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A suggested index for assessment of vulnerability of a location to climate change

T.N. BALASUBRAMANIAN, A. ARIVUDAI NAMBI and DIYA PAUL
M.S. Swaminathan Research Foundation, Chennai 600 113, Tamil Nadu, India

ABSTRACT

With a view to develop a tool to assess the vulnerability of a region to local climate 15 criteria / vulnerability proxies as main factors relevant to reflect their impact on local climate were selected based on the experts' opinion. Each criterion was provided with an optimum value. The value below and above the optimum were considered to indicate lesser and severe vulnerability respectively and scores were assigned accordingly. An interaction table was developed between the 15 criteria selected. By adding main factor points with interaction points for a particular region, one could assess the vulnerability nature of the region selected for studying the impacts to climate change based on the five scales framed for this purpose. A trial run was made for two locations and the results were found valid.

***Keywords*:** Climate change, vulnerability, region, assess and empirical tool

Today, climate change is one of the important issues receiving the attention from several quarters in the society. Many scientists have reported the possible consequences as a result of climate change across the world (Shukla *et al*., 2003).

The extent of impact of the projected climate change/variability in the Indian context needs to be addressed because of India's larger geographical area, population and heavy dependence on agriculture for food security.

Nick Brooks *et al*., (2005) indicated that vulnerability depends critically on context and factors that make a system vulnerable to a hazard. This depends on the nature of the system and the type of hazard in question. The glossary of the TAR (IPCC, 2001) defined vulnerability as "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed, it's sensitivity, and it's adaptive capacity". Sumana Bhattacharya *et al.*, (2003) indicated that assessment of vulnerability drew on a wide range of physical, biological and social science disciplines, and consequently employed variety of methods and tools. In a paper on a three dimensional surface as a tool for analysing vulnerability,

Table 1: Required information for computing final vulnerability scale for village / mandal / district / state

Sr. No.	Criteria	Scales		
		Severe	**Moderate**	**Less**
1.	Population density per km^2: ***Optimum; 300/km^2**	> +75 to100% from optimum	+26 to74% from optimum	+ 25% from optimum
2.	Rate of population growth per annum: **Optimum; 2%**	> 4%	3 to 4%	2 to 3%
3.	Village forest cover: **Optimum; 33% of geographical area**	<10%	11 to 15%	16 to 32%
4.	Ground water: **Optimum; White;**	Black (over exploitation)	Grey (moderate exploitation)	White to grey (severe exploitation)
5.	Water resource: **Optimum; Tank / river / stream / pond**	No source	Any one alone	Any two
6.	Soil degradation: **Optimum; 10% of the soil with-erosion (sheet erosion) and salinity**	75 to 100%	26 to 74%	11 to 25%
7.	Rate of food production per annum: **Optimum; > 4%**	< 1%	1 to 2%	2.1 to 3.9%
8.	Irrigated existing area: **Optimum; 33% of the cropped area**	0 to 15% of the cropped area	16 to 25%	26 to 32%
9.	Poverty per cent of population: **Optimum: 33%**	70 to 90%	50 to 70%	33 to 49%
10.	Literacy: **Optimum: 65.4%**	< 25%	26 to 50%	51 to 65%
11.	Per capita income: **Optimum; Rs.60/day**	< Rs.30	Rs.31 to 40	Rs.41 to 59
12.	Income source: **Optimum; On/Off farm activities**	Off farm alone	On farm alone	Both on farm and off farm
13.	Land holding size: **Optimum; 2 Hectares**	< 0.4 ha.	0.41 to 1.5 ha.	1.6 to 2.0 ha.
14.	Seasonal dry spell: **Optimum; 10% of seasonal days (12 days *viz*.; three No of 4 days continuous Dry Spell–DS-)**	15 Nos. DS	9 to 15 Nos. DS	5 to 8 Nos. DS
15.	Frequency of pest and disease out break: **Optimum;** Annually once	4 times / year	3 times / year	2 times / year

* The values given in the optimum is based on Indian average and standard given by Government of India respectively.

Table 2: Criteria in the cells / vulnerability scale

	Criteria / Points	Severe	Moderate	Less
Cell 1	Population density	100	50	25
	Village forest cover			
	Water resource / water bodies			
	Rate of food production			
	Area under irrigation			
	Literacy			
Cell 2	Rate of population growth	75	38	19
	Ground water availability			
	Poverty per cent			
Cell 3	Per capita income	50	25	12.5
	Income source			
	Seasonal dry spell			
	Pest and disease out break			
	Land holding size			
	Soil degradation			
	Total direct points (main-factor)	1125*	564**	282.0***
	Total interaction points	2976	1026	-
	Grand Total	**4101**	**1590**	**282.0**

* All criteria are assumed to be severe, ** moderate, *** less

Luers *et al.*, (2005) found that such a surface provided a structure for distinguishing on which farm units and wheat yields were most vulnerable. They highlighted the relative importance of soil and management factors contributing to the vulnerability of farm units exposed to changes in average temperature and prices. Nick Brooks *et al.*, (2005) presented a methodology for assessing vulnerability to climate related mortality based on empirical analysis, which addressed the sensitivity of vulnerability assessments to different sets of subjective weightage. In this context, an attempt has been made here to develop a suitable tool to assess the vulnerability of a region to the anticipated impact from climate change at the M.S. Swaminathan Research Foundation (MSSRF), Chennai, India.

MATERIALS AND METHODS

Based on some fundamental questions like why, when, how and where a system is vulnerable to climate change, vulnerability

Table 3: Basic for interaction (points/ Marks in %)

Interaction between	Criteria in Cell 1 to Cell 1	Criteria in Cell 1 to Cell 2	Criteria in Cell 1 to Cell 3	Criteria in Cell 2 to Cell 1	Criteria in Cell 2 to Cell 2	Criteria in Cell 2 to Cell 3	Criteria in Cell 3 to Cell 1	Criteria in Cell 3 to Cell 2	Criteria in Cell 3 to Cell 3
S x S	30 *	15	8	15	30	15	8	15	15
S x M M x S	15	8	4	8	15	8	4	8	8
S x L	0	0	0	0	0	0	0	0	0
M x M L x S	10	5	3	5	10	5	3	5	5
M x L L x M L x L	0	0	0	0	0	0	0	0	0

S= Severe, M=Moderate, L=Less, * Percent of points from the severe category of 100 points given to criteria in cell 1.

proxies (criteria) were selected for the study.

A questionnaire was developed with 15 criteria as vulnerability proxies (Table1) to collect primary and secondary data from the proposed study area. These criteria were selected with due care to indicate the sensitiveness of the particular site and also based on experts' opinion. Each criterion was given an optimum value based on National/State average value and the value below or above the optimum indicated their sensitiveness to severe, moderate and lesser vulnerability.

These 15 criteria had been sub classified into three cells (Table 2) and points are assigned. First cell consisted of first six criteria. If the value of the each criterion of the cell reflects severe (S) as per the scale given against each, 100 points were given. Similarly for moderate (M) and lesser (L) category, 50 and 25 points were given respectively. The second cell consisted of three criteria, which had lesser impact as compared to criteria given in the first cell.

The third cell consisted of last six criteria, which were considered relatively less important to criteria given in cell 1 and 2. Thus, points were awarded based on the collected data and this was considered as *main factor effect*. Points given to severe, moderate and less category for the criterion were decided by the experts based on the expected damage to the system. In interaction the first criterion in the cell 1 interacted with 5 criteria within cell 1 and also with 3 and 6 criteria respectively given in the cell 2 and 3. Similarly each criterion has 15 interactions. A new table for 2025 (15 x 15 x 9) interaction with points to be

Table 4: Study locations

		Location A (Madanapalli, AP)		Location B (Nalgonda, AP)	
		Category of main effect	**Mark / points scored**	**Category of main effect**	**Mark / points scored**
Cell 1	Population density	M	50.0	S	100.0
	Village forest cover	L	25.0	L	25.0
	Water resource	M	50.0	M	50.0
	Role of food production	M	50.0	L	25.0
	Area under irrigation	S	100.0	S	100.0
	Literacy	M	50.0	M	50.0
Cell 2	Rate of population growth	M	38.0	M	38.0
	Ground water	M	38.0	S	75.0
	Poverty per cent	M	38.0	L	19.0
Cell 3	Per capita income	M	25.0	M	25.0
	Income source	S	50.0	M	25.0
	Seasonal dry spell	S	50.0	S	50.0
	Pest and disease out break	L	12.5	L	12.5
	Land holding size	M	25.0	M	25.0
	Soil degradation	S	50.0	S	50.0
Total main effect points		-	**651.5**	-	**669.5**
Total interaction points		-	**1001.0**	-	**905.0**
Grand Total		-	**1652.5**	-	**1574.5**

S=Severe; M=Moderate; L=Less

given was developed based on assumptions for the main factors in cell 1 to cell 1, 2, 3; cell 2 to cell 1, 2 & 3, etc., in respect of nine combinations of s x s; s x m; s x l (Table 3). Based on the direct and interaction points obtained for a particular area, the vulnerability scale of a region/ area was classified into five scales.

Vulnerability Scale; (refer Table 2)

Severe	: 4101 points
Moderate to severe	: 591 to 4101 points
Moderate	: 1590 points
Low to moderate	: 282 to 1589 points
Low	: < 282 points

RESULTS AND DISCUSSION

A trial run was made with two locations (A & B) data to test and verify

Table 5: Interaction effects (points / marks)

			Cell – 1																	
			PD			VFC			WR			RFP			IA			LIT		
			S	M	L	S	M	L	S	M	L	S	M	L	S	M	L	S	M	L
Cell–1		S				30	15	0	30	15	0	30	15	0	30	15	0	30	15	0
	PD	M		0		15	10	0	15	10	0	15	10	0	15	10	0	15	10	0
		L				10	0	0	10	0	0	10	0	0	10	0	0	10	0	0
	VFC	S	30	15	0				30	15	0	30	15	0	30	15	0	30	15	0
		M	15	10	0		0		15	10	0	15	10	0	15	10	0	15	10	0
		L	10	0	0				10	0	0	10	0	0	10	0	0	10	0	0
	WR	S	30	15	0	30	15	0				30	15	0	30	15	0	30	15	0
		M	15	10	0	15	10	0		0		15	10	0	15	10	0	15	10	0
		L	10	0	0	10	0	0				10	0	0	10	0	0	10	0	0
	RFP	S	30	15	0	30	15	0	30	15	0				30	15	0	30	15	0
		M	15	10	0	15	10	0	15	10	0		0		15	10	0	15	10	0
		L	10	0	0	10	0	0	10	0	0				10	0	0	10	0	0
	IA	S	30	15	0	30	15	0	30	15	0	30	15	0				30	15	0
		M	15	10	0	15	10	0	15	10	0	15	10	0		0		15	10	0
		L	10	0	0	10	0	0	10	0	0	10	0	0				10	0	0
	LIT	S	30	15	0	30	15	0	30	15	0	30	15	0	30	15	0			
		M	15	10	0	15	10	0	15	10	0	15	10	0	15	10	0		0	
		L	10	0	0	10	0	0	10	0	0	10	0	0	10	0	0			
Cell–2	RPG GW PP	S	15	8	0	15	8	0	15	8	0	15	8	0	15	8	0	15	8	0
		M	8	5	0	8	5	0	8	5	0	8	5	0	8	5	0	8	5	0
		L	5	0	0	5	0	0	5	0	0	5	0	0	5	0	0	5	0	0
Cell–3	PCI IS SDS PDB LHS SD	S	8	4	0	8	4	0	8	4	0	8	4	0	8	4	0	8	4	0
		M	4	3	0	4	3	0	4	3	0	4	3	0	4	3	0	4	3	0
		L	3	0	0	3	0	0	3	0	0	3	0	0	3	0	0	3	0	0

the preciseness of the model developed (Table 4). The location A was Madanapalli of Andhra Pradesh ($78^0$45’20" E & $13^0$15’47" N) with a southwest monsoon normal rainfall of 393 mm. The location B was Nalgonda of Andhra Pradesh ($79^0$12’23" E & $17^0$2’38" N). The normal southwest monsoon is 551 mm. Both locations A & B belonged to semi-arid climate. For each criterion datum was collected and converted into scale and accordingly points were assigned. Values from interaction table (Table 5) were picked out between criteria and the total interaction marks/points were arrived at. By adding points from main effect to the interaction points, total marks/points were computed separately for the two study locations. In doing so, the obtained marks were 1652.5 for location **A** and 1574.5 for location **B**.

Table 5: Interaction effects continued....

			Cell – 2								
			RPG			GW			PP		
			S	M	L	S	M	L	S	M	L
Cell–1	PD VFC WR RFP IA LIT	S	15	8	0	15	8	0	15	8	0
		M	8	5	0	8	5	0	8	5	0
		L	5	0	0	5	0	0	5	0	0
Cell–2	RPG	S				30	15	0	30	15	0
		M		0		15	10	0	15	10	0
		L				10	0	0	10	0	0
	GW	S	30	15	0				30	15	0
		M	15	10	0		0		15	10	0
		L	10	0	0				10	0	0
	PP	S	30	15	0	30	15	0			
		M	15	10	0	15	10	0		0	
		L	10	0	0	10	0	0			
Cell–3	PCI IS SDS PDB LHS SD	S	15	8	0	15	8	0	15	8	0
		M	8	5	0	8	5	0	8	5	0
		L	5	0	0	5	0	0	5	0	0

Based on the total points given for vulnerability scale (five categories), it could be construed that the location **A** fell in moderate to severe category for climate change, while the location **B** fell into low to moderate category. Using this approach, the vulnerability category of any area could be determined and accordingly, strategic planning could be taken up.

A software in this line is being developed based on the format discussed above at MSSRF, Chennai to compute the final vulnerability scale by giving inputs from the collected data of the questionnaire (http://www.appleg.in/weather)

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Table 5: Interaction effects continued....

			Cell – 3																	
			PCI			IS			SDS			PDB			LHS			SD		
			S	M	L	S	M	L	S	M	L	S	M	L	S	M	L	S	M	L
Cell–1	PD VFC WR RFP IA LIT	S	8	4	0	8	4	0	8	4	0	8	4	0	8	4	0	8	4	0
		M	4	3	0	4	3	0	4	3	0	4	3	0	4	3	0	4	3	0
		L	3	0	0	3	0	0	3	0	0	3	0	0	3	0	0	3	0	0
Cell–2	RPG GW PP	S	15	8	0	15	8	0	15	8	0	15	8	0	15	8	0	15	8	0
		M	8	5	0	8	5	0	8	5	0	8	5	0	8	5	0	8	5	0
		L	5	0	0	5	0	0	5	0	0	5	0	0	5	0	0	5	0	0
Cell–3	PCI	S				8	4	0	8	4	0	8	4	0	8	4	0	8	4	0
		M		0		4	3	0	4	3	0	4	3	0	4	3	0	4	3	0
		L				3	0	0	3	0	0	3	0	0	3	0	0	3	0	0
	IS	S	8	4	0				8	4	0	8	4	0	8	4	0	8	4	0
		M	4	3	0		0		4	3	0	4	3	0	4	3	0	4	3	0
		L	3	0	0				3	0	0	3	0	0	3	0	0	3	0	0
	SDS	S	8	4	0	8	4	0				8	4	0	8	4	0	8	4	0
		M	4	3	0	4	3	0		0		4	3	0	4	3	0	4	3	0
		L	3	0	0	3	0	0				3	0	0	3	0	0	3	0	0
	PDB	S	8	4	0	8	4	0	8	4	0				8	4	0	8	4	0
		M	4	3	0	4	3	0	4	3	0		0		4	3	0	4	3	0
		L	3	0	0	3	0	0	3	0	0				3	0	0	3	0	0
	LHS	S	8	4	0	8	4	0	8	4	0	8	4	0				8	4	0
		M	4	3	0	4	3	0	4	3	0	4	3	0		0		4	3	0
		L	3	0	0	3	0	0	3	0	0	3	0	0				3	0	0
	SD	S	8	4	0	8	4	0	8	4	0	8	4	0	8	4	0			
		M	4	3	0	4	3	0	4	3	0	4	3	0	4	3	0		0	
		L	3	0	0	3	0	0	3	0	0	3	0	0	3	0	0			

PD = Population Density; VFC = Village Forest Cover; WR = Water Resource (Water bodies); RFP = Rate of Food Production; IA = Irrigated Area; LIT = Literacy; RPG = Rate of Population Growth; GW = Ground Water; PP = Poverty Percent; PCI = Per Capita Income; IS = Income Source; SDS = Seasonal Dry Spell; PDB = Pest and Disease Outbreak; LHS = Land Holding Size; SD = Soil Degradation

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