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Risk Assessment of Flood for Various Spatial and Temporal Mining Scales Using Flood Vulnerability Index [FVI] – A Case Study of Madhubani Kosi River Flood Affected District in North Bihar, India

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INTRODUCTION

Several countries experience fatalities, injuries, property damage, economic and social disruption resulting from natural disasters. The natural hazards kill thousands of people and destroy billions of dollars' worth habitat and property each year. The rapid growth of the world's population has escalated both the frequency and severity of the natural disasters. Flood disaster has a special place in natural hazards. Floods are the costliest types of natural hazards in the world and constitute 31% of the economic losses resulting from natural catastrophes.[1]

Statement of Actual Problem

(1) Kosi flowing through plains of north Bihar has moved about 120 km westwards during past 220 years (Wells and Dorr 1987). Flow regulation has only added to larger shifting of river channels.
(2) River flood is due to heavy rainfall by which rivers will overflow on its banks as natural phenomenon.
(3) One factor of river flood can be low absorbing capacity of ground.
(4) Here, the flood of river Kosi, which has a little bit flavor of flash flood, in terms of its intensity of occurrence.
(5) It encounters an enormous amount of human and animal causalities, public property damage, annihilate social living of society every year and huge expenditure comes to surmount this pre-known natural disaster.

In view of the massive destruction and losses that take place every year due to flooding in north Bihar, many researchers tried to clinch the interest of government and international agencies to implement the theory of check and balance so far as investment in disaster risk reduction program is concerned.

Flood Zones Map of Bihar

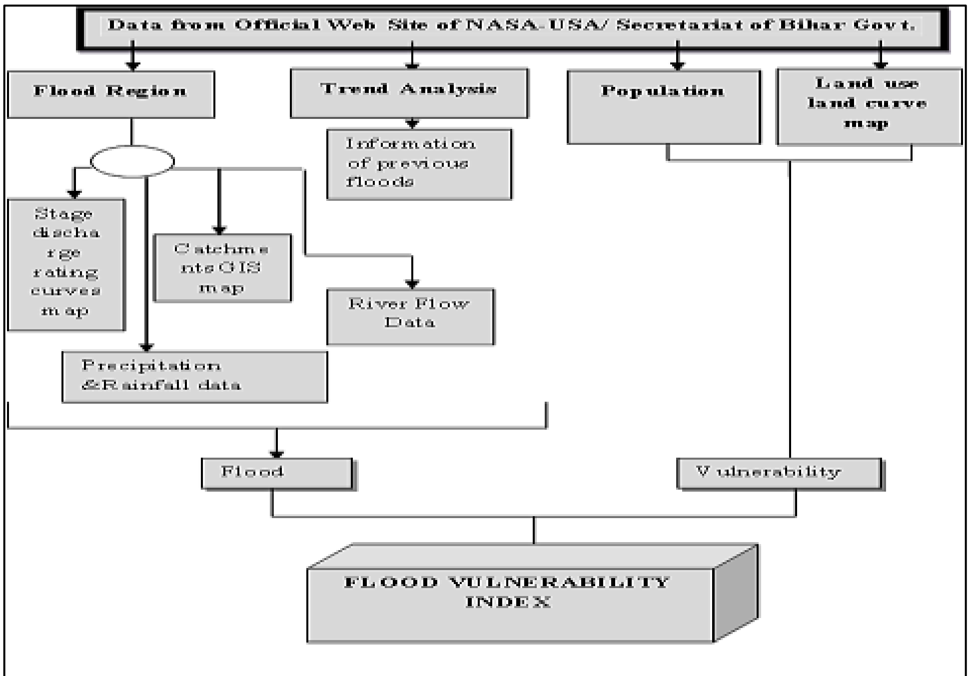
Disaster Management Cycle for Natural Disaster (Flood) – A Summary

'Disaster management cycle' is a normative model of applicable programming intrusions at sequential stages in the describing of a disaster event. Following are five recognized activity areas for cooperation:

1. Risk assessment: by data investigation and results.
2. Disaster preparedness: natural disasters like flood are normally categorized & known as two kinds such that 'Slow-onset' hazards and 'Rapid-onset' natural disasters. The uncharacteristic feature of the rapid-onset danger is that they have an unfamiliar probability which provides nearly no prospect for warning before there impacts are felt.
3. Disaster prevention and mitigation through early warning system: Simulation process has been used for this. Annual flooding in North Bihar happens among the month of July to August every year whose effect is rapid. Thus, slow-onset disaster hazards can be organized through the community capability building & preparedness programs.
4. Mainstreaming disaster risk management in development cooperation sector through flood vulnerability index (i.e. FVI).
5. Disaster risk management as part of rehabilitation & reconstruction: limitation of this research.

METHODOLOGY

In point of fact, defining the flood susceptible zones in the study area two stages was commenced. First of all is determining the contributory factors affecting flood in the study area and furthermore, is applying the Multi-Criteria Evaluation technique in discover the flood susceptible areas grounded on the flood associated factors of the study area. In assessing the flood susceptible areas, Pair-wise Comparison Method was used. It is an integral part of analytical hierarchy process (AHP) proposed.[2] These benefits in detecting the flood susceptible areas in the study area by classifying the most flood important criteria based on the decision makers' predilections. Following Figure exemplifies the procedural flow of the study.



Research Methodology

Research Methodology

Research design	Exploratory research design
Data type	Secondary data
Data source	For statistical forecasting data – Bihar Secretariat (Govt. of Bihar) Data for AHP – official website of NASA
Sampling used	Area sampling and judgmental sampling (in flood affected 14 districts of North Bihar)
Sample size	Fourteen heavily/majorly flood affected districts of North Bihar (that had been the main focus area of United Nations Development Program (UNDP) during year 2002–2006).

Research Hypothesis

1	Null hypothesis (H_0)	There is no relationship between occurrence of flood/intensity of flood and FVI for mitigation to flood affected areas.
2	Alternative hypothesis (H_1)	There is certain connection among existence of flood/amount of flood and FVI for mitigation to flood affected areas.
3	Hypothesis testing	Employing AHP for quantify the decision parameters used to evaluate FVI on 27 climate and hydrological parameters along with 15 socio-economic parameters responsible for flood, result is obtained. But the use of Chi-square test did not validate the trend analysis, as of assumption considered that we cannot quantify the value of human life (causalities) in term of capital as because human life is invaluable, it is a non-parametric degree which cannot quantified.

Multi Criteria Analysis

First and foremost, this method is much more complicated than ranking and rating methods, it has been criticized by the way of receiving the ratios of importance. With this linear time series analysis of these 14 Kosi flood affected 14 districts of north Bihar we are converting subjective assessments of relative importance into a linear set of numeric weights.

Significance for Selection of Madhubani as Study Area

Government of India & United Nations Disaster Risk Management program has been implemented in the State of Bihar, since 2002 in the multi-hazard prone following14 – districts along with other 17 states of the country. The program is being executed by Ministry of Home Affairs, Govt. of India and was implemented by Disaster Management Department, Govt. of Bihar. The program is supported both financially and technically by United Nations Development Program. A work plan is approved by the government for implementation of the program from state to village level.(Figure 1)

Sample Space

Samastipur	Khagria	Madhubani	Patna	Saharsa	Munger
Begusrai	Araria	Supaul	Kishanganj	Madhepura	Sitamarhi
Muzzafurpur	Darbhanga				

For evaluation of most & frequently flood affected districts, trend analyses have been performed on aforesaid districts (as per UNDP). A sample mechanism (one of among 14 affected districts) has been illustrated bellow. Hallucination of Linear Time Series — Quantitative forecasting method is used for long range forecast as a non-parametric measure.

	Value of Damaged Crops	Value of Damaged Residential Buildings	Damage Value of Public Property	Cash Dole Compensation distributed	Total Amount (Rs)	
	(Rs Lakh)	(Rs. Lakh)	(Rs. Lakhs)	(Rs. Lakhs)		
1991	8.13	2.64	0.5	0	11.27	
1992	0	0	0	0	0	
1993	34	184.55	210.76	0.03	429.34	
1994	0	0	0	0	0	
1995	689.76	212.54	127.2	19.01	1048.51	
1996	448.8	0.5	0	0.03	449.33	
1997	1.57	0	0	0.11	1.68	
1998	302.24	47.45	0	130.81	480.5	
1999	1619.36	309.17	845.5	0.58	2774.61	
2000	172.58	760.4	2	26.78	961.76	
2001	320.82	328.24	107	42.86	798.92	
					6955.92	**Trend**
2002	13330.6	31180.43	5311.01	268.89	50090.93	1436.098
2003	6	0	0	0	6	1570.055
2004	5500	6192.73	13771.7	805.78	26270.21	1704.012
2005	67.47	0.4	0	0	67.87	1837.969
2006	180.34	6	0	0	186.34	1971.926
					76621.35	**8520.062**

Trendline				
Years	**X**	**Y**	**X*X**	**X*Y**
1991	1	11.27	1	11.27
1992	2	0	4	0
1993	3	429.34	9	1288.02
1994	4	0	16	0
1995	5	1048.51	25	5242.55
1996	6	449.33	36	2695.98
1997	7	1.68	49	11.76
1998	8	480.5	64	3844
1999	9	2774.61	81	24971.49
2000	10	961.76	100	9617.6
2001	11	798.92	121	8788.12
Σ	**66**	**6955.92**	**506**	**56470.79**

Calculate Time Series Y = a + b * x ; where slope → b = (Δy/Δx)		
	Actual	**Trends**
2002	50090.93	1436.098
2003	6	1570.055
2004	26270.21	1704.012
2005	67.87	1837.969
2006	186.34	1971.926
	13939.88	**5973.865**

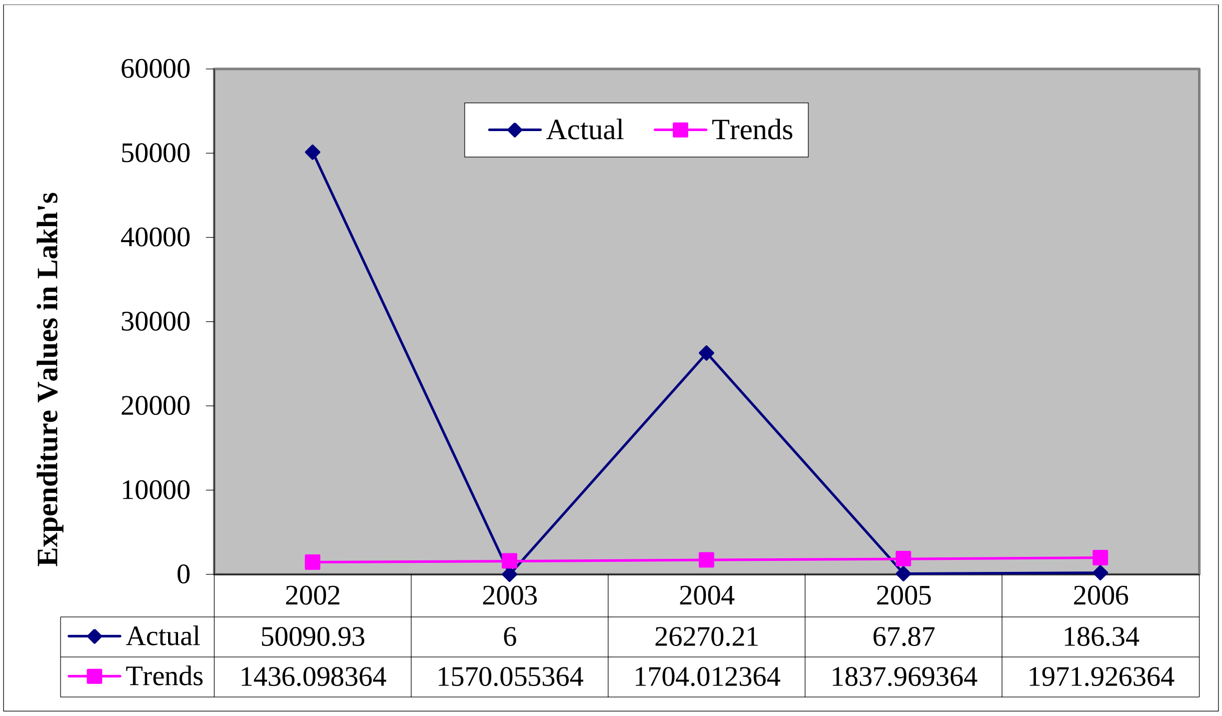


Fig. 1. *NIDM Bihar: National Disaster Risk Reduction Portal.*

Calculation Considering Abnormal Flooding Year -2004

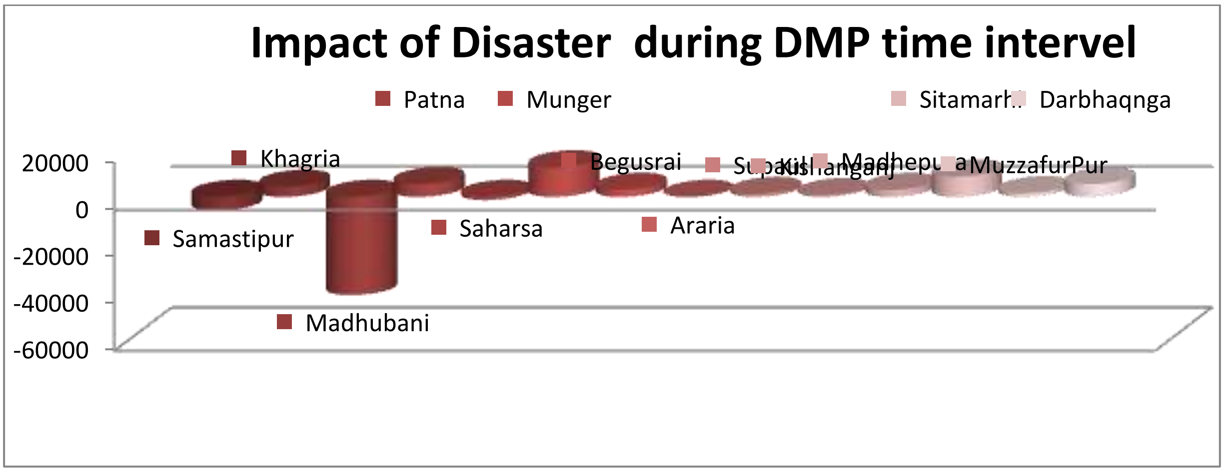
Time Series — Quantitative forecasting technique for extended range forecast on basis of following facts:

1) Past information about the capricious being forecasted is obtainable (from year 1991 to 2006).
2) Available information is quantitative (in terms of amount of rupees)

	Samastipur	Khagria	Madhubani	Patna	Saharsa	Munger	Begusrai	Araria
2002	-6709.88	-209.51	50090.93	1021.78	-3260.13	2111.67	-531.74	-3160.71
2003	-1370.30	738.35	6.00	693.87	370.31	2038.09	546.46	530.49
2004	747.12	1194.77	0.00	1170.33	485.19	2570.85	951.18	802.74
2005	683.43	1209.24	67.87	1242.00	487.98	2800.45	999.83	859.34
2006	820.13	1348.72	186.34	1313.68	543.12	3030.04	1048.48	915.94
	-5829.50	**4281.58**	**50351.14**	**5441.67**	**-1373.54**	**12551.09**	**3014.22**	**-52.22**

3) Reasonable supposition is that, the pattern of past will stay in the future.

	Supaul	Kishanganj	Madhepura	Sitamarhi	MuzzafurPur	Darbhaqnga
2002	-436.88	-234.57	409.02	-9407.91	-1496.73	-4705.55
2003	350.75	229.92	570.62	4194.75	2142.09	2322.95
2004	426.64	241.01	612.79	4560.66	3301.22	2517.35
2005	428.33	252.10	654.95	4609.92	3490.96	2537.65
2006	461.09	249.01	697.12	4622.62	-5865.29	2742.94
	1229.92	**737.47**	**2944.50**	**8580.05**	**1572.25**	**5415.34**



Above study shows that among 14 districts 'Madhubani' is one which have least impact of rehabilitation and mitigation efforts.

ANALYSIS

Temporal Vulnerability

Monthly assessment of numeric values of FVI for period of time starting from January 1979 to August 2014; a total for 428 months secondary data. (Figure 2)

District Name	Latitude Longitude Pointer Location(as Under)(scale): 2mi=2kms)			
	North	East	West	South
MADHUBANI	**26.376338**	**86.097766**	**86.049529**	**26.316036**

Spatial Vulnerability

Choice of criterions that has a spatial reference is multi-criteria decision analysis and has significance in causing flood in the study area.

Selection of vulnerability domains and indicators

Several studies designate that suitable vulnerability areas and displays can play a significant role for spatial vulnerability assessment (Kienberger et al., 2009). It is hard to straight amount vulnerability due to its multidimensional features. For its spatial measurement, different physical, social, economic, and environmental dimensions should be taken into account. For the present study, vulnerability domains and indicators are selected which shall reflect major study area characteristics. This is based on consultations with the disaster experts and the community people and on literature review.[3-4]

1. Reporting Area For Land Utilization Statistics
2. Forests
3. Not Available For Cultivation

3.1 Area Under Non Agricultural Uses
3.2 Barren and Un-Cultivable Land
3.3 TOTAL (3.1 +3.2)

4. Other Uncultivated Land Excluding Fallow(unplanted) Land

4.1 Permanent Pastures and Other Grazing Lands
4.2 Land Under Misc Tree Crops and Groves not Included in Net Area
4.3 Cultivable Waste Land
4.4 Total (4.1 +4.2+4.3)

5. Fallow Land

5.1 Fallow Lands Other than Current Fallows
5.2 Current Fallow
5.3 Total (5.1 +5.2)

6. Net Area sown (planted)
7. Total cropped area
8. TV PENITRATION

8.1 Upto 2007
8.2 From 2007 to 2014

9. Total Population (Upto 2011)

9.1 Percentage Of population of India
9.2 Percentage of growth (2001 -2011)
9.3 Rural population
9.4 Urban population

9.5 Area
9.6 Density of population
9.7 Sex ratio
10. GDP
11. Increase in Sex ratio (Difference between 2011 and 2001)
12. Percentage increase in literacy rate from 2001 – 2013
13. HOUSE HOLD SIZE
14. Male with low Body Mass Index (BMI)
15. Female with low Body Mass Index (BMI)

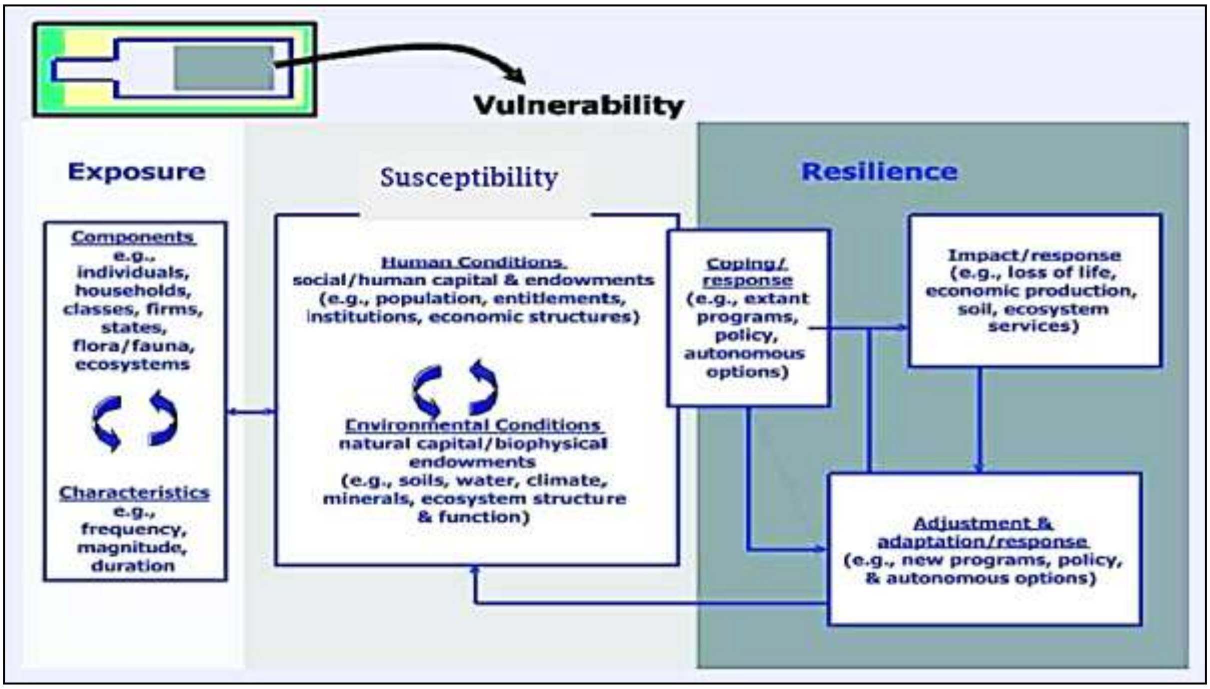


Fig. 2. *A framework for vulnerability analysis in sustainability science by B. L. Turner IIa,b,c, Roger E. Kaspersonb,d, Pamela A. Matsone, James J. McCarthyf, Robert W. Corellg, Lindsey Christensene, Noelle Eckleyg,h, Jeanne X. Kaspersonb,d, Amy Luerse, Marybeth L. Martellog, Colin Polskya,b,g, Alexander Pulsiphera,b, and Andrew Schillerb*

Assigning Relative Weights

The analytic hierarchy process (AHP) is used under the current tactic for building primacies and handing over weights to the certain vulnerability domains and indicators. The AHP is a multi-criteria decision making method that uses hierarchical structures to represent a problem and then develop priorities for alternatives based on the judgements of the experts or users (Saaty, 1980). It provides a widespread and balanced context for configuring a decision problem. It is a process to derive ratio scales from paired comparisons. The method deals with the consistency of the judgements given by the experts or users. Under the AHP, pairwise comparisons are used to determine the relative importance of each alternative in terms of each criterion.[5] A pairwise comparison matrix is used to compare and rank the selected vulnerability domains and indicators through the judgements by the experts. A pairwise comparison matrix consists of elements expressed on a numerical scale. The experts are asked to prioritize the vulnerability domains and indicators on the basis of a pairwise comparison weighting scale. The weighting scale consists of nine qualitative terms that are associated with nine quantitative values.[6-9] The scale enables the decision-maker to incorporate experience and knowledge intuitively and indicate how many times an element dominates another with respect to the criterion. Following Figure 3 shows how the weights of the respective indicators under each domain are also determined, and the consistency level of the expert judgements is maintained.

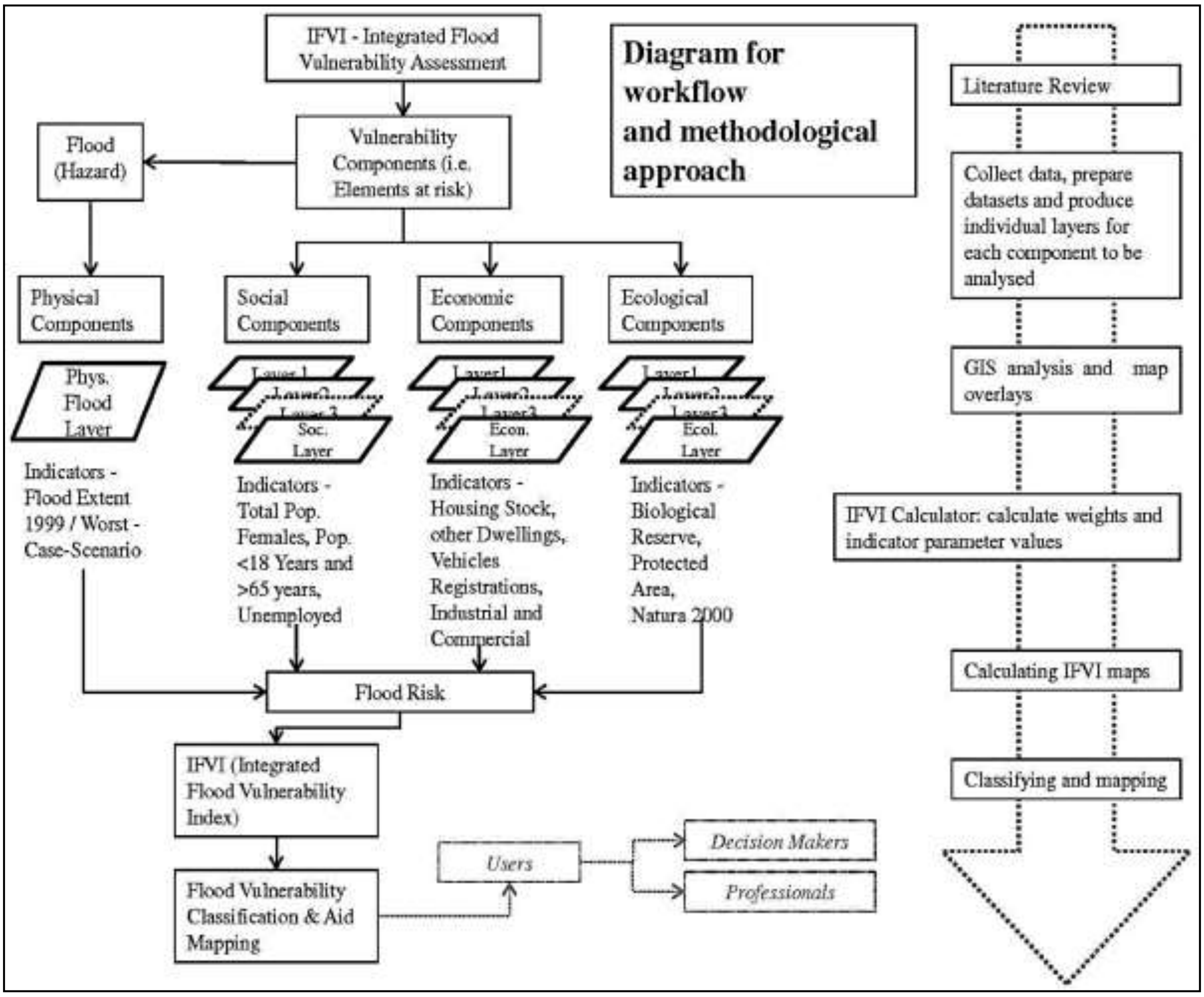


Fig. 3. *Towards an Integrated Flood Vulnerability Index – A Flood Risk Assessment By Christoph Sebald University of Twenty (Faculty of Geo-Information Sciences and Earth Observation).*

FINDINGS AND RESULTS

The Kosi river in north Bihar plains shows extreme variability in terms of flood magnitude and frequency (both spatially and temporally).

During study it was found that only hydrological data is not enough for the assessment of flood vulnerability index [FVI] as vulnerability depends on multi-dimensional factors. So, hydrogeological data can be meaningfully integrated with population and socioeconomic data to create Flood Vulnerability Index [FVI] database on monthly basis.

FVI has been calculated using climate, hydrogeological as well as population and socioeconomic data. Such efforts are a part of non-structural measures of flood management to reduce short term and long term damages. Analysis of 'FVI'is valuable and powerful tool for policy and decision makers along with and insurers. It helps to prioritize investments and makes the decision making process more transparent. Identifying areas with high flood vulnerability may guide the decision making process towards preparedness to mitigate the impact of flood.

It is found that MADHUBANI is one of the most vulnerable district, whose numeric FVI value is as under (on a scale of Maximun 1.00):

District Name	Numeric Values Of Flood Vulnerability Index [F.V.I.] Based On 428 Months Study
Madhubani	0.999143905882665

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APPENDIX

As per Census 2011 for Madhubani District, Bihar

Actual Population	4,487,379
Male	2,329,313
Female	2,158,066
Population Growth	25.51%
Area Sq. Km	3,501
Density/km2	1,282
Proportion to Bihar Population	4.31%
Sex Ratio (Per 1000)	926
Child Sex Ratio (0–6 Age)	936
Average Literacy	58.62
Male Literacy	70.14
Female Literacy	46.16
Total Child Population (0–6 Age)	810,479
Male Population (0–6 Age)	418,616
Female Population (0–6 Age)	391,863
Literates	2,155,338
Male Literates	1,340,085
Female Literates	815,253
Child Proportion (0-6 Age)	18.06%
Boys Proportion (0-6 Age)	17.97%
Girls Proportion (0-6 Age)	18.16%

Madhubani Houseless Census

In 2011, total 356 families live on footpath or without any roof cover in Madhubani district of Bihar. Total Population of all who lived without roof at the time of Census 2011 numbers to 1,699. This approx 0.04% of total population of Madhubani district.

Madhubani Literacy Rate 2011

Average literacy rate of Madhubani in 2011 were 58.62 compared to 41.97 of 2001. If things are looked out at gender wise, male and female literacy were 70.14 and 46.16 respectively. For 2001 census, same figures stood at 56.79 and 26.25 in Madhubani District. Total literate in Madhubani District were 2,155,338 of which male and female were 1,340,085 and 815,253 respectively. In 2001, Madhubani District had 1,195,776 in its district.

Madhubani Population 2015

What is the population of Madhubani in 2015? The fact is last census for Madhubani district was done only in 2011 and next such census would only be in 2021. There is no actual figure for population of Madhubani district situated in Bihar. As per 2011, Madhubani population is 4,487,379