"Catastrophic Risk Assessment, Using Integrated Multi-Criteria Flood Vulnerability Index for Various Spatial and Temporal Mining Scales : A Case Study of Kosi Flood Affected Five Districts"

Prince Divakar Saxena*1, and Sanjay Pande2

ABSTRACT

Human population worldwide is vulnerable to natural disasters, which are increasing due to the consequences of socio-economical and land-use developments and due to climate change. In recent years the impacts of floods have gained importance because of the increasing amount of people who are affected by its adverse effects.

In this study a methodology to compute a flood vulnerability index, based on indicators, is developed, aiming at assessing the conditions which favour flood damages at various levels: river basin, sub-catchment and urban area. This methodology can be used as a tool for decision making to direct investments at the most needed sectors. Its implementation could guide policy makers to analyse actions towards better dealing with floods.

The methodology involves two concepts. First, vulnerability, which covers three related concepts called factors of vulnerability: exposure, susceptibility and resilience. The other concept concerns the actual flooding; understanding which elements of a system is suffering from this natural disaster. Three main components of a system are recognized which are affected by flooding: social, economical and environmental The interaction between the vulnerability factors and the components serves as the base of the proposed methodology.

The methodology has been applied in various case studies spatial and temporal scales, which resulted in interesting observations on how vulnerability can be reflected by quantifiable indicators. The testing results indicate that the FVI of a river basin as a whole can be better reflected by the average FVI of its sub-catchments, thereby improving decision-making processes at regional levels. However, the average FVI of urban areas does not reflect the FVI of the sub-catchment or river basin in which they are located.

***Keywords** : Flood vulnerability Index, United Nations Development Program, Digital Elevation Model.*

1. INTRODUCTION

Over the past decade, the number of people reportedly affected by disasters which globally increased by one-third; reported deaths were up by 84%. If trends continue, it is estimated that, by 2050, natural disasters will have a global cost of over $300 billion a year and will be a key element in the failure to meet the Millennium Development Goals by 2015.

Disaster risk reduction is broad development & application, strategies & practices to minimize vulnerabilities & disaster risks for affected communities through prevention, mitigation & preparedness [1].

It was argued that, inadequate (insufficient) attention to disaster risk reduction can hinder progress in poverty alleviation and development. The focus of national attention has tended to come after disaster events rather than on preparing for disasters before

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they occur. Eg. "Jamnagar refinery of Reliance: difference of opinion between Dheeru Bhai Ambani and his sons".

1.1 Global Estimates for Cost of Disasters

According to the World Bank estimates from 1990-2000, natural disasters resulted in damage constituting between 2 to 15 p ercent of an exposed country's annual Gross Domestic Product (GDP) which represents the costs of replacing physical assets at current prices. These estim ates are consistent with those provided by the Internat ional Monetary Fund which demonstrates that betwee n 1997 and 2001 the damage per large disaster was over 5 percent of GDP on an average in low-income countries like India. Impact on GDP is often used as an indicator of the impact of disasters [2]. Trend Analysis during research illustrates this concept and a dvocates relevance of study objectives with referenc e to Kosi River whose flood affects about 14 distric ts of North Bihar, India.

1.2 Disaster Management Cycle for Natural Disaster (Flood) — A Summary

'Disaster Management Cycle' is a normative model of appropriate programming int erventions at sequential stages in the unfolding of a d isaster event. Following are five identified activity a reas for cooperation:

- **Risk Assessment:** By data analysis and findings.
- **Disaster Preparedness:** Natural disasters like flood are generally classified & recognized as two types such that 'Slow-onset' h azards and 'Rapid-onset' natural disasters. The peculiar feature of the rapid-onset hazard is that the y have an unknown probability which gives no opp ortunity for warning before there impacts are felt.
- **Disaster Prevention and Mitigation through Early Warning System:** Simulation process has been used for this. **Annual flooding in North Bihar takes place between the month of July to August every year** whose impact is rapid. Thus, slow-onset disaster hazards can be controlled through the communi ty capacity building & preparedness programs.
- **Mainstreaming Disaster Risk Management in Development Cooperation Sector** through Flood Vulnerability Index (FVI).
- **Disaster Risk Management as part of Rehabilitation & Reconstructio n:** Limitation of this research.

1.3 Statement of Actual Problem

- Kosi flowing through plains of north Bihar has moved about 120 kms westwards during past 220 years (Wells and Dorr, 1987). Flow regulation has only contributed to greater shiftin g of river channels .
- River flood is due to heavy ra infall by which rivers will overflow on its banks as natural phenomenon.
- One factor of river flood can be low absorbing capacity of ground.
- Here the flood of river Kosi, which has a little bit flavor of flash flood, in terms of its intensity of occurrence.
- It encounters an enormous amou nt of human and animal causalities, public property damage, annihilate social living of so ciety….. every year and huge expenditure comes to surmount this pre-known natural disaster.
- **Kosi flowing through plains of north Bihar has moved about 120 km westwards during past 220 years** (Wells and Dorr 1987). Flow r egulation has only contributed to greater shifting of river channels of Floodplain Rivers in India by Gopal B. of School of Environmental Sciences, Jawaharlal Nehru University, N ew Delhi 110067, India). In view of the massive destruction and losses that take place every y ear due to flooding in north Bihar, many researche rs 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.

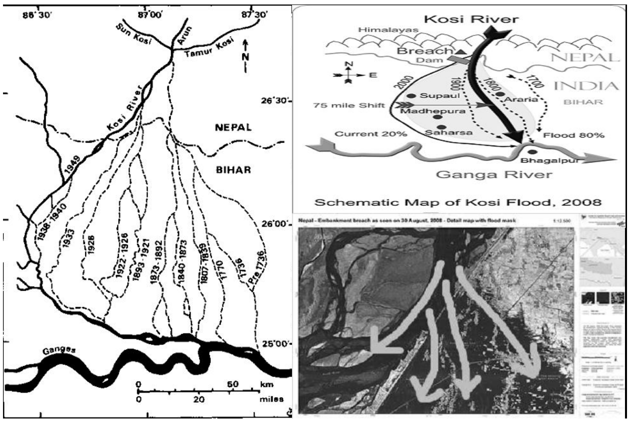

Fig.1. Shifting of Kosi River Channels

2. RESEARCH OBJECTIVE

An insurance provider, scientist may have different views on disaster than a social reformer. It depends on the cultural settings, mind sets, ideologies & scientific approaches. Nevertheless, in all definitions, there are two common elements: one, the extent of damage and loss, which is considered to be very high, and two, the inability of people, regions or countries affected to cope with most undesirable, unwilling and uncertain natural disaster [3] .

The basic purpose of this research is to utilize technological innovation through software simulation, to help, design and do make an optimal decision that can contribute to the welfare of a country and its people. The disaster risk (of a region, a family, or a person) is therefore made up of two elements: hazard and vulnerability. Under the sponsorship of the International Strategy for Disaster Reduction (ISDR) * an updated glossary (dictionary) was issued in May, 2001, which marks a major step forward in standardizing terms in disaster risk management.

Disaster Risk = Hazard × Vulnerability
(Helplessness*)

* Because of weak, early warning system for disaster prevention and mitigation, it will increase the vulnerability factor.

(Hazards are extreme natural events with a certain degree of probability of having adverse effect on a locality or region; its intensity and probability can differ by place. Vulnerability on the other hand is an inadequate ability to protect oneself against the adverse impacts of natural events.)

In the context of disaster, 'vulnerability' can be seen to have two basic elements: exposure and susceptibility to harm.

Disaster Risk $\propto$ Vulnerability

In this case, the objective of study is to reduce vulnerability factor with the aid of technology by generating early warning system and its intensity, before the occurrence of disaster and it will automatically reduce the disaster risk [4].

3. RESEARCH METHODOLOGY

Research Design	Exploratory Research Design.
Data Type	Primary Data.
Data Source	For statistical forecasting data - Bihar Secretariat (Govt. of Bihar)
Sampling Used	Area Sampling and Judgmental Sampling (in flood affected 5 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).

4. RESEARCH HYPOTHESIS

Null Hypothesis (H_0)	There is no relationship between occurrence of flood /intensity of flood for mitigation to flood affected areas.
Alternative Hypothesis (H_1)	There is definite relationship between occurrence of flood / intensity of flood for mitigation to flood affected areas.
Hypothesis Testing	Employing various climate and Hydrological parameters along with many socio economic parameters responsible for flood, but the use of Chi Square Test didn't validate the trend analysis, as of assumption considered that we can't quantify the value of human life (causalities) in term of capital as because human life is invaluable, it's a non-parametric measure which can't quantified.

5. ANALYSIS

Government of India & United Nations Disaster Risk Management program has been implemented in the State of Bihar, since 2002 in the multi-hazard prone14 - 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.

Sample Space

- Samastipur • Araria • Saharsa
- Madhubani • Muzzafurpur

Table 1 : Samastipur Comparative Data Rural & Urban Population in 2011

Population (%)	**96.54%**	3.46
Total Population	**4,107,725**	147,057
Male Population	2,150,966	77,466
Female Population	1,956,759	69,591
Sex Ratio	**910**	898
Child Sex Ratio (0-6)	942	897
Child Population (0-6)	**764,004**	20,199
Male Child (0-6)	393,421	10,647
Female Child (0-6)	370,583	9,552
Literates	**2,110,007**	104,491
Male Literates	1,274,768	58,638
Female Literates	835,239	45,853
Average Literacy	**63.10 %**	82.37 %
Male Literacy	72.53 %	87.76 %
Female Literacy	52.66 %	76.37 %

Source: http://samastipur.bih.nic.in/census.aspx
DOE: Oct 25, 2014 [21:07]

Table 2: Samastipur Comparative Census Data Changes

	2011	2001
Actual Population	**4,254,782**	3,394,793
Male	2,228,432	1,760,692
Female	2,026,350	1,634,101
Population Growth	**25.33%**	25.63%
Area Sq. Km	2904	2904
Density/Sq.^{2}	1465	1169
Proportion to Bihar	4.10%	4.09%
Sex Ratio (Per 1000)	**909**	928
Child Sex Ratio (0-6	941	938
Average Literacy	**63.81**	45.13
Male Literacy	73.09	57.59
Female Literacy	53.52	31.67
Total Child	**784,203**	711,168
Male Population (0-6	404,068	366,978
Female Population (0-	380,135	344,190
Literates	**2,214,498**	1,211,152
Male Literates	1,333,406	802,593
Female Literates	881,092	408,559
Child Proportion (0-6	**18.43%**	20.95%
Boys Proportion (0-6	18.13%	20.84%
Girls Proportion (0-6	18.76%	21.06%

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For evaluation of most & frequ ently flood affected districts, trend analyses have been performed on aforesaid districts (as per UNDP). A sample mechanism (one of among 14 aff ected districts) has been illustrated bellow. Hallu cination of Linear Time Series - Quantitative forecast ing method is used for long range forecast as a non-p arametric measure.

Table-3: Linear Time Series Quantitative Forecasting Method as a Non-parametric Test

Year	Value of Damaged Crop (in Rs. Lakh)	Value of Damaged Residential Buildings (in Rs. Lakh)	Damage Value of Public Property (in Rs. Lakh)	Cash Dole Compensation Distributed (in Rs. Lakh)	Total Amount (in Rs. Lakh)	
1991	294.15	55	5.25	0	354.4	
1992	0	0	0	0	0	
1993	471.88	15.82	0	0.1	487.8	
1994	385.13	22.67	0	0	407.8	
1995	222.2	8.4	28.5	6	265.1	
1996	736.83	25	0	5.48	767.31	
1997	65.8	13.37	0	1.55	80.72	
1998	1124.41	102	1.83	128.78	1357.02	
1999	281.34	33.7	0	49.32	364.36	
2000	53.49	18.59	1	5.02	78.1	
2001	459.11	266.7	88.01	15.85	829.67	
					4992.28	**TREND**
2002	4487.33	1745.85	932.5	218	7383.68	**673.7976**
2003	1213.33	620	233.5	13.93	2080.76	**710.4566**
2004	5510.35	10613.75	27662.5	412.32	44198.92	**747.1156**
2005	100	0	0	0.34	100.34	**783.7746**
2006	0	0	0	0.3	0.3	**820.4336**
				Σ	**53764**	**3735.578**

Table -4: Calculation for Trend line

Years	X	Y	X*X	X*Y
1991	1	354.4	1	354.4
1992	2	0	4	0
1993	3	487.8	9	1463.4
1994	4	407.8	16	1631.2
1995	5	265.1	25	1325.5
1996	6	767.31	36	4603.86
1997	7	80.72	49	565.04
1998	8	1357.02	64	10856.16
1999	9	364.36	81	3279.24
2000	10	78.1	100	781
2001	11	829.67	121	9126.37
Σ	**66**	**4992.28**	**506**	**33986.17**

Table - 5: Calculation of future trend 2002-2006

Calculate Time Series Y = a + b * x ;
where slope → b = $(\Delta y/\Delta x)$

	Actual	Trends
2002	7383.68	673.7976
2003	2080.76	710.4566
2004	44198.92	747.1156
2005	100.34	783.7746
2006	0.3	820.4336
	53764	3735.578

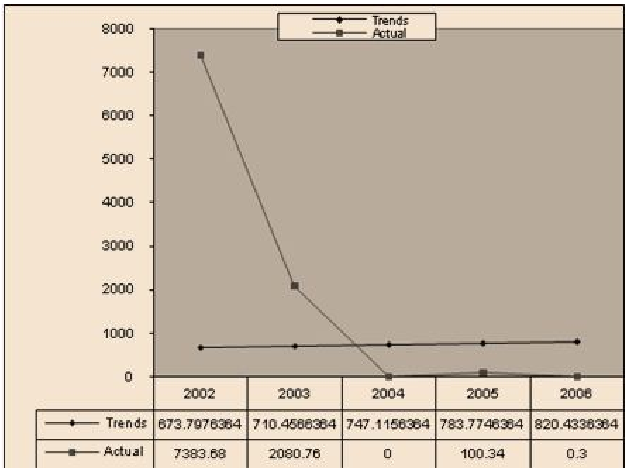


Fig.3. Calculation Considering without Year-2004

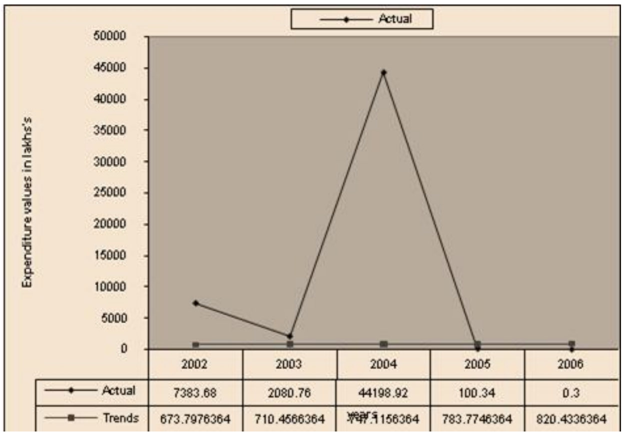


Fig.4. Calculation Considering with Year-2004

Time Series - Quantitative for ecasting method for long range forecast on basis of fol lowing facts:

1) Past information about the vaiable being forecasted is available (from year 1991 to 2006).
2) Available information is quant itative (in terms of amount in rupees)
3) Reasonable assumption is that, the pattern of past will continue into the future.

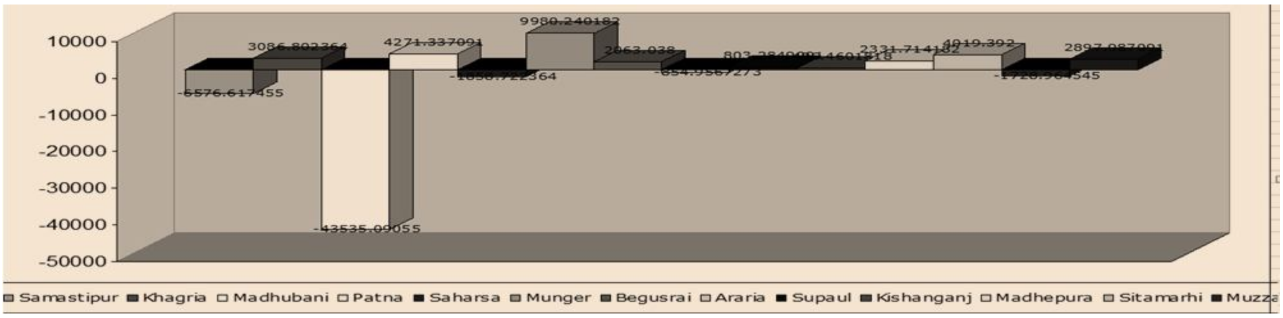


Fig. 5: UNDP - Natural Disaster Management Program Effectiveness in 14-districts of Bihar Between 2002-2006 (annual benefits valued in Rs./ Lakhs). **(without abnormal year 2004)**

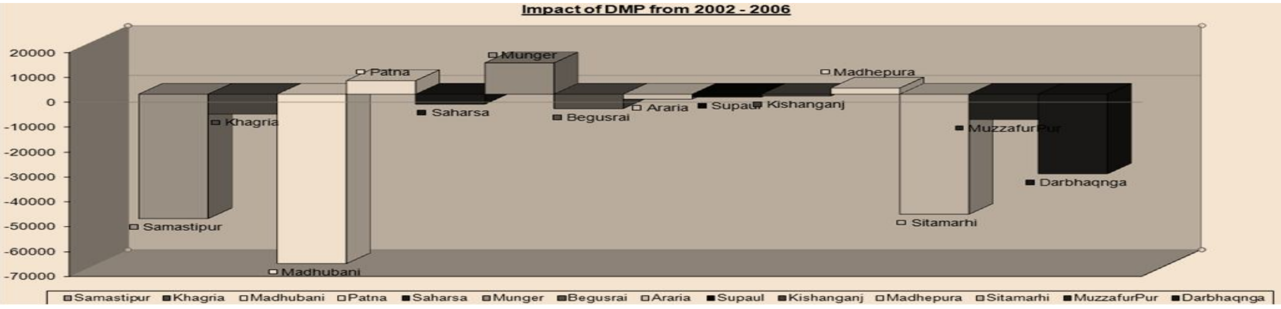


Fig. 6: UNDP - Natural Disaster Management Program Effectiveness in 14-districts of Bihar Between 2002-2006. **(with abnormal year 2004)**

6. FINDINGS AND EXECUTION

On the basis of sixteen years (i.e.1991 to 2006), secondary data -a trend analysis is computed from 2002-2006.(with and without in cluding abnormal year 2004, during joint venture of UNDP-NDMP along with Disaster Management Department, Govt. of Bihar).The analysis clearly sh ows that among sixteen chosen districts of north Biha r, five (i.e. Samastipur, Madhubani, Saharsa, Araria & Muzzafurpur) are always experiencing the heavy flood impact. So, river flood simulation is accomplish ed on these five districts to know, how the reasons of flood on the basis of following responsible factors:

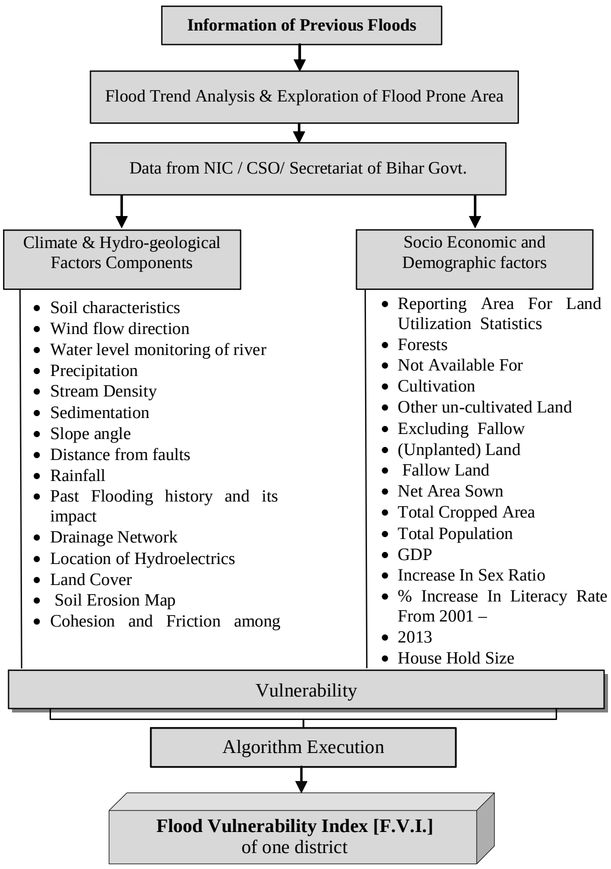


Fig.7. Research Mythology Diagram

Model developed by temporal an d spatial mining shows the most likely value fr om classed soil attribute data. Even within small areas of the same soil, soil attributes can be very variabl e.

6.1 Soil Physical Characteristics

- **Topsoil Gravel Content:** The amount of stoniness affects workability and root p enetrability of the soil [5-7].
- **Particle Size:** Particle size class describes in broad terms the proportions of sand, silt and clay in the fine earth fraction of the soi l except in the case of skeletal soils (> 35% coarse fraction) where it applies to the whole soil. Par ticle size is important for soil traffic ability, soil workability and moisture storage capacity and permeabil ity.

6.2 Soil Drainage Parameters

- **Potential rooting dept:** Potential rooting depth describes the depth (in centim eters) to a layer that may impede root extension. Suc h a layer may be defined by penetration resista nce, poor aeration or very low available water capacity. Potential rooting depth can be important for plant growth and soil workability.
- **Soil Permeability:** Soil permability is importan t forease of drainage, risk of w ater logging, effluent absorption potential, leaching and water loss hazards.
- **Depth to a Slowly Permeable Ho rizon:** Depth to a slowly permeable horizon describes the depth (in centimeters) to a horizon in which the permeability is less than 4mm/ hr as measured by techniques outlined in Griffit hs (1985). Permability is important for ease of drainage, risk of water logging, effluent absorption p otential, leaching and water loss.
- **Internal Soil Drainage:** Internal soil drainage is described as a class. Drainage classes are assessed either using criteria of soil depth and chroma, or from reference to diagnostic h orizons. Soil drainage is important for the supply of oxygen to the plant root zone, waterlogging and wa ter drainage.

6.3 Soil Environment Parameters

- **Flood return interval:** Frequency of flooding is important for most land activi tes.
- **Soil temperature regime:** The soil temperature regime relates to the soil tem perature (ºK) at above described depth in 'cm' depth. Soil temperature affects crop suitability and yield; that is directly proportional to the clutch of soil on plant roots. And deforestation is one major cause of flooding and shifting of flood path (as in case of Kosi).

6.4 Soil Moisture Properties

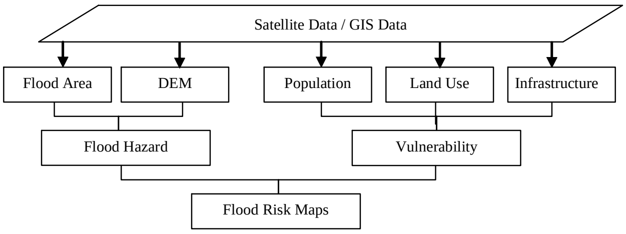
- Land areas are classified according to four key soil physical attributes: prof ile total available water, profile readily available wate r, macroporosity 0–60 cm depth and macroporosity 60 cm–400 cm depth.
- **Profile Total Available Water:** . Profile total available water is important f or droughtiness and overall water availability.
- **Macroporosity (0–60 cm):** Macroporosity is an expression of the air-filled p orosity of the soil at 'field capacity'. Values are m inimum values over the specified profile section (0–60 cm), and are expressed as a percentage of t he soil volume. The classes originate from the work of Gradwell (1960) and Gradwell and Birrell (1979), and are described more fully in Webb a nd Wilson (1995). Supply of oxygen to plant root s, waterlogging and ease of drainage.
- **Macroporosity (60 cm–400 cm):** Macroporosity is an expression of the air-fi lled porosity of the soil at 'field capacity'. Values ar e minimum values over the specified profile section (60 cm–400 cm), and are expressed as a percentage of the soil volume. The classes originate from the work of Gradwell (1960) and Gradwell and Birrell (1979), and are

described more fully in Webb a nd Wilson (1995). Supply of oxygen to plant root s, waterlogging and ease of drainage at depth in t he soil profile.

Table-6: Latitude Longitude Pointer Location

S. No.	District Name	Latitude Longitude Pointer Location (as Under) (scale: 2mi=2kms)			
		North	**East**	**West**	**South**
1	Samastipur	25.881002	85.80783	85.741397	25.842539
2	Madhubani	26.376338	86.097766	86.049529	26.316036
3	Saharsa	25.925011	86.657355	86.538565	25.835432
4	Araria	26.437377	87.698145	87.159814	25.97533
5	Muzzafurpur	26.169305	85.422423	85.346892	26.078062

7. ALGORITHM



Flow Chart

1. Data mining has been used on above Latitude Longitude Pointer Locations fr om January-1979 to August-2013 on multiple par ameters given in above Research methodology dia gram.
2. Then entire data (of individua l location) is visualized in two dependent variables.
   2.1 Time interval (in months), when flood occurrence is not possible (i. e. summer season).
   2.2 Time interval (in months), when flood occurrence is possible (i.e. rainy & winter season)
3. By using statistical tools in SPSS-14, analysis is performed to derive an equatio n which provides estimates of dependent variable on the basis of more than two dependent variables. As $f(x_1)$ and $f(x_2)$ given billow.
4. Using SIMULATION impact of climate, hydrological and Socio-economi cal component is obtained of individual locatio n; to evaluate the flood vulnerability index [FVI] of t hat location.
5. After evaluation of FVI for fi ve districts (of study region) hierarchies is execute d for most disasters district and list all the all five districts in decreasing order of flood vulnerability i ndex [8-15].

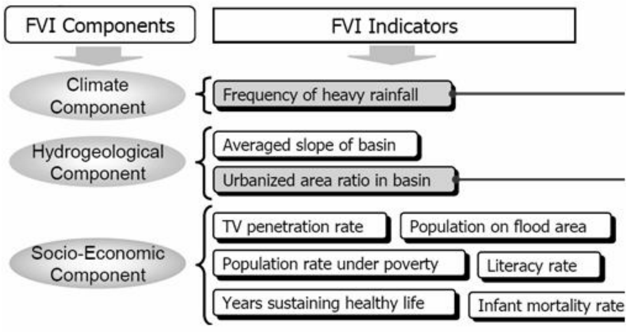
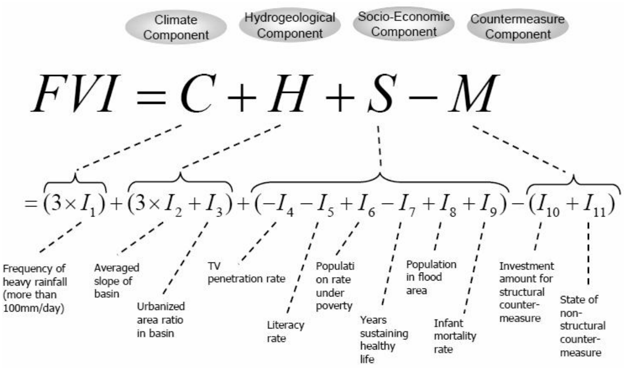
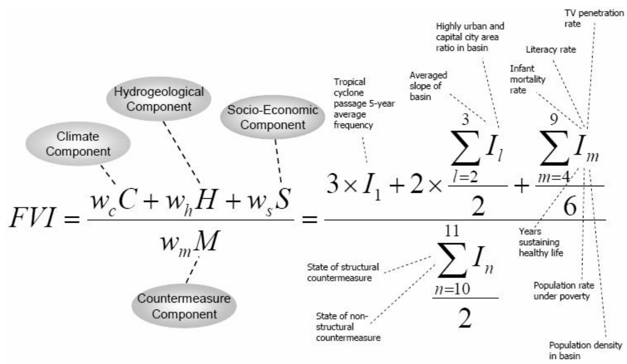


Fig.8. Major Factors Effecting Flood Vulnerability Index





8. CONCLUSION

A FVI is calculated for indivi dual (heavily flood affected) five districts of no rth Bihar and then applying Simulation we generate correla tive Flood Vulnerability Index among five districts, which depicts the most disasters district and list al l the five in decreasing order of vulnerability index.

Obtaining real-time data, we c an instantaneously measure Flood Vulnerability Index for individual district and then forecast com parative most vulnerable district among five. It helps in decision making using GDSS (Group Decision Support S ystem) for optimal resource allocation for rehabilitation to reduce the overall impact of flood.

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