Vulnerability and Climate Change: An Analysis of the Eastern Coastal Districts of India

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Vulnerability and Climate Change: An Analysis of the Eastern Coastal Districts of India*

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Abstract

This paper attempts to construct a picture of socioeconomic context of vulnerability by focusing on indicators that measure both the state of development of the region as well as its capacity to progress further. The first aspect is reflected through agricultural and industrial development, while the second through infrastructure and others. In this study, the climate change impacts are examined from agriculture, infrastructure and demographic characteristics. The analysis is carried out at the district level. Vulnerability of a particular district is measured by the frequency of occurrence of extreme events, in this case the occurrence of cyclones, storms and depressions. From the data on the frequency of occurrence of extreme events it is clear that the districts in the states of Orissa and Andhra Pradesh are highly vulnerable than the other states. The study aims to build a vulnerability index and rank the various coastal districts of these highly vulnerable states in terms of their performance on the index. The index tries to capture a comprehensive scale of vulnerability by including many indicators that serve as proxies. The analysis carried out in this paper points out that the clusters of districts of poor infrastructure and demographic development are also the regions of maximum vulnerability. Some districts exhibit very low rate of growth in infrastructure, alongside a high growth rate of population. Also these districts show a higher density of population. Hence any occurrence of extreme events is likely to be more catastrophic in nature for the people living in these districts. People living in absolute poverty [those who cannot afford US $2 a day] will not be able to cope up with the challenges posed by climate change. Therefore, the analysis carried out in this paper suggests that climate change policies have to be integrated with sustainable development strategies in general, and poverty alleviation measures, in particular.

JEL Classification: Q54, R1

Keywords: Vulnerability, Climate Change, IPCC, India

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1. Introduction:

A growing body of literature in the past two decades has examined climate change as the most important issue in global environment, and analysed vulnerability and biodiversity loss arising out of the same. The lack of formal methodologies in the area of climate change - vulnerability relationship poses a big challenge and also an opportunity to continue research in this area. Study by Intergovernmental Panel on Climate Change (IPCC), links vulnerability with climatic change, and point out that the vulnerability of a region depends to a great extent on its wealth, and that poverty limits adaptive capabilities (IPCC, 2000). Further, they argue that socio-economic systems "typically are more vulnerable in developing countries where economic and institutional circumstances are less favourable". Also a common theme in the climate change impacts and vulnerability literature is the idea that countries, regions, economic sectors and social groups differ in their degree of vulnerability to climate change (Bohle et.al., 1994). This is due partly to the fact that changes in climatic patterns are uneven and are also not evenly distributed around the globe. Though vulnerability differs substantially across regions, it is recognized that "even within regions… impacts, adaptive capacity and vulnerability will vary" (IPCC, 2001). With respect to Africa, studies point out that climate change, mainly through increased extremes and temporal/spatial shifts, will worsen food security (IPCC, 2001). In the Indian scenario it is also likely that there will be an increase in the frequency of heavy rainfall events in South and Southeast Asia. The average temperature change is predicted to be in the range of 2.33° C to 4.78° C with a doubling in CO_2 concentrations (Watson et.al, 1998). Most of the other studies try to measure the vulnerability of a region to specific events like sea level rise, changes in temperature, rainfall etc. The present study attempts to analyse the pattern of vulnerability and human security of the people living on the eastern coast of India. Specifically, an attempt is being made to examine the relationship, if any, between climate-change and vulnerability for the people living in the eastern coastal districts of India.

Vulnerability is often reflected in the condition of the economic system as well as the socioeconomic characteristics of the population living in that system. This paper attempts to construct a picture of socioeconomic context of vulnerability by focusing on indicators that measure both the state of development of the region as well as its capacity to progress further. The first aspect is reflected through agricultural and industrial development, while the second through infrastructure and others. In this study, the climate change impacts are examined from agriculture, infrastructure and demographic characteristics. The analysis is carried out at the district level. Vulnerability of a particular district is measured by the frequency of occurrence of extreme events, in this case the occurrence of cyclones, storms and depressions. The study aims to build a vulnerability index and rank the various coastal districts on the eastern coast in terms of their performance on the index. The index tries to capture a comprehensive scale of vulnerability by including many indicators that serve as proxies. Specifically, the paper looks at four different sources of vulnerability: viz., the climatic factors, demographic factors, agricultural factors and occupational factors. Also a composite index has been created for the infrastructure development for the districts in question. The results from the index on vulnerability, infrastructure, agricultural development and demographic patterns are compared to capture the true nature of vulnerability of the people living in these areas.

The data sources for this study are (i) infrastructure from Statistical Abstracts, published by Directorate of Economics and Statistics of respective state governments, (ii) cyclonic events from the Indian Meteorological Department, (iii) agricultural activities from the District Level Database of International Crop Research Institute in Semi-arid Tropics (ICRISAT), and the demographic aspects from various Census Publications, Government of India. The methodology includes review of literature and use of descriptive statistics, building of indices for capturing vulnerability and the use of simple and rank correlations, and cluster analysis.

Section 2 provides a brief review of literature, while climate change and vulnerability concerns for India are discussed in section 3. Characteristics of the vulnerability of the eastern coastal districts of India is described in section 4. In section 5, Vulnerability Index for the Eastern Coastal Districts of India is presented, and the summary and conclusions are given in section 6.

2. Literature Review:

This section provides a brief review of literature linking climate change with vulnerability in coastal zones. The discussion in this section is largely based on studies on developing countries. The focus of much of the literature presented here is on impacts of climate change on vulnerability of population dependent on agriculture and local and global infrastructure development in that region. Fischer et.al., (2002) undertook a comprehensive and integrated global ecological-economic assessment of climate change on agro-ecosystem. They used a Food and Agricultural Organization of United Nations (FAO) and International Institute for Applied Systems Analysis (IIASA) analysis methodology. This is again based on agro-ecological zones methodology. Here a GIS based framework is combined with crop modeling and environmental matching procedures to identify crop-specific environmental limitations under various conditions. This facilitates a detailed assessment of climate change impact and agricultural vulnerability. Gazala Mansuri and Andrew Healy (2002) have done a study on Rural Pakistan in their paper "Vulnerability Prediction in Rural Pakistan". Here the authors describe vulnerability as "the probability that a household will experience a future period of poverty". It takes into consideration permanent and changing household characteristics. They suggest a measure that identifies vulnerable households. They also test it by using data set from rural Pakistan. For doing so they rely on two sets of assumptions; one, that shocks are normally distributed to expenditure and the second assumption involves sampling from empirical distribution. They also compare each measure by comparing actual outcomes to the prediction of each model.

Table 1: IPCC indicators for assessment of vulnerability

Sensitivity or Adaptive capacity category	**Proxy variables**
Settlement/ Infrastructure Sensitivity	Population at flood risk from SLR, Population without access to clean water and sanitation
Food security	Cereals Production/area, Animal protein consumption per capita
Ecosystem Sensitivity	% Land Managed, Fertilizer use
Human Health Sensitivity	Completed Fertility, Life expectancy
Water Resource Sensitivity	Renewable supply and inflow, Water use
Economic Capacity	GDP (market)/ capita, Gini Index

Human and Civic Resources	Dependency Ratio, Literacy
Environmental Capacity	Population Density, SO_2/ Area and % Land Managed

Source: IPCC, 2001

In the paper "Measuring Vulnerability" by Ethan Ligon and Laura Schechter, the authors have constructed a measure of vulnerability whereby they can quantify loss from different sources of uncertainty and also welfare loss associated with poverty. They also test it by applying their measure to panel data from Bulgaria in 1994 (Ethan Ligon and Laura Schechter, 2002). Study on "Coping with Seasonality and Drought" (Chen, 1991) analyses coping strategies of the poor. He suggests that one way of measuring vulnerability can be by assessing the number of income or food generating strategies that are available to the households in an affected area. Study by Riebsane, et.al., (1991) covers the drought in United States during the years 1987-1989. Here they propose some vulnerability-reduction strategies available to wealthy nations. These vulnerability-reduction strategies are changing farm policies, building reservoirs, establishing new insurance and aid programs and taking sensitive lands out of food production.

Within the UNFCCC, indicators of vulnerability have been defined that can be used to study vulnerability and adaptive capacity and identify areas (countries or regions) that are vulnerable. The comprehensive vulnerability index developed by the IPCC includes the following indicators as the proxy variables and tries to develop an index by taking the geometric mean of the various proxies after standardizing them. Table 1 lists the various proxies used by the IPCC.

3. Climate Change and Vulnerability in India:

India is the seventh largest country in the world with a geographical area extending from 8˚ 4′ to 37˚ 6′ in the north and from 68˚ 7′ to 97˚ 25′ in the east. It is bounded by the world's highest mountain range The Himalayas in the north and bounded by Bay of Bengal, Arabian Sea and the Indian Ocean in the south. The coastline along the southern part of India is about 7500 Km. long.

Table 2: Key Socio-Economic Indicators for India

Indicators	Dimensions
Geographical Area	329 Mha
Population	980 million
Urban Population	32 %
Literacy Rate	52.21 %
Gross Domestic Product (GDP) at current Prices	Rs. 16124 billion
GDP growth rate 1997/1998 – 1998/1999	6.8 %
Net National Product (NNP) at current prices	Rs.14315 billion
Per capita NNP at current prices	Rs.14682 billion

Source: Shukla, et.al., (2002)

In developing countries like India, climate change could represent an additional stress on ecological and socioeconomic systems that are already facing tremendous pressures due to rapid urbanization, industrialization and economic development. With its huge and growing

population, a 7500-km long densely populated and low-lying coastline, and an economy that is closely tied to its natural resource base, India is considerably vulnerable to the impacts of climate change (DOD. 2002). Despite the rapid growth of India's industrial and service sectors over the past decade, agriculture continues to dominate India's economy. Among a population of almost 1 billion people, approximately 68% are directly or indirectly involved in the agricultural sector. Because the majority of Indian agriculture is rainfed, climatic changes that alter temperature and precipitation patterns may pose serious threats to agricultural production. Scenarios generated by computer models show that India could experience warmer and wetter conditions as a result of climate change, including an increase in the frequency and intensity of heavy rains (Watson et al. 1996). The net impacts of climate change on agricultural output in India are uncertain, yet specific regions and certain groups of farmers, particularly those farming on marginal, rainfed lands, are likely to suffer significant damages as the result of climate change (Dinar et al. 1998, cited in Selvaraj et al. 2002). West coast agricultural regions, including Gujarat, Maharashtra and Karnataka, are expected to be among the most negatively affected by climate change (Sanghi et al 1998, cited in Selvaraj et al. 2002).

With regard to agriculture, the main rationale for economic reforms in India is to remove distortions and create an appropriate incentive structure for increasing agricultural production (Gulati and Kelley 1999) which is likely to produce new patterns of climatic vulnerability. With respect to infrastructure provision, it can be seen that in areas where investments in agricultural infrastructure have lagged, such as Maharashtra and Madhya Pradesh, rates of growth in agricultural productivity and poverty reduction have also lagged (Datt and Ravillion 1995). Climate change may further exacerbate these regional differences, because regions with limited irrigation infrastructure are also the areas where agriculture is most vulnerable to climate variability and change (Rao 1994).

India is one of the most important countries in the world with regard to the environment. With a large and growing population, India's emissions of greenhouse gases are increasing. Potential climate impacts in India include sea level rise, changes in the monsoon (timing and intensities), increased severe storms and flooding, and drought. And its continuing dependence upon agriculture for food and livelihood (67%, 1995 estimate) makes the Indian people vulnerable to climate variation and change. The climate change and its potential impacts on agriculture are addressed by several studies in recent times. There are a number of studies in the agricultural sector that signify the effect of climate change. Seshu and Cady (1984) have estimated a decrease in rice yield at the rate of 0.71 ton/ha with an increase in minimum temperature from 18^{o}C to 19^{o}C and a decrease of 0.41 ton/ha with a temperature increase from 22^{o}C to 23^{o}C. Sinha and Swaminathan (1991) show that a 2^{o}C increase in mean air temperature could decrease rice yield by about 0.75 ton/hectare in the high yield areas and by about 0.06 ton/hectare in the low yield coastal regions. Also, a 0.5^{o}C increase in winter temperature would reduce wheat crop duration by seven days and reduce yield by 0.45 ton/hectare. Additionally an increase in winter temperature of 0.5^{o}C would thereby result in a 10% reduction in wheat production in the high yield states of Punjab, Haryana and Uttar Pradesh. The study by Achanta (1993) concluded that the impact on rice production would be positive in the absence of nutrient and water limitations. Rao and Sinha (1994) in their crop-simulation study have estimated that under a 2 times carbon dioxide climate change scenario, the wheat yields could decrease by 28%–68% without considering the carbon dioxide fertilization effects. Aggarawal and Sinha (1994) showed that in North India, a 2^{o}C increase would reduce yields in most places.

With regards to India it can be said that the Eastern Coast is more vulnerable than the Western Coast with respect to the frequency of occurrence of extreme events like cyclones and depressions (Patwardhan et.al., 2003). Therefore, in this paper we concentrate on the vulnerability scenario in the eastern coastal districts of India. Within the eastern coast the districts in Orissa and Andhra Pradesh are the most vulnerable in terms of exposure to storms, super storms and depressions. The following table shows the district wise distribution of the three types of cyclones i.e. depression, storm and severe storm from 1877 to 1990, in the districts of these two coastal states.

Table 3: District wise distribution of cyclones in the districts of Orissa and Andhra Pradesh

District	Frequency of severe storms, storms and depressions
Puri	84
Cuttack	80
Balasore	76
Srikakulam	70
Vishakapatnam	31
East Godavari	31
Nellore	30
Ganjam	28
Krishna	25
Prakasam	7
Vizanagaram	5
Guntur	2
West Godavari	2
Dhenkanal	0

4. Characteristics of the vulnerable eastern coastal districts of India:

4.1 Demography and Literacy in the Coastal Zones of India:

The coastal zone is an important and critical region for India, which is endowed with a coastline of over 7500 km. 3 of the 4 major Indian metropolitan areas are located in the coastal region (Mumbai, Kolkata and Chennai). The total area occupied by coastal districts is around 379610 sq. km, with an average population density of 455 persons per sq. km, which is about 1.5 times the national average of 324. On the eastern coast we have 2 metropolitan cities Kolkata and Chennai. Table 4 provides the population density for the coastal states in India in the coastal region.

Table 4: Population density of Indian coastal states (2001 census)

State	**Population density (per sq. km.)**
West Bengal	904

Orissa	236
Andhra Pradesh	275
Tamil Nadu	478

The impacts of climate change on infrastructure and to the population take place through a variety of ways. Physical infrastructure is directly affected by climate related changes. The economy of the area in concern can also be affected in an indirect way. This is through the change in market demand for goods and services produced in the concerned area. In terms of our analysis we see that the most vulnerable areas to climatic changes as accounted by the frequency of storms, severe storms and depressions perform very low in terms of infrastructure. Relief services post extreme events are dependent on physical and social infrastructure such as roads, communication, banks etc., and the lack of these can inhibit effective provision of relief services. Therefore the presence of infrastructure services in a particular region will seriously affect the vulnerability condition of that area. Taking some of the indicators of infrastructure development as proxies for poverty, one can figure out the different aspects of vulnerability. Therefore the vulnerability will increase in the sense that these areas are less resilient in coping with the shocks of climatic changes. In terms of demography, human settlements and the people living in the area also directly affected by the negative shocks like cyclones, floods, droughts, sea level rise etc. Here we find that the density of population in these coastal districts of India is quite high. This increases the scale of vulnerability because a larger proportion of the population is exposed to extreme events.

In the demographic set up we will be looking at four indicators population, literates, literacy (number of literates divided by the population of a particular district) and sex ratio. The demographic structure of coastal districts in India is characterized by large population growth in the last decades. The density of population is quite high in these districts. The literacy rate is also not very high. Figure 1 below summaries the growth rates of population, literates, literacy rate and sex ratio in the coastal districts.

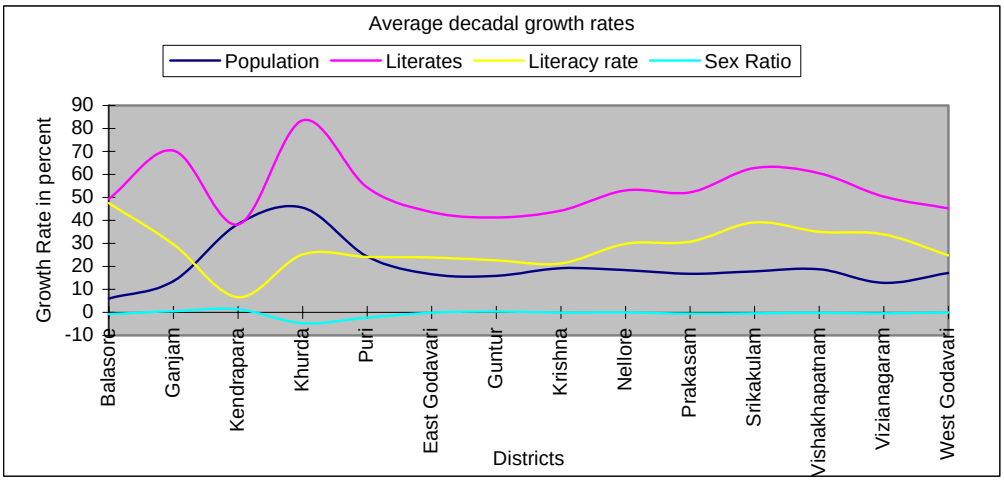

Figure 1: Average decadal growth rates of indicators of demography and literacy for Orissa and Andhra Pradesh

From the figure above we see that the average decadal growth rate in population across the districts has been around 20-25 percent as measured by average decadal growth rate. The highest growth rate is observed in Thane district, which is due to the large-scale migration of people from all other states to this part. Similarly the high growth rate in Surat is also due to this reason. If we look at the growth rate of literates we see that the average is 40-45 percent. But if we consider the literacy rate the mean is around 20-25 percent. This suggests that although the literates have increased by a greater amount the literacy rate has not experienced a high growth rate. This also means that the growth of literacy has been out weighed by the growth in population. Looking at the sex ratio we see many negative values implying that the sex ratio has decreased in many of the districts. The negative values are far more than the positive values suggesting that overall there has been a decline in sex ratio in the last three decades as measured by their average decadal growth. For arranging the districts into relatively homogeneous groups we made use of cluster analysis.

Table 5: Results of Cluster analysis for demographic indicators for coastal districts in Orissa and Andhra Pradesh:

No. of Clusters	Districts
1	Guntur, Krishna, Nellore, Prakasam, Vizianagram, Puri
2	Srikakulam, Vishakapatnam, Ganjam

From table 5 above we see that there are two clusters. There is no distinct pattern and each cluster is a combination of districts from various states. These particular clusters follow a similar pattern of growth on the basis of the indicators in consideration. Most of the districts in cluster 1 show a high rate of growth of population and also exhibit similar trends in terms of literacy, literates and sex ratio. Cluster 2 represents districts with lower growth rates in population but higher growth rates in literates and literacy rate. Also the district of Ganjam shows a positive growth in terms of sex ratio.

4.2 Infrastructure Developments in Coastal Districts of India:

Infrastructure plays a key role in influencing vulnerability and enhancing adaptive capacity. For comparing the infrastructural development of the coastal districts in India an infrastructure index has been developed based on integration of some key variables. The following indicators were used in the calculation of Infrastructure Index. The time period of reference coincides with the planning periods of India.

1. Finance:
    - Number of Banks (Scheduled Commercial including regional rural banks)
2. Education:
    - Total number of Schools (Primary and Secondary)
    - Total number of Teachers (Primary and Secondary)
3. Health:
    - Total medical institutions (Hospitals and Dispensaries)
    - Total medical beds available
4. Transport
    - Number of motor vehicles

Data on all the above variables was collected on a district level for the time periods 1980, 1985, 1990 and 1995. The population figures used for 1985 are the same as that of 1981 and that for 1995 are same as of 1991. The population data was collected for the time periods 1981 and 1991. Figure 2 and Table 6 below shows the performance of districts as measured by Infrastructure Index per lakh of population. The infrastructure index was calculated according to the formula:

$$\text{INDEX} = [\text{Indicator}_I / \sum_{D=1}^{n} \text{Indicator}_I + \ldots + \text{Indicator}_J / \sum_{D=1}^{n} \text{Indicator}_J] \,/\, \text{Population}_D$$

Here, D refers to various districts in consideration (1, 2… n) and
Indicators (I ……. J) are the various indicators used

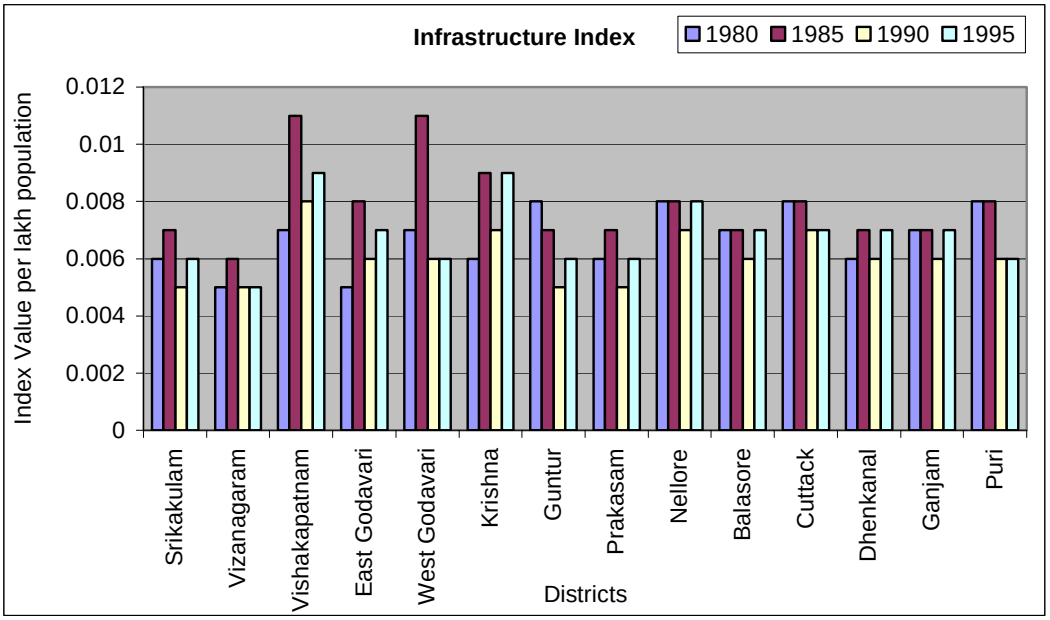

Figure 2: Absolute value of Infrastructure per hundred thousand population in eastern coastal districts of India

Table 6: Growth Rate of Infrastructure Index and frequency of extreme events in eastern coastal districts of India:

District	80-85	85-90	90-95	Rank	Frequency of severe storms, storms and depressions
Puri	0.34	-14.88	9.56	11	84
Cuttack	2.29	-13.31	11.55	9	80
Balasore	-0.70	-21.33	15.95	5	76
Srikakulam	10.54	-21.71	7.80	13	70
Vishakapatnam	51.08	-27.96	19.34	3	31
East Godavari	49.83	-23.18	8.60	12	31
Nellore	3.86	-20.61	15.91	6	30
Ganjam	7.33	-14.07	11.38	10	28
Krishna	70.22	-29.12	29.84	1	25
Prakasam	22.33	-29.83	15.45	7	7
Vizanagaram	16.69	-23.60	7.42	14	5

Guntur	-10.59	-25.97	25.64	2	2
West Godavari	49.19	-37.55	12.88	8	2
Dhenkanal	10.98	-13.62	17.37	4	0

The ranking has been done according to the growth rate of Infrastructure Index during the period 1990 to 1995. Frequency refers to total number of Depressions, Storms and Severe Storms from 1877 to 1990. The infrastructure levels show an increase in terms of the indicators measured over the first period that is from 1980 to 1985. In the second period of the analysis that is from 1985 to 1990 there is overall decrease in infrastructure levels as measured in terms of indicators across all the districts. One of the reasons for this can be that during this time period there were many district divisions and reallocations for the formation of new districts. Again in the last part of our study that is from 1990 to 1995 we see that there is growth in terms of infrastructure index. In general districts in Andhra Pradesh have high level of infrastructure growth followed by Orissa. From the figures in table 6 corresponding to the frequency of depressions, storms and severe storms we see that of the top ten districts in terms of frequencies of events, only one district (Krishna) scores high in terms of infrastructure growth, while all the others have low growth rates in infrastructure. A district like Puri, which has the maximum number of these events, is ranked quite low in terms of infrastructure index. The maximum vulnerability as measured in terms of historic data for cyclones is to the districts in the state of Orissa and these perform quite badly in terms of indicators considered in infrastructure index. Next vulnerable districts are that of Andhra Pradesh but districts like Srikakulam and East Godavari are also lowly ranked. On the whole the vulnerable districts perform low in terms of infrastructure setup as considered by the infrastructure index. Therefore to conclude we can say that lower the district is in terms of infrastructure index and the growth of it, the more exposed it is to climate change and hence people living in this region are likely to be highly vulnerable. Rehabilitation of people and the place would require tremendous effort and huge resources.

5. Vulnerability Index for the Eastern Coastal Districts of India:

In this section, the analysis of the index of vulnerability of the eastern coastal districts of India is presented. The vulnerability index, measured here, tries to capture a more comprehensive scale of vulnerability. This is done by including many indicators that serve as proxies to look at different aspects of vulnerability. In other words we assume that vulnerability can arise out of a variety of factors. In particular we look at four different sources of vulnerability. This includes the climatic factors, demographic factors, agricultural factors and occupational factors which are trivial in determining the overall vulnerability of an area. The idea is to prepare an index to map the vulnerability among the various coastal districts of the eastern coast of India and rank the districts in terms of vulnerability. Figure 3 shows the framework undertaken to estimate the extent of vulnerability through the vulnerability index. The construction of the Index is based on the districts of Orissa, Andhra Pradesh and Tamilnadu which are states or provinces on the eastern coast of India. The methodology used to calculate the vulnerability index follows the basic approach developed by (Anand and Sen, 1994) for the calculation of the human development index (HDI). To construct the vulnerability index for the different coastal districts we go through the steps as described below.

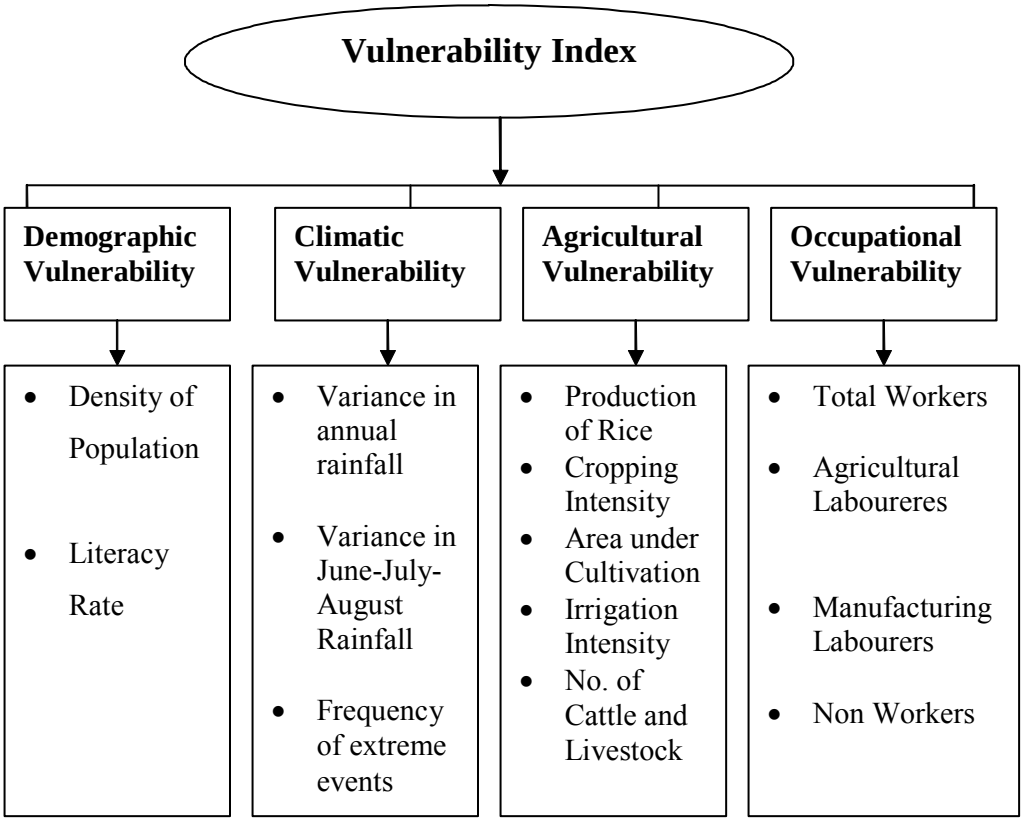

Figure 3: Sources and Dimensions of Vulnerability

Methodology for calculation of the index:

Step 1: Calculate a dimension index of the each of the indicators for a district (X_I) by using the formula

(Actual X_I – Minimum X_I) / (Maximum X_I – Minimum X_I)

Step 2: Calculate a average index for each of the four sources of vulnerability viz. Demographic, Climatic, Agricultural and Occupational vulnerability. This is done by taking a simple average of the indicators in each category.

$$\text{Average Index}_i = [\text{Indicator 1} + \ldots\ldots\ldots + \text{Indicator J}] / J$$

Step 3: Aggregate across all the sources of vulnerability by the following formula.

$$\text{Vulnerability Index} = \left[\sum_{i=1}^{n} (\text{Average Index}_i)^{\alpha} \right]^{1/\alpha} / n$$

Where,
J = Number of indicators in each source of vulnerability
n = Number of sources of vulnerability (in the present case n = α = 4)

After the values of the index are calculated for all the districts a ranking of the various districts can be carried out to identify the most vulnerable districts in terms of the indicators used for measurement. This analysis will be repeated for different time periods 1971, 1981 and 1991 in order to see how the vulnerability profile has changed over the years for the districts in terms of the indicators used to measure the vulnerability.

The following table shows the values of the vulnerability index at the three different time periods and the corresponding ranks of the districts at the three different time periods. In the table a rank of one shows the maximum vulnerable district and the vulnerability decreases as we go on increasing the rank.

Table 7: Vulnerability Index and Ranks for eastern coastal districts

Districts	1971	Rank	1981	Rank	1991	Rank
Srikakulam	0.027	15	0.017	10	0.022	16
Visakhapatnam	0.013	10	0.010	5	0.015	10
East Godavari	0.018	14	0.015	9	0.022	15
West Godavari	0.014	11	0.018	11	0.017	12
Krishna	0.011	6	0.012	7	0.013	8
Guntur	0.017	13	0.020	13	0.020	14
Nellore	0.005	2	0.009	3	0.007	4
Chengalpattu	0.012	8	0.013	8	0.018	13
Tiruchirapalli	0.016	12	0.019	12	0.015	11
Tanjavur	0.037	18	0.030	15	0.031	17
Madurai	0.005	3	0.002	2	0.014	9
Ramanathpuram	0.007	4	0.011	6	0.007	3
Tiruvelvelli	0.011	7	0.021	14	0.012	7
Kanyakumari	0.087	19	0.097	19	0.065	19
Balasore	0.035	17	0.050	18	0.006	2
Cuttack	0.030	16	0.039	16	0.044	18
Dhenkanal	0.001	1	0.001	1	0.002	1
Ganjam	0.009	5	0.010	4	0.010	6
Puri	0.013	9	0.042	17	0.009	5

From table 7 above, it can be seen that the vulnerability profile has undergone a complete change for some of the districts being considered. But one fact is quite evident that some of the districts of Orissa are the most vulnerable ones throughout the time frame of consideration. Especially the district Dhenkanal remains the most vulnerable district throughout. This is also the case in reality. This district comprises of the areas now divided into Kendrapara and Jagatsinghpur which are the most affected areas due to tropical cyclones and storms. The districts of Andhra Pradesh show a decline in vulnerability over the years. There is also the same decreasing trend in terms of the districts of Tamilnadu. The following figure shows the vulnerability among the different districts. For this the value of vulnerability index is subtracted from absolute one for all the districts. Therefore a higher value of the index now shows higher vulnerability.

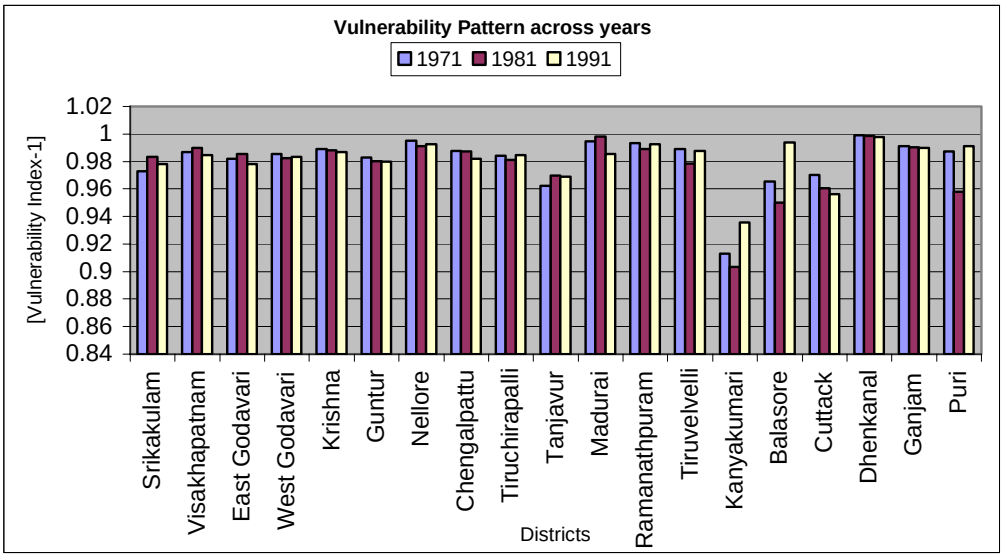

Figure 4: Vulnerability pattern across eastern coastal districts in India

From figure 4, it can be seen that the vulnerability of the people is very high in the districts of Orissa and Andhra Pradesh as compared to that of Tamilnadu. There is a decreasing trend in case of the districts of Andhra Pradesh from 1981 to 1991. This can be due to the better disaster mitigation policies of the Andhra Pradesh government. They are actively involved in the adaptation of disaster mitigation policies and have developed suitable mitigation strategy to help the vulnerable people out of the problem. The index takes into account a variety of sources of vulnerability into consideration. Therefore the variation in the index can be due to all these factors. The sources like demographic and agricultural vulnerability have a direct impact on the people living in the area. The areas along the coastline of India are thickly populated and are also prime agriculture producing lands. Therefore any changes on to these sources will have a direct impact on the vulnerability of the people living in this region. The next source, which is climatic vulnerability, will also have an impact on the vulnerability of the people through their impact on the agricultural production and the demographic structure. As far as occupational vulnerability is concerned, it will also influence the vulnerability of the people. The occupational structure of an area has very important significance. The more the people become vulnerable the more will be the change in the occupational structure of the workforce. Hence this is also related to the overall vulnerability of the people living in the particular region. From the above figure another

observation that is quite worth noticing is that the vulnerability index although has increased (decreased) but the changes that have occurred are not very large. Therefore in some districts overall vulnerability of the people has decreased but that change is not that significant.

To check whether the ranks assigned in Table 7 are significant or not we do a Spearman's rank correlation analysis. This will also show how the indices moved vis a vis each other. The following table [Table 8] reports the results obtained out of the analysis.

Table 8: Results of Spearman's Rank Correlation for Vulnerability Index

	Vulnerability Index 1971	Vulnerability Index 1981	Vulnerability Index 1991
Vulnerability Index 1971	1		
Vulnerability Index 1981	0.819**	1	
Vulnerability Index 1991	0.718**	0.433*	1

** implies significance at 1% level and * implies significance at 5% level (2- tailed).

From the above table (Table 8), we can see that the district ranks are highly significant and correlated with each other. This further means that the rankings assigned in terms of vulnerability to different districts are significant. The strength of the correlation is also very high; to the tune of 0.8 suggesting a high degree of correlation of each index vis a vis each other. Also the various ranks that we assigned to the different districts are over the different time periods are also significant. For a deeper analysis of the nature of vulnerability we have to look at the linkages between the vulnerability index, infrastructure index and frequency of occurrence of extreme events in these districts.

Table 9: Correlation results for Infrastructure, Vulnerability Indices and frequency of occurrence of extreme events

	Infrastructure Index -81	Infrastructure Index -91	Vulnerability Index -81	Vulnerability Index -91	Events-81	Events-91
Infrastructure Index-81	1					
Infrastructure Index -91	0.132	1				
Vulnerability Index -81	0.428	-0.116	1			
Vulnerability Index -91	0.126	0.054	0.268*	1		
Events-81	0.629**	N.A.	0.828**	N.A.	1	
Events-91	N.A.	0.355	N.A.	0.479	N.A.	1

** implies significance at 1% level and * implies significance at 5% level (2- tailed); N.A.= Not Applicable

From the above table (Table 9), we can note that some of the correlation results are significant either at one percent or five percent significance levels. It is interesting to see that Infrastructure Index of 1981 and the frequency of occurrence of extreme events is highly correlated and is also significant at one percent level. Also the vulnerability index of 1981 and 1991 are highly correlated and significant. This is understood since the frequency of occurrence of extreme events is one of the sources of vulnerability considered in the study. But the important thing that is noteworthy is that there is also correlation between vulnerability index of 1981 and 1991. This result is of great importance for analysis and policy formulation purposes. This correlation coefficient of 0.268 suggests that past vulnerability also has some effect on the present vulnerability. In other words the vulnerability pattern is interrelated across different time periods. If the people of any region have been vulnerable for past certain periods then they are more likely to be vulnerable in the present period also. This result will be of quite relevance to policy makers in fact. The various disaster mitigation policies should try to incorporate this result in their planning and formulation purposes. The most policies will be of great importance to the people in these regions. The distribution of people is highly skewed in favour of the poor in the coastal districts of India. The incidence of poverty is also on the higher side in these coastal districts of India. Also there is a high amount of inequality in the distribution of resources in these regions. Further one can also see that the occurrences of extreme events especially cyclones and storms is very high in these districts. Therefore the people in these regions must have suitable disaster mitigation and management policies to hedge against the greater vulnerability that they face. Policy makers should completely take into consideration the fact that is the people have been vulnerable in the past than there is a higher probability of them being vulnerable in the current period also. Therefore a suitable policy for them should also include their past vulnerability also. Being vulnerable in the past also has an important implication for the adaptive capacity of the people also. The adaptive capacity of the people in these regions becomes less as for the past many seasons they have been vulnerable and this drains out their resources for adaptation at future time periods. Assuming a finite time period and limited resources framework for the people the results can be very interesting. Given the limited resources the people have to allocate these resources throughout the time period of their survival. Therefore being vulnerable for a greater period is like having more strain on their present resources. Therefore these people face a steeper budget constraint. The tradeoff between their resources and adaptive capacity is much stricter. All these findings should be addressed and incorporated while forming a suitable disaster mitigation policy for them.

6. Summary and Conclusions:

Given the facts about the likely impacts of climate change, India has several reasons to be concerned about climate change. India being a developing country is primarily dependent on climate sensitive factors like agriculture and forestry, which account for a major portion of its GDP and also has low financial adaptive capacity. This makes India more vulnerable. Although there is uncertainty about the degree of the impacts because of coexistence of many processes like presence of multiple climatic conditions, non climatic stress and regional scale variations there is bound to be some impact.

The studies pertaining vulnerability from the extreme climatic events in India as well as the data on exposure indicate that the coastal districts on the East Coast experience extreme events such as storms and depressions more than districts on the western coast, with the exception of a few districts in Gujarat. Impacts of these events, apart from those related

to life and property are likely to be on agriculture, infrastructure and on the population and human settlements of the area in concern. The eastern coast districts are major producers of rice in India, and adverse effects of climate change will have an impact on production and availability of food grains in the country. The literature shows that these shortfalls have the potential to create market imbalances which can further lead to fluctuations in the market and prices of food. Agricultural production in these coastal areas is heavily dependent on climatic conditions, as despite the availability of irrigation facilities they are heavily dependent on rainfall.

The analysis carried out in this paper points out that the clusters of districts of poor infrastructure and demographic development are also the regions of maximum vulnerability. Some districts exhibit very low rate of growth in infrastructure, alongside a high growth rate of population. Also these districts show a higher density of population. Hence any occurrence of extreme events is likely to be more catastrophic in nature for the people living in these districts. Moreover, the lower the district is in terms of infrastructure index and the growth of it, the more exposed it is to the potential damage from extreme events and hence people living in these regions are likely to be highly vulnerable. Lower levels of infrastructure will result in lower adaptive capacity of the people to hedge against the catastrophe. Further, people living in absolute poverty [those who cannot afford US $2 a day] will not be able to cope up with the challenges posed by climate change. Therefore, the analysis carried out in this paper suggests that climate change policies have to be integrated with sustainable development strategies in general, and poverty alleviation measures, in particular.

From the analysis of the results obtained from the infrastructure and demographic sector, frequency of extreme events and the vulnerability index we have many important interesting observations. The clusters of districts of low infrastructure and demographic development are also the regions of maximum vulnerability. The growth rate of infrastructure index is very low and growth rate of population is on the higher side. Also these districts show a high value for the density of population. Hence any occurrence of extreme events is likely to be catastrophic in nature for the people. Also the low levels of infrastructure in these districts will have an impact on the adaptation levels of the people. Also the damages to physical infrastructure will be to a greater extent in these districts due to the high vulnerability. This will make the problem of adaptation more chronic in nature. On the part of policy formulation a greater attention is required from policy makers to this problem. As pointed in the report low levels development and high poverty in the areas is a much greater problem to be dealt with as this has a direct impact on the prospects of current and future vulnerability of the people living in these areas.

It is true that in the case of a developing country like India fundamental issues like alleviation of poverty and fulfilling the basic conditions for human development are of primary concern but the importance of climate change cannot be neglected. What is required is a development strategy that encompasses both these concerns. Therefore climate change policies have to be integrated with sustainable development strategy such as control of pollution. Evidence of observed impacts of regional climate changes from socioeconomic systems is much scanty than from physical and biological systems. Methodologically it is very difficult to separate climate effects from other factors such as technological change and economic development, because of the complexities of these systems. Vulnerability to climate change and climate variability is a function of exposure and adaptive capacity. Exposure varies from region to region, sector to sector, and community-to-community and adaptive capacity may be even more variable. The adaptive capacity of socioeconomic systems also contributes to the difficulty of documenting effects of regional climate changes;

observable effects may be adaptations to a climate change rather than direct impacts. A lot will depend on area in concern, the amount of economic activity, physical infrastructure, and social infrastructure of the area and also nature of disaster management policies formulated by the policy makers to hedge against the extreme impacts of climate change. Also the extent of the impacts will depend on the disaster mitigation strategies available at the area in concern. Also a more comprehensive study should try to capture the linkages between poverty and climate change. Poor people and poor countries find it difficult to cope with climate variability. Floods in Mozambique, hurricane Mitch for example challenge the poverty reduction programs. They have a negative impact also on the relief and rehabilitation efforts and result in loss of assets thereby reducing the ability of the poor to cope up with the impacts of climate change. Impacts from climate change severely threaten the developmental efforts and opportunities across developing countries. This increases the vulnerability of the people in developing countries. People living in poverty will not be able to cope with the challenges posed by climate change. The situation becomes devastating for the people living in abject poverty that is the people living significantly below poverty line. Actions to enhance the ability of the poor to cope up with climate change should aim not only to reduce poverty but also increase the resilience of the poor.

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