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Computation of Flood Vulnerability Index [FVI] for KOSI River Flood Affected Samastipur District of North Bihar – India, by Employing Multi-Parametric Approach of Simulation

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Abstract : River creates landforms areas that are built by sediments with old and new deposits are known as Flood Plain and a river with a complete floodplain is considered to be "healthy" river. Increasing human intervention in watersheds and extensive deforestation has resulted in a deficiency in recent floodplain deposits. In addition, an increase in the relative proportion near river side as the river side fertile soil is suitable for farming is one of the major causes of damaging of flood plains. One of the major factors contributing to flood events is encroachment on floodplains. Although occurrence of flood is natural phenomenon but increased surface runoff along with such obstruction to natural flood ways has created floods vulnerable.

In this study, a methodology to calculate flood vulnerability index, which is on the basis of various indicators, is developed. It aims at evaluating various conditions that favour flood damages at various landforms created *viz*.,: river basin, sub-catchment and urban area.

This research also helps in decision making for direct investments in needing sectors. In addition to this it can also help people in administration to deal with floods.

The methodology includes two concepts:

1. Vulnerability including related concepts called factors of vulnerability: exposure, susceptibility and resilience.
2. Actual flooding understanding which elements of a system is suffering from this natural disaster.

Overall objective of this study is "Sustainable Reduction in Disaster Risk in Samastipur District", this research essentially aims and recommend at strengthening community, Local self-governments and district administration's response, preparedness and mitigation measures in some pre specified (with the help of proposed software) of the most vulnerable areas. So that local administration can rescues society to reduce the impact of disaster.

Keywords : Flood Vulnerability Index, Flood detection, Quantitative forecasting method of floods, Flood vulnerability, Group decision Support system [GDSS], Disaster Management Programme [DMP], United Nations development Program (UNDP).

1. STATEMENT OF ACTUAL PROBLEM

- In the past 220 years Kosi has flown about 120 km westwards in the plains of North Bihar (Wells and Dorr 1987).
- Flow regulation has enhanced shifting of river waterway.
- As natural phenomenon river flood is created due to heavy rainfall by overflow on the bank.
- Main cause of flood is low absorption of ground.

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- Here the flood of river Kosi, which has a little bit flavour of flash flood, in terms of its intensity of occurrence.
- Flood encounters immense amount of human and animal loss, public property damage, destroy social living of society.
- Due to this natural disaster every year, huge expenditure is surmounted.

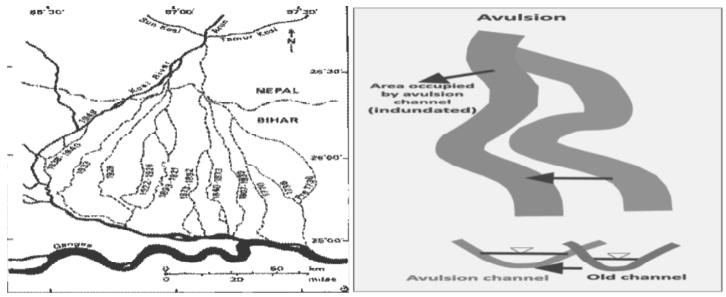


Fig. 1. An Avulsion results into Inundation due to Movement of a River to a New Location.

The wide spread and pervasive nature of the problem is evident from the following table.

Zone	*Total Geographical Area (in L Ha)*	*Flood Prone Area (In L ha)*	*Percentage of flood Prone of total Area zone wise*	*Length of flood Protective Embankments*	*Protected Area (in L Ha) (in Km)*
North Bihar	58.50	44.46	76.02	2952	27.16
Central Bihar	35.31	24.34	53.35	478	2.00
Total	93.81	68.80	67.48	3430	29.16

Source: Bihar Flood Report 2007, Memorandum Part –III, CWC, Sector wise detail report

Following figure illustrates pedagogy for Flood Risk Analysis and Protocol for hazard prediction and develops an early warning system to reduce the impact of disaster on society.

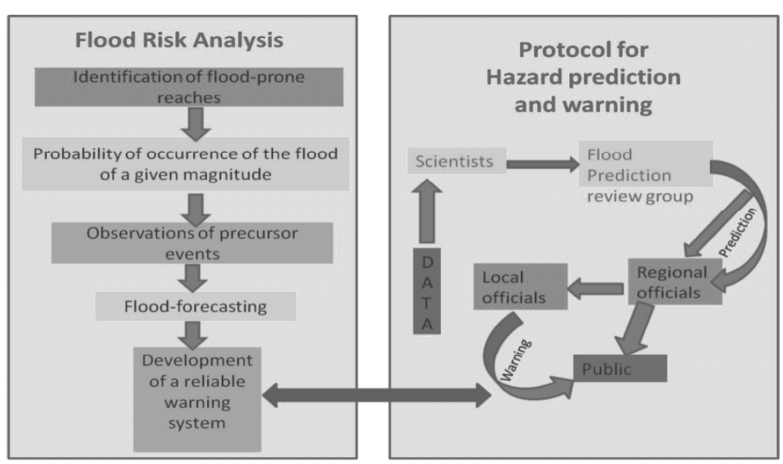


Fig. 2. "Prediction of Flood and computation of Early warning system to Reduce damage"

Research Objective : An insurance provider, scientist may have different views on disaster than a social reformer. 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 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. So we conclude that,

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.

Table 1.

	Value of Damaged Crops	*Value of Damaged Residental Buildings*	*Damage Value of Public Property*	*Cash Dole Compensation distributed*	*Total Amount (Rs.)*	
	(Rs Lakh)	*(Rs. Lakh)*	*(Rs. Lakh)*	*(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
					53764	**3735.578**

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

	Value of Damaged Crops	***Value of Damaged Residental Buildings***	***Damage Value of Public Property***	***Cash Dole Compensation distributed***	***Total Amount (Rs.)***
	(Rs Lakh)	***(Rs. Lakh)***	***(Rs. Lakh)***	***(Rs. Lakh)***	
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	
66	4992.28	506	33986.17		
	bar X =	6			
	bar Y =	453.8436			
	B=	36.659			
	A=	233.8896			
	cap Y=	673.7976			
	710.4566				
	747.1156				
	783.7746				
	820.4336				
	Actual	Trends			
2002	7383.68	673.7976	-6709.88		
2003	2080.76	710.4566	-1370.3		
2004	44198.92	747.1156	-43451.8		
2005	100.34	783.7746	683.4346		
2006	0.3	820.4336	820.1336		
	53764	**3735.578**			

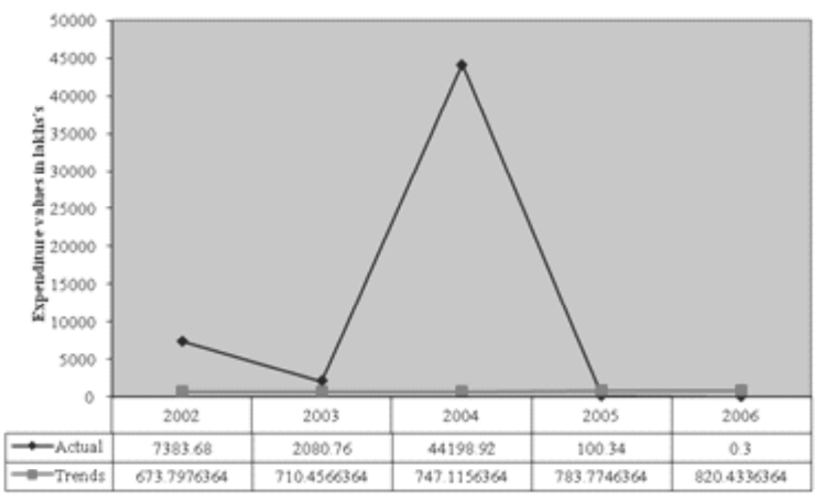


Fig. 3.

In above figure five year actual and linear trend analysis advocates that Samastipur is a flood affected districts in north Bihar- India.

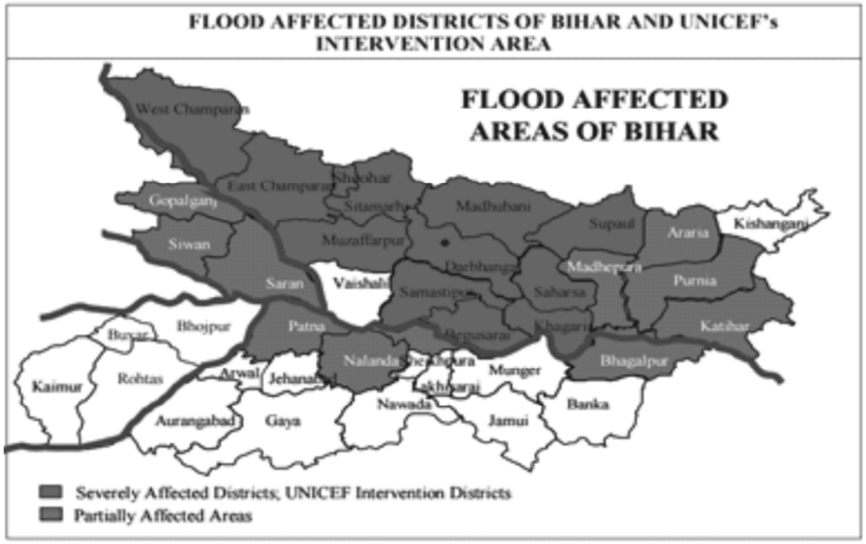


Fig. 4.

To validate region where flood affects almost every year, a time series- Quantitative forecasting method is used for long range forecast on the basic of following facts:

- Past information about the variable being forecast; is available (from year 1991 to 2001).
- Available information is quantitative (in terms of, amount in rupees)
- A reasonable assumption is that the pattern of past will continue into the future.

Research Methodology

Research Design	Exploratory Research Design.
Data Type	Secondary Data.
Data Source	• For statistical forecasting data - Bihar Secretariat (Govt. of Bihar)· • Data for Simulation - Official Website of NASA • NIC/Census data of Govt. of India
Sampling Used	Area Sampling and Judgmental Sampling
Sample Size	Samastipur is one, among five heavily 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

Null Hypothesis (A):	There will be minimum occurrence of flood during the month of May to
(H0)	November every year.
(B) :	There will be no relationship between intensity of flood and Flood Vulnerability Index [F.V.I.], for mitigation to flood affected areas.
Hypothesis Testing	If numerical weight of Climate and Hydrogeological Factors is greater than 1 then there will not be any “Flood” else there will be “Flood”.

Collecting the Data

To analyse following dominant land and surface factors :

1. Forcing (such as surface meteorology and radiation)
2. State (such as soil moisture and temperature)
3. Flux (such as evaporation and sensible heat flux)

Within LandClimateHydrogeological (function used in following algorithm) conditions; monthly data (starting from January-1979 to August-2014) is fetched using file transfer protocol from official website of NASA, and stored in CPU for farther execution on it .

Specific lat long scale used for this data mining is as under:

Table 2. Lat Long Scale for Spatial Data-Mining

District Name	*Latitude Longitude Pointer Location (as Under)(scale: 2mi = 2kms)*			
	North	*East*	*West*	*South*
Samastipur	25.881002	85.807830	85.741397	25.842539

Data Analysis

Total 27 factors considered for analysing the impact of LandClimateHydrogeological (function used in following algorithm) components, on occurrence of flood, seven are of different dimensions and near surface specific humidity is dimension less. So, researcher cannot determine the quantitative relationship among such variables. Such type of data is termed as 'non-metric' data.

As correlation and regression techniques are not applicable for non-metric data, so in these circumstances researcher is applying 'Linear Discriminant Analysis' that enables the researcher to predict the quantitative relation among mutually exclusive data elements (such as non-metric data).

Discriminant analysis promotes a scoring system, on the basis of which it classifies individual data elements in the most likely classes. In mathematical equations of LDA; not only the values of the Discriminant coefficient but also the positive or negative sings of these coefficients are equally relevant. Positive or negative sign of data item in Mathematical equation elaborates that individual data component belong to that category or not and the numeric value before sing emphasis the magnitude of support.

To obtain desired results LDA gives following algorithm that processing mathematical formulation (on total 427 months, monthly data) for assessment of Land, Climate and Hydrogeological Components over study area:

Table 3. Impact of Bihar Floods and State Response

Districts Camps	*Blocks Affected*	*Lives lost*	*Boats Deployed*	*Relief Camps*	*Medical*
Samastipur	19	175	754	276	51

Source: http://www.unicef.org/evaldatabase/files/2008_India_Floods_Emergency__Response.pdf

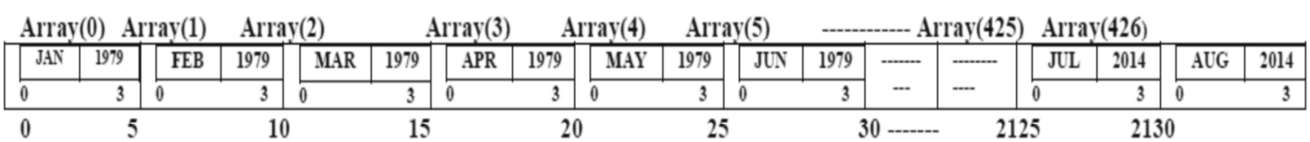
Table 4.

Description	*Rural*	*Urban*
Literates	2,040,582	102,298
Population (%)	96.53 %	3.47 %
Total Population	4,113,769	147,797
Male Population	2,152,273	77,730
Female Population	1,961,496	70,067
Sex Ratio	911	901

Source: http://www.censusindia.gov.in/2011census/dchb/1019_PART_B_DCHB_SAMASTIPUR.pdf

Algorithm for Flood Vulnerability Index [F.V.I.] computation

```
Void SAMASTIPUR( )
{
Begin
Int: i, j, k, m;
long double : value1, value2; FVI = 0,FVIm;
struct    {
char month(3);
int year (4);
}  Array(427);// there are total 427 records in Array(k); starting from JAN1979 to AUG2014
for (k = 0; k < 427; k ++)
{
write ("enter the 'month' and 'year' starting from JAN1979 onwards");
read ("%s, %d", Array(k).month, &Array (k).year);
//initialization of array
}
write("enter the 'starting' month and year for flood Vulnerability Index (FVI) estimation");
read("%s, %d", Array(i).month, &Array(i).year);
//starting record (in month & Year) is initialized as ith logicallocation of Array
write("enter the 'ending' month and year for flood Vulnerability Index (FVI) estimation ");
read("%s, %d", Array(j).month, &Array(j).year);
//ending record (in month & Year) is initialized as jth logical location of Array
/* Logical Addressing :
```




```
physical addressing:*/
if (j < i)
exit(1);   /*if logical value of ending month & Year (i.e.'j') is smaller than logical value of starting
month & Year (i.e.'i'), then exit*/
else
for (m =  logical location of Array(i); m < = logical location of Array(j) ;  m ++)
Begin
value1 = Land Climate Hydro geological Data(G1, H1,I1,J1,k,l,m);
value2 = Population Socio Economic Data();
FVI = ((value1 + value2)/2);
write(" Flood Vulnerability Index =  %Lf", &FVI);
FVIm = FVI;
End
Write("Resultant Flood Vulnerability Index (FVI) for selected time duration will be =
%Lf",&median(FVIm));
End
```

//END OF SAMASTIPUR() function

Land Climate Hydrogeological Data(G1, H1,I1, J1, *k*, *l*, *m*)

Begin

long double : *k*, *l*, *m*,G1,H1,I1,J1,F1 = 0;

write("Enter the values of :Near surface specific humidity, Near surface wind Magnitude, Surface Pressure");

read (" %Lf, %Lf, %Lf",&k,&l,&m);

G1 = *g*();

H1 = *h*();

I1 = I();

J1 = *j*( );

Value1 = ((0.40975179056133*g(x)) – (0.636477761191054*h(x)) +
(0.653121974750474*i(x)) + (0.451129718711898*j(x)) +
(0.630889891120117*k) – (0.234615652062864*l)-
(0.0695464807516757*m));

return(Value1);

End

//end of function LandClimateHydrogeologicalData(*g*( ), *h*( ), *i*( ), *j* ( ), *k*, *l*, *m*);

g( )

Begin

long double : *g*1, *g*2, *g*3, *g*4, *g*5, *g*6, *g*7,G = 0;

write ("Enter the values of: Average layer 4 (100-200 cm) soil temperature, Average layer 3 (40-100 cm) soil temperature, Deep soil temperature, Average layer 2 (10-40 cm) soil temperature, Near surface air temperature, Average layer 1 (0-10 cm) soil temperature , Average surface temperature");

read (" %Lf, %Lf, %Lf, %Lf, %Lf, %Lf, %Lf", &g1,&g2,&g3,&g4,&g5,&g6,&g7);

G = ((0.673082256593763 * *g*1(*x*)) + (0.402765331464704 * *g*2(*x*)) +
(0.281762184228599 * *g*3(*x*)) + (0.276170783309992 * *g*4(*x*))+
(0.2316553492387 * *g*5(*x*))+ (0.204674835404771 **g*6(*x*))+
(0.190510066427232 * *g*7(*x*)));

return(G);

End

//end of function *g*();

h( )

Begin

long double : *h*1, *h*2, *h*3, *h*4, *h*5, *h*6, *h*7, H = 0;

write ("Enter the values of: Latent heat flux Ground heat flux, Net longwave radiation, Surface incident long wave radiation, Surface incident shortwave radiation, Net shortwave radiation, Sensible heat flux, Ground heat flux");

read(" %Lf, %Lf, %Lf, %Lf, %Lf, %Lf,%Lf",&h1,&h2,&h3,&h4,&h5,&h6,&h7);

H = (–(0.495034455183463 **h*1(*x*)) – (0.406890003084864 **h*2(*x*)) –
–(0.362373234711186 **h*3(*x*))+ (0.142754695925954 **h*4(*x*))+
(0.141302145545916 **h*5(*x*)) + (0.125878006823456 * *h*6(*x*))+
(0.116485544423381 **h*7(*x*)));

End

```
//end of function h();
i( )
Begin
long double : i1, i2, i3, i4, i5, i6, I = 0;
write ("Enter the values of: Average layer 4 (100-200 cm) soil moisture,Average layer 1 (0-10 cm) soil moisture, Average layer 2 (10-40 cm) soil moisture, Average layer 5 (200-350 cm) soil moisture,Average layer 3 (40-100 cm) soil moisture,Total canopy water storage");
read(" %Lf, %Lf, %Lf, %Lf, %Lf, %Lf",&i1,&i2,&i3,&i4,&i5,&i6);
I = (((0.776585922257536*i1(x)) + ( 0.745776097426174*i2(x)) +
     ( 0.678180720261499*i3(x)) + ( 0.500792725339721*i4(x)) +
     ( 0.492194856093907*i5(x)) + ( 0.427401061924336*i6(x)))
);
return(I);
End
//end of function i();
j( )
Begin
long double : j1, j2, j3, j4, J = 0;
write ("Enter the values of: Total evaporation, Rainfall rate, Subsurface runoff , Surface runoff ");
read(" %Lf, %Lf, %Lf, %Lf ",&j1,&j2,&j3,&j4);
        J = (((0.888109636425971*j1(x)) + ( 0.651107932475691 * j2(x)) +
     ( 0.5176086212317*j3(x))+( 0.428810758414187*j4(x))));
return(J);
End
//end of function j();
}
PopulationSocioEconomicData()
Begin
Int: p;
float :f20,f21,f22,f19,f23,f24,f18,f25,f26,f17,f27,f28,f16,f29,f210,f15,f211,f212,f14,f213,f214,f215,f13,
 f216,f217, f218,f219, f220, f221,f222;
long double :
w1,w2,w3,w4,w5,w6,w7,w8,w9,w10,w11,w12,w13,w14,w15,w16,w17,w18,w19,w20,w21,w22, F2;
write("Total Population Person,Total Population Male, Total Population Female, Literates Population Person,
Literates Population Male, Literates Population Female, Illiterate Persons, Illiterate Male, Illiterate Female,
Total Worker Population Person, Total Worker Population Male, Total Worker Population Female,
Total Non Working Population Person, Non Working Population Male, Non Working Population Female,
Total Population of infants (0-6years), Population of infants (0-6years) Male, Population of infants (0-6years)
Female, Total Number of Households, House Type Permanent, House Type Semi- Permanent, House Type
Temporary, Total inhabited villages, Drinking water facility, Electricity availability, Educational institutes,
Medical centres, Road connectivity, communication services, Transport services");
read("%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f",
&f20,&f21,&f22,&f19,&f23,&f24,&f18,&f25,&f26,&f17,&f27,&f28,&f16,&f29,&f210,&f15,&f211,&f212,
&f14,&f213,&f214,&f215,&f13,& f216,& f217,& f218,&f219,& f220,& f221,& f222);
```

```
//(Relative weight of Total Population Male)//                      w1   =  (f21/f20);
//(Relative weight of Total Population Female)//                    w2   =  (f22/f20);
//(Relative weight of Literates Population Male)//                  w3   =  (f23 /f19);
//(Relative weight of Literates Population Female)//                w4   =  (f24/f19);
//(Relative weight of Illiterate Male)//                            w5   =  (f25/f18);
//(Relative weight of Illiterate Female)//                          w6   =  (f26/f18);
//(Relative weight of Total Worker Population Male)//               w7   =  (f27/f17);
//(Relative weight of Total Worker Population Female)//             w8   =  (f28/f17);
//(Relative weight of Non Working Population Male)//                w9   =  (f29/f16);
//(Relative weight of Non Working Population Female)//              w10  =  (f210/f16);
//(Relative weight of Population of infants (0-6years) Male)//      w11  =  (f211/f15);
//(Relative weight of Population of infants (0-6years) Female)//    w12  =  (f212/f15);
//(Relative weight of House Type Permanent)//                       w13  =  (f213/f14);
//(Relative weight of House Type  Semi- Permanent)//                w14  =  (f214/f14);
//(Relative weight of House Type Temporary)//                       w15  =  (f215/f14);
//(Relative weight of Drinking water facility)//                    w16  =  (f216/f13);
//(Relative weight of Electricity availability)//                   w17  =  (f217/f13);
//(Relative weight of Educational institutes)//                     w18  =  (f218/f13);
//(Relative weight of Medical centers)//                            w19  =  (f219/f13);
//(Relative weight of Road connectivity)//                          w20  =  (f220/f13);
//(Relative weight of communication services)//                     w21  =  (f221/f13);
//(Relative weight of Transport services)//                         w22  =  (f222/f13);
for (p = 1;  p < 23; p++)
Value2 = sum (wp);
return(Value2);
End
//end of PopulationSocioEconomicData()
```

Testing of Results

Samastipur district has been found that among 428 months study (starting from January 1979 to August 2014) the actual results obtained support hypothesis in 373 months, so it gives 87.1495327102804 % favours or advocates tautness of hypothesis and expresses that forecast is ‘True’.

District	support hypothesis level (in%) for correctness of forecast, based on 428 months study	If we alter our hypothesis that flood will occur only in June to October every year (instead of flood occurs only from May to November) then support hypothesis level (in%) for correctness of forecast, based on 428 months study
Samastipur	87.1495327102804%	93.4579439252336%

Findings 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 for a time interval starting from January 1979 to August 2014.

FVI has been calculated using Land, Climate and Hydrogeological Components as well as Population and Socio Economic 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 is a powerful tool for policy and decision makers along with insurers. It helps to prioritize investments and makes the decision making process more transparent by identifying areas with high flood vulnerability may guide the decision make process towards preparedness to mitigate the impact of flood.

Monthly assessment of numeric values of FVI for period of time starting from January 1979 to August 2014; for badly flood affected following five districts of North Bihar.

2. CONCLUSION

The State of Bihar is the most flood affected state in the country, accounting for 17% of the flood prone area of the country. Under the flagship of the programme, the multi hazard prone state of Bihar has implemented the natural disaster risk management programme in Samastipur as one of the 14 most hazard prone districts of the state. The basic objective of the programme is to create community capacities for vulnerability reduction. From the state to village levels Disaster Management Committees have been formed to carry out programme implementation and funds are being released to the districts.

The programme has been structured on the following lines mentioned here under:

- The state Disaster Management Policy is being prepared which will facilitate in effective disaster management at various levels.
- Large scale awareness generation among various stakeholders including government officials, Panchayati Raj representatives and common mass is being carried out at various levels through state level exhibition like 'Chetna', rally among school students, slogans and wall paintings in buildings on various Do's and Don'ts on Disasters, slides in Cinema halls, and competitions among school children in various schools are being conducted.
- Various Capacity Building training Programmes are being conducted on role of various agencies in Pre, During and Post Disaster situations.
- Many of the engineers, architects are being sent to various IITs of the country from time to time to undertake training on earthquake resistivity of building technologies.
- Multi-hazard preparedness planning are being prepared from the district to village level along with specialized training on search, rescue and first aid training to build the capacity of the Community to face any disaster.

The conclusions concerning the development of FVI methodology and the applicability is a positive catlistic tool that aid the administration scientifically for detection of more vulnerable area within district and then forecast comparative most vulnerable area within Samastipur as follows:

1. FVI provides a method to systematically express the vulnerability of a river system to disruption factors, such as floods.
2. Vulnerability can be reflected by three factors: exposure, susceptibility and resilience.
3. The river and urban systems can be damaged regarding four different components: social, economical, environmental and physical. Floods can be a cause of these damages.
4. The FVI is applicable in three different spatial scales: river basin, sub catchment and urban area scales;
5. FVI is a powerful tool for policy and decision-makers to prioritize investments and makes the decision making process more transparent. Identifying areas with a high flood vulnerability may guide the decision making process towards a better way of dealing with floods by societies.
6. FVI offers easy to understand results, with the use of a single value to characterize high or low vulnerability. This also allows continuous data interpretation for more in-depth analysis and it is suitable to policy-makers.

7. Finally, the proposed methodology to calculate a FVI provides an approach to quantify how much floods are affecting, or can affect, the livelihood of a spatial scale: in all the aspects that make a society function properly.
8. A FVI is calculated by Area clustering within region for heavily flood affected Samastipur district of north Bihar; depicts the most disasters area that numerically grade on one to five in decreasing order of vulnerability index.
9. Obtaining real-time online data, administration can instantaneously measure Flood Vulnerability Index for individual area with in district and then forecast comparative most vulnerable area within Samastipur; where flood impact is going to be serious. It helps in decision making using GDSS (Group Decision Support System) for optimal resource allocation for rehabilitation to reduce the overall impact of flood.

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