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Climate Change Vulnerability in Agriculture Sector: Indexing and Mapping of Four Southern Indian States[φ]

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Abstract:

Agriculture is the sector most vulnerable to climate change due to its high dependence on climate and weather conditions. Climate change is a main challenge for agriculture, food security and rural livelihoods for millions of people in India. Among India's population of more than one billion people, about 68% are directly or indirectly involved in the agricultural sector. This sector is particularly vulnerable to present-day climate variability. In this paper an attempt is made to map and analyze the vulnerability to climate change in different districts of four south Indian states: Andhra Pradesh, Karnataka, Tamil Nadu and Kerala. We have taken five sources of vulnerability indicators: socio-demographic, climatic, agricultural, occupational and common property resources vulnerabilities to compute the composite vulnerability index. The composite vulnerability index suggests that, Adilabad, Chamarajanagar, Thiruvarur and Kasaragod are the most vulnerable districts of Andhra Pradesh, Karnataka, Tamil Nadu and Kerala respectively, whereas Hyderabad, Belgaum, Thoothukkudi, Kottayam are the least vulnerable districts.

Key words: Vulnerability, agriculture, climate change

JEL Classification: Q 54, I31, H84

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1. Introduction

Climate change will have a profound impact on human and eco-systems during the coming decades through variations in global average temperature and rainfall. A growing body of literature in the past two decades has identified climate change as the prime issue in global environment, analyzed the associated vulnerability and biodiversity loss (Fourth Assessment Report of the Intergovernmental Panel on Climate Change). Vulnerability is the degree to which a system is susceptible to or unable to cope with adverse effects of climate change including climate variability and extremes (IPCC, 2001a). According to Fussel (2007), climate related vulnerability assessments are based on the characteristics of the vulnerable system spanning over physical, economic and social factors. The Intergovernmental Panel on Climate Change (IPCC), in its second assessment report, defines vulnerability as "the extent to which climate change may damage or harm a system." It adds that vulnerability "depends not only on a system's sensitivity, but also on its ability to adapt to new climatic conditions" (IPCC, 2001).

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. The study by IPCC links vulnerability with climatic change, and points out that the vulnerability of a region depends to a great extent on its wealth, and that poverty limits adaptive capabilities (IPCC, 2000). Further, it argues that the socio-economic systems "typically are more vulnerable in developing countries where economic and institutional circumstances are less favourable". 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 the 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). The study by Daily and Ehrlich (1990) explains a simple, globally aggregated, stochastic-simulation model to examine the effects of rapid climate change on agriculture and human population. This model follows population size, production, consumption and storage of grain under different climate scenario over a 20 years projection time. This study also highlights the effectiveness of reducing population growth rates as a strategy for minimizing the impact of global climate change and maintaining food supplies for everyone (Daily and Ehrlich, 1990).

In the Indian scenario it is also likely that there will be an increase in the frequency of heavy rainfall events. Globally, 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 southern states in India. Specifically, an attempt is being made to examine the relationship, if any, between climate change and vulnerability for the people living in different ecosystems of southern states 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 the vulnerability index by focusing on indicators that measure both the state of development of the region as well as its capacity to progress further. In this study, the climate change impacts are examined from agriculture, occupational and demographic characteristics. The analysis is carried out at the district level. The 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 districts in the southern states of India namely Andhra Pradesh, Tamil Nadu, Karnataka and Kerala 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, this paper looks at four different sources of vulnerability: viz., the demographic factors, agricultural factors, occupational factors, climatic &common property resource (CPR) factors. Based on this, a composite index has been created for the districts in the above mentioned southern states.

2. Premise of the study

As per the fourth assessment report of IPCC, the warning of the climate change system is now unequivocal, as is now evident from observations of increases in global air and ocean temperatures, widespread melting of snow and ice, and rising sea level. Importantly, developing nations are adversely affected in comparison to the developed nations (Mendelson et al., 2006; Stern, 2006). For instance, during the period 2000-04 on an average annual basis, one in 19 people living in developing world was affected by climate distress (HDR 2007), and further, flooding affected the lives of the 68 million people in east Asia and 40 million people in south Asia (HDR, 2007). In Asia during 2007 more than 14 million people in India and 7 million people in Bangladesh, and more than 1000 people lost their lives across south Asia (HDR, 2007:67).

These climate disasters, therefore, make the livelihood of the people more susceptible in India as they are already vulnerable to the conventional problems of poverty and food security etc. It is argued that India is particularly vulnerable to predicated climate change impacts because of its high population density, low adaptive capacity, several unique and valuable ecosystem (coral reef, large deltaic regions with rich biodiversity, desert ecosystem, Himalaya ecosystem, coastal ecosystem etc), and vast low altitude agriculture activities (Roy,2007). India is home to the largest number of hunger and derived people in the world- to be precise 360 million undernourished and 300 million poor people. Sustainable supply of food itself is emerging as a critical issue. The growth rate in food grains production is slow, rather decreased during 1996-2008. It increased by just 1.2 per cent per annum: from 199 to 230 million tons, as against an annual rate of growth of 3.5 per cent achieved during the 1980.

Agricultural productivity is sensitive to two broad classes of climate-induced effects:(1)direct effect from changes in temperature, precipitation, and carbon dioxide concentrations (2) indirect effects through change in soil moisture and the distribution and frequency of infestation by pests and diseases.

3. Climate Change Vulnerability and Adoptive Strategies: A Review

In this section, an attempt is made to understand the critical and detailed review of literature on climate change and agriculture with a specific focus on India. It has two parts. While part one explains about vulnerability, climate change and agriculture, second parts discuss about copping and adoptive strategies.

3.1 Climate Change and Agriculture

Kumar and Balasubramanian (2010) in their paper attempt to supplement the existing knowledge of vulnerability assessment in the context of rice cultivation in the northern Indian states. The main focuses of this study is on the vulnerability of rice yields to temperature and rainfall fluctuations for the Northern states of Punjab, Haryana, Uttar Pradesh and Uttaranchal in India. They conclude that regions that are presently ‘poor’ need not become ‘vulnerable’ under climate change conditions. In another study Kumar (2009) addresses two important issues: (a) extent of change in climate sensitivity of Indian agriculture over time; (b) importance of accounting for spatial features in the assessment of climate sensitivity. The data on rainfall was generated from India Meteorological Department. For the point of analysis the dataset is divided into three different periods of approximately equal length: 1956-1970; 1971-1985; 1986- 1999. These periods roughly communicated to the pre-green revolution, green-revolution, and post-green revolution periods of Indian agriculture and also present insights on shifting nature of climate sensitivity of Indian agriculture over time. The study finds the presence of significant positive spatial autocorrelation, necessitating estimation of climate sensitivity while controlling for the same.

By taking the data on forty two crops and livestock commodities including both irrigated and rainfed production and disaggregated into sixty-four geographical sub-regions, Adams (1989) analyses the impacts of climate change on the agriculture sector, especially of U.S.A. Swain and Swain (2011), in their study in Odisha examine the nature and determinants of drought risk and vulnerability experienced by selected blocks of drought-prone Bolangir district in western Odisha. In this study they considered nineteen key drought vulnerability factors of which, six were biophysical factors and thirteen were socio-economic factors. The indexing and vulnerability profile method have been used for assessing the nature of drought vulnerability, coping capacity and risk in this analysis. The conclusions arrived at are that three most influential biophysical factors of drought vulnerability are rainfall variability, drought intensity and shortage of available water holding capacity of soil and the three most influential socioeconomic factors are: low irrigation development, poor crop insurance coverage and smaller forest area. It is found that while drought risk varies widely across the study blocks and drought vulnerability and physical exposure to drought vary moderately, the coping capacity of the study blocks differ marginally. However, the level of coping capacity has been found significantly lower than the level of drought risk and vulnerability in the study.

A study by Gupta (2005) tried to examine the future emissions scenarios in India. This study has two parts. While the first part explains highlighting the extent of India's vulnerability to climate change, the second part attempts to critically analyze the initiatives undertaken at home to mitigate greenhouse gas (GHG) emissions. Gupta concludes that the Indian economy, which mainly depends on natural resources, climate change could represent an additional stress on agriculture, forestry, coastlines, water resources and human health. Pretty et. al (2002) study analyzed the technical options in agriculture for reducing greenhouse gas emissions and increasing sinks, arising from three distinct mechanisms, such as increasing carbon sinks in soil organic matter and above ground biomass; avoiding carbon emissions from farms by reducing direct and indirect energy use; and increasing renewable-energy production from biomass. It reviews the best-practice sustainable agriculture and renewable-resource-management projects and initiatives in China and India, and analyzes the annual net sinks being created by these projects, and the potential market value of the carbon sequestered (Pretty et. al 2002).

Kshirsagar et al. (2002) in their study analyze farmers' perceptions regarding the relative performance of a range of improved and traditional varieties of crops that are currently being grown in eastern India. They applied two models in this study namely varietal diversity index (VDI) and Niche index (NI).The results indicate that quality characteristics loom very large in farmers' choice of rice varieties. Bhatia et al (2004) in their study explained that agriculture contributes methane and nitrous oxide to the atmosphere, which are the two important sources of greenhouse gases that causing global warming. Due to the diverse soil, land-use types and climatic conditions, there are uncertainties in quantification of greenhouse gas emission from agricultural soils in India. An inventory of the emission of methane and nitrous oxide from different states in India was prepared using the methodology given by the Inter-Governmental Panel on Climate Change (Bhatia et al 2004).

Using common pool land without taking into consideration the rural needs would result in conflicts and extreme hardship for the poor (Gundimeda 2005).The research carried out by Somanathan and Somanathan (2009) discusses the ways in which climatic changes might affect the lives of the poor. Rising temperatures, changes in rainfall patterns, and an increased frequency of floods and droughts are likely to have serious effects on rural populations in the absence of policies that actively help these households adjust to their changing geography. They anticipated the hazards of the climate change take account of decreased crop yields, the departure of mountain glaciers and snow packs, more extreme weather events such as floods, droughts and storms, increased coastal flooding, and species extinctions. They discussed each one of these and their expected impact on the poor.

A study by Jodha et al. (2012) examines the farmers' adaptation strategies against climatic variability in arid and semi-arid regions of India. Further, it also assesses the farmers' perceptions and coping practices are largely governed by village level variables governed by the weather conditions. This study mainly based on the synthesis of village, farm and plot level information collected through different studies in arid and semi-arid regions of India over a period of almost thirty years. According to them, it has two main parts. The part one explains the adaptation practices, which has covered risk generating features of the communities' natural resource base (ii) long and short term weather patterns and (iii) extreme events such as severe droughts. The second part illustrates the farmers' perceptions about climatic (weather) variability and their potential adaptation practices, it includes preparedness, covering both collectively and individually managed steps are considered. Finally, they have pointed out that diagnose and understand farmers' adaptation strategies against climate variability with a focus on the dynamics, diversity and flexibility of adaptations, involving seek for and encouragement of approaches and options to connect the opportunities in the changing economic, technological and institutional opportunities, which may even go over the ones developed by farmers in the subsistence-oriented, locally-focused contexts. The implementation of the above suggestions highlighting dynamism, diversity and flexibility would need both enhancement and reorientation of the capacities of the farmers and rural communities, as well as that of the institutional arrangements and innovations supporting them.

A paper on social vulnerability to climate change and the architecture of entitlements by Adger and Kelly (1999), attempts to be critical and analytical about conceptual model of vulnerability to climate change as the first step in evaluating and understanding the social and economic processes. The vulnerability as defined here pertains to individuals and social groups. The vulnerability of any group is determined by the availability of resources and, crucially, by the right of individuals and groups to call on these resources. From this point of view they also extended the concept of entitlements and developed within neoclassical and institutional economics. Within this conceptual framework, vulnerability can be seen as a socially-constructed phenomenon which has been influenced by institutional and economic dynamics. Further, they also develop substitute indicators of vulnerability associated with the structure of economic relations and the entitlements which govern them, and shows how these can be applied to a district in coastal lowland Vietnam. They conclude that the socio-economic and biophysical processes that determine vulnerability are manifest at the local, national, regional and global level, but that the state of vulnerability itself is associated with a specific population.

The main objectives of Paltasingh et al. (2012)study is to examine the impact of weather on rice yield in Odisha since rice is the staple food and covers about70 per cent of cultivated area in this state. Further, it also estimates both theoretically and empirically the superiority of aridity index approach. This study is confined to rice crops only. Rainfall and temperature are the two important weather factors that affect crop yields due to their direct and indirect influences on agricultural practices. In order to find changing rainfall dependence of rice yield through this aridity index approach for three different periods are estimated. They construct a new weather index for examining the favorableness of weather every year. The study finds that the dependence of agriculture on rainfall in Odisha has declined slightly possibly because of the developments in irrigation and other facilities.

Kumar et al. (2004) in their paper on “climate impacts on Indian agriculture, using historic production statistics for major crops” examine the influence of monsoon rainfall and some of its potential predictors such as ,Pacific and Indian Ocean sea-surface temperatures, Darwin sea-level pressure on crop production. The study finds that the crop response to monsoon rainfall has some predictability, even before the start of the growing season. This is a necessary but not sufficient condition for farm and policy applications of long-lead climate forecasts. Exploiting this predictability will require further work with refined predictors and prediction systems, higher resolution crop and rainfall data, and perhaps process-level models of crop response. The results also indicate, at the very coarse state scale, what major crops and regions show the greatest sensitivity to the predictable components of monsoon rainfall. This type of analysis, at a finer spatial scale, could provide useful information for targeting interventions.

A study conducted by Moorthy et al. (2012) examines the impact of historic climate change trends over a 50-year period, and develops a model that accommodates a number of farmer adaptation possibilities. The study sheds light on the importance of uncertainty in future impacts. Projections of future trends are estimated with considerable error, and do not benefit from realized year-to-year data for the periods of study and they also suggested that adaptation may play a role in mitigating adverse climate change effects.

Samuel and Adeola (2009) in their study examine the people’s perception about climate change and strategies employed to adapt in South Western Nigeria. Data was collected from administered questionnaire and held Focus Group Discussions to elicit information, where 350 valid responses were used for further analysis. The Logit model was used to analyze the determinants of the perception and adaptation level of climate change. This study conclude that there is a need for agricultural economists and other stakeholders in environmental management and agricultural sustainability in developing countries to come to terms with negative impacts of climate change and likely positive and beneficial response strategies to global warming.

Innes and Kane (1995) study discuss about the effects, problems and opportunities of climate change on agriculture sector. A study on Adapting to Climate Variability in Semi-arid Regions by Reddy et al, (2010) attempts to understand farmers’ adaptability to climate variability using the Sustainable Rural Livelihoods (SRL) framework in two differently endowed locations in the semi-arid region of Andhra Pradesh (AP), South India. The study indicated that the aggregate picture do not hold good at the household level. As against the observations at the aggregate level, neither physical capital nor financial capital turned out to be significant at the household level. This indicates the importance of assessing the adaptation levels at the household level inorder to arrive at better insights for policy purposes.

A research study carried out by Nhemachena and Hassan (2007) on micro level analysis of farmers’ adaptation to climate change in Southern Africa describes farmer perceptions to changes in long-term temperature and precipitation as well as various farm-level adaptation measures and barriers to adaptation at the farm household level data based on a cross-sectional study of three countries namely South Africa, Zambia and

Zimbabwe. A multivariate discrete choice model is used to identify the determinants of farm-level adaptation strategies. Adaptation to climate change involves changes in agricultural management practices in response to changes in climate conditions. It often involves a combination of various individual responses at the farm-level and assumes that farmers have access to alternative practices and technologies available in the region. The study confirmed that access to credit and extension and awareness of climate change are some of the important determinants of farm-level adaptation. An important policy message from these results is that enhanced access to credit, information as well as to markets can significantly increase farm-level adaptation.

The review based paper by Kashyapi et al (2008) makes a critical review on the impact of climate change aimed at providing the global overview on the subject. The impacts of the projected changes in climate include changes in many aspects of biodiversity. Further study also observed changes in agricultural crops with reference to phenology, management practices, pests and diseases and yields. They also looked at impacts of climate change on agriculture of different continents. The study covered increase in the temperature, changes in the precipitation, sea-level rise and concentration of atmospheric CO2. Agriculture is the largest employer in the world and the most weather dependent, of all the human activities. Simultaneously, agriculture is the most vulnerable to weather and climate risks. Of total annual crop losses in the world agriculture are mainly due to direct weather impacts *viz.* droughts, floods, untimely rain, frost, hail, heat and cold waves and severe storms. The main conclusion emerging from this global impact studies is that the climate change has the potential to change significantly the productivity of agriculture. Some high productive areas may become less productive or vice-versa. It is also suggested the tropical and sub-tropical regions may be more likely to suffer by droughts and loss in crop productivity.

A study by Guiteras (2007) aims at estimating the economic impacts of climate change on Indian agriculture in the short-term and medium-term. The district level panel data was used in this study. Since agriculture contributed roughly 20 percent of India's GDP, this implies a cost of climate change of 1 to 1.8 percent of GDP per year over the medium run. According to his estimates, derived from short-run weather effects are also related for predicting the medium-run economic impact of climate change if farmers are constrained in their ability to recognize and adapt quickly to changing mean climate. The predicted medium-run impact is negative and statistically significant. From his estimated result, he also suggested that climate change is likely to impose significant costs on the Indian economy unless farmers can quickly recognize and adapt to increasing temperatures. Such rapid adaptation may be less plausible in a developing country, where access to information and capital is limited.

Anandhi (2010) in his paper "assessing impact of climate change on season length in Karnataka for IPCC SRES scenarios" discuses the uncertainty of season length in Karnataka state, India. The changes in seasons and season length are an indicator in this study. In this study, the seasons are classified based on meteorological variables such as wet and dry seasons based on rainfall; warm and cold seasons based on temperature; windy and non-windy seasons based on wind; and their combinations. The study finds that no distinct cluster could be obtained when the number of seasons was increased beyond three.

The paper by Shashidahra and Reddy (2002) examines the farmer adaptation strategies to climate change in Upper Krishna Project area of Karnataka state. Both primary and secondary data was used for this study. The study finds that awareness of climate change is an important component of farm-level adaptation. The study also reveals that temperature has increased over the years, rainfall is characterized by large inter annual variability with previous three years being very dry. The study also suggested appropriate polices to help farmers adapt the changes in climatic conditions like crop development, improving climate information forecasting, and promoting appropriate farm-level adaptation measures such as use of irrigation technologies. The study by Antle (1995) examines the impacts of climate change on agricultural resources and production with given technology and institutions in developing countries, especially tropical agriculture. This study also analyses the challenging task to predict how agricultural technologies and institutions may evolve over the next thirty, sixty, or one hundred years.

A study by Ashalatha et al(2012) assesses the impacts of drought assesses the impact of drought on the yield of rainfed crops to identify the level of awareness on the climate change and to identify the factors influencing decision making influencing the decision making on the coping mechanisms to mitigate the impacts of climate change. Primary and secondary data were used in this study. The study revealed that the climatic variation as incidence of drought have significant impact on the production of rainfed crops. The small and medium farmers were more vulnerable to climate change and to a larger extent, adopted coping mechanisms for climate change compared to large farmers. It also suggested that as the impacts of climate change are is growing day by day, it should be addressed through policy viewpoint at the earliest to avoid short term effects such as yield and income loss and long-term effects such as suspend agricultural profession by the rainfed farmers.

3.2 Studies on Vulnerability

Through a scan of literature, one could find several research papers in the area of climate change vulnerability. These studies help us in not only identifying important indicators but also help understanding the methodological nuances. Rao et al. (2013) presents the analysis of vulnerability of agriculture to climate change and variability at the district level considering the fact that most of the development planning and programme implementation is done at district level in India. Also, most of the non-climatic data that is integral to assessment of vulnerability to climate change and adaptation planning is also available at district level. The analysis was done for the 572 rural districts as appearing in the 2001 Census of India. The study found that looking at different indicators related to climatic projections also showed some districts where the annual rainfall is likely to increase and the number of rainy days to increase which actually present some opportunities for harvesting more rain water which can be helpful in improving crop production and productivity. The study suggested that there is a need to redesign rain water harvesting structures and strategies to handle higher runoff in a shorter period so that surplus water is harvested while preventing soil loss too. There are also some districts where the incidence of drought is projected to decline. Plans and strategies are therefore to be put in place to optimize crop yields and incomes from such improved situation. Such opportunities can be gainfully harnessed which, will be a significant step towards making Indian agriculture more climate resilient and smart.

The study by Mendelsohn and Dinar (2003) examines the interaction between climate, water and agriculture. This study tests whether surface water withdrawal can help to explain the variation of farm values across the United States and whether adding these variables to the standard 'Ricardian model' changes the measured climate sensitivity of agriculture. It updates the American cross-sectional agricultural studies by using the 1997 U.S. Census of agriculture and takes data on water variables from the U.S. Geological Survey, 1995. A study by O'brien and Mileti (1992) on "Citizen Participation in Emergency Response Following the Loma Prieta Earthquake" examines the vulnerability to climate change and stated that in addition to economic well-being and stability, being important in the resilience of populations to environmental shocks, the structure and health of the population may play a key role in determining vulnerability. Age is an important consideration as the elderly and young persons are inherently more susceptible to environmental risk and hazard exposures. Generally, populations with low dependency ratio and in good health are likely to have the widest coping ranges and thus be least vulnerable in the face of hazard exposures. Further, they also suggest that collective identification may be necessary but not sufficient cause for collective actions in response to disaster.

Handmer et al., (1999) examined the coping mechanisms to environmental shock or hazard brought about by biophysical vulnerability. The factors like institutional stability and strength of public infrastructure are of crucial importance in determining the vulnerability to climate change. A well-connected population with appropriate public infrastructure will be able to deal with a hazard effectively and reduce the vulnerability. Such a society could be said to have low social vulnerability. If there is an absence of institutional capacity in terms of knowledge about the event and ability to deal with it, then such a high vulnerability is likely to ensure that biophysical risk turns into an impact on the human population.

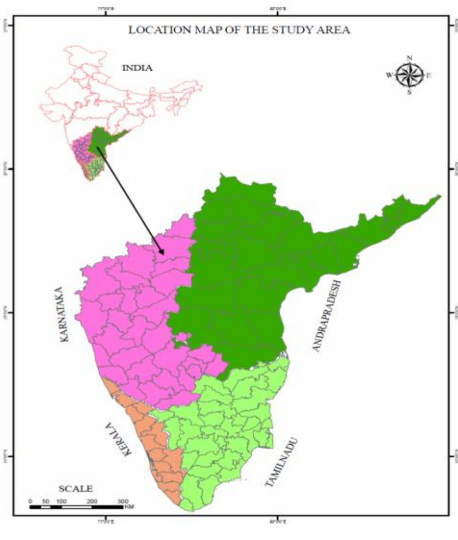
A research work was carried out by Atkins et al. (1998) calculated the methodology for measurement of vulnerability and to construction of a suitable composite vulnerability index for developing countries and island states. The composite vulnerability indices were presented for a sample of 110 developing countries for which appropriate data were available. The index suggests that small states are especially prone to vulnerable when compared to large states. Among the small states, such as Cape Verde and Trinidad and Tobago are estimated to suffer relatively low levels of vulnerability and majority of the states estimated to experience relatively high vulnerability and the states like Tonga, Antigua and Barbedas being more vulnerable to external economic and environmental factors.

A study was conducted by Christopher Easter, (1999) estimates a vulnerability index for the commonwealth countries, which is based on two principles. Firstly, the impact of external shocks over which the country has affected and secondly the resilience of a country to withstand and recover from such shocks. The analysis used a sample of 111 developing countries of which 37 small and 74 large for which relevant data were available. The results indicated that among the 50 most vulnerable countries, 33 were small states with in this 27 are least developed countries and 23 are islands. In the least vulnerable 50 countries, only two were small states.

A study on assessing Indian cities for vulnerability to climate change by Kelkar et al.(2011) critically evaluates the vulnerability of Indian cities to climate change in the context of sustainable development. City-scale indicators are developed for multiple dimensions of security and vulnerability. Factor analysis is employed to construct a vulnerability ranking of 46 major Indian cities. The study reveals that high aggregate levels of wealth do not necessarily make a city less vulnerable, and cities with diversified economic opportunities could adapt better to the new risks posed by climate change than cities with unipolar opportunities. Finally, highly polluted cities are more vulnerable to the health impacts of climate change, and cities with severe groundwater depletion will find it difficult to cope with increased rainfall variability. The study also suggested that the policymaking by fostering greater appreciation of the multi-dimensional aspects of sustainability and vulnerability.

A study conducted by Heltberg and Bonch-Osmolovskiy (2011) on mapping vulnerability to climate change develops a methodology for regional disaggregated estimation and mapping of the areas that are ex-ante the most vulnerable to the impacts of climate change and variability and applies it to Tajikistan, a mountainous country highly vulnerable to the impacts of climate change. They have constructed the vulnerability index as a function of exposure to climate variability and natural disasters, sensitivity to the impacts of that exposure, and capacity to adapt to ongoing and future climatic changes. The study found that vulnerability varies according to socio-economic and institutional development in ways that do not follow directly from exposure or elevation: in climate change, geography is not destiny. And also indicate that urban areas are by far the least vulnerable while RRS oblast, in particular its eastern mountainous areas, is the most vulnerable and the remote GBAO mountains rank in the middle.

Given this scenario, the main objective of this study is to understand and map the vulnerability to climate change across districts of four southern states of India. **Map 1:**



4. Data sources and study region

Four Southern states in India were selected for this study. Map 1 shows the location map of study area. The states include Andhra Pradesh, Tamil Nadu, Karnataka and Kerala. There are 21 indicators used for the construction of vulnerability indices using the data of the period 2011. Out of the 21 indicators, 9 indicators are related to socio-demographic vulnerability, 4 indicators are on occupational vulnerability, 4 indicators deal with agricultural vulnerability and the rest 4 indicators represented the climate and CPR vulnerability component. The data pertaining to various socio-demographic, occupational, agricultural indicators were collected and compiled from different sources, including census in India 2011 and Directorate of Economics and Statistics of respective states governments. Rainfall data was collected from the India Meteorological Department (IMD). Vulnerability is very often reflected in the state of the economic system as well as the socio-economic features of the population living in the system. In order to understand this, we intend to compute vulnerability index covering socio-demographic, occupational, agricultural, climatic and CPR dimensions across various districts and ecosystems in southern states of India. Based on these indicators, we constructed a composite vulnerability index.

5. Methodology

There are several methods for evaluating the level of vulnerability each one having some or other limitation. One of the major limitations arises from the assumptions made about the vulnerability indicators and weightage assigned to those in the aggregate index. Some of these methods for combining the effect of various indicators are presented here along with their limitations.

One of the important and widely used methods is Principal Component Analysis method. This method is generally based on restrictive assumptions regarding the vulnerability indicators. It assumes that the variable indicators are linearly related. When non-linearity is present, the component analysis is not appropriate. Further, one cannot assign any special meaning to the transformed variables with respect to socio-economic vulnerability. They are artificial orthogonal variables not directly identifiable with a particular economic situation. In such situation multiple factor analysis method has advantage. The main advantage of this method is the 'factor loading' that can be used as weights for combining the effects of various indicators. However, this method does not serve the purpose to arrive at a meaningful and comparable composite index of vulnerability when the indicators are presented in different scale of measurements.

Another method known as aggregation method is the simple addition of the values of the vulnerability indicators is taken as composite index of vulnerability. The method is not suitable as the composite index of vulnerability obtained by the use of the method depends on the units in which the data are recorded.

In a monetary index vulnerability indicators are converted into monetary values and total of these values is taken as the composite index of vulnerability. Monetary values of vulnerability indicators may change from place to place and from time to time. In this way this method affects the composite index adversely. One more difficulty may also come in this method because all the indicators cannot be converted into monetary values. Indicators like 'death rate', 'birth rate', 'sex ratio', literacy rate' etc. cannot be converted into monetary values.

In ranking method each unit is allotted ranks based on different vulnerability indicators. Sum of ranks for all the indicators of the unit is taken as the composite index of vulnerability. Ranking procedure does not take into account the magnitude of differences between indicators and units.

Having understood various methods of indexing, availability of types of data and keeping in view the limitations of the above methods, the following procedure for estimation of composite index is followed in this study.

Normalization of indicators using functional relationship:

A normalization procedure was adopted for adjusting indicator values to take the values between 0 and 1 using following formula;

Step 1: The dimension index for each of the indicator for each ecosystem (xi) is computed as

$$X_{ij} = \frac{X_{ij} - MinX_i}{MaxX_i - MinX_i} \qquad (1)$$

Whenever an indicator has negative relationship with vulnerability then the index is calculated as

$$X_{ij} = \frac{Min\, X_i - X_{ij}}{MaxX_i - MinX_i} \qquad (2)$$

This is possible when, for example, higher literacy leads to lower vulnerability.

Where, Xij is the normalized value of vulnerability indicator, X_{ij} is the value of ith vulnerability indicator in the jth block, 'Min Xi and 'Max Xi ' denote to the minimum and maximum value of the ith vulnerability indicator across different ecosystem.

Step 2: Calculate an average index for each of the five sources of vulnerability viz. Socio-demographic, Climatic, Agricultural and Occupational, CPR vulnerability. This is done by taking a simple average of the indicators in each category.

Average Vulnerability Index $(AVI)_i$ = [Indicator 1 +………. + Indicator J] / J (3)

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

$$\text{Composite vulnerability index} = \frac{\left[\sum_{i=1}^{n}(AVI_i)^{\alpha}\right]^{1/\alpha}}{n} \qquad (4)$$

where *n* is the number of sources of vulnerability and $\alpha = n$.The vulnerability indices can be worked out for each period of time and they can be compared to assess the changes in vulnerabilities over the period of time.

6. Mapping the vulnerability in four southern states of India

In this section an attempt is made to understand and map the vulnerability to climate change through a district level analysis. It covers four southern states namely Andhra Pradesh, Tamil Nadu, Karnataka and Kerala. There are 21 indicators used for the construction of vulnerability indices at particular time period of 2011. Out of the 21 indicators, 9 indicators are concerned with socio-demographic vulnerability, 4 indicators are related to occupational vulnerability, 4 indicators deal with agricultural vulnerability and the rest 4 indicators represent the climate and CPR vulnerability. The data pertaining to various socio-demographic, occupational, agricultural indicators were collected and compiled from different sources, like census in India 2011, Directorate of Economics and

Statistics of respective state. Rainfall data was collected from the India Meteorological Department. Vulnerability is often reflected in the state of the economic system as well as the socio-economic features of the population living in the system. In order to understand this we intend to compute vulnerability index covering socio-Demographic, Occupational, Agricultural, Climatic and CPR dimensions across various ecosystems in India. Further, we constructed a vulnerability index of each ecosystem of India. Finally we constructed composite vulnerability index.

6.1 Functional Relationship of Indicators with Vulnerability

The table 1 shows the functional relationship between the indicators and vulnerability. In this study we used the following broadly classified categories namely, socio-economic& demographic, occupational, climatic, CPR and agricultural indicators.

Table: 1-Functional Relationship between Indicators and Vulnerability.

Components	Indicators	Functional Relationship
Socio-Demographic	a) Average HH Size	+
	b) Density of population (persons per sq. km)	+
	c) % of female	+
	d) Growth of Population	+
	e) % of SC Population	+
	f) % of ST Population	+
	g) % Literacy	-
	h) Sex ratio	+
	i) BPL	+
Occupational	a) % of Marginal workers	+
	b) % of Non Workers	+
	c) % of cultivators	-
	d) % of agricultural workers	+
Agricultural	a) Cropping intensity	-
	b) % of irrigation area	-
	c) % of Fallow land	-
	d) % of net sown area	-
Common Property Resources	% OF CPR to TGA	-
	% of animal livestock to CPR	+
Climate change	a) Rain fall variation	+
	b) Drought area	+

Source: prepared by the authors (2013)

The density of population of the district was found to influence its demographic vulnerability and consequently the overall vulnerability to climate change. It was assumed to be positively related to the vulnerability to climate change, *i.e.*, with the increase in the number of persons per sq. km., the vulnerability would increase due to its direct impact on global warming. The literacy rate, on the other hand, was presumed to have a negative functional relationship with demographic vulnerability and thereby, on the overall vulnerability. Literacy rate points out the adaptability of the population to both adverse impacts caused by shocks and the opportunities created. It also implies the proportion of expenditure on education in total public expenditure which indicates investment in human capital.

Similarly, the percentage cropping intensities and the total cropped area and % of rice cultivation area in the district, each of these comprising the agricultural indicators, were also hypothesized to have a negative Influence on the vulnerability to climate change. Climatic vulnerability was assumed to be positively related to the indicators such as variances in annual rainfall. This indicated that any increase in the variability of these climatic indicators would increase the vulnerability of the districts.

7. Results and discussions

7.1 Andhra Pradesh

The District-wise Vulnerability Indices of Andhra Pradesh have been worked out for different districts for socio- demographic and agricultural sector, occupational, climate and common property resources indictor. The districts have been ranked on the basis of vulnerability indices.

The District-wise Vulnerability Indices of Andhra Pradesh along with the rank of the districts are given in Table 2 and depicted in the Map 2. In case of socio-demographic index, Mahabubnagar was found to be the first place in vulnerable districts in the State whereas the district of West Godavari was on the last place. The vulnerability indices varied from 0.5201 to 0.2632. As regards overall occupational vulnerability, the district of Srikakulam was on the first place and the district of Hyderabad was on the last place. The vulnerability indices varied from 0.648 to 0.387.In case of agricultural indictor, Vizianagaram district is placed on the first position and Hyderabad is placed on the last position. The vulnerability indices varied from 0.655 to 0.00. With regards to common property resource indicator, the district of Hyderabad was found to have the first rank in the State whereas the district of Ananthapur was ranked at the last position. The vulnerability indices varied from 1.00 to 0.286. In case of overall climate vulnerability, the district of Karimnagar occupied the first place in the State and the district of Hyderabad was found to be at the last position. The composite indices vulnerability varied from 0.719 to 0.51.

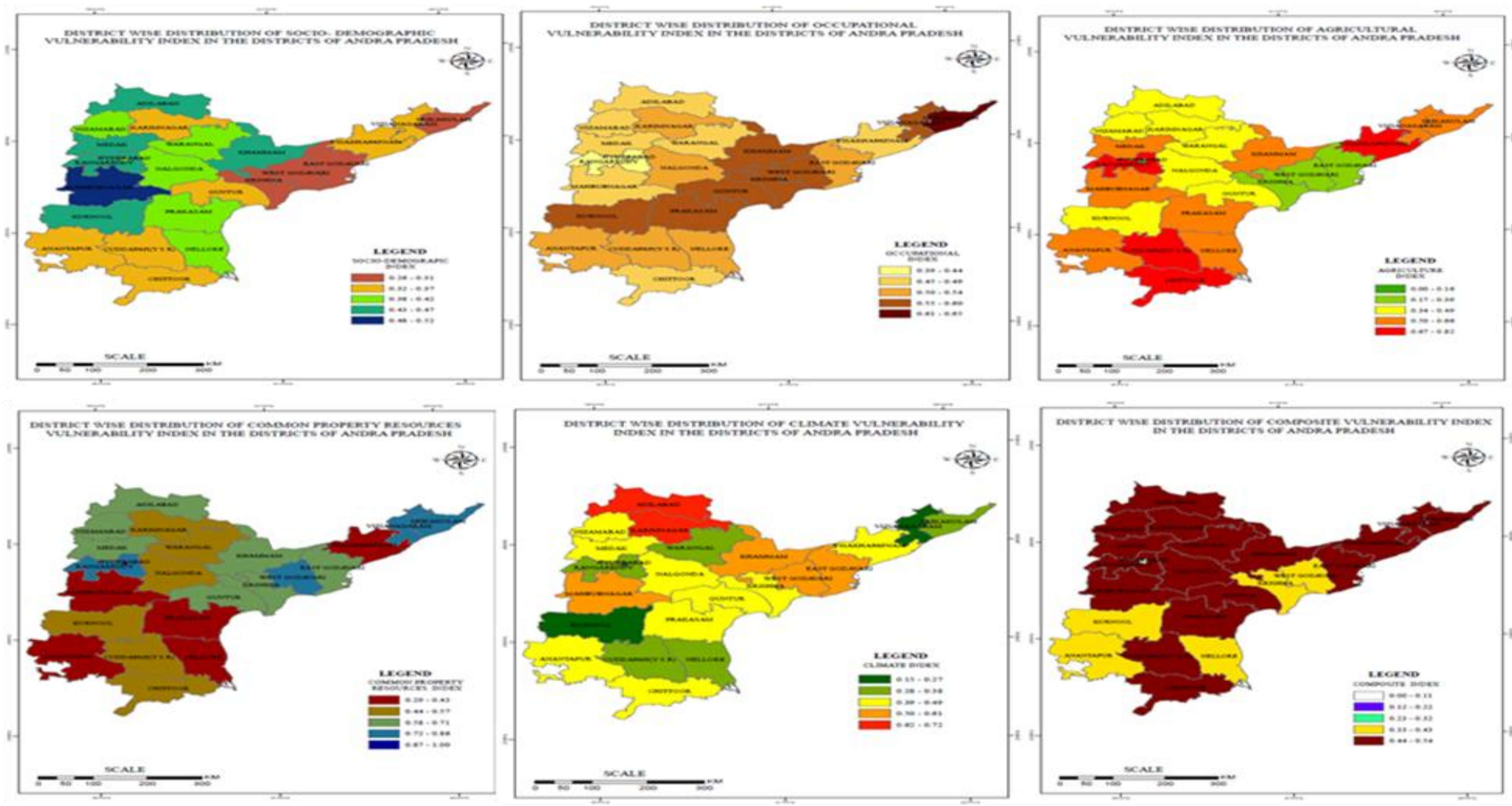
Table-2:District-wise Vulnerability Indices of Andhra Pradesh

District	Socio- Demo Vulnerability Index	Rank	Occupational Vulnerability Index	Rank	Agricultural Vulnerability Index	Rank	CPR Vulnerability Index	Rank	Climate Vulnerability Index	Rank
Adilabad	0.4679	2	0.4594	20	0.441	15	0.71200	6	0.67183	2
Anantapur	0.3651	13	0.5334	10	0.573	7	0.28654	23	0.40597	12
Chittoor	0.3337	18	0.4410	21	0.707	2	0.47809	16	0.39317	14
East Godavari	0.2768	21	0.5290	12	0.304	20	0.70780	7	0.51601	5
Guntur	0.3357	17	0.5561	7	0.349	19	0.62356	11	0.38333	15
Hyderabad	0.3765	12	0.3872	23	0.000	23	1.00000	1	0.15196	23
Karimnagar	0.3391	16	0.5156	13	0.350	18	0.54181	13	0.71911	1
Khammam	0.4223	5	0.5836	2	0.521	10	0.58297	12	0.56297	4
Krishna	0.2671	22	0.5652	4	0.290	21	0.70738	8	0.47573	8
Kurnool	0.4617	3	0.5646	5	0.420	16	0.51897	14	0.19293	22
Mahbubnagar	0.5201	1	0.4785	17	0.629	6	0.35188	22	0.50000	6
Medak	0.4607	4	0.4651	19	0.509	12	0.67104	10	0.40615	11
Nalgonda	0.3877	10	0.5416	9	0.467	13	0.44888	18	0.40444	13
Nizamabad	0.4071	7	0.4861	16	0.395	17	0.69511	9	0.47865	7
Prakasam	0.4029	8	0.5636	6	0.572	8	0.39330	19	0.47397	10
Rangareddy	0.4203	6	0.4002	22	0.824	1	0.74909	5	0.36123	16
SPSR Nellore	0.3783	11	0.5329	11	0.515	11	0.39024	20	0.29751	20
Srikakulam	0.3092	20	0.6482	1	0.563	9	0.76719	3	0.33073	18
Visakhapatnam	0.3237	19	0.4720	18	0.663	4	0.36782	21	0.47498	9
Vizianagaram	0.3473	14	0.5552	8	0.655	5	0.78557	2	0.25475	21
Warangal	0.3995	9	0.4867	15	0.450	14	0.51887	15	0.34248	17
West Godavari	0.2632	23	0.5750	3	0.183	22	0.75932	4	0.57565	3
Y.S.R.	0.3429	15	0.4960	14	0.680	3	0.47797	17	0.32714	19

Source: 1. Census of India, 2011.
2. Directorate of economics and statistical organization of Andhra Pradesh
3. Meteorology Departments of India

Map 2:

Mapping District-wise Vulnerability Indices of Andhra Pradesh



Having looked at District-wise Vulnerability Indices of Andhra Pradesh, now we will turn to the composite indices of vulnerability have been worked out for different district' in Andhra Pradesh. The composite indices of vulnerability along with the district ranks are given in the Table 3. The districts have been ranked on the basis of vulnerability indices. The Table 3 shows that the rank 1 shows most vulnerable district and the vulnerability decreases as we go on increasing the rank. In Andhra Pradesh, Adilabad district is the most vulnerable district when we calculate the composite index of a few important indicators such as Socio- demographic and occupational, agricultural and climatic, CPR indicators. According to the composite vulnerability index, Hyderabad is the least vulnerable district of Andhra Pradesh. The composite indices of vulnerability varied from 0.538 to 0.00

Table-3: Composite index of Vulnerability across Districts of Andhra Pradesh

District	Composite Vulnerability Index	Rank
Adilabad	0.53866	1
Khammam	0.53084	2
Rangareddy	0.51852	3
Medak	0.49494	4
Srikakulam	0.49127	5
Mahbubnagar	0.48753	6
Nizamabad	0.48192	7
Vizianagaram	0.47926	8
Prakasam	0.47508	9
Karimnagar	0.47379	10
Chittoor	0.45526	11
Y.S.R.	0.44823	12
Nalgonda	0.44682	13
Visakhapatnam	0.44622	14
East Godavari	0.43867	15
Guntur	0.43502	16
Warangal	0.43483	17
Krishna	0.43010	18
Anantapur	0.41950	19
West Godavari	0.41372	20
Nellore	0.41323	21
Kurnool	0.40539	22
Hyderabad	0.00000	23

Source: 1. Census of India, 2011.
2. Directorate of economics and statistical organization of Andhra Pradesh.
3. Meteorology Departments of India

7.2 Karnataka

The district-wise indices of vulnerability have been worked out for different districts for socio- economic indicators, occupational indicators, and agricultural sector, CPR, and climate change indicators. The districts have been ranked on the basis of vulnerability indices. The districts-wise indices of vulnerability in Karnataka along with the rank of the district are given in Table 4 and depicted in Map 3.

Table-4: Districts wise indices of vulnerability in Karnataka

District	Socio- Demographic Vulnerability Index	Rank	Occupational Vulnerability Index	Rank	Agricultural Vulnerability Index	Rank	Climate Vulnerability Index	Rank	CPR Vulneralability Index	Rank
Bagalkot	0.4804	12	0.5147	17	0.6564	4	0.6607	4	0.5261	22
Bangalore	0.3788	24	0.4319	29	0.6090	7	0.2838	24	0.9470	1
Bangalore Rural	0.4147	17	0.7478	1	0.5571	13	0.9079	1	0.9079	3
Belgaum	0.4058	19	0.4662	22	0.4209	26	0.1971	29	0.4417	25
Bellary	0.5882	3	0.5268	14	0.5447	16	0.3552	19	0.4453	24
Bidar	0.5421	4	0.5293	13	0.5168	19	0.6534	5	0.6534	18
Bijapur	0.4783	13	0.4966	19	0.3828	28	0.2654	25	0.7031	15
Chamarajanagar	0.5266	7	0.6142	4	0.5540	15	0.7070	3	0.8060	7
Chikkaballapura	0.5046	9	0.6732	2	0.3347	29	0.6384	6	0.6384	19
Chikmagalur	0.3824	23	0.5194	16	0.5134	20	0.3016	23	0.7364	10
Chitradurga	0.5359	5	0.6055	5	0.5751	10	0.3917	13	0.3803	27
Dakshina Kannada	0.2786	30	0.4719	21	0.5245	18	0.5861	7	0.8114	6
Davanagere	0.4834	11	0.5252	15	0.4964	21	0.3029	22	0.6981	16
Dharwad	0.3764	25	0.4508	27	0.5370	17	0.3567	18	0.8248	5
Gadag	0.4275	15	0.5530	10	0.4331	24	0.2275	27	0.7812	9
Gulbarga	0.5254	8	0.5410	11	0.3236	30	0.4845	9	0.7081	14
Hassan	0.3910	21	0.4511	26	0.6063	8	0.5277	8	0.6265	20
Haveri	0.4222	16	0.5561	9	0.5957	9	0.3434	20	0.5504	21
Kodagu	0.3565	27	0.4931	20	0.6227	6	0.2600	26	0.7268	11
Kolar	0.4885	10	0.6384	3	0.6294	5	0.3723	17	0.3723	28
Koppal	0.5313	6	0.6041	6	0.5596	12	0.3811	16	0.7240	12
Mandya	0.3881	22	0.4611	23	0.6836	2	0.3882	15	0.6818	17
Mysore	0.4615	14	0.4606	24	0.4304	25	0.4523	11	0.5147	23

Raichur	0.6163	2	0.5827	7	0.5570	14	0.1353	30	0.4381	26
Ramanagara	0.3945	20	0.3896	30	0.4762	23	0.8032	2	0.8032	8
Shimoga	0.3675	26	0.4976	18	0.3967	27	0.3268	21	0.8337	4
Tumkur	0.4099	18	0.5353	12	0.5620	11	0.4381	12	0.3567	29
Udupi	0.3057	28	0.4341	28	0.4814	22	0.2038	28	0.9247	2
Uttara Kannada	0.2922	29	0.4548	25	0.6716	3	0.4829	10	0.7086	13
Yadgir	0.6463	1	0.5770	8	0.7030	1	0.3889	14	0.2829	30

Source: 1. Census of India, 2011.
2. Directorate of economics and statistical organization of Karnataka
3. Meteorology Departments of India

Map 3:

Mapping District-wise Vulnerability Indices of Karnataka

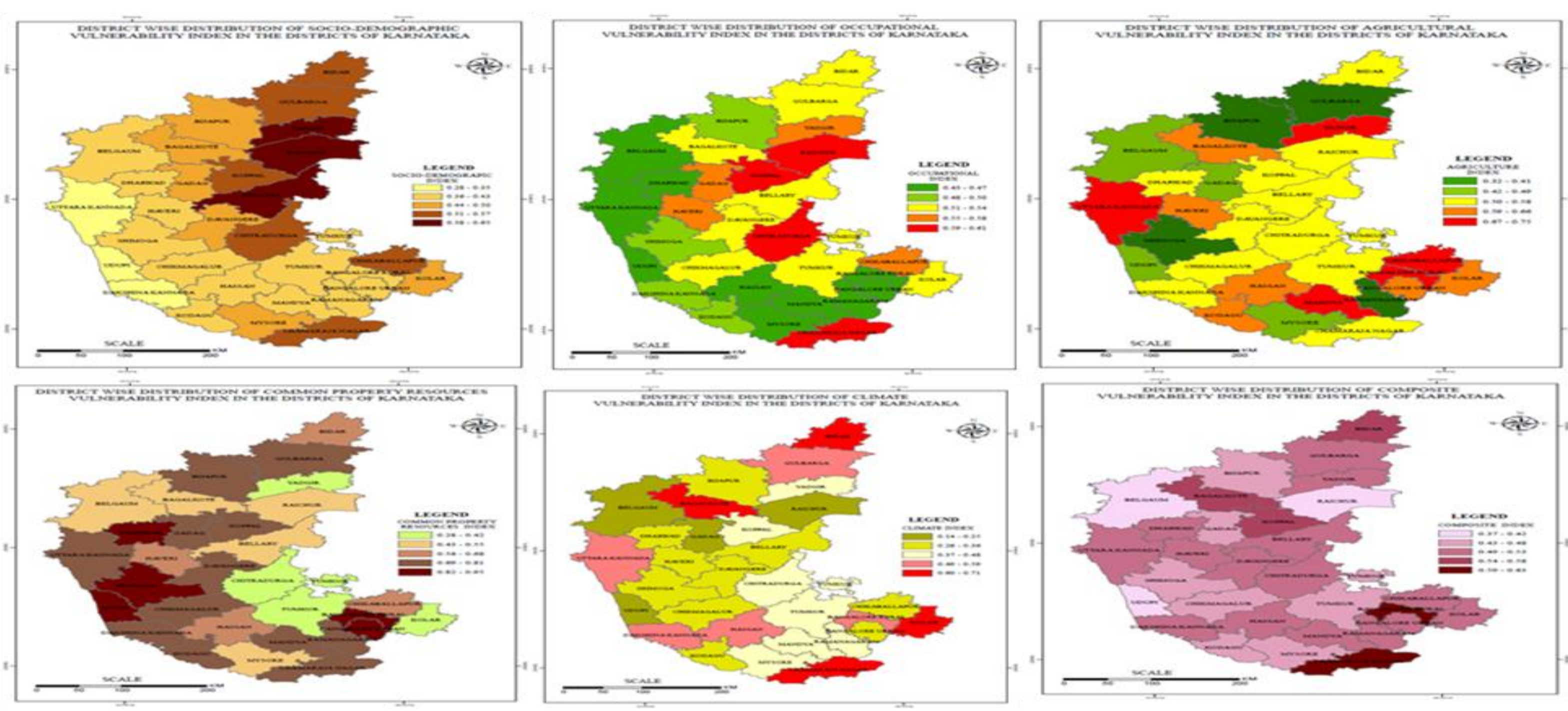


Table-5: Districts wise indices of composite vulnerability Index in Karnataka.

Districts	Composite Vulnerability Index	Rank
Chamarajanagar	0.6336	1
Bangalore Rural	0.5908	2
Bidar	0.5758	3
Bagalkot	0.5627	4
Koppal	0.5483	5
Chikkaballapura	0.5271	6
Kolar	0.5210	7
Hassan	0.5125	8
Dakshina Kannada	0.5049	9
Mandya	0.5036	10
Gulbarga	0.5010	11
Uttara Kannada	0.4977	12
Yadgir	0.4920	13
Chitradurga	0.4884	14
Dharwad	0.4849	15
Bangalore	0.4848	16
Bellary	0.4845	17
Davanagere	0.4843	18
Haveri	0.4836	19
Ramanagara	0.4835	20
Chikmagalur	0.4688	21
Mysore	0.4631	22
Kodagu	0.4604	23
Shimoga	0.4562	24
Tumkur	0.4539	25
Gadag	0.4487	26
Bijapur	0.4425	27
Udupi	0.4132	28
Raichur	0.4119	29
Belgaum	0.3700	30

Source: 1. Census of India, 2011.
2. Directorate of economics and statistical organization of Karnataka
3. Meteorology Departments of India

It may be seen from the table-4 that in the case of socio- economic vulnerability index, the district of Yadgir is ranked first and the district of Dakshina Kannada is ranked last. The indices of vulnerability differ from 0.278 to 0.646. With respect to occupational indicators, the district of Chitradurga is found to occupy the first position and the district of Bangalore is on the last place. The districts wise indices of vulnerability vary from

0.431 to 0.605. As regards agricultural indictors, the district of Bagalkot is on the first place and Shimoga is on the last place. The vulnerability indices vary from 0.397 to 0.656. On the other hand, the district of Chamarajanagar is first place and Raichur district is last position under climate indictor. The vulnerability indices vary from 0.135 to 0.707. Finally, in the case of common property resources, the district of Udupi is on the first position and Yadgir is on the last place. The district-wise indices of vulnerability vary from 0.282 to 924.

Apart from this, the district-wise composite indices of vulnerability have been worked out for different districts for socio- economic indicator, occupational indicators, agricultural sector, CPR, and climate change indicators. Higher the districts index more will be a level of vulnerability. The districts have been ranked on the basis of vulnerability indices. The districts-wise indices of vulnerability in Karnataka along with the rank of the district are given in Table 5. According to composite vulnerability index, the district of Chamarajanagar was to be placed on first position that of Belgaum district was placed on last position. The composite vulnerability index values differed from 0.633 to 0.3700.

7.3 Tamil Nadu

Vulnerability is often reflected in the state of the economic system as well as the socio-economic features of the population living in that system. By considering climate change relevant parameters, vulnerability index at district level was computed based on the following dimensions: Socio-Demographic, Occupational, Agricultural, Climatic and CPR etc. The index attempts to capture a comprehensive scale of vulnerability by including important indicators that serve as proxies. The District-wise Vulnerability Indices of Tamil Nadu along with the rank of the districts are given in Table 6 and depicted in the Map 4.

In the case of Socio-demographic Vulnerability Index, The district of Viluppuram was placed first rank and Kanniyakumari district was placed last position. The value of vulnerability indices varied from 0.217 to 0.634. According to Occupational Vulnerability Index, the Theni district was occupied to have first rank and that of district of Perambalur was noticed last position. The value of vulnerability indices varied from 0.453 to 0.637. The district of Virudhunagar was placed first position and district of Tiruppur was placed at last position with respective of Agricultural Vulnerability Index. The values of vulnerability indices differ from 0.134 to 0.683. As per the Common Property Resources Vulnerability Index, Chennai district was placed first rank and that of Tirunelveli district was paced last rank. The index values of vulnerability vary from 0.037 to 0.961.Under Climate Vulnerability Index, the first place was occupied by Nagapattinam district and that of Thoothukkudi district was placed at last position .the value of vulnerability indices vary from 0.025 to 0.829.

Table-6: Districts wise indices of vulnerability in Tamil Nadu

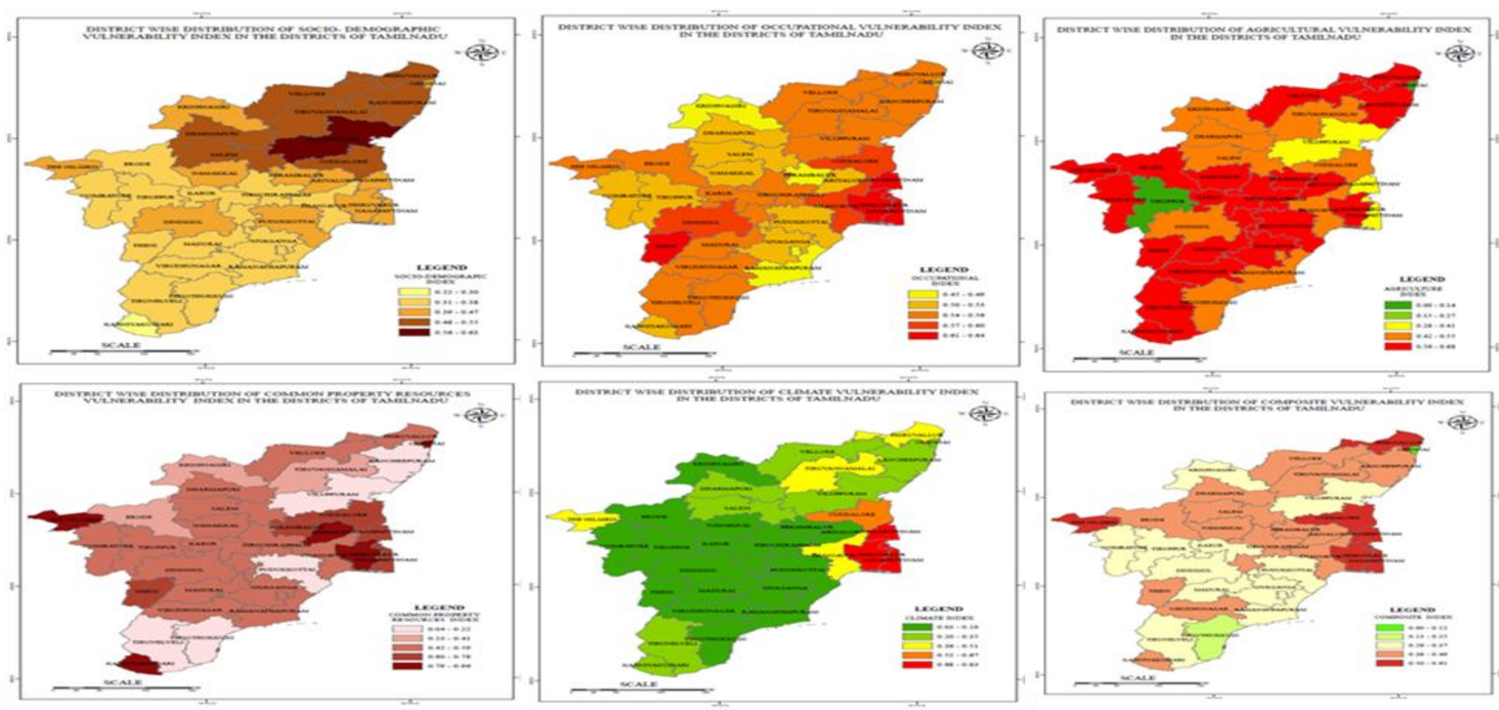
District	Socio- Demographic Vulnerability Index	Rank	Occupational Vulnerability Index	Rank	Agricultural Vulnerability Index	Rank	Common Property Resources Vulnerability Index	Rank	Climate Vulnerability Index	Rank
Ariyalur	0.3969	13	0.5149	23	0.5469	19	0.8802	4	0.1811	17
Chennai	0.3867	18	0.5000	28	0.0000	32	0.9612	1	0.3008	10
Coimbatore	0.3402	25	0.5243	20	0.6270	6	0.5382	15	0.0607	30
Cuddalore	0.4861	6	0.5823	4	0.4249	27	0.6301	8	0.5797	3
Dharmapuri	0.5165	3	0.4947	29	0.5385	20	0.5879	10	0.2930	11
Dindigul	0.4003	12	0.5670	6	0.5154	22	0.5266	16	0.0926	28
Erode	0.3260	27	0.5321	16	0.6705	2	0.3822	26	0.1562	21
Kancheepuram	0.5154	4	0.5283	18	0.5810	13	0.2126	28	0.3370	8
Kanniyakumari	0.2178	32	0.5243	21	0.6019	9	0.8859	3	0.2903	12
Karur	0.3619	20	0.5467	12	0.6041	8	0.5829	11	0.0556	31
Krishnagiri	0.4611	9	0.4770	30	0.5003	25	0.2840	27	0.1582	20
Madurai	0.3412	24	0.5565	8	0.5732	15	0.4907	21	0.1021	26
Nagapattinam	0.3943	15	0.6163	2	0.3625	30	0.6048	9	0.8298	1
Namakkal	0.4245	11	0.5118	25	0.5672	16	0.5763	12	0.1819	16
Perambalur	0.4261	10	0.4530	32	0.5840	12	0.6881	7	0.1704	18
Pudukkottai	0.3952	14	0.5056	26	0.5617	17	0.1321	29	0.1278	24
Ramanathapuram	0.3698	19	0.4548	31	0.4800	26	0.5171	17	0.0715	29
Salem	0.4803	8	0.5181	22	0.5043	24	0.4318	24	0.3099	9
Sivaganga	0.3455	23	0.5018	27	0.6366	5	0.4980	19	0.0979	27
Thanjavur	0.3515	21	0.5750	5	0.4202	28	0.5514	13	0.4702	5
The Nilgiris	0.3942	16	0.5516	10	0.6041	7	0.9353	2	0.4919	4
Theni	0.3259	28	0.6377	1	0.5798	14	0.7566	6	0.1692	19
Thiruvallur	0.4868	5	0.5348	15	0.5967	10	0.4738	23	0.4351	6
Thiruvarur	0.3930	17	0.6139	3	0.6640	4	0.7778	5	0.7025	2
Thoothukkudi	0.3015	31	0.5559	9	0.5122	23	0.0760	31	0.0257	32
Tiruchirappalli	0.3480	22	0.5365	14	0.5592	18	0.4921	20	0.1491	22

Tirunelveli	0.3268	26	0.5479	11	0.6684	3	0.0374	32	0.2131	15
Tiruppur	0.3162	29	0.5147	24	0.1343	31	0.5000	18	0.1454	23
Tiruvannamalai	0.5176	2	0.5295	17	0.5267	21	0.3917	25	0.3659	7
Vellore	0.4839	7	0.5278	19	0.5898	11	0.4822	22	0.2307	14
Viluppuram	0.6344	1	0.5579	7	0.3671	29	0.1195	30	0.2684	13
Virudhunagar	0.3131	30	0.5429	13	0.6833	1	0.5482	14	0.1075	25

Source: 1. Census of India, 2011.
2. Directorate of economics and statistical organization ofTamil Nadu
3. Meteorology Departments of India

Map 4:

Mapping District-wise Vulnerability Indices of Tamil Nadu



After having close look at district-wise vulnerability index, now we will examine the composite vulnerability index for District wise in Tamil Nadu (Table7). The district of Thiruvarur was occupied the first rank and the district of Thoothukkudi was placed at last position. The composite index of vulnerability varied from 0.614 to 0.175.

Table-7: Districts wise indices of composite vulnerability Index in Tamil Nadu

Districts	Composite Vulnerability Index	Rank
Thiruvarur	0.614383	1
The Nilgiris	0.570518	2
Nagapattinam	0.53591	3
Cuddalore	0.535249	4
Thiruvallur	0.502448	5
Dharmapuri	0.473122	6
Thanjavur	0.466168	7
Tiruvannamalai	0.460405	8
Ariyalur	0.446843	9
Kanniyakumari	0.446152	10
Salem	0.44158	16
Vellore	0.441424	15
Theni	0.434165	14
Perambalur	0.420939	13
Namakkal	0.419034	11
Kancheepuram	0.408233	12
Tiruchirappalli	0.377471	27
Erode	0.370102	26
Virudhunagar	0.369052	25
Dindigul	0.355839	24
Madurai	0.352669	23
Sivaganga	0.351659	22
Krishnagiri	0.345804	2
Viluppuram	0.334139	20
Karur	0.329344	19
Coimbatore	0.32553	18
Ramanathapuram	0.312594	17
Pudukkottai	0.285446	29
Tiruppur	0.275561	28
Tirunelveli	0.248767	30
Thoothukkudi	0.175753	31
Chennai	0.000000	32

Source: 1. Census of India, 2011.
2. Directorate of economics and statistical organization ofTamil Nadu
3. Meteorology Departments of India

7.4 Kerala

The district-wise indices of vulnerability in respect of socio- economic, occupational, agricultural, common property resources and climate change indictors have been calculated for about 14 districts belonging to the Kerala state given in the Table 8 and depicted in the Map 5. It would be interest to examine level of vulnerability separately for different districts.

The district of Malappuram was found to occupy the first place, whereas the district of Pathanamthitta was on the last position in respect of socio-economic vulnerability. The indices of vulnerability are varied from 0.265 to 0.621. In terms of occupational vulnerability index, the district of Palakkad was ranked first and the district of Kottayam was ranked last. The value of vulnerability indices varied from 0.480 to 0.589. With regard to agricultural vulnerability index, the district of Ernakulam was found to have the first rank in the State whereas the district of Palakkad was ranked at the last position. The value of vulnerability indices varied from 0.214 to 0.752. In the matter of the common property resources vulnerability index, the district of Wayanad occupied the first place in the State and that of Kottayam district was found to be at the last position. The value of vulnerability indices varied from 0.180 to 0.958. As per the climate change vulnerability index, the district of Idukki stood at first place and the district of Kollam was placed at last position. The value of vulnerability indices varied from0.246 to 0.854.

The composite index of vulnerability is worked out for different district' in Kerala. The composite indices of vulnerability were worked out based on 25 indicators representing such as Socio- demographic and occupational, agricultural and climatic, CPR indicators. The composite indices of vulnerability along with the district ranks are given in Table.9. The districts have been ranked on the basis of vulnerability indices. The Table 9 shows that the rank 1 shows most vulnerable district and the vulnerability decreases as we go on increasing the rank. In Kerala, Kasaragod district is the most vulnerable district in the state of Kerala. As far as the composite vulnerability index, Kottayam is the least vulnerable district of Kerala. The composite indices of vulnerability differed from 0.560 to 0.375.

Table-8: Districts wise indices of vulnerability in Kerala

Districts	Socio-Demographic Vulnerability Index	Rank	Occupational Vulnerability Index	Rank	Agricultural Vulnerability Index	Rank	Common Property Resources Vulneralability Index	Rank	Climate Vulnerability Index	Rank
Alappuzha	0.42238	9	0.519	3	0.5056	7	0.4739	9	0.3467	10
Ernakulam	0.38968	10	0.488	11	0.7525	1	0.4053	10	0.7782	2
Idukki	0.34798	12	0.488	11	0.4641	10	0.3057	13	0.8547	1
Kannur	0.37844	11	0.514	4	0.4373	11	0.5110	6	0.4809	8
Kasaragod	0.44716	8	0.495	10	0.5386	5	0.8152	3	0.5715	4
Kollam	0.46282	6	0.496	9	0.5395	4	0.3830	11	0.2464	13
Kottayam	0.32345	13	0.480	13	0.5021	8	0.1808	14	0.5261	5
Malappura	0.64215	1	0.511	5	0.4729	9	0.5043	7	0.4038	9
ozhikode	0.47994	4	0.507	7	0.4036	12	0.5169	5	0.5016	7
Palakkad	0.54582	2	0.589	1	0.2141	14	0.6671	4	0.0000	14
Pathanamt	0.25293	14	0.481	12	0.5767	3	0.9348	2	0.3336	12
Thiruvana	0.51949	3	0.510	6	0.5098	6	0.5001	8	0.3350	11
Thrissur	0.46636	5	0.497	8	0.6443	2	0.3498	12	0.7600	3
Wayanad	0.44743	7	0.540	2	0.3991	13	0.9589	1	0.5161	6

Source: 1. Census of India, 2011.
2. Directorate of economics and statistical organization of Kerala
3. Meteorology Departments of India

Map 5:

Mapping District-wise Vulnerability Indices of Kerala

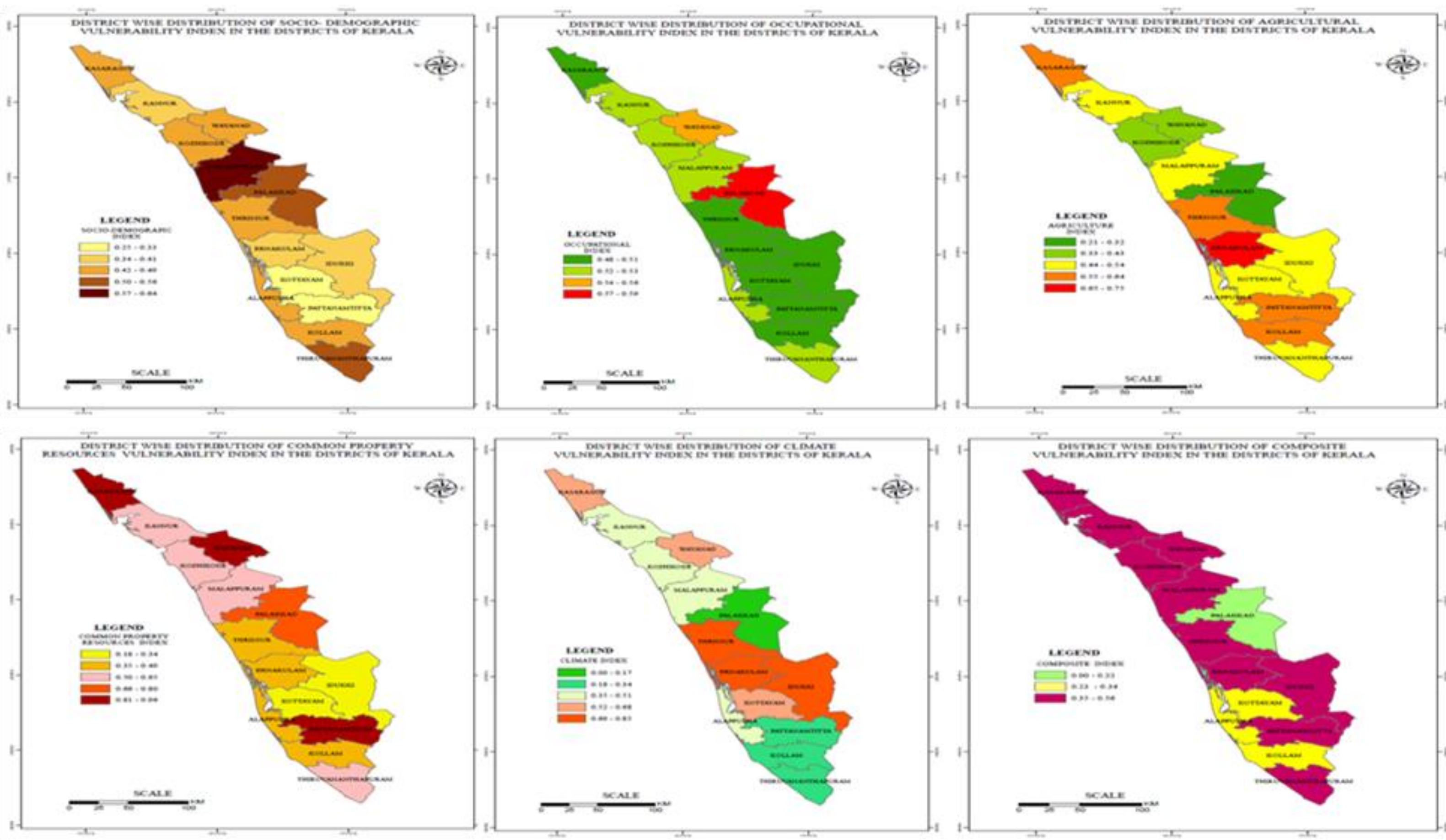


Table-9: Indices of Composite vulnerability index in Kerala

Districts	Composite Vulnerability Index	Rank
Kasaragod	0.560989	1
Wayanad	0.544202	2
Ernakulam	0.538062	3
Thrissur	0.524509	4
Malappuram	0.50105	5
Kozhikode	0.479978	6
Thiruvananthapuram	0.468728	8
Pathanamthitta	0.465574	7
Kannur	0.461307	9
Idukki	0.46009	10
Alappuzha	0.448748	11
Kollam	0.41076	12
Kottayam	0.374984	13
Palakkad	0.0000	14

Source: 1. Census of India, 2011.
2. Directorate of economics and statistical organization of Kerala
3. Meteorology Departments of India

8. Conclusion

This work would attempt to understand and analyze the vulnerability due to climate change across different ecosystems at the most possible decentralized level. We examined the vulnerability through four different Sub-indicator of socio-demographic, agriculture, occupational, CPR and climate in respective states among different districts. In order to capture the vulnerability from four different states the composite vulnerability index (CVI) was developed and used. This indicates the vulnerability situation of different districts in four states. Having done this, it is important to understand the coping mechanism among the population to such vulnerability. This calls for micro level study in such vulnerable environment. We have plans to do the study at primary level keeping the vulnerable districts across different agro-eco system in mind.

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