Trans.Inst.Indian Geographers
ISSN 0970-9851

Measuring Vulnerability of Agricultural Sector towards Climate Change in Gujarat

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Abstract

Climate change and variability pose a serious threat to agriculture sector as the sector is highly volatile towards any change in climatic parameters. In this way, agriculture sector is highly vulnerable to the implications of climate change. Gujarat agriculture has achieved significant growth in recent years. Nonetheless, the sector reports year to year fluctuation in agricultural production and particularly in the production of food grains. This indicates that the sector has an inherent vulnerability which does not allow it to with stand with climatic shocks and threats. The potential risk due to climate change and variability does not depend only on climatic parameters but also varies as per the inherent vulnerability of the sector itself. It is, therefore, important to measure the vulnerability of the sector for any serious contemplation of adaptation planning. This paper makes an effort to identify the indicators of vulnerability for agriculture sector towards climatic variability and change in Gujarat. It further assesses the determinants of vulnerability of the sector towards climate change. It also explored the regional model of vulnerability by quantifying indicators to derive vulnerability index. Such an exercise is carried out at district level units and therefore very useful for agricultural adaptation at district level planning. It finally helps policy makers by deriving ranks and helping in prioritizing their interventions in agricultural development planning.

Key Words : *Agriculture, climate change, variability index, IPCC*

Introduction

Climate Change in its simple meaning isa significant and lasting change in statisticaldistribution of weather patterns over a longer period of time.The science of climate change analysis in India observedan increasein annualmean temperature by 0.51degreecentigrade from 1901 to 2007. Moreover, the rate of increase was observed to be higher in the last three decades (1971-2007). Some of the more prominent observations on climatic phenomena included (INCCA, 2010); higher warming trend in post monsoon and winter. (0.80°C per 100 year), high rate of increase in mean temp for the period 1971-2007, significant increase in minimum temperature (0.17 ° C per decade) and extreme temperature events such as increase in number of hot days and decrease in number of cold days more significantly in the coastal region. In short, it is very clear from the scientific observations that climate change is happening in India with a persistent rate.

Climate Change and agriculture have two ways relationship of cause and impact.Agriculture is one of theemitters for greenhouse gases. The agriculture practices are the main activities which contribute a major portion of methane and

NO2 emissionsin atmosphere. At the same time climate change would have significant impact on the sector. IPCC observed that climate change implications such as increase in carbon dioxide, temperature, altered precipitation and increase in extreme events would have collective impact on growth of vegetation. (IPCC, 2007). Although there is high uncertainty prevailing in predictions, there is a general consensus that climate change and variability will have significant impact on food security through the impact on plant's growth and yield. It is argued by many scientists that even if increase in carbon dioxide is likely to be beneficial to several crops, associated increase in temperatures, and increased variability of rainfall would considerably impact food production in adverse manner. Recent IPCC report and a few other global studies indicate a probability of 10 to 40% loss in crop production in India with increases in temperature by 2080 or 2100. (INCCA, 2010)Indian Network on Climate Change Assessment(INCCA) is a network working on climate change issues and negotiations at an international platform. INCCA also endorses the IPCC observation and quotes that "unless we adapt, there is a probability of 10-40% losses in crop production in India by 2080-2100 due to global warming". It further states that droughts, floods, tropical cyclones, heavy precipitation events, hot extremes and heat waves are known to negatively impact on agricultural production and farmers' livelihood. (INCCA, 2010 p.67) In short, it is now fact that Agricultural sector is prone to climatic variability and climate change.

Climate change impact on Indian agricultural sector has been studied in different ways. A group of researchers studies this phenomenon in terms of impact of increase in temperature and climatic variability on crop yield and production. Such studies are mainly carried out by agricultural scientists. Such studies conduct experiments in controlled environment or laboratory based experiments. Such studies are specific to crop and climatic condition. Economists go beyond this model and assess the impact of climate change on income of farmers by agro-economic models. Such studies apply simulation models of laboratory based experiments to multi-location/multi-season field experiments. Third group of researchers, who follow the IPCC methodology, assess the vulnerability of the agricultural sector towards climate change. Such studies use statistical methods and/or Geographical Information System. This study follows the IPCC methodology with the modifications suitable to regional situation of Gujarat. This paper aims to assess the vulnerability profile of Agriculture sector in Gujarat. It further develops vulnerability Index through quantitative approach. It adopts the methodology of IPCC for assessing vulnerability profile.

Methodology

The risk due to the climate change and variability is not only a function of climatic variability and change but also equally a function of vulnerability of the elements, which are exposed to climate change threat. Vulnerability by its simple definition refers to the susceptibility of a person, group, sector, society, region or system to any external risk. In this context external risk is defined in terms of climatic variability. In fact, it is not possible to define vulnerability

precisely. The concept of vulnerability provides flexibility to accommodate a number of phenomena under it. Therefore, the term vulnerability is relative and explanation of the term depends upon various factors. It is now well accepted that vulnerability is an extent to which an external threat (in this case climate change) may damage or harm a system. It depends on system's sensitivity and ability to adapt to new conditions. Therefore, it is required to measure prevailing vulnerability in the sector along with assessing potential risk due to climate change and variability threats.

IPCC defines 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 (IPCC 2007) IPCC conceptualizes vulnerability as a function of three major components namely; exposure, sensitivity and adaptive capacity. Exposure is mainly characterized by climatic phenomena. Sensitivity is the inherent characteristic of the system which symbolizes dose-response relationship connecting exposure and impact. While adaptive capacity is a property of the system to adjust with current variability or future change i.e. current coping mechanism. This study is limited to the assessment of vulnerability of agriculture sector for the current scenario. Vulnerability analysis in this study is carried out by identifying most prominent and representative indicators of each of the three components of vulnerability. Subsequently, the indicators are clubbed together to derive an index of overall vulnerability of the sector. Separate methodology is applied to each of the component for combining and deriving various indices.

Indicators need to be robust, evident, self-expressive, replicable, comparable and easy to understand. The selection of indicators is a technical challenge. Based on UNDP's approach and other literature, the indicators are selected. For instance, Human Development Index is an important indicator of vulnerability which explains the status of human condition in a given region. This exercise is limited to the indicators which could be derived based on availability of information at district level in state of Gujarat. Some of the indicators are inversely related to vulnerability. For instance, indicators selected under the category of adaptive capacity are inversely related to vulnerability and can enhance the resilience of the sector and community towards the intensive effects of climatic changes.In order to derive various indices in this study, various indicators have been identified under the three components; namely exposure, sensitivity and adaptive capacity. The study has collected district wise data of all the significant and relevant parameters. Such data on elements at risk are collected from various concerned state level departments or from published sources.

Exposure indicators: Exposure variables are those which expose the sector towards current and future climatic variability. Highly exposed indicators make the agriculture of that region more vulnerable towards climate change. The study has considered two major indicators under this category. These are;

1. Relative variability of Rainfall: Relative variability is calculated for rainfall for a longer period of time (about thirty years). As the variability increases the sector become more vulnerable. This

is calculated by collecting district wise data of mean annual rainfall from 1081 to 2011)

2. Inter-annual variability of rainfall in terms of percentage: This is calculated by deriving percentage of variation in rainfall for successive years. High inter-annual variability can increase the vulnerability of the sector.

Both the above variables were normalized by using following equation

$$\frac{X - MIN}{MIX - MIN}$$

The data were then replaced by calculated normalized data.

Exposure Index is derived by taking Geometric mean of Relative Variability and Inter-annual variability percentage. The intention of using geometric mean is mainly due to the reason that the range of data sets for both the parameters vary largely over space. Therefore, the use of geometric mean is appropriate for this analysis.

Sensitivity Indicators: The second set of indicators is sensitivity indicators which make the sector more or less sensitive towards climate change. The agriculture activities are based on the status of both physical resources and human intervention. Therefore, there are two major factors contributing to the sensitivity of the sector towards climate change. They are physical and human aspects. Physical aspects include the availability and quality of land and water resources. While human aspects include the characteristics of human resources who are dependent on agriculture. The following indicators were selected under sensitivity analysis. The selection of indicators was based on expert consultation and availability of data.

Physical sensitivity Indicators

- Cropping Intensity
- Percentage of degraded land
- Percentage of villages having excess Fluoride
- Percentage of villages having excess Nitrate
- Percentage of villages having excess Salinity
- Percentage of area under small and marginal farmers
- Percentage of non-irrigated area
- Level of ground water Development

Human Sensitivity Indicators

- Dependency ratio
- Poverty rates
- Percentage of small and marginal farmers
- Percentage of agricultural labour
- Adult literacy rate

Similarly, indicators of adaptive capacity were derived from expert consultation and literature review. Indicators selected under the category of adaptive capacity are as following

- Agricultural Credit (Rs. per capita)
- Road density (per sq. km)
- Percentage villages not having electricity
- Percentage villages not connected with pucca roads
- Percentage villages having no high school
- Percentage villages sub-centres do not have buildings
- Inter district variation in relative index of development
- Per capita bank deposit

- Fertilizer used per hectare
- Machineries used hectare

In order to derive sensitivity and adaptive capacity indices, factor Analysis was used. The major intention to use factor analysis was to minimize the number of variables and to provide weightage to the derived factors for Sensitivity and Adaptive Capacity. For each significant factor, the weightage was given as per the Eigen value. Thus the sensitivity index and adaptive capacity index were derived separately.

IPCC provides the following formula for deriving vulnerability index for any sector.

$$VI = \frac{\text{Exposure} * \text{Sensitivity}}{\text{Adaptive Capacity}}$$

In this manner, Vulnerability Index for agriculture sector was calculated for each and every district. Later on, districts were ranked From Higher to lower Order according to index value. Subsequently, districts were classified in fourdifferent groups with the help of Mean and Standard Deviation. Districts having vulnerability index values higher than mean plus SD were considered as highly vulnerable. District, which, showed vulnerability index value higher than mean but less than mean plus standard deviation were clubbed together and given a name as moderately vulnerable. Districts with vulnerability index value less than mean but more than mean minus SD are considered as less vulnerable districts. Districts having vulnerability index value less than mean minus SD are believed to be non vulnerable districts.

The vulnerability assessment in this paper is limited to the baseline scenario or current scenario for the year of 2001. Based on this similar exercise can be derived for a decadal variation i.e. for 1991, 2001 and 2011. Such analysis will be helpful to simulate the projected scenario. However, projected scenario is not a scope of this paper. Therefore, paper has considered only one decade data. The analysis has some limitation due to selection of proxy indicators. Further, unavailability of data is also a major constraint for this study. However, this paper provides very useful analysis to assess the current status of vulnerability towards climate change.

Result and Discussion

Gujarat state has achieved persistent and significantly high rate of agricultural growth in the last decade. However, the growth is characterized by some inherent salient features. The state agriculture has reported high fluctuation in food grain production mainly due to its rain fed nature. This is how the state agricultural sector is characterized by its nature of scarcity of water. Rainfall in the state remains inadequate and unevenly distributed. About 27% of Gujarat geographical area is drought prone (Mehta N., 2011). Spatial distribution of relative rainfall variability shows that Kutch district has reported the highest relative variability of rainfall followed by Jamnagar district. However, interannual variability is recorded highest in Jamngar district which make this district more vulnerable towards any external risk. Districts lying in northern region of the state also experiences high variability of rainfall. The districts of south Gujarat and coastal region experiences less variability. Kutch and Junagadh also recorded high inter annual variability affecting rain fed crop production adversely.

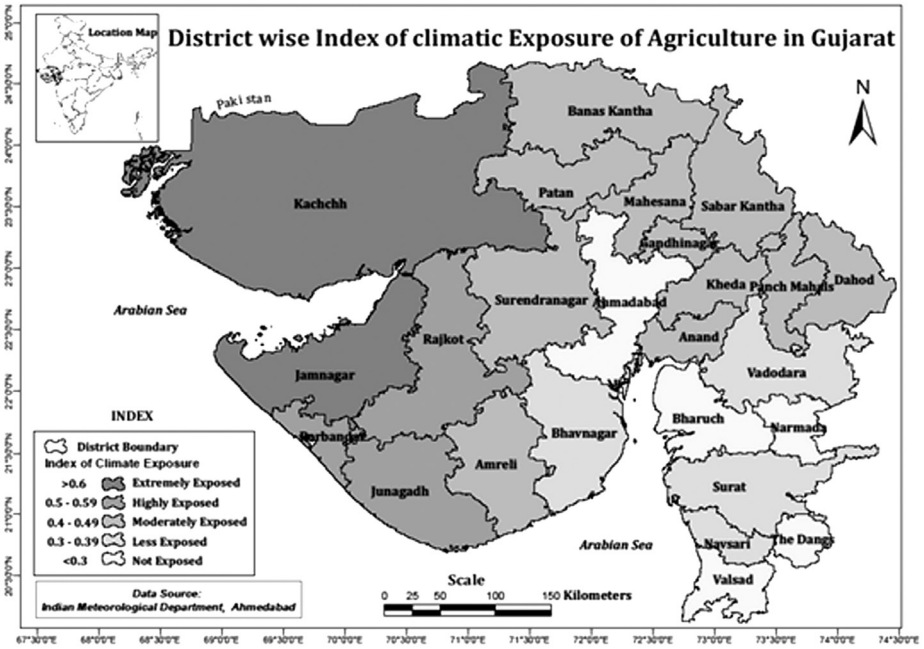

Fig. 1: Climatic Exposure across the district of Gujarat

As far as agricultural sensitivity is concerned, the Middle Eastern districts are the most sensitive areas. Most of these districts possess a high proportion of tribal population. Lack of irrigation, technology and credit facilities along with high incidence of poverty make these districts sensitive towards any external risk. Bhavanagar having high salinity also shows high sensitivity towards climate exposure.

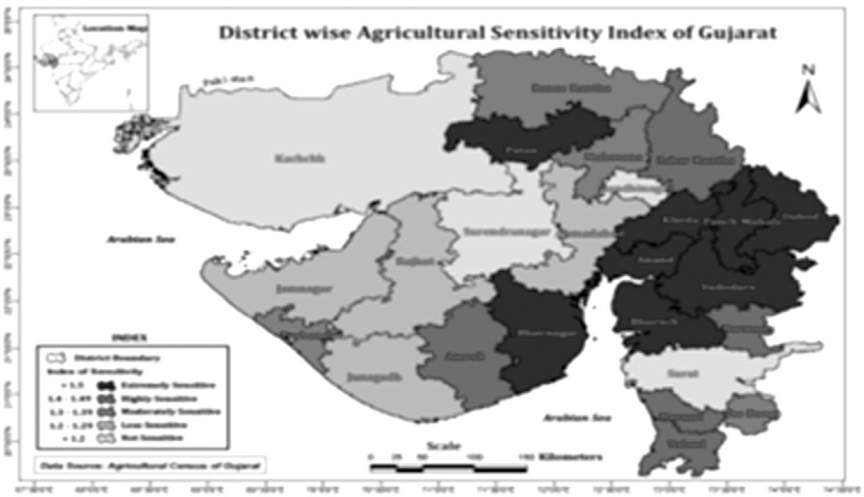

Fig.2: District wise Agricultural Sensitivity Index of Gujarat.

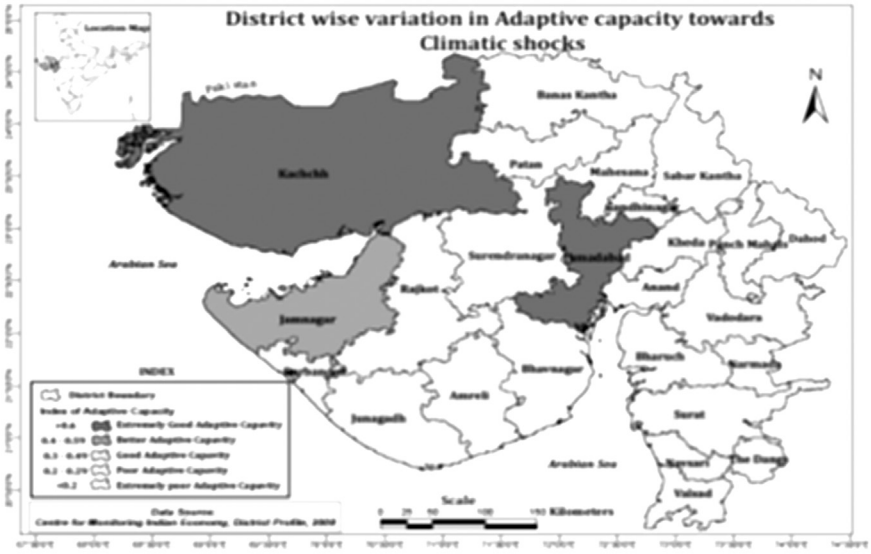

Fig. 3: District wise variation in Adaptive Capacity towards Climatic shocks.

It is interesting to note here that adaptive capacity is high in Ahmedabad and Kutch districts. It is obvious for Ahmedabad is a commercial city and therefore developed in terms of adaptive capacity. Similarly, Kutch being drought prone district for the years has developed adaptive capacity gradually over a period of time.

Table 1: Indices of the Components of Agricultural Vulnerability in Gujarat

Districts	Climate Exposure	Adaptive Capacity	Sensitivity Index	Vulnerability Index	Physical Sensitivity	Human Sensitivity	Social Sensitivity
Ahmedabad	0.2788	0.6649	1.2026	0.5042	0.3108	0.5752	0.3166
Gandhinagar	0.4033	0.3870	1.1362	1.1840	0.3594	0.6204	0.1564
Rajkot	0.5509	0.3625	1.2053	1.8317	0.2640	0.5379	0.4034
Navsari	0.3191	0.3086	1.4001	1.4474	0.3765	0.6187	0.4049
Surat	0.3191	0.3024	1.0995	1.1600	0.2120	0.6055	0.2821
Bharuch	0.2587	0.3118	1.5452	1.2822	0.3023	0.7283	0.5146
Valsad	0.0274	0.3553	1.4485	0.1117	0.3599	0.5637	0.5250
Porbandar	0.5307	0.3387	1.3233	2.0736	0.3073	0.5129	0.5032
Junagadh	0.5307	0.3426	1.2478	1.9331	0.3146	0.4978	0.4355
Jamnagar	0.9426	0.5726	1.2700	2.0904	0.2819	0.3348	0.6533
Vadodara	0.3697	0.3902	1.5767	1.4936	0.3123	0.6008	0.6637
Kheda	0.4060	0.3030	1.6879	2.2615	0.4392	0.6009	0.6478

Anand	0.4060	0.2969	1.7306	2.3666	0.5830	0.6956	0.4519
Mehsana	0.4649	0.2569	1.3240	2.3962	0.5429	0.5832	0.1979
Amreli	0.4843	0.2660	1.4150	2.5767	0.3823	0.4559	0.5768
Bhavnagar	0.3151	0.2640	1.6107	1.9222	0.5115	0.5006	0.5986
Sabarkantha	0.4449	0.1755	1.4802	3.7530	0.4020	0.5464	0.5319
Kachchh	0.8897	0.6413	1.1465	1.5907	0.2438	0.4500	0.4527
Narmada	0.2587	0.2074	1.4658	1.8280	0.3026	0.5862	0.5769
Patan	0.4649	0.2369	1.5893	3.1182	0.4947	0.4480	0.6465
Surendranagar	0.4501	0.2504	0.9757	1.7537	0.2441	0.4286	0.3030
Panchmahals	0.4033	0.2520	1.6065	2.5713	0.3699	0.5053	0.7314
Banaskantha	0.4957	0.2219	1.3068	2.9193	0.4094	0.2472	0.6501
Dangs	0.1876	0.3169	1.3546	0.8020	0.1571	0.4171	0.7805
Dohad	0.4033	0.1354	1.5479	4.6123	0.3725	0.4161	0.7593
Mean	0.42	0.33	1.39	1.98	0.35	0.52	0.51
SD	0.19	0.13	0.20	0.98	0.10	0.11	0.17

The table 1 shows the vulnerability index for all the districts of Gujarat. Looking into various indices, it shows that the average score and standard deviation for the sensitivity index are higher compared to those of climatic exposure and adaptive capacity. This means that the sensitivity of the sector is the major determinants of vulnerability of an agricultural sector towards external shocks. Sensitivity Index is derived from the existing sensitivity of physical as well as human resources of the sector.The average score for human sensitivity (0.52) is higher than that of physical sensitivity (0.35). It is very clear from the analysis that lower human development can increase the vulnerability of agricultural sectortowards any external shocks.

Districts showing higher vulnerability include Sabarkantha, Banaskantha, Patan and Dahod. All these districts have also reported higher degree of human sensitivity of the sector. These districts have also achieved lower human development. Geographically these districts are located in North-Eastern part of Gujarat. In fact, tribal population of Gujarat is mainly concentrated in these districts. Tribal regions are backward in terms of education achievement, access to technology and market. It is worth noting here that Bordered districts of Gujarat show higher vulnerability although they are less exposed to climatic variability. Thus, in spite of having less climatic variability, these districts are more vulnerable towards external shocks in general and climatic shocks in particular. It seems that the Government of Gujarat has made many efforts to provide better infrastructure, market and modern technology in tribal areas. However, with the inherent human capability of less education and poor health, tribal are not able to capture the opportunities provided to them. This indicates that there is need to strengthen the basic human capabilities in these backward areas. This would make them resilient towards future climatic risk.

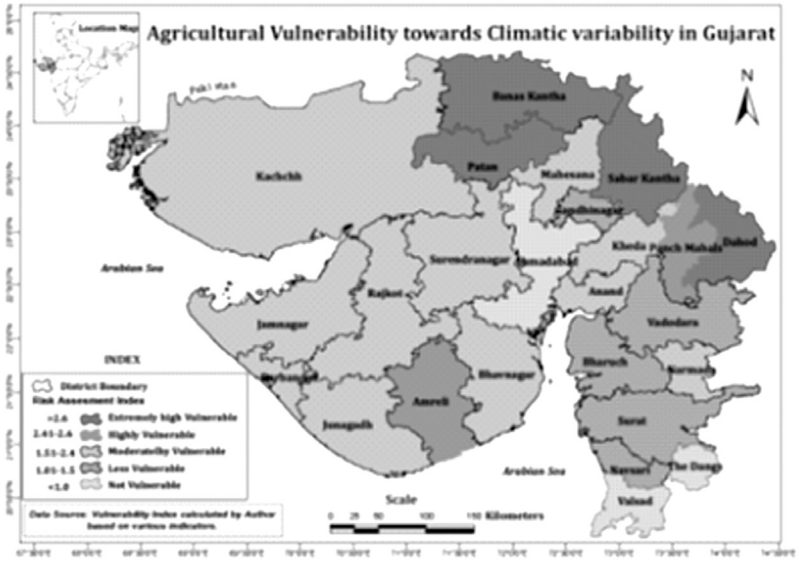

Fig. 4: Agricultural Vulnerability towards Climatic Variability in Gujarat

The above analysis clearly indicates that the pattern of agricultural vulnerability can be explained by various components of vulnerability. Therefore, in order to reduce the agricultural vulnerability of the region, it is important to address thesecomponents of vulnerability. Addressing these components can essentially reduce disaster risks by reducing vulnerability. The Agricultural vulnerability index derived from these components represents the relative position of districts within the state. Agricultural vulnerability index, in this context, provides the rankingof districts for the intervention of development planning. It clearly shows that if the state has to reduce the vulnerability, it will have to address the inherent sensitivity of the agricultural sector. This can be addressed by strengthening the capability of small and marginal farmers by providing them better accessibility to education and health. The training and skill building are also important so that they can access the available technology, market and infrastructure for improving the sustainability of farm production. Backward districts require a priority attention to reduce the vulnerability of the agricultural sector towards potential risk of climate change.

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