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DETERMINANTS OF VULNERABILITY TO AGRICULTURE IN KOSI REGION OF BIHAR

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Abstract

Climate is the primary determinant of agricultural productivity. Their impact has multi-dimensional effect on humanities in terms of several socio-economic parameters. The present study was conducted to find out the different climatic and socio-economic indicators/ factors of vulnerability to agriculture in Kosi region of Bihar. Eight districts of Bihar were selected purposively. The study was based on secondary data from 1976 to 2015. To construct the index, Patnaik and Narayanan's method with equal weight and simple average method were used. A region with highest index was said to be most vulnerable and it is given the rank 1. It revealed that, the population density of the district was found to influence the demographic vulnerability and consequently the overall vulnerability to climate change was hypothesized to be positively related to the vulnerability. The literacy rate was hypothesized to have a negative functional relationship with demographic vulnerability and thereby, on the overall vulnerability to climate change. Other determinants were variance in annual rainfall as well as minimum and maximum temperature variance, indicated that any increase in the variability of the climatic indicators would increase the vulnerability of the districts. It could be seen that higher yields of crops led to higher incomes of the farmers and thereby increasing their risk bearing ability to various shocks. District- wise analysis indicated that, as per ranking Kishanganj district placed at the first position by contributing (46%) towards the vulnerability due to agricultural indicators, it implies that Kishanganj was most vulnerable district of Kosi region of Bihar. Therefore, it is suggested that climate change has devastating impacts on agriculture. It is important to focus on the impacts of climate change on level of income/ productivity of crop, level of education, cropping intensity, and re-establish the links with poverty, livelihood and environment.

Key words: Climate Change, Vulnerability, Demographic vulnerability, Adaptive capacity.

Introduction

Vulnerability to climate change is a concept for natural hazards, public health, poverty and its impacts. It is determined by the Exposure, Sensitivity and Adaptive Capacity. The main objectives of this study are to determine climatic and socio-economic indicators/factors of vulnerability to agriculture in Kosi region of Bihar. Because, it have been used extensively in interdisciplinary research to explain the degree to which a socio-economic and environmental systems suffers from climate change. Bihar is one of the most vulnerable states of the county. Floods and droughts are various forms of disasters prevalent in the state. Among natural disasters, flood is the most common and a regular phenomenon in Bihar resulting in enormous loss of life and property. Year to year variability in climate contributes to rural poverty where the exposure is high and adaptive capacity is low. The effects of climatic variability on farming witnessed by delayed sowing, changes in cropping patterns, higher occurrence of pest and diseases, frequent and persistent droughts, less availability of water in tanks and canals for irrigation, reduced profits due to increased prices of inputs and wages as well as stagnation of output prices., (Singh *et al.*, 2009). Most of the models predict that the damages will adversely affect the small farmers, especially in the rain- fed areas. Identifying factors of vulnerability to climate change are aimed at formulation of public policy that reduces the risks associated with climate change.

Climate and agriculture are complementary to each other. Climate change affects the agriculture and the livelihoods of rural people due to changes in temperature,

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precipitation extreme heat waves, heavy rainfall etc. In our state like Bihar, the small and marginal farmers are more vulnerable due to the current and future climate change impacts and mainly depend on agriculture. Change in climate contributes to rural poverty where the exposure is high and adaptive capacity is low.

Importance of study in Kosi Region of Bihar

Kosi region is located in North Bihar of the Country. Under this region Districts namely Supaul, Saharsa, Madhepura, Araria, Purnia, Katihar, Khagaria and Kishanganj are located. Bihar is India's most flood-prone State, with 76 % of the population, in the north Bihar living under the recurring threat of flood devastation. About 68800 sq Km. Out of total geographical area of 94160 sq. Km. comprising 73.06% is flood affected. Bihar has experienced extensive and frequent loss of life and property over the last several decades (Sinha and Jain, 1998). The flood affected areas of Bihar in zone 2, 8 districts out of 36 districts in the State. The worst affected districts were Saharsa, Supaul, Katihar, Purnia, Madhepura, Khagaria, Araria and Kishanganj. The Damage caused due to flood are roughly 5-6 million of families in 20 districts damaged 5.12 lakhs houses and estimated crop losses was about 1.64 million ha leading to a loss of the value of about Rs 113.6 billion. This study has been planned to identify the extent of damage due to natural calamities and indicators like climatic and socio-economic which is most important factors of vulnerability and on such events no study has been carried out so far in our state.

Materials and Methods

The present study was conducted to identify the different climatic and socio-economic indicators/factors of vulnerability in selected district of Kosi region of Bihar. The study was based on secondary data from the period (P1 1976-1985, P2 1986-1995, P3 1996-2005 and P4 2006-2015) and was collected from various published source like Indian Meteorology Departments (IMD), DES, Patna, Ministry of Agriculture, Govt. of India. Keeping in view the availability of data, eight districts (Supaul, Saharsa, Madhepura, Araria, Purnia, Katihar, Khagaria, and Kishanganj) of Kosi region of Bihar were selected.

The simple average method and Patnaik and Narayanan's method of equal weight were used to find out the major determinant of vulnerability to agriculture. In order to obtain the value free from the units, they were normalized so that they all lie between 0 and 1. Before normalization, factors associated with vulnerability were identified and their functional relationship was found out using the collected secondary data of different years/ censuses data on selected variables.

Normalization was usually done of the variables having increasing/decreasing functional relationship with

Functional relationship of indicators

Sl. No.	Components	Indicators		Functional Relationship
1.	Demographic	a	Density of population (persons per sq. km)	↑
		b	Literacy rate (per cent)	↓
		c	Infant mortality rate(death/'000infants)	↑
2.	Climatic	a	Variance of annual rainfall (mm)	↑
		b	Variance of minimum temperature (°C)	↑
		c	Variance of maximum temperature (°C)	↑
		d	Variance of diurnal temperature(°C)	↑
3.	Agricultural	a	Total food grains (Kg/ha)	↓
		b	Productivity of major crops (Kg/ha)	↓
		c	Cropping intensity (per cent)	↓
		d	Livestock population (number per hectare of gross cropped area)	↓
4.	Occupational	a	Number of cultivators (per hectare of net sown area)	↓
		b	Agricultural labourers (per hectare of net sown area)	↓
		c	Industrial workers (per hectare of net sown area)	↓
		d	total workers (per hectare of net sown area)	↓
		e	Non-workers (per hectare of net sown area)	↓

vulnerability with the formula

Where,

$$U_{ij} = \frac{X_{ij} \text{ - } Min\ X_{ij}}{Max\ X_{ij} \text{ - } Min\ X_{ij}} \quad \ldots\ldots\ldots\ldots\ (1)$$

Xij is the value assigned by ith respondent on jth component Min Xj is minimum score on jth component Max Xj is maximum score on jth component Uij is unit value of ith respondent on jth component

And for those variables have decreasing functional relationship with vulnerability the normalization was done by using the formula respectively.

$$U_{ij} = \frac{Max\ X_{ij} \text{ - } X_{ij}}{Max\ X_{ij} \text{ - } Min\ X_{ij}} \quad \ldots\ldots\ldots\ldots\ (2)$$

After computing the normalized scores, the index was constructed by giving equal weights to all indicators/ components or unequal weights.

Simple Average of the Scores: When equal weights were given to all the variables, simple average of all the normalized scores to construct the vulnerability index.

$$VI = \frac{\sum_j U_{ij}}{k}$$

Finally, the vulnerability indices were used to rank for different regions in terms of vulnerability. A region with highest index was said to be most vulnerable and it is given the rank 1, the region with least vulnerable assigned rank 8.

Patnaik and Narayanan Method: In this method (Patnaik and Narayanan, 2005), possible sources of vulnerability were identified and for each source several sub-indicators are identified. Sources of vulnerability were demographic, climatic, agricultural and occupational, after normalization, the average index (AI) for each source of vulnerability was worked out and then the overall vulnerability index was computed by employing the following formula:

$$VI = \frac{\left[\sum_{i=1}^{n} (AI_i)^{\alpha}\right]^{\frac{1}{\alpha}}}{n}$$

Where, AI= Average index, *n* is the number of sources of vulnerability and á= *n*.

After the values of the index were calculated for all the districts for different period of time and they were compared to assess the changes in vulnerabilities a ranking of the various districts can be carried out to identify the most vulnerable districts in terms of the indicators used for measurement.

Expert judgement method

The weights are assigned based on expert opinion. Garrett's ranking technique is involved to reveal the importance of each component based on their unit value after normalization. The experts in this field are asked to rank the mentioned four components according to vulnerability. The percentage positions thus obtained are transformed into scores on a scale of 100 points by using Garrett's table. The average score was derived from the obtained scores. This is termed as scale value (Sj) of each component. The unit values (Uij) of each combinations and category of experts were multiplied by respective component scale value, by summed up and divided by total scale value to get vulnerability Index (VI) of each of the combinations in different categories of experts. The value of SI is in percentage. Higher the VI higher will be the vulnerability of the district.

$$VI = \frac{\sum_{i=1}^{n} U_{ij} * S_j}{\sum_{i=1}^{n} S_j}$$

Garrett's ranking technique

Mean score for each constraint has been ranked by arranging them in descending order.

$$\text{Percentage position} = \frac{100(R_{ij} - 0.50)}{N_j}$$

Where,

R = Rank given for the i item by the j individual and

N = Number of items ranked by the j individual.

Results and Discussion

Vulnerability depends on the factors that make a system vulnerable. The factors that make a rural area in Kosi region vulnerable to flood, drought and other extreme weather events were social factors, economic factors, and climatic factors. These are developmental factors including poverty, health status, economic inequality and elements of governance.

The Identified factors associated to vulnerability was estimated, and found that the density of population (Persons/km²) was maximum in Kishanganj district and was minimum in Khagaria district (table 1). Climatic factors indicated that Kishanganj district was most vulnerable district due to heavy rainfall (2265 mm) and temperature (39.21ºC) and least vulnerable district was Katihar (1233mm) (table 2). In agriculture, Production of food grains (tones/ha.) was maximum in Saharsa (154053) and least production of food grains was in Khagaria district (102190) (table 3). There are four major sources of vulnerability, demographic factors, climatic factors, agricultural factors and occupational factors. Weight of each factor was estimated and the vulnerability index of agriculture to climate change in the districts of Kosi region was developed and found that, Kisanganj district of Kosi region was most vulnerable, whereas the Katihar and Araria districts was least vulnerable district due to having higher adaptive capacity *i.e.* high literacy rate, better yield of crop, high cropping intensity etc.

Quite often the objective risks will uncertain due to weather fluctuations, susceptibility to pests, uncertainty regarding timely availability of crucial inputs etc. However, it could be seen that higher yields of crops led to higher income of the farmers and thereby increasing their risk bearing ability to various shocks. An increase in the livestock population per gross cropped area also results in an increase in the farmer's incomes through various animal husbandry based activities, thereby its negative functional relationship towards vulnerability. Similarly, the percentage of total food crops and non-food crops, the cropping and irrigation intensities and the net sown area in the district, each of these comprising the agricultural indicators, were also hypothesised to have a negative influence on the vulnerability to climate change.

Lastly, all the occupational indicators were hypothesised to have a negative functional relationship to climate change as greater employment meant more secure incomes which would in turn increase the risk bearing capacities of the people.

Construction of the vulnerability index:

Quantitative assessment of vulnerability is usually done by constructing 'vulnerability index'. The temporal assessment of vulnerability from the period (1976-1985, 1986-1995, 1996-2005, 2006-2015), (1976-2015) by the unequal weight method indicated that Kishanganj district was again ranked as most vulnerable district and the Katihar was the least vulnerable district as mentioned in Table in all selected period.

However estimated V.I by Patnaik and Narayanan method indicated that, the maximum vulnerability to agriculture was estimated in between the year 1986-1995 *i.e.* in P2 period. The value of vulnerability indices during the same was 0.893 followed by the period of 1976-85 and 0.892 respectively, however spatial vulnerability was maximum in Kishanganj district and minimum was in Katihar district of Bihar (0.33). It was assumed that vulnerability could arise out of a variety of factors. However, more specifically four major sources of vulnerability were taken into consideration. These included the demographic factors, climatic factors, agricultural factors and occupational factors. It may be seen from table 4 that out of the eight districts selected in the year 1976-1985 the district of Kishanganj ranked again first *i.e.* most vulnerable and the district of Araria ranked last that means least vulnerable district in the overall vulnerability to climate change during that period. In 1986-1995, the district of Kishanganj ranked first in the overall vulnerability to climate change among all the selected districts and Khagaria district placed to the second position, followed by Purnia district at the third. It can be seen from the Table no 5 that Kishanganj district were classified as highly vulnerable districts followed by Katihar, Supaul and Araria and the least vulnerable district was Araria, Katihar and Madhepura in different period.

Source wise contribution of vulnerability:

Sources wise contribution of vulnerability to Agriculture indicated that contribution of agricultural

Table 1: Demographic features of the districts of Kosi Region of Bihar.

District	Population Density (Persons/km²)	Literacy Rate (%)	Infant Mortality Rate (death/ '000infants)
Supaul	22.69	48.11	4.17
Saharsa	19.17	46.91	4.47
Madhepura	19.40	44.19	4.88
Araria	23.67	46.02	4.73
Purnea	22.40	43.36	4.30
Katihar	21.74	41.81	4.40
Kishanganj	23.90	44.60	4.80
Khagaria	18.98	53.72	4.90

Source: Field survey 2016

Table 2: Climatic features of Kosi region of Bihar.

District	Rainfall (mm)	Max temp. (ºc)	Min. temp. (ºc)	Diurnal temp. (ºc)
Supaul	1470	30.55	16.06	11.40
Saharsa	1370	27.06	17.35	11.41
Madhepura	1239	35.54	18.81	11.75
Araria	1822	33.4	16.01	13.08
Purnia	1407	35.93	16.8	12.84
Katihar	1233	36.38	16.23	12.99
Kishangaj	2265	39.21	13.7	12.36
Khagaria	1345	36.38	20.17	11.35

Table 3: Sources wise percentage contribution of vulnerability index

District	Demo-graphic	Cli-mate	Agricul-tural	Occup-ational	Overall contr.	Rank
Kishanganj	6.71	10.52	46.18	36.59	12.98	1
Khagaria	13.2	14.82	36.62	35.35	12.85	2
Supaul	11.32	20.52	25.53	42.64	10.69	3
Purnia	20.35	26.72	36.22	16.71	9.12	4
Madhepura	17.37	24.57	22.62	35.44	9	5
Saharsa	19.36	16.07	32.42	32.14	8.99	6
Araria	9.75	24.48	42.67	23.1	5.89	7
Katihar	36.13	27.92	23.43	12.53	5.83	8
Overall	15.42	19.41	33.92	31.25	100	

(Source: compiled by Authors)

factors followed by an Occupational variable was maximum *i.e.* 33.92 %and 31.25% respectively to the Climate change and least contribution was Climatic and Demographic variable *i.e.* 19.4 & 15.42 respectively in table 3. However, district wise analysis indicated that Kishanganj followed by Khagaria, Supaul, Purnia where as the least vulnerable district was Katihar. The vulnerability indices over the period (1976-2015) through expert judgement methods, Degree of vulnerability due to exposure indicated that Kishanganj district (≥ 47.74) was falling under highly vulnerable district followed by Supaul, Saharsha, Madhepura, Araria, Khagaria, Purnia (26.82- 47.74), Katihar (≤ 26.82) was the least vulnerable. However due to sensitivity Purnia, Katihar(≥ 66.28)

Table 6: Rankingof district on the basis of associated factors of vulnerability.

Scale	Level	Name of district
Exposure		
≥47.74	Highly	Kishanganj
26.82-47.74	Moderate	Supaul, Saharsa, Madhepura, Khagaria, Purnea, Araria
≤26.82	Least	Katihar
Sensitivity		
≥66.28	Highly	Purnea ,Katihar
36.79-66.28	Moderate	Saharsa, Madhepura, Kishanganj, Khagaria, Araria
≤36.79	Least	Supaul
Adaptive Capacity		
≥73.58	Highly	Kishanganj
28.32-73.58	Moderate	Supaul, Saharsa, Madhepura, Araria, Purnea, Khagaria
≤28.32	Least	Katihar

Source: Field Survey, 2016

Table 4: Vulnerability index for the period 1976-2015 (Simple Average Score Method)

District	P-I (1976-1985)		P-II (1986-1995)		P-III (1996-2005)		P-IV (2006-2015)		(1976-2015)	
	Vul. Index	Rank	Vul. Index	Rank	Vul. Index	Rank	Vul. Index	Rank	Vul. Index	Rank
Kishanganj	0.71	1	0.71	1	3.53	1	1.21	1	0.69	1
Khagaria	0.62	2	0.64	2	3.13	2	0.94	2	0.66	2
Supaul	0.42	7	0.45	5	2.12	5	0.37	8	0.55	3
Purnia	0.48	4	0.49	3	2.24	3	0.67	6	0.51	4
Madhepura	0.46	6	0.37	8	1.93	6	0.72	4	0.45	6
Saharsa	0.5	3	0.49	4	2.13	4	0.75	3	0.46	5
Araria	0.34	8	0.4	6	1.75	7	0.61	7	0.32	8
Katihar	0.46	5	0.37	7	1.74	8	0.71	5	0.33	7

(Source: compiled by the Authors)

Table 5: Vulnerability index for the period 1976-2015(Patnaik and Narayanan Method)

District	P-I (1976-1985)		P-II (1986-1995)		P-III (1996-2005)		P-IV (2006-2015)		(1976-2015)	
	Vul. Index	Rank	Vul. Index	Rank	Vul. Index	Rank	Vul. Index	Rank	Vul. Index	Rank
Kishanganj	0.89	1	0.89	1	0.024	1	0.59	1	0.81	1
Khagaria	0.78	2	0.8	2	0.021	3	0.51	4	0.8	2
Supaul	0.53	7	0.57	5	0.021	2	0.54	2	0.67	3
Purnia	0.6	4	0.61	3	0.019	4	0.52	3	0.57	4
Madhepura	0.58	5	0.46	8	0.012	8	0.3	8	0.56	5
Saharsa	0.63	3	0.61	4	0.014	7	0.37	6	0.56	6
Araria	0.42	8	0.5	6	0.015	6	0.36	7	0.37	7
Katihar	0.57	6	0.46	7	0.016	5	0.38	5	0.36	8

(Source: compiled by the Authors)

district was more vulnerable followed by, Madhepura, Saharsha, Kishanganj Khagaria, araria (36.79-66.28), and supaul ($\leq$ 36.79) was least vulnerable district and it was observed that the impact of adaptive capacity to assess the vulnerability again Kishanganj ($\geq$ 73.58) district was assessed as highly vulnerable followed by Supaul, Saharsa, Madhepura, Araria, Purnea, Khagaria (28.32-73.58) and Katihar ($\leq$ 28.32) indicated the least vulnerable districts in table 6 as per factors associated towards the vulnerability.

Conclusion and suggestions

Identification of determinants of prone area will help the Government and non-Government agencies to priorities and to direct their fund for the development of these districts. Unless these priorities regions are not focused in improving the adaptive capacity from the shock resulting from extreme events and climate variability could be devastating for the rural livelihood. It could reflect the evidence on the impact of climate change on agriculture in Kosi region of Bihar, where poverty and agricultural performance are related. This finding poses an important question for future research, for the welfare of Bihar agriculture, how quickly will Bihar farmers be able to adjust their farming practices to adapt to the changing climate and what policies or technologies will enable rapid adaptation to climate change. Temporal as well as spatial vulnerability index of selected district revealed that the agricultural sector was the principal contributor to the overall vulnerability to climate change. Since the occupational indicators were the second largest contributors towards overall vulnerability, thus, to reduce the climate change impact, the policy makers must focus on generating better employment opportunities including income diversification options for the people in the regions where the incidences of out-migration are high. In highly vulnerable district, policy makers should enact measures to support effective management of environmental resources; adaptation policies should increase the sustainability of farming and food systems to climate change impacts by increasing food production.

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