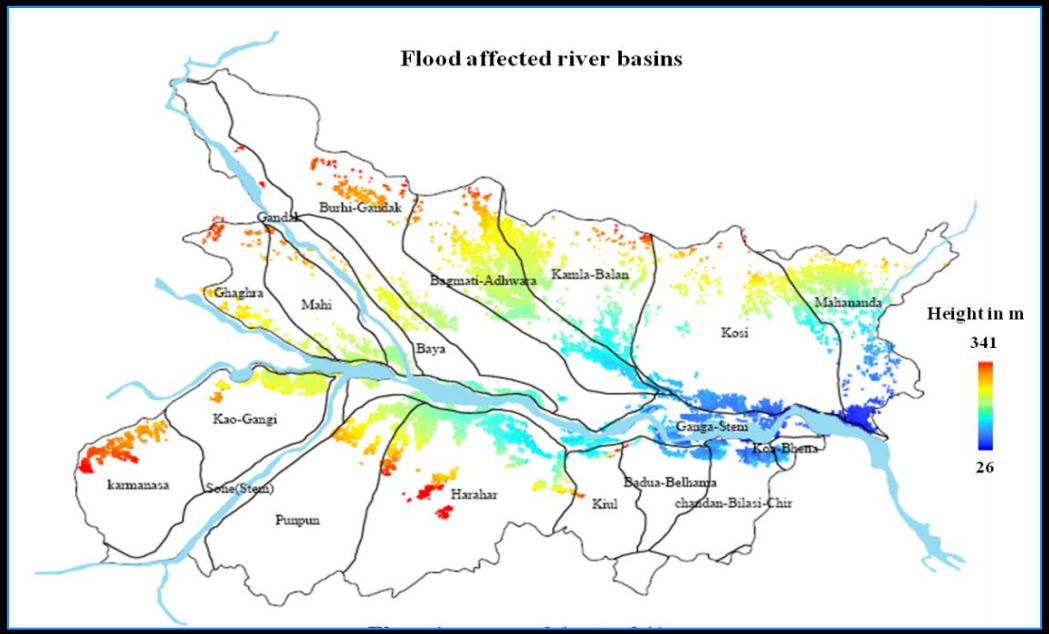
- Floods occured in Bagmati-Adhwara, Mahananda, Kosi, Kamala Balan and Burhi Gandak River basins
- Northern part of Bihar was highly affected by floods.
- Eastern parts of the state were also affected.
- Though the intensity of the flooding was higher as compared to 2009, but the distribution of flood was more widespread. 23 districts of Bihar were flood affected.

2011 Flood


July
August
September
<100
100-200
200-300
300-400
400-600
600-800
>800


9th July 2011
17th August 2011
01st Oct 2011

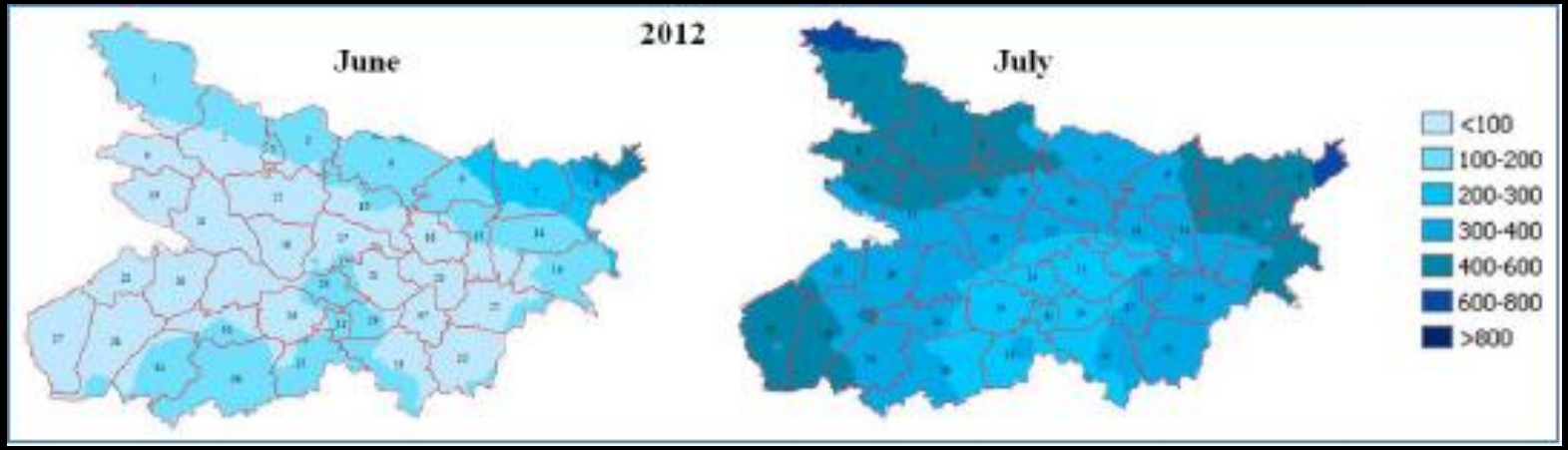

Flood Inundated area of 2011
Total = 8710.26 Sq Km

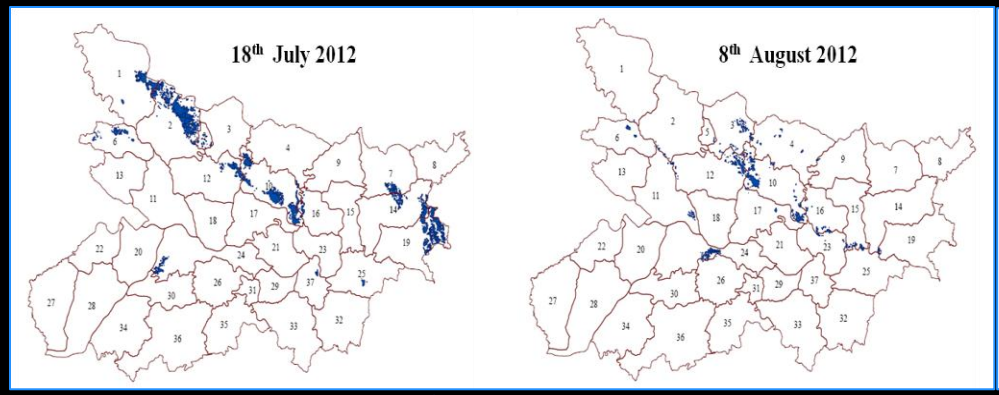

Flood affected river basins
Gandak
Burhi-Gandak
Ghaghra
Mahi
Baya
Bagmati-Adhwara
Kamla-Balan
Kosi
Mahananda
Kao-Gangi
karmanasa
Sone(Stem)
Punpun
Harahar
Kiul
Badua-Belhama
chandan-Bilasi-Chir
Gauga-Stem
Kos-Bhem
Height in m
341
26

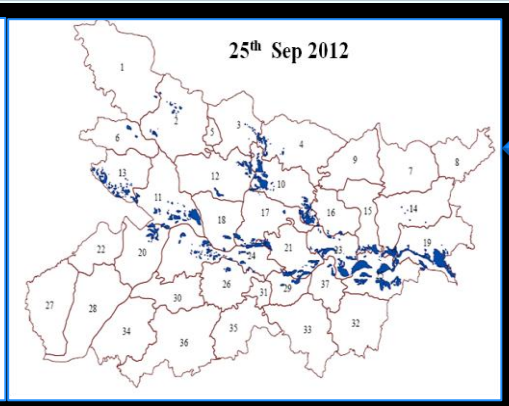
Flood 2011

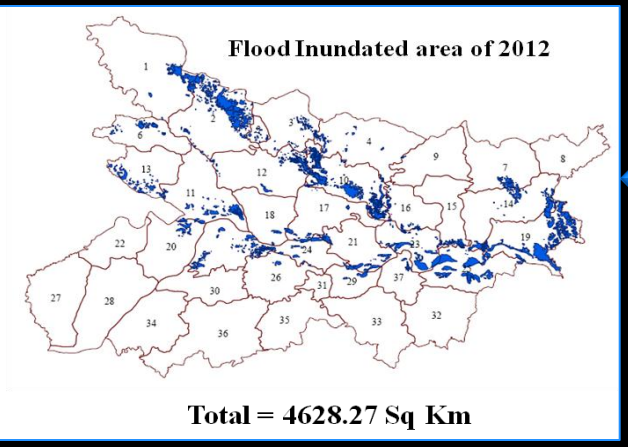
- Kosi, Mahananda, Gandak, Bodhi, and Bagmati witnessed rapid increase in water levels.
- More than a hundred villages were inundated in the flood prone districts of Muzaffarpur, Gopalganj, Purnia, Araria, Saharsa, Madhepura, Bagaha, and East and West Champaran.
- Floods occurred in parts of Bagmati-Adhwara, Mahananda, Kosi, Kamala Balan, Burhi-Gandak, Punpun, Harhar, and Kao-Gangi River basins, along with northern and eastern parts of Bihar, southern areas were also affected.
- The intensity of the flood was higher in comparison to 2009 and 2010 with widespread distribution

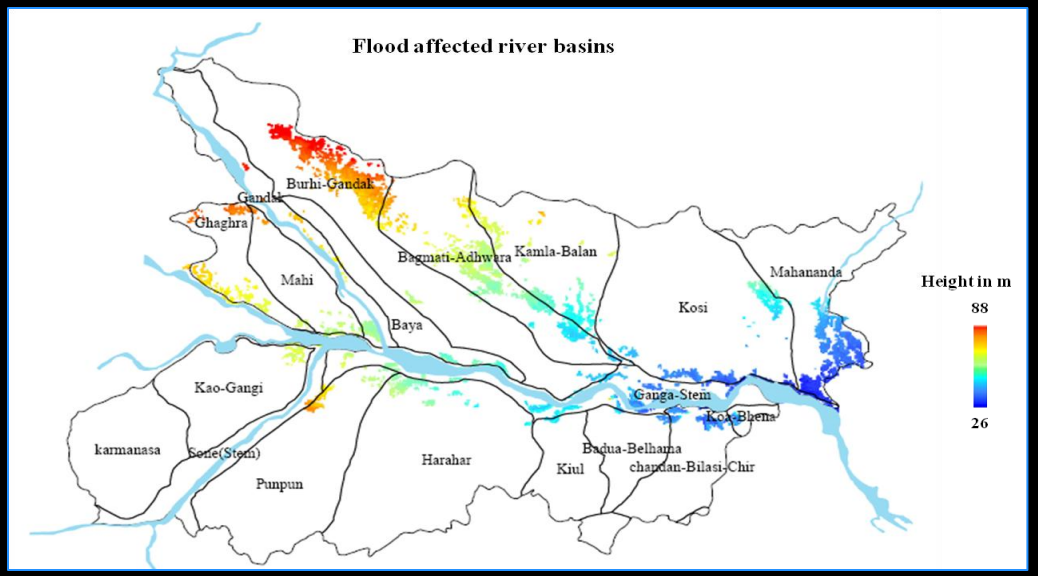
2012 Flood


2012
June
July
<100
100-200
200-300
300-400
400-600
600-800
>800


18th July 2012
8th August 2012


25th Sep 2012


Flood Inundated area of 2012
Total = 4628.27 Sq Km


Flood affected river basins
Burhi-Gandak
Gandak
Ghaghra
Bagmati-Adhwara
Kamla-Balan
Mahananda
Mahi
Kosi
Baya
Kao-Gangi
Ganga-Stem
Kosi-Bhena
karmanasa
Sone(Stem)
Harahar
Badua-Belhana
Kiul
chandan-Bilasi-Chir
Punpun
Height in m
88
26

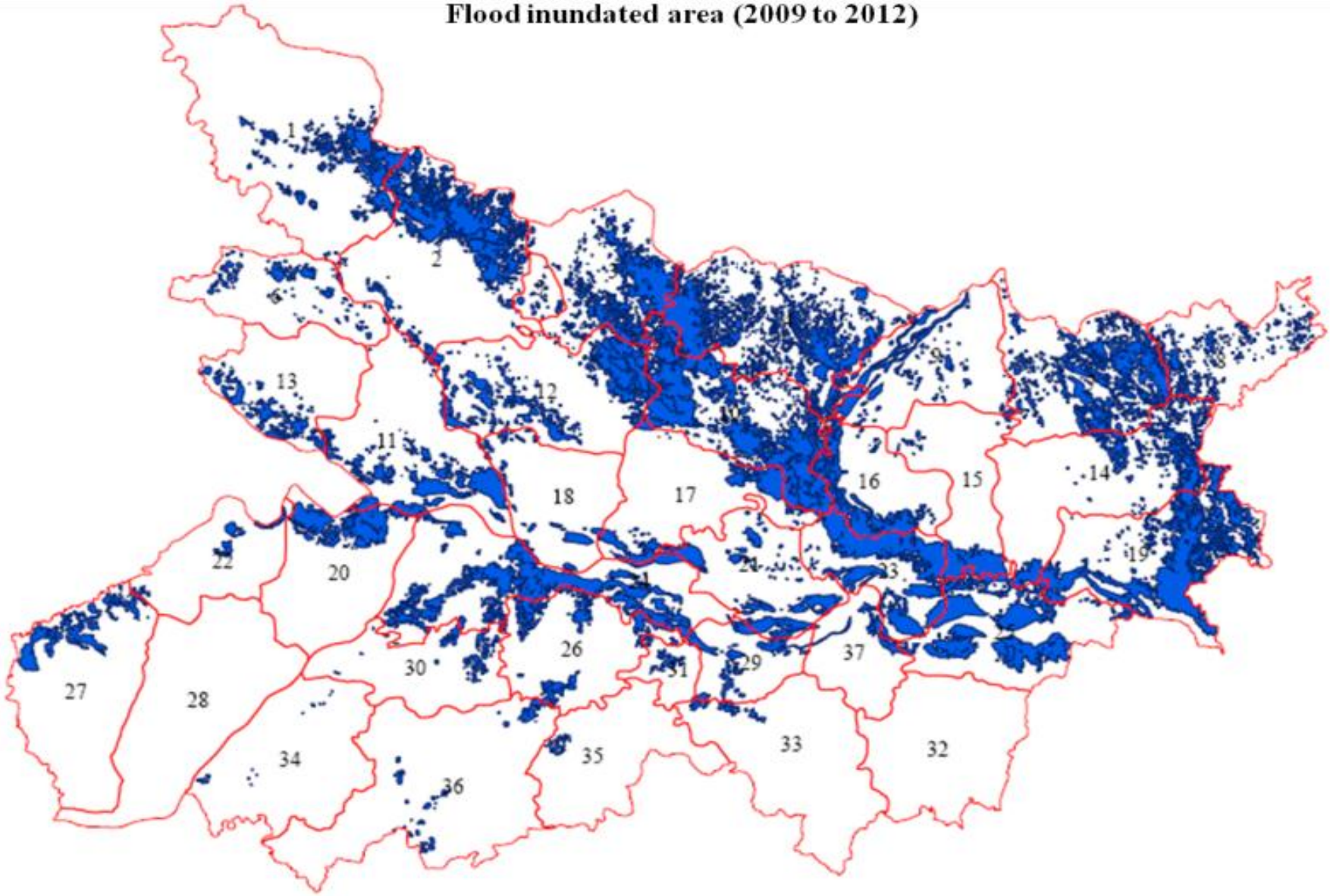
Flood 2012

- After the devastating flood of 2011, low intensity flood situation occurred in 2012
- The major affected districts were Darbhanga, Kathihar, Muzaffarpur, Purnia, Khagaria, Patna, and East & West Champaran.
- Floods occurred in parts of Bagmati-Adhwara, Mahananda, Burhi-Gandak and Kamala-Balan River basins

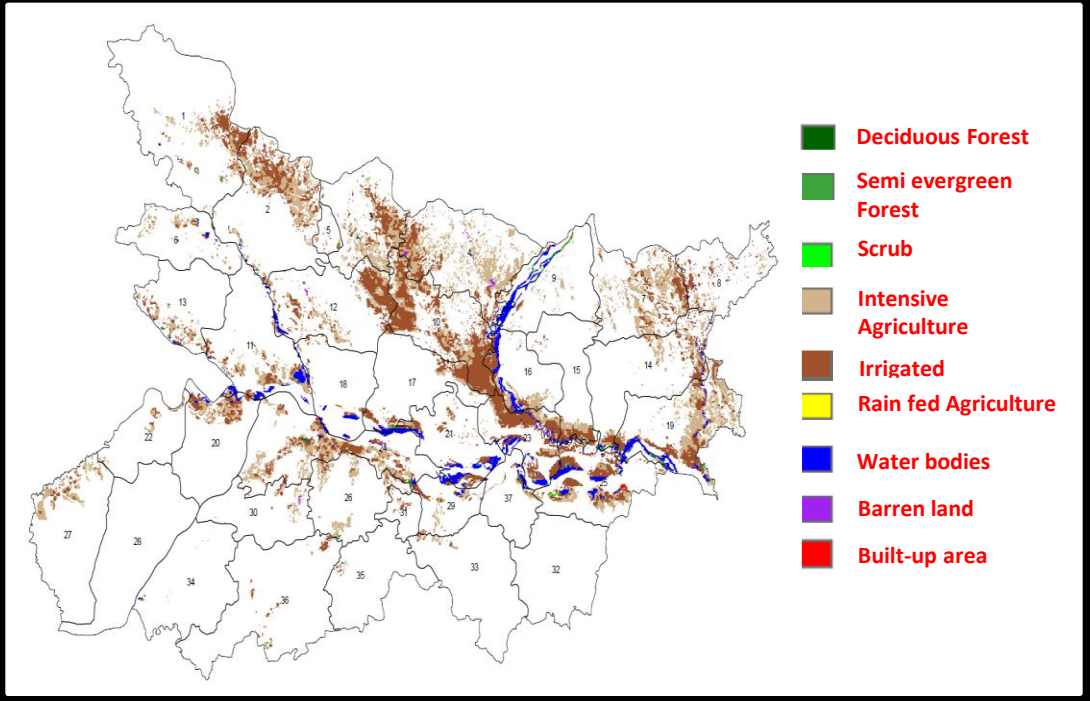
Conclusion

- The northern of the state, along with some parts of the east, are particularly susceptible to floods.
- In general, Darbhanga, Kathihar, Muzaffarpur, Purnia, Khagaria, Patna, and Champaran districts get affected by floods during every year.
- The analysis for last few years has shown that the year 2011 experienced the highest flooding.
- Flood inundated areas since last few years were integrated and the flood prone areas of Bihar have been delineated. The total flood prone area of Bihar is 14,950 sq km, which is 15.88% of its total geographical area

Flood inundated area (2009 to 2012)

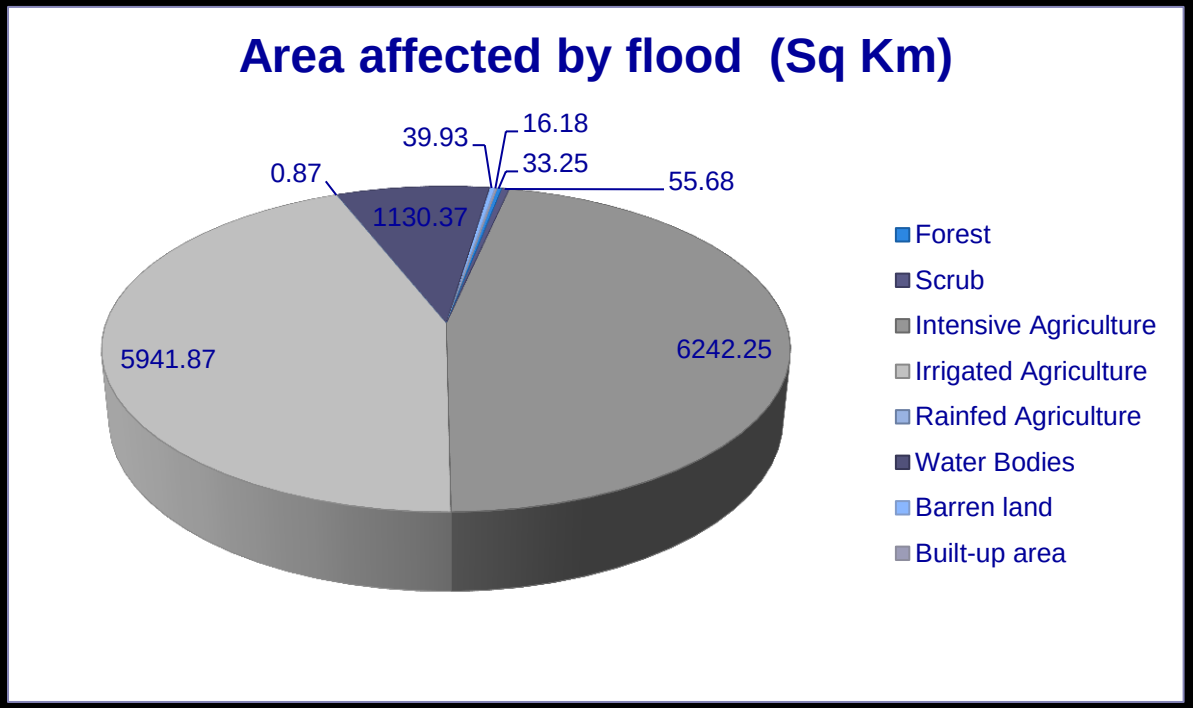


Total = 14950 Sq Km

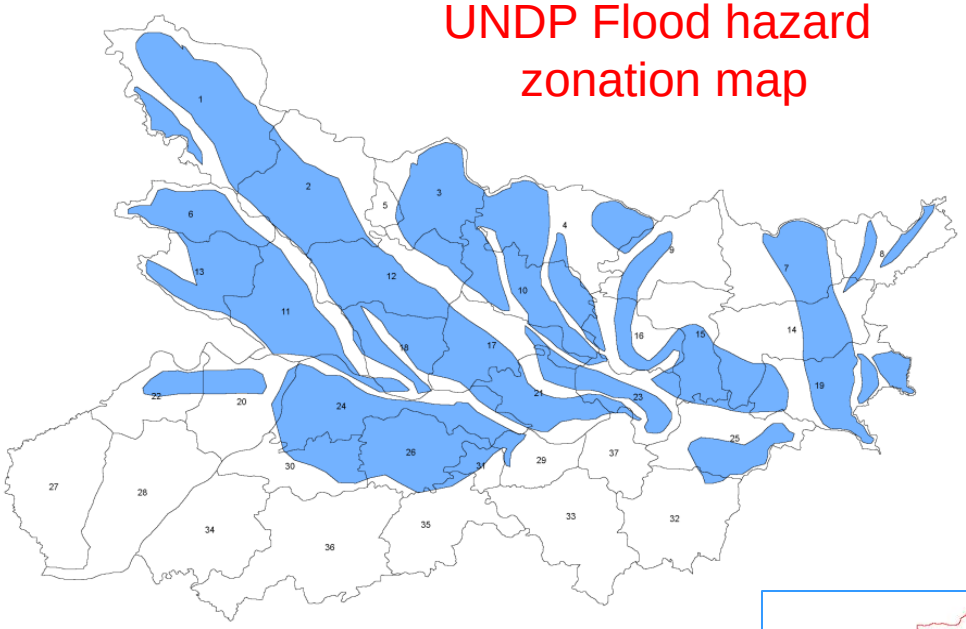


Destruction of natural resources and economic activity

Is that not hampering the growth trend of the state?

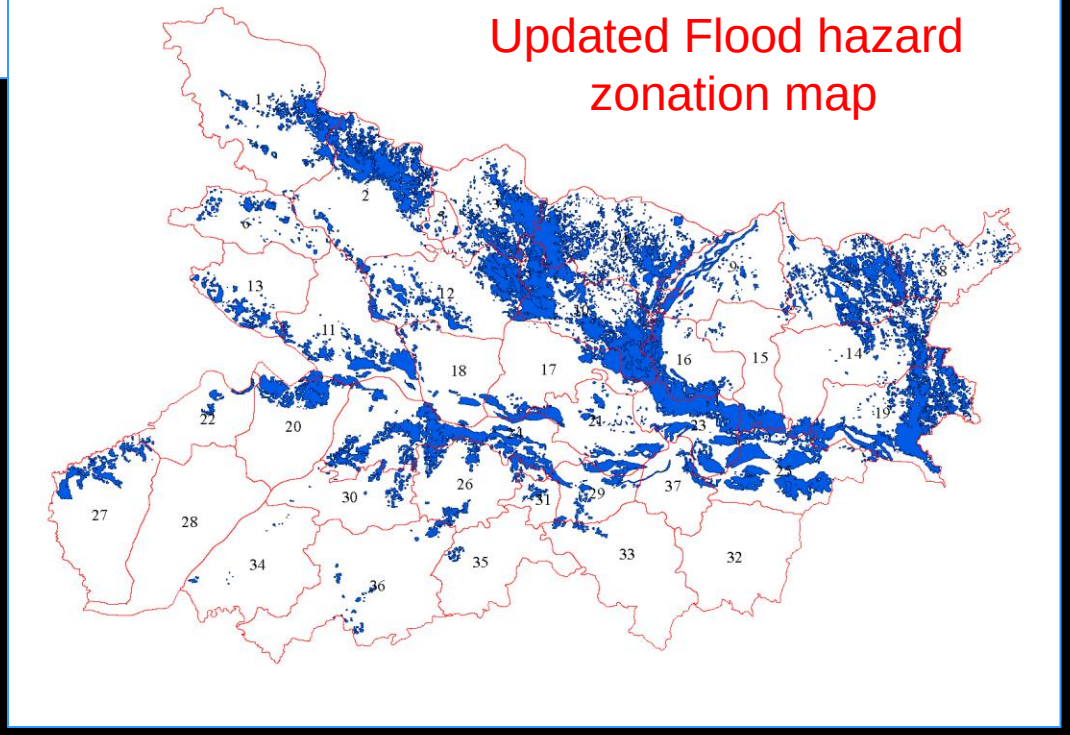


UNDP Flood hazard zonation map

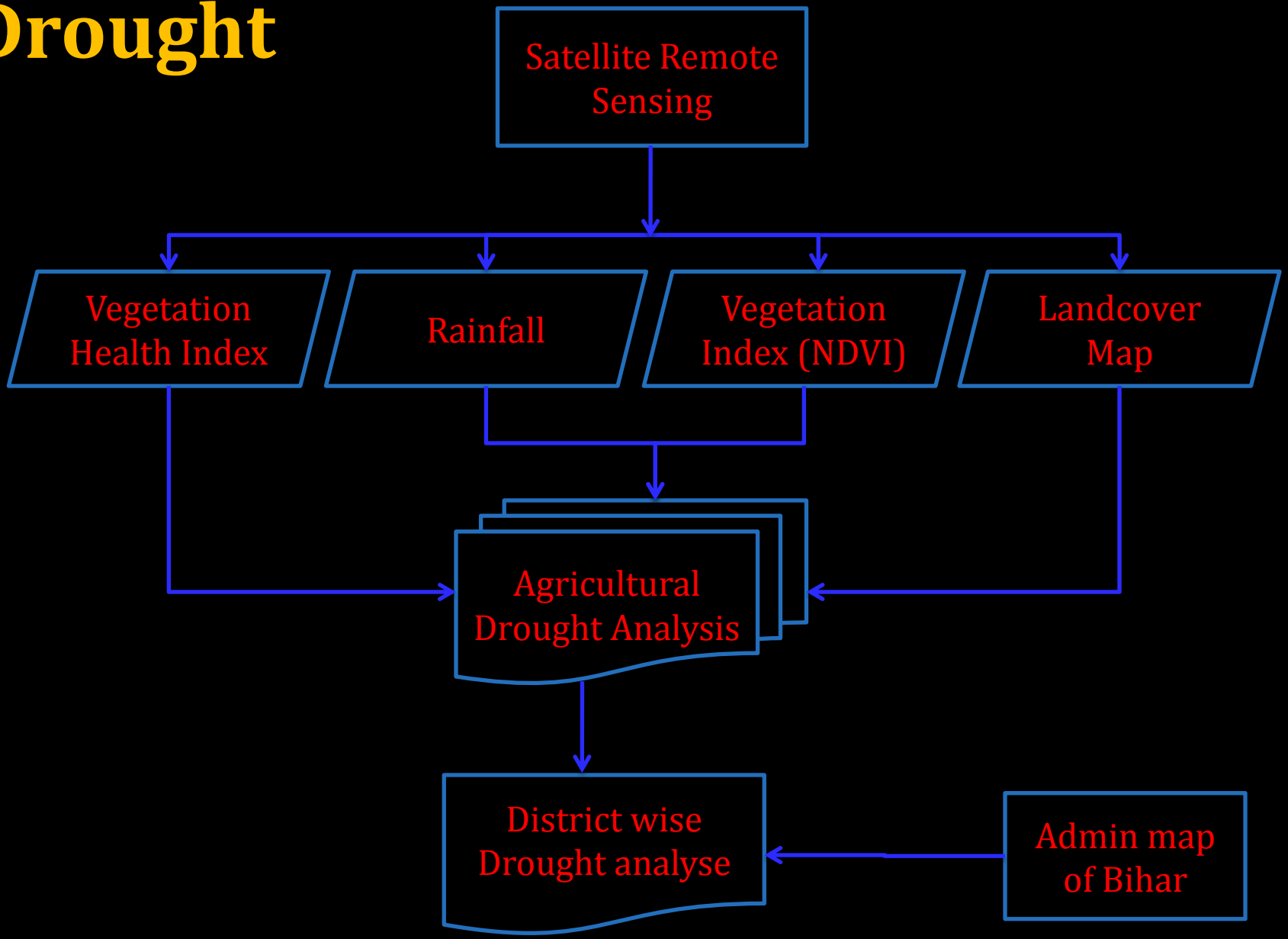


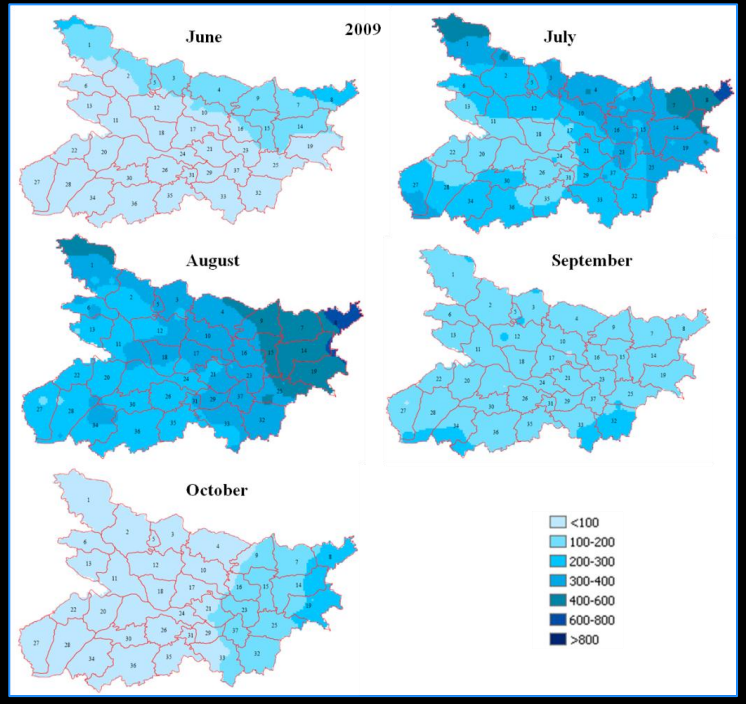
Updating the previous work

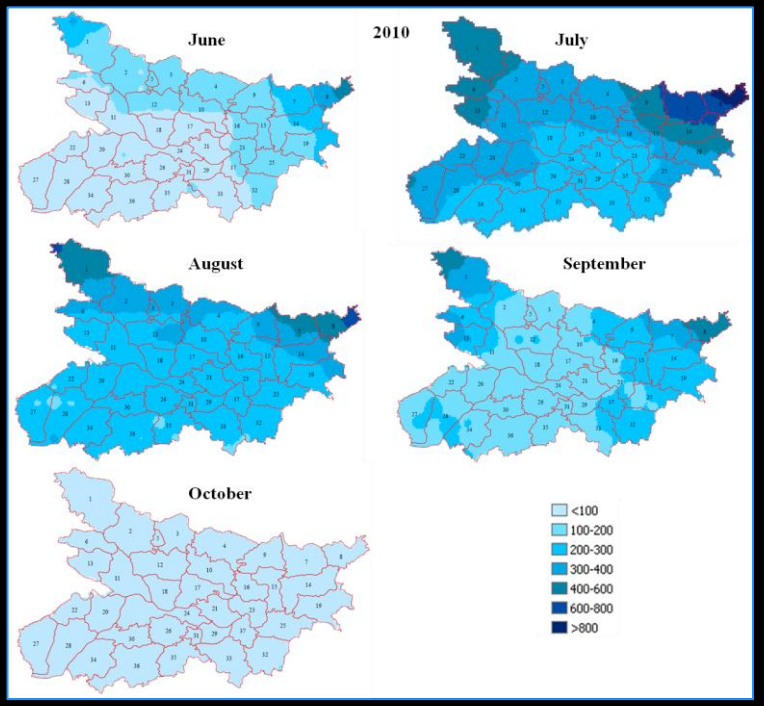
Updated Flood hazard zonation map

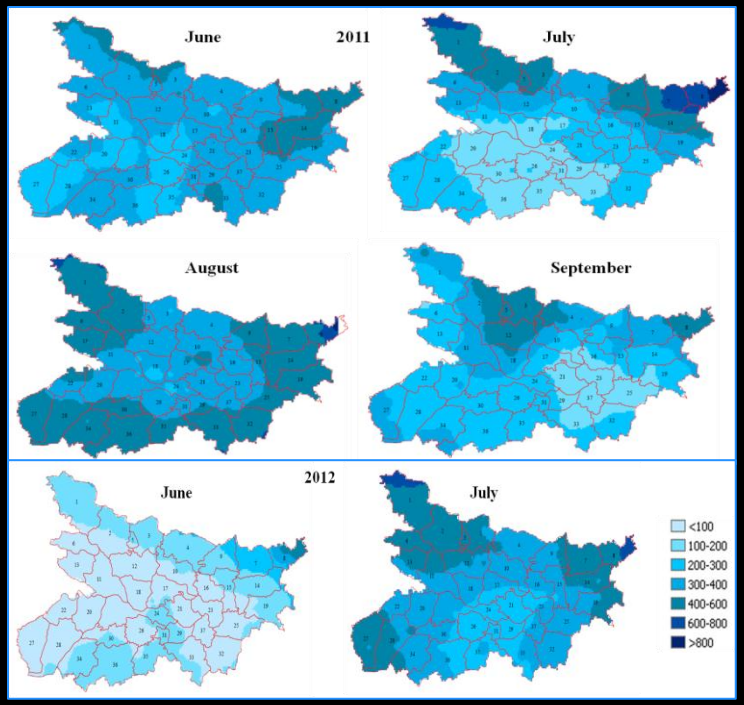


Drought

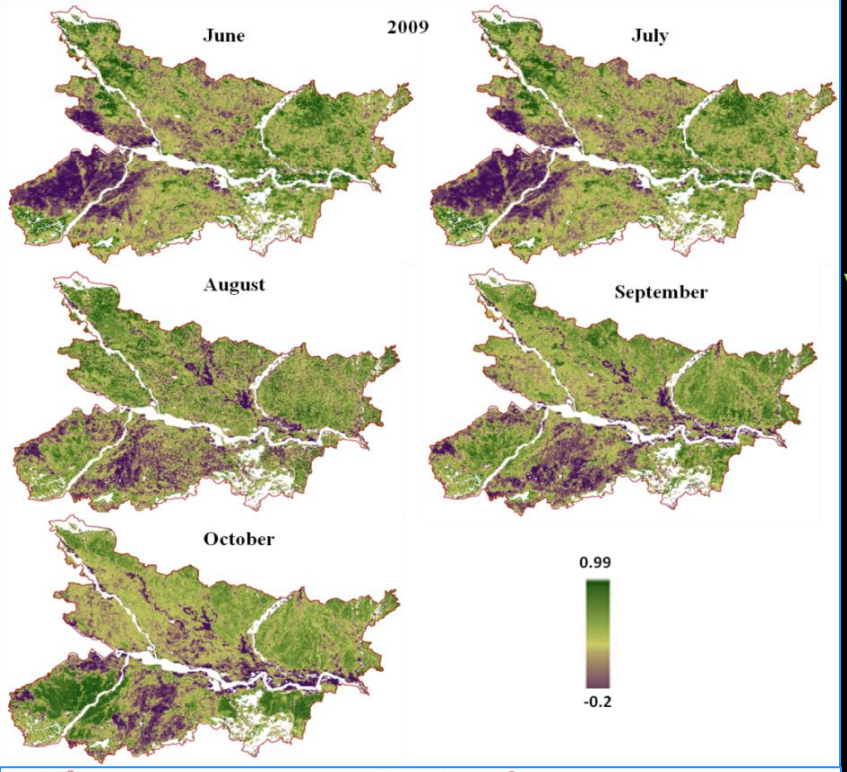

Satellite Remote Sensing
Vegetation Health Index
Rainfall
Vegetation Index (NDVI)
Landcover Map
Agricultural Drought Analysis
District wise Drought analyse
Admin map of Bihar

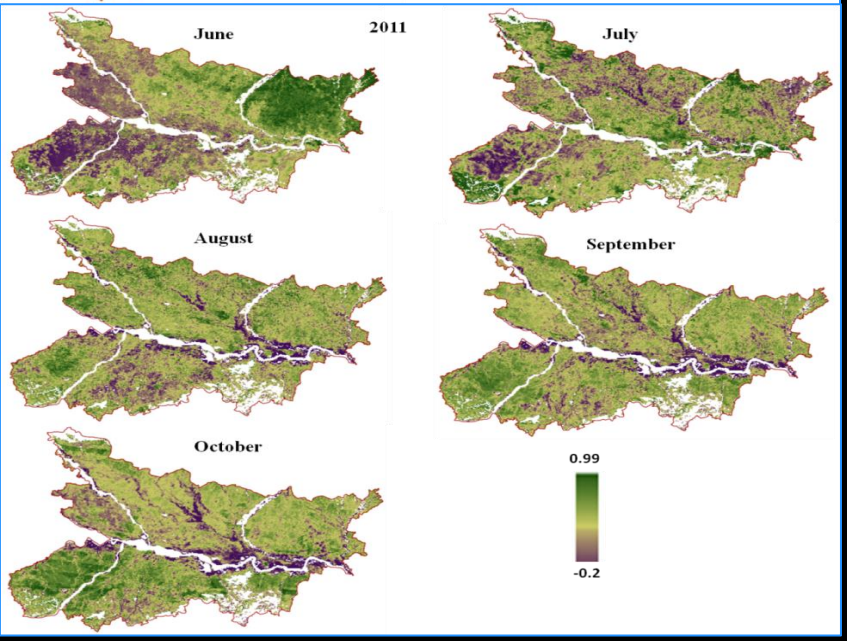




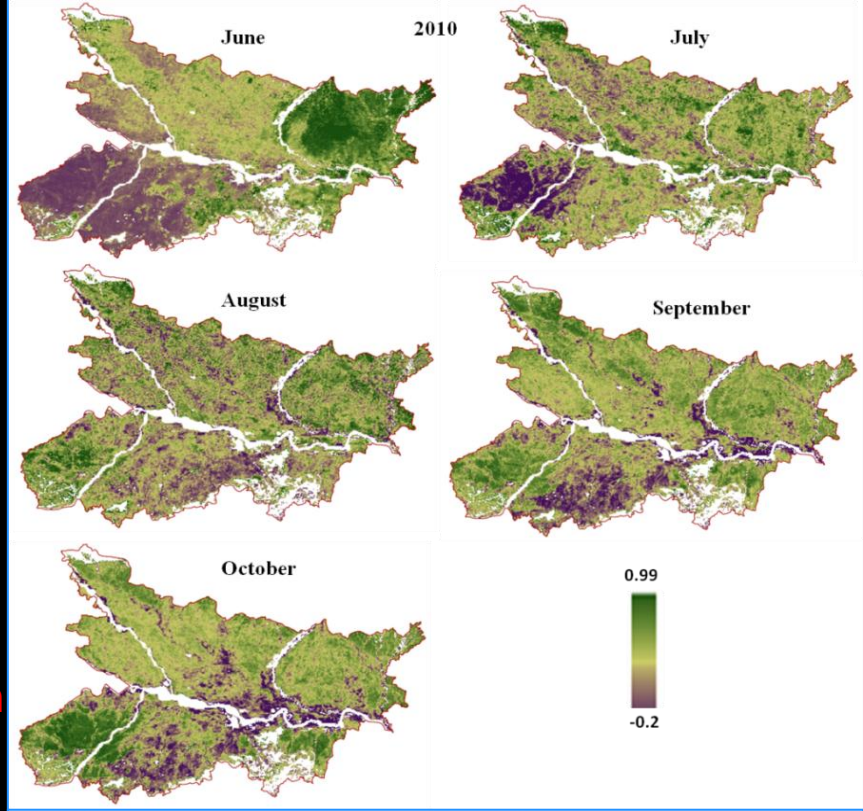


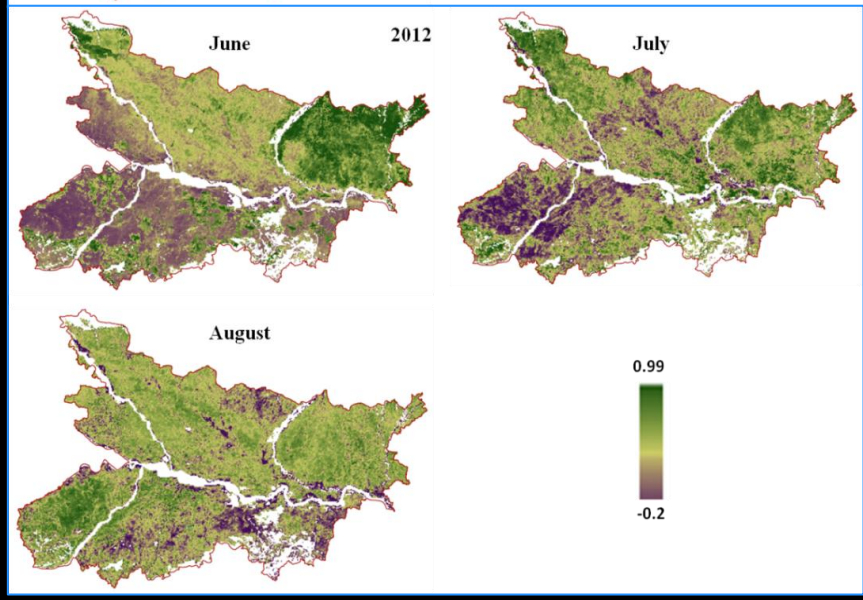
Rainfall in Bihar from 2009 to 2012 shows maximum rainfall in 2011 and less rainfall in 2009 and 2010

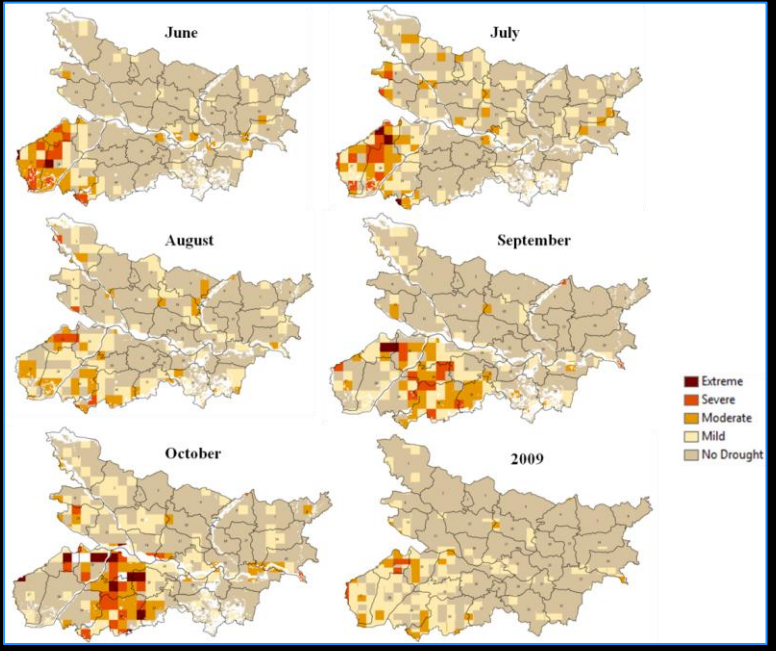


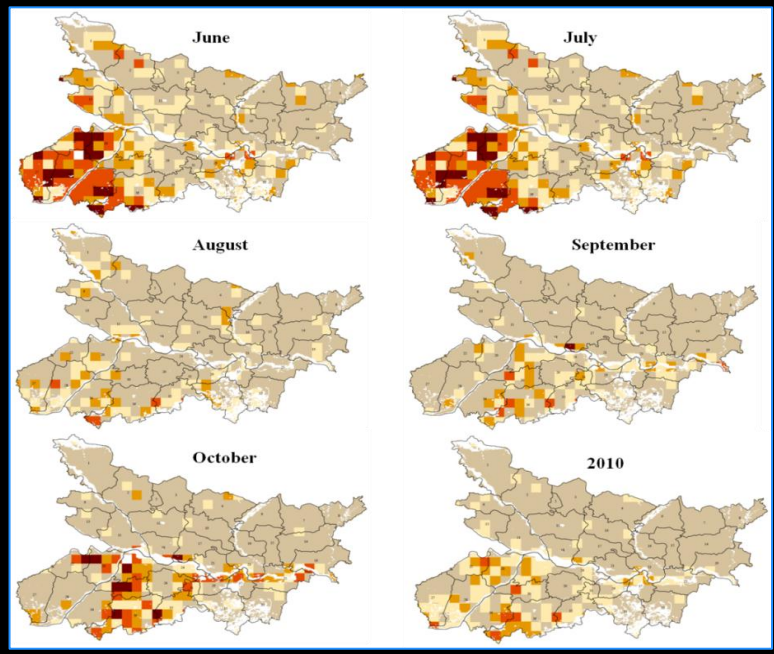


Vegetation Health Index of Bihar from 2009 to 2012 shows Maximum In year 2011 and less in 2009 and 2010

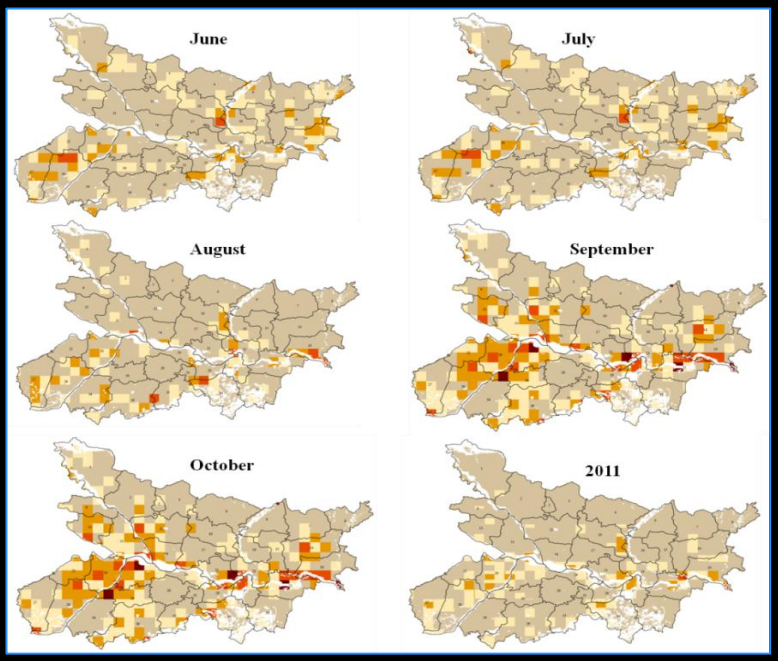


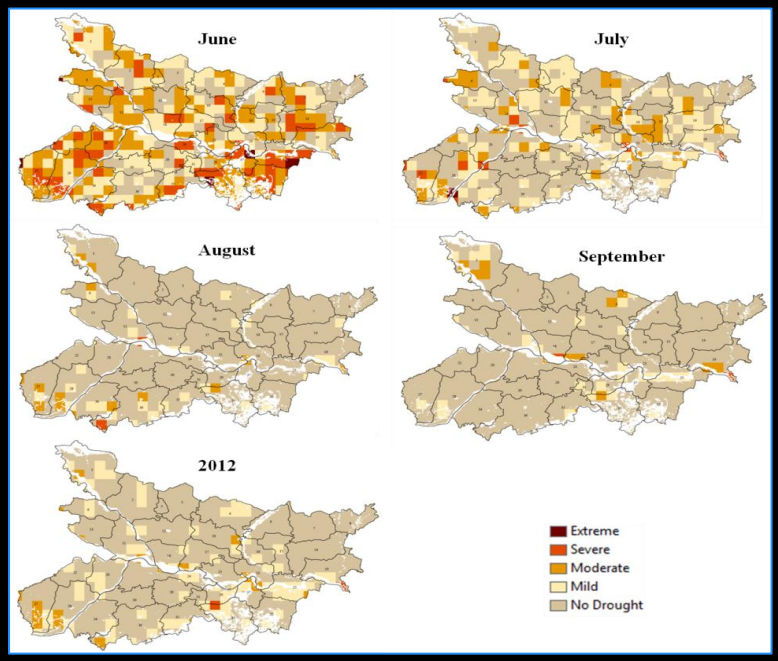


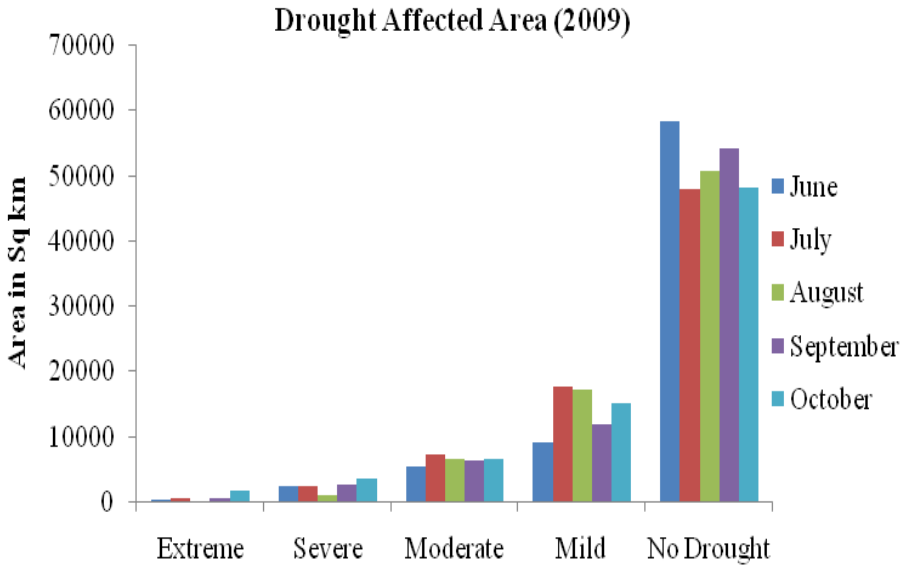


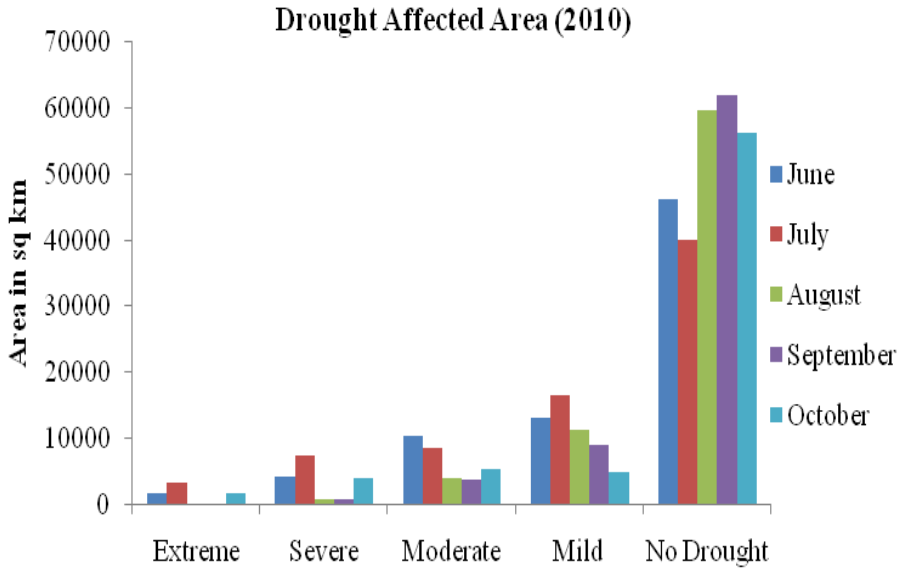


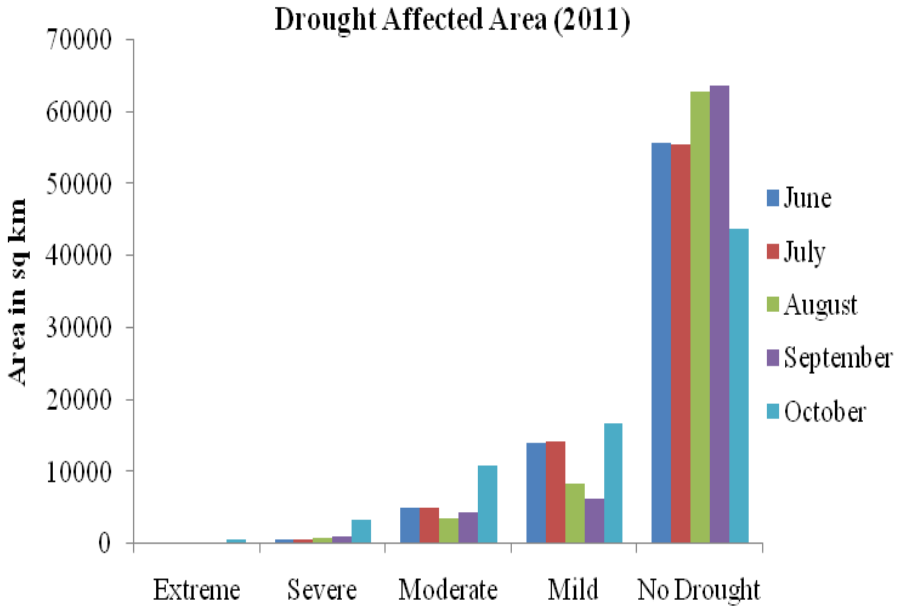
Drought affected areas of Bihar during 2009 to 2012 shows Minimum in 2011 while Intensity and spatial distribution of drought is much more in 2009 and 2010

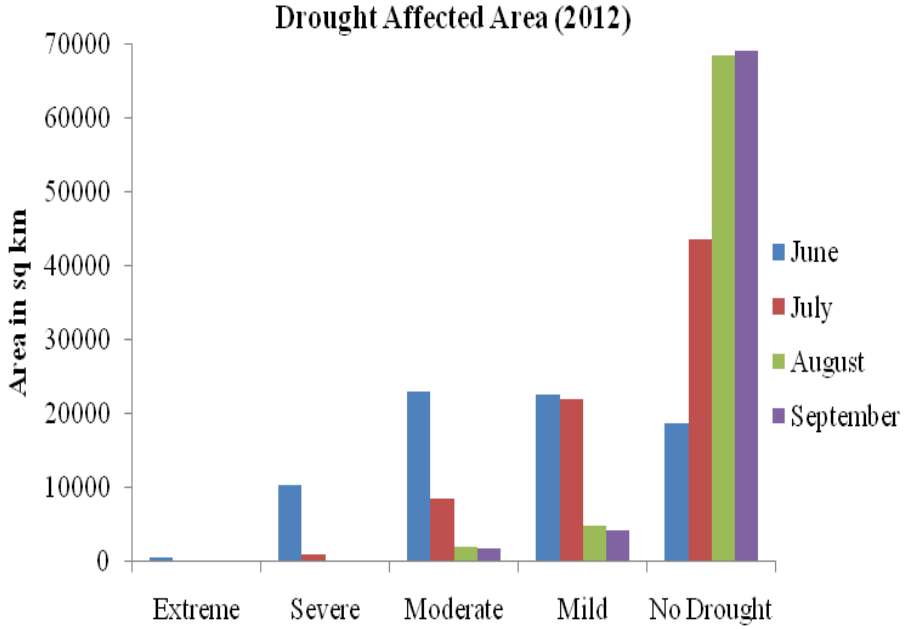




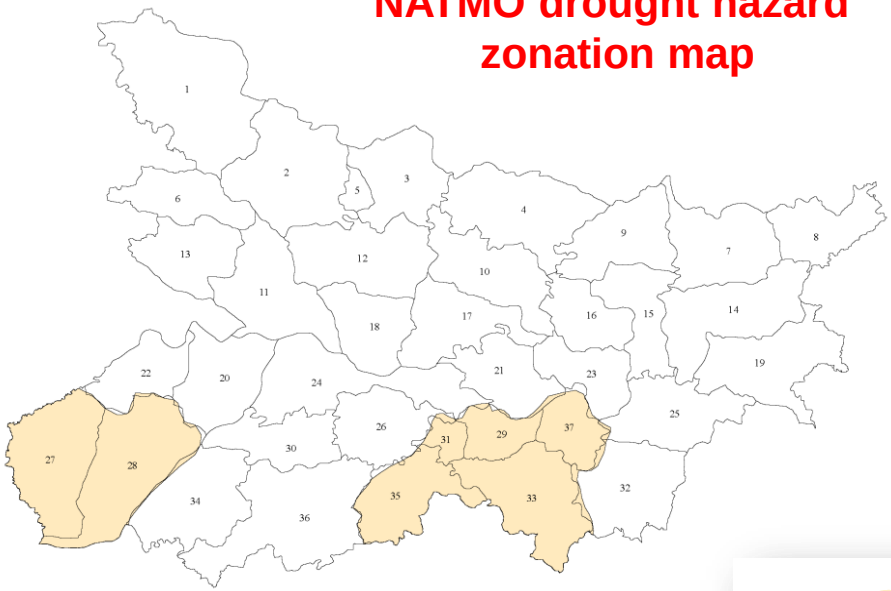

Drought Affected Area (2009)
Area in Sq km
70000
60000
50000
40000
30000
20000
10000
0
Extreme
Severe
Moderate
Mild
No Drought
June
July
August
September
October


Drought Affected Area (2010)
Area in sq km
70000
60000
50000
40000
30000
20000
10000
0
Extreme
Severe
Moderate
Mild
No Drought
June
July
August
September
October


Drought Affected Area (2011)
Area in sq km
70000
60000
50000
40000
30000
20000
10000
0
Extreme
Severe
Moderate
Mild
No Drought
June
July
August
September
October

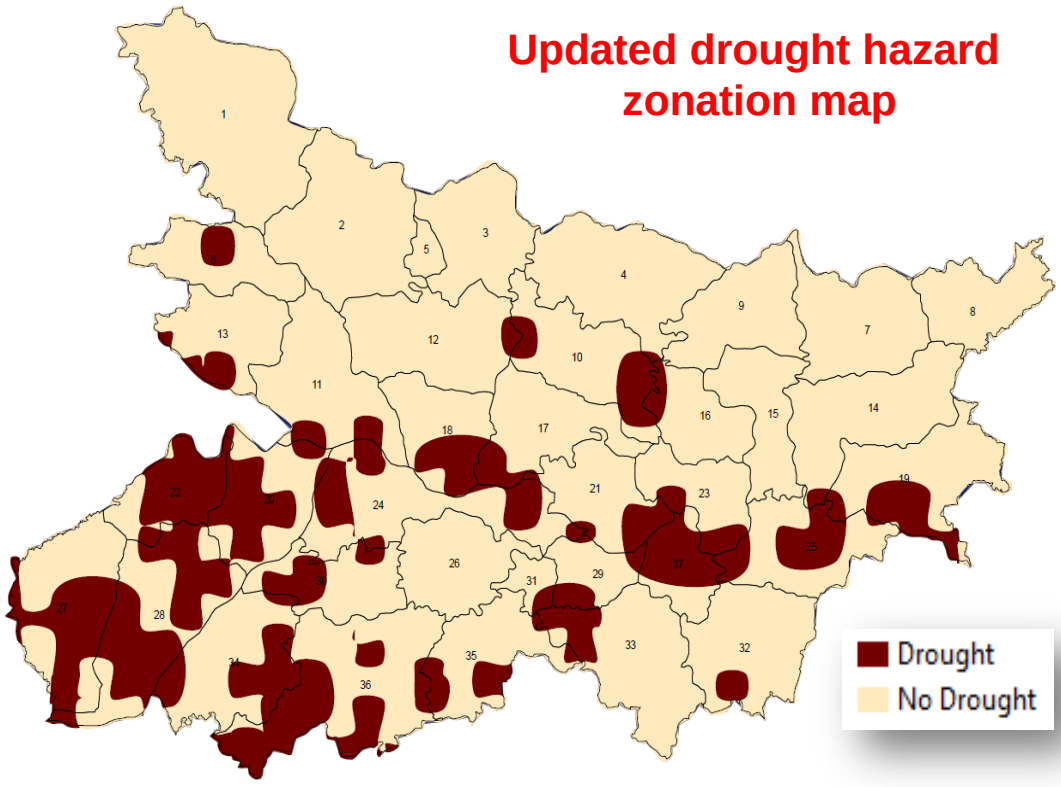

Drought Affected Area (2012)
Area in sq km
70000
60000
50000
40000
30000
20000
10000
0
Extreme
Severe
Moderate
Mild
No Drought
June
July
August
September

NATMO drought hazard zonation map



Updating the previous work

Updated drought hazard zonation map



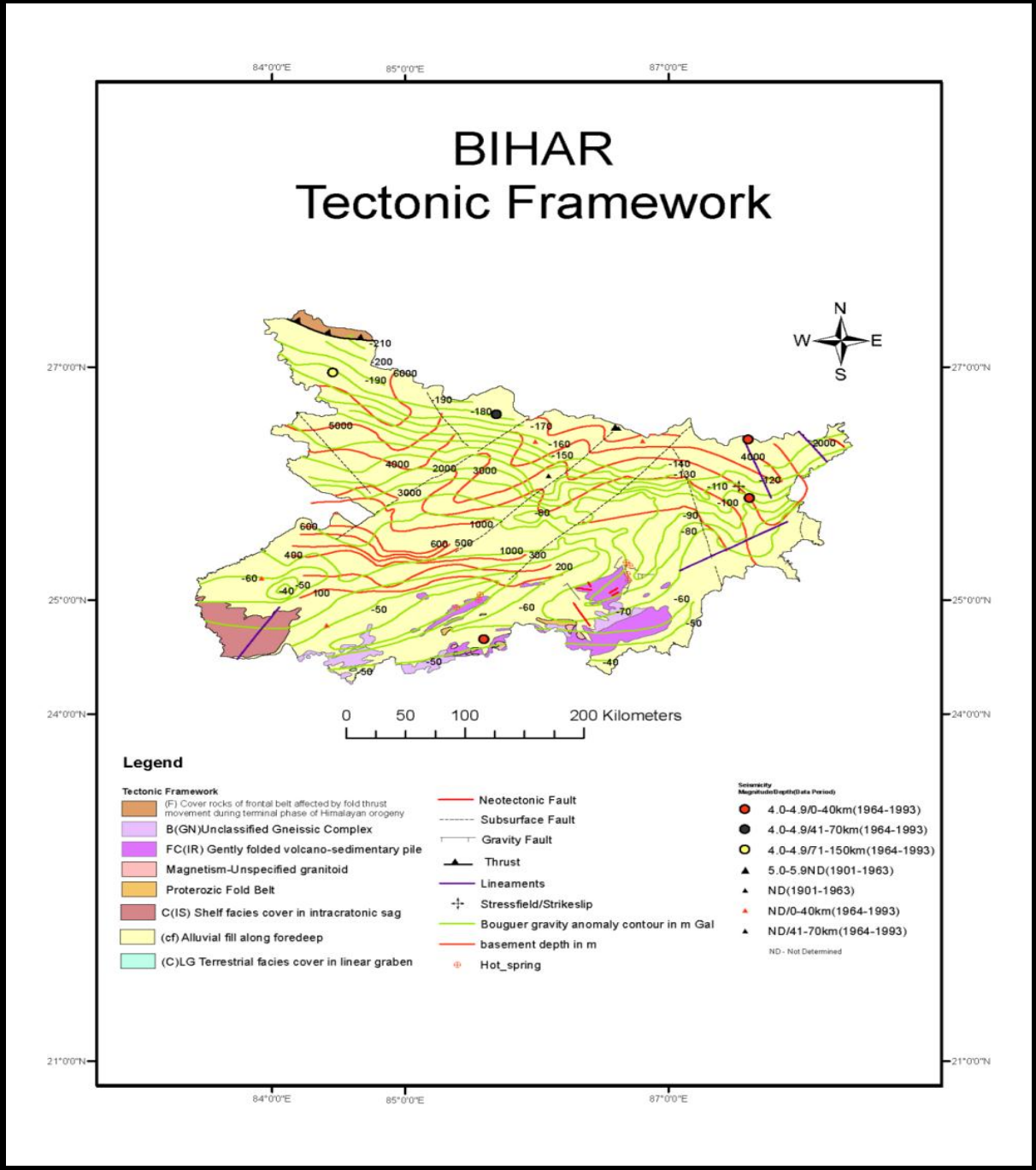
Conclusion

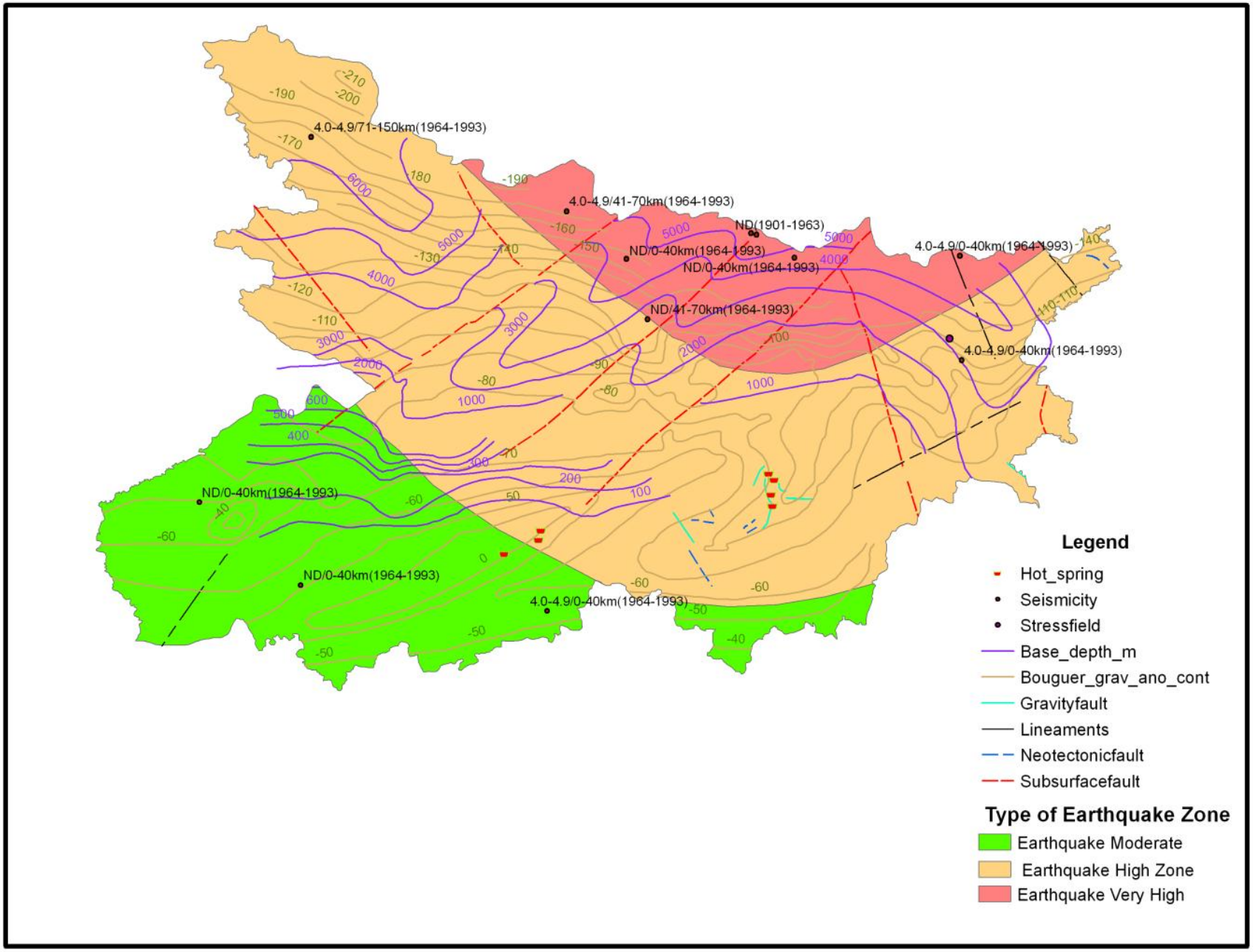
- Analysis of droughts in Bihar suggests that the southern part of river Ganga faces severe drought every year during Kharif season.
- The main reason for these droughts is the onset of monsoons and its uneven spatial distribution.
- The pre-monsoon droughts are more severe as compared to those in the post-monsoon season.
- A shifting pattern of pre-monsoon and post-monsoon droughts has been observed. June, July, and October are the most drought prone months.
- Ten districts of Bihar those are mostly affected by drought:

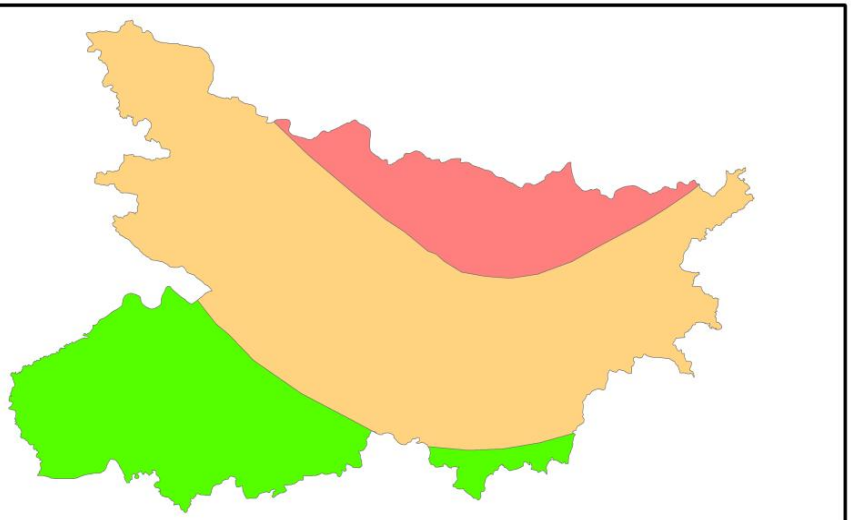
Kaimur	Bhojpur	Siwan
Rohtas	Gaya	Gopalganj
Aurangabad	Jahanabad	
Buxar	Patna	

Earthquake

Tectonic and earthquake zonation maps have been compiled using secondary data and other available maps, their analysis and finally transferred into the GIS platform and staellite images

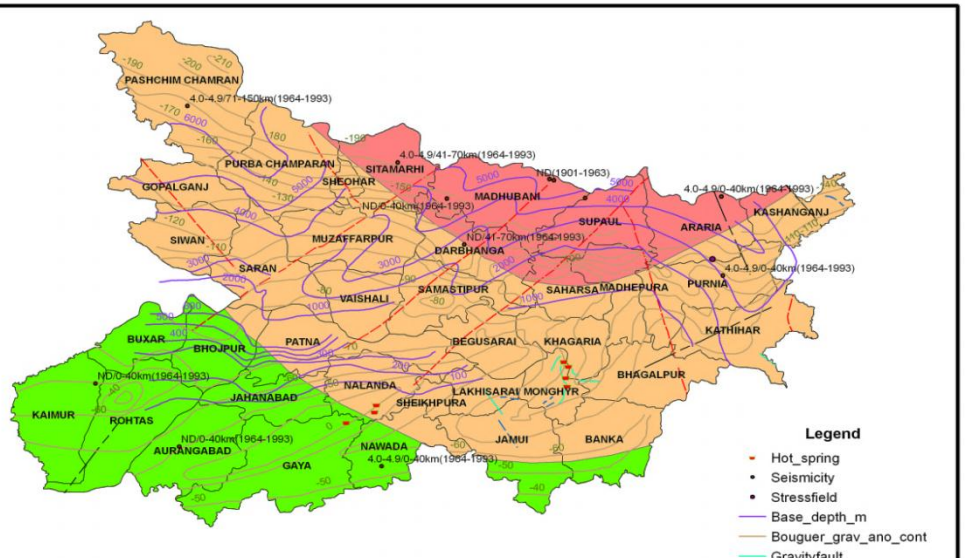



4.0-4.9/71-150km(1964-1993)
4.0-4.9/41-70km(1964-1993)
ND(1901-1963)
ND/0-40km(1964-1993)
ND/0-40km(1964-1993)
4.0-4.9/0-40km(1964-1993)
ND/41-70km(1964-1993)
4.0-4.9/0-40km(1964-1993)
ND/0-40km(1964-1993)
ND/0-40km(1964-1993)
4.0-4.9/0-40km(1964-1993)
Legend
Hot_spring
Seismicity
Stressfield
Base_depth_m
Bouguer_grav_ano_cont
Gravityfault
Lineaments
Neotectonicfault
Subsurfacefault
Type of Earthquake Zone
Earthquake Moderate
Earthquake High Zone
Earthquake Very High



UNDP Earthquake hazard zonation map

Updating the previous work

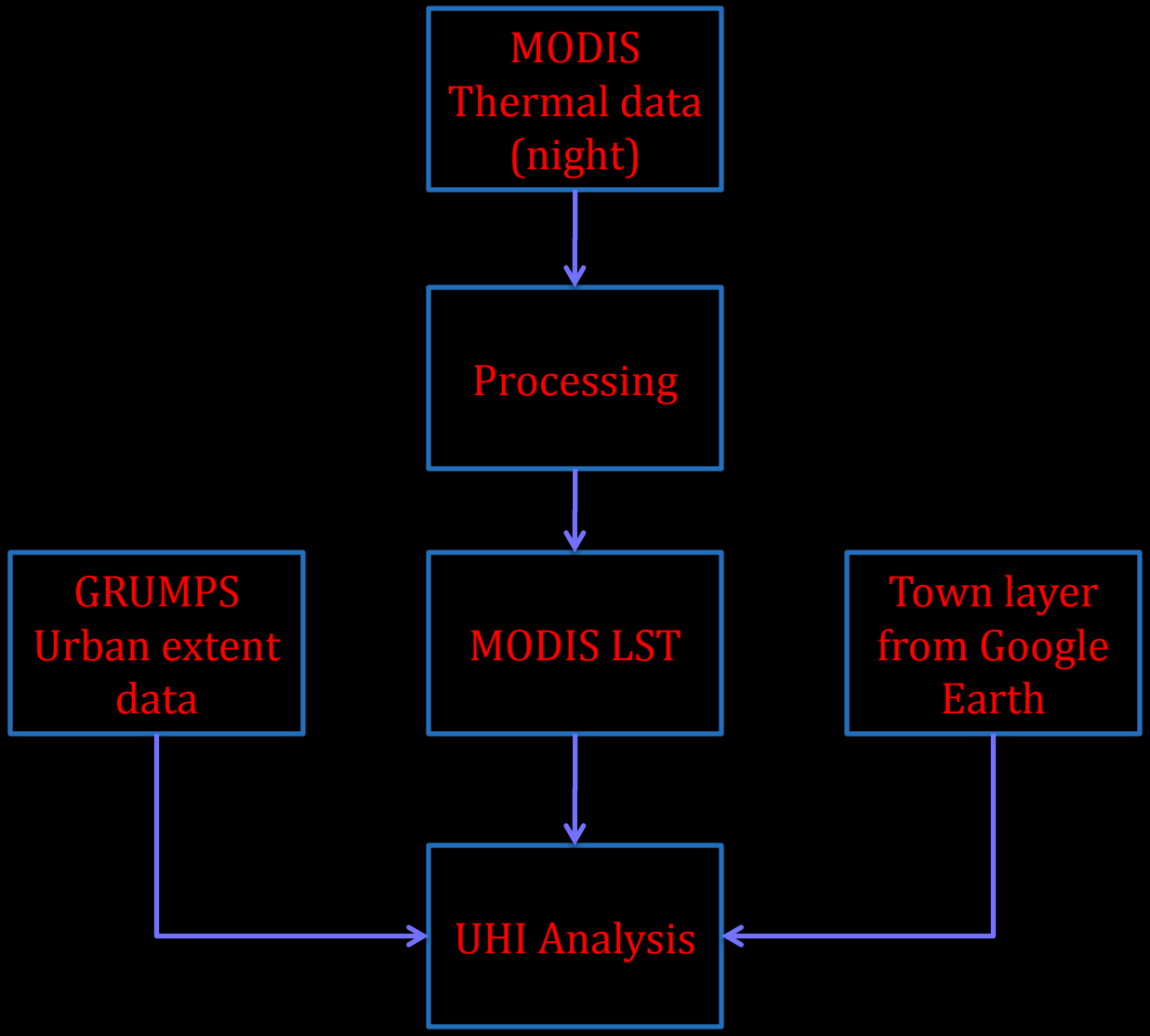


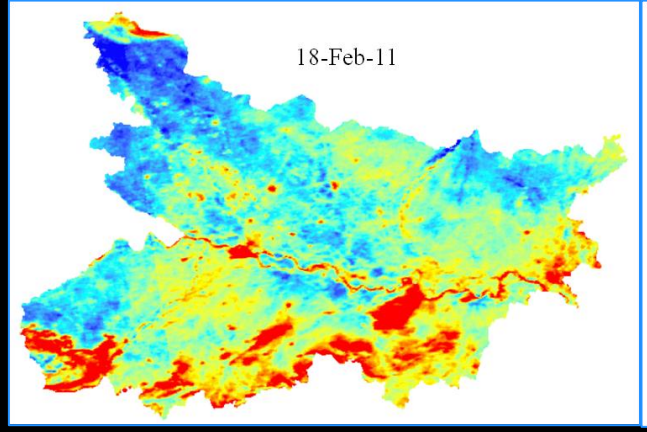
Updated Earthquake hazard zonation map

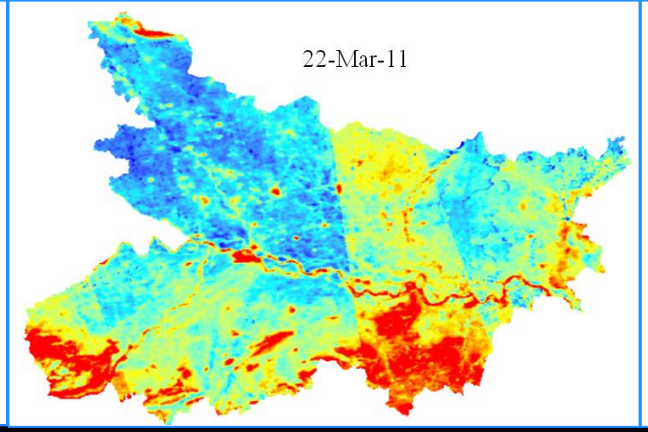
Conclusion

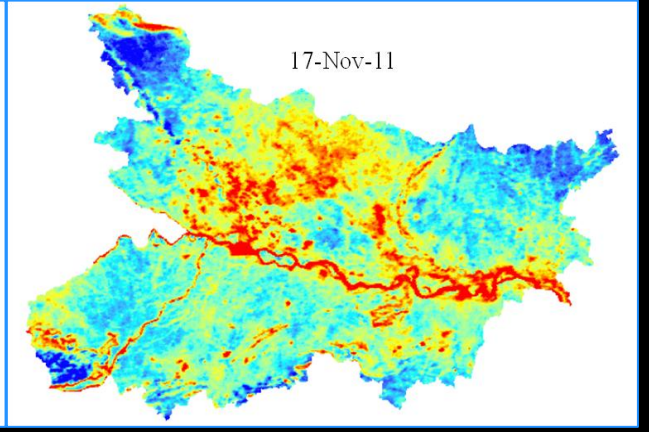
- The compilation of the available earthquake maps are showing some serious data gaps in tectonic framework of Bihar
- The earlier and latest zonation are almost similar, but needs to identify the potential impact on other geological processes and also the stability of other land features
- The exact level of location specific impacts to be estimated along the weak zones, if earthquake occurs

Urban Heat Islands

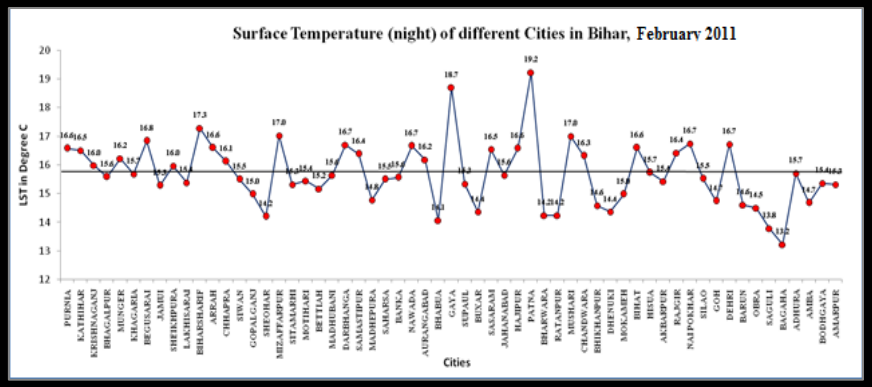


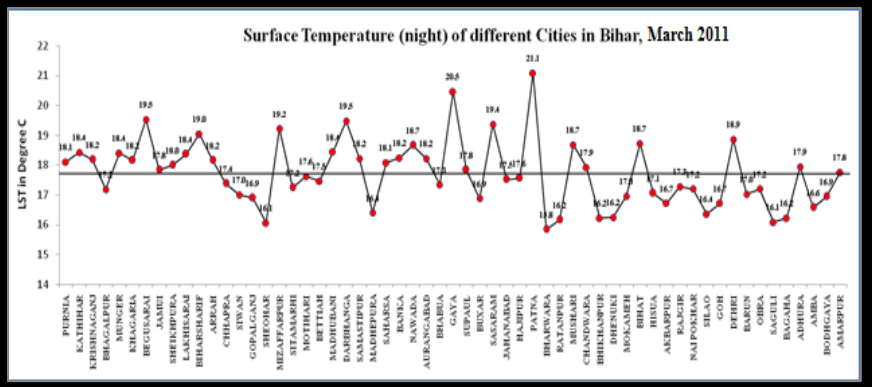


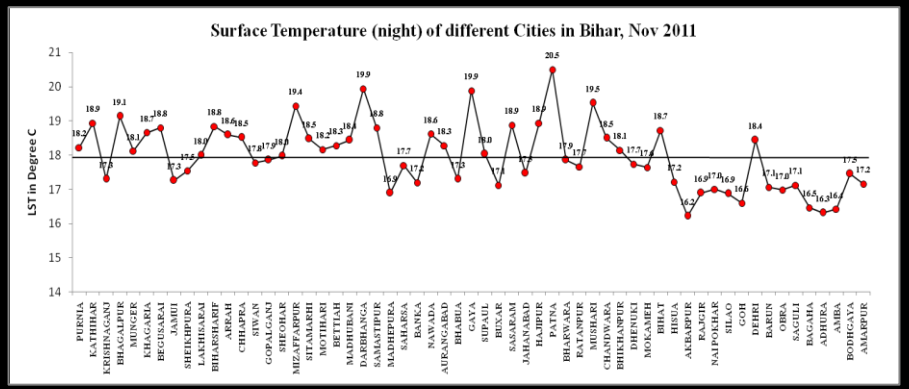


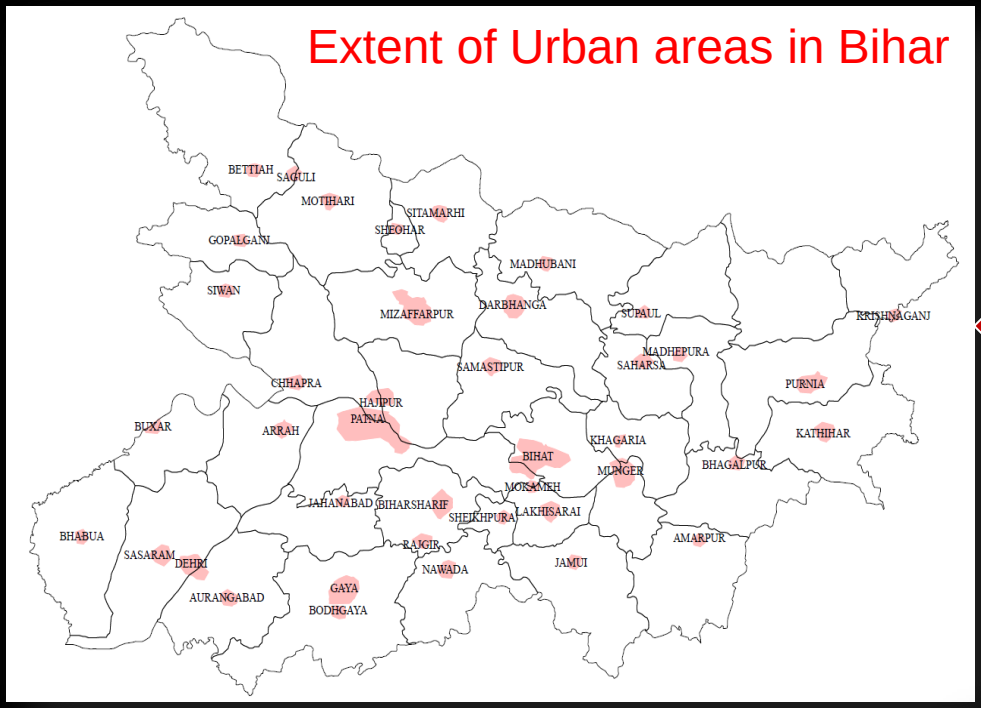


The night time temperature of the urban areas is much higher than the surroundings including rural areas. It is observed that the major cities have higher temperature as compared to the less populated cities, and quantified.



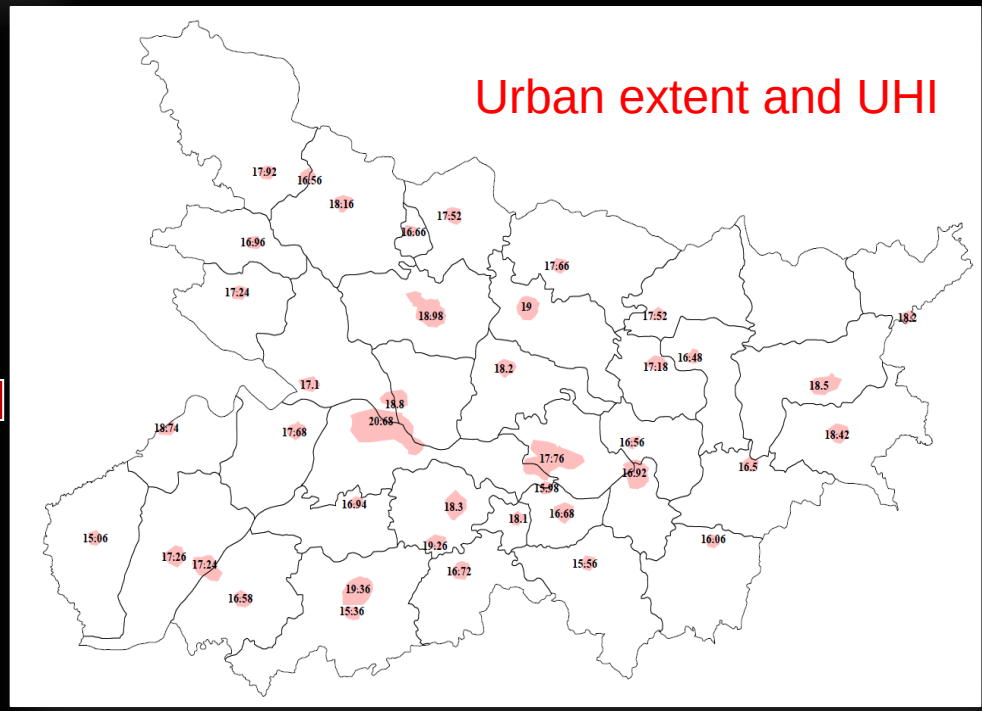






The geographical extent of urban areas in Bihar. It indicates the physical extent of the various cities of Bihar estimated from DMSP night time light data sets.

Urban extent with night time land surface temperature.
It indicates that temperature is higher in urban extent.
It signifies that urban extent is a significant potential for urban heat islands



Conclusion

- The results achieved from the satellite data indicate that Bihar is suffering from urban heat island (UHI) effect.

- The night time land surface temperature is higher in urban areas than in rural areas. With rapid urbanization and growth of population density, the impervious surface area is increasing in the cities.

- Finally, all these factors are leading towards the formation of heat islands.

Comment: The climate change scenario and release of greenhouse gases (GHGs) are also responsible for the formation of UHI. It is an accumulated effect of human activity level and climate change. Hence, the identification of different driving forces responsible for UHI and analysis of air temperature data in relation with climate change scenario are necessary to assess the environmental monitoring in the context of climate-change.

Multi-hazard zonation map using Spatial Decision Support System (SDSS) technique

$$S_{HZ} = f \int_{i=1-10}^{w_i} (Fl, Drt, E_q)$$

Where;

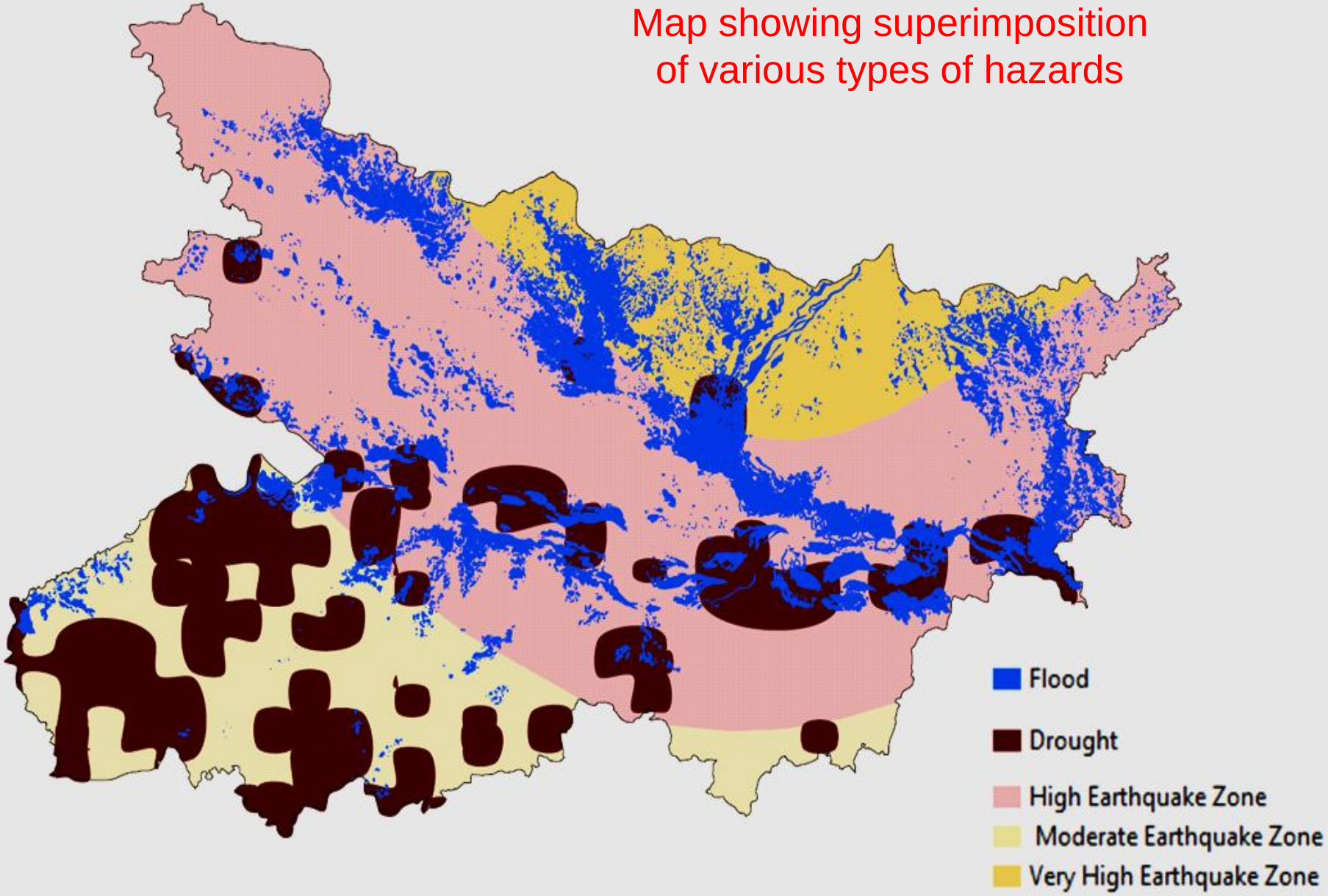
S_{HZ} = Schematic Hazard Zonation

Fl = Flood

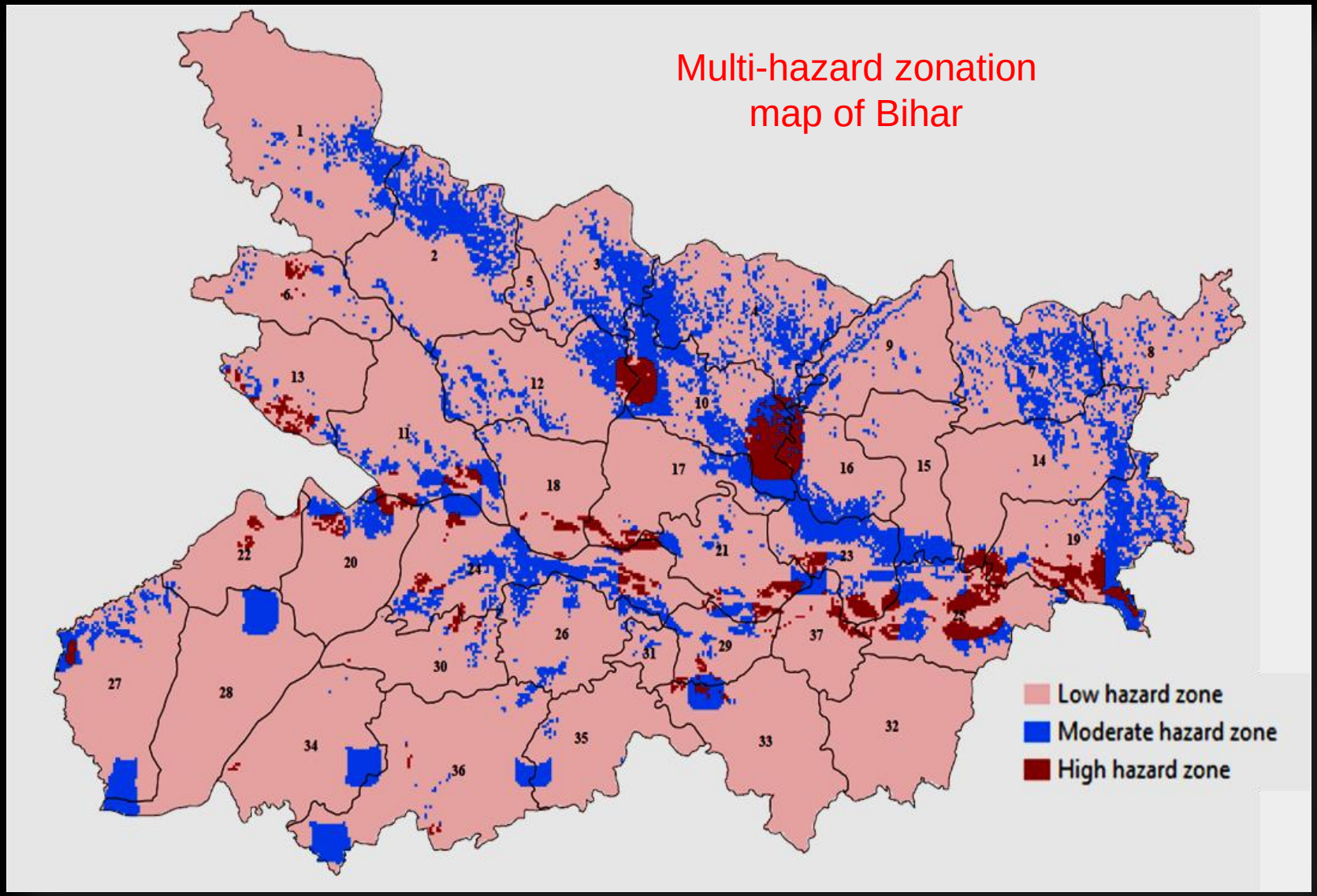
Drt = Drought

E_q = Earthquake

Map showing superimposition of various types of hazards



Combining different categories of hazards to come up with the level of vulnerability



Can we now locate the areas with different ranking of vulnerability?

Can we use them in the process of development planning??

Vulnerability is the function of time and it depends on

Societal Situations

- Poverty
- Limited access to
  - Power structures
  - Resources
- Ideologies
- Economic systems

Aggravating Factors

Lack of
- Local institutions
- Education/training
- Appropriate skills
- Local investment
- Local markets
- Press freedom

Macro-forces
- Population expansion
- Urbanization
- Environmental degradation

Unsafe conditions

Fragile Physical Environment
- Dangerous locations
- Dangerous constructions of buildings & infrastructure

Fragile Local Economy
- Livelihoods at risk
- Low income levels

Public Actions

Options to approach this problem?

- Do nothing
- Avoid or remove the problem and send away the Hazard somewhere else
- Weaken the Hazard
- Do not allow the vulnerable people and society to live in the hazardous areas.
- Convert vulnerable people/society/environment and vulnerable economy in the hazardous areas into non vulnerable one

or

- Reduce the Vulnerability of people, society, environment & economy and make use the natural event for economic growth & livelihood enhancement
- Prepare very well to face this hazard much before it strikes

Basically we are towards the Disaster Proofing of Development by making a comprehensive Preparedness Plan creating further scope for better development perspective

Paradigm Shift

Present Emphasis

Managing response to disasters

Getting changed to

Managing risks and the underlying conditions that lead to disasters

But hardly we are doing anything for

Preparedness

We are only responding to a situation

This is what Preparedness is

All these are to be done much before disasters strike

1. Awareness, sensitization & training
2. Skill development and Knowledge transfer
3. Risk assessment
4. Hazard Analysis
5. Vulnerability reduction
6. Capacity enhancement
7. Prediction and warning System
8. Mitigation and preventive measures

Level of Preparedness?

- can be measured by the components within it

Preparedness is equal to

- Preparation of PLANS and ACTIONS there from, for
  - Our Response in the next Emergency
  - Our Rehabilitation plan following that
  - Our Preventive and Mitigation Measures to be taken and being taken before the disaster arrives
  - Our success and involvement for Support Activities in
    - R & D
    - Technology Transfer
    - Education & Training
    - Public Awareness
    - Mock Rehearsal
- All that above preparations or preparedness is only to **MINIMIZE** the Impact of the coming hazard

Preparedness – Impact – Rescue, Relief & Rehabilitation

- **The more we are "prepared", lesser will be the impact of disaster**

- **The lesser the impact of disaster, lesser will be requirements of Rescue, Relief and Rehabilitation**

- How efficiently and effectively we manage a disaster depends on, how meticulously we are prepared for that?

Disaster = Hazard + Absence of Preparedness

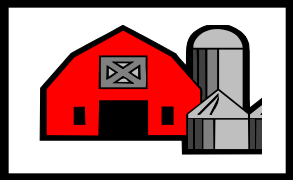
Disaster Management – potentials & possibilities for Bihar

An example on Flood Management

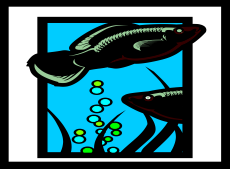
Activities -

- **Prepare relative elevation map with close contours**
2. **Demarcate the river basins and identify their carrying capacity**
3. **Risk analysis for the vulnerable people, property and resources**
3. **Prescribe probable structural changes and land alteration**

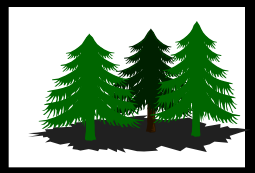
G R O W T H



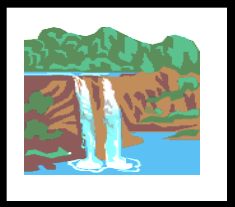
Agriculture
Crop Yields
Irrigation Demand
Food Processing



Fisheries



Forestry
Forest Composition
Geographic Range of Forests, Health and Productivity

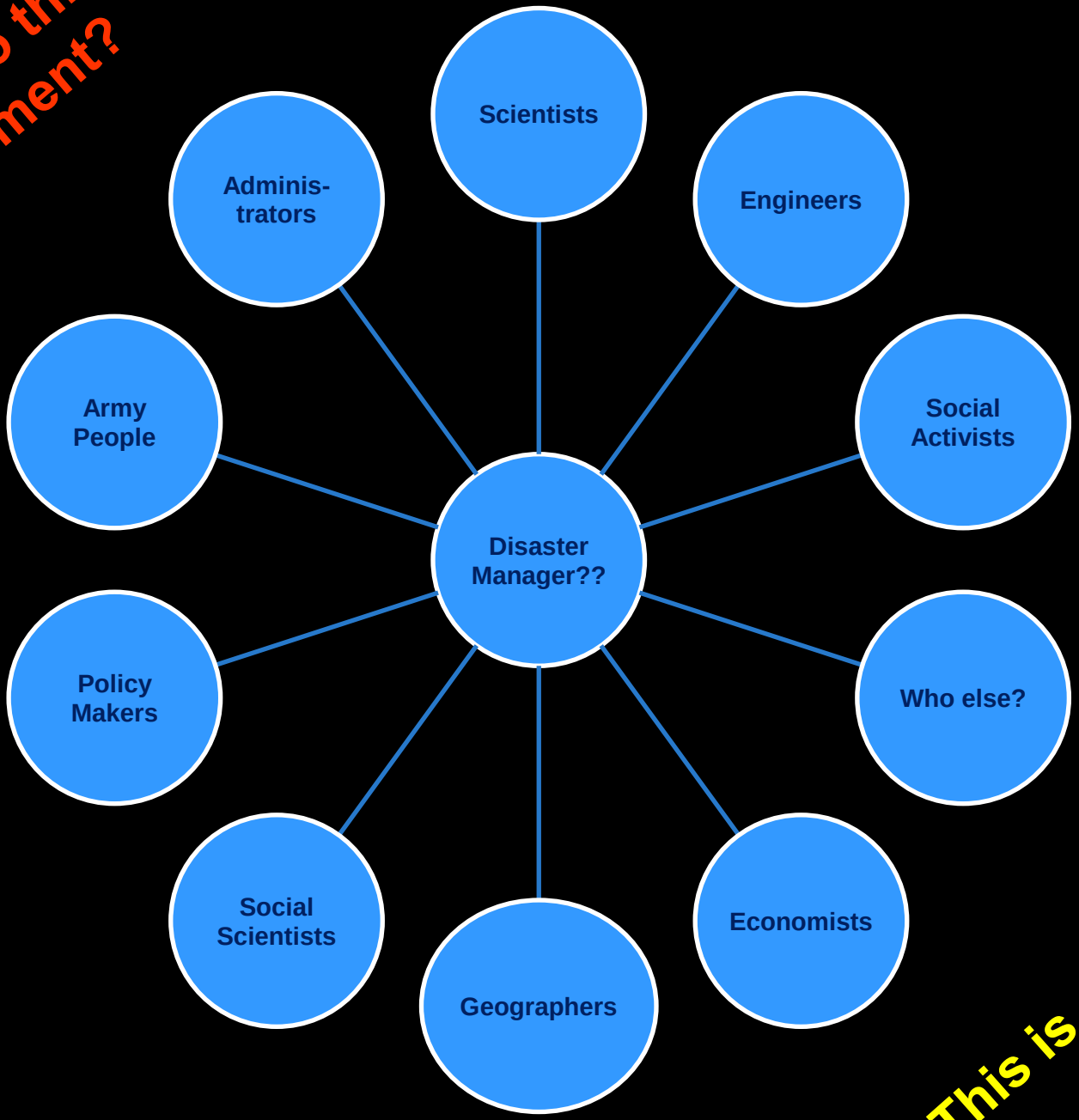


Water Resources
Water Supply
Water Quality

Energy
Hydroelectricity generation

Biodiversity
Species and Natural Areas
Gain of Habitat and Species

Who will do this management?



This is a Collective Effort

RECOMMEDATIONS

Category-I	Action needed	Remarks
Stress on more activities	• Block level natural hazards zonation • Analysis of frequency, magnitude and scope of the historical events to estimate the expected damage that may occur from such events • Perform Risk Analysis and Hazard Analysis procedures • Combine climate map and population map with all possible analysis • Formulation of comprehensive preparedness plan for damage minimization • Effective functioning of EOC and formulated SOPs • Awareness and capacity building for the community • Ensure growth in every possible policy formulations	Serious effort must be put in to address the characterization, minimization and, policy formulation for disaster management strategies with clear linkages to climate change scenario

RECOMMEDATIONS

Category-II	Actions needed	Remarks
Allow paradigm shift in thought process	Formulate the procedures to/for - • Deal with the rural and urban disasters in different ways • Actual assessment of the damages • Reaching out to the cut off villages • Evacuation of the local community and tourists • Restoration of communication with the villages and transportation of essential commodities • Protection of crops, livestock, etc. • Tackle the added situation of VVIP visits, media management, political opportunism and keeping up employees working in relief operations along with the morale of public at large Indulge the processes of - • Mobilizing villagers to remove silt from water ponds and check dams, and for strengthening embankments. • Harvesting of rainwater and recharging of wells • Implementing a properly planned watershed programme integrating farm ponds, village ponds and check dams • Encouraging cultivation of low water using, drought-resistant crops and crop varieties; • Introducing a higher productivity fodder crop like hybrid Napier and the practice of sowing tree crops in the peripheral areas. • Ensuring the sustainability and flourishing capacity of the society	Mindset and attitude towards disaster management should be shifted from emergency response to preparedness effort for minimizing the damage

RECOMMEDATIONS

Category-III	Actions needed	Remarks
Use modern Techniques with knowledge and objective	• 'Do fantastic science' • Delineate properly the catchments and exact basin capacity to retain water • Detect change in river courses through time • Match these with the amount of rainfall based on microclimatic study • Measure rainfall and surface water availability in comparison to threshold value for minimum needs for agriculture, domestic and industrial need • Pre and post monsoon ground water level fluctuations • Minimize potential loss from total water availability after monsoon • Optimize soil moisture along with the crop and field irrigation demand • Check the vegetation growth • Take special care for dam safety and embankment stability • Installing reliable early warning systems • Constructing reservoirs with large storage in upland or interlinking of river basins • Deeper introspection with the traditional housing construction and design new building codes for the earthquake prone areas for seismic strengthening and proper retrofitting	Make maximum use of Remote Sensing and GIS techniques for fast, actual, and conclusive assessment blended with ground reality and perception.

Thank you

for your kind patience