Working Paper

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Drivers of Vulnerability towards Climate Variability in Gujarat

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List of Abbreviations

CRED	Centre for Research on the Epidemiology of Disasters
DDP	District development Programme
DPAP	Drought Prone Area Development Programme
GDI	Gender Development Index
GEI	Gender Empowerment Index
GOI	Government of India
GSDMA	Gujarat State Disaster management Authority
HDI	Human Development Index
IMD	Indian Meteorological Department
IMR	Infant Mortality Rates
IPCC	Intergovernmental Panel on Climate Change
ML	Medium and Large
MNREGA	Mahatma Gandhi National Rural Employment Guarantee Act
OFDA	Office of U.S. Foreign Disaster Assistance
SC/ST	Scheduled Castes and Scheduled Tribes
SPSS	Statistical Package for Social Science
SS	Small Scale
TFR	Total Fertility Rate
UNDP	United Nations Development Programme
UN/ISRD	United Nations International Strategy for Disaster Reduction

Drivers of Vulnerability towards Climate Variability in Gujarat

Shital Hardik Shukla*

Abstract:

One of the implications of climate change is its extreme variability. Such variability is often reflected in climate-induced disasters. The potential risk due to such climate-induced disasters also depends upon the existing pattern of vulnerability in the state. In this context, measuring vulnerability due to the climate-induced disasters is the first necessary step for any serious contemplation of climate change adaptation strategies. Identifying the determinants of vulnerability is an emerging technique which can systematically assess and analyze vulnerability and risk due to future possible climatic hazards. This paper makes an attempt to identify the determinants of existing vulnerability pattern in the state by using factor analysis. It then explores the regional model for assessing the pattern of vulnerability through identification of drivers of vulnerability. The paper intends to help policy makers by deriving ranks for prioritizing their interventions in development planning.

Key Words: Climatic Variability, Vulnerability Assessment, Adaptation Strategies, Disaster Risk Reduction, Development Planning

JEL Classification: Q54, I31, Q56, D8, H84

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1. Introduction:

One of the implications of climate change is its extreme variability. Such variability is often reflected in climate-induced disasters. The potential risk due to such climate-induced disasters also depends upon the existing pattern of vulnerability in the state. In this context, measuring vulnerability due to climate-induced disasters is the first necessary step for any serious contemplation of climate change adaptation strategies. Identifying vulnerability determinants is an emerging technique which can systematically assess and analyze vulnerability and risk due to future possible climatic hazards. It can reveal many adverse effects which are led by climatic variability on society. Therefore, it helps state as well as society for preparing and adopting adequate and successful measures for reducing the risk factors. In other words, quantifying vulnerability can show direction for preventing losses and adaptation towards climate change. Therefore, measuring vulnerability can help decision makers in prioritizing their intervention for climate change adaptation strategies under development policies. This can facilitate mainstreaming climate change adaptation into development goals. This paper makes an attempt to identify the vulnerability indicators at state level. It further goes beyond identifying the indicators of vulnerability and also endeavors to quantify those indicators at district level. It then explores a regional model for assessing the pattern of vulnerability within the state and identifying the determinants of vulnerability existing in the state. Such an exercise is useful for identifying the most vulnerable district in the state for regional planning. Although indicators are not comprehensive like the concept, yet they tend to help policy makers by deriving relative numbers and helping in prioritizing the planning process in a relative ranking.

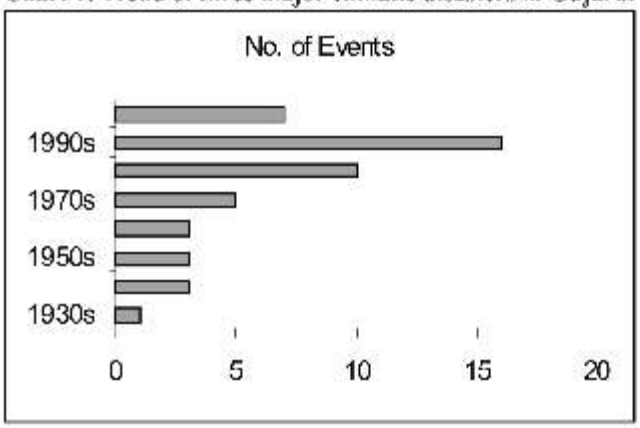
The paper is divided into six parts. The first section introduces the subject and explains its importance. The second section provides the trend of climatic variability in Gujarat. It also establishes relationship between climatic variability and climate induced disasters. The third section provides methodological approach to measure risk and vulnerability indicators for the state of Gujarat. The fourth section assesses the risk due to climatic vulnerability and explores a regional model of vulnerability for the state. The fifth section calculates risk due to three selected disasters separately.

2. Trends of Climatic Variability and their Management in Gujarat:

Climatic variability is often manifested in climate induced disasters. Global level trend on climate induced disasters shows a drastic increase in frequency and intensity (IPCC, 2007). This has subsequently increased the risk due to climate induced disasters. It is well established that the risk assessment reduces risk more effectively and helps achieving development goals at regional level. Risk assessment requires a systematic measurement of risk over particular geographical location. As risk is a function of climatic hazard and vulnerability, both the factors need to be measured separately and then interlink them for planning purpose. Climatic variability in this paper is measured in terms of annual variability in weather for a longer period of time. Rainfall, being an important climatic characteristic, is used here as an indicator of climate. If the variability in annual rainfall reaches an extremity point, it is experienced in terms of climatic disaster. In other words, the climatic disasters are characterized by extreme variability in rainfall for a longer period of time. Therefore, the climatic extremity is observed as annual variability in rain fall, which is an important climatic characteristic. The study has assessed the risk due to climate induced disaster by estimating a

probability and intensity of disasters derived from the past trend. The study has considered three major climatic variability induced disasters namely; flood, drought and cyclone. The past trend of these hazards has been prepared by collecting information from EM-DAT series from OFDA/CRED International Disaster Database. This has been updated and improved by crosschecking the information collected form the relief department of government of Gujarat. Data on climatic hazards have been obtained for the last 80 years. Such a large data set can provide very useful information on past trend of climatic hazards in the state. An annual probability has been calculated from this time series data for three selected climate induced disasters. The information collected on climatic hazards incorporated the immediate impact in terms of death toll, people affected and economic damage.

Chart 1: Trend of three major climatic disasters in Gujarat



Source: EM-DAT: The OFDA/CRED International Disaster Database

The observation made by Centre for Research on the Epidemiology of Disasters (CRED) under international disaster database very clearly indicates that climatic disaster in Gujarat state has increased more than three times during the last two decades. It indicates that the frequency of climatic disasters has increased sharply

over a period of time. This implies that there will be an increase in risk due to potential climatic disasters in the state.

2.1 Classification of Climate Induced Disasters:

Although, all the three disasters selected in this study are influenced by a common factor which is climatic variability, they can further be distinguished by the nature of an event. Hazards those who strike suddenly and cannot be predicted well in advance convert into rapid-onset disasters. In this study cyclone and flood can be categorized as occurrence of rapid onset climate induced disasters. It is impossible to forecast such events well in advance. Forecasting time varies between few hours to few days. On the other hand slow onset disasters can be predicted well in advance.

In fact, they are the implications of continuous occurrence of natural events resulting in disasters. Drought can be categorized under slow onset disasters. Planning commission defines drought prone area as per the pattern and quantum of rain/ precipitation. It declares drought when the rain during the main crop season of an area, makes traditional cultivation of main crops hazardous in three years or more out of every 10 years (GOI, 1981). It implies that the drought declaration is the process of long span scarcity of water in a region.

All the three selected disasters are different as far as short term impact is concerned. Deaths due to cyclone and flood are common and happen immediately, unlike drought. However, the consequent events of drought can lead to food insecurity for marginalized people. In addition to this, an extreme poverty and mal nutrition can sometimes lead to the death related consequences. In spite of having their distinct nature, the risk due to these disasters is still a function of intensity of hazardous occurrence and vulnerability of the region. Therefore, the process of vulnerability assessment remains

same for all the three selected disasters.

2.2 Institutional Setup for Managing Climate Induced Disasters at the State Level:

Disaster management practices in the state can follow both short term and long term strategies. The short term strategies include relief and reconstruction activities which are carried out just after the disaster strikes. The commissionaire of relief in Government of Gujarat is the nodal agency to provide relief for all types of disasters. Long term strategies to mitigate the adverse effects of disasters are mainly looked after by Gujarat State Disaster Management Authority (GSDMA). However, GSDMA mainly concentrate on rapid onset disasters. Long term measures for drought mitigation are carried out by rural development department. Some of the important mitigation strategies for drought include area development plans such as DDP, DPAP, Watershed planning, natural resource management and employment guaranty programmes such as MNREGA. The role of such centrally sponsored schemes in mitigating drought impact has remained significant. The implementation of such disaster risk reduction strategies for all these disasters heavily depends on area prone to disasters. Most of the disaster management plan prepared for particular disaster delineates the area prone to that disaster in the state. The process of implementing risk reduction strategies does not consider vulnerability issues while executing the risk reduction plan. The risk calculated for each of these three disasters in this paper incorporates vulnerability measurement.

3. Risk Assessment for Gujarat: A Methodological Approach

It is assumed here that risk due to climate induced disaster depends on probability and intensity of such extreme events. Annual probability can be estimated by calculating frequency of these three major climatic disasters. As far as intensity is

concerned, it can be estimated by assessing an impact of such disaster. Three different indicators of impact are derived for assessing intensity of the climatic disaster. These are coefficient of mortality, coefficient of social vulnerability and coefficient of economic vulnerability. Methodology for calculating these coefficients is adopted from UNDP's approach. Coefficient of mortality is derived by calculating total death toll divided by total population of the state. 2001 data has been selected as the base year. Coefficient of social vulnerability has been derived by dividing total affected people with total population of the base year. Coefficient of economic vulnerability is derived by dividing total damage with gross domestic product of the selected base year.

Further, risk also depends on the vulnerability of the region which is exposed to the selected climatic disasters. Therefore, vulnerability index is carried out separately. Vulnerability by its simple definition refers to the susceptibility of a person, group, society, region or system to any external risk. In this context external risk is defined in terms of climatic variability. Such variability is manifested by the climate extremes in terms of climatic disasters. Although there are number of attempts made to define vulnerability it lead to simple meaning explained in above definition. 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. United Nation's International Strategy for Disaster Reduction (UN/ISRD) defines the vulnerability as *"the condition determined by physical, social, economic and environmental factors, which increase the susceptibility of a community to the impact of hazards"* (UN/ISRD, 2004).

Vulnerability 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, an area under forest can protect the region and community from an intensive effect of climatic disasters.

In order to derive vulnerability index in this paper, various demographic, physical, economic, social and environmental indicators have been identified and clubbed together. The indicators selected under each category of factors are shown in table 1. About 42 indicators have been selected under four major groups which are responsible for existing vulnerability in the state of Gujarat.

Table 1: List of indicators derived for quantifying vulnerability:

No.	District	Mean	SD	CV
	Demographic Indicators			
1	Density2001	345	187	54.3
2	decadal GR 1991-2001	20.8	8.1	38.8
3	Growth Rate of Urban Population	21.6	29.9	138.3
4	Dependency ratio	1.0	0.2	17.5
5	Pace of urban Growth	47.5	74.4	156.5
	Economic Indicators			
6	Poverty	41.8	17.5	41.8
7	% of agri labour	25.7	6.8	26.4
8	Per capita ML Fixed Investment	14057	23769	169.1
9	Per capita SS Fixed Investment	1223	897	73.3
10	% of nonirrigated area	68.8	16.8	24.4
11	Per capita bank deposit,2000	7495	5922	79.0
12	Credit (Rs. per capita),2001-02	3837	4478	116.7
13	Small Scale Unit per 1000 population	3	2	64.6
14	ML Scale Unit per 100000 population	3	3	110.9
	Social Indicators			
15	Percentage of SC/ST population	6.7	3.2	47.7
16	Adult Literacy Rate	66.0	9.1	13.8
17	% of female illiteracy	80.5	5.1	6.3
18	Net Enrolment Ratio	66.7	12.8	19.1
19	Juvenile Sc Ratio	890.0	43.0	4.8
20	HDI	0.5	0.1	14.0
21	GDI	0.5	0.1	18.2
22	GEI	0.3	0.1	21.8
23	IMR	67.3	13.5	20.1
24	TFR	2.8	0.6	21.1
25	% Villages not having tap water	43.7	21.9	50.2
26	% Villages not having electricity	23.2	14.9	64.3
27	% Villages not having Sanitation facility	62.5	14.7	23.5
28	% villages not connected with pucca roads	8.3	4.4	53.3
29	% villages having no high school	95.2	3.6	3.7
30	% villages sub-centres do not have buildings	54.7	14.0	25.6
31	Road density (per sq. km)	0.54	0.16	30.3
32	% of households not having drinking water	77.3	10.7	13.9
33	% of households not having electricity	23.2	14.9	64.3
34	% of households not having toilets	62.5	14.7	23.5
35	% of households with Kachcha house	46.2	21.4	46.3
	Environmental Indicators			
36	% of deurnded land	13.0	8.3	63.9
37	% share forest area to geoe. Area 1997	12.2	16.8	137.5
38	Level of ground water Development% 1997	75.4	37.4	49.6
39	% of villages having excess Fluoride	14.3	13.5	94.9
40	% of villages having excess Nitrate	3.7	3.4	92.6
41	% of villages having excess Salinity	7.1	6.5	90.5
42	inter district variation in relative index of development	0.3	0.1	47.7

Sources: Census of India, 2001, District Statistical Outline, 2001
Note: SD- Standard Deviation, CV – Coefficient of Variation

Above table represents the selected indicators along with basic statistics. Data have been collected from published sources. It shows that the coefficient of variation is extremely high for the indicators such as level of urbanization and industrialization. This indicates that the regional disparity is very high in the state in case of urbanization and industrialization. Further, a forest cover is unevenly distributed in the state making regional variation very high. On the other hand, some of the variables have indicated low disparity within the state. Such variables are female literacy rates, juvenile sex ratio and villages having no high school. The status of all these three indicators is poor in the state. As far as environmental indicators are concerned, the disparity is quite high making some district more vulnerable. High disparity in many selected variables among the districts shows the significant regional variation in the status of vulnerability. This signifies the fact that it is worth assessing the vulnerability status within the state and incorporating such measurement into risk calculation.

As the number of indicators is large and overlapping, the principle component analysis was carried out to reduce the number of indicators and derive the determinants of vulnerability. SPSS (Statistical Package for Social Science) was used for carrying out principle component analysis method. The major aim to use this technique was to reduce the complexity of information and reduce the observed variables by clubbing them together in a hidden factor which represents the number of variables. The variables were scaled up in order to compare with each other. The formula used for scaling up remained X = X – (Mean-2SD)/SD for each data set.

Thereafter, vulnerability index has been calculated by giving weightage equivalent to Eigen value to each determinant of vulnerability. The model derived four major

regional determinants of vulnerability existing in the state. These are vulnerable people, vulnerable surrounding, exposure to climatic hazards and vulnerable resources. These are explained in detail in the following section.

4.Risk due to Climatic Disasters

4.1 Probability of Climatic Disasters:

The probabilities of various natural climatic disasters differ in the state. Following table presents the annual probability of three major climatic disasters faced by the state.

Table 2: Annual Probability of three selected climatic disasters in Gujarat

Type of Disasters	Frequency of three major disasters during the last 80 years	Annual Probability
Slow onset		
Drought	6	7.5
Rapid onset		
Flood	20	25
Cyclones	14	17.5

Source: EM-DAT: The OFDA/CRED International Disaster Database

It is interesting to note here that an annual probability of flood is the highest among all the three selected climatic disasters. This is followed by cyclone and drought with probabilities of 17.5% and 7.5% respectively. Drought is also very frequent phenomena in the state with arid and semiarid climate. However it is not considered as disasters when there is partial drought. In fact one of the estimates in Gujarat shows that the state faces drought in every three years. Having a quite high annual probability, the flood causes high financial burden on the state which ultimately has severe implications on the state economy.

4.2 Impact of Disasters on the State:

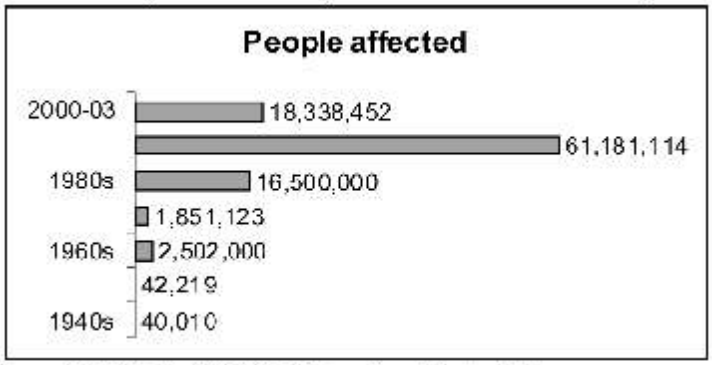
The immediate impact of climatic disasters is considered by death toll it created from its impact. Table 3 portrays death toll due to various climatic disasters over a period of time. It is clear from the table that climatic disasters have significant social adverse effects. Trends in causalities show that the trend for flood up to 1980s is increasing. The decade of 1990s shows a decline in death toll. This is in spite of the fact that this decade has experienced a number of floods. Basically, preparedness and mitigation actions have played major role in protecting life of local people from flood. The irrigation department of the state government devotes a substantial proportion of its budget for flood mitigation strategies. Such strategies mainly include structural measures. Further, death toll due to cyclone has increased over a period of time. The sudden onset of this disaster does not give chance to protect lives of coastal community. Although there is early warning system working very well, the local community does not follow the warning mainly because it is a question of survival of their livelihood. Death due to drought is uncommon. Unless and until, there is severe drought, death does not happen. It is important to note here that the state has experienced death due to drought mainly because of heat wave along with the drought or suicide due to debt burden in the period of drought. The state faced drought in the year of 2000 which was the worst-ever drought in the last 100 years. This drought was accompanied by a heat wave. For the first time, deaths were reported by various sources. The state government, although, did not reported the total death toll, it announced the first death on its website (http://gujaratonline.com/newsroom/drought). There were other sources which also reported death toll of drought 2000 in Gujarat. However, due to non reliability of other sources and easy comparison, the figures reported in the OFDA/CRED International Disaster Database were considered for analysis.

Table 3: Death toll due to various climatic disasters in Gujarat

Decade	Slow Onset	Rapid Onset	
	Drought/Heat Wave	Flood	Cyclone
1921 30	0	0	56
1941-50	0	45	0
1951-60	0	17	0
1961-70	0	100	0
1971-80	0	1348	172
1981-90	0	2139	1171
1991-1999	0	1948	3149
2000-03	20	233	5
Total	20	5830	4553

Source: "EM-DAT: The OFDA/CRED International Disaster Database

Chart 2 People affected by climatic disaster in Gujarat



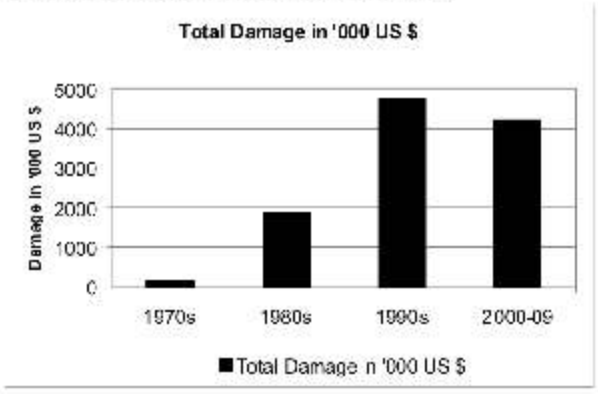
Source: "EM-DAT: The OFDA/CRED International Disaster Database

Although there in an inconsistency in data on people affected by various climatic disasters, an overall pattern is very clear showing that the reported number of people affected by various disasters has increased sharply over a period of time. Furthermore, the intensity of effect was observed highest in the decade of nineties in which the state faced severe negative social implications of a number of disasters.

**Drought's first victim (April 8)* SEBALIA (Sabarkantha): Starvation resulting out of severe drought claimed its first victim in the state at this village in Khedbrahma taluka with the death of Ditabhai (35) on Thursday morning.

With regards to adverse economic impact of climatic disasters, a dramatic increase observed since 1970 in a data set. The increase in decadal loss from 1970s to 1990s is very high. Economic losses during 1990s are 30 times higher than those during 1970s. Further, the economic loss during the years of 2001 and 2002 was around 4.2 million US $, which is almost 88% of economic loss due to the damage during 1990s. This indicates that the severity of damage is increasing over a period of time in the state. This confirms the fact that the trend of human suffering and economic losses is worsening in Gujarat.

Chart 3: Damage due to Climatic Disasters



Source: "EM-DAT: The OFDA/CRED International Disaster Database, www.em-dat.net - Université catholique de Louvain - Brussels - Belgium"

Comparing the impact of various climatic disasters, cyclones are the worst disasters which have made tremendous economic loss (4.3 million US$) in the state. This is in spite of the fact that many minor disasters (flood and cyclones) with less economic impact are not taken into consideration while estimating economic losses.

4.3 Intensity Indicators of Climatic Disasters:

Three indicators of impact are derived in order to measure the risk intensity of climatic disasters. It is assumed here that the higher impact of disaster is mainly due to greater intensity. Table 4 denotes the coefficients of vulnerability. Coefficient of mortality

is the highest for flood, which is followed by cyclone and drought. Paradoxical to this coefficient of social vulnerability is the highest for drought and the lowest for cyclone. This shows that the social impact of drought is prevalent in the state.

Table 4: Indicators of risk intensity due to disasters

Risk Intensity Indicators	Flood	Cyclone	Drought/Heat Wave
Average Death toll (M)	13463	5069	685
Coefficient of mortality (CM)	26.6	10	1.4
Number of people affected (SV)	256118523	10733839	391175000
Coefficient of Social Vulnerability (CSV)	5.1	0.2	7.7
Average Economic loss Rs in US $ (EV)	1901669	4323056	676359
Coefficient of economic vulnerability (CEV)	12.2	27.7	4.3

Source: Calculated by Author from EM-DAT: The OFDA/CRED International Disaster Database

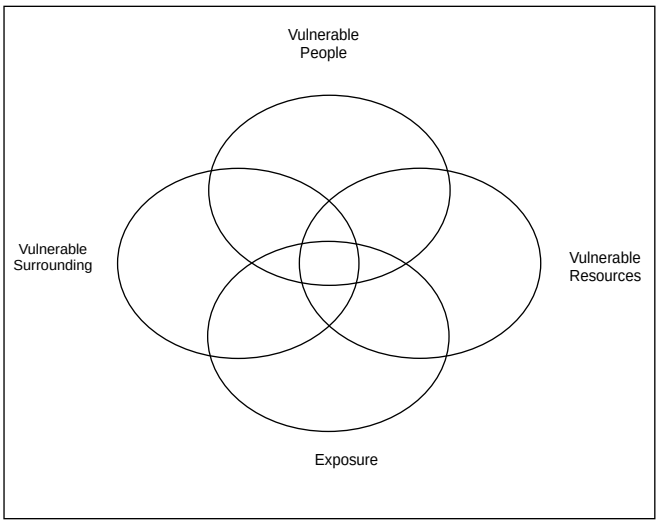
Majority of the rural population in the state is dependent on rain fed agriculture for their livelihood maintenance. The drought affects the livelihood of people at a great extent. It is interesting to note here that the coefficient of economic vulnerability is the highest for the cyclone. The coastal area of the state is highly prone to cyclone. Further, the port led economy has developed the coastal area with higher economic growth. Densely populated and economically well developed coastal region put the region more exposed to cyclones and therefore, the probability of economic damage due to cyclone is exponentially high in the state. In short, given a similar external shocks in terms of various climatic hazards, the risk varies greatly over space. This is mainly because the difference within the vulnerability aspects over space, community and regions.

5. Determinants of Vulnerability:

As discussed in the earlier section, vulnerability indicators are identified and measured

through principle component analysis. Indicators are operational representation of attributes showing qualities or characteristics of vulnerability. Identification of indicators is carried out by refereeing various studies which showed a contribution of inherent characteristic of a society in increasing the external risk. Such characteristic includes various dimensions of a society or a region including socio-economic, environmental, political and institutional aspects. The first step towards analysis was to club overlapping indicators and identifies the drivers of vulnerability pattern in Gujarat. The analysis resulted into four determinants of vulnerability which persuaded the vulnerability pattern in the state of Gujarat. These four determinants are vulnerable people, vulnerable surrounding, exposure and vulnerable resources. The figure 1 represents the conceptual model depicting determinants of vulnerability towards climatic variability. Let us examine how each determinant of vulnerability derived form an exercise is contributing towards an increased risk of climatic disasters.

Figure 1: Measuring Vulnerability: A Conceptual Model



1.Vulnerable people: The first important determinant of vulnerability derived from the exercise is vulnerable people. Almost 35% of variation in variables is explained by this determinant. The variables under this determinant mainly represent the marginalized groups of the society. These are proportion of dependents, proportion of schedule caste and schedule tribe, persons below poverty line, female agricultural labour, destitute, and illiterate females. These variables capture an inability to recover from or absorb the shock of climatic disasters. Higher the numbers in these variables make the district more vulnerable. Although the climatic risk remains same, such identified groups will be higher at the risk than the elite groups of the society. In other words, the impact of climate variability will be disproportionate on vulnerable people. Vulnerable people are mainly marginalized groups with relative inherent socio-economic weaknesses which increase the direct impact of climatic disasters. Some of the other indicators falling into this category are outcome indicators which include human development index, gender development index, gender empowerment measure and infant mortality rates. Apart from gender empowerment measure all the other three indicators are negatively related. Lower the values of these indices make the district more vulnerable. These indicators are characterized mainly by human development approach, which defines development as a process of enlarging people's choices. It puts people at the centre of development. These indicators represent capabilities of the community to adapt to new conditions. Lower indices of human and gender development represents less capability and fewer choices for people to cope up with climatic variability. In this way, vulnerability is determined by level of human development of the community. The vulnerability explained by these variables has major role in determining vulnerability pattern of the state. These variables have played a significant role in making backward districts such as Dahod,

Panchmahal and drought prone districts such as Kachchh and Surendranagar highly vulnerable.

2. The second set of determinants of vulnerability is mainly relating to an exposure which incorporates the growth of population and economy. About 13 % of variation in variables is explained by this determinant. It is obvious that the densely populated areas with high industrial growth and even higher economic growth are more vulnerable. These indicators portend the region's susceptibility to climatic disasters whatever their type or intensity. Most of the districts having higher exposure are located in the coastal areas. For instance; Jamnagar, Rajkot, Porbanadar and Amreli.

Table 5: Ranking of districts by major drivers of vulnerability

Sl No	District	Vulnerable people	District	Vulnerable surrounding	District	Exposure	District	Vulnerable resources
1	Dohad	26.5	Dohad	16.4	Gandhinagar	15.2	Sabarkantha	15.6
2	Dangs	24.8	Dangs	15.3	Ahmedabad	14.2	Valsad	15.6
3	Navsari	21.8	Navsari	13.9	Jamnagar	14.1	Vadodara	14.3
4	Panchmahals	21.1	Surendranagar	12.4	Rajkot	13.2	Junagadh	14.3
5	Surendranagar	15.0	Panchmahals	11.9	Patan	12.9	Panchmahals	13.3
6	Narmada	13.4	Kachchh	10.0	Porbandar	10.5	Patan	12.9
7	Kachchh	12.6	Jamnagar	9.6	Amreli	10.4	Ahmedabad	12.9
8	Vadodara	10.6	Valsad	9.6	Mehsana	10.2	Bharuch	12.7
9	Mehsana	9..	Vadodara	8.8	Bhavnagar	8.5	Kachchh	11.5
10	Banaskantha	8.8	Narmada	8.6	Junagadh	8.0	Surat	11.0
11	Sabarkantha	8.5	Surat	8.4	Bharuch	7.9	Amreli	9.9
12	Jamnagar	8.0	Bharuch	8.2	Sabarkantha	7.7	Anand	8.9
13	Junagadh	8.0	Junagadh	8.2	Banaskantha	7.7	Kheda	8.9
14	Valsad	7.4	Bhavnagar	8.1	Anand	7.5	Porbandar	8.9
15	Amreli	7.1	Banaskantha	8.0	Narmada	7.3	Narmada	7.9
16	Surat	6..	Mehsana	8.0	Vadodara	7.2	Gandhinagar	7.7
17	Gandhinagar	5.8	Porbandar	7.7	Navsari	7.0	Rajkot	6.9
18	Bhavnagar	5.2	Anand	6.9	Kheda	6.8	Dangs	6.4
19	Bharuch	4..	Amreli	6.7	Kachchh	6.8	Navsari	6.4
20	Kheda	1.8	Sabarkantha	6.5	Panchmahals	6.7	Mehsana	6.0
21	Patan	1.4	Kheda	6.3	Dangs	6.5	Surendranagar	6.0
22	Anand	0.8	Rajkot	5.5	Valsad	6.3	Banaskantha	5.1
23	Porbandar	0.7	Gandhinagar	4.8	Surendranagar	5.5	Dohad	3.0
24	Ahmedabad	0.2	Patan	4.2	Surat	5.1	Bhavnagar	2.3
25	Rajkot	0.	Ahmedabad	2.3	Dohad	3.1	Jamnagar	1.8

Source: Calculated by Author from various published sources, 2001

3.The third set of variables which shapes the vulnerability is called vulnerable surrounding. About 10% of variation in variables is explained by vulnerable surrounding. An easy access to basic services for human being provides better surrounding. Lack of such services makes people of that region more vulnerable towards the selected disasters. This is because lacking accessibility creates an adverse situation for people at the time of climatic disasters. The important basic services in this category involve access to drinking water and sanitation, access to health and education and access to pakka road and electricity. When disaster strikes, an inadequate access to such basic services not only increases the impact of disasters but also reduces the chances of survival. These variables have played major role in determining vulnerability in backward districts such as Dohad, Dangs, Panchmahal and Surendranagar as well as coastal districts such as Kachchh Jamnagar and Valsad.

4. The forth category derived from the analysis was named as vulnerable resources of the region which make it more vulnerable towards the selected disasters. About 7% of variation in variables is explained by this determinant. The contributory indicators in this category of determinants are degraded forest land, waste land, overused ground water and deteriorated quality of drinking water sources. Degraded resources do not support the community livelihood at the time of disaster such as drought, flood and cyclone and therefore make people of that region more vulnerable towards disasters. In other words, deteriorated resources create an unfavourable situation during the time of climatic disaster. In Gujarat, the poor base of natural resources in Sabarkantha, Valsad, Vadodara, Junagadh and Panchmahal put these districts in vulnerable region.

Table 6: Relative vulnerability Index at district level in Gujarat

District	Vulnerability Index	District	Vulnerability Index
Panchmahals	13.3	Mehsana	8.3
Dangs	13.2	Bharuch	8.2
Dohad	12.3	Patan	7.9
Navsari	12.3	Surat	7.7
Vadodara	10.2	Banaskantha	7.4
Kachchh	10.2	Porbandar	7
Surendranagar	9.7	Jamnagar	6.7
Valsad	9.7	Anand	6.1
Junagadh	9.6	Kheda	6
Sabarkantha	9.6	Ahmedabad	6
Narmada	9.3	Rajkot	4.8
Amreli	8.5	Bhavnagar	4.3
Gandhinagar	8.4		

Source: Derived from a model of Vulnerability, 2001

The above analysis clearly indicates that the pattern of vulnerability can be explained by four major set of determinants of vulnerability. Therefore, in order to reduce the vulnerability, it is important to address these drivers of vulnerability. Addressing these drivers can essentially reduce the risk due to climatic disaster by reducing vulnerability. The vulnerability index derived from these drivers represents relative position of districts within the state. Vulnerability index, in this context, helps in prioritizing the district for development planning. The table 6 presents the vulnerability index.

As far as vulnerability pattern in Gujarat is concerned, the backward districts namely Panchmahal, Dangs and Dohad are at higher risk. Given a similar climatic hazard scenario within the state, these districts have higher chances of potential losses at the time of climatic extremities.

6. Applying Vulnerability Analysis to Calculate Risk:

Let us examine the applicability of the vulnerability index for assessing the risk due to three selected disasters in Gujarat Separately. The separate exercise was carried out because the mitigation strategies for each disaster are developed by separate departments. However, the method for deriving risk index has remained similar for all the three disasters.

6.1 Slow onset Disasters: Drought:

Drought is defined meteorologically as the situation in which rainfall in a particular year over a region is less than 75% of long term normal or average (*Ray K.C. S, 2000).* Indian Meteorological Department further divides the drought as per severity. If the deficit experienced in rainfall is in the range of 26 to 50%, it is declared as moderate drought while the deficit is more than 50%, severe drought is declared. Nonetheless, drought becomes visible when it is declared as agricultural and hydrological drought. Planning commission considers drought as a major factor contributing to regional imbalances in the development of the country. Therefore, it focuses on identifying the drought prone areas for planning and implementation of various block development programmes. Such efforts can help developing drought prone areas in such a way that the adverse impact of drought can be minimized. The following table indicates risk calculated from drought prone area as well as vulnerability index. The drought prone area index is derived from the department of revenue, government of Gujarat. It is important to mention here that the drought is declared by the state government in their relief manual. Such declaration helps in identifying the areas for implementing block area development plan. The declaration of drought prone areas considers various factors into account. Such factors include the deficiency in rainfall, availability

of ground and surface water, loss of agricultural production in the previous kharif and rabi season, the estimation of current year production etc. If vulnerability index is incorporated into drought prone area index, it provides an overall risk index due to drought. Now let us examine the importance and need of risk calculation.

Table 7: District wise variation in risk due to drought

No.	District	Drought prone Area Index	Risk Index due to drought	Ranking as per Risk
1	Panchmahals	10	133	1
2	Kachchh	10	102	2
3	Surendranagar	10	97	3
4	Amreli	11	93.5	4
5	Dohad	7	86.1	5
6	Jamnagar	9	60.3	6
7	Junagadh	6	57.6	7
8	Rajkot	12	57.6	8
9	Banaskantha	7	51.8	9
10	Vadodara	5	51	10
11	Narmada	4	37.2	11
12	Ahmedabad	6	36	12
13	Bharuch	4	32.8	13
14	Patan	4	31.6	14
15	Valsad	3	29.1	15
16	Bhavnagar	6	25.8	16
17	Porbandar	2	14	17
18	Dangs	1	13.2	18
19	Navsari	1	12.3	19
20	Sabarkantha	1	9.6	20
21	Gandhinagar	NA	-	-
22	Mehsana	NA	-	-
23	Surat	NA	-	-
24	Anand	NA	-	-
25	Kheda	NA	-	-

Source: Relief Department, Government of Gujarat, Risk is calculated by Author

The calculation of risk is important in two ways; first of all, it is important to prioritize the area of intervention for reducing regional imbalances at the time during drought. When vulnerability is considered into the risk calculation, the prioritization of an area intervention also changes. For instance, let us compare the case of Panchmahal and Rajkot. Drought prone area index shows that Rajkot district is more prone to drought compared to Panchmahal. However, risk index represents that Panchmahal is more vulnerable to drought than Rajkot. Therefore, if drought mitigation strategies need to be effective, they need to consider the regional imbalance into deliberation. An effective drought mitigation strategies need to prioritize Panchmahal for implementing area development plan.

Secondly the exercise of risk calculation is helpful in selecting the district for prioritizing implementation when similar drought prone areas are delineated in more than one district. For instance, Panchmahal, Kachchh and Surendranagar being similarly affected by drought prone areas, the vulnerability index helps in prioritizing Panchmahal district for mitigating drought risk reduction strategies. Such prioritization process not only helps in implementing the development programmes effectively but also helps in an effective investment at the time of constraint fund. Such efforts of calculating risk can help in the process of convergence of disaster risk reduction strategies with development planning strategies; as it also helps in reducing the regional disparity in the state.

6.2 Rapid Onset Disasters: Cyclone and Flood

The similar exercise was carried out for Rapid Onset disasters. The following table represents the risk calculation for flood.

Table 8: District wise risk due to flood in Gujarat

No.	District	Flood Prone area	Risk Index	Ranking as per Risk
1	Dangs	100	1320	1
2	Navsari	100	1230	2
3	Valsad	100	970	3
4	Panchmahals	73	967	4
5	Junagadh	86	823	5
6	Kachchh	80	816	6
7	Surendranagar	80	776	7
8	Dohad	57	703	8
9	Porbandar	100	700	9
10	Vadodara	67	680	10
11	Gandhinagar	75	630	11
12	Amreli	73	618	12
13	Jamnagar	90	603	13
14	Sabarkantha	62	591	14
15	Bharuch	63	513	15
16	Kheda	80	480	16
17	Rajkot	100	480	17
18	Narmada	50	465	18
19	Patan	50	395	19
20	Bhavnagar	91	391	20
21	Ahmedabad	64	382	21
22	Surat	47	359	22
23	Anand	50	305	23
24	Banaskantha	33	247	24
25	Mehsana	NA	-	25

Source: Flood prone area is derived from Flood Control Cell and Risk Index is calculated by Author

Flood being a rapid onset disaster needs a special attention during the process of flood management planning. Flood is experienced when the water overflows its natural or artificial banks onto dry lands. Although, the flood can be natural or manmade, the basic inflow of water has linkage with heavy rainfall. Therefore, it is normally considered as climate induced disasters. Government of Gujarat has formed a flood control cell to deal with flood situation. The flood control cell has prepared a flood memorandum for managing the adverse effects of flood. The flood

memorandum has been prepared basically for flood forecasting and preparedness for reducing the risk due to flood. Under the memorandum, the list of flood affected villages is prepared on the basis of discharge and gauge information collected from various sites of reservoirs and dams. It is assumed here that area under such villages is highly prone to flood. If the vulnerability index is merged into area prone index, one can derive the risk index due to flood. Although the flood relief and reconstruction depends on ground truth data at a time of flood, the disaster risk reduction strategies need a vulnerability analysis to be incorporated in risk calculation.

Table 9: District wise risk due to cyclone in Gujarat

No.	District	Cyclone prone Area	Risk Index	Ranking as per Risk
1	Panchmahals	100	1330	1
2	Dangs	100	1320	2
3	Vadodara	100	1020	3
4	Valsad	100	970	4
5	Narmada	100	930	5
6	Gandhinagar	100	840	6
7	Bharuch	100	820	7
8	Surat	100	770	8
9	Banaskantha	100	740	9
10	Junagadh	74.5	715.2	10
11	Jamnagar	91	609.7	11
12	Kheda	100	600	12
13	Porbandar	74.5	521.5	13
14	Mehsana	59.7	495.51	14
15	Patan	59.7	471.63	15
16	Kachchh	36.3	370.26	16
17	Amreli	32	272	17
18	Bhavnagar	62.6	269.18	18
19	Ahmedabad	25	150	19
20	Rajkot	21.3	102.24	20
21	Dohad	NA	-	-
22	Navsari	NA	-	-
23	Surendranagar	NA	-	-
24	Sabarkantha	NA	-	-
25	Anand	NA	-	-

Source: Vulnerability Atlas, BMTPC and Risk is calculated by Author

Data on cyclone prone area has been collected from the vulnerability Atlas prepared by Building Materials and Technology Promotion Council. The BMTPC classifies the cyclone affected areas into various damage risk zone as per the speed of wind. Nonetheless, Indian Meteorological Department considers the cyclones which are having more than 60 km per hour wind speed are considered as severe cyclone and they cause damage in an affected area. As far as Gujarat state is concerned, the velocity of wind experienced in the past cyclones has remained higher than 158.4 km per hour. The risk of damage due to cyclone higher than 158.4 km per hour is considered to be very high and intensive. Therefore, the area prone to cyclones in Gujarat has considered only the frequency of occurrence of cyclones and has not accounted the intensity of cyclone. The risk calculation for cyclone is highly useful because many districts of Gujarat fall in a similar category of cyclone prone areas. It is clear from the table that the vulnerability differentiates the risk due to cyclone in districts facing similar damage due to disasters. The risk calculation is more important when planning for long term mitigation strategies such as land use planning, improving livelihood of vulnerable people, resource planning etc. in such a way that minimize the risk.

7. Conclusion:

It is possible to assess the risk due to climatic variability. Such an exercise is quite useful at a state as well as district level planning. The development activities at district level have to incorporate the vulnerability analysis for assessing risk due to climatic disasters. This can ultimately help in formulating climate change adaptation strategies. It is very important to see that the development activities do not increase the vulnerability towards climatic variability. The district level

planning can further look into the block level planning for further prioritization of development activities. This will be an effective way to mainstream the disaster risk reduction and climate change adaptation strategies into the development goals.

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