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Full Length Research Paper

"Mapping the regional variation in potential vulnerability in Indian Agriculture to climate change"- An exercise through constructing vulnerability index

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India is potentially vulnerable to adverse impacts in agriculture on account of climate change. The Anticipated changes in water availability (surface, freshwater and ground water), temperature rise, soil degradation and the suggested increase in extreme events such as the drought, floods and cyclones will affect agricultural severely. The present paper aims to develop the vulnerability profile of agricultural systems of the Indian states to the changing climate scenarios. It develops two sub indices, namely, Bio-Physical vulnerability index and Socio-Economic vulnerability index to develop the final overall vulnerability index. Bio-Physical vulnerability index has been constructed by considering five indicators, namely: (1) Cropping intensity, (2) Percentage of area under leguminous crops, (3) Percentage of degraded area to total geographical area, (4) Unexploited surface water available for future and (5) Unexploited surface water available for future. The Socio-Economic Vulnerability index has been computed by considering four indicators like: Irrigation intensity, Percentage of people below poverty line, Percentage of agricultural workers to total workers, Literacy rate. Modified UNDP method has been used in developing all the indicators. It has been found that most of the states which are having very high or high vulnerability are centered on the central and north-central part of India.

Key words: Climate change, vulnerability, environmental sustainability.

INTRODUCTION

Agriculture is the backbone of Indian economy more specifically of the rural livelihood security system. However, the contribution of agriculture to GDP has been steadily declining over the years (nearly 25% to the total at present). But the share of agriculture in providing employment and livelihoods to a majority of population continues to remain intact (agriculture provides employment about two-thirds of the total workforce) in spite of the diversification of economic activity. It is also an important instrument of poverty eradication and employment generation (Planning commission 1997; 2002). Among India's population, more than one billion people (about 68%) are directly or indirectly involved in the agricultural sector. Indian agriculture is now facing the several problems like regional variation in productivity is still persisting, the yield has been stagnated or decline over most of the regions, the yield of food grains in major producing, states like Punjab and Haryana has reached a plateau, more than 60% net sown area is still under rained agriculture etc. Above all, the projected climate change is a single largest threat for sustainable agriculture in India. This sector due to its heavy reliance on climatic factors is particularly vulnerable to present-day climate variability, including erratic rainfall and increase in average surface temperature. Predictions made by the scientists by using global circulation model shows that India could experience warmer and wetter conditions as a result of climate change, particularly if the summer monsoon becomes more intense (Mitra et al., 2002). Contrary to this some scientists using the same model assessed that increased rates of evapotranspiration due to the higher temperatures may offset the increased precipitation, leading to negative impacts on soil moisture. There are also considerable uncertainties associated with climate model projections of tropical monsoon behavior, and simulations that include sulfate aerosol forcing indicate decreasing summer monsoon rainfall (Lal et al., 1998). The picture of climate change in India is not crystal clear because it suffers from good esti-

estimates. Scientists at the Centre for science and environment predict that the semi-arid regions of Western India are expected to receive higher than normal rainfall as the temperature soar, while central India will experience a decrease of between 10 to 20% in winter rainfall by 2050, Average surface temperature is likely to increase about 2-4°C by 2050, rainfall intensity is likely to increase by 1 to 4 mm/day, frequency and intensity of the weather extreme events such as cyclone, drought, flood will increase. But still there is a lack of accuracy of measurement of change in climate at regional level.

Indian agriculture is still heavily dependent on climate as indicated from the fact that nearly 60% of the net sown area is under rain fed agriculture. Broadly, agricultural productivity is sensitive to climate-induced effect both directly and indirectly- direct effect from changes in temperature, rainfall amount, pattern and intensity, increased frequency of extreme climate event like drought, flood, cyclones etc., and indirect effect through changes in soil moisture, acceleration of various land degradation effects etc., (IPCC, 1997, 2001). Although the direct temperature and CO_2 effects of climate change may lead to productivity increases for some irrigated crops there is general consensus that major agricultural production areas are likely to be adversely affected by climate change, particularly in areas that become increasingly water-stressed (Dinar et al., 1998; Kumar and Parikh, 2001; Lal et al., 1998; Gadgil, 1995).

The study on impact of predicted climate change on particular crop and over particular agricultural region is few. A 2°C increase in temperature will lead to a reduction in rice yield by 0.75 ton/hectare in high yield areas and coastal regions. On the other hand a 0.5°C increase in winter temperature will lead to a reduction in wheat crop duration by seven days, which will intern reduce yield by 0.45 ton/hectare (Swaminathan and Sinha, 1991). An increase in temperature will lead to 10% reduction in wheat yield in high yielding states of Punjab, Haryana and Uttar Pradesh. World Bank report (1998) analyzed climate change effects on Indian agriculture, through annual net revenues, by using Ricardian method. The three methodologies, as adopted in the study, found Indian Agriculture sensitive to warming. The analyses further showed year-to-year climate sensitivity to the system's response. The studies revealed that net revenues fall precipitously with warmer April's, but also sensitive to warmer January and July. Crop revenues increased with October temperatures. Net revenues were also sensitive to precipitation, but the effects were smaller and offsetting. A warming scenario of +2.0°C rises in mean temperature and a +7% increase in mean precipitation levels will create reduction in the netrevenues, as revealed from the three approaches. The impact is differential on spatial and temporal scales. But the study seemed to be weak for linking with the biophysical aspects.

However, the vulnerability of agricultural production to climate change depends not only on the physiological response of the affected plant, but also on the ability of the affected socio-economic systems of production to cope with changes in agricultural production or the factors like changes in the frequency of droughts or floods which effects the agricultural production. The adaptability of farmers in India is severely restricted by the heavy reliance on natural factors and the lack of complementary inputs and institutional support systems. The central challenge of sustainable agriculture in India today is to meet the food demand of the present generation without sacrificing the needs of future generations. This cannot be achieved without the systemic integration of the social, economic pillars of agriculture to combat with the climatic variability such as changes in water availability (surface, freshwater and ground water), temperature rise, soil degradation and the suggested increase in extreme events such as the drought, floods and cyclones. Recognizing the perceived adverse impact of climate change on Indian Agriculture to maintain the sustainability of the food production India is left with two option either increase adoptability of the agricultural system at the various states or mitigate the climate change. The agricultural system which has high adaptive capacity is less vulnerable to be effected adversely to climate change and vice-versa.

In this regard a brief note on theoretical understanding of Agricultural vulnerability has put forwarded in this section. Vulnerability is 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 change and variation to which a system is exposed as well as the system's sensitivity and adaptive capacity. Vulnerability to climate change varies across regions, sectors, and social groups. Understanding the regional and local dimensions of vulnerability is essential to develop appropriate and targeted adaptation efforts (McCarthy et al., 2001).

Vulnerability of Agricultural systems to climate change is generally understood to be a function of a range of biophysical and socio-economic factors. The most recent report of the Intergovernmental Panel on Climate Change (IPCC) provides a useful typology suggesting that vulnerability may be characterized as a function of three components: adaptive capacity, sensitivity, and exposure.

Adaptive capacity describes the ability of a system to adjust to actual or expected climate stresses, or to cope with the consequences. It is considered "a function of wealth, technology, education, information, skills, infrastructure, access to resources, and stability and management capabilities" (McCarthy et al., 2001: 8). Sensitivity refers to the degree to which a system will respond to a change in climate, either positively or negatively. Exposure relates to the degree of climate stress upon a particular unit of analysis, it may be represented as either long-term change in climate conditions, or by changes in climate variability, including the magnitude and frequency of extreme event.

In developing Agricultural vulnerability profile, it has been assumed that climate change exposure (that is, ongoing and future exposure) will affect current sensitivity, either positively or negatively, and that farmers will respond to these changes in climate sensitivity if they have sufficient adaptive capacity. Thus the vulnerability profile is constructed by combining indices for adaptive capacity with sensitivity indices that take into account exposure to climate change. Study on agricultural vulnerability in India is very much limited most of study confines to impact of predicted changes in temperature and rainfall on individual crops and agricultural regions. Concentrated efforts to understand vulnerability at regional or at local level only made by TERI and individual study done by Karen O'Brien et al. (2004).

In developing vulnerability profiles TERI considered three dimensions such as Biophysical factors, social factors and technological factors. Biophysical factors that influence agricultural production includes soil conditions and groundwater availability. The social factors that influence adaptive capacity comprise indicators representing the percentage of workers employed in agriculture, the percentage of landless labourers in the agricultural workforce, human capital (as represented by literacy levels), gender discrimination, (as measured by excess girl child mortality), and child mortality and fertility (as measured by female literacy rates). Technological factors that influence adaptive capacity include irrigation and infrastructure. Irrigation was measured by net irrigated area as a percentage of net sown area, while infra-structure was measured by the existing Infrastructure development index (CMIE, 2000).

While Karen et al. (2004) measure the vulnerability of Indian agriculture have identified significant biophysical, socioeconomic, and technological factors that influence agricultural production. The bio-physical indicators used in the profile consisted of soil conditions (quality and depth) and ground water availability. Indicators for soil quality include the depth of the soil cover and severity of soil degradation, while indicators of groundwater availability are based on estimates of the total amount of replenishable groundwater available annually. Socioeconomic factors consisted of levels of human and social capital, and the presence or lack of alternative economic activeties Human capital was represented by adult literacy rates, while social capital was measured by degree of gender equity in a district Presence of alternative economic activities is measured by the percentage of the district workforce that is employed in agriculture and by the percentage of landless laborers in the agricultural workforce.

Both of the study considers very few representative indicators and hence, suffers from the problem of coverage and able to capture very limited information about vulnerability of Indian Agriculture to climate change. Therefore, the present paper aimed at development of vulnerability Profile for agriculture at the state level of India considering of indicators covers wide range of information about vulnerability profile of Indian Agriculture to climate change.

METHODS

The Agricultural vulnerability index has been created very carefully by considering the best representative indicators. The present study tried to cover almost all the dimension of bio-physical vulnerability and socio-economic vulnerability by considering six indicators and four indicators respectively.

Bio-physical vulnerability

Bio-physical vulnerability is the physiological response of the affected plants to changing climatic conditions. It is defined by the following indicators (Table 1).

Cropping intensity

It is the ratio of the gross cropped area to net sown area and is expressed as percentage. It is indicative of the good health and better moisture retention capacity of the soil. Better soil has higher cropping intensity. Hence, high crop intensity indicates low bio-physical vulnerability and vice-versa. Information regarding this is taken from Agriculture Census (2001), Ministry of Agriculture, Government of India.

Percentage of area under leguminous crops

It ensures the sustainable crop patterns because most of the legumes can convert the nitrogen gas from air into soluble form of nitrogen that is, ammonia. They can adopt the harsh climatic conditions. Hence the higher percentage of which represents the low bio-physical vulnerability and vice versa. Data on this is taken from Agriculture Census (2001), Ministry of Agriculture, Government of India.

Percentage of degraded area to total geographical area

Land degradation due to salinisation, erosion, water logging etc. refers to degradation of quantity and quality of soil that result in loss of biological productivity of land and enhance the bio-physical vulnerability. The source of information of this is FSI, State of Forest Report (2001). "Forest Survey of India, Government of India.

Unexploited surface water available for future

It represents the future availability of the surface water which indicates potential availability of surface water for irrigation which can reduce the dependency on climate for water and lessen the bio-physical vulnerability. Data on this is taken from CWC, Surface Water Statistics (2000), Central Water Commission, Government of India.

Unexploited ground available for future

It also represents the future availability of the ground water for irrigation which can reduce the dependency on climate for water and lessen the bio-physical vulnerability. Informa-tion regarding this is taken from CGWB (1996), Ground-water statistics (2000). Ministry of Water Resources, Government of India.

Table 1. Bio-Physical vulnerability index.

Source	Cropping intensity	(%) of degraded area to TGA	(%) of leguminous crops to total crops	Future availability of surface water	Future availability of ground water	Bio-Physical vulnerability index	Modified index (1- original index)	Rank
Andhra Pradesh	0.21	0.75	0.69	0.40	0.74	0.557	0.443	20
Arunachal Pradesh	0.34	0.84	0.00	0.47	1.00	0.530	0.470	16
Assam	0.47	0.68	0.08	0.78	0.93	0.587	0.413	24
Bihar	0.34	0.85	0.24	0.56	0.67	0.530	0.470	17
Goa	0.16	0.84	0.00	0.75	0.92	0.534	0.466	18
Gujarat	0.06	0.69	0.70	0.59	0.51	0.508	0.492	12
Haryana	0.79	0.92	0.18	0.28	0.24	0.484	0.516	9
Himachal Pradesh	0.83	0.61	0.10	0.52	0.83	0.578	0.422	23
Jammu and Kashmir	0.48	0.91	0.08	0.09	0.99	0.508	0.492	11
Karnataka	0.13	0.88	0.67	0.24	0.67	0.518	0.482	14
Kerala	0.27	1.00	0.04	0.46	0.81	0.515	0.485	13
Madhya Pradesh	0.29	0.78	1.00	0.65	0.81	0.706	0.294	25
Maharashtra	0.22	0.76	0.48	0.34	0.65	0.493	0.507	10
Manipur	0.56	0.00	0.00	0.51	1.00	0.414	0.586	6
Meghalaya	0.16	0.25	0.00	0.69	0.96	0.413	0.587	5
Mizoram	0.00	0.70	0.00	1.00	0.00	0.340	0.660	3
Nagaland	0.05	0.13	0.00	0.15	0.00	0.065	0.935	1
Orissa	0.38	0.83	0.25	0.52	0.85	0.566	0.434	22
Punjab	1.00	1.00	0.03	0.07	0.02	0.423	0.577	8
Rajasthan	0.31	0.74	0.70	0.07	0.27	0.419	0.581	7
Sikkim	0.33	0.51	0.00	0.66	0.00	0.299	0.701	2
Tamil Nadu	0.14	0.76	0.69	0.00	0.37	0.394	0.606	4
Tripura	0.63	0.83	0.00	0.70	0.67	0.565	0.435	21
Uttar Pradesh	0.52	0.91	0.30	0.41	0.58	0.545	0.455	19
West Bengal	0.76	0.96	0.07	0.14	0.68	0.520	0.480	15

Source: Authors own calculation from various sources.

.Socio-economic vulnerability

It represents the lack of adoptability of the farmers and the lack of complementary inputs and institutional support systems. It is defined by the following indicators.

Irrigation intensity

This represents the efficient utilization of water and less dependency on rainfall and reduces the socio-economic vulnerability. Data on this is taken from Agriculture Census-(2001), Ministry of Agriculture, Government of India.

Percentage of people below poverty line

This group of population is expected to be worst victim of the decrease in food production and higher proportion of which will enhances the socio-economic vulnerability. This information is taken from State of Poverty in India, Planning Commission report, Government of India.

Percentage of agricultural workers to total workers

This is an indicator of relative economic deficiency and reflects heavily dependence on agriculture and enhances the socio-economic vulnerability. This information is taken from Census of India, 2001, Government of India.

Literacy rate

Literate population indicates real human resource stock and literate population has the higher capability of adaptation of new technology and reduces the socio-economic vulnerability. This data is taken from Census of India (2001), Government of India.

Modified UNDP method has been used in constructing both bio-physical vulnerability index and socio-economic vulnerability index. The following procedure has been adopted in converting the indicators into normalized form. The indicators that have been used in the construction of the food availability index are both negative and positive in nature. First the best and the worst values in an indicator are identified. The best and the worst values are depends on the nature of the indicators. In case of a positive indicator, the highest value will be treated as the best value and the lowest, will be considered as the worst value. Similarly, if the indicator is negative in nature, then the lowest value will be considered as the best value and the highest, the worst value. Once the best and worst values are identified, the following formula is used to obtain normalize values:

$$NVij = 1 - \left(\frac{\{Best\ Xi - Observed\ Xij\}}{\{Best\ Xi - Worst\ Xi\}} \right)$$

Normalized values always lies between 0 and 1. As the value of a particular indicator inclined towards 1 indicates better performance and vice-versa.

Two dimension index that is, bio-physical vulnerability index and socio-economic vulnerability index has been computed by using the following formula:

$$D_i = \frac{\sum NVij}{n}$$

NVij = Sum of all normalized indicator. I=1…9 denotes specific indicators (X_1=Cropping intensity, X_2=Percentage of area under leguminous crops, X_3=Percentage of degraded area to total geographical area, X_4=Unexploited surface water available for future, X_5=Unexploited surface water available for future, X_6=Irrigation intensity X_7=Percentage of people below poverty line, X_8=Percentage of agricultural workers to total workers, X_9=Literacy rate)

j=1…29 means State

n= Total number of indicator used in calculating the indicator

D_i= Dimension index

The overall vulnerability index has been computed on the basis of following formula: $\sum D_i$/ Total number of dimension index

Since all the representative indicators of Agricultural vulnerability are negative in nature to vulnerability that is, higher value of which indicates lower vulnerability and vice versa, the final index is modified by the following equations so that now higher value is indicating higher vulnerability and vice versa. Modified index= 1- Original index value.

RESULTS

Indian agriculture faces the challenge of feeding a billion people in a changing climatic scenario. Agriculture is the predominant means of livelihood for a large number of peasant cultivators and agricultural laborers, for whom it is not easy to shift to other occupations. Due to their low financial and technological adaptability, such groups are potentially vulnerable to both climatic changes. Therefore, the present study made a modest attempt to develop the vulnerability profiles of agriculture to climate change in various Indian states. Vulnerability was seen as a composite of adaptive capacity and climate sensitivity. However, the vulnerability of agricultural system to climate change depends not only on the physiological response of the affected plant, but also on the ability of the affected socio-economic systems of production to cope with changes in climatic factors like changes in the frequency of droughts or floods which effects the agricultural production. Hence, the Agricultural Vulnerability Profile is composite of Bio-Physical vulnerability and Socio-Economic vulnerability (Tables 1 to 5).

The bio-physical vulnerability profile in India clearly indicates that three states (about 12%) namely, Nagaland, Sikkim, Mizoram have very high bio-physical vulnerability. The very high bio-physical mainly influenced by the over exploitation of the surface water and land degradation due to slope erosion. There are five states (about 20%), namely, Tamil Nadu, Meghalaya, Manipur, Rajasthan, and Punjab have high levels of bio-physical vulnerabilities. It is to be noted that major cereal producing state like Tamil Nadu and Punjab belong to High bio-physical vulnerability class because of the over exploitation of the ground water and surface water which makes it high vulnerable. Eleven states (about 44%) belong to the medium vulnerability category these include Haryana, Maharashtra, Jammu and Kashmir, Gujarat, Kerala, Karnataka, West Bengal, Arunachal Pradesh, Bihar, Goa, Uttar Pradesh. There are five states (about 20%) like Andhra Pradesh, Tripura, Orissa, Himachal Pradesh and Assam belongs to the low vulnerability category. Only one state that is, Madhya Pradesh has very low bio-physical vulnerability. The states which are having very low and low vulnerability are very wisely utilized the ground water and surface water and the areaunder leguminous crops are relatively higher which can adopt the harsh climate (Figure 1).

The socio-economic vulnerability profile in India clearly indicates that nine states (about 36%) namely Bihar, Madhya Pradesh, Arunachal Pradesh, Orissa, Meghalaya, Assam, Nagaland, Sikkim, and Uttar Pradesh. Very high socio-economic vulnerability in these states is mainly influenced by the high poverty rate and literacy rate which will reduce the adoptability of the farmers to climate change. There are nine states (about 20%), namely, Manipur, Rajasthan, Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu, Mizoram, West Bengal, Gujarat have high levels of socio-economic vulnerabilities. Two states (about 8%) belong to the Medium vulnerability category these include Tripura, Jammu and Kashmir. There are no states in low vulnerability category. While five states (about 20%), namely, Haryana, Kerala, Punjab, Himachal Pradesh, Goa has very low socio-economic vulnerability. The states which are having very low and

Table 2. Regional variation bio-physical vulnerability.

Vulnerability	Class range (index value)	Name of the State	Number of State	Percentage (%) of State
Very low	<0.350	Madhya Pradesh.	1	4
Low	0.351-0.450	Andhra Pradesh, Tripura, Orissa, Himachal Pradesh, Assam.	5	20
Medium	0.451-0.550	Haryana, Maharashtra ,Jammu and Kashmir, Gujarat, Kerala, Karnataka, West Bengal, Arunachal Pradesh, Bihar, Goa, Uttar Pradesh.	11	44
High	0.551-0.650	Tamil Nadu, Meghalaya, Manipur, Rajasthan, Punjab.	5	20
Very high	>0.650	Nagaland, Sikkim, Mizoram.	3	12

Source: Authors own calculation from various sources.

Table 3. Regional variation socio-economic vulnerability.

Vulnerability	Class range (index value)	Name of the States	Number of States	Percentage (%) of States
Very Low	<0.350	Haryana, Kerala, Punjab, Himachal Pradesh, Goa.	5	20
Low	0.351-0.450	-	0	0
Medium	0.451-0.550	Tripura, Jammu and Kashmir.	2	8
High	0.551-0.650	Manipur, Rajasthan, Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu, Mizoram, West Bengal, Gujarat.	9	36
Very High	>0.650	Bihar, Madhya Pradesh, Arunachal Pradesh, Orissa, Meghalaya, Assam, Nagaland, Sikkim, Uttar Pradesh.	9	36

Source: Authors own calculation from various sources.

Table 4. Socio-Economic vulnerability index.

Source	Irrigation intensity	(%) of agricultural worker to total workers, 2001	Literacy rate, 2001	Poverty rate, 1999 to 2000	Socio-Economic vulnerability index	Modified index (1-original index)	Rank
Andhra Pradesh	0.39	0.18	0.31	0.72	0.401	0.599	16
Arunachal Pradesh	0.00	0.23	0.17	0.31	0.176	0.824	24
Assam	0.00	0.46	0.39	0.25	0.275	0.725	17
Bihar	0.33	0.05	0.00	0.10	0.123	0.877	18
Goa	0.63	1.00	0.80	0.98	0.853	0.147	12
Gujarat	0.28	0.24	0.52	0.76	0.447	0.553	9
Haryana	0.89	0.36	0.49	0.88	0.652	0.348	23

Table 4. Contd.

Himachal Pradesh	0.90	0.20	0.68	0.90	0.672	0.328	11
Jammu and Kashmir	0.52	0.40	0.16	1.00	0.520	0.480	14
Karnataka	0.29	0.21	0.45	0.62	0.391	0.609	13
Kerala	0.14	0.99	1.00	0.80	0.731	0.269	25
Madhya Pradesh	0.05	0.00	0.38	0.22	0.163	0.837	10
Maharashtra	0.18	0.10	0.69	0.51	0.369	0.631	6
Manipur	0.17	0.35	0.49	0.43	0.361	0.639	5
Meghalaya	0.17	0.19	0.36	0.30	0.257	0.743	3
Mizoram	0.13	0.07	0.94	0.63	0.443	0.557	1
Nagaland	0.18	0.14	0.45	0.33	0.277	0.723	22
Orissa	0.15	0.23	0.37	0.00	0.187	0.813	8
Punjab	1.00	0.56	0.52	0.94	0.753	0.247	7
Rajasthan	0.28	0.14	0.31	0.73	0.365	0.635	2
Sikkim	0.00	0.41	0.51	0.24	0.290	0.710	4
Tamil Nadu	0.23	0.27	0.60	0.60	0.424	0.576	21
Tripura	0.82	0.45	0.60	0.29	0.541	0.459	19
Uttar Pradesh	0.45	0.14	0.23	0.37	0.295	0.705	15
West Bengal	0.34	0.47	0.50	0.46	0.444	0.556	16

Source: Authors own calculation from various sources.

low vulnerability are very able to translate the economic prosperity with social development through increase in literacy rate, diversion of economy and reduction of poverty rate. The location of the states having very high socio-economic vulnerability is showing a characteristic location pattern, most of them belong to the Central and Northern part together they are forming a contiguous belt (Figure 2).

Overall regional variation (Figure 3) in vulnerability of agricultural system to climate change has been computed simply by averaging the bio-physical vulnerability index value and the socio-economic vulnerability index value (Tables 2 and 3). It is found that there are four states like Bihar, Nagaland, Sikkim, and Meghalaya have very high levels of overall vulnerability out of these four in Nagaland, Sikkim, and Meghalaya bio-physical factors are mainly responsible for the very high vulnerability while in Bihar it is mainly contributed by the social factors. There are ten states (about 40%), namely, Arunachal Pradesh, Orissa, Manipur, Mizoram, Rajasthan, Tamil Nadu, Uttar Pradesh, Maharashtra, Assam, Madhya Pradesh have high levels of Overall vulnerabilities. Five states (about 20%) belong to the medium vulnerability category these include Karnataka, Gujarat, Andhra Pradesh, West Bengal, Jammu and Kashmir. There are five states (about 20%), Haryana, Punjab, Tripura, Kerala, Himachal Pradesh in low vulnerability category. While one states (about 4%), namely, Goa have very low vulnerability. The vulnerability profiles in India clearly indicates that most of the states which are having very high or high levels of vulnerability are clustered around central and the North-Central part here the states are performing very bad in the human resource development and hence, are very much vulnerable to be effect by the changing climate scenarios (Table 6 and Figure 3).

The aforementioned discussions can be summarized in the following manner. Firstly, the bio-physical vulnerability and the social vulnerability are not truly overlapped some regions are bio-physically not much vulnerable but are lack of social development which makes them very low adoptability to climate change. Secondly, most of the states which are having very high or high vulnerability are clustered around Central and North-Central India. Thirdly, most of the states belong to North and West part of India are Bio-Physically vulnerable but are socio-economically developed

Table 5. Regional variation in the vulnerability of the agricultural system.

States name	Socio-Economic vulnerability index	Bio-Physical vulnerability index	Overall vulnerability index	Rank in overall vulnerability index
Andhra Pradesh	0.599	0.443	0.521	17
Arunachal Pradesh	0.824	0.47	0.647	5
Assam	0.725	0.413	0.569	12
Bihar	0.877	0.47	0.674	3
Goa	0.147	0.466	0.307	25
Gujarat	0.553	0.492	0.522	16
Haryana	0.348	0.516	0.432	21
Himachal Pradesh	0.328	0.422	0.375	24
Jammu and Kashmir	0.48	0.492	0.486	19
Karnataka	0.609	0.482	0.545	15
Kerala	0.269	0.485	0.377	23
Madhya Pradesh	0.837	0.294	0.565	14
Maharashtra	0.631	0.507	0.569	13
Manipur	0.639	0.586	0.613	7
Meghalaya	0.743	0.587	0.665	4
Mizoram	0.557	0.66	0.608	8
Nagaland	0.723	0.935	0.829	1
Orissa	0.813	0.434	0.623	6
Punjab	0.247	0.577	0.412	22
Rajasthan	0.635	0.581	0.608	9
Sikkim	0.71	0.701	0.705	2
Tamil Nadu	0.576	0.606	0.591	10
Tripura	0.459	0.435	0.447	20
Uttar Pradesh	0.705	0.455	0.58	11
West Bengal	0.556	0.48	0.518	18

Source: Authors own calculation.

Table 6. Regional variation overall vulnerability.

Vulnerability	Class range (index value)	Name of the State	Number of State	Percentage (%) of State
Very low	<0.350	Goa.	1	4
Low	0.351-0.450	Haryana, Punjab, Tripura, Kerala, Himachal Pradesh.	5	20
Medium	0.451-0.550	Karnataka, Gujarat, Andhra Pradesh, West Bengal, Jammu and Kashmir.	5	20
High	0.551-0.650	Arunachal Pradesh, Orissa, Manipur, Mizoram, Rajasthan, Tamil Nadu, Uttar Pradesh, Maharashtra, Assam, Madhya Pradesh.	10	40
Very high	>0.650	Bihar, Nagaland, Sikkim, Meghalaya.	4	16

Source: Authors own calculation from various sources.

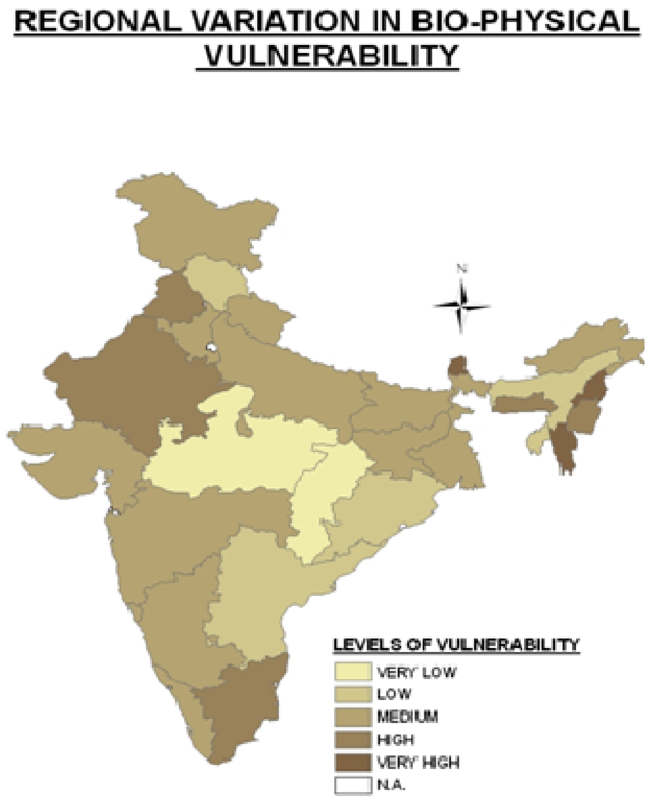

Figure 1. Regional variation bi-physical vulnerability.

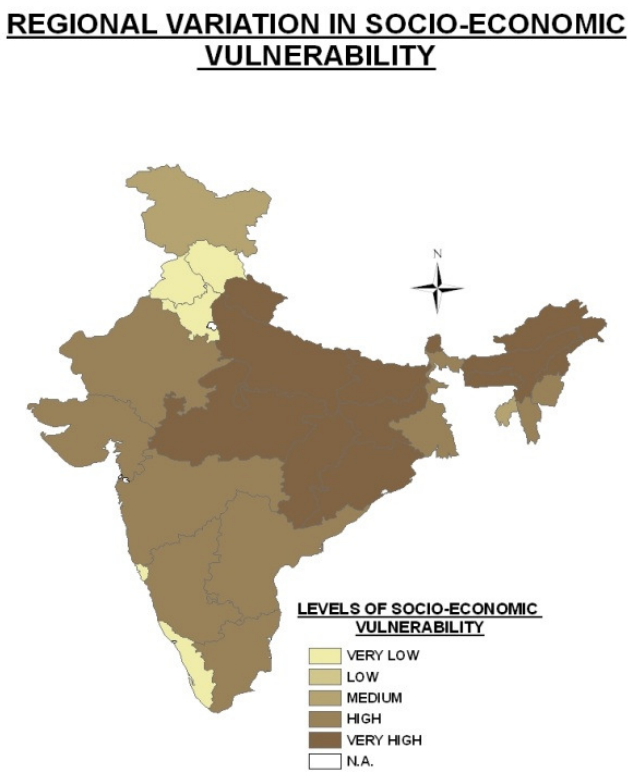

Figure 2. Regional variation socio-economic vulnerability.

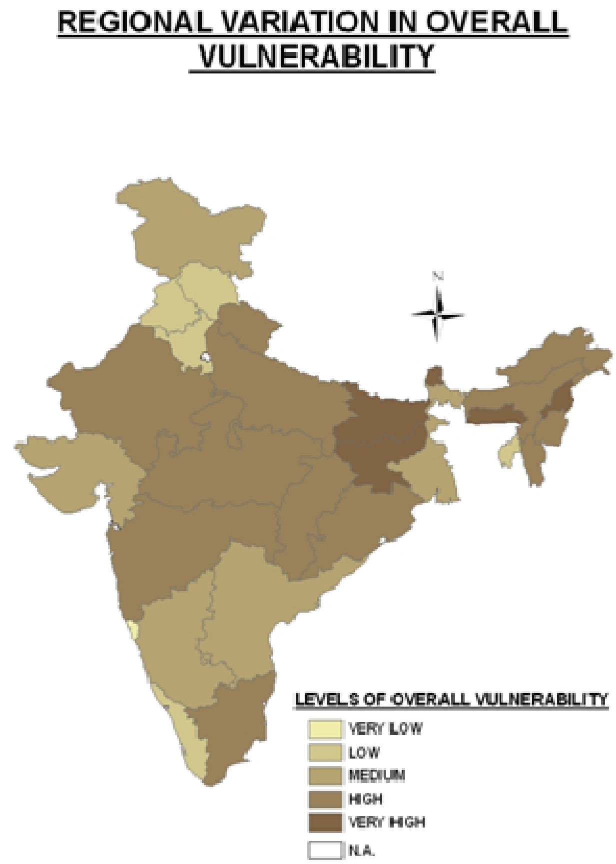

Figure 3. Regional variation overall vulnerability.

and are capable of high adaptation. Fourthly, most of the states of central India and North Central India are socio-economically vulnerable.

DISCUSSIONS

The likely climate change scenarios have very strong adverse impact on the agricultural system. Like the regional variation in agricultural development there is vast regional disparity exists in the levels of adoptive capacity of the Indian states so far as the vulnerability of the agricultural system is concerned. Numerous physical and socio-economic factors come into play in enhancing or constraining the current capacity of farmers to cope with adverse changes. Prominent among the physical factors are cropping patterns, crop diversification, and shifts to drought /salt resistant varieties. The most important socioeconomic factors include ownership of assets (like land, cattle, pump-sets, and agricultural implements), access to services (like banking, health, and education), and infrastructural support (like irrigation, markets, and transport /communication networks). Policies that are designed to fortify current coping capacity also have the power to strengthen long-term adaptive capacity. Some of the adoptive measures which could be beneficial regardless of how or whether climate changes – include, identification of the present vulnerabilities of agricultural systems, agricultural research to develop new crop varieties, improved training and general education of populations dependent on agriculture, food programs and other social security programs to provide insurance against supply changes.

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