CONSTRUCTION OF COMPOSITE VULNERABILITY INDEX: A DISTRICT-WISE ANALYSIS FOR KARNATAKA STATE, INDIA

Jyoti Nair (Research Intern)*

Kaiser Manzoor (Research Associate)*

Sunil Nautiyal (Associate Professor)*

Abstract

Karnataka is one among the states in India likely to be impacted seriously by climate change due to its heavy reliance on monsoon-dependent rain-fed agriculture (80% of cropland), frequent occurrence of drought and floods, monsoon-dependent seasonal flow of the rivers, large coastal fishing community and biodiversity-rich Western Ghats. Therefore, with the help of the current research work, we have developed district-wise vulnerability for a broader assessment of climate change impacts in Karnataka.

* Institute for Social and Economic Change (ISEC), Bangalore

Introduction

Index calculation is a method to measure complex sub-systems with which a single number is assigned to represent them such that it is easier to comprehend and helps better policy decision making through quantitative representation of the concept. Vulnerability is a complex concept which encompasses the interaction of a social (or human) and an ecological (or environmental) sub-system (Hinkel 2011). The IPCC Third Assessment Report (TAR) referring to climate change describes vulnerability as "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Here, Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity." (IPCC 2001: p 995). Vulnerability indicators are often employed to bridge the gap between academic work and political need. Vulnerability indicator can be defined as a variable which is an operational representation of a characteristic or quality of a system able to provide information regarding the susceptibility, coping capacity and resilience of a system to an impact of albeit ill-defined event linked with a hazard of natural origin (Birkmann 2006). It helps to formulate the complex phenomena into a single number (Vincent 2004) which can be easily understood by a non-expert. Important to note is that the vulnerability evaluated by the index can also be time independent (Hinkel 2011), in which case is unable to measure the dynamic processes (Vincent 2004). In case of socio-ecological systems where the human interface of the system is at focus, healthy economic conditions act as a safety net in the case of environmental stresses and shocks, through anticipatory coping strategies such as insurance and post-event response to a shock Vulnerability includes (Vincent 2004):

Area Profile

Karnataka is located between 11°30' North and 18°30' North latitude and 74° East and 78° East longitude. Karnataka has a total area of 1,91,791 sq km and accounts for 5.83% of the total area of the country. The state is situated on a tableland where the Western and Eastern Ghats converge into the Nilgiri hill complex in the Deccan Plateau region of India. Karnataka is bound by Maharashtra and Goa states in the West, by Kerala and Tamil Nadu in the South and by Andhra Pradesh in the East. Karnataka has one of the highest average elevations at 1,500 feet. The population density which stands at 319 persons per sq km is considerably lower than the

national average of 382 as per 2011 census. Based on physiographic features Karnataka can be divided into four regions: 1) The Coastal region, 2) The Malnad (hilly) region, 3) The Northern plateau and 4) The Southern plateau. The state observes diverse climates from arid to semi-arid in the plateau regions, sub-humid to humid tropical in the Ghats and humid tropical monsoon climate in the west coast plains due to geographic and physiographic characteristics. About 77% of the total geographical area of the state, covering its interior part,is arid or semi-arid with the state contributing 15% of the total semi-arid or 3% of the total arid areas of the country. Karnataka experiences typical tropical climate comprising four distinct seasons in the year: winter (January to February), summer (March to May), monsoon (June to September), and post-monsoon (October to December). Agriculture is the mainstay of the people in the state. Cultivators and agricultural labourers form about 56 per cent of the workforce (2001 census)[1]. Karnataka is divided in to 10 agro-climatic zones 64.6% of the total geographical area of the state is under cultivation and farmers and agricultural labourers account to more than half of the total workforce of Karnataka. Agriculture in the state is characterised by wide crop diversification. Out of the net area sown, only 25 per cent is irrigated. According to the Karnataka State Action Plan on Climate Change[2], 2011, northern districts of the state are likely to have more drought incidences in the coming future. Food production in the state is largely dependent upon the annual precipitation.

IJMRA

[1] (Karnataka State Action Plan on Climate Change, 2011)(State of Environment Report Karnataka. 2010)(Karnataka Human Development Report, 2005)

[2] Karnataka State Action Plan on Climate Change, 2011. Draft Report(September 17, 2011), Environmental Management and Policy Research Institute, The Energy Resource Institute, Bangalore, India

North-Eastern Transition Zone
North-Eastern Dry Zone
Northern Dry Zone
Central Dry Zone
Eastern Dry Zone
Southern Dry Zone
Southern Transition Zone
Northern Transition zone
Hilly Zone
. Coastal Zone

Figure 1: Agro-climatic Zones of Karnataka (source Karnataka State Action Plan on Climate Change, 2011)

Some of the reasons for decline of agriculture in the state as included in the State of Environment Report[3] for the state include i) Shrinking Land-Man Ratio, ii) Depleting vegetation cover, iii) Inadequate and unpredictable water resources, iv) High dependence on rainfall, and v) Increasing cost of production. Scientific studies[1] indicate that agriculture is the most vulnerable sector to climate change. Water[1] resources of Karnataka have been under extreme pressure due to increasing demand. Agriculture being the largest consumer of water resources is one of the essential economical activities of the state. The state puts development of irrigation facilities on priority in order to enhance agricultural production as well as the livelihood of rural poor. The rapid urbanisation of the state also challenges government to ensure safe supply of potable water to its citizens. Recent trends have indicated that the water quantity available to meet such demands is depleting over decades. There is social, bio-physical and economic diversity in

[3] State of Environment Report Karnataka. 2010. Pre-submission draft (April 6, 2011) Environmental Management and Policy Research Institute, Bangalore, India

Karnataka. It is necessary that the vulnerability of the natural environment to the projected change is connected with the social system. Since the natural environment is sensitive to the perceived changes, it is necessary to equip the society against the impact. The diverse nature in Karnataka makes it susceptible to the projected environmental changes due to climate change. Thus, to enhance preparedness it is necessary to understand the present capacity of the society to adapt. If the population characteristics are low economic status, low institutional capacity and heavy dependence on natural resources it results in poor preparedness and thus the subsequent impacts are likely to be high (Vincent 2004).

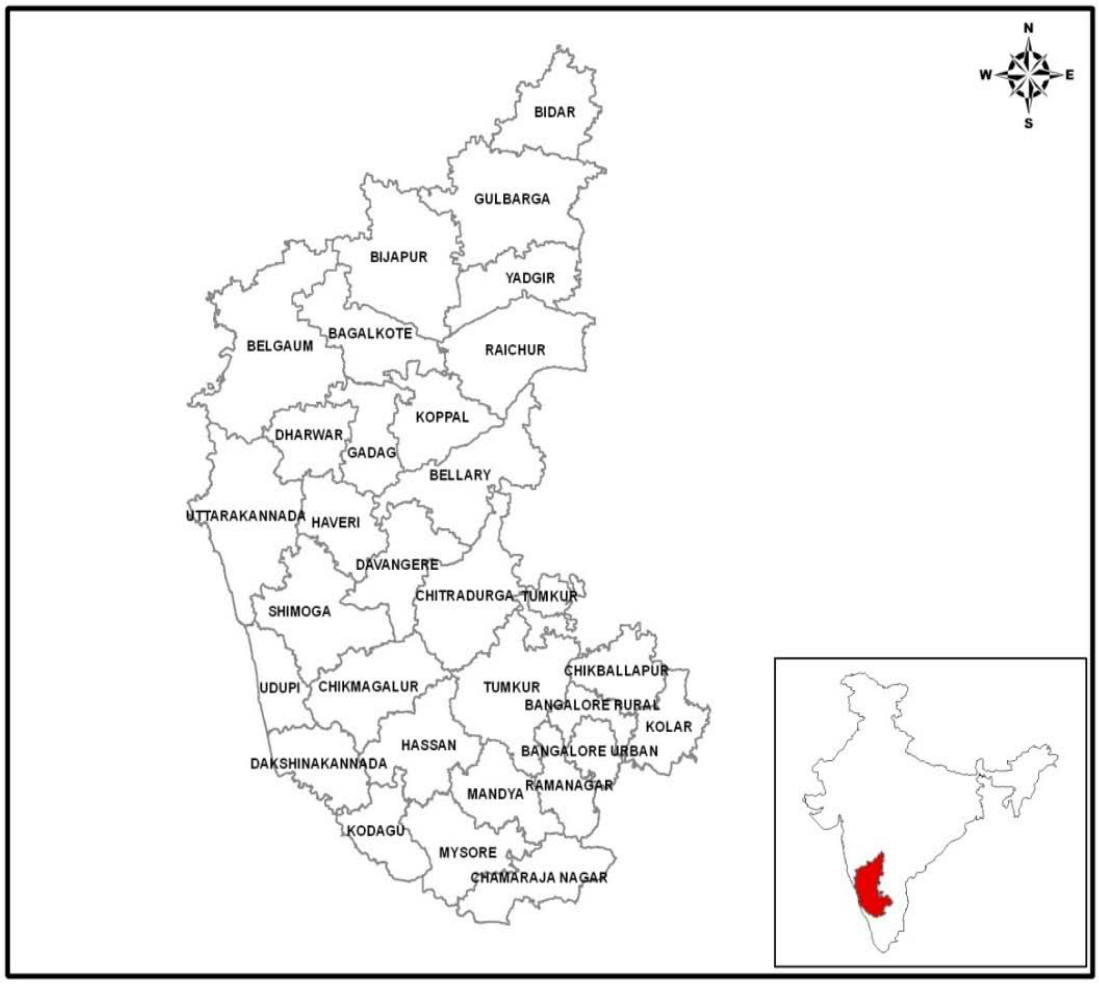

Figure 2: Map of Karnataka indicating all districts

Methodology

The methodology is broadly adopted from the OECD Handbook on construction of composite index. The OECD (Organisation of Economic Cooperation and Development) is a unique forum where the governments of 30 democracies work together to address the economic, social and environmental challenges of globalisation. Composite indicators (CIs) which compare country performance are increasingly recognised as a useful tool in policy analysis and public communication. The numbers of CIs in existence around the world are growing year after year (for a recent review see Bandura 2006, which cites more than 160 composite indicators). Such composite indicators provide simple comparisons of countries that can be used to illustrate complex and sometimes elusive issues in wide-ranging fields, *e.g*., environment, economy, society or technological development (Handbook OEC 2008).

Selection of indicators

Driving force-Pressure-State-Impact-Response Framework is applied for the selection of the set of indicators. According to the DPSIR framework, social and economic developments are driving forces that exert pressure on the environment, which leads to changes in the state of the environment. In turn, these changes lead to impacts on human health, ecosystems and materials that may elicit a societal response that feeds back on the driving forces, pressures, or on the state or impacts directly (Niemeijer & de Groot 2006, Omann *et al* 2009).

Building causal network to assess relationship between indicators

Generally for the selection of the indicators, the individual characteristics of the indicators are taken or they are chosen according to expert judgements, ignoring the interrelationship. The indicators in the set chosen must cover particular aspects of the problem in hand; thus it is beneficial to have a framework which helps choose the set of indicators which together answer the question. For the selection of the indicators, Niemeijer & de Groot, 2008 proposed e-DPSIR, which is used for the selection of the set of indicators on a whole and not individual indicator selection; rationalised using the causal network such that associations of the indicators with each other are determined.

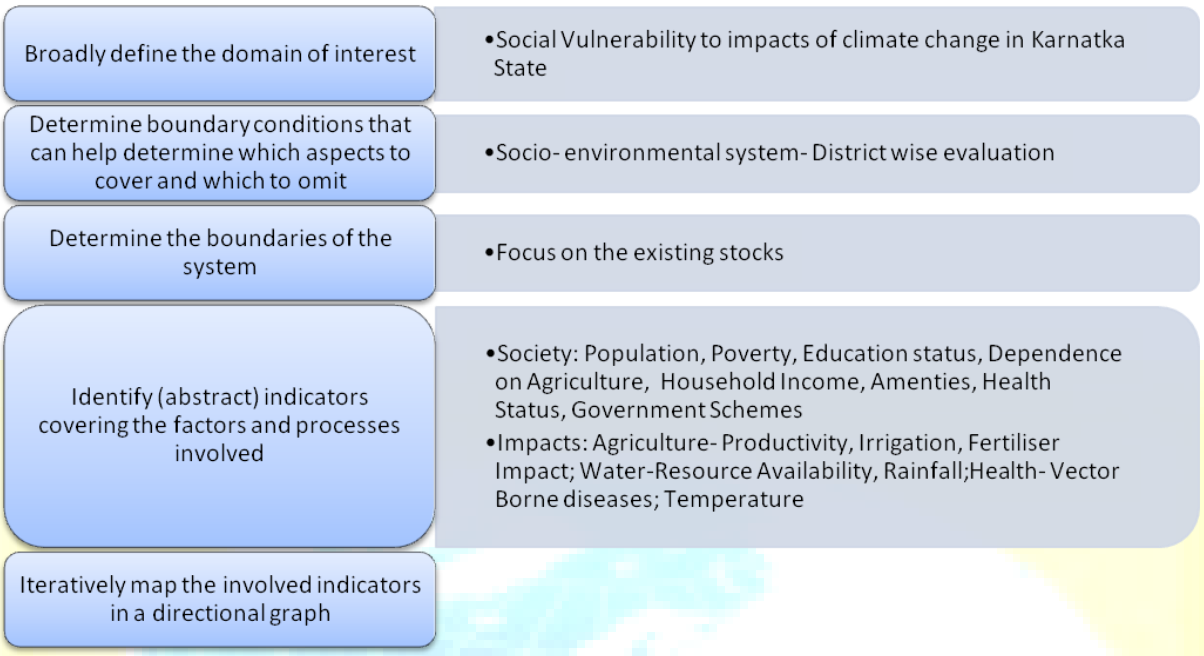

Figure 3: Steps to Build Causal Network (Niemeijer & de Groot 2008). The second column indicates the steps chosen with reference to the present study.

The DPSIR framework was applied for the selection of the indicators for this Karnataka study. The DPSIR framework was applied for the selection of the indicators to study the vulnerability index in the Karnataka state.

These indicators were identified from the review of literature as well as published research articles and government documents for the State of Karnataka.

Table 1: First selection of abstract indicators to be included in the causal network

DRIVING FORCE	Population, Economic Development, Climate
PRESSURE	Fertiliser Use, Urban Population, Population increase, Natural Resource Dependency
STATE	Water Availability, Irrigation Facility, Agriculture Productivity, Education status, Available amenities
IMPACT	Variability in productivity, Poverty, Decline in Ground water table, Temperature rise, vector borne diseases
RESPONSE	Agricultural Schemes, Protected area, alternative livelihood

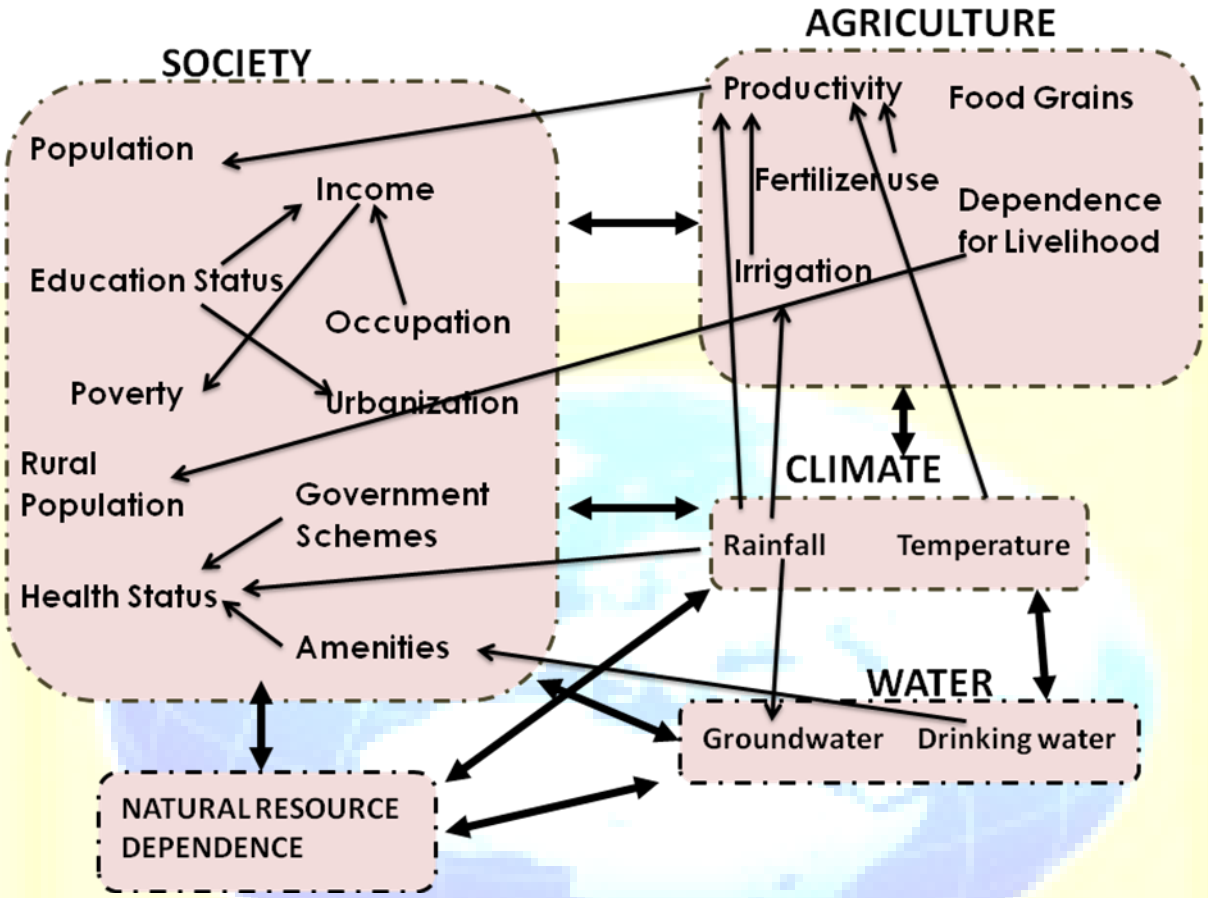

Figure 4. Causal network for selection of indicators to measure social vulnerability

Table 2: List of Indicators: This list is the final set of the indicators chosen to calculate the vulnerability index

COMPONENTS	INDICATORS		FUNCTIONALITY	SOURCE
SOCIO-ECONOMIC	Social Structure	Rural/Urban Population	+	Census 2011
		Population Density	+	
		Per Capita Income	-	Karnataka At a Glance 2009-10
	Literacy Rate	Male	-	Census 2011
		Female		
AGRICULTURE	Cropping Intensity		+	Agriculture, Directorate of Economics & Statistics, 2008-09
	Irrigation Intensity		+	
	District Domestic Product (Agriculture)		+	Karnataka State, State Domestic Product & District Domestic Product. Handbook. 2009 - 10
	Livestock per hectare Net sown area		–	Karnataka At a Glance 2009-10
	Average food grain product per thousand hectares of total cropped area		+	Agriculture, Directorate of Economics & Statistics, 2008-09
	Forested Area (% of total)		–	Karnataka At a Glance 2009-10
HEALTH	Incidences of Vector-borne Diseases		+	Department of Health & Family welfare
	Incidences of Water-Borne Diseases		+	Department of Health & Family welfare
WATER	Ground Water Level Fluctuation Nov 2011 (wrt.		+	CGWB Report, 2011

	Nov 2001-Nov 2010 Mean)		
	Households access to safe drinking water	-	Karnataka At a Glance 2009-10
	Domestic Water Requirement (Excluding Cattle) (Rural/Urban)	+	Indiastat.com 2004
	Water Quality (Unfit/No. of examined units)	+	Department of Health & Family welfare
CLIMATE	Rainfall Variability (1901-2002)	+	Karnataka State Climate Change Action Plan
	Temperature variability (1901-2002)	+	Karnataka State Climate Change Action Plan

Social

Any natural phenomenon with negative consequence can be called disastrous when there are human causalities involved. Society becomes vulnerable to the impacts of climate change due to the dependence on the natural environment for survival. According to the Malthusian theory of population the environment can sustain the ever growing population up to a certain limit and then it imparts natural checks to limit the growth, as with the case of examples of famines. Similarly, as the population density grows the region becomes more susceptible to changes in the immediate environment and thus follows up to become vulnerable to the situation. Climate change is a cross-cutting phenomenon which makes people vulnerable by impacting the very source of survival. According to the 2011 Census of India, the total population of Karnataka is 6,11,30,704. Of this, 3,10,57,742 (50.89%) are male and 3,00,72,962 (49.11%) are female. Between 2001 and 2011, there has been a decrease in decadal rate of increase in population of 15.67%, Population density is 319 per sq km, the sex ratio is 968 females to 1000 males and 33.98% of the people of Karnataka live in urban areas. The literacy rate is 75.60% with 82.85% of males and 68.13% of females being literate. Index calculation and the respective ranks are mentioned in the table below. Ranking is done such that the highest rank depicts the highly vulnerable district.

Table 3: District-wise Social Index ranking

SOCIAL		
Districts	**Index**	**Rank**
Chamaraja Nagar	0.707449	1
Koppal	0.632607	2
Mandya	0.573708	3
Yadagiri	0.523783	4
Chitradurga	0.382085	5
Hassan	0.364334	6
Chikkaballapura	0.360379	7
Raichur	0.360283	8
Bijapur	0.351148	9
Bidar	0.322793	10
Tumkur	0.319278	11
Haveri	0.303498	12
Chikmagalur	0.272941	13
Gulbarga	0.17906	14
Ramanagara	0.164688	15
Kodagu	0.161433	16
Belgaum	0.148159	17
Uttara Kannada	0.097487	18
Bagalkot	0.066371	19
Gadag	0.008736	20
Kolar	-0.00589	21
Davanagere	-0.0222	22
Shimoga	-0.09406	23
Udupi	-0.23674	24
Mysore	-0.2416	25
Bellary	-0.30158	26
Bangalore (R)	-0.40674	27
Dharwad	-0.49305	28
Dakshina Kannada	-0.70664	29
Bangalore	-3.79173	30

Among the social indicators, Per capita Income and Literacy Rate are taken as negative measures of vulnerability implying that higher the income and literacy rate, less is the vulnerability. Rural-to-urban population ratio is taken to indicate the rural proportion in the population as in the rural area there is higher and direct dependence on the natural resources than in the urban land. With

the advent of climate change, the resource base and the livelihood of the rural mass will be affected. Comparing the decadal population growth map and the district index, we find that the vulnerable districts are those wherein the population has gained momentum. Also, we assume that Bangalore has got the best rank due to the highest per capita income availability, highest literacy rate and lesser rural/urban ratio in the district. Chamarajnagar is most vulnerable due to the low literacy rate, lowest per capita income.

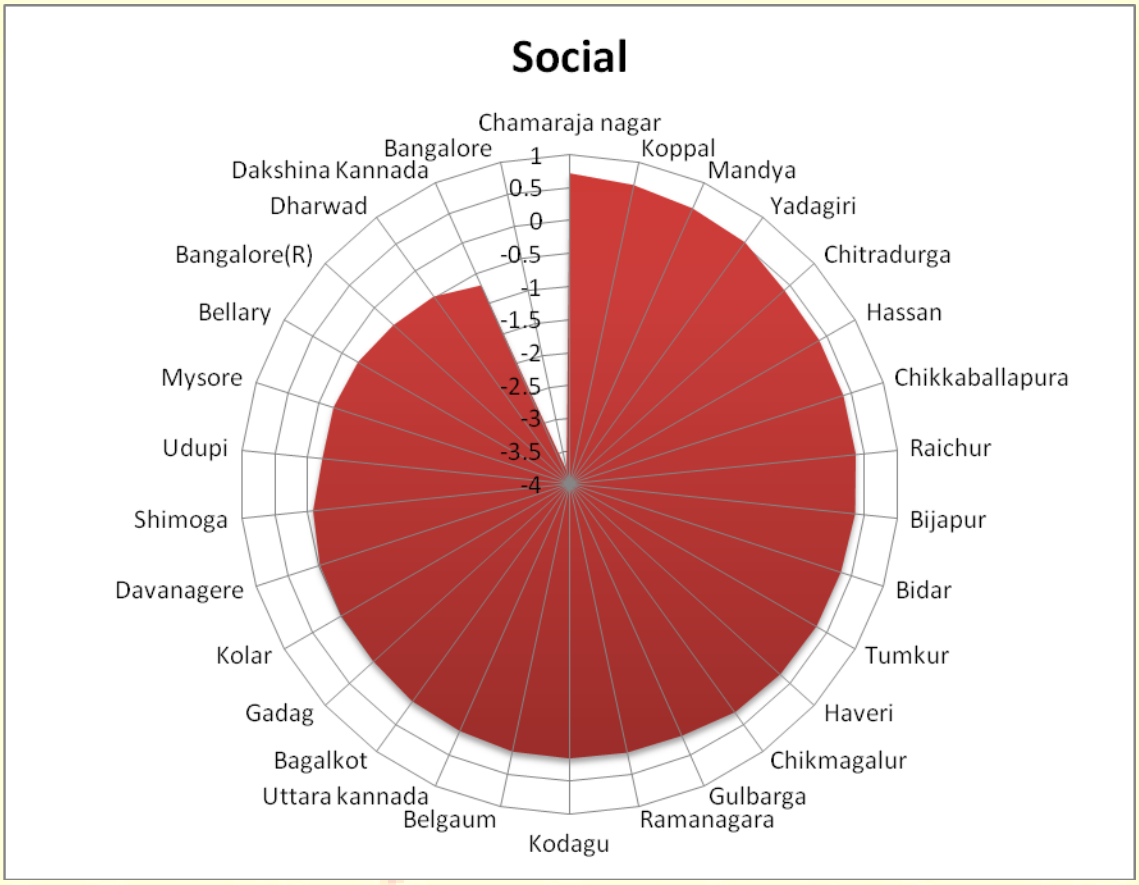

Figure 5: Social index value distribution across the districts

Health

The geographical and temporal distribution and the incidence of several vector borne diseases such as malaria and dengue are sensitive to temperature and rainfall. Warmer temperatures, shifting rainfall patterns and increasing humidity influence the transmission of diseases by vectors. As a consequence, higher temperatures possibly will influence the incidence of diseases such as malaria, dengue fever, yellow fever, and several types of encephalitis.

Index calculations for Health factors are shown in Table 4. Ranking is given alongside, depicting the highest rank for highly vulnerable region.

Table 4: District-wise Health Index ranking

HEALTH		
District	**Index**	**Rank**
Yadagiri	-0.80187	1
Koppal	-0.6617	2
Chamaraja Nagar	-0.59005	3
Dakshina Kannada	-0.58268	4
Gulbarga	-0.57483	5
Bellary	-0.52818	6
Belgaum	-0.45703	7
Shimoga	-0.3616	8
Bidar	-0.30792	9
Udupi	-0.30436	10
Raichur	-0.25107	11
Chikmagalur	-0.24668	12
Bijapur	-0.17366	13
Mysore	-0.17254	14
Hassan	-0.16607	15
Mandya	-0.16248	16
Bangalore	-0.10632	17
Bangalore (R)	-0.06085	18
Davanagere	-0.00014	19
Uttara Kannada	0.083176	20
Chitradurga	0.106399	21
Kodagu	0.147197	22
Haveri	0.154158	23
Gadag	0.390734	24
Tumkur	0.402207	25
Bagalkot	0.467512	26
Ramanagara	0.687184	27
Chikkaballapura	0.88983	28
Kolar	1.20403	29
Dharwad	1.977597	30

For the index calculations Incidence of Vector-borne and Water-borne diseases were taken. Vector-borne diseases included Chikungunya, Malaria and Dengue. Water-borne diseases included Viral Hepatitis, Typhoid, Gastroenteritis and Cholera.

Mainly cluster of districts from the northern and dry zones of Karnataka are found to be most vulnerable in health aspect.

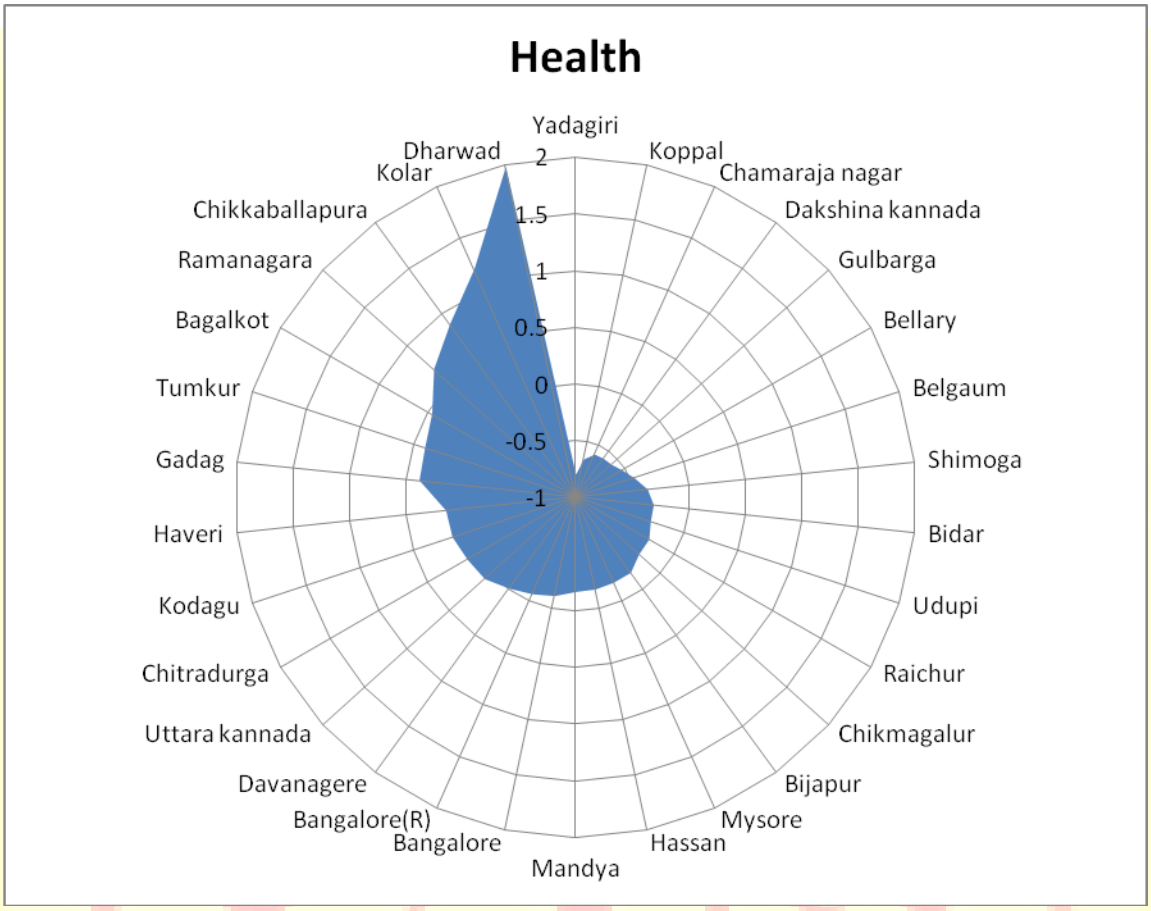

Figure 6: Health index value distribution across the districts

Agriculture

Changes in the climate affect agricultural productivity in two major ways. Direct effects are changes in temperature, precipitation and CO_2 concentrations. Indirect effects include changes in soil moisture content and the distribution and frequency of infestation by pests and diseases. 64.6% of Karnataka's geographical area is under cultivation. Farmers and agricultural labourers

account for 56.5% of the total workforce of Karnataka as per Census 2001. Agriculture thus provides livelihood for the majority of the population. Agriculture in Karnataka is heavily dependent on southwest monsoon. Only 26.5% of the sown area is irrigated.

Table 5: District-wise Agriculture index ranking

AGRICULTURE		
District	**Index**	**Rank**
Kolar	-0.80739	1
Kodagu	-0.78769	2
Bidar	-0.72451	3
Chitradurga	-0.63625	4
Bangalore	-0.60411	5
Chikmagalur	-0.5452	6
Gulbarga	-0.49984	7
Tumkur	-0.49203	8
Gadag	-0.47914	9
Bangalore (R)	-0.41343	10
Haveri	-0.39505	11
Bijapur	-0.34565	12
Koppal	-0.02825	13
Chamaraja Nagar	0.055048	14
Udupi	0.06867	15
Dakshina Kannada	0.251194	16
Dharwad	0.256834	17
Bagalkot	0.259042	18
Mandya	0.36237	19
Hassan	0.385801	20
Raichur	0.395052	21
Bellary	0.40851	22
Belgaum	0.428564	23
Uttara Kannada	0.567882	24
Davanagere	0.652419	25
Mysore	0.881337	26
Shimoga	1.785791	27

The indicator on livestock is taken as negative measure of vulnerability as we assume that more livestock would contribute to an alternative source of income. Kodagu though under Hilly region

and has come up with second rank probably due to more of plantation crops which are produced there. Bangalore also comes in first few ranks due to low agriculture variable values in the data due to it urban nature.

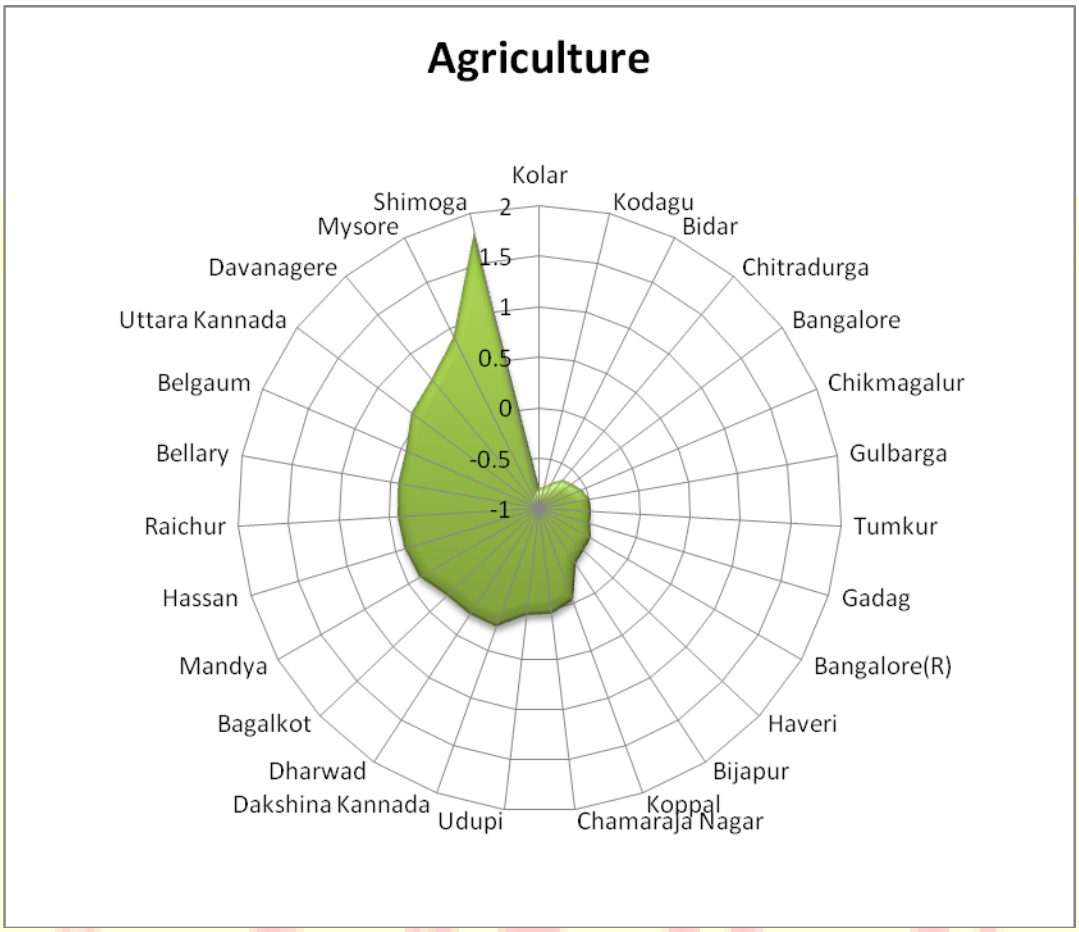

Figure 7: Agriculture index value distribution across the districts

Water

Water is a necessary resource for ecology and economy. Water ensures livelihoods, health, welfare, production, food security. Water crisis is increasingly being viewed in terms of increasing imbalance between water supply and demand. Water resources of Karnataka state are fast dwindling with a growing population and increasing utilization of water for expanding economic activities. Water demand for consumptive (drinking, health and sanitation needs) and productive uses (agricultural, industrial production, power generation, mining operations and navigation, and recreational activities) has increased tremendously while water supply has declined with depletion and degradation of water resources causing water distress or scarcity in

the state. Depletion of quantity and degradation of quality of water has restricted the availability of water for consumptive and productive uses and consequently caused "negative externality" which imposes economic and social cost on the society.

Index calculation and rank in ascending order of vulnerability is given in the following table.

Table 6: District-wise Water Indicator Ranking

WATER		
District	**Index**	**Rank**
Dharwad	-1.61219045	1
Bangalore	-1.007503632	2
Shimoga	-0.800319803	3
Dakshina Kannada	-0.71893721	4
Haveri	-0.53306615	5
Mysore	-0.502232695	6
Bellary	-0.477844729	7
Bagalkot	-0.44908232	8
Gadag	-0.349900352	9
Tumkur	-0.343546573	10
Gulbarga	-0.343359587	11
Davanagere	-0.340972104	12
Belgaum	-0.247778119	13
Bangalore (R)	-0.126140826	14
Bidar	0.012114895	15
Uttara Kannada	0.170763822	16
Kolar	0.231708071	17
Bijapur	0.264193447	18
Hassan	0.317269087	19
Chitradurga	0.451856338	20
Raichur	0.518371816	21
Koppal	0.599107306	22
Chikmagalur	0.647355268	23
Udupi	0.990806799	24
Chamaraja Nagar	1.007996945	25
Kodagu	1.22985059	26
Mandya	1.411480167	27

The Household access to safe drinking water is taken as negative measure to assess vulnerability, i.e., more the value decrease in vulnerability.

There is no pattern seen in the geographical distribution of the water index, probably due to the diversity of the variables used within the index.

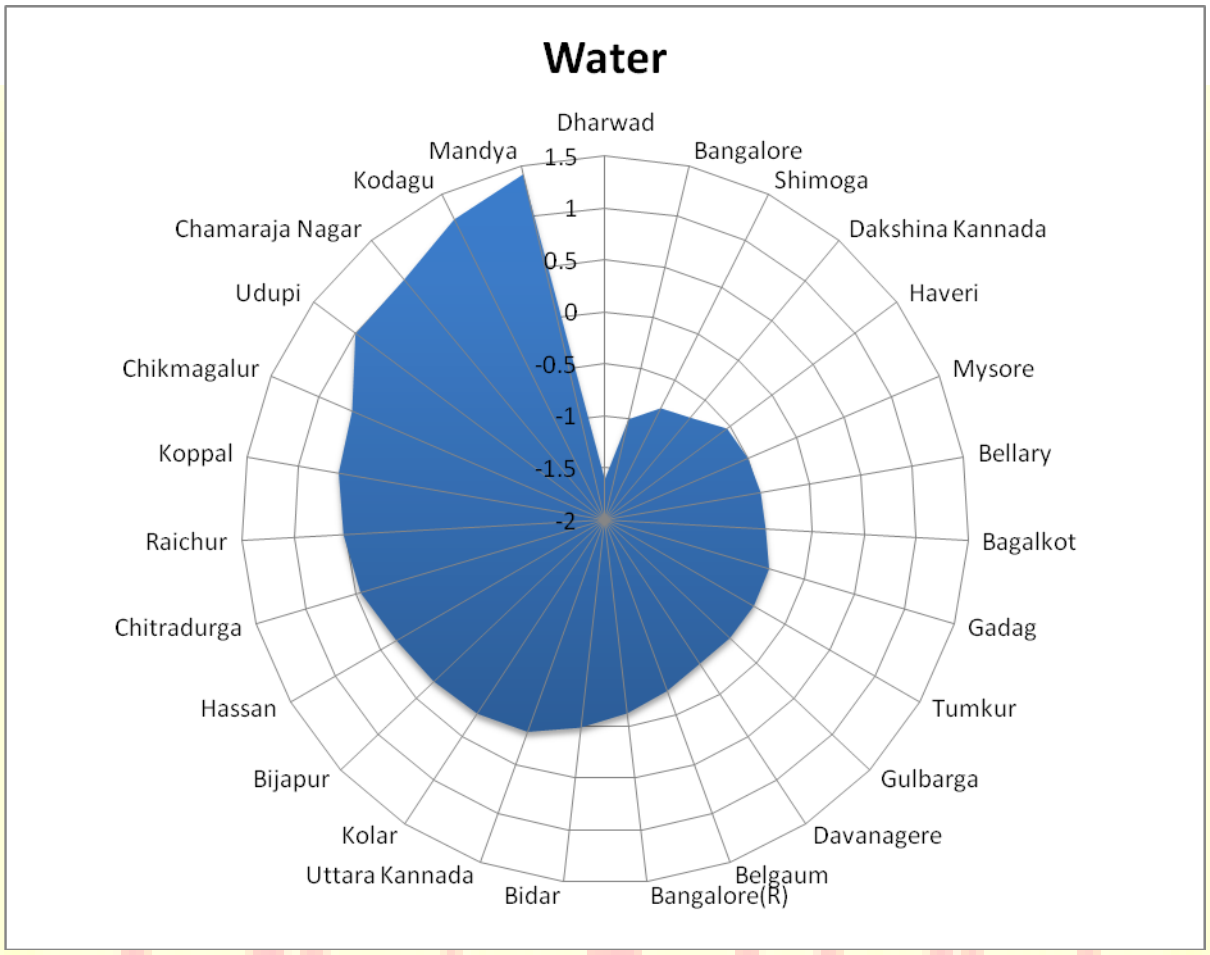

Figure 8: Water index value distribution across the districts

Climate

Climate change influences through the change in pattern of rainfall and temperature. Northern districts of Karnataka are most affected by the variability in the climate due to their inherent fragile ecosystem.

Table 7: District-wise Climate Index Ranking

CLIMATE		
District	**Index**	**Rank**
Bidar	1.739806258	1
Gulbarga	1.296846193	2
Yadagiri	1.086310321	3
Bijapur	0.927838938	4
Raichur	0.921802435	5
Koppal	0.921359208	6
Bellary	0.795090553	7
Gadag	0.753601494	8
Bagalkot	0.700707442	9
Chikkaballapura	0.652229596	10
Kolar	0.550097286	11
Belgaum	0.532166364	12
Chitradurga	0.348619637	13
Tumkur	0.310889463	14
Bangalore (R)	0.286468848	15
Dharwad	0.251733825	16
Bangalore	0.04649397	17
Davanagere	-0.032751536	18
Ramanagara	-0.220890031	19
Haveri	-0.312988883	20
Mandya	-0.428146482	21
Kodagu	-0.578147514	22
Hassan	-0.623656778	23
Mysore	-0.875407403	24
Chamaraja Nagar	-0.913147541	25
Chikmagalur	-1.116955649	26
Uttara Kannada	-	27

	1.137842462	
Shimoga	-1.282706731	28
Dakshina Kannada	-2.120611872	29
Udupi	-2.478808948	30

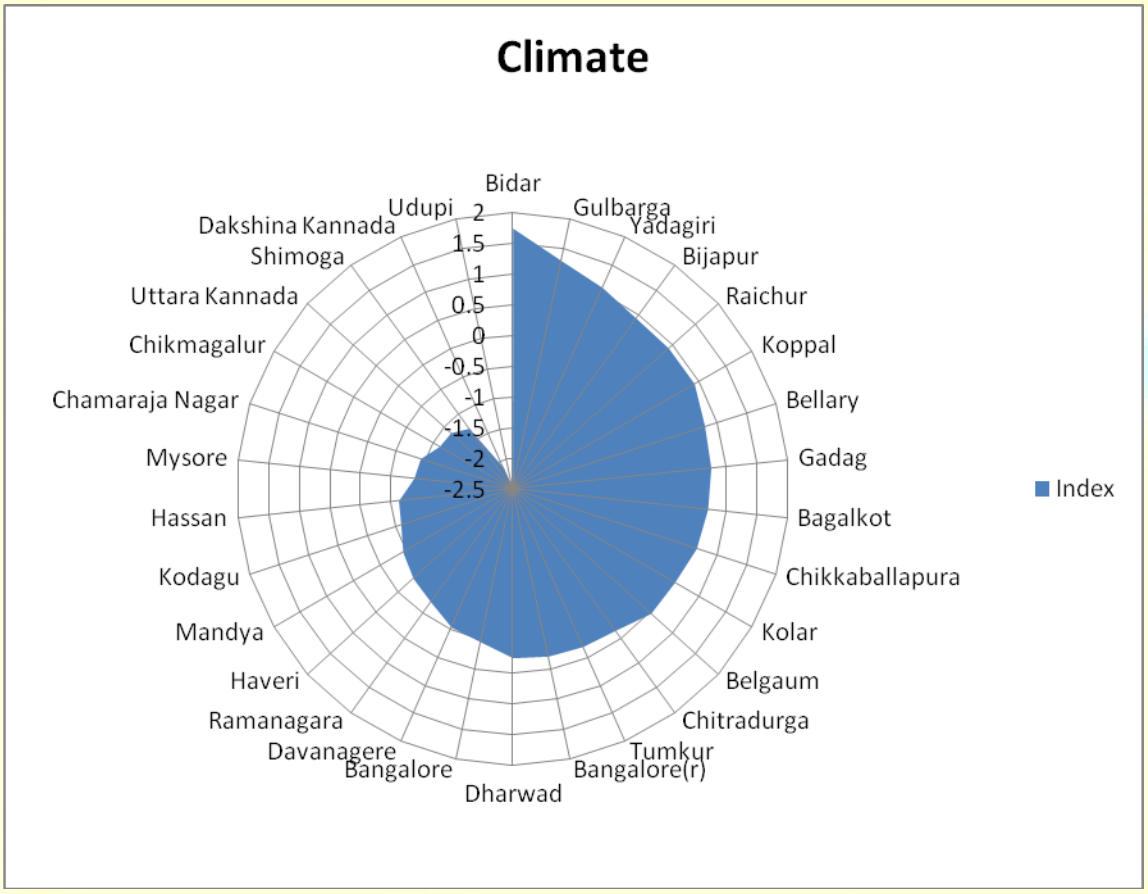

Figure 9: Climate index value distribution across the districts

The index is distributed along the agro-climatic zones depicting the variable climate in the region.

The composite index was aggregated by simple averaging of the components. Table 8 gives the composite index for the districts.

Table 8: Composite Index

DISTRICT	COMPOSITE INDEX	RANK
Chikkaballapura	0.401	1
Raichur	0.389	2
Mandya	0.351	3
Koppal	0.293	4
Kolar	0.235	5
Bagalkot	0.209	6
Bidar	0.208	7
Bijapur	0.205	8
Yadagiri	0.162	9
Chitradurga	0.131	10
Ramanagara	0.126	11
Belgaum	0.081	12
Dharwad	0.076	13
Gadag	0.065	14
Hassan	0.056	15
Chamaraja Nagar	0.053	16
Davanagere	0.051	17
Tumkur	0.039	18
Kodagu	0.035	19
Gulbarga	0.012	20
Bellary	-0.021	21
Uttara Kannada	-0.044	22
Bangalore (R)	-0.144	23
Shimoga	-0.151	24
Haveri	-0.157	25
Mysore	-0.182	26
Chikmagalur	-0.218	27
Udupi	-0.392	28
Dakshina Kannada	-0.776	29
Bangalore	-1.093	30

References

Birkmann, J (2006). Indicators and Criteria for Measuring Vulnerability: Theoretical Bases and Requirements. In: Birkmann, J (Ed.) *Measuring Vulnerability to Natural Hazards – Towards Disaster Resilient Societies*, United University Press: 55-77.

Census of India, Online Webpage of Census of India, Registrar-General and Census Commissioner, India.

Cutter, S L (1996). Vulnerability to Environmental Hazards. *Progress in Human Geography:* 529-539.

Cutter, S L, B J Boruff, W L Shirley (2003). Social Vulnerability to Environmental Hazards. *Social Science Quarterly*, 84 (2): 242–261.

Doherty, K, R Adams, & N Davey (2004). Non-Euclidean Norms and Data Normalization. In *Proc. 12th Euro. Symp. Artificial Neural Networks* (ed M Verleysen), Bruges, Belgium, 28–30 April 2004: 181–186. Bruges, Belgium: D-side Publications.

Environmental Performance Index and Pilot Trend (2012): Environmental Performance Index

Guillaumont, Patrick (1999). On the Economic Vulnerability of Low Income Countries. CERDI-CNRS, Universite d Auvergne: 4.

Hahn, M B, A M Riederer and S O Foster (2009). The Livelihood Vulnerability Index: A Pragmatic Approach to Assessing Risks from Climate Variability and Change – A Case Study in Mozambique. *Global Environmental Change*, 19(1): 74-88.

Hammond, A, A Adriaanse, E Rodenburg, D Bryant & R Woodward (1995). Environmental Indicators: A Systematic Approach to Measuring and Reporting on Environmental Policy Performance in the Context of Sustainable Development. Washington DC: World Resources Institute.

Handbook on Constructing Composite Indicators: Methodology and User Guide, OECD (2008): 13.

Hinkel, J (2011). Indicators of Vulnerability and Adaptive Capacity: Towards a Clarification of the Science–Policy Interface. *Global Environmental Change*, 21(1): 198-208.

Jorn Birkmann (2006). Indicators and Criteria for Measuring Vulnerability: Theoretical Bases and Requirements, UNU: 57.

Kaly, U L , C R Pratt and R Howorth (2002). Towards Managing Environmental Vulnerability in Small Island Developing States (SIDS). SOPAC Miscellaneous Report 461: 16.

Karnataka Human Development Report 2005 (2005). Planning and Statistics Department & Government of Karnataka.

Karnataka State Action Plan on Climate Change (2011). Draft Report (September 17, 2011). Environmental Management and Policy Research Institute, The Energy Resource Institute, Bangalore, India.

Niemeijer, D & R S Groot (2006). Framing Environmental Indicators: Moving from Causal Chains to Causal Networks. *Environment, Development and Sustainability*, 10(1).

Niemeijer, D (2002). Developing Indicators for Environmental Policy: Data-driven and Theory-driven Approaches Examined by Example. *Environmental Science and Policy*, 5: 91-103.

Niemeijer, D and R de Groot (2008). A Conceptual Framework for Selecting Environmental Indicator Sets. *Ecological Indicators*, 8(1): 14-25.

Omann, I, A Stocker & J Jäger (2009). Climate Change as a Threat to Biodiversity: An Application of the DPSIR Approach. *Ecological Economics*, 69(1): 24-31.

Organisation for Economic Co-operation and Development (OECD) (2008). *Handbook on Constructing Composite Indicators: Methodology and User Guide*. [pdf], ISBN 978-92-64-04345-9.

State of Environment Report Karnataka (2010). Presubmission Draft (April 6, 2011) Environmental Management and Policy Research Institute, Bangalore, India.

Suarez-Alvarez, M M, D T Pham, M Y Prostov and Y I Prostov (2013). Statistical Approach to Normalization of Feature Vectors and Clustering of Mixed Datasets. Proceedings of Royal Society, **468:** 2630–2651. doi: 10.1098/rspa.2011.0704.

Sullivan, C (2002). Calculating a Water Poverty Index. *World Development*, 30(7): 1195-1210. Available at: ttp://linkinghub.elsevier.com/retrieve/pii/S0305750X02000359.

Sullivan, C and J Meigh (2005). Targeting Attention on Local Vulnerabilities using an Integrated Index Approach: The Example of the Climate Vulnerability Index. *Water Science and Technology: A Journal of the International Association on Water Pollution Research*, 51(5): 69-78. Available at: http://www.ncbi.nlm.nih.gov/pubmed/15918360.

Vincent, K (2004). Creating an Index of Social Vulnerability to Climate Change in Africa. Norwich, UK: Tyndall Center for Climate Change Research.

Yale Center for Environmental Law & Policy, Yale University, Center for International Earth Science Information Network, Columbia University, in collaboration with World Economic Forum, Geneva, Switzerland, Joint Research Centre of the European Commission, Ispra, Italy http://epi.yale.edu