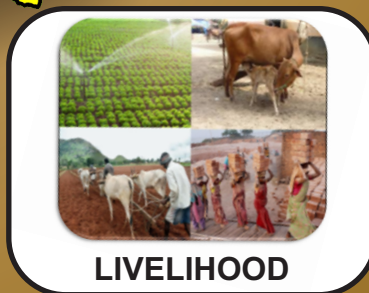
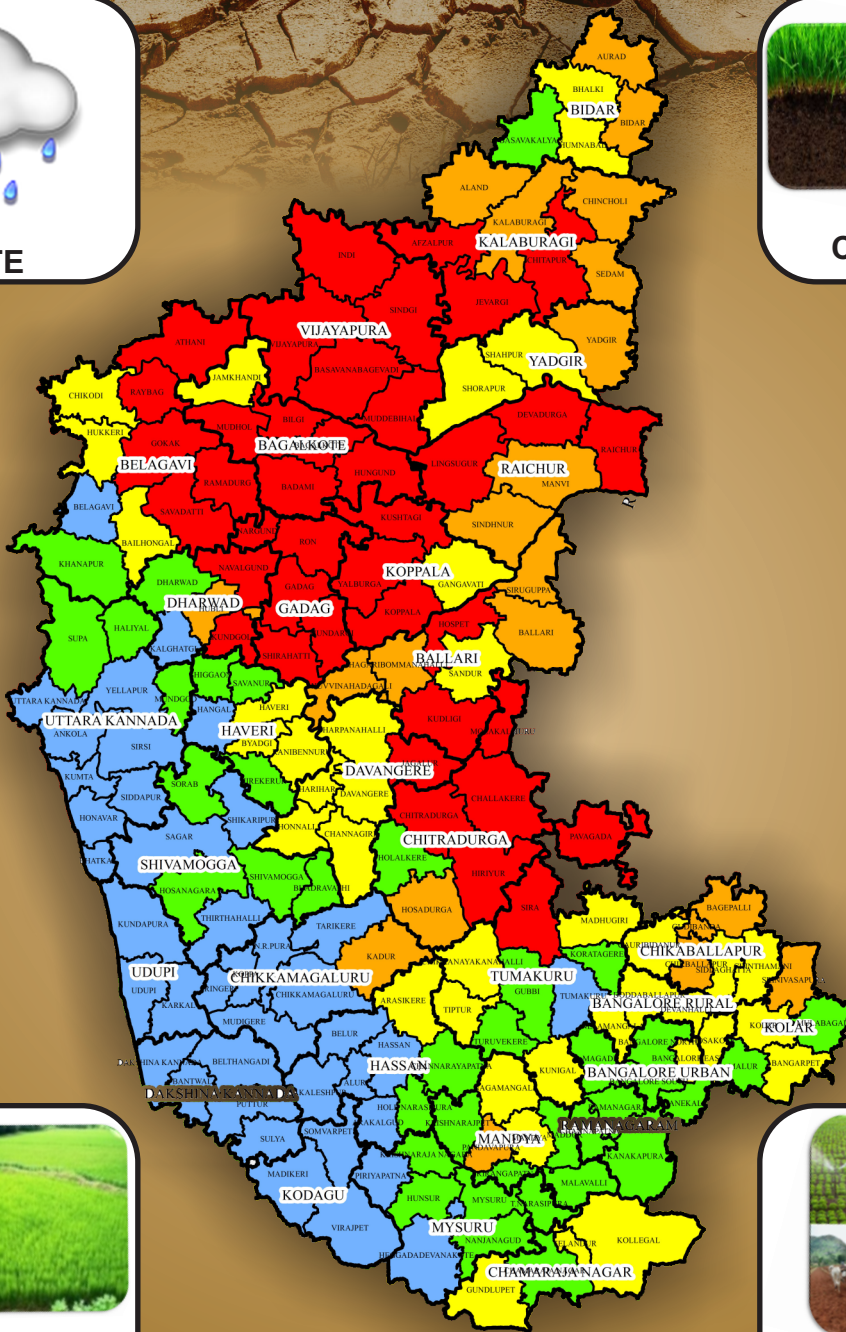


DROUGHT VULNERABILITY ASSESSMENT IN KARNATAKA



Karnataka State

Natural Disaster Monitoring Centre (KSNDMC)

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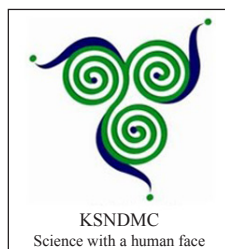
January - 2017

DROUGHT VULNERABILITY ASSESSMENT

in

KARNATAKA

**(A COMPOSITE INDEX: USING CLIMATIC, SOIL, CROP COVER
AND LIVELIHOOD COMPONENTS)**



Karnataka State Natural Disaster Monitoring Centre (KSNDMC)

Department of Revenue

Government of Karnataka

Bengaluru

DROUGHT VULNERABILITY ASSESSMENT IN KARNATAKA

(A COMPOSITE INDEX: USING CLIMATIC, SOIL, CROP COVER AND LIVELI HOOD COMPONENTS)

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on
“**DROUGHT VULNERABILITY ASSESSMENT IN KARNATAKA**”

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ABOUT THE INSTITUTE

Karnataka state Natural Disaster Monitoring Centre (KSNDMC), an autonomous institute affiliated to Department of Revenue (Disaster Management), GoK, is a nodal centre in the state to monitor various natural disasters in the state. The center was established in 1988 as a Drought Monitoring Cell (DMC) and subsequently renamed as Karnataka state Natural Disaster Monitoring Centre in 2007 with the mandate to monitor all the Natural Disasters viz. Drought, Flood, Earthquake, Landslide, Hailstorm in the state. The proactive and innovative approach, adopted by the KSNDMC for Disaster monitoring is an unique model in the country. KSNDMC has been serving as a common platform to various response players to achieve synergy in the field of disaster management.

KSNDMC has installed weather monitoring stations network which comprises 922 Solar Powered GPRS enabled Telemetric Weather Stations (TWS at 250 sq km each) and 6000 Telemetric Rain Gauge Stations (TRG at ~25 sq km each). The data on Rainfall, Temperature, Relative Humidity, Wind Speed and Wind Direction are being collected at every 15 minutes is being analyzed, maps and reports are generated through auto mode. The Grampanchayath level weather forecast has also been developed. The Alerts, Reports and Advisories are being disseminated to officers of all line-departments working at State level to Grampanchayath level through email, SMS and GIS web-portal www.ksndmc.org. To disseminate weather related information, forecasts and advisories directly to the farming community a 24x7 interactive Help Desk “VARUNA MITRA” is operational at KSNDMC. Lakhs of farmers are utilizing VARUNA MITRA services for planning their agricultural activities which is helping them to reduce crop loss due to any weather aberration.

Technical inputs are being provided also to State and District level Disaster Management Authorities. Agriculture, Horticulture, Irrigation, Fisherman community, Transport, Energy Sectors are the beneficiaries of the services of KSNDMC. The Centre has been providing data and technical inputs for implementing Weather Based Crop Insurance Scheme in the state. The models for deriving dynamic “potential evapo-transpiration” based on real time data, hydrological model for issuing dynamic flood warning system for Bengaluru city area also being developed.

As part of capacity building activity KSNDMC has been active in Human Resource Development mainly through imparting training to Govt officers, farmers, general public and students/faculty of schools/colleges.

G.S. Srinivasa Reddy

Director

Karnataka State Natural Disaster Monitoring Centre

FOREWORD

Karnataka State is facing frequent drought conditions due to uncertainty of rainfall and spatio-temporal variation in different regions. Due to these variations in rainfall distribution, the State experiences extreme weather conditions like drought or flood or both drought and flood simultaneously in different regions. Frequent drought and floods have caused colossal loss to crops and lives, while society loses its livelihood and rhythm of life and people are forced to migrate for their sustenance.

Looking at the severity and magnitude of the droughts in the State an attempt is made through this study “to assess the vulnerability” of each taluk of different regions, through a composite index developed from major parameters like climate, crop cover, soil and livelihood supported by 28 sub-components relevant to drought. Based on the severity of vulnerability, the drought proofing measures at each taluk level and at drought vulnerability class level are indicated. Additionally the extent of drought vulnerability in each agro-climatic zone and its effect on different groups of population is estimated.

This publication “**Drought vulnerability Assessment in Karnataka (A Composite index-using climate, soil, crop cover and livelihood components)**” would be a prime document for administrators, departmental officers, scientists, NGO’s and others for planning and implementing holistic drought proofing measures to improve the socio-economic condition of the rural community. For research/students, this document provides sufficient information on drought vulnerability to motivate them for further research in this line.

T.M. Vijaya Bhaskar

Additional Chief Secretary &
Development Commissioner

PREFACE

It gives me immense pleasure to pen this preface for an excellent technical report on Vulnerability assessment due to drought in Karnataka. The report covers climate, soil, crops as well as livelihood using which a composite index of Vulnerability to drought has been developed. The report brings out an alarming result that 80 percent of taluks in Karnataka State are drought prone in majority of the years with a 3 to 5 year cycle. Further, the parts of the state are prone to Landslides, Cyclones, Earthquakes, Floods, Hailstorms and Thunderstorms threatening life and property and virtually every district is prone to a disaster resulting in crop failure and economic loss. Considering 2011-15, 65% of the taluks were affected by drought.

The report highlights drought due to meteorological, hydrological, surface water and groundwater factors. And recommends groundwater recharge measures in almost all the taluks of the state as more than 80 percent of water for drinking purpose and more than 50 percent of water used for irrigation is from groundwater in the State. The report lists in detail the names of taluks under each class of climate based index, climate crop cover index, climate-soil index, and more importantly livelihood based index.

Considering the composite drought vulnerability index, in each district, taluks have been identified to be vulnerable for policy makers to develop and implement appropriate policies. Accordingly there are 44 very highly vulnerable taluks (above Chitradurga district) in northern Karnataka, 21 highly vulnerable taluks, in northern Karnataka. In each taluk, drought proofing measures based on the intensity of vulnerability to drought, have been suggested. The major drought proofing measure in most of the taluks of vulnerability to drought is to improve groundwater situation through recharge. The report highlights Resilience index which points to the capacity/action of the people to recover from the effect of drought. The fig 23 which highlights taluks with different degrees of drought resilience, shows that taluks with high resilience are located in southern Karnataka while taluks with medium resilience are located in northern Karnataka.

In a nutshell, the report concludes that considering vulnerability to drought, Northern dry zone is highly vulnerable (81%), followed by North-eastern dry zone (65%), Central dry zone (49%), North-eastern transition zone (62%) and North-eastern dry zone (35%). The dry agroclimatic zones of the State (zone 2, 3, 4, 5,6) and transition zone (1) have extensive areas under drought vulnerability and only two zones namely, the hilly and coastal zones (zones 9 & 10) are slightly vulnerable to drought in the state.

I heartily congratulate the Director of KSNDMC Dr. G.S. Srinivasa Reddy and all his team members for bringing out this excellent publication, full of facts, figures and substantiation, prepared on scientific basis reflecting the extent and impact of drought, along with possible solutions to address the drought considering resilience capacities in different taluks. This report is worthy of reference in research institutes, University libraries and for policy makers, including the legal experts who need reference material for their arguments considering rights to natural resources including water.

Prof. M.G. Chandrakanth

Director

Institute for Social & Economic Change, Bangalore

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EXECUTIVE SUMMARY

Karnataka, one of the India's eighth largest state in terms of geographical area (19.1M. sq.km) is home to 6.11 crore people (2011 Census) accounting for 5.05% of India's population. It has the net cultivated area (2010-11) of 10.5 M Ha, net irrigated area of 3.49 M Ha and net rainfed area of 7.01M Ha. Due to both spatial and temporal variation in rain fall, the disasters like droughts and floods occur simultaneously in the different regions of the state. Droughts are more common than the other disasters in the state thus affecting rain fed production system.

Looking to the gravity of droughty situations in the state, a multi-pronged /multi component two tier approach was undertaken to assess the vulnerability at taluk level .Under this study four major components and twenty eight sub-components/indicators that are relevant to drought were considered over a period and analysed to develop the composite index of Drought Vulnerability. Drought proofing measures as per the limitations in the taluk and also DVI-class wise were highlighted. Resilience and its relevance to vulnerability were discussed. Besides, the severity and the extent of vulnerability in each Agro-Climatic zone were estimated.

The major components of the study deals with the Climate (CI), Climate – Crop cover (CCI), soils (CSI) and livelihood aspects (LI). Each major and sub-component are selected to study the effect of drought behaviour independently, hence the indices of each major component also express the vulnerability of the taluk, with respect to this major component. The sub-components of each major component in turn may function positively or negatively towards drought within the gambit of the major component.

Climate based indices derived from seven sub-components indicate the vulnerability of the taluks with respect to climate. Out of 176 taluks, 50 taluks are very highly vulnerable, while 82 taluks have high vulnerability, 27 taluks are moderately vulnerable and 17 taluks have low to very low vulnerability. This clearly indicates that the rainfall related components and their variability in the state is unpredictable and uncertain. This uncertainty has resulted in droughts or droughty situations with varying intensity in majority of the taluks in the state.

Climate Crop Cover based indices arrived from the twelve sub-components indicate that majority of the area has very low vulnerability (50 taluks) and low vulnerability (53). Very highly vulnerable (8), highly vulnerable (29) and moderately vulnerable (36) taluks are less in number. The severity and extent of vulnerability is in lower side as per the index which may be due to the cropping patterns in the state during both south-west and north-east monsoon seasons covering large areas.

Climatic Soil based index: This indices were estimated based on the length of growing period (LGP) in the Taluks. This LGP was arrived from the rainfall, PET and AWC of the major soils through water balance approach. As per these indices, it is evident that moderately vulnerable (59) , highly vulnerable (47) and very highly vulnerable (24) taluks are more in number than very slightly vulnerable (13) and slightly vulnerable (33) taluks. It may be due to the soil variation in addition to the rainfall variability in the different Taluks of the state.

Livelihood index: Livelihood index deals with the vulnerability of the society to adverse effects of drought or the affected society due to the impact of the drought. For arriving at this index, eight sub-

components were considered. This index expresses the capacity of the society to cope up the impact of drought. As per this LI index, it is evident that major area (73 Taluks) is slightly vulnerable and moderately vulnerable (45 Taluks), while highly vulnerable (26 Taluks) and very highly vulnerable (12 Taluks) areas occupy relatively less taluks. This reflects that the societal behaviour and its capacity in different Taluks vary and hence the impact of drought also varies in different Taluks.

From the above indices, it is evident that 'CI' index accounts to the exposure that provides information on the extent, duration of stress to the system, while the CCI index, reflect the sensitivity of the system or area to the stress due to drought. The CSI and LI indices indicate the inherent bearing capacity of the system and the capacity of the society to withstand or thwart the stress developed due to the impact of drought respectively.

The composite index developed based on these four indices indicate that about 65 Taluks are highly and very highly vulnerable, 34 Taluks are moderately vulnerable, about 38 Taluks are slightly vulnerable and 39 Taluks are very slightly vulnerable. Hence, the moderately, highly, very highly vulnerable Taluks (99) are to be treated separately with all the implementable holistic drought proofing measures such as Jalsaheli, Pani Panchayats and Watershed approach (NWDPPRA) for storing and sharing the water resources, planning for less water demanding crops, measures to improve the farmers home taking money, food grain supply through 'FPS', weather based agro-advisories, revival of streams, water courses and the village tanks through MGNREGA scheme. Additionally provision of subsidy for farm ponds and farm inputs, improvement of wage structure, credit facility to reduce the indebtedness when the production is under threat, information of market prices and creating self-marketing facility would fetch good returns.

As per the 2011 census, the total house holdings in taluks under different drought vulnerability classes and the different groups of population indicate that about 38% of house holdings are in the taluks of high and very high drought vulnerability. Of the different groups of population about 41% of total population, 97% constitute minority and under-privileged (SC & ST) population, 41% of total workers and 53% of agricultural workers are in taluks of high and very high vulnerability.

Resilience index indicates the capacity of the people to recover from the effect of drought. It reveals that about 72 taluks are highly resilient and 17 taluks are very highly resilient, while 49 taluks are moderately resilient. The variability in the resilience may be because of the differences in the available resources and with standing capacities of the households. This may also depend on their abilities to face adverse consequences of the situation with the help of additional avenues that supplement their income. About 30 taluks are slightly and 8 taluks are very slightly resilient, which may be due to the low availability of the resources, less awareness, less co-operation and low interest of the people to raise to the occasion to thwart the effect of drought.

The overlay of drought vulnerability classes over the Agro-climatic zones indicate that Northern dry zone (81%), North-eastern dry zone (65%) and Central dry zone (49%) have extensive areas of very high drought vulnerability, North-eastern transition zone (62%), North-eastern dry zone (35%) have much area under of high drought vulnerability in the state. In general, the dry zones (2, 3, 4, 5, 6) and transition zone (1) have extensive areas of moderate, high to very high drought vulnerability, while hilly and coastal zones (9 & 10) have extensive areas (68 & 100%) of very slight drought vulnerability.

Chapter 1.

INTRODUCTION

1.1. Generalities :

The state of Karnataka is located between 11.50° to 18.50° N latitudes and 74.25° to 78.50° E longitudes and covers an area of 19.1 M ha which accounts for 5.8 percent of the total area of the country. It is home to 61.5 million people (2011 Census) accounting for 5.05% of India's population. The state's population has by 15.7% during the last decade.

The state is composed of 30 districts divided into 176 Taluks (Fig.1). These Taluks are further divided into 747 hoblis. The state is bounded by Goa in the northwest, Maharashtra in the north, Andhra Pradesh in the east, Tamil Nadu in the south and Kerala in the south west. It has four major regions namely 1) North Interior Karnataka, 2) South Interior Karnataka, 3) Malnad region and 4) Coastal region. It has four administrative divisions namely 1) Mysore division, 2) Gulbarga division, 3) Belgaum division and 4) Bengaluru division.

The climate of the State is determined mainly by the geographical location with respect to the Sea, monsoon winds and physiography. Karnataka State has sub-Humid- humid monsoonic climate on the West Coast and Western Ghats and semi-arid to arid (very warm) climate in central and northern districts of plateau region. The year is divided into four seasons viz., winter (December-January-February), summer (March to May); South-West monsoon (June to September) and North East monsoon (October to November). The occurrence of rainfall and its spatial distribution is highly variable and not dependable. Taluk wise Normal rainfall of the state vary from 408 mm to 5051 mm. Rainfall contribution is very high, from Southwest Monsoon Season (around 80% of the state rainfall), it is seen that the annual rainfall is highest (5051mm) over the Western Ghats and lowest (408mm) in the eastern parts of Chitradurga district. Taluk wise annual rainfall variation is increasing over most of the taluks in south interior Karnataka. More than 2/3rd of the state receives less than 750 mm of rainfall. Taluk wise Annual variability (CV) of the rainfall ranges from 16 to 40%. The atmospheric temperature in the state ranges from 23°C to 43°C in summer and 9 °C to 27 °C in winter. Hailstorms are common in plateau region of the state during pre-monsoon period.

Out of the total 19.1 M Ha in Karnataka the net cultivated area (2010-11) was 10.5 M Ha, net irrigated area 3.49 M Ha and net rainfed cultivated area 7.01 M Ha. Karnataka has the second largest area under rain-fed agriculture after Rajasthan in the country. Nearly 55% of total food grain production and 74% of oilseeds production come from rain-fed agriculture in Karnataka. Therefore rain-fed agriculture plays an important role in total food grain production in the state. Further the rain-fed agriculture has substantial untapped potential, this can be brought to use by increasing the crop yields in the dry land areas through the adoption of proper dry-land production technologies.

Physiographically the state has been divided into four regions namely 1) South Deccan Plateau 2) Western Ghats 3) Eastern Ghats and 4) West Coast plains. There are different kinds of soils in these regions of the state. Because of complex topographic, geologic, vegetation and climatic conditions, there are different kinds of soils in the state. These soil resources are characterized, mapped (Shivaprasad, et al,1996) and grouped taxonomically under Alfisols (27% of TGA), Inceptisols (25% of TGA), Entisols (16% of TGA), Vertisols (15% of TGA). Ultisols, Aridisols, and Mollisols cover 8%, 5%,

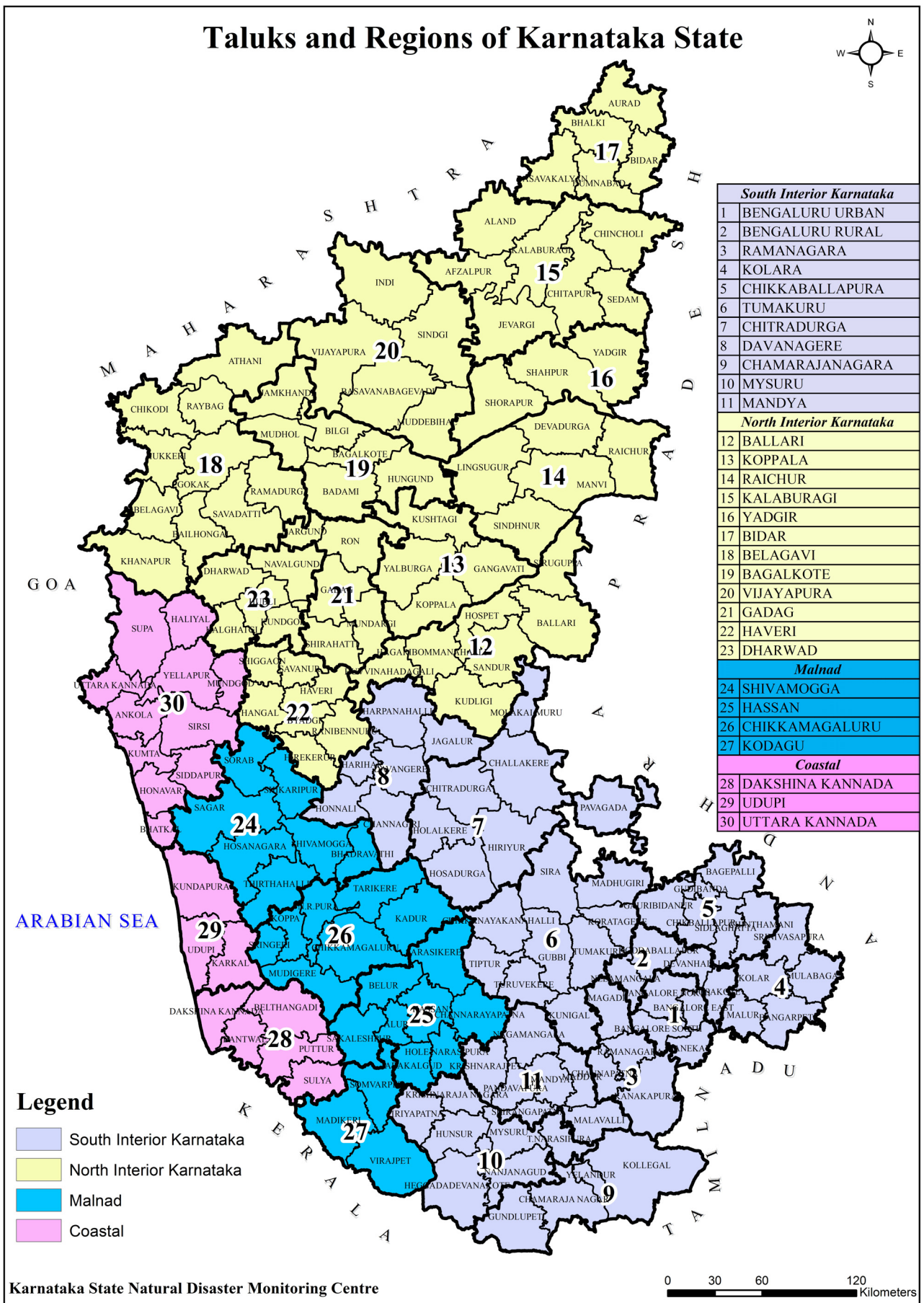


Fig.1. Taluks and Regions of Karnataka

1%, of TGA respectively. Traditionally, these soils can be grouped (Fig.2) under five categories Viz., Red soils, Lateritic soils, Black soils, Alluvial soils, Forest soils. The extent, characters and constraints are described briefly as under:

- **Red soils** are extensive (35.15% of TGA) and are predominant soils in the state. They occupy almost all physiographic regions of the state. Red soils, generally red or reddish brown, shallow to very deep, well drained and generally with a clay enriched sub surface-horizon and are derived from granites, gneiss and other metamorphic rocks either in situ or from the rock materials washed by rainwater to lower levels under hot, semi-arid to warm, humid, subtropical climatic conditions. These soils are formed under well drained condition. These include red loams, red gravelly soils and red earths. The major soil related constraints for crop production are very shallow to shallow rooting depth, coarse texture, high gravel content, low moisture retentivity, low fertility, surface crusting & compaction, soil erosion, low CEC and base saturation, low nutrient status. These soils are suitable for supporting a variety of agricultural, horticultural and plantation crops under efficient soil, water and nutrient management practices.
- **Lateritic soils** are (12.1% of TGA) dark red in colour and commonly found in area of high altitude and heavy rainfall in Karnataka. Laterite is a geological term and means literally a rock. The term laterite is highly ferruginous, vesicular and apparently unstratified deposits observed in Western Ghat region in the state. The laterites are formed in tropical and subtropical climates having alternate wet and dry seasons through laterization process. It is a compact to vesicular rock like material composed essentially of a mixture of the hydrated oxides of iron and aluminium with small amounts of manganese/titanic oxides. Under humid and warm condition (in the hilly terrain) such soils have high content of iron and magnesium but are well drained and porous. The major limitations of such soils are: deficiency of phosphates accentuated by high phosphate fixing capacity as Fe and Al phosphate, high acidity, toxicity of aluminium and manganese, deficiency of potassium, calcium, magnesium, zinc and boron. The low level laterites are suitable for growing paddy, banana, coconut, arecanut, cocoa, cashew, coffee, tea, rubber etc.
- **Black soils** are found mainly in the Deccan plateau region (6.9% of TGA) covering large parts of North Interior Karnataka region. The soils are formed by disintegration of volcanic basaltic lava. The colour of the soil is generally black due to presence of compounds of aluminium and iron. Black soils are well known group of soils characterized by dark grey to black colour, high clay content, neutral to slightly alkaline reaction and wide and deep cracks during summer. They are locally known as *regurs*. The depth of the soil varies from less than a metre to several metres and in many cases it overlies weathered rocks (parent material) known as murrum. Such soils are highly clayey, the clay content varying from 35 to 60 per cent and sometimes even upto 80 per cent in valleys or depressions. The process of churning causes mixing in deep soils and causes development of special surface features like gilgai microrelief, deep and wide cracks (of >1 cm width) upto a depth of >50 cm and closely intersecting slickensides. The soils are characterized by swelling and shrinkage, plasticity and stickiness. These soils have impeded drainage and low permeability. The soils are generally calcareous, neutral to slightly alkaline in reaction. High cation exchange capacity (30-50 [cmol(P⁺)kg⁻¹]), high base status, high contents of exchangeable calcium and magnesium are characteristics of these soils. They are however, poor in organic matter, nitrogen and available phosphorus. These soils are very fertile and predominantly used for growing cotton, millet, sorghum, soybean etc. in the state. Under irrigated conditions sugarcane is grown in Karnataka.

- **Alluvial Soils:** By definition alluvial soils are formed on parent material transported by different agencies viz. water, ice, wind and gravity. These soils are developed (16.1% of TGA) from riverine deposits and are found in the lower topographic situations. Alluvium is very thick and is variable according to the geomorphic position and the source of river transporting the sediments. The soils are calcareous/non calcareous and are very deep, the solum sometimes extending over a few hundred meters. The textures are variable ranging from very coarse to fine. They are fairly sufficient in phosphorous and well supplied with potassium and lime but are deficient in nitrogen and organic matter content. They are generally alkaline in reaction. Due to the injudicious use of irrigation water some such soils remain waterlogged and pose problems to soil salinity and/or sodicity. These soils are deficient in N, P and humus and require judicious application of manures and fertilizers for sustainable farming. Some of these soils show deficiency in zinc and sodium because of intensive cultivation problems, viz. nutrient deficiencies of sulphur and zinc. Soils developed on coastal alluvium are found along sea coast of Karnataka. Stretches of coastal sands or sandy soils where salinity and water table do not pose problems are put under plantation of coconut, cashew. These are one of the best agricultural soils and used for growing most agricultural crops, like rice, sugarcane, maize, groundnut, potato and sunflower.
- **Forest soils:** These soils occupy (6.1% of TGA) Western ghat region of the state. The climatic condition and altitude control the kind of forest species growing in different areas, the kind of vegetation and topography control the soil profile development. The soils vary from deep alluvium in the river basins and lower slopes to highly immature residual gravelly on higher altitudes. Areas of steep relief are mostly devoid of soil. Various types of crops are grown in different regions like rice in valley, orchards on slopes in almost all areas.

The taluka wise major soils as per the occurrence based on soil map (Shivaprasad, et al, 1996) of the state are considered for the study.

1.2 AGRO-CLIMATIC ZONES:

Karnataka State is divided into four regions namely south interior Karnataka, North interior Karnataka, Malnad and Coastal Karnataka. These are divided into ten (Fig.3) Agro-Climatic Zones by UAS, Bengaluru under NARP program. Among these ACZ zones, there are five dry zones (2, 3, 4, 5 & 6) with relatively low rainfall and more erratic distribution. Similarly, along the eastern part of the hill zones to the west of the dry zones with relatively more rainfall with less erratic distribution and a small portion in the north-eastern part of the State were also identified as transition zones (1, 7 & 8). The hill and coastal belts cover the two distinct zones (9 & 10). The districts/Taluks covered under each ACZ are presented in Table 1.

These 10 Agro-climatic zones could be grouped in to three categories namely :

- a) **Dry Zones :** North Eastern Dry Zone (2), Northern Dry Zone (3), Central Dry Zone (4), Southeastern Dry Zone (5) and Southern Dry Zone (6)
- b) **Transition Zones :** North-Eastern Transition Zone (1), Southern Transition Zone (7) and Northern Transition Zone (8)
- c) **Hill and Coastal Zones:** Hilly Zone (9) and Coastal Zone (10)

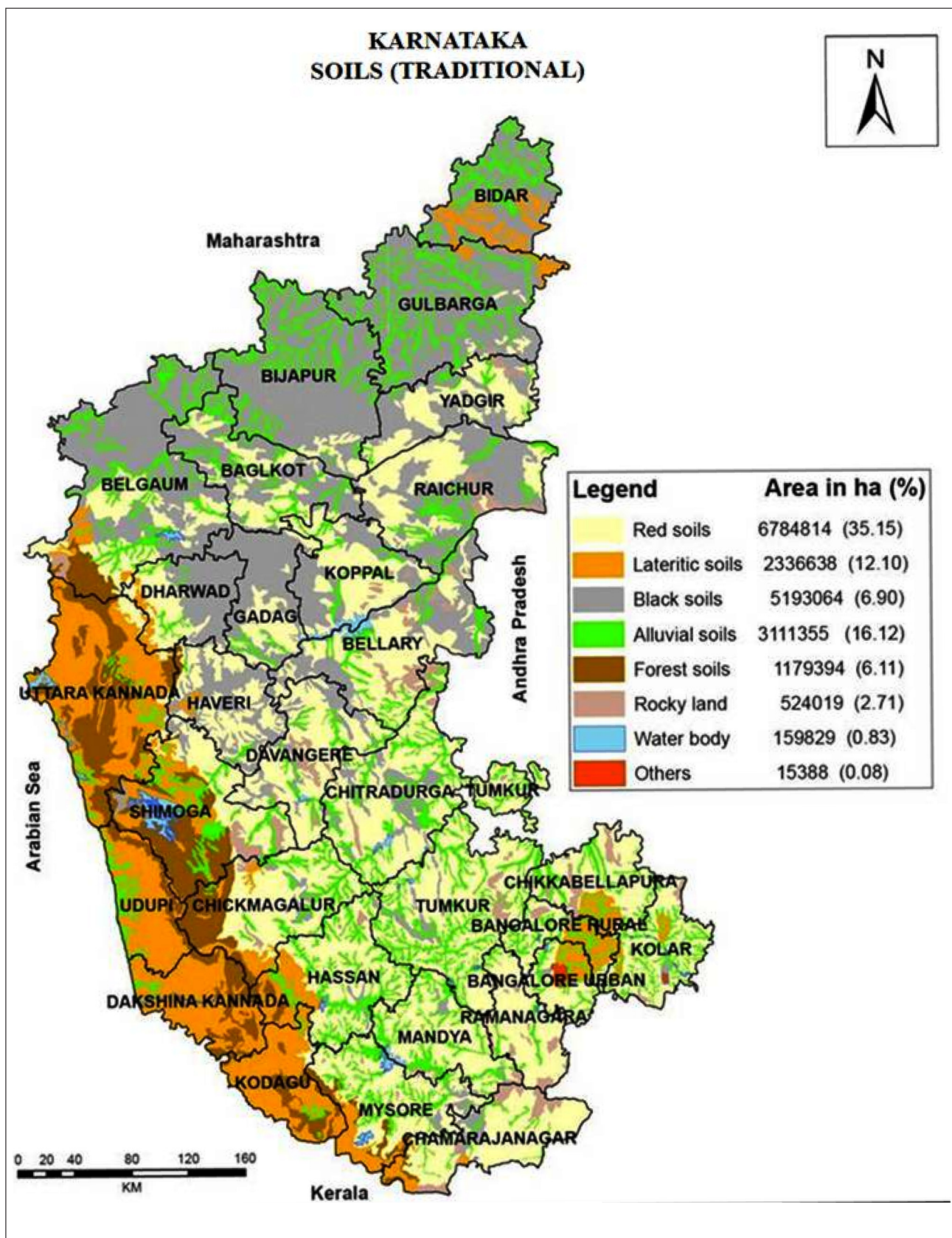


Fig.2. Soils of Karnataka

Table 1. Taluks covered in each of the agro-climatic zone of Karnataka.

<i>Sl. No</i>	<i>Agro-Climatic Zones</i>	<i>District</i>	<i>No of Taluks</i>	<i>Taluks</i>
1	North Eastern Transition Zone	KALABURGI	2	Aland,Chincholi
		BIDAR	5	Bhalki, Basavakalyan, Bidar,Humnabad, Aurad
2	North Eastern Dry Zone	RAICHUR	3	Raichur, Deodurga, Manvi
		KALABURGI	5	Afzalpur, Chitapur, Kalaburgi, Jewargi, Sedam
		YADGIR	3	Shorapur, Shahapur, Yadgir,
3	Northern Dry Zone	DAVANGERE	1	Harapannahalli,
		BALLARI	7	Ballari, H.B. Halli, Hadagali, Hospet, Kudligi, Sandur, Siruguppa,
		KOPPAL	4	Gangavathi, Koppal, Kushtagi, Yelbarga,
		RAICHUR	2	Lingsugur, Sindhur,
		BELGAVI	5	Ramdurg, Gokak, Raibag, Soundatti, Athani
		BAGALKOTE	6	Badami, Bagalkote, Hungund, Jamakhandi, Mudhol, Bilgi,
		VIJAYAPURA	5	Basavana bagewadi, Vijayapura, Indi, Muddebhihal, Sindagi,
		GADAG	4	Ron, Naragund, Gadag, Mundargi,
4	Central Dry Zone	DHARWAD	1	Navalgund,
		TUMAKURU	6	Madhugiri, Pavagada, Koratagere, C.N.Halli, Sira, Tiptur
		CHITRADURGA	6	Chitradurga, Hiriya, Hosadurga, Holalkere, Molakalmuru, Chellakere
		DAVANGERE	3	Davangere, Harihara,Jagalur,
		HASSAN	1	Arasikere,
5	Eastern dry zone	CHIKKAMAGALURU	1	Kadur,
		BENGALURU-URBAN	4	Anekal, Bengaluru-N, Bengaluru-S, Bengaluru-E
		BENGALURU-RURAL	4	Devanahalli, Doddballapur, Hosakote, Nelamangala,
		RAMANAGARAM	4	Channapatna, Kanakapura, Magadi, Ramnagar,
		KOLAR	5	Bangarapet, Kolar, Malur, Mulabagal, Srinivasapura
		CHIKBALLAPUR	6	Bagepalli, Chikballapur, Chintamani, Gudibanda, Gouribidanur, Sidlaghatta, Gubbi, Tumakuru,
6	Southern dryzone	TUMAKURU	2	Turuvekere, Kunigal,
		CHAMARAJANAGAR	4	Kollegal,Chamarajanagar, Yelandur, Gundlupet
		MYSURU	4	K.R.Nagar, T.Narasipur a, Mysuru, Nanjanagud,
		MANDYA	7	Nagamangala, Srirangapatna, Malavalli, Maddur, Mandya, Pandavapura, K.R.pet,
		HASSAN	2	Channarayapatna, Hassan,
7	Southern transition zone	DAVANGERE	2	Honnali, Channagiri
		MYSURU	3	H.D.Kote, Hunsur, Periyapatna,
		SHIVA MOGGA	3	Bhadravathi, Shivamogga,Shikaripur,
		HASSAN	4	H.N.Pura, Alur, Arkalgud, Belur
		CHIKKAMAGALURU	1	Tarikere,

<i>Sl. No</i>	<i>Agro-Climatic Zones</i>	<i>District</i>	<i>No of Taluks</i>	<i>Taluks</i>
8	Northern transition zone	BELGAVI	4	Hukkeri, Chikkodi, Bailhongal, Belgavi,
		GADAG	1	Shirahatti,
		HAVERI	6	Haveri, Shiggoan, Savanur, Byadgi, Hirekerur, Ranibennur
		DHARWAD	3	Kundgol, Hubli, Dharwad
9	Hilly zone	BELGAUM	1	Khanapur,
		HAVERI	1	Hanagal,
		DHARWAD	1	Kalaghatgi,
		SHIVA MOGGA	4	Sorab, Tirthahalli, Sagar, Hosanagar
		HASSAN	1	Sakaleshpur,
		CHIKKAMAGALURU	5	Koppa, Sringeri, Mudigere, Narasimharajapura, Chikkamagaluru,
		KODAGU	3	Virajpet, Somwarpet, Madikeri
		UTTARA KANNADA	6	Sirsi, Siddapur, Yellapur, Supa, Haliyal, Mundgod
10	Coastal zone	DAKSHINA KANNADA	5	Bantwal, Belthangadi, Mangaluru, Puttur, Sulya
		UDUPI	3	Udupi, Karkala, Kundapur,
		UTTARA KANNADA	5	Karwar, Kumta, Honnavar, Bhatkal, Ankola

1.3 AGRO-ECOLOGICAL ZONES:

The Karnataka state is divided into six Agro-eco sub-regions based on physiography, bio-climate. Using available water capacity of the dominant soils, weekly rainfall and potential evapo-transpiration, the length of growing period (LGP) was calculated through water balance approach. Taking this LGP as base, seventeen Agro-Eco Zones (AEZ) were demarcated (Naidu et al, 2006). The 10 agro-climatic zones covering the 30 districts of the state and corresponding Agro-ecological zones (17) are listed in Table 2. These Agro-Eco Zones form the homogenous areas for crop planning.

Agroclimatic Zones of Karnataka

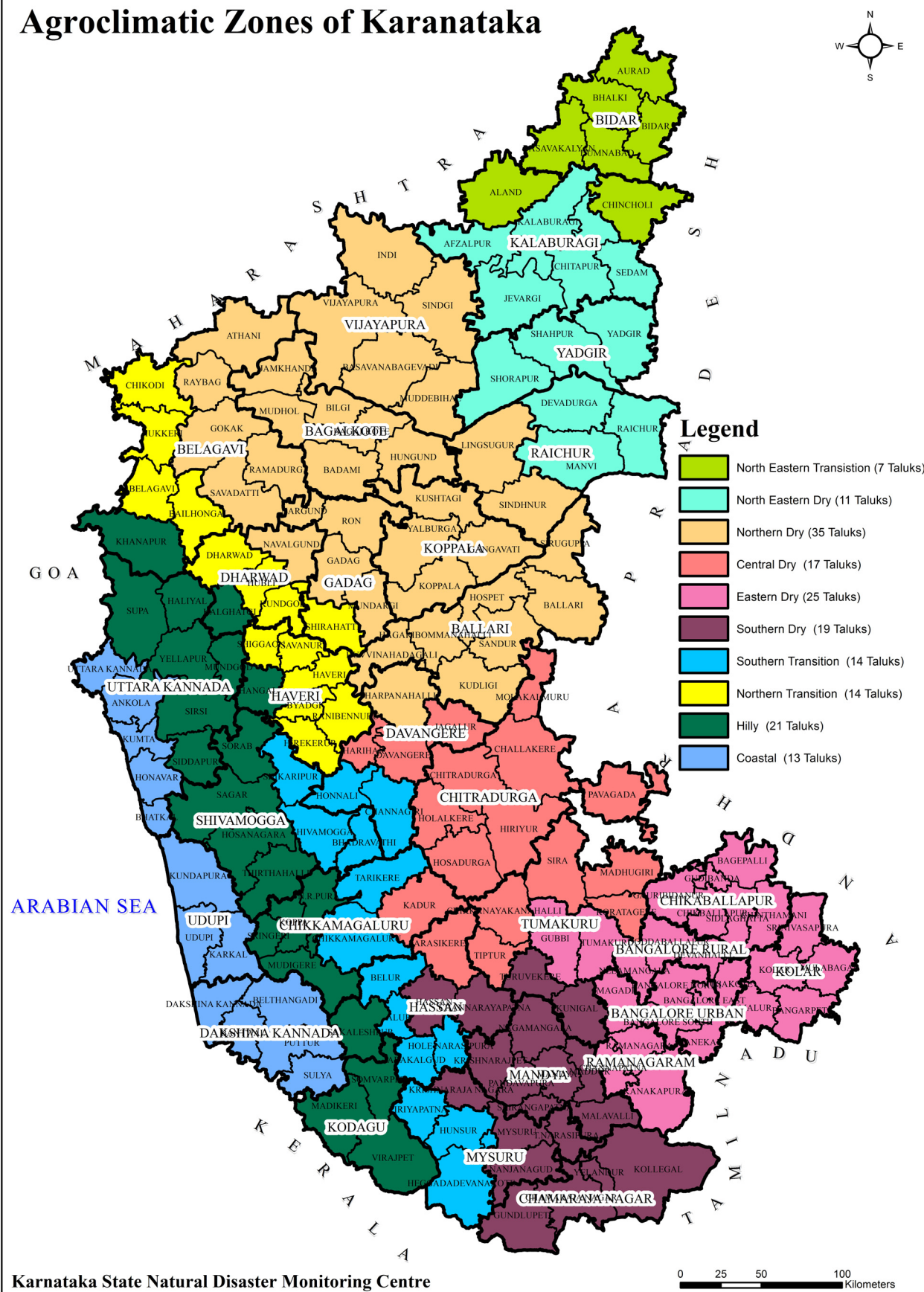


Fig.3. Agroclimatic Zones of Karnataka

Table 2. Agro-climatic zones, Agro-ecological zones in Karnataka

<i>Sl. No</i>	<i>ACZ</i>	<i>District</i>	<i>AEZ (NBSSLUP)</i>
1	North Eastern Transition Zone	KALABURGI BIDAR	1 & 2 1 & 2
2	North Eastern Dry Zone	RAICHUR KALABURGI YADGIR	1, 2 & 4 1, 2 & 4 1, 2 & 4
3	Northern Dry Zone	DAVANGERE BALLARI KOPPAL RAICHUR BELGAVI BAGALKOTE VIJAYAPURA GADAG DHARWAD	1, 2 & 3 1, 2 & 3 1, 2 & 3 1, 2 & 3 1, 2 & 3 1, 2 & 3 1, 2 & 3 1, 2 & 3 1, 2 & 3
4	Central Dry Zone	TUMAKURU CHITRADURGA DAVANGERE HASSAN CHIKKAMAGALURU	5 5 5 5 5
5	Eastern dry zone	BENGALURU-URBAN BENGALURU-RURAL RAMANAGARAM KOLAR CHIKBALLAPUR TUMAKURU	7 & 8 7 & 8 7 & 8 7 & 8 7 & 8 7 & 8
6	Southern dry zone	TUMAKURU CHAMARAJANAGAR MYSURU MANDYA HASSAN	6, 7 & 8 6, 7 & 8 6, 7 & 8 6, 7 & 8 6, 7 & 8
7	Southern transition zone	DAVANGERE MYSURU SHIVA MOGGA HASSAN CHIKKAMAGALURU	9 & 10 9 & 10 9 & 10 9 & 10 9 & 10
8	Northern transition zone	BELGAVI GADAG HAVERI DHARWAD	11, 12 & 13 11, 12 & 13 11, 12 & 13 11, 12 & 13
9	Hilly zone	BELGAVI HAVERI DHARWAD SHIVA MOGGA HASSAN CHIKKAMAGALURU KODAGU UTTARA KANNADA	12, 13 & 14 12, 13 & 14 12, 13 & 14 12, 13, 14 & 15 12, 13, 14 & 15 12, 13, 14 & 15 12, 13, 14 & 15 12, 13, 14 & 15
10	Coastal zone	DAKSHINA KANNADA UDUPI UTTARA KANNADA	16 & 17 16 & 17 16 & 17

Chapter 2.

DROUGHTS: GLOBAL, NATIONAL & STATE PERSPECTIVE

Drought is a period of below average precipitation in a given region resulting in prolonged shortage in water supply both in surface and sub-surface. It occurs due to consecutive monsoon failures. A drought can be short lived as few as 15 days or can last for months or years. It can have a substantial effect on the Agriculture, human population, livestock and ecosystem in the affected region. Droughts either of short duration or of long duration, both will have deleterious effect on the socio-economic conditions of the local population/society especially it affects the small and marginal farmers who are already facing food and livelihood insecurity.

Annual dry seasons in the tropics significantly increase the chances of a drought thus developing a chance for subsequent bush/forest fires. Periods of heat can significantly worsen drought conditions by hastening evaporation of water. There are two types of droughts i) Conceptual ii) Operational. The Conceptual droughts are those droughts that spell out the meaning of drought and its effects. For example drought is a prolonged period of deficient precipitation which causes extensive damage to crops (Plate 1) resulting in low yields. Whereas the operational droughts identify the beginning, end and severity. This is known by comparing the current situation with the historical average. The threshold value identified as beginning of drought is 75% of the actual precipitation over a specified time.

Usually arid and semi arid regions in the tropics are prone to droughts due to low precipitation and high temporal and spatial variations in temperature. These high temperatures can cause higher potential evapo-transpiration leading to droughts of varying severity.



Plate 1. Effect of drought in Karnataka : Fields.

Adaptability to these droughty situations is very much observed in the plant species. Many of the plant species in the drought prone areas have small, waxy coated leaves and cuticles with minimum surface area (Keddy, 2007). Many plant species especially the xerophytes such as *Cacti* and other desert grasses grow in these areas with small or no leaves thus limiting the loss of water through transpiration. Most of the arid/semi-arid ecosystems generally have low or limited crop productivity. Effect of drought is different on different sections of the society. In general, the poor and marginal farmers with limited alternative income sources are most vulnerable in these two ecosystems, thus, causing mass migrations in search of livelihood.

2.1 CONSEQUENCES OF DROUGHTS

Droughts can have significant environmental, agricultural, health risks, economic and social consequences. The effect on society varies with its vulnerability (plate.2). The marginal subsistence



Plate 2. Drinking water scarcity in drought affected area

farmers migrate since they lack other alternative income source. Drought can also reduce water quality because low water flows reduce dilution of pollutants and increase contamination of remaining water sources.

Common consequences of droughts:

- Diminished crop yields and milk/meat products from livestock.
- Lack of water for drinking, irrigation and industrial uses.
- Damage to eco-system.
- Hunger, its related deaths
- Too less water to support crops.

- Malnutrition related diseases.
- Mass migration, resulting internal migrants and international refugees.
- Reduced hydroelectric production.
- Snake migration which results in snake bites.
- Social unrest, war over natural resources, including water and food.
- Wild fires in the forest and domestic areas due to high temperature.
- Oxidation of acid sulphate soils due to low groundwater levels.

2.2 GLOBAL HISTORY OF DROUGHTS

Drought is a normal recurring feature of the climate in most parts of the world. These earliest climatic events are well documented. Migrations in 9500 BC from Chile have been linked to the exodus of early humans out of Africa and into the other parts of the world in 1,35,000 years ago.

Well-known historical droughts include:

- 1900 : India - deaths between 0.25 to 3.25 million
- 1921-22: Soviet Union in which over 5 million perished from starvation due to drought.
- 1928-30: North-east China resulting in over 3 million deaths by famine.
- 1936 & 1941: Sichuan province China experienced worst drought resulting in 5 million and 2.5 million deaths respectively.
- 1997-09: Millennium Drought in Australia led to a water supply crisis across much of the country. As a result, many desalinisation plants were built for the first time.
- 2006 : Sichuan province China experienced its worst drought in modern times with nearly 8 million people and over 7 million cattle facing water shortages
- 12- year: Drought in South-West Australia, South-East Australia, Victoria and northern Tasmania was very severe.
- Longest drought was recorded in the Atacama desert of Chile (400 years).
- The Amazon basin in 2005 experienced worst drought in 100 years.
- The Australian Millennial drought broke in 2010 due to severe ecological damage. There was a prediction that 'Perth' may be the world's first 'Ghost Metropolis' with little water to sustain its population unless the protective measures are taken to minimize the damage.
- A few million people were affected due to droughts in East Africa and Western Sahel area.

Drought is a regular companion in India. In 1951, the drought affected area was 34 % while in 1972, it affected 42 percent of the area. In 1985 and 2009, the drought affected area was 42.3 percent and 59 percent respectively. Again in 2015, the spread of drought was 39 percent of the area in the country affecting food production in West Bengal, Uttar Pradesh, Madhya Pradesh and acute water shortage in Maharashtra, Andhra Pradesh, Telangana and Karnataka States.

2.3 NATIONAL PERSPECTIVE OF DROUGHTS

Droughts in India are quite common and wide spread, some part or the other is affected by drought or drought like situation. Due to drought and acute shortage of drinking water, there is mass migration in search of green patches for the livelihood from the villages. There are several occasions wherein the people in whole village leave their dwellings and migrate to the nearby towns/cities in search of jobs, this, leads to abandoned villages/ghost villages in due course of time. This kind of situation exists in many of the villages/towns of majority of the states in India with no more water either in ground or surface to sustain the existing and growing population.

Drought in 2015 affected many of the food producing states of India. With deficit rainfall in 2013-2014, there was 5% reduction in food grain production in India.

The monsoon deficit and the percent area affected in the country from 1951 to 2015 (Table 3) indicate that the rain fall deficit ranged from -7.1 to -26 percent, while the percent affected area was upto a maximum of 42.3% in 1985 and to as low as 10% in 2002.

Table 3. Drought affected area in India

<i>Year</i>	<i>Monsoon deficit</i>	<i>%Area affected</i>
1951	-18.7	34
1965	-18.2	37
1966	-13.2	34
1972	-26	40
1974	-12	33
1979	-18	35
1982	-14.5	29
1985	-7.1	42.3
1987	-25	17.9
2002	-19	10
2014	-12	25
2015	-14	39

Source: Ministry of agriculture & farmers welfare

During 2015, Maharashtra state declared drought in 37% of the villages, since they received less than 50% of the normal rain fall. Most of the villages in Marathwada region of the state in general and Lathur town/district in particular is worst hit due to consecutive droughts and droughty situations causing acute surface and ground water scarcity (Mahapatra, 2016). Proper water management perhaps would have saved the thirsty population in the city and around areas. Nevertheless the government introduced water trains to tackle the grave situation but there is no solace. Hence a day may not be far off to christen “Lathur” a ghost town due to the migration of the people from the town, if this situation continues.

2.4 DROUGHTS IN KARNATAKA STATE

Occurrence of droughts in Karnataka state is common phenomenon, due to spatial and temporal variation in rainfall which ranges from 4747 mm in coastal region, followed by Malnad region with 3500 mm to as low as 477 mm in south interior Karnataka. There is both temporal and spatial variability within the region (Chadrashekhara & Venugopal, 1995). Besides, there is temporal variability between

and within the seasons. Due to this variability both spatially and temporally different regions are prone to disasters like floods and droughts simultaneously in the state. The State is regularly affected by drought (Plate.3) though, less by flood. The drought affected area covers almost the entire rainfed agricultural area. Nearly 80% of these taluks (KSNDMC) in the State are drought prone (Fig.4).



Plate 3. Effect of Drought in Karnataka : Tanks

Rainfall is an important element of economic growth of an area or region, especially in a country like India, where a large number of people are occupied in agricultural activities. The amount of rainfall does not show an equal distribution, either in space or in time. It varies from heavy rain to scanty in different parts. It also has great regional and temporal variations in distribution. The study of rainfall distribution pattern and its temporal variations is very important, as the country's economy is highly dependent on agriculture(Venkataraman,2003). This kind of information is very useful for farming community, government and non government bodies and scientific institutions and universities. Therefore, the study has been conducted in order to help policy makers and developers to make more informed decisions and especially the farmers to take necessary steps in cultivation process.

2.4.1: Criteria for delineation of Drought Prone areas

Till date the indicators used (Drought Manual 2009, Ministry of Agriculture and Cooperation, Govt. of India) for deciding drought prone areas of Karnataka state by KSNDMC are:

- **Rainfall deficiency of more than 20% of the normal:** Rainfall deficiency is calculated based on the observed data (collected through telemetric Rain Gauges) against Normal Rainfall.
- **≥ 4 consecutive weeks of dry spell:** If the Rainfall is less than 50% of the Normal in any week then that week will be considered as dry week. Four or more such dry weeks recorded consecutively during the season then that will be considered as an Indicator of Drought.

KARNATAKA

Drought Affected Taluks

2001 - 2015

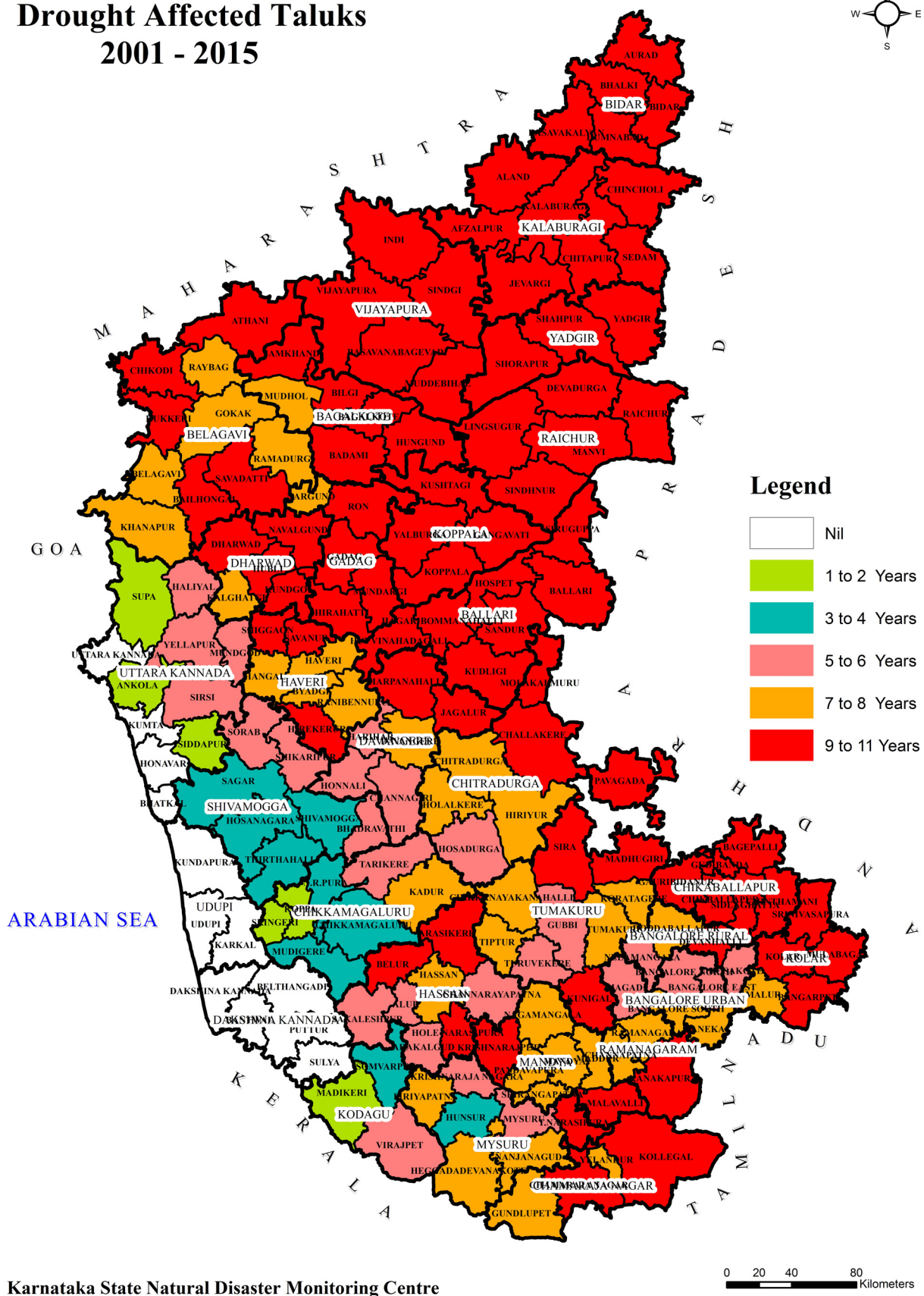


Fig.4. Frequency of Drought affected Taluks in Karnataka

- **Moisture Adequacy Index (MAI):** Moisture adequacy index is calculated based on weekly rain fall, Available water capacity of soils, potential evapotranspiration (PET) and actual evapotranspiration (AET) in the area through water balance approach. The MAI is obtained by the ratio of AET and PET (through the formula $MAI = AET/PET \times 100$) during the phenological stages of the crops. Agricultural drought is determined based on MAI (Table 4) as under:

Table 4. Agricultural Drought code

<i>MAI=(AE/PE)*100 (During different Phenophases)</i>	<i>Drought Intensity</i>	<i>Phenophase growth stage wise</i>		
		<i>Seedling (S)</i>	<i>Vegetative (V)</i>	<i>Reproductive (R)</i>
76-100	No Drought	S ₀	V ₀	R ₀
51-75	Mild Drought	S ₁	V ₁	R ₁
26-50	Moderate Drought	S ₂	V ₂	R ₂
25 or less	Severe drought	S ₃	V ₃	R ₃

Intensity of agricultural drought				
<i>Sr.No</i>	<i>No drought</i>	<i>Mild</i>	<i>Moderate</i>	<i>Severe</i>
1	S ₀ V ₀ R ₀	S ₀ V ₀ R ₂	S ₀ V ₀ R ₃	S ₀ V ₂ R ₃
2	S ₀ V ₀ R ₁	S ₀ V ₁ R ₂	S ₀ V ₁ R ₃	S ₀ V ₃ R ₂
3	S ₀ V ₁ R ₀	S ₀ V ₂ R ₀	S ₀ V ₂ R ₂	S ₀ V ₃ R ₃
4	S ₁ V ₀ R ₀	S ₀ V ₂ R ₁	S ₀ V ₃ R ₀	S ₁ V ₂ R ₃
5	S ₁ V ₀ R ₁	S ₁ V ₀ R ₂	S ₀ V ₃ R ₁	S ₁ V ₃ R ₃
6	S ₁ V ₁ R ₀	S ₁ V ₁ R ₁	S ₁ V ₀ R ₃	S ₀ V ₂ R ₃
7	S ₀ V ₁ R ₁	S ₁ V ₁ R ₂	S ₁ V ₁ R ₃	S ₂ V ₀ R ₃

Source: Vittal, Kar and Rao, CAZRI

Generally If MAI is less than 50% in a given area during the season then this area is considered as Droughty area.

- **Normalized Difference Vegetation Index (NDVI):** This is an Index derived from the satellite image based on the coverage and vigour or health of the crop. If the index value is more than 0.4 then the crop health is considered to be good and when the value is less than 0.4 then the crop is considered to be under stress. This is considered along with crop area affected by deficit rainfall, for identifying areas affected by drought. $NDVI = (NIR - VIS) / (NIR + VIS)$ where VIS, NIR are spectral reflectance measurements in visible and near infrared regions.
- **Sowing Status:** If the sowing is less than 50% in any area during the season then it is an Indicator of Drought. Also, if more than 33% of the sown crop lost during the season that is also considered as indicator.

Based on the above criteria the drought affected Taluks in Karnataka state were identified at Hobli level with high spatial and temporal resolution rainfall data obtained from its network of telemetric rain gauges from 2001-2015 (Fig. 5).

This indicates that in these fifteen years, three years (2005, 2007 & 2010) have no drought or droughty situation. In rest of the 12 years 2003 was a severe drought year since 162 Taluks out of 176

Taluks (92%) were reeling under drought. In 2002 & 2012 out of 176 Taluks 159 Taluks (90%) and 157 Taluks (89%) were affected by drought. Among these 12 years in 2001 & 2014 the drought was less intense (18-19%) and only 33 to 34 Taluks were affected while in all the 10 years the drought was wide spread (>50%) and severe to very severe in the state.

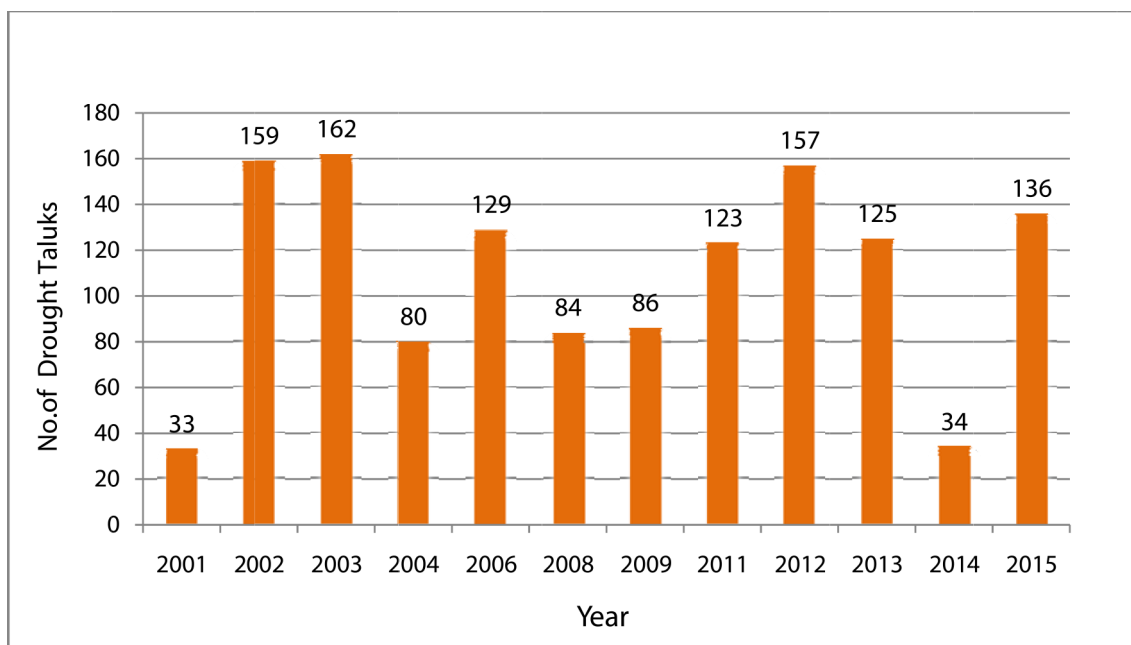


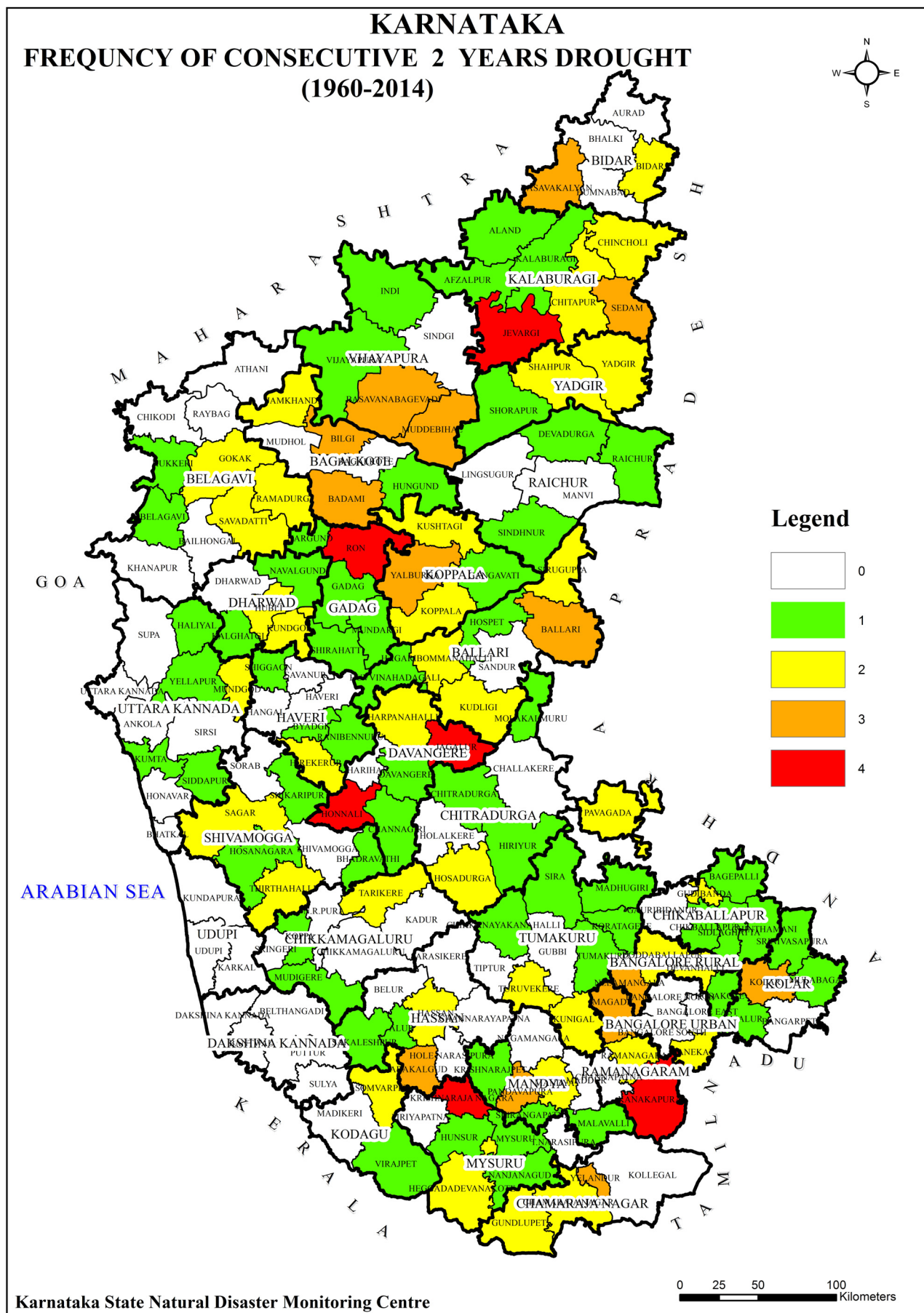
Fig. 5. Number of Drought affected Taluks (2001-2015)

Among the Taluks (Table 5, Fig. 6a, 6b) Kanakpura, Mulbagal, Bagepalli, Pavagada, Sira, Challakere, Jagalur, Ballari, Hadagali, Siruguppa, Kushtagi, Yelburga, Deodurga, Lingusugur, Manvi, Raichur, Kalaburgi, Shahapur, Shorapur, Yadgir, Bidar, Balki, Humnabad, Bailhongal, Bagalkote, Bilgi, Hungund, Jamkhandi, Basavanabagewadi, Vijayapura, Indi, Muddebihal, Sindagi, Mundargi, Hirekerur and Kundagol have 10 years of drought, i.e about 71% probability and Chikballapur, Aland, Chincholi, Jewargi, Aurad and Shirahatti Taluks have 11 years of drought with 79% probability. Majority of these Taluks belong SIK & NIK regions. About 87 Taluks have experienced drought in 7-9 years i.e with >50% probability. In rest of the Taluks that belong to Malnad and Coastal regions the drought was observed in 0 to 6 years with a probability of 0 to <49%.

Table 5. Drought affected taluks in different regions (2001-2015)

<i>Period</i>		<i>2001-2010</i>		<i>2011-2015</i>	
<i>Region</i>	<i>Total Taluks</i>	<i>Avg No. Drought Taluks</i>	<i>% of Drought Taluks</i>	<i>Avg No. Drought Taluks</i>	<i>% of Drought Taluks</i>
SIK	63	38	61	48	76
NIK	69	54	78	54	78
MALNAD	25	11	42	11	43
COASTAL	19	2	12	3	14
Total	176	105	59	115	65

Source: Karnataka State Natural Disaster Monitoring Centre.



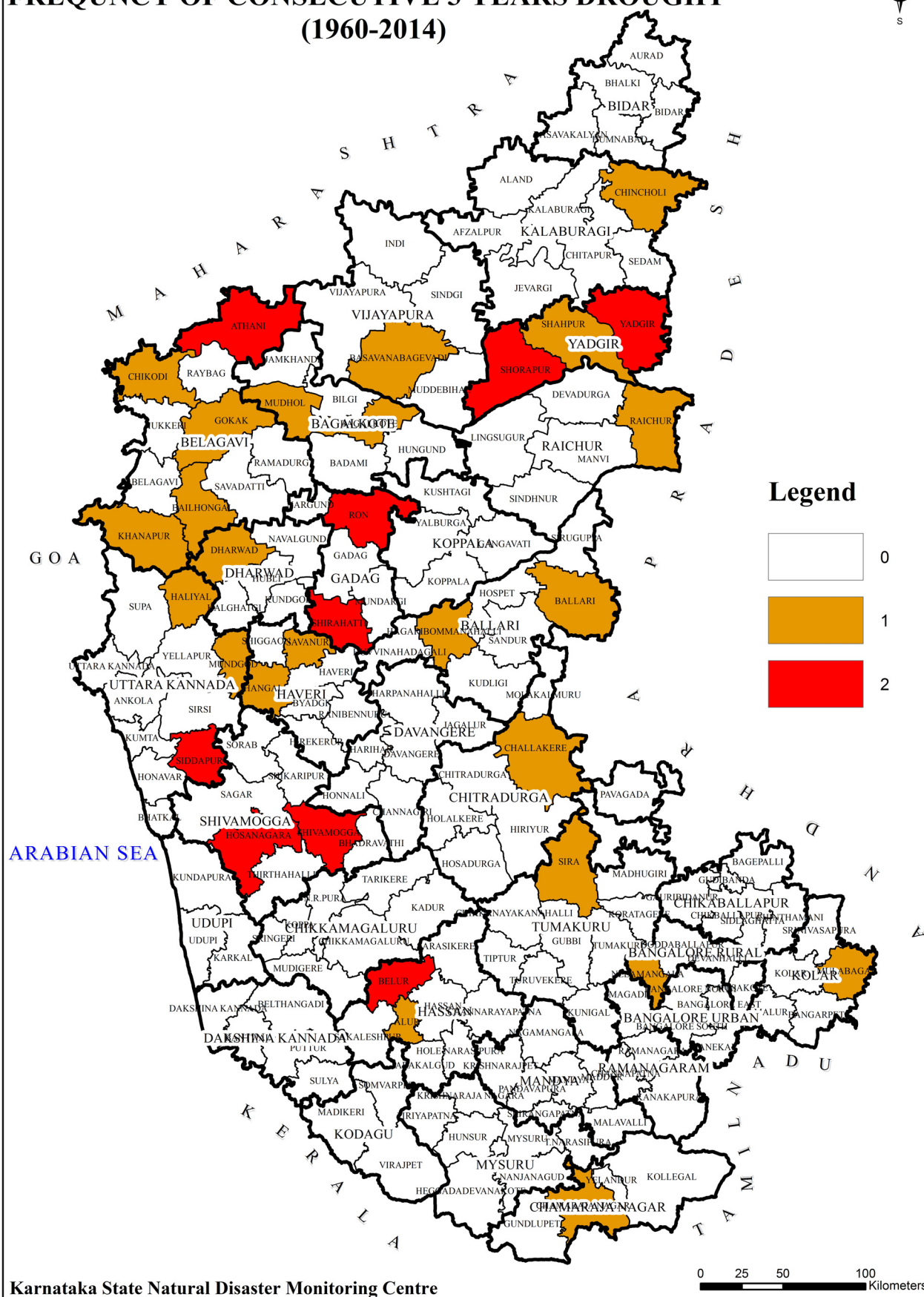


Fig.6b. Drought affected taluks Consecutively three years (1960-2014)

In Karnataka there are four regions with varying (arid-semiarid and sub-humid-humid) climatic conditions. In each of these regions, the total number of Taluks and the percent to total Taluks affected by drought in each region during 2001 to 2010 and 2011 to 2015 (Table 5) are compiled. In 2001-2010 about 105 Taluks on an average (59%) are affected by drought in all the regions while in 2011-2015 on an average 115 Taluks (65%) are affected by drought. It shows that on an average there is an increase in drought affected Taluks within a short period of five years in the state indicating variability. Among the regions NIK showed the highest average number of Taluks (54) prone to drought both during 2001-2010 and 2011-2015 while the number of Taluks prone to drought is least in Coastal region. Percent of drought prone Taluks during 2001-2010 in these regions follow this order: NIK (78%) > SIK (61%) > MALNAD (42%) > COASTAL (12%).

The similar trend of proneness to drought is observed among the regions during 2011-2015 also with a little variation in the number of Taluks and percentage. The time series analysis of precipitation from 1960-2014 in Karnataka state indicate that there are areas of 2 consecutive years of droughts (Fig. 6a) with different severities and areas of 3 consecutive years of droughts (Fig. 6b) with varying severities.

2.5. TYPES OF DROUGHTS

Mainly four types of droughts are identified globally. They are 1) Meteorological Drought, 2) Hydrological Drought, 3) Agricultural Drought and 4) Socio-economic Drought. The first three deal with the physical phenomenon while the last one is based on supply and demand problem through the short fall of water. While in India, seven types of droughts are recognized and are listed as:

1) Meteorological Drought

This drought is short lived. The main causes for this drought are: i) Lean monsoon, ii) Late onset or early withdrawal of rain, iii) Prolonged breaks during monsoon. Meteorological Drought usually precedes all other kinds of droughts. It occurs when seasonal rainfall in an area is less than 25% of its normal value. It is classified as moderate drought if the rain fall deficit is 26-50% and severe when the deficit is more than 50% of the normal.

2) Hydrological Drought

As per the Central Water Commission (CWC) a particular year may be considered as hydrological drought year, if the runoff is less than 75% of the normal runoff and when there is shortage of water for normal/specific needs. This drought could occur even when the rainfall is average that diminishes the reserves.

A) **Surface water Drought:** This is due to i) deforestation ii) indiscriminate mining, construction iii) disturbing the natural water ways. This affects the stream flow, inflow to reservoirs, lakes & ponds.

B) **Ground water Drought:** Excessive pumping of ground water without replenishment.

3) Agricultural Drought

It is the direct impact of meteorological and hydrological droughts on crop yields. This is

due to soil moisture deficiency during crop growth period , plant water stress leading to wilting and reduced bio-mass and yields. The criteria followed for agricultural drought in Karnataka state Disaster Monitoring Centre (KSNDMC) are as per the Guidelines in the Drought Manual, 2009, Ministry of Agriculture & cooperation, Govt. of India (as given in section 2.4.1).

4) Soil Moisture Drought

It occurs when water supply to soil solum is less and the evaporative demand is more due to high temperature, high winds, low relative humidity. It is also due to low infiltration, low storage/ AWC and deep percolation.

5) Socio-economic Drought

Reduction in the availability of food/income loss due to failure of crops. This affects the socio-economic fabric of the society and leads to compulsive migrations from the village to cities in search of greener pastures for their food and livelihood.

6) Ecological Drought

When Drought affects the ecosystem, ecoenvironment and its production system significantly as a consequence of distress induced environmental damage.

7) Famine

If those droughts prolong for longer periods, there will be large scale deficiency of food/ feed/water that leads to large scale mass starvation causing deaths.

2.6. EARLIER APPROACHES FOR DELINEATION OF DROUGHT PRONE AREAS

Drought Prone areas and drought vulnerability areas identification have distinct boundary. In general, the identification of drought prone areas is dealt with few indices developed based on a few indicators related to drought, while the drought vulnerability assessment has wider perspective and is based on many indicators pertinent to the hazardous event (drought). It also deals with the adaptive capacity of the society and its resilient attitude to overcome the droughty situations.

Most of the criteria for delineation of the drought prone areas in the state and national level were based on rainfall. A threshold value of <750 mm of annual rainfall (Irrigation Commission, 1972) is considered to demarcate the drought prone areas. At times, this criteria may not hold good since some of the areas with annual rainfall >750 mm also experience the droughty conditions. Indian Meteorological Department (IMD) considers a year with annual rainfall of 75% or less of normal as drought year. Further, the rainfall deficit of 25% of normal value in an area, is considered for meteorological drought.

Additionally many indices used for demarcating drought prone areas are usually developed from one or two components/parameters/indicators like rainfall, Potential Evapo-Transpiration (PET) and Actual Evapo-Transpiration (AET). Among these indices , Standardized Precipitation Index (SPI) based on precipitation, Aridity Index Anomaly (AIA) based on rainfall, PET & AET, Palmer Drought

Severity Index (PDSI) based on moisture conditions between the locations temporally, Crop Moisture Index (CMI) compares degree to which crop moisture requirements are met, Normalized Difference Vegetative Index (NDVI) based on vegetation vigour and cover; Moisture Adequacy Index (MAI) based on weekly water balance, Soil Moisture Deficit Index (SDMI) based on soil moisture deficit, Evapo-transpiration Deficit Index (ETDI) based on evapo-transpiration deficit and Drought Severity Index (DSI) are usually used for identifying drought prone areas.

Attempts were also made to delineate drought prone areas based on climate soil based approach (Challa & Wadodker, 1998, Naidu et al, 2005). Here weekly rainfall, available water capacity, potential evapo-transpiration were considered and the length of growing period (LGP) was arrived. As per the LGP, the severity and extent of drought prone areas were demarcated (Fig.7). Additionally, the droughts may occur in early, mid or late season. The moisture stress during the crop growth stages which causes for yield variation, may also be used as drought indicator. All these earlier methods are aimed at causal factor(s) and their impact on the exposed area and assessment of the severity of the hazard. These methods, however gave low or no priority to assess the affected society.

2.6.1 Present approach and its importance

Looking to the limitations in the earlier approaches, a holistic multi component, two-tier approach was used to develop a composite index to assess drought vulnerability. For this approach, the spatio-temporal variability in the climatic conditions leading to droughts and other related conditions in the state, spatial variability in the soils, irrigation and crop growing environment, socio-economic variability in the farming conditions at Taluk level were used for developing a composite index and suggest drought proofing measures to alleviate the effect/risk of drought in general on the livelihood of the people in the drought affected area.

Assessment of Drought Vulnerability is multi dimensional than only the delineation of drought prone areas since it considers many indicators, encompassing physical, social, economical, environmental and institutional features. The indices such as exposure, sensitivity and adaptivity and their composite index were used to delineate vulnerable areas (Murthy et al, 2015; Madhuri et al, 2014; LIU xiaoqian et al, 2013). In the present approach, four major components covering climate, crop-cover, soil and livelihood that are relevant to drought were considered. These major components are supported by 28 sub-components for developing major component-wise indices. The four major component-wise indices are used to develop composite index of drought vulnerability for 176 taluks in the state.

The present approach considers multi-component data sets over a time period. The time series data sets and their major component-wise analysis separately provides an excellent opportunity to show their functional relationship precisely and helps to develop effective composite index of drought vulnerability at taluk level.

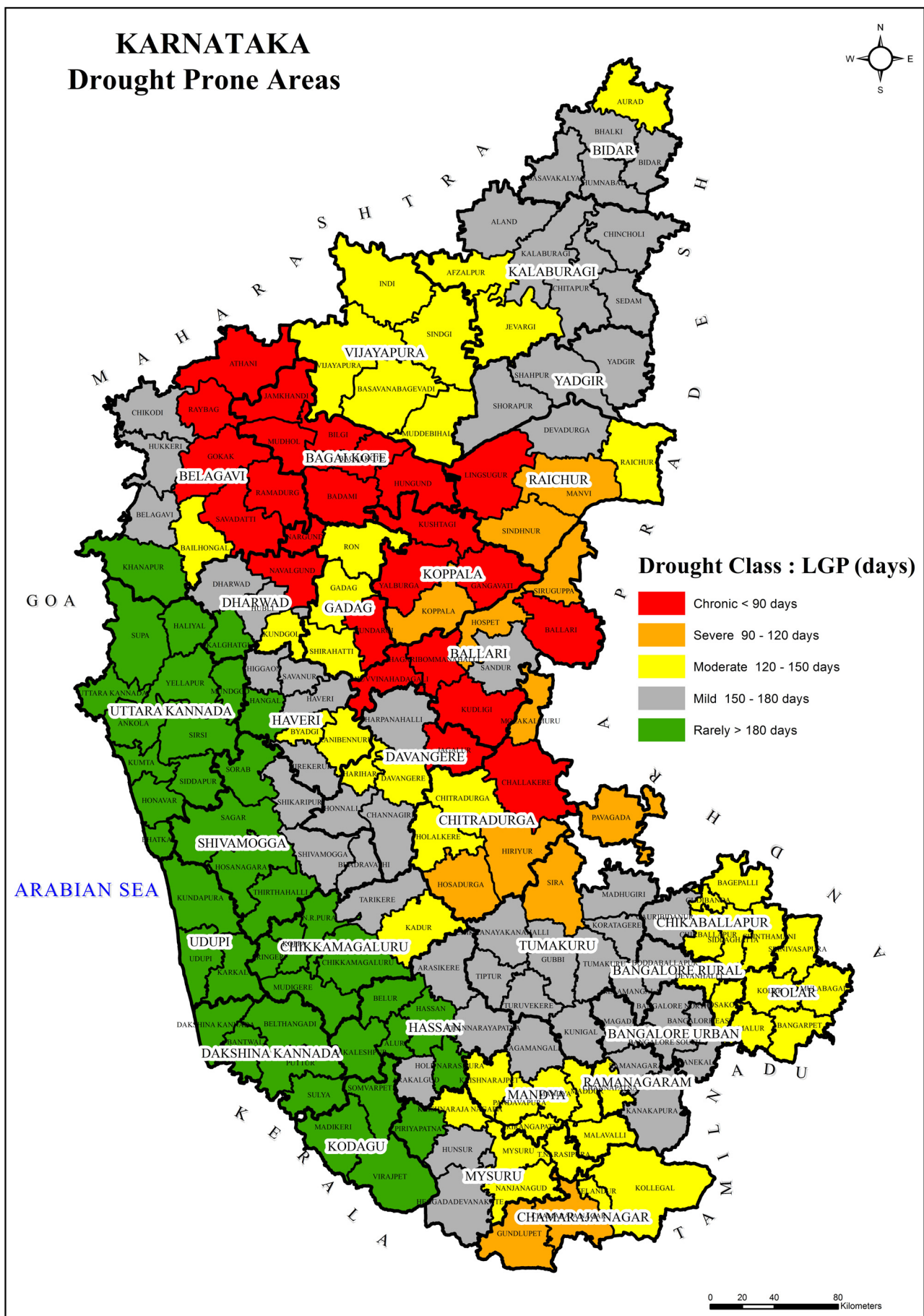


Fig.7. Drought Prone areas in Karnataka

Chapter 3.

VULNERABILITY CONCEPT: IT'S DEVELOPMENT

Vulnerability refers to the frangible nature of a system faced with various types of potential disasters. Vulnerability is derived from Latin root “Vulnerare” meaning the wound. This is dynamic and changes with time and space. Vulnerability is multi dimensional that encompasses physical, social, economic, environmental and institutional features (Birkmann, 2005). It is the capacity to anticipate, cope with, resist and recover from the impact of natural disasters. Cardona’s (1999) concept of vulnerability consisted three factors. They are

- 1) **Physical exposure** and susceptibility which is designated as hard risk and viewed as being **hazard dependent**,
- 2) **Fragility of the socio-economic system**, which is viewed as soft risk and being **non hazard dependent**,
- 3) **Lack of resilience** to cope and recover, this is also defined as soft risk and being **nonhazard dependent**.

The vulnerability concept and its growth of applicability (Birkmann, 2006 & 2007) could be presented in five spheres (Fig.8), initially the vulnerability was viewed to explain the internal risk factor i.e Intrensic vulnerability of the exposed community, social group or ecosystem. Later it is thought to be human centered that points out the damage or likelihood injury to the people at risk. In due course it is felt that vulnerability is dualistic that deals with susceptibility and ability or capacity to cope with and recover from hazardous event. In later days the vulnerability is understood as multifaceted concept that covers exposure, sensitivity, susceptibility, coping capacity, adaptation and response to the perturbations and stresses. Thus the figure-8 depicts the widening of the vulnerability concept from physical structure analysis to multi dimensional approach since it encompasses physical, social, economic, environmental and institutional features.

3.1. MEASURING VULNERABILITY

The purpose of assessing vulnerability is to identify the detrimental external events. their potentials and social response to those events or appropriate actions that can be taken to reduce vulnerability before the potential for damage is realized. The vulnerability assessment can also be linked to sustainable livelihood framework since it covers human, natural, financial, social and physical aspects.

Mapping vulnerability to drought is a challenging task because drought is also a complex and least understood phenomenon which lacks universal criteria and definition. Many workers used three dimintions (Murthy et al, 2015; Madhuri et al, 2014; LIU Xiaoqian et al, 2013) for assessing vulnerability i.e exposure, sensitivity and adaptive capacity. The indicators used for expressing these three dimintions are:

a) Exposure: precipitation, rainy days, b) Sensitivity: crop cover through NDVI and c) Adaptive capacity: soil, irrigation, land holdings. There are few more models (Wisner et al, 2004) like PAR model (the Pressure And Release model) which deals with two forces: those forces that generate or

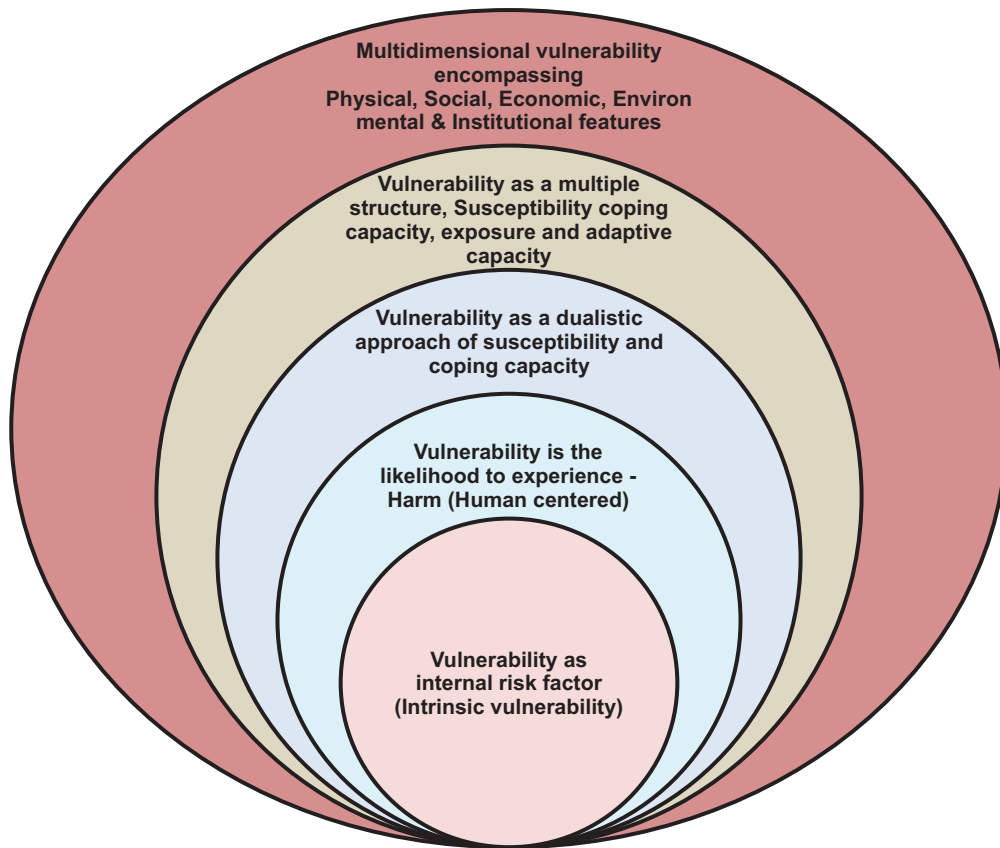


Fig.8. Concepts of vulnerability (Birkmann, 2005)

cause vulnerability and the hazardous event itself. Cardona (1999) developed a conceptual holistic approach which views as physical damage from exposure & physical susceptibility and impact factor from socio-economic fragilities and lack of resilience.

3.2 VULNERABILITY-RESILIENCE

There are different kinds of opinions about vulnerability and resilience. Many workers are of the opinion that the vulnerability and resilience are independent entities that coexist in a situation (Madhuri et al, 2014; UNDRO, 1982). A few are of the opinion that they are inversely related i.e if one increases, the other decreases (Wilson, 2012). At times it is felt that vulnerability encompasses the resilience since the former covers the capacity of the affected society to thwart the effect of disaster (Turner, 2010).

Resilience reflects the ability of the affected society which is entirely based on the qualities of the households. The qualities like robustness, rapidity & resourcefulness (Bruneau et al, 2003). These qualities are related to their technical awareness, education, swiftness in taking action, physical and mental involvement, community approach rather than individualistic attitude to tackle the situation. At times, irrespective of the inherent resilience, the household's impassive and apathetic approach, expecting much from the government also delays the recuperation from the droughts/disasters.

With the background information on droughts their causes, consequences, distribution and severities that affect the fragile, economically and socially oppressed societies, an attempt is made at Taluk level in Karnataka state, to assess the drought vulnerability and resilience through a multi component, two tier composite index approach. This approach envisages the use of four major

components and twenty eight sub-components. Drought proofing measures at Taluk level as per severity class were also suggested. Drought resilience at taluk level was ascertained. The extent of drought vulnerability in each Agro-Climatic Zone was estimated. The effect of drought vulnerability on different groups of population was assessed.

Chapter 4

METHODOLOGY

4.1. FRAME WORK FOR DEVELOPING COMPOSITE INDEX ON DROUGHT VULNERABILITY

The framework provides information on the basis of selection of major components and sub components for developing a combined / composite index (OECD, 2008). The composite index thus developed clearly depicts the vulnerability of any taluk with respect to drought. For the development of the composite index, the major components and sub-components selected are relevant and prime contributors to drought vulnerability. The input data base considered for the study and the steps followed to arrive at the composite index (Fig.9) are as under:

4.2 STEPS FOR THE APPROACH

The approach has been dealt under the following eight steps:

1. Identification and selection of relevant components:
 - a) Major-components
 - b) Sub-components (indicators)
2. Collection & Compilation of the sub- components under each major component
3. Data Analysis:
 - a) Normalization of the selected sub-components (indicators)
 - b) Assignment of weight ages for the sub-components (indicators)
4. Computation of the sub-components under each major component as individual Index
5. Delineation of different classes at fixed class interval based on the Values of each Index
6. Preparation of maps
 - I. Climate based Index (CI)
 - II. Climate/Crop cover based Index (CCI)
 - III. Climate-Soil based Index (CSI)
 - IV. Livelihood based Index (LI)
7. Development of **Composite index** for drought vulnerability (DVI)
8. Categorisation of the Taluks under different levels of vulnerability:
 1. Very Slightly Vulnerable;
 2. Slightly Vulnerable
 3. Moderately Vulnerable;
 4. Highly Vulnerable;
 5. Very Highly Vulnerable

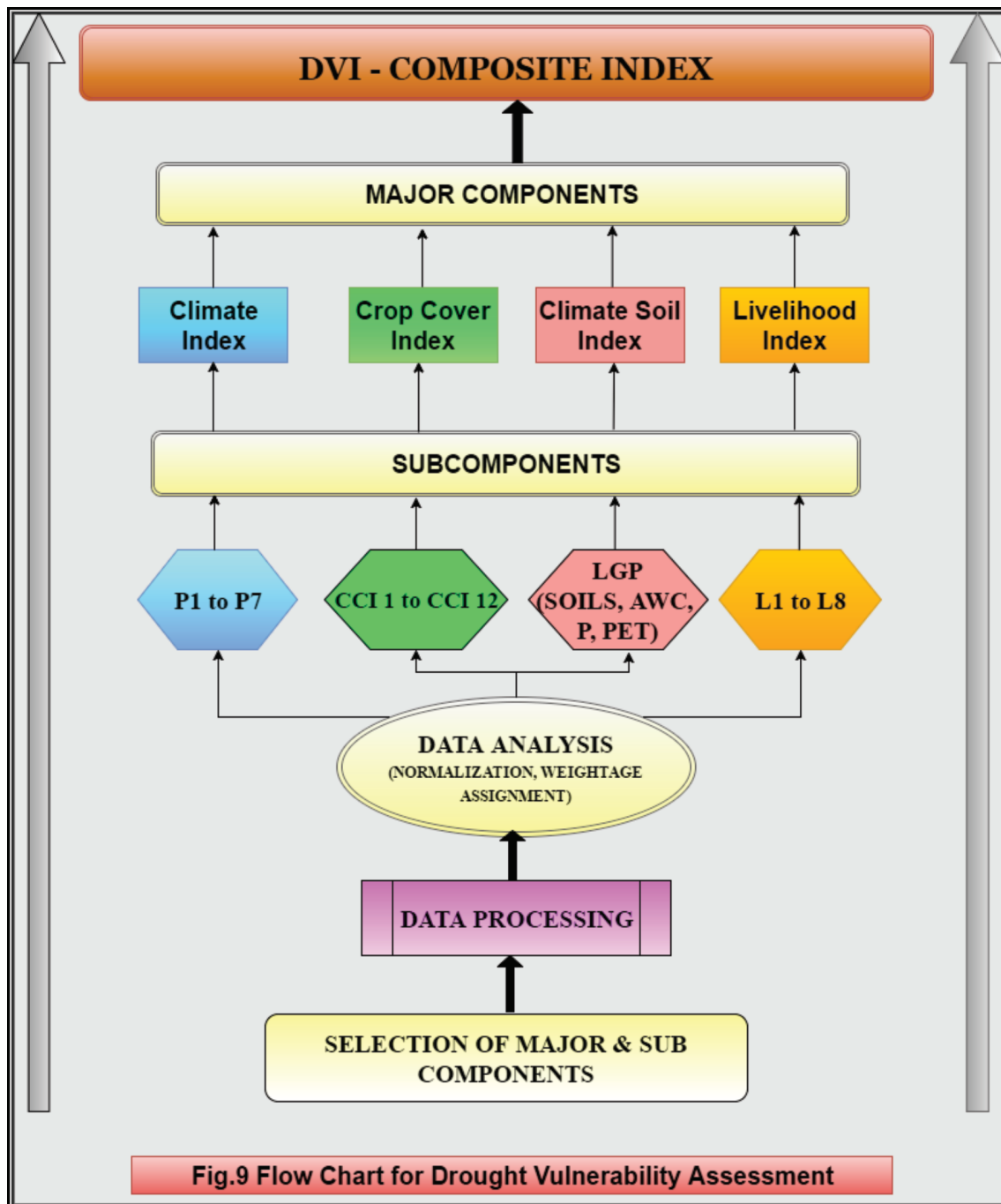


Fig.9 Flow Chart for Drought Vulnerability Assessment

4.3 MAJOR COMPONENTS AND SUB- COMPONENTS

For this study four major components namely, climate based, climate-soil based, climate crop cover based and livelihood based components that are relevant to drought vulnerability were selected. Under each major component, the sub-components (indicators) that have direct relevance with respect to drought vulnerability are considered.

4.3.1 Assumptions for selection of Major & Sub-Components

The following criteria are considered for the selection of major and sub-components:

1. Each major component express vulnerability partially

2. The sub-components selected under each of the major component are relevant & reflect the behavioral pattern with respect to the major component
3. Each of the sub-components considered is either directly or indirectly contribute/express the drought vulnerability in an area.
4. The combination of the four Major components, express the phenomena of location specific drought vulnerability in an apt way.

4.4 DATA BASE COMPILATION & PROCESSING

The time series data of these sub-components at taluk level for different periods as per the availability are collected and compiled for further analysis under each major component. Each sub-component is treated as an independent variable during the analysis and is presumed to contribute either positively or negatively towards the major component with respect to drought vulnerability in an area.

4.4.1. Climate Based Index (C I)

The Karnataka State is regularly affected by drought. The drought affected area covers nearly 80% of the taluks in the State, almost the entire area under rain fed agriculture. The occurrence and spatial distribution of rainfall is variable and not dependable. Taluk wise Normal rainfall of the state (Fig. 10) varies from 408 mm to 5051 mm. Of the total rainfall received, around 80% is from Southwest Monsoon (June to September) and the remaining 20% is through pre monsoon and North East monsoon. It is observed that the annual rainfall is highest over the Western Ghats and lowest in the eastern parts of Chitradurga district, near Challakere. Taluk wise Annual variability (CV) of the rainfall ranges from 16 to 40%.

To know the variability of rain fall spatially and temporally KSNDMC has designed and installed a network of Telemetric Rain Gauges (TRG) at 5986 Gramapanchayaths (~25 sq. km each) and Telemetric Weather Stations at all 747 Hoblis (~250 sq. km each) across the state. TRG is used to measure the Rainfall and TWS measure four parameters such as Temperature (°C), Relative Humidity (%), Wind Speed (m/s) and Wind Direction (degrees).

Rainfall is an important subcomponent or Indicator of an area or region. The study of rainfall distribution pattern and its temporal variation is very important in assessing the vulnerability, since the rainfall and its aberrations, directly affects the crop performance in the area.

Taluk wise historical rainfall data of Karnataka State for 55 years (1960 to 2014) was considered for the study. Average rainfall over the 55 years period is considered as Normal rainfall.

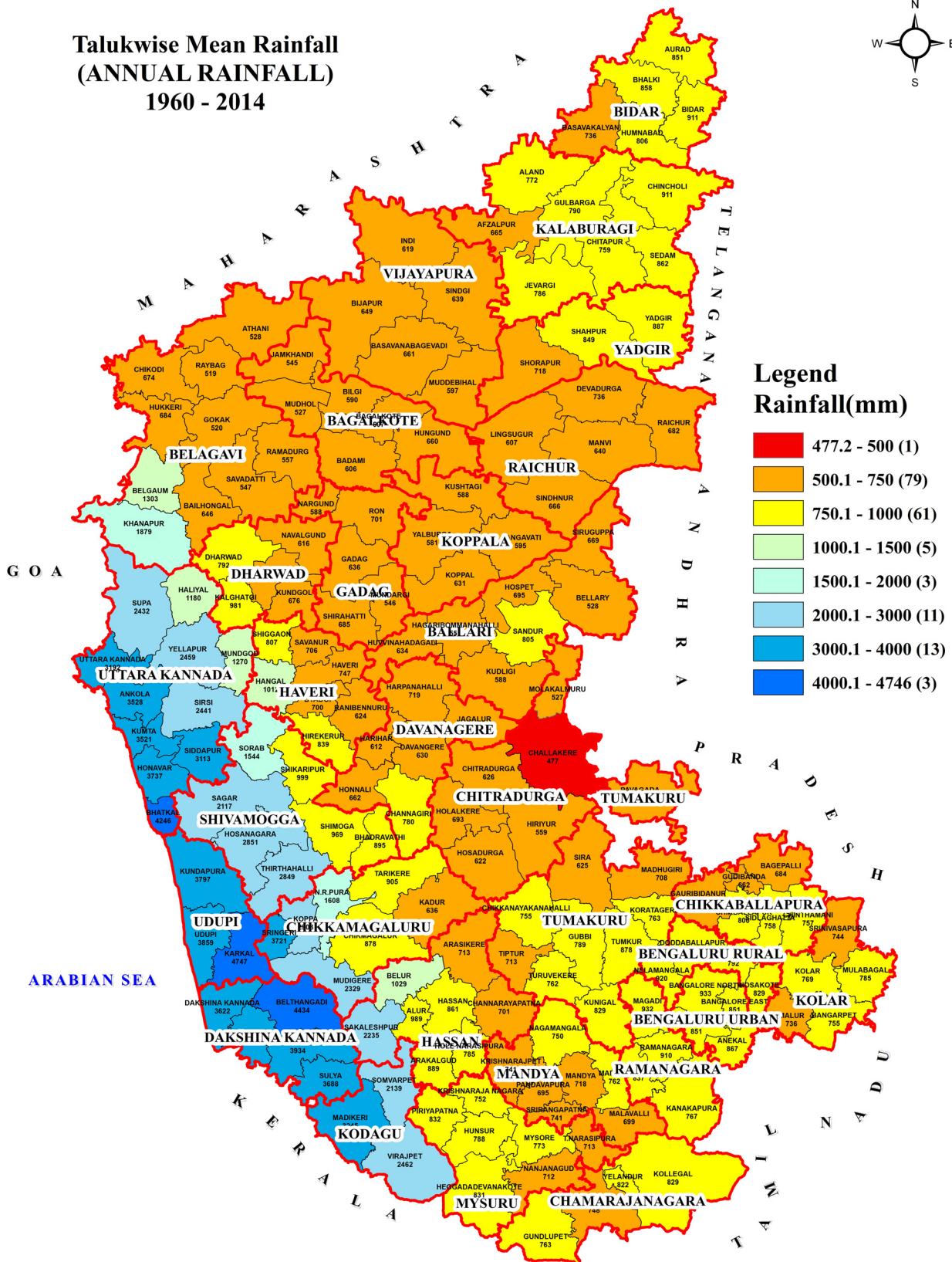
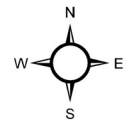
- **Coefficient of Variation (CV):** The coefficient of Variation (CV) is defined as the ratio of the standard deviation (SD) to the normal, multiplied by 100.

$$CV = \frac{SD \text{ of the rainfall}}{Mean Rainfall} * 100$$

CV shows consistency of the rainfall. If CV is very high, the variability in rainfall is high indicating the possibility of drought. CV of South west monsoon and North east Monsoon is used as indicators in drought vulnerability study to find out drought condition.

Karnataka State Natural Disaster Monitoring Centre

Talukwise Mean Rainfall (ANNUAL RAINFALL) 1960 - 2014



Rainfall Range	477.2 - 500	500.1 - 750	750.1 - 1000	1000.1 - 1500	1500.1 - 2000	2000.1 - 3000	3000.1 - 4000	4000.1 - 4747
No. Of Taluks	1	79	61	5	3	11	13	3
%	1	45	35	3	2	6	7	2

0 15 30 60 90 120
Kilometers

Fig.10. Taluk wise Annual Mean Rainfall (1960-2014)

- **Rainy day:** if a day receives 2.5mm of rainfall then that day is called as a rainy day.
- **Average rainy days:** Average rainy days over the period.

$$\frac{\text{Sum of rainy days in a given period}}{\text{Length of the Period in days}}$$

Average Rainy days over the Seasons are very important to know the condition of drought. If the number of rainy days are very less in the Monsoon, then there is possibility of Drought. So Average Rainy days for three seasons (Premonsoon, South west monsoon, North east monsoon) and Annual have been considered for the study.

Additionally Aridity index and Aridity index Anomaly were estimated for each Taluk over the years by using the following equation:

$$\text{i) Aridity Index } AI = \frac{PET - AET}{PET} * 100$$

Where

- PET denotes the normal water need/demand of the crops at location
- AET denotes the actual evapo-transpiration obtained from water balance approach with the use of available water capacity (AWC) of the soil in that location.
- (PET-AET) denotes the water deficit.

- ii) **Aridity index Anomaly (AIA):** Weekly actual aridity index and normal aridity index are computed by the above formula from the weekly actual rainfall and weekly normal rainfall at a location. The difference between the actual aridity and normal aridity for the week is the AIA for that location. This AIA indicate the water shortage over a long time normal/climatic value.

For Aridity index Anomaly there are two conditions, those are

- If AIA value is negative or zero, this would imply that the area/location would experience less arid/droughty conditions than normal.
- If AIA value is positive, this would indicate that the location experiences more arid/droughty conditions than the normal.

Hence all areas with negative or zero values of AIA are treated as humid areas. As per the positive values of the AIA three different drought classes that indicate the intensity of drought (Mild:1-25%; Moderate:26-50%; Severe:>50%) are also in vogue.

The aridity index anomaly values obtained for each Taluk over the years were averaged for each Taluk and these values are used under the study.

For the calculation of climate based (CI) vulnerability Index, the sub components (Indicators) used are as under :

Sub-components (Indicators)

For this climate based index the following seven sub- components (Indicators) and their variability over a period, which effectively express the vulnerability at Taluk level are considered.

P1- (SWM) South West monsoon rainfall coefficient of variation (CV)

P2- (NEM) North East monsoon rainfall coefficient of variation (CV)

P3- (PMARD) Pre monsoon average rainy days

P4- (SWARD) South West monsoon average rainy days

P5- (NEARD) North East monsoon average rainy days

P6- (ANNARD) Annual average rainy days

P7- (AIA) Aridity Index Anomaly

As per the above indicators the data was analyzed for each of the Taluks over a period of 55 years and kept for further use in the calculation of climate based Index (CI).

4.4.2 Climate & Soil Based index (C S I)

In order to assess drought vulnerability at Taluk level in Karnataka state a climate-soil based (CSI) index is developed. For this index, weekly actual precipitation and normal PET of the period 1980-2014 (34years) at Taluk level were considered. Major soils (3) from each Taluk were identified and AWC (available water capacity) of these soils was estimated. With the use of actual weekly precipitation, normal PET, AWC of these soils water balance program was run and weekly MAI (moisture adequacy index) were estimated for each soil at Taluk level for 34 years. The contiguous weeks/days with MAI values 50-75% and >75% were estimated at each Taluk and soil level over a period from 1980 to 2014. For each Taluk, the actual number of weeks were decided based on the mode(repetition of number of weeks) over 34 years. Based on these number of weeks, the days (the length) of moisture availability or the length of growing period (LGP) for the Taluk was estimated. The LGP values are tabulated for all Taluks for further use in the climate soil- based index (CSI) calculations. For this index the number of days of moisture availability or Length of Growing Period (LGP) at Taluk level is considered as an indicator (sub-component) for further calculations of Climate-soil based index (CSI).

i) Length of Growing Period (L G P):

(AWC- Solum depth, texture, gravelliness & stoniness)

ii) $(AET/PET)*100=MAI\%$

Days with MAI>50% are considered for LGP

4.4.3 Climate -Crop Cover Based Index (C C I)

The crop vigour and extent of crop cover in an area is directly related to the weather parameters and their variability. To measure this relationship the Normalized Difference Vegetation index (NDVI) during the crop season was estimated from 2000-2015 through remote sensing. In this study Terra MODIS 250 m monthly NDVI composites for the period from sowing to senescence stage of the crop were derived. Since crop vigour and extent of crop cover is clearly observable during *kharif* season, NDVI for August to October months is considered as the integrated NDVI (summation of NDVI for three months) corresponding to this south west monsoon period (SWIN). This gives a better estimate of crop cover in an area. The maximum NDVI of the south west monsoon season (SWMN) indicates

maximum crop coverage. The NDVI of August month (AUNDVI) usually indicates the vigorous vegetative growth stage of the crops in the region. The *kharif* season's integrated NDVI (SWIN), the seasons maximum NDVI (SWMN) and August NDVI were estimated for each year for a period of 15 years (2000-2015) for each Taluk. The *arithmetic* mean of SWIN, SWMN and August NDVI of 15 years was estimated at Taluk level. The co-efficient of variation (CV) for SWIN, SWMN and August NDVI was also calculated.

Similarly the integrated NDVI (NEIN) coinciding the *rabi* crop season (October to December) was also calculated based on the summation of NDVI of these three months for a period of Fifteen years (2000-2015). The maximum NDVI of the season (NEM) that indicates maximum crop cover and the maximum NDVI of November month, coinciding the peak vegetative growth of the *rabi* crops was considered. The NEIN, NEM and NDVI of November values for a period of fifteen years at Taluk were estimated. The annual arithmetic mean of NEIN, NEM and NDVI of November was computed Taluk wise. The coefficient of variation (CV) for NEIN, NEM and NDVI of November was also calculated at Taluk level.

In this climate-crop cover based index (CCI), the influence of climatic parameters on the crop canopy and spread through Normalised Difference Vegetation Index (NDVI) in *kharif* and *rabi* seasons was estimated. The twelve sub-components (Indicators) considered for arriving at the CCI are as under:

Sub-components (Indicators)

- CC1- South West Monsoon Integrated NDVI (SWIN)
- CC2- CV of SWIN
- CC3- South West Monsoon Maximum NDVI (SWMN)
- CC4- CV OF SWMN
- CC5- August Month's - NDVI
- CC6- CV of August NDVI
- CC7- North East Monsoon integrated NDVI (NEIN)
- CC8- CV of NEIN
- CC9- North East Monsoon Maximum NDVI (NEM)
- CC10- CV of NEM
- CC11- November Month's NDVI
- CC12- CV of November Month's NDVI

The average values of the above sub-components are tabulated and are to be used for further analysis in estimation of Climate- crop cover based index (CCI) at taluk level of the state.

4.4.4 Livelihood Based Index (L I)

The adaptation or coping capacity or resilience against a disaster/drought can be assessed only through analysis of the existing socio-economic fabric of the affected society. Any disaster/drought usually has its effect on both movable and immovable assets of the living population in the active zone

of the drought. It disrupts the very livelihood infrastructure of the exposed society by destroying their property and savings. It is well known that the adaptive capacity of the people varies based on their access to the resources, literacy rate, working hands in a house hold and the exposure to the recent information, knowledge base of the affected people in the zone. The adaptive capacity to resist or buffer the effect of distress differs with the size of holdings of the households in the locality. The social vulnerability indicates the uneven preparedness of the people to distress in the locality. The livelihood of the society/community is dependent on the socio-economic conditions in the area. In general the exposed population to disasters such as continuous/recurring droughts, floods has little or no strength to thwart the effects of disasters. The livelihood index that reflects the social vulnerability is dependent upon many factors/indicators. Among them, a few indicators (seven) which are of prime importance for vulnerability over a period (1985-2002) and the percent literacy (one) for 2001 & 2011 are considered while developing livelihood index (LI). The sub-components (Indicators) considered for the LI index are as under:

Sub-components (indicators)

- L1-Ratio of irrigated to total cultivated area per cent
- L2- Ratio of Number of marginal to total holdings per cent
- L3- Ratio of Number of small to total holdings per cent
- L4- Ratio of Number of semi-medium to total holdings per cent
- L5- Ratio of Number of medium to total holdings per cent
- L6- Ratio of Number of big (large) to total holdings per cent
- L7- Ratio of working to total population per cent
- L8- Ratio of Number of literates to total population per cent

The percent values of each indicator over the period were averaged and used as data base for further analysis in developing the LI- Index.

Chapter 5

DATA BASE-ANALYSIS

The input indicators (sub-components) under these four Major components are : Seven for Climate based index (CI), twelve for Climate-Crop cover based index (CCI), one for Climate-Soil based index (CSI), and eight for livelihood based index (LI). In all twenty eight indicators, are considered for the approach in arriving at drought vulnerability at Taluk level in Karnataka state. The data for these sub-components over a period were compiled and analyzed as under:

5.1 NORMALIZATION OF INPUT DATA

Normalization is required prior to any data aggregation as the indicators in a data set often have different measurement units. The input data was normalized to eliminate the differences in the units of indicators and their functional relationships within its major component index. For normalization of data there are nine methods in vogue..The different methods (Freudenberg, 2003; Jacobs et al., 2004) are listed as under:

1. Ranking is the simplest normalization technique 2. Standardization (or z-scores) converts indicators to a common scale with a mean of zero and standard deviation of one, 3. Min-Max method normalizes indicators: 4. Distance to a reference measure the relative position of a given indicator vis-à-vis a reference point and widens the range, 5. Categorical scale assigns a score for each indicator. Categories can be numerical, 6. Indicators above or below the mean are transformed, 7. Method for cyclical indicators 8. Balance of opinions 9. Percentage of annual differences over consecutive years.

Out of those nine methods, the Mini-Max method was considered appropriate and was followed for this study. In this method, the normalized indicators will have an identical range [0, 1] obtained by subtracting the minimum value and dividing by the range of the indicator values. Usually, extreme values/or outliers could distort the transformed indicator during normalization. On the other hand, normalization by Mini-Max Method could widen the range of indicators lying within a small interval, increasing the effect on the composite indicator more than the z-score transformation.

In this method, based on the relationship of an indicator to the major component index, the following formulae are used:

- i) If an indicator/sub-component 'x' in 't' number of Taluks has positive functional relation to respective major component, for normalization the following formula is used

$$X_i - \text{normalized value} = \frac{X_i - X_{min}}{X_{max} - X_{min}}$$

- ii) and if the indicator/ sub-component has negative functional relationship with the respective major component , the normalization formula is

By this normalization all the values of indicators will be ranging from 0 to 1 and their direction of change is same.

$$X_i - \text{normalized value} = \frac{X_{max} - X_i}{X_{max} - X_{min}}$$

The normalized values of all the 28 sub-components were calculated by Mini-Max method for all 176 Taluks of the state and these values were used for further index calculations. The Major component wise symbols for all sub-components are presented in Table 6.

Table 6. List of Major and Sub-Components (Indicators) in the Study.

<i>S.No.</i>	<i>Symbol</i>	<i>INDICATOR</i>	<i>SHORT FORM</i>
CLIMATE BASED			
1.	P1	South west monsoon-coefficient of Variation	SWMCV
2.	P2	North east monsoon-coefficient of Variation	NEMCV
3.	P3	Pre-monsoon Average Rainy days	PMARAD
4.	P4	South west monsoon Average Rainy days	SWARD
5.	P5	North east monsoon Average Rainy days	NEARD
6.	P6	Annual Average Rainy days	ANNARD
7.	P7	Percent Aridity Index Anomaly	AIA
CLIMATE CROP COVER BASED			
1.	CC1	South west Monsoon Integrated NDVI	SWIN
2.	CC2	South west Monsoon Integrated NDVI- CV	SWIN- CV
3.	CC3	South west Monsoon Maximum NDVI	SWMN
4.	CC4	South west Monsoon Maximum NDVI-CV	SWMN-CV
5.	CC5	August NDVI	AU NDVI
6.	CC6	August NDVI-CV	AU NDVI-CV
7.	CC7	North East Monsoon Integrated NDVI	NEIN
8.	CC8	North East Monsoon Integrated NDVI-CV	NEIN-CV
9.	CC9	North East Monsoon Maximum NDVI	NEM
10.	CC10	North East Monsoon Maximum NDVI-CV	NEM-CV
11.	CC11	November NDVI	NOV.NDVI
12.	CC12	November NDVI-CV	NOV.NDVI -CV
CLIMATE- SOIL-BASED			
1.	S	Length of Growing Period in days	LGP
LIVELIHOOD BASED			
1.	L1	Irrigated area to total cultivated area- Percent	IRP
2.	L2	Total workers to Total population - Percent	WORP
3.	L3	No.of Marginal Holdings to Total Holdings-Percent	MAHP
4.	L4	No.of Small Holdings to Total Holdings- Percent	SAHP
5.	L5	No.of Semi-medium Holdings to Total Holdings-Percent	SMHP
6.	L6	No.of Medium Holdings to Total Holdings-Percent	MHP
7.	L7	No.of Large(big) Holdings to Total Holdings-Percent	LHP
8.	L8	Percent Literacy(above 6 years of age)	LP

5.2 WEIGHTAGE FOR THE (INDICATORS) SUB-COMPONENTS

After normalization of input data of the indicators, assigning the weight age to these normalized values of indicators gains a key role in assessing the vulnerability. Different workers used various methods (Li et al, 2006; Chen et al, 2013; Brooks, et al, 2005) and the weight ages were given based on relative importance of the indicator towards vulnerability. Some used Principal Component Analysis (PCA) to have weight ages for the indicators (Chen et al, 2013). A few used equal weight ages to each indicator, this may lead to the under estimation of the risk assessment (Julich, 2015). In this study the method used for assigning the weight ages is based on the assumption that the weight ages vary inversely with variance over Taluks .So the weight age ‘wj’ is determined by

$$W_j = \frac{C}{\sqrt{\text{var}(x_{ij})}}$$

Where

W_j =weight age factor of the jth indicator.

x_{ij} = Normalized value of jth indicator and of the ith Taluk

c = normalizing constant,

While “c” is the normalizing constant

$$c = \left[\sum_{j=1}^k \sqrt{\text{var}_i(x_{ij})} \right]^{-1}$$

By the assignment of weight ages to these components (Brooks et al, 2005) through this method, the large variations ,if any, in these subcomponents will not dominate over the contribution of other sub components within the major component . Relative weight ages of sub-components under each major component obtained by the above method are presented in Table.7.

Table 7. Relative weightages of sub-components under each major component.

<i>CLIMATE BASED</i>		<i>CLIMATE-CROP BASED</i>		<i>CLIMATE-SOIL BASED</i>		<i>LIVELIHOOD BASED</i>	
<i>Sub-Component</i>	<i>Weight Age</i>	<i>Sub-Component</i>	<i>Weight Age</i>	<i>Sub-Component</i>	<i>Weight Age</i>	<i>Sub-Component</i>	<i>Weight Age</i>
0.14	C1	0.07	S	nil	L1	0.12	
0.17	C2	0.09			L2	0.16	
0.15	C3	0.07			L3	0.10	
0.11	C4	0.09			L4	0.16	
0.15	C5	0.07			L5	0.10	
0.12	C6	0.11			L6	0.11	
0.16	C7	0.08			L7	0.11	
	C8	0.09			L8	0.13	
	C9	0.08					
	C10	0.10					
	C11	0.08					
	C12	0.07					

In general the weight ages range from 0 to 1 i.e Weight age “w” is ($0 < w < 1$) and $\sum_{j=1}^k w_j = 1$. These weight ages ranged from 0.11 to 0.17 in climate based, 0.07 to 0.11 in climate-crop cover based and 0.10 to 0.16 in livelihood based major components. For soil based major component, the weight age was not assigned since the sub-component “LGP” was only one indicator. Nevertheless, the LGP was arrived through the use of soil based factors /variables like AWC, Solum depth, texture, gravelliness & stoniness and climate related factors like AET, PET and MAI calculated over the years and averaged for each Taluk.

5.3 DEVELOPMENT OF INDICES FOR MAJOR COMPONENTS

$$\bar{y}_i = \left[\sum_{j=1}^k w_j x_{ij} \right]$$

Composite index of ith Taluk $\bar{y}_i$ is assumed to be a linear sum of x_{ij}

Using respective weight ages and the normalized score values of each sub-component, the effective value of each sub-component at Taluk(-value) was arrived (Iyengar & Sudarshan, 1982; Hiremath & Shiyani, 2012). These values of sub-components are presented under each Major component. These values depict the contribution of each sub-component towards the index of the particular major component.

5.4 CONTRIBUTION OF SUB-COMPONENTS TOWARDS MAJOR COMPONENT INDICES

There are four major components namely

- 1) Climate - based Index (CI);
- 2) Climate-crop cover based index (CCI);
- 3) Climate-soil based index (CSI) and
- 4) Livelihood based index.

Under each major component, the relevant sub components (indicators) were selected. In all there are 28 indicators in the study.

5.4.1 Climate Based Index (CI)

Seven sub-components (Indicators) P1 to P7 are considered for assessing the climate based index. Among these seven sub-components South West Monsoon coefficient of variation (SWM-CV), North East Monsoon coefficient of variation (NEM-CV) and AIA have positive functional relationship and their effect is directly proportional to the values of CI index while the other four sub components such as PMARD, SWARD, NEARD, ANNARD have negative functional relationship with the CI index.

The average contribution of different sub-components (P1 to P7) towards the climate based index (176 Taluks) ranged from 12 to 18%. The sub-components SWM-CV (P1) and NEM-CV (P2) contributed least while NEARD (P5) & PMARD (P3) contributed highest to the CI-index.

The contribution of the seven sub-components to the CI index was in the following order: NEARD (P5) > PMARD (P3) > AIA (P7) > ANNARD (P6) > SWARD (P4) > NEM-CV (P2.) > SWM-CV (P1).

* Note : Voluminous table avoided

5.4.2 Climate-Crop Cover Based Index (CCI):

Twelve sub-components namely SWIN(CC1), SWIN-CV(CC2), SMN (CC3), SMN-CV (CC4), AUNDVI (CC5), AUNDVI-CV (CC6), NEIN (CC7), NEIN-CV (CC8), NEM (CC9), NEM-CV (CC10), NOV-NDVI (CC11) and NOVNDVI-CV (CC12) were considered for developing climate crop cover based index(CCI). Among these sub-components CC1, CC3, CC5, CC7, CC9 and CC11 were found to have negative functional relation and contribute accordingly towards the CCI-Index while the other six sub-components viz., CC2, CC4, CC6, CC8, CC10 and CC12 have positive relationship towards the index and their values are directly related to the CCI-Index.

The average (of 176 Taluks) contribution of these twelve sub components towards CCI-index ranged from 7 to 11 percent. Least contribution of 7% was observed from CC10 and CC12 while the sub-component CC8 contributed maximum 11% towards the CCI-index.

The average (of 176 Taluks) contribution of these twelve sub- components towards the CCI- index values are in the following order:

CC8 > CC7 > CC1, CC3, CC5 & CC9 > CC2, CC4, CC6 & CC11 > CC10 and CC12

* Note : Voluminous table avoided

5.4.3 Climate-Soil Based Index (CSI)

Based on rainfall, PET, AWC of the major soils in the Taluk, the weekly MAI over the years (1980-2014) was estimated at Taluk level through water balance program.

Taking into consideration, the weeks with MAI > 50% at Taluk level over the years, the Length of Growing Period (LGP) in days for each Taluk was calculated. It is observed that the LGP has negative functional relationship and contribute accordingly towards CSI-index values.

* Note : Voluminous table avoided

5.4.4 Livelihood Based Index

For assessing livelihood based index eight sub-components namely 1) ratio of percent irrigated area to total cultivated area IRP (L1), % working population WOPR to total population (L2), % number of marginal to total holdings MAHP (L3), % number of small to total holdings SAHP (L4), % number of medium to total holdings SMHP (L5), % number of semi-medium to total holdings MHP (L6), % number of big to total holdings LHP (L7) and % Literacy LP (L8) that reflects the socio-economic condition on the society were considered.

Among these five sub-components, it is observed that L1, L5, L6, L7 & L8 were found to exhibit positive functional relationship with Livelihood index while L2, L3 & L4 were found to have negative functional relationship with livelihood index. In other words, the seven sub-components namely L1, L5, L6, L7 and L8 support the drought adaptability/drought resilience while the other three sub-components (L2, L3 & L4) support drought vulnerability.

In general, the farming systems with predominantly marginal and poor farmers are most vulnerable to droughts. Based on, the maximum and minimum values of each sub-component five classes are identified with fixed class interval. These classes (1, 2, 3, 4 & 5) were assigned to each of the Taluks. The major component wise maps (Fig.11 to 17) were generated based on the classes.

* Note : Voluminous table avoided

On an average (of 176 Taluks) the relative contribution of sub-components towards LI ranged from 8 to 15%. The least contribution was from L3 and L5 while the maximum contribution was from L1, L2 and L7.

The extent of contribution of sub-components towards the livelihood index was in the following order: L1, L2 & L7 > L4 > L6 > L8 & L3.

The linear sum of these values of all sub-components and their average value ($\bar{y}_i$) is presumed to be the drought vulnerability index value for each major component at Taluk level. Thus four indices namely, climate based index (CI), climate-crop cover based index (CCI), climate-soil based index (CSI) and livelihood based index (LI) were developed. These values are presented in Table 8.

5.5 Major component wise indices values

These major component wise indices (Table 8) and their values in different Taluks are discussed as under:

5.5.1 Climate based index (CI)

The climate based index values of different Taluks indicate that the values range from 0.056 to 0.836. It is observed that the humid & per humid Taluks of Uttara Kannada, Dakshina Kannada and Udupi districts of Coastal region and all three Taluks of Kodagu district of Malnad region showed lower values indicating very slight to slight vulnerability. Rest of the Taluks mostly of districts of SIK & NIK regions have high index values which relate to the moderate, high and very high vulnerability due to variation in rain fall and related sub-components in all the seasons. In these SIK & NIK regions, some Taluks like Shorapur (0.836) of Yadgir district and Chincholi (0.807) of Kalaburgi district showed higher index values indicating very high vulnerability.

5.5.2 Climate Crop cover based index (CCI)

The index values of CCI (Table 8) ranged from 0.191 in Shikaripur Taluk of Shivamogga district to 0.803 in Molkalmorru taluk of Chitradurga district. The lower values in Malnad region and Coastal region taluks indicate low vulnerability and higher values in South Interior Karnataka (SIK) & North Interior Karnataka (NIK) taluks indicate high vulnerability.

5.5.3 Climate –Soil Based Index (CSI)

The parameters considered for calculation of this index (CSI) are the spatial annual variation in rainfall, potential evapo-transpiration, major soil type and its texture, solum depth and available water capacity (AWC). Using the above parameters, the moisture adequacy index (MAI) in different weeks of the year for each Taluk was calculated through water balance program. Based on the MAI (>50%)

values the length of growing period (LGP) for each Taluk over a period (1980-2014) was estimated. The number of days of LGP, thus estimated for 176 Taluks, was normalized. These normalized values were considered as CSI index values for further calculations.

The CSI index values (Table 8) ranged from 0.37 in Ron Taluk of Gadag district to 1.00 in Sringeri Taluk of Chikkamangaluru district. The lower values were observed in the drought vulnerable areas while higher values in less vulnerable areas.

5.5.4 Livelihood Based Index

The livelihood based index values (Table 8) ranged from 0.32 in Sindagi Taluk of Vijayapura district to 0.72 in Nagamangala Taluk of Mandya district. The variability among Taluks in the state is limited possibly because of similar physical settings in the Taluks. By this index it is evident that the Taluks with better natural resources supplemented by irrigation have better capacity to withstand the shock due to weather aberrations. Usually the Taluks in the vicinity of cities/towns have better resilience /adaptive capacity since these cities/towns provide ample opportunities for the livelihood of the existing population. Additionally the Taluks with higher percent of literacy show better livelihood opportunities. Nevertheless, this, at times may result in rural to urban migration in search of greener patches in the cities.

As per the minimum and maximum indices values in 176 Taluks under each Major component, five classes with fixed class interval were arrived. These classes (1,2,3,4 & 5) were assigned to each taluk based on index value of the Taluk.

Based on the class, such as 1) very slightly vulnerable, 2) slightly vulnerable, 3) moderately vulnerable, 4) highly vulnerable, 5) very highly vulnerable, all the 176 Taluks were categorized (Table 9). Major component wise (CI, CCI, CSI & LI) drought vulnerability index maps indicating the different classes were prepared (Fig. 18 to Fig. 21).

5.6 FREQUENCY AND PERCENT DISTRIBUTION OF TALUKS

The number of Taluks in each category/class is presented in Tables 10 to 13 under each major component and their percent distribution is expressed under each major index

5.6.1 Climate Based Index (CI)

As per the major component (CI), the number of Taluks under the Vulnerability (Table.10) classes are in the following order: Taluks 82 (highly vulnerable) > 50 (very highly vulnerable) > 27 (Moderately vulnerable) > 11 (slightly vulnerable) > 6 (very slightly vulnerable). Under each class of vulnerability, the percent distribution of the Taluks follow this order: 47% (under class 4) > 28% (under class 5) > 15% (under class 3) > 6% (class 2), 4% (under class 1).

As per this climate based index, 76% of the Taluks are prone to high and very high drought vulnerability, while 24% are very slight to slightly and moderately vulnerable. This clearly depicts that majority of the Taluks in the state are vulnerable to meteorological drought or drought like situations over the years due to aberrant weather conditions.

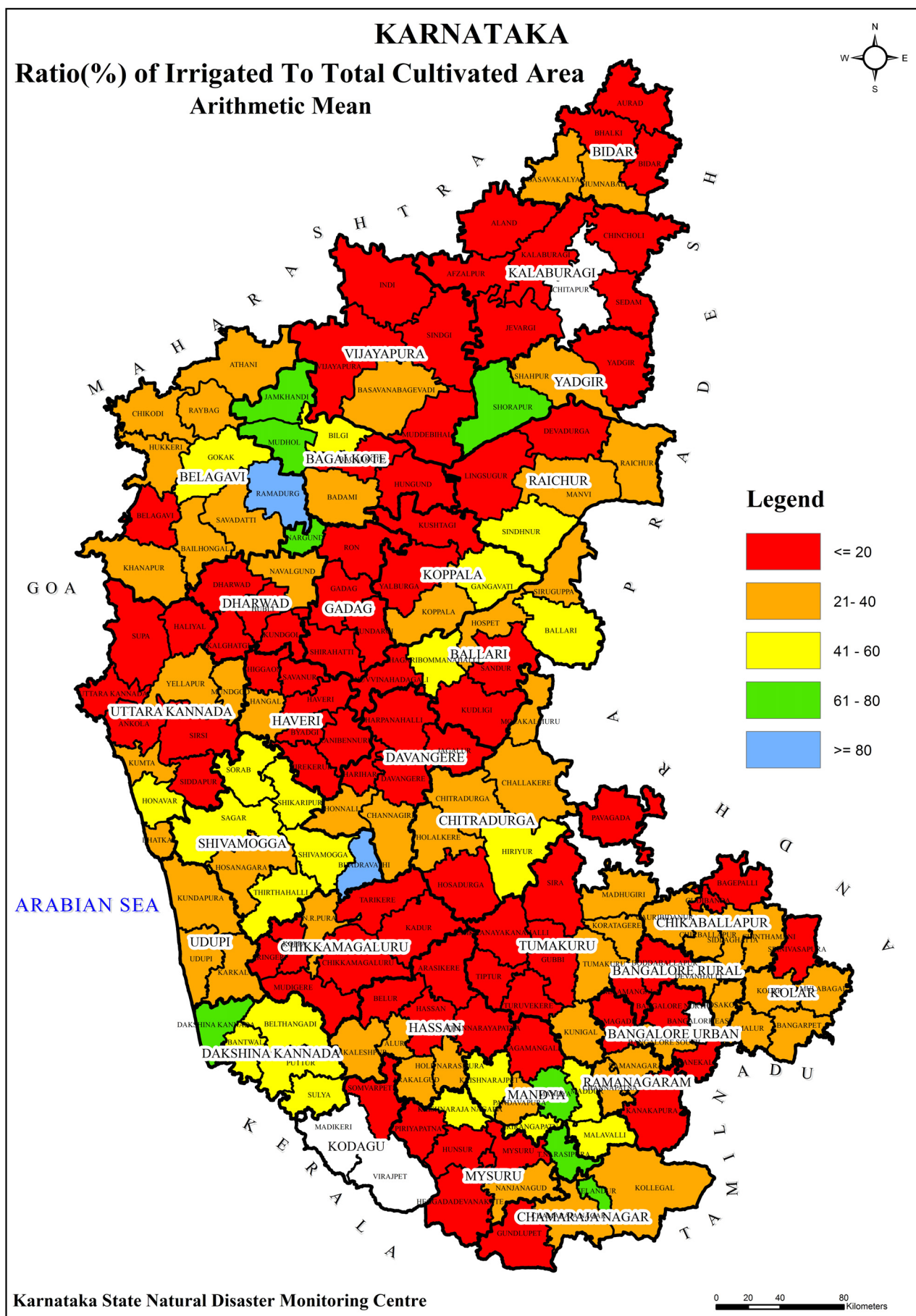


Fig.11. Ratio of Irrigated to total cultivated area

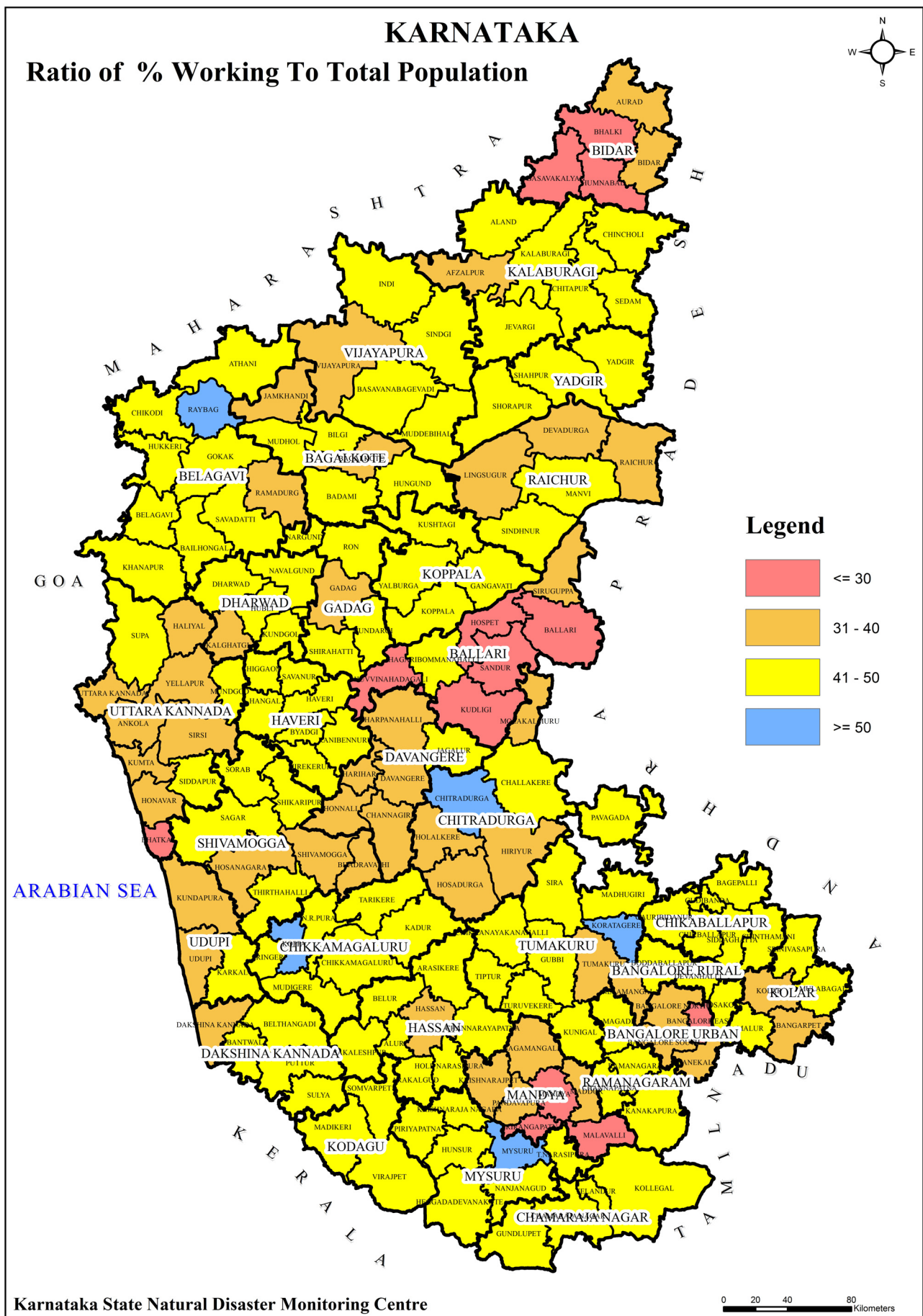
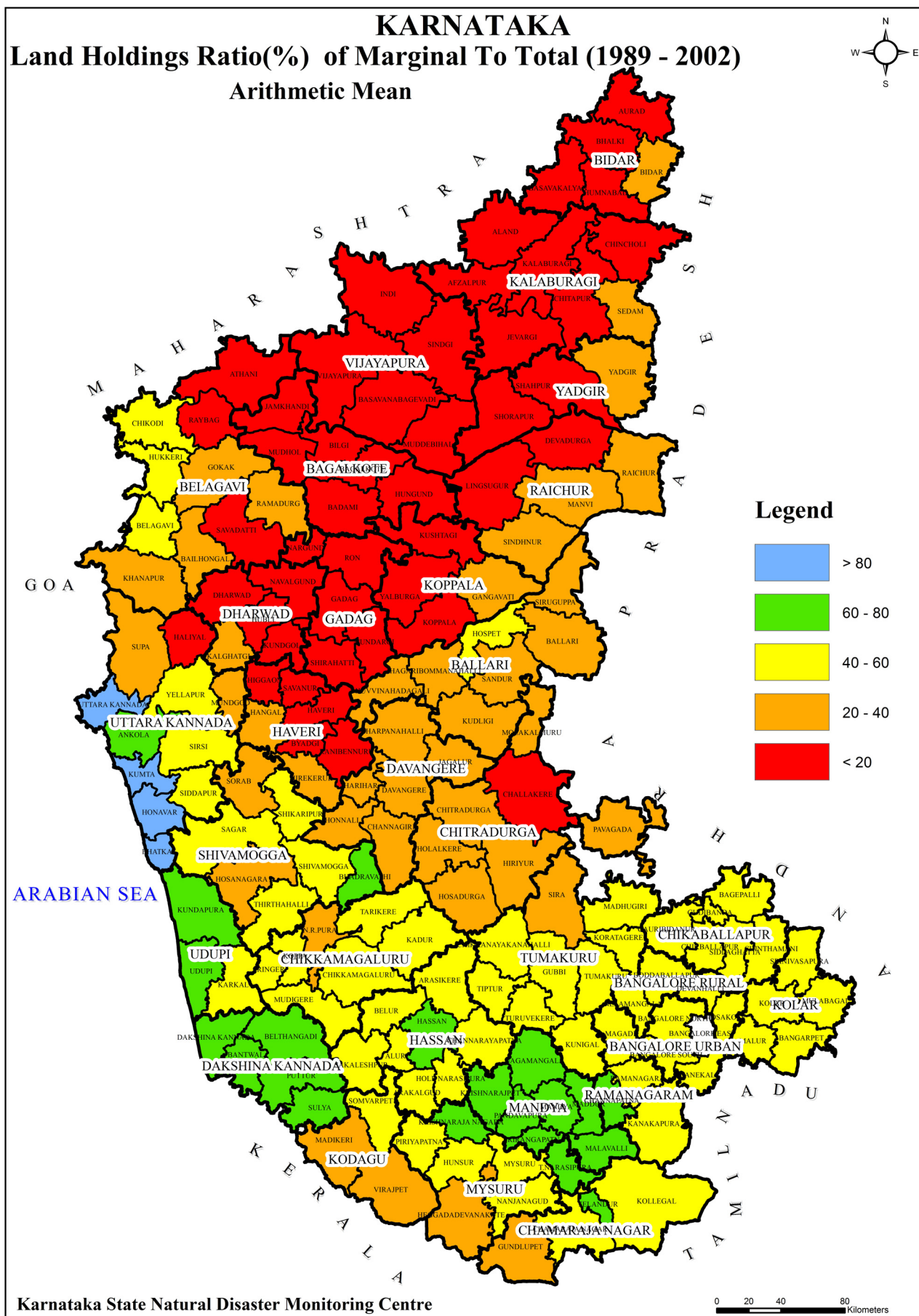


Fig.12. Ratio of Working to total Population





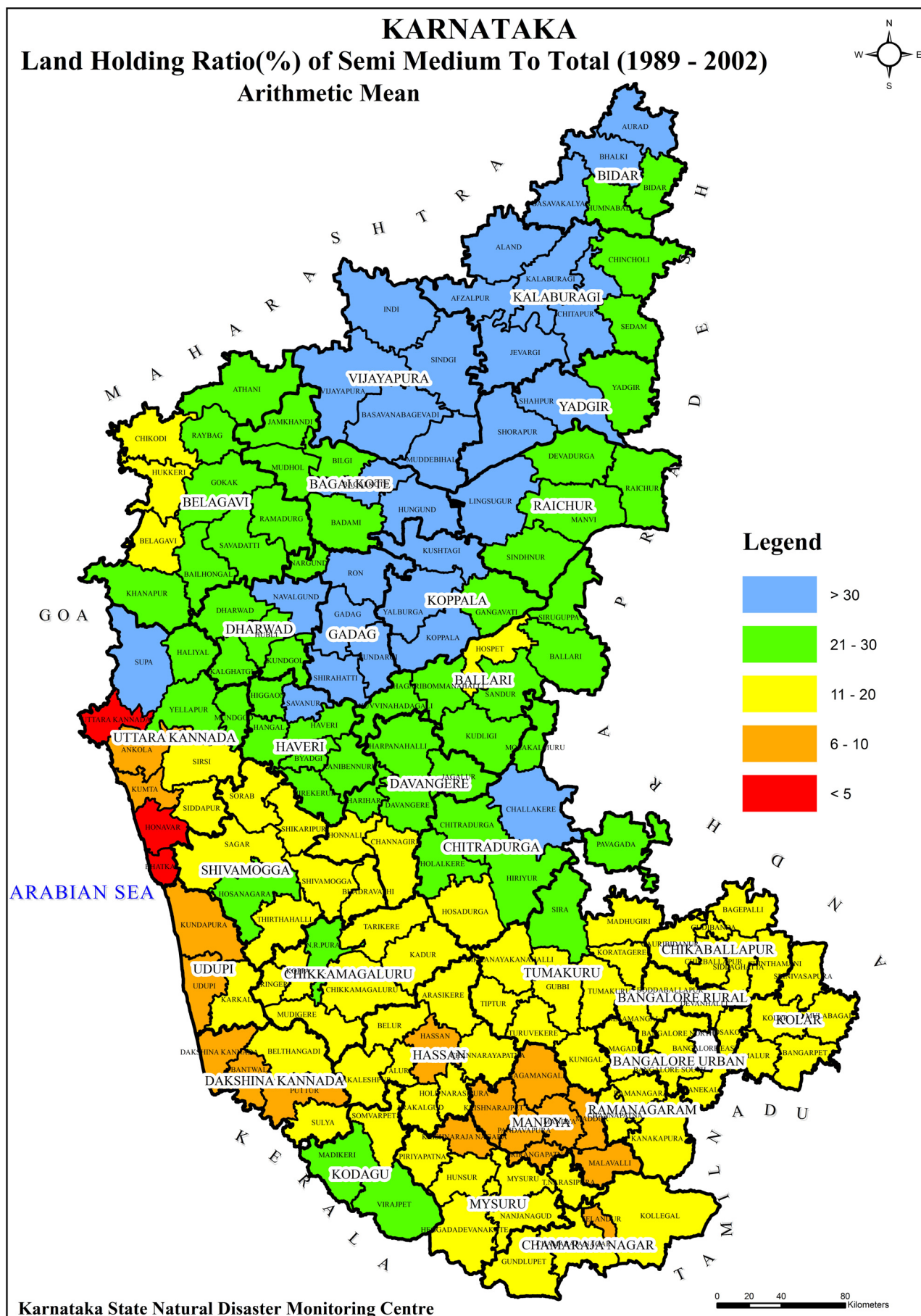
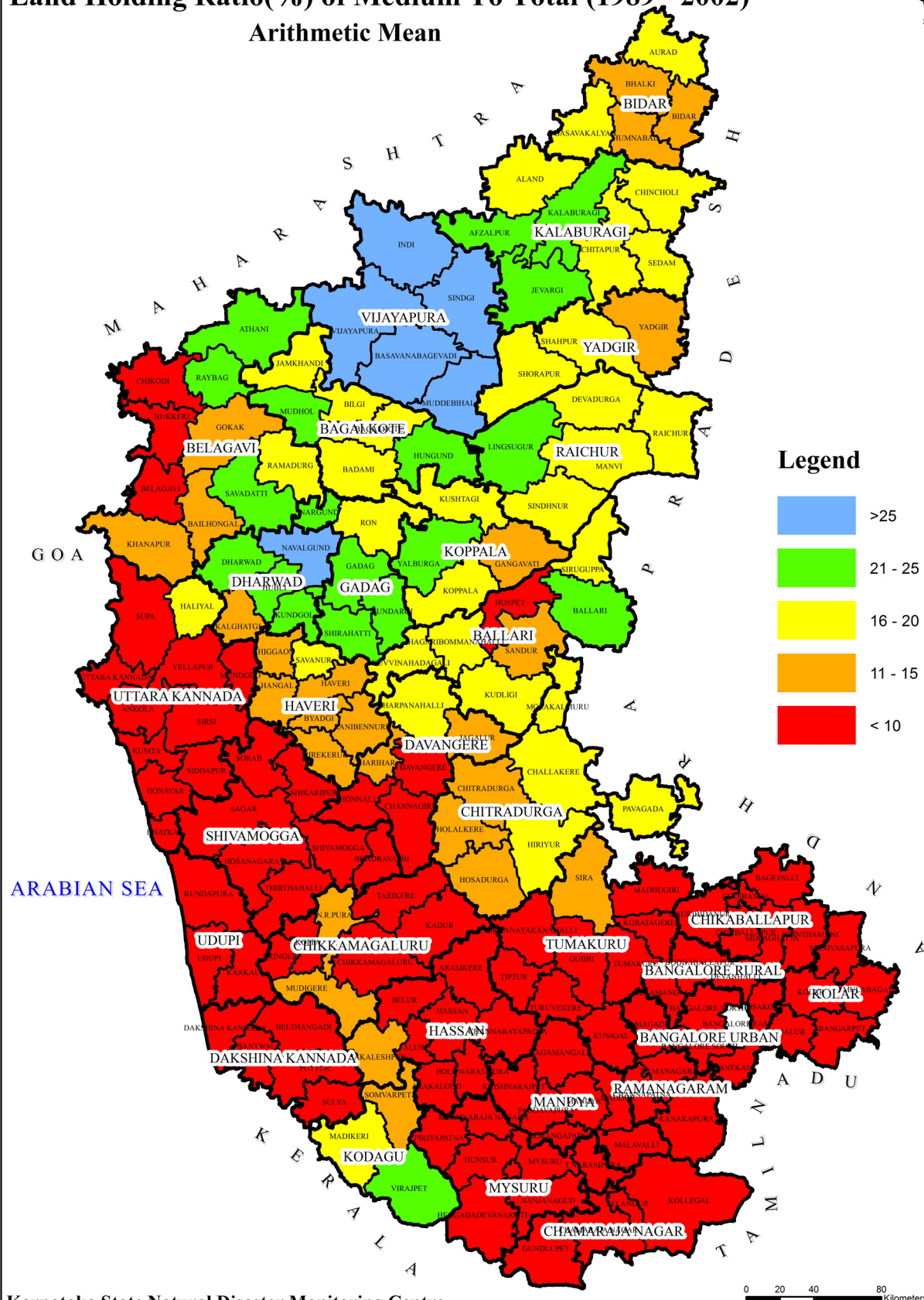
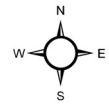


Fig.15. Land Holdings Ratio (%) of Semi Medium To Total

KARNATAKA

Land Holding Ratio(%) of Medium To Total (1989 - 2002)

Arithmetic Mean



Karnataka State Natural Disaster Monitoring Centre

Fig.16. Land Holdings Ratio (%) of Medium To Total

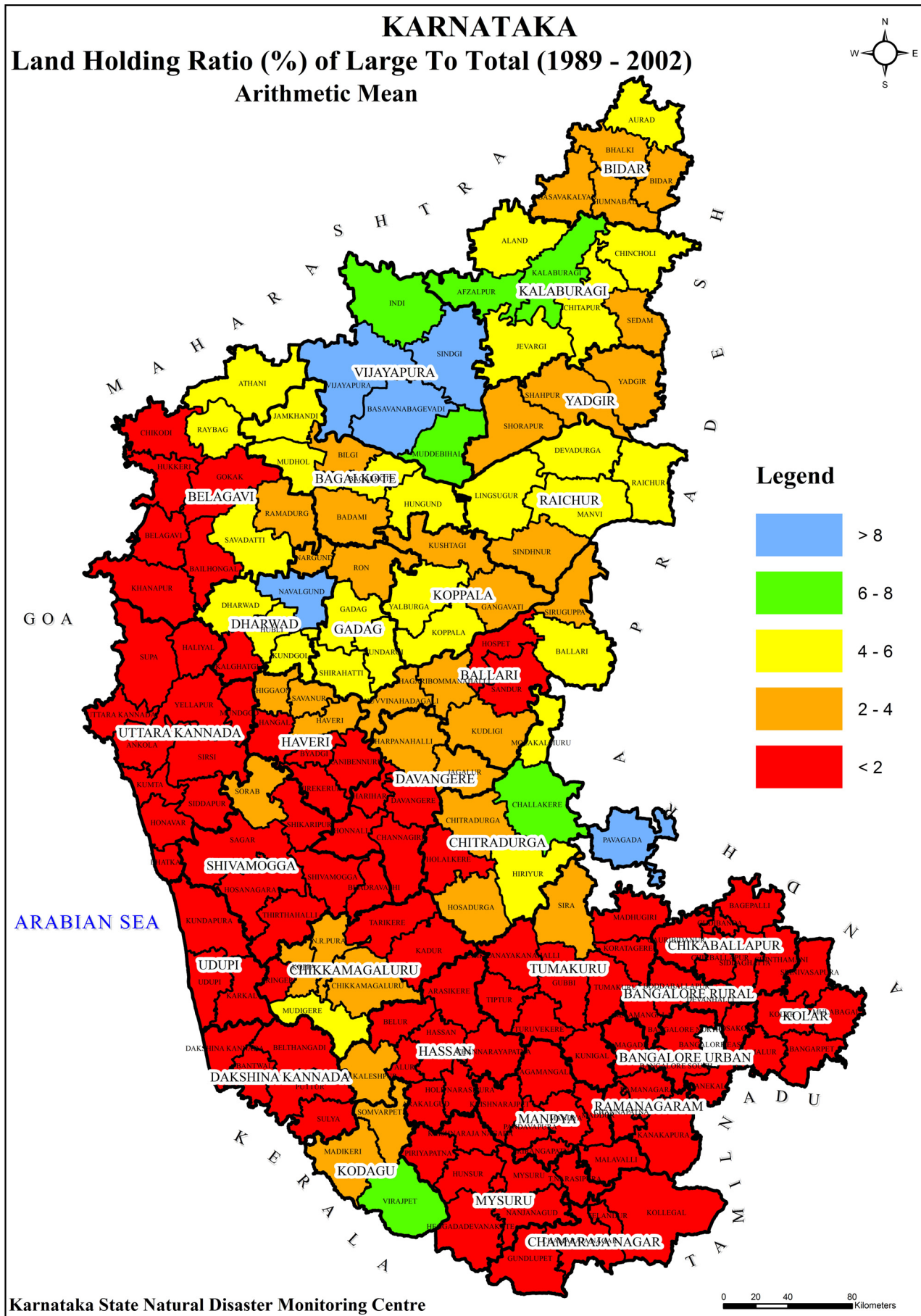


Fig.17. Land Holdings Ratio (%) of Large To Total

Table 8. Major component wise Index values

<i>Sl.No.</i>	<i>District</i>	<i>Taluk</i>	<i>LI</i>	<i>CCI</i>	<i>CSI</i>	<i>CI</i>
1	BENGALURU-URBAN	ANEKAL	0.62	0.464	0.630	0.533
2		BENGALURU NORTH	0.60	0.482	0.630	0.504
3		BENGALURU SOUTH	0.60	0.421	0.519	0.519
4		BENGALURU EAST	0.60	0.564	0.481	0.521
5	BENGALURU-RURAL	DEVANAHALLI	0.59	0.502	0.444	0.591
6		DODBALLAPUR	0.62	0.444	0.481	0.588
7		HOSAKOTE	0.59	0.505	0.444	0.575
8		NELAMANGALA	0.60	0.454	0.444	0.558
9	RAMANAGARAM	CHANNAPATNA	0.63	0.356	0.593	0.566
10		KANAKAPURA	0.65	0.388	0.704	0.587
11		MAGADI	0.63	0.412	0.519	0.535
12		RAMANAGARA	0.60	0.346	0.593	0.610
13	KOLAR	BANGARAPET	0.65	0.459	0.370	0.595
14		KOLAR	0.61	0.494	0.407	0.558
15		MALUR	0.63	0.500	0.630	0.507
16		MULABAGAL	0.63	0.532	0.630	0.574
17		SRINIVASAPURA	0.62	0.486	0.222	0.580
18	CHIKBALLAPUR	BAGEPALLI	0.61	0.614	0.296	0.674
19		CHIKBALLAPUR	0.63	0.519	0.296	0.551
20		CHINTAMANI	0.60	0.526	0.444	0.589
21		GAURIBIDANUR	0.61	0.452	0.444	0.669
22		GUDIBANDA	0.63	0.551	0.370	0.657
23		SIDLAGHATTA	0.63	0.547	0.519	0.559
24	TUMAKURU	C.N. HALLI	0.60	0.531	0.444	0.625
25		GUBBI	0.62	0.470	0.667	0.577
26		KORATAGERE	0.59	0.416	0.630	0.570
27		KUNIGAL	0.61	0.432	0.444	0.543
28		MADHUGIRI	0.59	0.573	0.593	0.573
29		PAVAGADA	0.43	0.643	0.111	0.721
30		SIRA	0.52	0.670	0.296	0.724
31		TIPTUR	0.60	0.362	0.407	0.607
32		TUMAKURU	0.59	0.435	0.926	0.520
33		TURUVEKERE	0.61	0.418	0.556	0.578
34	CHITRADURGA	CHALLAKERE	0.40	0.736	0.222	0.737
35		CHITRADURGA	0.44	0.500	0.259	0.640
36	CHITRADURGA	HIRIYUR	0.46	0.706	0.333	0.651
37		HOLALKERE	0.55	0.379	0.593	0.537
38		HOSADURGA	0.61	0.626	0.481	0.645
39		MOLAKALMURU	0.48	0.803	0.000	0.722
40	DAVANGERE	CHANNAGIRI	0.64	0.226	0.333	0.616
41		DAVANGERE	0.62	0.236	0.259	0.686
42		HARAPANAHALLI	0.54	0.456	0.481	0.618
43		HARIHAR	0.61	0.205	0.296	0.672
44		HONNALI	0.58	0.265	0.333	0.594
45		JAGALUR	0.52	0.548	0.185	0.677
46	CHAMARAJANAGAR	CHAMARAJANAGAR	0.68	0.505	0.519	0.553
47		GUNDLUPET	0.67	0.615	0.444	0.551
48		KOLLEGAL	0.64	0.475	0.444	0.618
49		YELANDUR	0.59	0.341	0.370	0.604

<i>Sl.No.</i>	<i>District</i>	<i>Taluk</i>	<i>LI</i>	<i>CCI</i>	<i>CSI</i>	<i>CI</i>
50	MYSURU	HEGGADADEVANAKOTE	0.69	0.291	0.556	0.507
51		HUNSUR	0.64	0.301	0.407	0.594
52		KRISHNARAJANAGAR	0.59	0.285	0.519	0.588
53		MYSURU	0.60	0.413	0.593	0.540
54		NANJANAGUD	0.63	0.403	0.556	0.515
55		PERIYAPATNA	0.62	0.283	0.593	0.481
56		T.NARASIPUR	0.58	0.246	0.444	0.573
57	MANDYA	KRISHNARAJAPET	0.68	0.362	0.556	0.571
58		MADDUR	0.67	0.205	0.519	0.590
59		MALAVALLI	0.71	0.368	0.593	0.592
60		MANDYA	0.65	0.267	0.259	0.592
61		NAGAMANGALA	0.72	0.426	0.370	0.581
62		PANDAVAPURA	0.71	0.459	0.259	0.634
63		SRIRANGAPATNA	0.66	0.281	0.333	0.526
64	BALLARI	BALLARI	0.46	0.307	0.259	0.692
65		HADAGALI	0.54	0.515	0.444	0.630
66		HAGARIBOMMANAHALLI	0.70	0.393	0.259	0.686
67		HOSPET	0.44	0.600	0.333	0.659
68		KUDLIGI	0.57	0.637	0.296	0.720
69		SANDUR	0.64	0.579	0.444	0.608
70		SIRUGUPPA	0.56	0.334	0.222	0.728
71	KOPPALA	GANGAVATHI	0.53	0.326	0.185	0.796
72		KOPPALA	0.47	0.602	0.259	0.758
73		KUSHTAGI	0.51	0.651	0.074	0.728
74		YELBURGA	0.44	0.636	0.000	0.772
75	RAICHUR	DEODURGA	0.56	0.636	0.259	0.748
76		LINGSUGUR	0.50	0.673	0.111	0.760
77		MANVI	0.50	0.402	0.296	0.733
78		RAICHUR	0.51	0.559	0.259	0.741
79		SINDHANUR	0.51	0.303	0.296	0.745
80	KALABURGI	AFZALPUR	0.48	0.583	0.407	0.730
81		ALAND	0.50	0.444	0.333	0.749
82		CHINCHOLI	0.51	0.296	0.370	0.807
83		CHITAPUR	0.47	0.375	0.222	0.735
84		KALABURGI	0.40	0.404	0.333	0.714
85		JEWARGI	0.48	0.505	0.296	0.762
86		SEDAM	0.56	0.375	0.296	0.761
87	YADGIR	SHAHAPUR	0.53	0.486	0.296	0.775
88		SHORAPUR	0.47	0.433	0.037	0.836
89		YADGIR	0.62	0.520	0.333	0.735
90	BIDAR	AURAD	0.54	0.333	0.296	0.753
91		BASAVAKALYAN	0.63	0.314	0.519	0.678
92		BHALKI	0.60	0.368	0.481	0.732
93		BIDAR	0.57	0.304	0.259	0.731
94		HUMNABAD	0.62	0.352	0.370	0.692
95	BELAGAVI	ATHANI	0.41	0.502	0.037	0.729
96		BAILHONGAL	0.54	0.330	0.407	0.641
97		BELAGAVI	0.58	0.226	0.630	0.517
98		CHIKKODI	0.54	0.296	0.407	0.678
99		GOKAK	0.51	0.369	0.074	0.724

<i>Sl.No.</i>	<i>District</i>	<i>Taluk</i>	<i>LI</i>	<i>CCI</i>	<i>CSI</i>	<i>CI</i>
100		HUKKERI	0.59	0.287	0.333	0.682
101		KHANAPUR	0.53	0.197	0.519	0.518
102		RAIBAGH	0.46	0.624	0.259	0.708
103		RAMDURGA	0.38	0.326	0.185	0.781
104		SOUNDATTI	0.40	0.636	0.111	0.711
105	BAGALKOTE	BADAMI	0.48	0.581	0.148	0.664
106		BAGALKOTE	0.46	0.630	0.111	0.754
107		BILGI	0.42	0.484	0.074	0.685
108		HUNGUND	0.45	0.654	0.444	0.708
109		JAMKHANDI	0.42	0.363	0.074	0.737
110		MUDHOL	0.40	0.331	0.111	0.698
111	VIJAYAPURA	BASAVANABAGEWADI	0.36	0.762	0.074	0.676
112		VIJAYAPURA	0.36	0.741	0.222	0.709
113		INDI	0.37	0.626	0.185	0.782
114		MUDEDEBIHAL	0.39	0.769	0.333	0.723
115		SINDGI	0.32	0.622	0.333	0.749
116	GADAG	GADAG	0.45	0.675	0.185	0.665
117		MUNDARGI	0.41	0.645	0.037	0.760
118		NARAGUND	0.36	0.771	0.111	0.708
119		RON	0.48	0.629	0.037	0.701
120		SHIRAHATTI	0.44	0.559	0.185	0.649
121	HAVERI	BYADGI	0.56	0.378	0.519	0.608
122		HANAGAL	0.55	0.290	0.741	0.561
123		HAVERI	0.52	0.481	0.593	0.548
124		HIREKERUR	0.56	0.301	0.630	0.529
125		RANIBENNUR	0.56	0.478	0.556	0.661
126		SAVANUR	0.52	0.512	0.815	0.592
127		SHIGGAON	0.54	0.312	0.741	0.550
128	DHARWAD	DHARWAD	0.46	0.382	0.667	0.573
129		HUBLI	0.42	0.490	0.444	0.624
130		KALGHATGI	0.58	0.327	0.778	0.553
131		KUNDGOL	0.44	0.559	0.259	0.568
132		NAVALGUND	0.32	0.803	0.222	0.628
133	SHIVAMOGGA	BHADRAVATHI	0.56	0.204	0.593	0.583
134		HOSANAGAR	0.58	0.308	0.630	0.493
135		SAGAR	0.54	0.295	0.778	0.434
136		SHIKARIPUR	0.58	0.191	0.667	0.484
137		SHIVAMOGGA	0.55	0.222	0.519	0.618
138		SORAB	0.50	0.214	0.704	0.586
139		TIRTHAHALLI	0.55	0.323	0.704	0.443
140	HASSAN	ALUR	0.60	0.273	0.667	0.550
141		ARKALGUD	0.65	0.195	0.593	0.540
142		ARASIKERE	0.65	0.421	0.481	0.602
143		BELUR	0.61	0.275	0.556	0.454
144		CHANNARAYAPATNA	0.64	0.311	0.593	0.592
145		HASSAN	0.69	0.320	0.815	0.513
146		HOLENARASIPUR	0.64	0.350	0.593	0.619
147		SAKALESHPUR	0.49	0.353	0.778	0.316

<i>Sl.No.</i>	<i>District</i>	<i>Taluk</i>	<i>LI</i>	<i>CCI</i>	<i>CSI</i>	<i>CI</i>
148	CHIKKAMAGALURU	CHIKKAMAGALURU	0.59	0.355	0.852	0.471
149		KADUR	0.59	0.480	0.296	0.544
150		KOPPA	0.51	0.329	0.815	0.266
151		MUDIGERE	0.49	0.369	0.741	0.260
152		NARASIMHARAJAPUR	0.49	0.254	0.815	0.357
153		SRINGERI	0.60	0.378	1.000	0.243
154		TARIKERE	0.61	0.287	0.741	0.494
155	KODAGU	MADIKERI	0.47	0.333	0.963	0.134
156		SOMWARPET	0.53	0.246	0.852	0.259
157		VIRAJPET	0.38	0.244	0.778	0.219
158	DAKSHINA KANNADA	BELTANGADI	0.55	0.362	0.852	0.140
159		BANTWAL	0.53	0.348	0.704	0.169
160		MANGALORE	0.52	0.275	0.630	0.240
161		PUTTUR	0.56	0.278	0.741	0.143
162		SULYA	0.56	0.233	0.889	0.056
163	UDUPI	KARKALA	0.53	0.323	0.852	0.131
164		KUNDAPUR	0.63	0.278	0.704	0.303
165		UDUPI	0.57	0.204	0.741	0.346
166	UTTARA KANNADA	ANKOLA	0.63	0.267	0.593	0.364
167		BHATKAL	0.67	0.291	0.556	0.389
168		HALIYAL	0.53	0.302	0.593	0.411
169		HONNAVAR	0.61	0.300	0.815	0.424
170		KARWAR	0.66	0.253	0.630	0.411
171		KUMTA	0.63	0.274	0.704	0.369
172		MUNDGOD	0.59	0.365	0.556	0.492
173		SIDDAPUR	0.62	0.349	0.704	0.434
174		SIRSI	0.57	0.310	0.741	0.487
175		SUPA	0.55	0.319	0.593	0.555
176		YELLAPUR	0.59	0.269	0.630	0.477

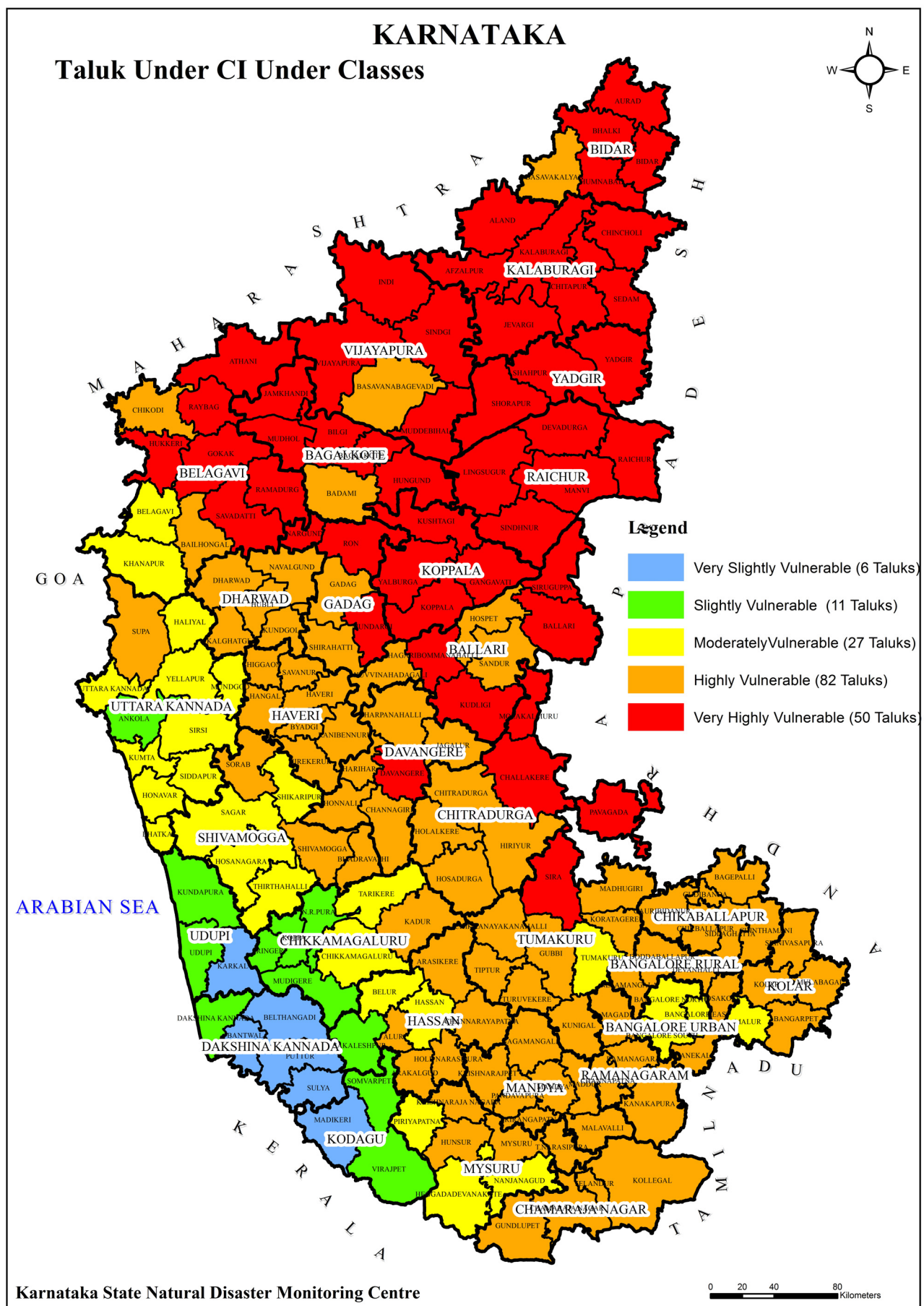
5.6.2 Climate Crop Cover Based Index (CCI)

The frequency and names of Taluks in the state as per CCI are presented in table 11. As per this major component (CCI), the number of Taluks under each class follow this order : 53 (slightly vulnerable – class 2), > 50 (vulnerable - class 1), > 36 (moderately vulnerable – class 3), > 29 (Highly vulnerable – class 4), > 8 (very highly vulnerable-class 5).

Percent vulnerability of these Taluks indicate that 30% (under class – 2), > 28% (under class 1), > 20% (under class – 3), > 16% (under class – 4), > 5% (under class – 5).

As per this CCI index, it is evident that almost 58% of the Taluks are very slight to slightly vulnerable, only 22% of Taluks show high to very high vulnerability.

This situation may be due to crop cover during both *kharif* and *rabi* seasons in major Taluks of SIK and NIK regions leading to higher NDVI in the state.



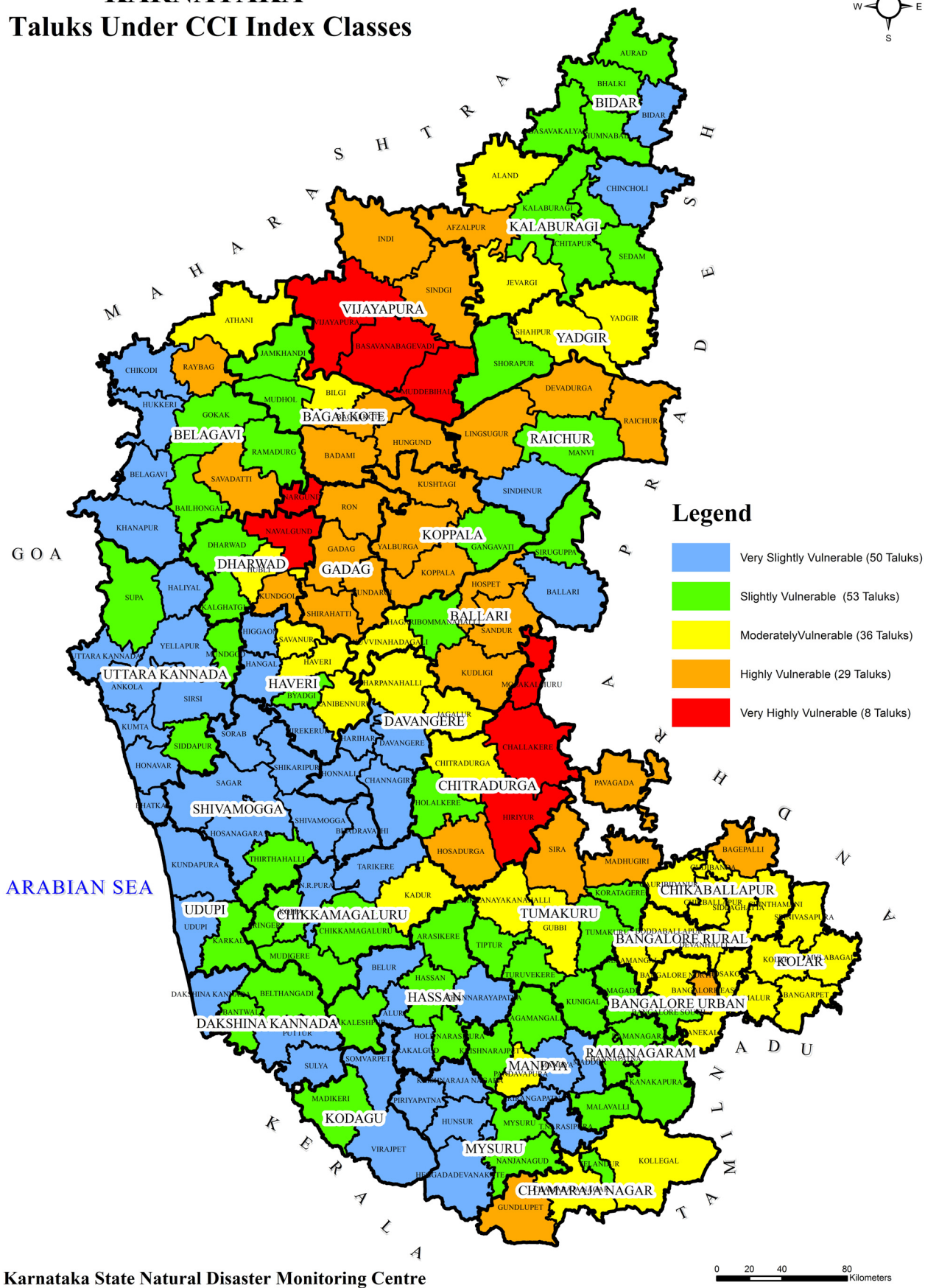


Fig.19. Climate Crop Cover Based Index (CCI)

5.6.3 Climate-soil based index (CSI)

As per this major component (CSI), the frequency and names of the Taluks under each class are presented in Table 12. It shows that the number of Taluks under each class follow this order: 59 (Moderately vulnerable - class 3), > 47 (highly vulnerable – class 4), > 33 (slightly vulnerable – class 2), > 24 (very highly vulnerable – class 5).

Percentage wise vulnerability of these Taluks is in the following order: 34% (under class – 3), > 27% (under class – 4), > 19% (under class – 2), > 13% (under class – 5), > 7% (under class – 1). It shows that about 40% of the Taluks are highly to very highly vulnerable, while 34% of the Taluks are moderately vulnerable and 26% of the Taluks are very slightly to slightly vulnerable in the state.

5.6.4 Livelihood Based Index (LI)

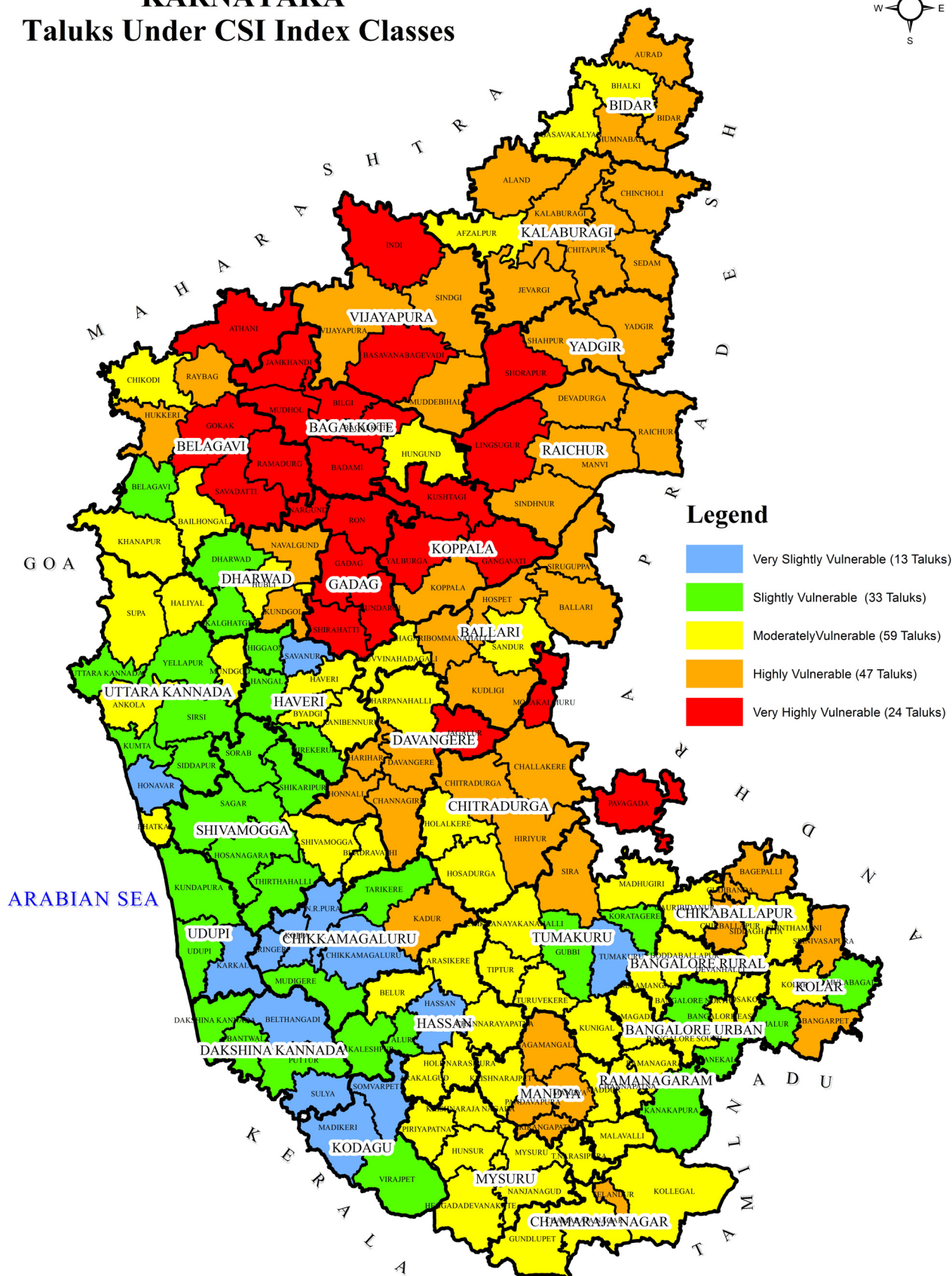
The livelihood based index deals with the capacity of the existing society to withstand drought/ drought like situations, i.e., this index depicts the adaptive capacity of the drought affected society (Ahsan & Warner, 2014). Since there is no direct method of validation of socioeconomic/ livelihood index, selection of indicators and assignment of weight ages are the strongest determinants of the index.

The capacity is based on the accessibility of the society to natural resources, technical knowledge about the resources, utilization, literacy and socio-economic fabric of the society.

As per this ‘LI’, the frequency and names of the Taluks under each class are presented in Table 13. The number of Taluks in each class follows this order: 73 (slightly vulnerable – class 2), > 45 (moderately vulnerable – class 3), > 26 (highly vulnerable – class 4), > 20 (very slightly-vulnerable – class 1), > 12 (very highly vulnerable – class 5).

Percent vulnerability of these Taluks under ‘LI’ in Karnataka state indicate the following order: 41% (under class – 2), > 26% (under class – 3), > 15% (under class – 4), > 11% (under class – 1), > 7% (under class – 5).

From the livelihood index, it is evident that about 52% of the Taluks (93) have the adaptive capacity to the risk of drought, since these Taluks have very slight to slight vulnerability to any eventuality. Besides about 26% (45) of the Taluks are moderately vulnerable, thus a limited number of Taluks (38) i.e., about 22% of Taluks have highly and very highly vulnerable with little or no risk bearing capacity. Usually from these Taluks, the rural to urban migration occurs in search of their livelihood.



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Table 9. Major Component wise Index Classes.

<i>Sl.No.</i>	<i>District</i>	<i>Taluk</i>	<i>LI</i>	<i>CCI</i>	<i>CSI</i>	<i>CI</i>
1	BENGALURU-URBAN	ANEKAL	2	3	2	4
2		BENGALURU NORTH	2	3	2	3
3		BENGALURU SOUTH	2	2	3	3
4		BENGALURU EAST	2	4	3	3
5	BENGALURU-RURAL	DEVANAHALLI	2	3	3	4
6		DODBALLAPUR	2	3	3	4
7		HOSAKOTE	2	3	3	4
8		NELAMANGALA	2	3	3	4
9	RAMANAGARAM	CHANNAPATNA	2	2	3	4
10		KANAKAPURA	1	2	2	4
11		MAGADI	2	2	3	4
12		RAMANAGARA	2	2	3	4
13	KOLAR	BANGARAPET	1	3	4	4
14		KOLAR	2	3	3	4
15		MALUR	2	3	2	3
16		MULABAGAL	2	3	2	4
17		SRINIVASAPURA	2	3	4	4
18	CHIKBALLAPUR	BAGEPALLI	2	4	4	4
19		CHIKBALLAPUR	2	3	4	4
20		CHINTAMANI	2	3	3	4
21		GAURIBIDANUR	2	3	3	4
22		GUDIBANDA	2	3	4	4
23		SIDLAGHATTA	2	3	3	4
24	TUMAKURU	C.N. HALLI	2	3	3	4
25		GUBBI	2	3	2	4
26		KORATAGERE	2	2	2	4
27		KUNIGAL	2	2	3	4
28		MADHUGIRI	2	4	3	4
29		PAVAGADA	4	4	5	5
30		SIRA	3	4	4	5
31		TIPTUR	2	2	3	4
32		TUMAKURU	2	2	1	3
33		TURUVEKERE	2	2	3	4
34	CHITRADURGA	CHALLAKERE	5	5	4	5
35		CHITRADURGA	4	3	4	4
36		HIRIYUR	4	5	4	4
37		HOLALKERE	3	2	3	4
38		HOSADURGA	2	4	3	4
39		MOLAKALMURU	3	5	5	5
40	DAVANGERE	CHANNAGIRI	2	1	4	4
41		DAVANGERE	2	1	4	5
42		HARAPANAHALLI	3	3	3	4
43		HARIHAR	2	1	4	4
44		HONNALI	2	1	4	4
45		JAGALUR	3	3	5	4
46	CHAMARAJANAGAR	CHAMARAJANAGAR	1	3	3	4
47		GUNDLUPET	1	4	3	4
48		KOLLEGAL	2	3	3	4
49		YELANDUR	2	2	4	4

<i>Sl.No.</i>	<i>District</i>	<i>Taluk</i>	<i>LI</i>	<i>CCI</i>	<i>CSI</i>	<i>CI</i>
50	MYSURU	HEGGADADEVANAKOTE	1	1	3	3
51		HUNSUR	2	1	3	4
52		KRISHNARAJANAGAR	2	1	3	4
53		MYSURU	2	2	3	4
54		NANJANAGUD	2	2	3	3
55		PERIYAPATNA	2	1	3	3
56		T.NARASIPUR	2	1	3	4
57	MANDYA	KRISHNARAJAPET	1	2	3	4
58		MADDUR	1	1	3	4
59		MALAVALLI	1	2	3	4
60		MANDYA	1	1	4	4
61		NAGAMANGALA	1	2	4	4
62		PANDAVAPURA	1	3	4	4
63		SRIRANGAPATNA	1	1	4	4
64	BALLARI	BALLARI	4	1	4	5
65		HADAGALI	3	3	3	4
66		HAGARIBOMMANAHALLI	1	2	4	5
67		HOSPET	4	4	4	4
68		KUDLIGI	2	4	4	5
69		SANDUR	1	4	3	4
70		SIRUGUPPA	2	2	4	5
71	KOPPALA	GANGAVATHI	3	2	5	5
72		KOPPALA	4	4	4	5
73		KUSHTAGI	3	4	5	5
74		YELBURGA	4	4	5	5
75	RAICHUR	DEODURGA	3	4	4	5
76		LINGSUGUR	3	4	5	5
77		MANVI	3	2	4	5
78		RAICHUR	3	4	4	5
79		SINDHANUR	3	1	4	5
80	KALABURGI	AFZALPUR	4	4	3	5
81		ALAND	3	3	4	5
82		CHINCHOLI	3	1	4	5
83		CHITAPUR	4	2	4	5
84		KALABURGI	5	2	4	5
85		JEWARGI	4	3	4	5
86		SEDAM	3	2	4	5
87	YADGIR	SHAHAPUR	3	3	4	5
88		SHORAPUR	4	2	5	5
89		YADGIR	2	3	4	5
90	BIDAR	AURAD	3	2	4	5
91		BASAVAKALYAN	2	2	3	4
92		BHALKI	2	2	3	5
93		BIDAR	2	1	4	5
94		HUMNABAD	2	2	4	5
95	BELAGAVI	ATHANI	4	3	5	5
96		BAILHONGAL	3	2	3	4
97		BELAGAVI	2	1	2	3
98		CHIKKODI	3	1	3	4
99		GOKAK	3	2	5	5

<i>Sl.No.</i>	<i>District</i>	<i>Taluk</i>	<i>LI</i>	<i>CCI</i>	<i>CSI</i>	<i>CI</i>
100		HUKKERI	2	1	4	5
101		KHANAPUR	3	1	3	3
102		RAIBAGH	4	4	4	5
103		RAMDURGA	5	2	5	5
104		SOUNDATTI	4	4	5	5
105	BAGALKOTE	BADAMI	3	4	5	4
106		BAGALKOTE	4	4	5	5
107		BILGI	4	3	5	5
108		HUNGUND	4	4	3	5
109		JAMKHANDI	4	2	5	5
110		MUDHOL	5	2	5	5
111	VIJAYAPURA	BASAVANABAGEWADI	5	5	5	4
112		VIJAYAPURA	5	5	4	5
113		INDI	5	4	5	5
114		MUDEDEBIHAL	5	5	4	5
115		SINDGI	5	4	4	5
116	GADAG	GADAG	4	4	5	4
117		MUNDARGI	4	4	5	5
118		NARAGUND	5	5	5	5
119		RON	4	4	5	5
120		SHIRAHATTI	4	4	5	4
121	HAVERI	BYADGI	3	2	3	4
122		HANAGAL	3	1	2	4
123		HAVERI	3	3	3	4
124		HIREKERUR	2	1	2	4
125		RANIBENNUR	3	3	3	4
126		SAVANUR	3	3	1	4
127		SHIGGAON	3	1	2	4
128	DHARWAD	DHARWAD	4	2	2	4
129		HUBLI	4	3	3	4
130		KALGHATGI	2	2	2	4
131		KUNDGOL	4	4	4	4
132		NAVALGUND	5	5	4	4
133	SHIVAMOGGA	BHADRAVATHI	2	1	3	4
134		HOSANAGAR	2	1	2	3
135		SAGAR	3	1	2	3
136		SHIKARIPUR	2	1	2	3
137		SHIVAMOGGA	3	1	3	4
138		SORAB	3	1	2	4
139		TIRTHAHALLI	3	2	2	3
140	HASSAN	ALUR	2	1	2	4
141		ARKALGUD	1	1	3	4
142		ARASIKERE	1	2	3	4
143		BELUR	2	1	3	3
144		CHANNARAYAPATNA	2	1	3	4
145		HASSAN	1	2	1	3
146		HOLENARASIPUR	1	2	3	4
147		SAKALESHPUR	3	2	2	2

<i>Sl.No.</i>	<i>District</i>	<i>Taluk</i>	<i>LI</i>	<i>CCI</i>	<i>CSI</i>	<i>CI</i>
148	CHIKKAMAGALURU	CHIKKAMAGALURU	2	2	1	3
149		KADUR	2	3	4	4
150		KOPPA	3	2	1	2
151		MUDIGERE	3	2	2	2
152		NARASIMHARAJAPUR	3	1	1	2
153		SRINGERI	2	2	1	2
154		TARIKERE	2	1	2	3
155	KODAGU	MADIKERI	4	2	1	1
156		SOMWARPET	3	1	1	2
157		VIRAJPET	5	1	2	2
158	DAKSHINA KANNADA	BELTANGADI	3	2	1	1
159		BANTWAL	3	2	2	1
160		MANGALORE	3	1	2	2
161		PUTTUR	2	1	2	1
162		SULYA	3	1	1	1
163	UDUPI	KARKALA	3	2	1	1
164		KUNDAPUR	2	1	2	2
165		UDUPI	2	1	2	2
166	UTTARA KANNADA	ANKOLA	2	1	3	2
167		BHATKAL	1	1	3	3
168		HALIYAL	3	1	3	3
169		HONNAVAR	2	1	1	3
170		KARWAR	1	1	2	3
171		KUMTA	2	1	2	3
172		MUNDGOD	2	2	3	3
173		SIDDAPUR	2	2	2	3
174		SIRSI	2	1	2	3
175		SUPA	3	2	3	4
176		YELLAPUR	2	1	2	3

Table 10. Frequency and names of Taluks under each class of climate based Index (CI)

<i>District</i>	<i>No. of taluks</i>	<i>1(6)</i>	<i>2(11)</i>	<i>CLIMATE BASED INDEX (CI)</i>	
				<i>3(27)</i>	<i>4(82)</i>
Bengaluru-Urban	4			Bengaluru North, Bengaluru South, Bengaluru East	Anekal
Bengaluru-Rural	4				Devanahalli, Doddballapur, Hosakote, Nelamangala
Ramanagaram	4				Channapatna, Kanakapura, Magadi, Ramanagara
Kolar	5			Malur	Kolar, Mulabagal, Bangarapet, Srinivasapura
Chikballapur	6				Bagepalli, Chikballapur, Chintamani, Sidlaghatta, Gauribidanur, Gudibanda
Tumakuru	10			Tumakuru	C.N. Halli, Koratagere, Madhugiri, Tiptur, Gubbi, Kunigal, Turuvekere
Chitradurga	6				Chitradurga, Hiriyur, Holalkere, Hosadurga, Challakere, Molakalmuru
Davangere	6				Channagiri, Honnali Harapanahalli, Harihar, Jagalur, Davangere
Chamarajanagar	4				Chamarajanagar, Gundlupet, Kollegal, Yelandur
Mysuru	7			Heggadadevanakote, Periyapatna, Nanjanagud	Hunsur, Krishnarajanagar, Mysuru, T.Narasipur
Mandya	7				Maddur, Malavalli, Nagamangala, Pandavapura, Sirangapatna, Krishnarajapet, Mandya

<i>District</i>	<i>No. of taluks</i>	<i>1(6)</i>	<i>2(11)</i>	<i>CLIMATE BASED INDEX (CI)</i>	<i>3(27)</i>	<i>4(82)</i>	<i>5(50)</i>
Ballari	7					Hadagali, Sadur, Hospet,	Ballari, Hagaribommanahalli, Kudligi, Siruguppa
Koppala	4						Gangavathi, Kushtagi, Koppala, Yelburga
Raichur	5						Deodurga, Lingsugur, Manvi, Raichur, Sindhanur
Yadgir	3						Shahapur, Shorapur, Yadgir
Bidar	5					Basavakalyan	Aurad, Bhalki, Bidar, Humnabad
Belagavi	10			Belagavi, Khanapur		Bailhongal, Chikkodi	Hukkeri, Raibagh, Soundatti, Gokak, Ramdurga, Athani
Bagalkote	6					Badami	Bagalkote, Jamkhandi, Mudhol, Bilgi, Hungund
Vijayapura	5					Muddebihal	Basavanabagewadi, Vijayapura, Indi, Sindgi
Gadag	5					Gadag, Shirahatti	Mundargi, Naragund, Ron
Haveri	7					Byadgi, Hanagal, Haveri, Hirekerur, Ranibennur, Savanur, Shiggaon	
Dharwad	5					Hubli, Kundgol, Navalgund, Dharwad, Kalghatgi	
Shivamogga	7			Hosanagar, Tirthahalli, Sagara, Shikaripur		Shivamogga, Bhadravathi, Soraba	
Hassan	8			Sakaleshpur	Belur, Hassan	Arasikere, Channarayapatna, Holenarasipur, Alur, Arkalgud,	

<i>District</i>	<i>No. of taluks</i>	<i>1(6)</i>	<i>2(11)</i>	<i>CLIMATE BASED INDEX (CI)</i>		
				<i>3(27)</i>	<i>4(82)</i>	<i>5(50)</i>
Chikkamagaluru	7		Mudigere, Narasimharajapur, Koppa, Sringeri	Chikkamagaluru, Tarikere	Kadur	
Kodagu	3	Madikeri	Somwarpet, Virajpet			
Dakshina Kannada	5	Beltangadi, Bantwal, Puttur, Sulya,	Mangalore			
Udupi	3	Karkala	Kundapur, Udupi			
Uttara Kannada	11		Ankola,	Honnavar, Bhatkal, Haliyal, Karwar, Kumta, Mundgod, Siddapur, Sirsi, Yellapur	Supa	

Table 11. Frequency and names of Taluks under each class of climate-crop cover based Index (CCI)

<i>District</i>	<i>No. of taluks</i>	<i>1(50)</i>	<i>2(53)</i>	<i>CCI</i>	<i>3(36)</i>	<i>4(29)</i>	<i>5(8)</i>
Bengaluru-Urban	4		Bengaluru South	Anekal, Bengaluru North		Bengaluru East	
Bengaluru-Rural	4			Devanahalli, Doddballapur, Hosakote, Nelamangal			
Ramanagaram	4		Channapatna, Kanakapura, Magadi, Ramanagara				
Kolar	5			Bangarapet, Kolar, Malur, Mulabagal, Srinivasapura			
Chikballapur	6			Chikballapur, Chintamani, Gauribidanur, Gudibanda, Sidlaghatta		Bagepalli	
Tumakuru	10		Koratagere, Kunigal, Tiptur Tumakuru, Turuvekere			Madhugiri, Pavagada, Sira	
Chitradurga	6		Holalker	Chitradurga		Hosadurga	Challakere, Hiriyur Molakalmuru
Davangere	6	Channagiri, Davangere, Harihar, Honnali		Harapanahalli, Jagalur			
Chamarajanagar	4		Yelandu	Chamarajanagar, Kollegal		Gundlupe	
Mysuru	7	Heggadadevanakote, Hunsur, Krishnarajanagar					
		Periyapatna, T.Narasipur		Mysuru, Nanjanagud			
Mandya	7	Maddur, Mandya, Srirangapatna	Krishnarajapet, Malavalli, Nagamangala	Pandavapur			
Ballari	7	Ballari	Hagaribommanahalli, Siruguppa	Hadagali		Hospet, Kudligi, Sandur	
Koppala	4		Gangavathi			Koppala, Kushtagi, Yelburga	

<i>District</i>	<i>No. of taluks</i>	<i>1(50)</i>	<i>2(53)</i>	<i>CCI</i>	<i>3(36)</i>	<i>4(29)</i>	<i>5(8)</i>
Raichur	5	Sindhani	Manvi			Deodurga, Lingsugur, Raichur	
Kalaburagi	7	Chinchol	Chitapur, Kalaburagi, Sedam	Aland, Jewargi		Afzalpur	
Yadgir	3		Shorapur	Shahapur, Yadgi			
Bidar	5	Bida	Aurad, Basavakalyan, Bhalki, Humnabad				
Belagavi	10	Belagavi, Chikkodi, Hukkeri, Khanapur	Bailhongal, Gokak, Ramdurg	Athani		Raibagh, Soundatti	
Bagalkote	6		Jamkhandi, Mudhol Bilgi			Badami, Bagalkote, Hungund	
Bijapur	5					Indi, Sindgi	Basavanabagewadi Bijapur, Muddebihal
Gadag	5					Gadag, Mundargi, Ron, Shirahatt	Naragund
Haveri	7	Hanagal, Hirekerur, Shiggaon	Byadgi	Haveri, Ranibennur, Savanur			
Dharwad	5		Dharwad, Kalghatgi Hubli			Kundgol	Navalgund
Shivamogga	7	Bhadravathi, Hosanagar, Sagar Shikaripur, Shivamogga, Sorab	Tirthahalli				
Hassan	8	Alur, Arkalgud, Belur, Channarayapatna	Arasikere, Hassan, Holenarasipur, Sakaleshpur				
Chikmagalur	7	Narasimharajapur, Tariker	Chikmagalur, Koppa, Mudigere, Sringeri	Kadur			

<i>District</i>	<i>No. of taluks</i>	<i>1(50)</i>	<i>2(53)</i>	<i>CCI</i>	<i>4(29)</i>	<i>5(8)</i>
Kodagu	3	Somwarpet, Virajpe	Madikeri			
Dakshina Kannada	5	Mangalore, Puttur, Sulya	Beltangadi, Bantwal			
Udupi	3	Kundapur, Udupi	Karkala			
Uttara Kannada	11	Ankola, Bhatkal, Haliyal, Honnavar, Karwar, Kumta, Sirsi, Yellapur	Mundgod, Siddapur, Supa			

Table 12. Frequency and names of Taluks under each class of climate-soil based Index (CSI)-contd

<i>District</i>	<i>No. of taluks</i>	<i>1(13)</i>	<i>2(33)</i>	<i>CLIMATE SOIL INDEX</i> <i>3(59)</i>	<i>4(47)</i>	<i>5(24)</i>
Bengaluru-Urban	4		Anekal, Bengaluru North	Bengaluru South, Bengaluru East		
Bengaluru-Rural	4			Devanahalli, Doddballapur, Hosakote, Nelamangala		
Ramanagaram	4		Kanakapura	Channapatna, Magadi, Ramanagara		
Kolar	5		Malur, Mulabagal	Kolar	Bangarapet, Srinivasapura	
Chikballapur	6			Chintamani, Gauribidanur, Sidlaghatta	Bagepalli, Chikballapur, Gudibanda	
Tumakuru	10	Tumakuru	Gubbi, Koratagere	C.N. Halli, Kunigal, Madhugiri, Tiptur, Turuvekere	Sira	Pavagada
Chitradurga	6			Holalkere, Hosadurga	Challakere, Chitradurga, Hiriyr	Molakalmuru
Davangere	6			Harapanahalli	Channagiri, Davangere, Harihar, Honnali	Jagalur
Chamarajanagar	4			Chamarajanagar, Gundlupet, Kollegal	Yelandur	
Mysuru	7			Heggadadevanakote, Hunsur, Krishnarajanagar, Mysuru, Nanjanagud, Periyapatna, T. Narasipura		
Mandya	7			Krishnarajapet, Maddur, Malavalli	Mandya, Nagamangala, Pandavapura, Srirangapatna	
Ballari	7			Hadagali, Sanduru	Ballari, Hagaribommanahalli, Hospet, Kudligi, Siruguppa	
Koppala	4				Koppala	Gangavathi, Kushtagi, Yelburga
Raichur	5				Deodurga, Manvi, Raichur, Sindhanuru	Lingsugur

<i>District</i>	<i>No. of taluks</i>	<i>1(13)</i>	<i>2(33)</i>	<i>CLIMATE SOIL INDEX</i>	<i>3(59)</i>	<i>4(47)</i>	<i>5(24)</i>
Kalaburagi	7			Afzalpur		Aland, Chincholi, Chitapur, Kalaburagi, Jewargi, Sedam	
Yadgir	3					Shahapur, Yadgi	Shorapur
Bidar	5			Basavakalyan, Bhalki		Aurad, Bidar, Humnabad	
Belagavi	10		Belagav	Bailhongal, Chikkodi, Khanapur		Hukkeri, Raibagh	Athani, Gokak, Ramdurga, Soundatti
Bagalkote	6			Hungund			Badami, Bagalkote, Bilgi, Jamkhandi, Mudhol
Bijapur	5					Bijapur, Muddebihal, Sindgi	Basavanabagewadi, Indi
Gadag	5						Gadag, Mundargi, Ron, Naragund, Shirahatt
Haveri	7	Savanur	Hanagal, Hirekerur, Shiggaon	Byadgi, Haveri, Ranibennur			
Dharwad	5		Dharwad, Kalghatgi Hubli			Kundgol, Navalgund	
Shivamogga	7		Hosanagar, Sagar, Shikaripur, Sorab, Tirthahalli	Bhadravathi, Shivamogga			
Hassan	8	Hassan	Alur, Sakaleshpur	Arkalgud, Arasikere, Belur, Channarayapatna, Holenarasipur			
Chikkamagaluru	7	Chikkamagaluru, Koppa, Narasimharajapur, Sringeri					
Kodagu	3	Madikeri, Somwarpet	Virajpet			Kadur	
DakshinaKannada	5	Beltangadi, Sulya	Bantwal, Mangalore, Puttur				
Udupi	3	Karkala	Kundapur, Udupi				
Uttara Kannada	11	Honnavar	Karwar, Kumta, Siddapur, Sirsi, Yellapur	Ankola, Bhatkal, Haliyal, Mundgod, Supa			

Table 13. Frequency and names of Taluks under each class of livelihood Index (LI)- contd

<i>District</i>	<i>No. of taluks</i>	<i>1(20)</i>	<i>2(73)</i>	<i>LIVELIHOOD BASED INDEX (LI)</i>	
				<i>3(45)</i>	<i>4(26)</i>
Bengaluru-Urban	4		Anekal, Bengaluru North, Bengaluru South, Bengaluru East		5(12)
Bengaluru-Rural	4		Devanahalli, Doddballapur, Hosakote, Nelamangala		
Ramanagaram	4	Kanakapura	Channapatna, Magadi, Ramanagara		
Kolar	5	Bangarapet	Kolar, Malur, Mulabagal, Srinivasapura		
Chikballapur	6		Bagepalli, Chikballapur, Chintamani, Gauribidanur, Gudibanda, Sidlaghatta		
Tumakuru	10		C.N. Halli, Gubbi, Koratagere, Kunigal, Madhugiri, Tiptur, Tumakuru, Turuvekere	Sira	Pavagada
Chitradurga	6		Hosadurga	Holalkere, Molakalmuru	Chitradurga, Hiriyur
Davangere	6		Channagiri, Davangere, Harihar, Honnali	Harapanahalli, Jagalur	
Chamarajanagar	4	Chamarajanagara, Gundlupet	Kollegal, Yelandur		
Mysuru	7	Heggadadevanakote	Hunsur, Krishnarajanagar, Mysuru, Nanjanagud, Periyapatna, T.Narasipura		
Mandya	7	Krishnarajapet, Maddur, Malavalli, Mandya, Nagamangala, Pandavapura, Sriirangapatna			

<i>District</i>	<i>No. of taluks</i>	<i>1(20)</i>	<i>2(73)</i>	<i>LIVELIHOOD BASED INDEX (LI)</i>	
				<i>3(45)</i>	<i>4(26)</i>
Ballari	7	Hagaribommanahalli, Sandur	Kudligi, Siruguppa	Hadagali	Ballari, Hospet
Koppala	4			Gangavathi, Kushtagi	Koppala, Yelburga
Raichur	5			Sindhaur, Lingsugur, Manvi, Raichur, Deodurga	
Kalaburagi	7			Aland, Chincholi, Sedam	Afzalpur, Chitapur, Jewargi
Yadgir	3		Yadgir	Shahapu	Shorapur
Bidar	5		Basavakalyan, Bhalki, Bidar, Humnabad	Aura	
Belagavi	10		Belagavi, Hukkeri	Bailhongal, Chikkodi, Gokak, Khanapur	Athani, Raibagh, Soundatti
Bagalkote	6		Badami		Bagalkote, Bilgi, Hungund, Jamkhandi
Vijayapura	5				B.Bagewadi, Vijayapura, Indi, Sindgi, Muddebihal,
Gadag	5				Gadag, Mundargi, Ron, Shirahatti
Haveri	7		Hirekerur	Byadgi, Hanagal, Haveri, Ranibennur, Savanur, Shiggaon	
Dharwad	5		Kalghatgi		Dharwad, Hubli, Kundgol
Shivamogga	7		Bhadravathi, Hosanagara, Shikaripur	Sagara, Shivamogga, Sorab, Tirthahalli	
Hassan	8	Arkalgud, Arasikere, Hassan, Holenarasipur	Alur, Belur, Channarayapatna	Sakaleshpura	
Chikkamagaluru	7		Chikkamagaluru, Kadur Sringeri, Tariker	Koppa, Mudigere, Narasimharajapur	

<i>District</i>	<i>No. of taluks</i>	<i>1(20)</i>	<i>2(73)</i>	<i>LIVELIHOOD BASED INDEX (LI)</i>		
				<i>3(45)</i>	<i>4(26)</i>	<i>5(12)</i>
Kodagu	3			Somwarpet	Madikeri	Virajpet
Dakshina Kannada	5		Puttur	Beltangadi, Bantwal, Mangalore, Sulya		
Udupi	3		Kundapur, Udupi	Karkala		
Uttara Kannada	11	Bhatkal, Karwar	Ankola, Honnavar, Kumta, Mundgod, Siddapur, Sirsi, Yellapur	Haliyal, Supa		

Chapter 6.

COMPOSITE DROUGHT VULNERABILITY INDEX (DVI)

Among the four indices developed based on the major components, the climatic index (CI) indicates its effect by virtue of duration/severity on the geographical area. While the CCI- Index indicates the sensitivity of the Taluk to the variable climatic conditions and it is reflected through crop vigour&cover. Hence these two indices (CI & CCI) combinedly indicate the impact of drought or severity of drought in a geographical area. Among the other two indices, the climate- soil-based index (CSI) indicates the inherent capacity of the system (area) to withstand the effect or severity. While the livelihood index exhibits the power of resilience or strength and adaptive capacity of the society affected by drought or any disastrous situation. There is no straight forward method to develop composite index from dissimilar sub components (Vincent, 2007). Attempts to study vulnerability through composite index, its mapping and zoning was done by many workers based on exposure, sensitivity and adaptive capacity (Murthy et al, 2015; LIU Xiaoqian et al, 2013). The exposure refers to the extent, duration and frequency of stress on the system. While sensitivity is the degree to which a system is affected either positively or negatively by a stress or perturbation. The adaptive capacity is the ability of the system to combat or cope with the actual or expected stress. It also includes the ability of the system to initiate measures to sustain the stress and prevent from future damage. In the present study of assessment of drought vulnerability, of the four major indices, the climate based index and climate-crop cover based index represent the exposure & sensitivity to drought/stress while climate soil based index shows the inherent capacity of the affected system to withstand the stress. The livelihood index indicates the ability/capacity of the affected society or households to restore normalcy. This reflects the resilient power of the existing society. The power of resilience is dependent on the interest, education, accessibility to resources and knowledge base of the affected society.

While developing a composite index of vulnerability for a Taluk, due importance was given to the positive and negative effects of these indices in a geographic area (Taluk). Thus the composite index of drought vulnerability is computed by the formula as under:

$$\text{Composite drought vulnerability (DVI)} = (\text{CI} + \text{CCI}) - (\text{LI} + \text{CSI})$$

The composite drought vulnerability index values (DVI) thus derived for each Taluk (Table 14) are subjected to normal distribution and through mean and standard deviation. As per the Table 14, the composite drought vulnerability index values ranged from 0.02 to 0.98. In general the sub-humid and humid areas have low index values indicating less vulnerability in these Taluks while the Taluks of arid-semiarid areas showed higher DVI values indicating their proneness to drought. The DVI values thus obtained are grouped into five classes based on minimum and maximum values at a fixed class interval. These classes were assigned to each Taluk. Based on the number of the class, the drought severity was assessed at Taluk level. The five classes are 1) Very slightly vulnerable, 2) Slightly vulnerable, 3) Moderately Vulnerable, 4) Highly Vulnerable, 5) Very highly vulnerable. The areas (Taluks) under each class were determined and presented in Table 14, Fig.22.

Table 14. Composite index of Drought Vulnerability in Karnataka.

<i>Sl. No.</i>	<i>District</i>	<i>Taluk</i>	<i>LI+CSI (C2)</i>	<i>CCI+CI (CI)</i>	<i>CI-C2</i>	<i>DVI</i>	<i>class</i>
1	BENGALURU-URBAN	ANEKAL	1.24	0.99	-0.25	0.31	2
2		BENGALURU NORTH	1.23	0.99	-0.25	0.31	2
3		BENGALURU SOUTH	1.11	0.94	-0.17	0.37	2
4		BENGALURU EAST	1.08	1.09	0.01	0.51	3
5	BENGALURU-RURAL	DEVANAHALLI	1.03	1.09	0.06	0.55	3
6		DODBALLAPUR	1.1	1.03	-0.07	0.45	3
7		HOSAKOTE	1.03	1.08	0.05	0.54	3
8		NELAMANGALA	1.04	1.01	-0.03	0.48	3
9	RAMANAGARAM	CHANNAPATNA	1.22	0.92	-0.30	0.28	2
10		KANAKAPURA	1.35	0.98	-0.38	0.23	2
11		MAGADI	1.14	0.95	-0.20	0.35	2
12		RAMANAGARA	1.2	0.96	-0.24	0.32	2
13	KOLAR	BANGARAPET	1.02	1.05	0.03	0.53	3
14		KOLAR	1.02	1.05	0.03	0.53	3
15		MALUR	1.26	1.01	-0.25	0.31	2
16		MULABAGAL	1.26	1.11	-0.15	0.38	2
17		SRINIVASAPURA	0.84	1.07	0.22	0.67	4
18	CHIKBALLAPUR	BAGEPALLI	0.9	1.29	0.39	0.78	4
19		CHIKBALLAPUR	0.93	1.07	0.14	0.61	4
20		CHINTAMANI	1.05	1.12	0.07	0.56	3
21		GAURIBIDANUR	1.05	1.12	0.07	0.56	3
22		GUDIBANDA	1	1.21	0.21	0.66	4
23		SIDLAGHATTA	1.15	1.11	-0.04	0.47	3
24	TUMAKURU	C.N. HALLI	1.05	1.16	0.11	0.59	3
25		GUBBI	1.29	1.05	-0.24	0.32	2
26		KORATAGERE	1.22	0.99	-0.23	0.32	2
27		KUNIGAL	1.05	0.97	-0.08	0.44	3
28		MADHUGIRI	1.18	1.15	-0.03	0.48	3
29		PAVAGADA	0.54	1.36	0.82	0.95	5
30		SIRA	0.82	1.39	0.58	0.88	5
31	TUMAKURU	TIPTUR	1.01	0.97	-0.04	0.47	3
32		TUMAKURU	1.51	0.96	-0.56	0.13	1
33		TURUVEKERE	1.17	1.00	-0.17	0.37	2
34	CHITRADURGA	CHALLAKERE	0.62	1.47	0.85	0.96	5
35		CHITRADURGA	0.7	1.14	0.44	0.81	5
36		HIRIYUR	0.79	1.36	0.57	0.88	5
37		HOLALKERE	1.15	0.92	-0.23	0.32	2
38		HOSADURGA	1.09	1.27	0.18	0.64	4
39		MOLAKALMURU	0.48	1.52	1.04	0.98	5
40	DAVANGERE	CHANNAGIRI	0.97	0.84	-0.13	0.40	3
41		DAVANGERE	0.88	0.92	0.05	0.54	3
42		HARAPANAHALLI	1.02	1.07	0.05	0.55	3
43		HARIHAR	0.91	0.88	-0.03	0.48	3
44		HONNALI	0.91	0.86	-0.05	0.46	3
45		JAGALUR	0.71	1.22	0.52	0.85	5

<i>Sl. No.</i>	<i>District</i>	<i>Taluk</i>	<i>LI+CSI (C2)</i>	<i>CCI+CI (C1)</i>	<i>C1-C2</i>	<i>DVI</i>	<i>class</i>
46	CHAMARAJANAGAR	CHAMARAJANAGAR	1.19	1.06	-0.14	0.40	2
47		GUNDLUPET	1.11	1.17	0.06	0.55	3
48		KOLLEGAL	1.08	1.09	0.01	0.51	3
49		YELANDUR	0.96	0.94	-0.02	0.49	3
50	MYSURU	H.D KOTE	1.24	0.80	-0.44	0.19	1
51		HUNSUR	1.05	0.89	-0.15	0.38	2
52		KRISHNARAJANAGAR	1.1	0.87	-0.23	0.32	2
53		MYSURU	1.19	0.95	-0.24	0.32	2
54		NANJANAGUD	1.19	0.92	-0.27	0.30	2
55		PERIYAPATNA	1.21	0.76	-0.45	0.19	1
56		T.NARASIPUR	1.02	0.82	-0.20	0.35	2
57	MANDYA	KRISHNARAJAPET	1.23	0.93	-0.30	0.28	2
58		MADDUR	1.18	0.79	-0.39	0.22	2
59		MALAVALLI	1.3	0.96	-0.34	0.25	2
60		MANDYA	0.91	0.86	-0.05	0.46	3
61		NAGAMANGALA	1.09	1.01	-0.08	0.44	3
62		PANDAVAPURA	0.97	1.09	0.12	0.60	4
63		SRIRANGAPATNA	1	0.81	-0.19	0.36	2
64	BALLARI	BALLARI	0.72	1.00	0.28	0.71	4
65		HADAGALI	0.98	1.14	0.16	0.63	4
66		H.B HALLI	0.96	1.08	0.12	0.60	4
67		HOSPET	0.78	1.26	0.48	0.83	5
68		KUDLIGI	0.86	1.36	0.49	0.84	5
69		SANDUR	1.09	1.19	0.10	0.58	3
70		SIRUGUPPA	0.78	1.06	0.28	0.71	4
71	KOPPALA	GANGAVATHI	0.72	1.12	0.41	0.80	5
72		KOPPALA	0.73	1.36	0.63	0.90	5
73		KUSHTAGI	0.58	1.38	0.80	0.95	5
74		YELBURGA	0.44	1.41	0.97	0.97	5
75	RAICHUR	DEODURGA	0.82	1.38	0.57	0.87	5
76		LINGSUGUR	0.62	1.43	0.82	0.95	5
77		MANVI	0.79	1.13	0.34	0.76	4
78		RAICHUR	0.77	1.30	0.53	0.86	5
79		SINDHANUR	0.8	1.05	0.24	0.69	4
80	KALABURAGI	AFZALPUR	0.89	1.31	0.43	0.81	5
81		ALAND	0.84	1.19	0.36	0.77	4
82		CHINCHOLI	0.88	1.10	0.22	0.68	4
83		CHITAPUR	0.69	1.11	0.42	0.80	5
84		KALABURAGI	0.73	1.12	0.39	0.78	4
85		JEWARGI	0.77	1.27	0.50	0.84	5
86		SEDAM	0.85	1.14	0.28	0.72	4
87	YADGIR	SHAHAPUR	0.83	1.26	0.43	0.81	5
88		SHORAPUR	0.5	1.27	0.77	0.94	5
89		YADGIR	0.95	1.26	0.31	0.73	4
90	BIDAR	AURAD	0.84	1.09	0.25	0.69	4
91		BASAVAKALYAN	1.15	0.99	-0.15	0.38	2
92		BHALKI	1.08	1.10	0.02	0.52	3
93		BIDAR	0.83	1.04	0.21	0.66	4
94		HUMNABAD	0.99	1.04	0.05	0.54	3

<i>Sl. No.</i>	<i>District</i>	<i>Taluk</i>	<i>LI+CSI (C2)</i>	<i>CCI+CI (C1)</i>	<i>C1-C2</i>	<i>DVI</i>	<i>class</i>
95	BELAGAVI	ATHANI	0.45	1.23	0.78	0.94	5
96		BAILHONGAL	0.94	0.97	0.03	0.53	3
97		BELAGAVI	1.21	0.74	-0.46	0.18	1
98		CHIKKODI	0.94	0.97	0.03	0.53	3
99		GOKAK	0.58	1.09	0.51	0.85	5
100		HUKKERI	0.92	0.97	0.05	0.54	3
101		KHANAPUR	1.04	0.72	-0.33	0.26	2
102		RAIBAGH	0.72	1.33	0.62	0.89	5
103		RAMDURGA	0.56	1.11	0.54	0.86	5
104		SOUNDATTI	0.51	1.35	0.83	0.95	5
105	BAGALKOTE	BADAMI	0.63	1.25	0.61	0.89	5
106		BAGALKOTE	0.57	1.38	0.81	0.95	5
107	BAGALKOTE	BILGI	0.5	1.17	0.67	0.91	5
108		HUNGUND	0.9	1.36	0.47	0.83	5
109		JAMKHANDI	0.5	1.10	0.60	0.89	5
110		MUDHOL	0.51	1.03	0.52	0.85	5
111	VIJAYAPURA	B. BAGEWADI	0.43	1.44	1.00	0.98	5
112		VIJAYAPURA	0.58	1.45	0.87	0.96	5
113		INDI	0.56	1.41	0.85	0.96	5
114		MUDEDEBIHAL	0.72	1.49	0.77	0.94	5
115		SINDGI	0.65	1.37	0.72	0.93	5
116	GADAG	GADAG	0.64	1.34	0.70	0.92	5
117		MUNDARGI	0.45	1.40	0.96	0.97	5
118		NARAGUND	0.47	1.48	1.01	0.98	5
119		RON	0.51	1.33	0.82	0.95	5
120		SHIRAHATTI	0.62	1.21	0.59	0.88	5
121	HAVERI	BYADGI	1.07	0.99	-0.09	0.43	3
122		HANAGAL	1.29	0.85	-0.44	0.19	1
123		HAVERI	1.11	1.03	-0.08	0.44	3
124		HIREKERUR	1.19	0.83	-0.36	0.23	2
125		RANIBENNUR	1.11	1.14	0.03	0.52	3
126		SAVANUR	1.34	1.10	-0.23	0.32	2
127		SHIGGAON	1.28	0.86	-0.41	0.21	2
128	DHARWAD	DHARWAD	1.13	0.96	-0.18	0.36	2
129		HUBLI	0.86	1.11	0.25	0.70	4
130		KALGHATGI	1.35	0.88	-0.47	0.17	1
131		KUNDGOL	0.7	1.13	0.42	0.80	5
132		NAVALGUND	0.54	1.43	0.89	0.96	5
133	SHIVAMOGGA	BHADRAVATHI	1.15	0.79	-0.37	0.23	2
134		HOSANAGAR	1.21	0.80	-0.41	0.21	2
135		SAGAR	1.32	0.73	-0.59	0.12	1
136		SHIKARIPUR	1.24	0.68	-0.57	0.13	1
137		SHIVAMOGGA	1.06	0.84	-0.23	0.33	2
138		SORAB	1.2	0.80	-0.40	0.21	2
139		TIRTHAHALLI	1.25	0.77	-0.48	0.17	1
140	HASSAN	ALUR	1.27	0.82	-0.44	0.19	1
141		ARKALGUD	1.24	0.74	-0.51	0.16	1
142		ARASIKERE	1.13	1.02	-0.11	0.42	3

<i>Sl. No.</i>	<i>District</i>	<i>Taluk</i>	<i>LI+CSI (C2)</i>	<i>CCI+CI (C1)</i>	<i>C1-C2</i>	<i>DVI</i>	<i>class</i>
143	HASSAN	BELUR	1.16	0.73	-0.43	0.19	1
144		CHANNARAYAPATNA	1.23	0.90	-0.33	0.26	2
145		HASSAN	1.51	0.83	-0.67	0.09	1
146		HOLENARASIPUR	1.23	0.97	-0.27	0.30	2
147		SAKALESHPUR	1.26	0.67	-0.59	0.12	1
148	CHIKKAMAGALURU	CHIKKAMAGALURU	1.44	0.83	-0.62	0.11	1
149		KADUR	0.89	1.02	0.14	0.61	4
150		KOPPA	1.33	0.59	-0.73	0.07	1
151		MUDIGERE	1.23	0.63	-0.60	0.11	1
152		NARASIMHARAJAPUR	1.3	0.61	-0.69	0.08	1
153		SRINGERI	1.6	0.62	-0.98	0.02	1
154		TARIKERE	1.35	0.78	-0.57	0.13	1
155	KODAGU	MADIKERI	1.44	0.47	-0.97	0.03	1
156		SOMWARPET	1.38	0.50	-0.87	0.04	1
157		VIRAJPET	1.15	0.46	-0.69	0.08	1
158	DAKSHINA KANNADA	BELTANGADI	1.4	0.50	-0.90	0.04	1
159		BANTWAL	1.23	0.52	-0.71	0.08	1
160		MANGALORE	1.15	0.51	-0.64	0.10	1
161		PUTTUR	1.3	0.42	-0.88	0.04	1
162		SULYA	1.45	0.29	-1.16	0.01	1
163	UDUPI	KARKALA	1.38	0.45	-0.93	0.03	1
164		KUNDAPUR	1.33	0.58	-0.75	0.07	1
165		UDUPI	1.32	0.55	-0.77	0.06	1
166	UTTARA KANNADA	ANKOLA	1.23	0.63	-0.59	0.12	1
167		BHATKAL	1.23	0.68	-0.55	0.14	1
168		HALIYAL	1.13	0.71	-0.41	0.21	2
169		HONNAVA R	1.42	0.72	-0.70	0.08	1
170		KARWAR	1.29	0.66	-0.63	0.11	1
171		KUMTA	1.33	0.64	-0.69	0.09	1
172		MUNDGOD	1.15	0.86	-0.29	0.28	2
173		SIDDAPUR	1.33	0.78	-0.54	0.14	1
174		SIRSI	1.32	0.80	-0.52	0.15	1
175		SUPA	1.14	0.87	-0.26	0.30	2
176		YELLAPUR	1.22	0.75	-0.47	0.17	1

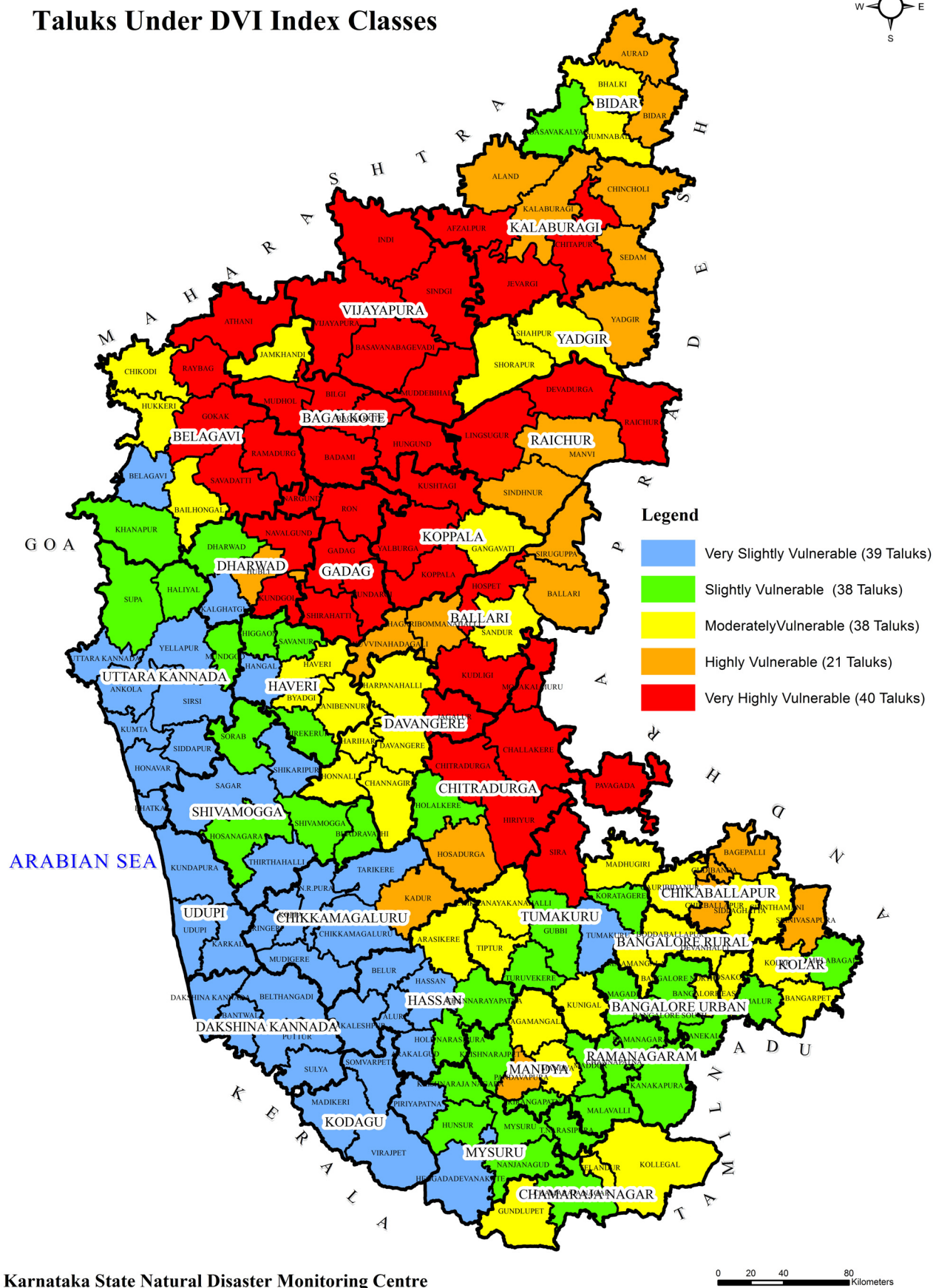


Fig.22. Taluks Under Drought Vulnerability Index (DVI)

Table 15. Frequency and Names of Taluks under different DVI Classes

<i>District</i>	<i>No. of taluks</i>	<i>1(39)</i>	<i>2(38)</i>	<i>Drought Vulnerability Index (DVI)</i> <i>3(38)</i>	<i>4(21)</i>	<i>5(40)</i>
Bengaluru-urban	4		Anekal, Bengaluru North, Bengaluru South	Bengaluru East		
Bengaluru-rural	4			Devanahalli, Hosakote, Doddballapur, Nelamangala		
Ramanagaram	4		Channapatna, Magadi, Kanakapura, Ramanagara			
Kolar	5		Malur, Mulbagal	Bangarapet, Kolar	Srinivasapura	
Chikballapur	6			Chintamani, Gauribidanur, Sidlaghatta	Chikballapur Bagepalli, Gudiband	
Tumakuru	10	Tumakuru	Gubbi, Koratagere, Turuvekere	C.N. Halli, Kunigal, Madhugiri, Tiptur		Pavagada, Sira
Chitradurga	6		Holalkere		Hosadurga	Challakere, Chitradurga, Hiriyur, Molakalmuru
Davangere	6			Channagiri, Davangere, Harihar Harapanahalli, Honnali		Jagalur
Chamarajanagar	4		Chamarajanagar	Gundlupet, Kollegal, Yelandur		
Mysuru	7	Heggadadevanakote, Periyapatna	Hunsur, Mysuru Krishnarajanagar, Nanjanagud, T. Narasipur			
Mandya	7		Krishnarajapet, Malavalli, Maddur, Srirangapatna	Mandya, Nagamangala	Pandavapura	
Ballari	7			Sandur	Ballari, Hadagali, Hagaribommanahalli, Siruguppa	Hospet, Kudligi
Koppala	4			Gangavathi		Koppala, Kushtagi Yelburga
Raichur	5				Manvi, Sindhanur	Deodurga, Lingsugur, Raichur

<i>District</i>	<i>No. of taluks</i>	<i>1(39)</i>	<i>2(38)</i>	<i>Drought Vulnerability Index (DVI)</i>	<i>3(38)</i>	<i>4(21)</i>	<i>5(40)</i>
Kalaburagi	7					Aland, Chincholi, Kalaburagi, Sedam	Chitapur, Afzalpur, Jewargi
Yadgir	3				Shahapur, Shorapur	Yadgir	
Bidar	5		Basavakalyan		Bhalki, Humnabad	Aurad, Bidar	
Belagavi	10	Belagavi	Khanapur		Bailhongal, Chikkodi, Hukkeri		Athani, Gokak, Raibagh, Ramdurga, Soundatti
Bagalkote	6				Jamkhandi		Badami, Bagalkote, Bilgi, Hungund, Mudhol
Vijayapura	5						Basavanabagewadi, Vijayapura, Indi, Muddebihal, Sindgi
Gadag	5						Gadag, Mundargi, Naragund, Ron, Shirahatti
Haveri	7	Hanagal	Hirekerur, Savanur, Byadgi, Shiggaon		Haveri, Ranibennur		
Dharwad	5	Kalghatgi	Dharwad			Hubli	Kundgol, Navalgund
Shivamogga	7	Sagar, Shikaripur, Tirthahalli	Bhadravathi, Hosanagar, Shivamogga, Sorab				
Hassan	8	Alur, Arkalgud, Belur, Hassan, Sakaleshpur	Channarayapatna, Holenarasipur		Arasikere		
Chikkamagaluru	7	Chikkamagaluru, Koppa, Mudigere, Narasimharajapur, Sringeri, Tarikere				Kadur	
Kodagu	3	Madikeri, Somwarpet, Virajpet					
Dakshina kannada	5	Beltangadi, Bantwal, Mangalore, Puttur, Sulya					

<i>District</i>	<i>No. of taluks</i>	<i>1(39)</i>	<i>2(38)</i>	<i>3(38)</i>	<i>Drought Vulnerability Index (DVI)</i>	<i>4(21)</i>	<i>5(40)</i>
Udupi	3	Karkala, Kundapur, Udupi					
Uttara kannada	11	Ankola, Bhatkal, Honnavar, Karwar, Kumta, Siddapur, Sirsi, Yellapur	Haliyal, Mundgod, Supa				

Note: In parenthesis number of taluks in each class.

(In these taluks, Gangavathi, Shahapura, Shorapura and Jamkhandi, as per the climatic index fall under very high vulnerability (class 5), since there is a surficial irrigation the effect of soil and climatic variation gets nullified, hence these taluks can be placed under moderate vulnerability.)

6.1 FREQUENCY, NAMES & PERCENT DISTRIBUTION OF TALUKS UNDER DIFFERENT DVI CLASSES

The Table. 15 clearly indicates (Fig.22) that the distribution of Taluks that need developmental planning are irrespective of physiographic or administrative regions. The frequency of the Taluks under drought vulnerability class (Table 15) indicates that the number of Taluks (44) under DVI class 5, followed by DVI class 1 (39), class 2 (38), class 3 (34) and class 4 (21). Thus, out of the 176 Taluks in the state, the number of Taluks under different DVI classes are distributed in the following order: 44 (under class – 5) > 39(class – 1) > 38 (under class – 2) > 34 (under class – 3) > 21 (under class – 4).

6.2 Drought Vulnerability in different Regions:

The percent distribution of the Taluks in four regions of the state (SIK – South-interior Karnataka, NIK-North-interior Karnataka, Malnad and Coastal) under different classes of drought vulnerability was estimated and presented in Table 16. It indicates a wide variability between the regions besides the variability within the region under different DVI classes. In the SIK region, the percent distribution of the Taluks under DVI classes follow this order: 38% (under class – 3) > 36% (under class – 2), > 11% (under class – 5), > 10% (under class – 4) > 5% (under class-1). Hence in this SIK region, maximum number of Taluks are moderately vulnerable to drought (38%), 37% of the Taluks fall under slightly vulnerable class. Only 10% of the Taluks in SIK region are under highly vulnerable class while 5% of the taluks are very slightly vulnerable.

Table 16. Percent of Taluks under DVI classes in different regions of Karnataka

<i>DVI Classes</i>	<i>% DISTRIBUTION OF TALUKS IN REGIONS</i>				<i>KARNATAKA (%)</i>
	<i>SIK</i>	<i>NIK</i>	<i>MALNAD</i>	<i>COASTAL</i>	
1 (VSV)	5	4	68	84	22
2 (SV)	36	9	24	16	22
3 (MV)	38	13	4	0	19
4 (HV)	10	20	4	0	12
5 (VHV)	11	54	0	0	25
Total	100	100	100	100	100

In the NIK (North-interior Karnataka) region, the percent distribution of Taluks (Table 16) under different DVI classes is as under: 54% (under class – 5) > 20% (under class – 4) > 13% (under class – 3) > 9% (under class – 2) > 4% (under class – 1). It indicates that almost 74% of the Taluks are prone to high and very high Drought Vulnerability and 13% of the Taluks are prone to moderate vulnerability. Only 13% of the Taluks are under very slightly to slightly vulnerable class.

In the Malnad region, maximum number of Taluks (68%) are very slightly vulnerable (class – 1), followed by slightly vulnerable (24%) class2. Only very few Taluks (4%) of the region are under moderately and highly vulnerable classes.

In the Coastal region, majority of the Taluks (84%) are very slightly vulnerable and 16% of the Taluks are slightly drought vulnerable.

In the Karnataka state, the percent distribution of Taluks under different DVI classes is as under: 25% (under class – 5), > 22% (under class-1 & 2), > 19% (under class – 3), > 12% (under class – 4). It clearly indicates that about 37% of the Taluks are highly and very highly drought vulnerable; hence they need immediate attention to alleviate the droughty situation in the state. About 19% of the Taluks are moderately vulnerable indicating projected problem in due course of time. This needs proper preplanning for this area.

Among the regions (SIK, NIK, Malnad & Coastal region), the NIK region has about 74% of the Taluks under very highly and highly vulnerable classes followed by SIK region (21%), while a limited number of Taluks (4%) in Malnad region are under highly vulnerable class. Hence, these Taluks in NIK, SIK and Malnad regions needs immediate drought proofing measures. The SIK region with 38% of the Taluks, NIK region with 13% of the Taluks and 4% of the Malnad region are under moderately vulnerable class, which shows that there is a problem in the near future and hence needs proper attention and careful planning.

6.3 DROUGHT VULNERABILITY IN DIFFERENT DISTRICTS

In order to assess vulnerability at district level in the state, the percent of Taluks under different DVI classes to total Taluks of each district was estimated and presented in Table 17. This clearly depicts the variation in the vulnerability of the districts of the state. From the above table, it is evident that Kodagu, Dakshina Kannada, Udupi (100%), Chikkamagaluru (86%), Uttara Kannada (73%), Hassan (63%) and Shivamogga (43%) are very slightly vulnerable (under class – 1). This shows that all the districts in Malnad and Coastal regions are very slightly vulnerable even though the percentage of vulnerable Taluks in these districts ranges from 43 to 100.

Five districts such as Ramanagara (100%), Bengaluru Urban (75%), Mysuru (71%), Mandya (58%) and Shivamoggaa (57%) have more than 50% of the Taluks under slightly vulnerable category. Bangalore Rural (100%), Davanagere (83%), Chamarajanagar (75%) and Chikkaballapura (50%) districts are moderately vulnerable and have percentage of Taluks ranging from 50% to 100% under this category. These Taluks in these districts need attention and planning since they are prone to vulnerability in near future.

The following districts Koppala (100%), Bagalkote (100%), Vijayapura (100%), Gadag (100%), Yadgir (67%), Chitradurga (66%) and Belagavi (50%) are with more than 50% of the taluks under very highly vulnerable class. While the districts under highly vulnerable classes are Kalaburagi & Ballari (57%), Chikballapur (50%), and Bidar (40%). Among these eleven districts, Koppala, Bagalkot, Bijapur and Gadag districts have 100% of their Taluks under very highly vulnerable class, while the other 7 districts have their Taluks under both highly and very highly vulnerable classes. The Taluks under these districts needs immediate drought proofing measures.

6.4 DROUGHT VULNERABILITY IN DIFFERENT GROUPS OF POPULATION

Based on the number of taluks under each drought vulnerability class, the total house holdings, total population, population under minority groups (SC & ST). Total workers and Agricultural workers in these taluks were ascertained (Census, 2011). The percentage distribution of each of the above groups in the taluks falling under each drought vulnerability class was estimated and presented in Table 18. It indicates that out of the total house holdings in the state 26% fall under the areas of very high drought

Table 17. Percent of Taluks under different DVI classes in districts of Karnataka

<i>DISTRICT</i>	<i>Taluks</i>	<i>CATEGORY %</i>					<i>Total</i>
		<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	
BENGALURU-URBAN	4	0	75	25	0	0	100
BENGALURU-RURAL	4	0	0	100	0	0	100
RAMANAGARAM	4	0	100	0	0	0	100
KOLAR	5	0	40	40	20	0	100
CHIKBALLAPUR	6	0	0	50	50	0	100
TUMAKURU	10	10	30	40	0	20	100
CHITRADURGA	6	0	17	0	17	66	100
DAVANGERE	6	0	0	83	0	17	100
CHAMARAJANAGAR	4	0	25	75	0	0	100
MYSURU	7	29	71	0	0	0	100
MANDYA	7	0	58	28	14	0	100
BALLARI	7	0	0	14	57	29	100
KOPPALA	4	0	0	0	0	100	100
RAICHUR	5	0	0	0	40	60	100
KALABURAGI	7	0	0	0	57	43	100
YADGIR	3	0	0	0	33	67	100
BIDAR	5	0	20	40	40	0	100
BELAGAVI	10	10	10	30	0	50	100
BAGALKOTE	6	0	0	0	0	100	100
VIJAYAPURA	5	0	0	0	0	100	100
GADAG	5	0	0	0	0	100	100
HAVERI	7	14	43	43	0	0	100
DHARWAD	5	20	20	0	20	40	100
SHIVAMOGGA	7	43	57	0	0	0	100
HASSAN	8	63	25	12	0	0	100
CHIKKAMAGALURU	7	86	0	0	14	0	100
KODAGU	3	100	0	0	0	0	100
DAKSHINA KANNADA	5	100	0	0	0	0	100
UDUPI	3	100	0	0	0	0	100
UTTARA KANNADA	11	73	27	0	0	0	100
Total	176	22	22	19	12	25	100

Table 18. Percent of Population under different classes of Drought Vulnerability

<i>S.No</i>	<i>DVI CLASS/ (%) POPULATION</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>
1	Total House Holdings	20	22	20	12	26
2	Total population	19	21	19	13	28
3	Minority Group (SC)	13	20	21	16	30
4	Minority group (ST)	12	16	21	16	35
5	Total workers	19	20	20	13	28
6	Agri.workers	10	17	20	16	37

Vulnerability (Class-5), 12% under highly vulnerable areas (Class-4), 20% under moderately drought vulnerable areas (Class-3), 22% under slightly vulnerable areas (Class-2), 20% under very slightly drought vulnerable areas. Hence out of total house holds about 38% are highly and very highly vulnerable. Of the total population about 41% of the population in the state are living in the highly to very highly drought vulnerable areas (of classes 4 & 5) while in the minority groups (45% of SC & 51% of ST) almost 96% of the population live in very high to high drought vulnerable areas. With regards to total workers, about 41% of them are in the areas of very high and high drought vulnerability. Out of the total Agricultural workers, 53% of them are to face the very high & high drought vulnerability.

Chapter 7.

DROUGHT PROOFING MEASURES

There are many strategies to deal with the droughts. These Drought proofing measures can be grouped into 1) Drought forecasting 2) monitoring and 3) mitigation measures. Knowledge on frequency, duration and spatial extent of past droughts helps in determining likelihood and severity of the future droughts. However the prediction of drought with accuracy has its own limitations since the drought is the result of the interplay of many climatological factors. Under monitoring measures the rainfall patterns, soil moisture and stream flows over a time scale determine the onset and end of droughts. Drought mitigation/proofing also requires an understanding of the vulnerability/resilience of the existing population/society. The measures include early warning systems, various forms of weather based crop-insurance schemes, emergency water supply augmentation and water demand reduction. Unless sound practicable measures are implemented, there will be social, economic uproar in the weaker sections of the society. This in-turn may lead to the loss to the people & live stock and deaths due to lack of water, food and livelihood. Under this grave situation, the vulnerable section of people may migrate in huge numbers to cities and towns in search of livelihood. Such exodus may be a severe concern to the town and city planners since it chokes the developmental planning.

To reduce the severity of such threats, insitu ameliorative drought proofing measures like the following are practiced/implemented with at most care and sincerity:

- Improving water availability both on the surface and sub-surface level, using measures like renovating the old tanks by desilting.
- Linking and cleaning the water courses leading to the tanks and water bodies.
- Interlinking of the village tanks to utilise excess water during sudden/heavy rainfall periods that cause floods.
- Water harvesting structures like farm ponds, check dams, percolation tanks and sinking pits for insitu conservation of water.
- Proper implementation of Employment Generation schemes in the lean period through MGNREGA.
- Weather forecasting and timely weather based agro-advisories during crop season.
- Watershed development approach as of NWDPA.
- Agro forestry to check soil erosion& wind.
- Growing low water demanding multi-diversified crops as per suitability.
- Crop water budgeting for proper water use efficiency.
- Weather based crop insurance (WBCIS).
- Soil management to check erosion, increase infiltration&mulching to check water loss.
- Implementation of public water conservation awareness programs.
- Social security schemes: drinking water, subsidies for farm inputs & machinery.

- Low interest credit facility and in emergency need based waiving of loans.
- Better and self marketing facilities with support price (MSP) in Ryot bazaars.
- Provision of online information of market prices.
- Ensure Food availability through procurement and distribution by proper PDS.

Based on drought vulnerable class, the drought proofing measures to be adopted for the taluks in the state are listed in Table 19. In general the Taluks with higher limitations are under high and very high vulnerability. These taluks need immediate implementation of drought proofing measures.

Table 19. DVI class wise drought proofing measures for Karnataka.

DVI Class	Drought Proofing Measures	Taluks
1	Proper implementation of Rain water, harvesting, storing & water sharing approaches. Provision of credit and subsidy for farm inputs and self marketing (selling of farm produce through cooperatives) facility to farmers.	Tumakuru, Heggadadevanakote, Periyapatna, Belagavi, Hanagal, Kalghatgi, , Sagar, Shikaripur, Tirthahalli, Alur, Arkalgud, Belur, Hassan, Sakaleshpur, Chik kamagaluru, Koppa, Mudigere, Narasimharajapur, Sringeri, Tarikere, Madikeri, Somwarpet, Virajpet, Beltangadi, Bantwal, Mangalore, Puttur, Sulya, Karkala, Kundapur, Udupi, Ankola, Bhatkal, Honnavar, Karwar, Kumta, Siddapur, Sirsi, Yellapur
2	Renovation of tanks, rain water harvesting by sinking pits. water storage through farm ponds. Resource sharing & saving through crop planning as per water budgeting and micro-irrigation as per NWDPR	Anekal, Bengaluru North, Bengaluru South, Kanakapura, Channapatna, Magadi, Ramanagara, Malur, Mulabagal, Gubbi, Koratagere, Turuvekere, Holalkere, Chamarajanagar, Hunsur, Krishnarajanagar, Mysuru, Nanjanagud, T, Narasipur, Krishnarajapet, Maddur, Malavalli, Srirangapatna, Basavakalyan, Hosanagar, Sorab, Khanapur, , Hirekerur, Savanur, Shiggaon, Dharwad, Bhadravathi Shivamogga, , Channarayapatna, Holenarasipur, Haliyal, Mundgod, Supa
3	Renovation of tanks, rain water harvesting by sinking pits. water storage by farm ponds. Resource sharing & saving through crop planning as per water budgeting and micro-irrigation as per NWDPR. Implementation of MGNREGA. Food supply through PDS. Proper seed & credit availability. Social security schemes-Crop insurance (WBCIS).	Bengaluru east, Devanahalli, Doddballapur, Hosakote, Nelamangala, Bangarapet, Kolar, Chintamani, Gauribidanur, Sidlaghatta, C.N. Halli, Kunigal, Madhugiri, Tiptur, Channagiri, Davangere, Harihar, Honnali, Gundlupet, Kollegal, Yelandur, Mandya, Nagamangala, Sandur, Bhalki, Humnabad, Bailhongal, Chikkodi, Hukkeri, Byadgi, Haveri, Ranibennur, Arasikere, Harapanahalli.
4	To improve ground water-measures like sinking pits, percolation tanks, farm ponds. Desilting of tanks & interlinking of tanks. Growing low water requiring crops & diversified crops. Implementation of watershed development approach & MGNREGA, weather based crop insurance. Soil management. subsidy for farm inputs. Credit facility.	Srinivasapura, Chikballapur, Bagepalli, Gudibanda, Hosadurga, Ballari, Hadagali, Siruguppa, Manvi, Pandavapura, Hagaribommanahalli, Sindhanur, Aland, Chincholi, Kalaburagi, Sedam, Yadgir, Aurad, Bidar, Hubli, Kadur,
5	Rainwater harvesting by sinking pits, farm ponds, Percolation tanks & water harvesting structures. Desilting tanks. Inter-connecting village tanks. water saving by micro-irrigation. resource planning through watershed development approach, growing low duty crops & suitable crops through crop water budgeting, contingent crop planning, soil management – check erosion, mulching & amendments. Provision of seeds & fertilizers. Implementation of MGNREGA & NWDPR. Weather based agro advisories. Farm input subsidy & Low interest credit facility. proper PDS.	Pavagada, Sira, Challakere, Chitradurga, Hiriya, Molakalmuru, Jagalur, Hospet, Kudligi, Koppala, Kushtagi, Yelburga, Deodurga, Lingsugur, Raichur, Afzalpur, Jewargi, Shahapur, Shorapur, Athani, Gok ak, Raibagh, Ramdurga, Soundatti, Badami, Bagalkote, Bilgi, Hungund, Jamkhandi, Mudhol, Basavanabagewadi, Bijapur, Indi, Muddebihal, Sindgi, Gadag, Mundargi, Naragund, Ron, Shirahatti, Kundgol, Navalgund, Chitapur, Gangavathi

Chapter 8.

DROUGHT VULNERABILITY-RESILIENCE

There are various approaches suggesting that the vulnerability and resilience co-exist in a system (Turner, 2003). At times it is felt that vulnerability and resilience differ and behave opposite to each other. It means if one increases the other decreases. UNDRO (1982) states that vulnerability and resilience are independent entities. Vulnerability shows the shock and stress absorbing capacity i.e the skills of the exposed community to thwart the impact of disaster (Berke et al, 2007). The ability of the community to overcome and re-establish their livelihood by strategy and knowledge is called resilience (Sapountzaki, 2012). The features of resilience are robustness, rapidity, resourcefulness and redundancy. The robustness refers to the capacity to confront, resist and surmount the distress without losing the spirit. Rapidity refers to the pace /speed at which the community rise over disruption and avoids future loss. Resourcefulness refers to the different options and knowledge base of the community. Redundancy refers to the ability of the house holds to the effective mobilization of resources. Eventhough communities are vulnerable, they may face the disaster with skill and courage and may live up to the occasion and survive. While the house holds that lack coordination and communal harmony with indifferent and apathetic attitude may not be resilient to adverse consequences. With this background information on vulnerability and resilience an attempt was made to assess resilience based on the sub-components of livelihood index. It is presumed that all the sub-components considered for estimation of livelihood vulnerability also contribute to the resilience/coping capacity of the affected system or society. In these resilience estimations at Taluk level the ratio of percent irrigated area to total cultivated area (L1), % working population to total population (L2), % number of medium to total holdings (L5), % number of big/large to total holdings (L7) and % Literacy(L8) are considered as key components with positive functional relation with Resilience while the components like % number of marginal to total holdings (L3), % number of small to total holdings (L4), % number of semi-medium to total holdings (L6) were considered to have negative functional relationship with the resilience capacity in the affected system.

The resilience index values obtained by summation of the above eight components were categorized based on maximum and minimum index values at a fixed class interval. The classes thus formed were assigned to each of the Taluks. As per the drought resilience classes, the frequency of Taluks under each class/category were identified and presented in Table 20 and Fig.23.

From the Table 20 it is evident that majority of the Taluks (72) fall under highly resilient (HR) category followed by moderately resilient (49) (MR) category, followed by low resilient (31) (LR) category, followed by very highly resilient (17) (VHR) category, followed by very low resilient (7) category. Hence the numbers of the Taluks under the resilience classes are as under: Highly resilient>moderately resilient>low resilient>very highly resilient>very low resilient. Majority of the Taluks in Vijayapura, Bagalkote, Dharwad and Chitradurga districts have low to very low resilience irrespective of their vicinity to towns/cities Highly, very highly and moderately resilient areas are spread all over the state irrespective of the regions.

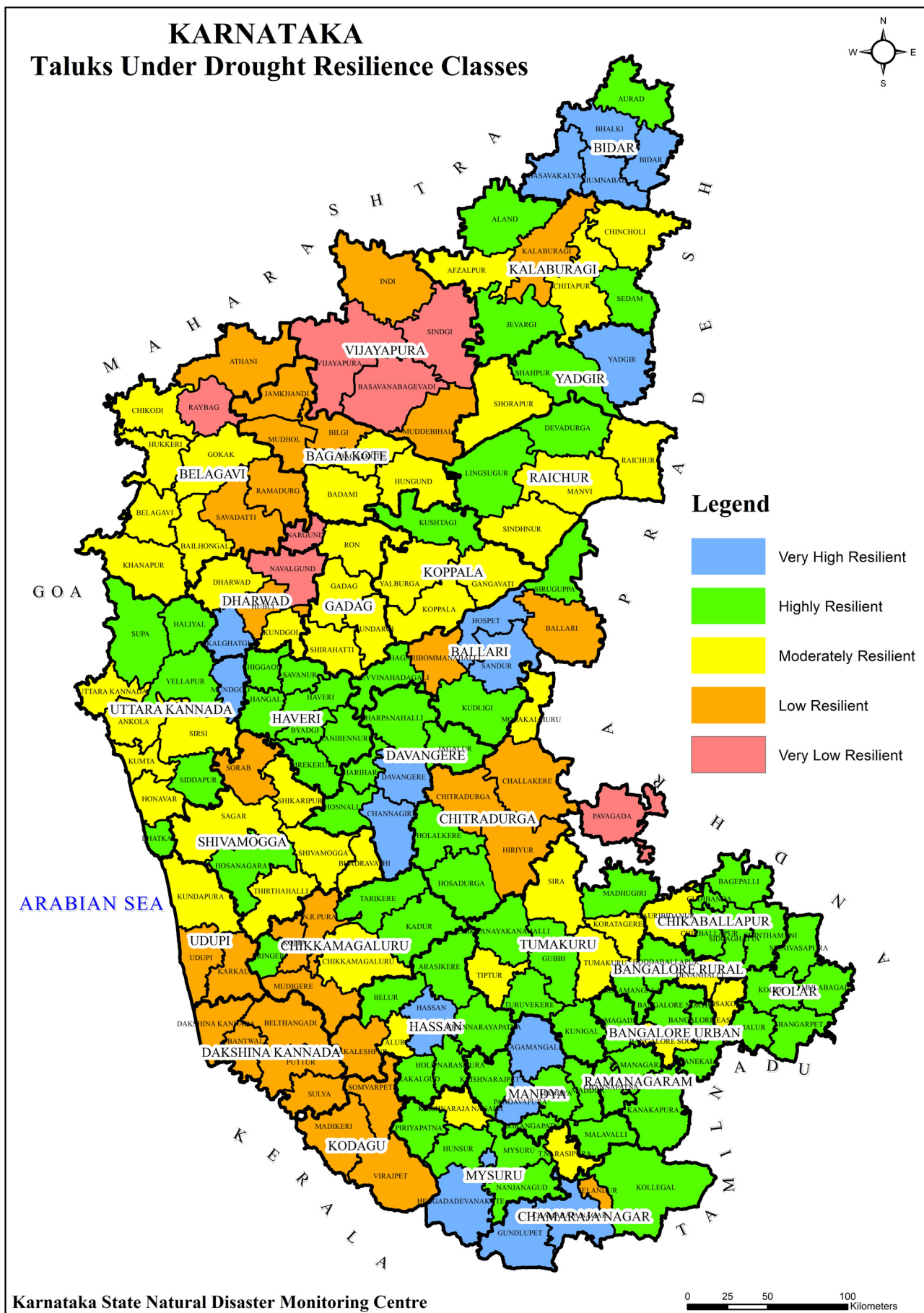


Fig.23. Drought Resilience Classes in Different Taluks of Karnataka

Table 20. Drought resilience classes in different Taluks of Karnataka

<i>Category</i>	<i>1 (VHR)</i>	<i>2 (HR)</i>	<i>3 (MR)</i>	<i>4(LR)</i>	<i>5(VLR)</i>
<i>Taluk</i>	<i>17</i>	<i>72</i>	<i>49</i>	<i>31</i>	<i>7</i>
<i>Names</i>					
	Channagiri	Anekal	Bengaluru South	Challakere	Pavagada
	Davangere	Bengaluru North	Devanahalli	Chitradurga	Ramdurga
	Chamaraja Nagar	Bengaluru East	Hosakote	Hiriyur	Basavanabagewadi
	Gundlupet	Dodballapur	Gauribidanur	Yelandur	Bijapur
	Heggadadevanakote	Nelamangala	Koratagere	Ballari	Sindgi
	Nagamangala	Channapatna	Sira	Hospet	Naragund
	Pandavapura	Kanakapura	Tiptur	Kalaburagi	Navalgund
	Hagaribommanahalli	Magadi	Tumakuru	Athani	
	Sandur	Ramanagara	Molakalmuru	Raibagh	
	Yadgir	Bangarapet	Krishnarajanagar	Soundatti	
	Basavakalyan	Kolar	T.narasipur	Bilgi	
	Bhalki	Malur	Gangavathi	Jamkhandi	
	Bidar	Mulabagal	Koppala	Mudhol	
	Humnabad	Srinivasapura	Yelburg a	Indi	
	Kalghatgi	Bagepalli	Manvi	Muddebihal	
	Hassan	Chikballapur	Raichur	Hubli	
	Mundgod	Chintamani	Sindhanur	Sorab	
		Gudibanda	Afzalpur	Sakaleshpur	
		Sidlaghatta	Chincholi	Koppa	
		C.N. Halli	Chitapur	Mudigere	
		Gubbi	Shorapur	Narasimharajapur	
		Kunigal	Bailhongal	Madikeri	
		Madhugiri	Belagavi	Somwarpet	
		Turuvekere	Chikkodi	Beltangadi	
		Holalkere	Gokak	Bantwal	
		Hosadurga	Hukkeri	Mangalore	
		Harapanahalli	Khanapur	Puttur	
		Harihar	Badami	Sulya	
		Honnali	Bagalkote	Karkala	
		Jagalur	Hungund	Udupi	
		Kollegal	Gadag	Virajpet	
		Hunsur	Mundargi		
		Mysuru	Ron		
		Nanjanagud	Shirahatti		
		Periyapatna	Dharwad		
		Krishnarajapet	Kundgol		
		Maddur	Bhadravathi		
		Malavalli	Sagar		
		Mandya	Shikaripur		
		Srirangapatna	Shivamogga		

<i>Category</i>	<i>1 (VHR)</i>	<i>2 (HR)</i>	<i>3 (MR)</i>	<i>4(LR)</i>	<i>5(VLR)</i>
<i>Taluk</i>	<i>17</i>	<i>72</i>	<i>49</i>	<i>31</i>	<i>7</i>
<i>Names</i>					
		Hadagali	Tirthahalli		
		Kudligi	Alur		
		Siruguppa	Chikmagalur		
		Kushtagi	Kundapur		
		Deodurga	Ankola		
		Lingsugur	Honnavar		
		Aland	Karwar		
		Jewargi	Kumta		
		Sedam	Sirsi		
		Shahapur			
		Aurad			
		Byadgi			
		Hanagal			
		Haveri			
		Hirekerur			
		Ranibennur			
		Savanur			
		Shiggaon			
		Hosanagar			
		Arkalgud			
		Arasikere			
		Belur			
		Channarayana Patna			
		Holenarasipur			
		Kadur			
		Sringeri			
		Tarikere			
		Bhatkal			
		Haliyal			
		Siddapur			
		Supa			
		Yellapur			

Note: VHR=Very highly resilient, HR=Highly resilient, MR=Moderately resilient, LR=low resilient, VLR=Very low resilient

Chapter 9.

DROUGHT VULNERABILITY-ACROSS AGRO-CLIMATIC ZONES

In order to know the extent and severity of drought vulnerability in the Agro-climatic zones, the drought vulnerability class map was superimposed over the Agro-climatic zone map of the state. The percent area of the drought vulnerability classes in each zone was estimated and presented in Table 21 & Fig. 24.

The table 21 indicates that the extent and severity of drought vulnerability varied among these Agro-climatic Zones (ACZ). The extent (%) of drought vulnerability classes in these Agro-Climatic Zones is presented in Table 21 as under :

Table 21. Extent of DVI Classes in Agro-climatic Zones.

<i>ACZ No. & Name</i>	<i>Area (Sq.km)</i>	<i>VSV</i>	<i>Extent in Percent</i>			
			<i>SV</i>	<i>MV</i>	<i>HV</i>	<i>VHV</i>
1. North Eastern Transition Zone	8736	0	14	24	62	0
2. North Eastern Dry Zone	17794	0	0	0	35	65
3. Northern Dry Zone	48140	0	0	6	13	81
4. Central Dry Zone	20124	0	9	28	14	49
5. Eastern Dry Zone	18497	6	44	36	14	0
6. Southern Dry Zone	17327	5	50	42	3	0
7. Southern Transition Zone	13456	60	25	15	0	0
8. Northern Transition Zone	11878	8	26	46	7	13
9. Hilly Zone	23942	68	32	0	0	0
10. Coastal Zone	11780	100	0	0	0	0

i) Very slightly vulnerable:

Under this vulnerability class, 100% of coastal zone, 68% of Hilly zone, 60% of southern transition zone, 8% of northern transition zone, 6% of eastern dry zone and 5% of southern dry zone is covered. This indicates that the extent of drought vulnerability under this class (VSV) varied among these Agro-climatic zones and its order of extent is as under: Coastal zone>Hilly Zone>Southern transition zone> Northern transition zone> Eastern dry zone >southern dry zone. Hence it is clear that majority of the area under coastal zone and hilly zone is very slightly vulnerable while least area in southern dry zone is under very slightly vulnerable class. The extent of VSV is spread over six (5, 6, 7, 8, 9 & 10) Agro-climatic zones (ACZ) except in the four (1, 2, 3 & 4) zones of the state.

ii) Slightly Vulnerable Class (SV):

Major area in Southern dry zone (50%) and least area in Central dry zone (9%) is under this slightly vulnerable class. Agro-climatic zone wise extent under this class follow this order: Southern dry zone> Eastern dry zone>> Hilly zone> Northern transition zone > Southern transition zone> North eastern transition zone >Central dry zone. The extent of slight vulnerability is observed in all

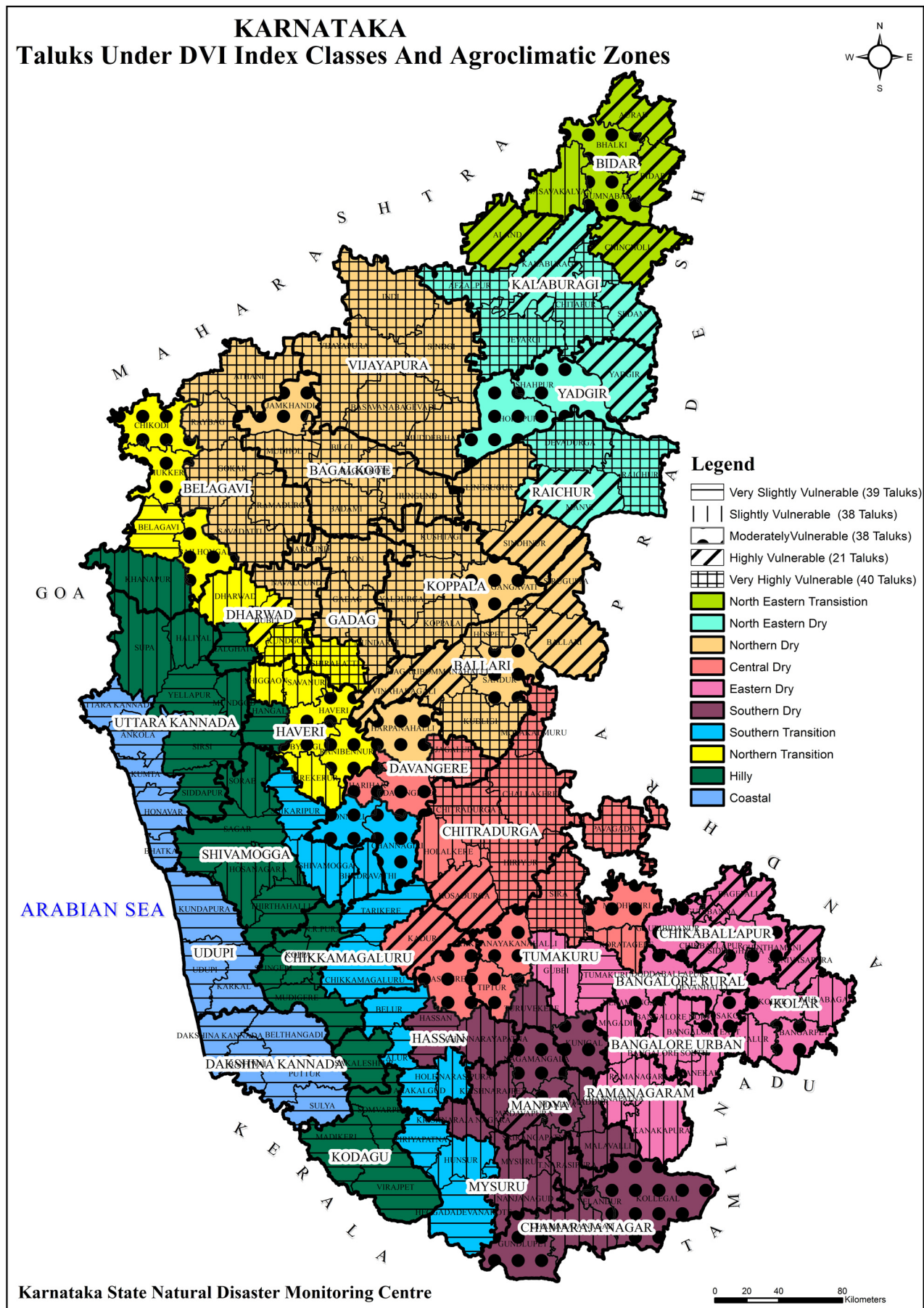


Fig.24. Taluks Under DVI Index Classes And Agroclimatic Zones

the seven Agro-climatic zones (1, 4, 5, 6, 7, 8, 9) except in the three zones (2, 3 & 10) of northern and coastal parts of the state.

iii) Moderately Vulnerable Class (MV):

Majority of the area (46%) under Northern transition zone and least area (6%) under Northern dry zone is moderately vulnerable. The extent of area under each zone is in the following order: Northern transition zone > Southern dry zone > Eastern dry zone > Central dry zone > North eastern transition zone > Southern transition zone > Northern dry zone. The moderately vulnerable area is spread over four dry zones (3, 4, 5 & 6) and the three transition zones (1, 7 & 8) in the state.

iv) Highly Vulnerable Class (HV):

Major area under this class is in North eastern transition zone (62%) and least area is under southern dryzone (3%). The extent of area under highly vulnerable class, however follow this order: North eastern transition zone > North eastern dry zone > > Central dry zone & Eastern dry zone > Northern dry zone > Northern transition zone > Southern dry zone. The extent of high vulnerability area is spread over six (1, 2, 3, 4, 5, 6 & 8) Agro-Climatic Zones except the Southern transition, Southern dry, Hilly and Coastal zones (7, 9 & 10). The highly vulnerable area is spread over dry zones and transition zones of the state.

v) Very Highly Vulnerable Class (VHV):

Major area under this class is in Northern dry zone (81%) and minimum area is in Northern transition zone (13%). The extent of very high vulnerability observed in these Agro-climatic zones is in the following order: Northern dry zone > North eastern dry zone > Central dry zone > > Northern transition zone. The very high vulnerability area is spread over the 3 dry zones (2, 3 & 4) and one transition zone (8) of the state indicating very high vulnerability.

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Annexture - 1
Taluk wise Normal Rainfall

<i>Sl. No.</i>	<i>District</i>	<i>Sl. No.</i>	<i>Taluk</i>	<i>Pre-Monsoon</i>	<i>South West Monsoon</i>	<i>North East Monsoon</i>	<i>Annual</i>	<i>No. of Rainy days</i>
1	BENGALURU-URBAN	1	ANEKAL	166	451	243	860	54
		2	BENGALURU-NORTH	151	462	219	832	58
		3	BENGALURU-SOUTH	170	468	241	880	54
		4	BENGALURU-EAST	163	440	234	837	54
2	BENGALURU-RURAL	5	DEVANAHALLI	128	440	220	788	50
		6	DODBALLAPUR	133	414	205	752	50
		7	HOSAKOTE	135	431	247	813	49
		8	NELAMANGALA	173	498	254	925	53
3	RAMANAGARA	9	CHANNAPATNA	184	423	236	843	50
		10	KANAKAPURA	183	372	225	780	48
		11	MAGADI	189	506	253	948	56
		12	RAMANAGARA	175	485	249	909	51
4	KOLARA	13	BANGARAPET	141	380	237	757	45
		14	KOLAR	126	408	242	775	46
		15	MALUR	135	371	232	738	45
		16	MULABAGAL	118	396	260	774	44
		17	SRINIVASAPURA	100	377	208	685	45
5	CHIKBALLAPURA	18	BAGEPALI	100	378	219	697	43
		19	CHIKBALLAPURA	111	452	226	789	53
		20	CHINTAMANI	120	386	244	751	45
		21	GAURIBIDANUR	103	384	192	679	43
		22	GUDIBANDA	97	413	204	714	42
		23	SIDLAGHATTA	119	409	239	767	47
6	TUMAKURU	24	C.N. HALLI	124	301	195	620	46
		25	GUBBI	139	374	202	715	49
		26	KORATAGERE	139	397	211	747	46
		27	KUNIGAL	185	449	235	868	52
		28	MADHUGIRI	107	348	201	655	44
		29	PAVAGADA	96	305	181	582	37
		30	SIRA	105	318	168	591	38
		31	TIPTUR	153	315	221	689	45
		32	TUMAKURU	159	493	248	900	53
		33	TURUVEKERE	157	352	218	727	46
7	CHITRADURGA	34	CHALLAKERE	72	220	116	408	30
		35	CHITRADURGA	109	315	183	607	47
		36	HIRIYUR	109	260	158	527	37
		37	HOLALKERE	109	337	179	625	53
		38	HOSADURGA	116	285	187	588	40
		39	MOLAKALMURU	93	282	165	539	35

<i>Sl. No.</i>	<i>District</i>	<i>Sl. No.</i>	<i>Taluk</i>	<i>Pre-Monsoon</i>	<i>South West Monsoon</i>	<i>North East Monsoon</i>	<i>Annual</i>	<i>No. of Rainy days</i>
8	DAVANGERE	40	CHANNAGIRI	106	391	179	676	60
		41	DAVANGERE	112	365	168	645	47
		42	HARAPANAHALLI	143	402	177	722	47
		43	HARIHAR	118	340	188	646	45
		44	HONNALI	122	399	184	704	49
		45	JAGALUR	98	309	146	553	38
9	CHAMARAJA-NAGARA	46	CHAMARAJA-NAGARA	227	290	252	769	47
		47	GUNDLUPETE	243	273	256	772	48
		48	KOLLEGALA	225	320	258	802	47
		49	YELANDURU	236	379	264	878	46
10	MYSURU	50	HEGGADADEVANA-KOTE	236	533	199	967	59
		51	HUNSURU	214	353	217	784	53
		52	KRISHNARAJA-NAGARA	195	328	214	737	49
		53	MYSURU	207	325	220	752	53
		54	NANJANAGUD	203	316	212	731	51
		55	PERIYAPATNA	183	461	202	846	63
		56	T.NARASIPURA	200	318	234	751	47
11	MANDYA	57	KRISHNARAJAPETE	190	306	226	722	49
		58	MADDURU	184	343	244	771	45
		59	MALAVALLI	195	316	236	746	44
		60	MANDYA	206	322	266	795	45
		61	NAGAMANGALA	153	277	222	652	43
		62	PANDAVAPURA	178	268	215	661	41
		63	SRIRANGAPATNA	187	291	218	696	49
12	BALLARI	64	BALLARI	79	289	150	518	35
		65	HADAGALI	119	362	156	637	43
		66	HOSPET	86	385	159	629	43
		67	HAGARIBOMMA-NAHALLI	107	313	120	540	37
		68	KUDLIGI	97	332	147	576	41
		69	SANDUR	109	431	160	700	53
		70	SIRUGUPPA	74	399	152	625	42
13	KOPPALA	71	GANGAVATHI	68	375	145	587	35
		72	KOPPALA	84	379	148	611	38
		73	KUSHTAGI	90	377	140	607	39
		74	YELBURGA	84	375	135	594	37
14	RAICHURU	75	DEODURGA	63	478	142	683	39
		76	LINGSUGUR	73	401	151	624	37
		77	MANVI	62	437	132	631	39
		78	RAICHURU	71	510	131	712	42
		79	SINDHANUR	70	441	163	674	39
15	KALABURAGI	80	AFZALPUR	69	503	121	693	43
		81	ALAND	68	604	127	798	47
		82	CHINCHOLI	67	727	132	925	50
		83	CHITAPUR	74	604	120	798	47

<i>Sl. District No.</i>	<i>Sl. Taluk No.</i>	<i>Pre- Monsoon</i>	<i>South West Monsoon</i>	<i>North East Monsoon</i>	<i>Annual</i>	<i>No. of Rainy days</i>
	84 KALABURAGI	78	627	116	821	48
	85 JEWARGI	70	567	145	782	44
	86 SEDAM	72	678	121	871	51
16 YADGIR	87 SHAHAPURA	76	616	154	846	43
	88 SHORAPURA	65	501	155	721	42
	89 YADGIRI	70	661	141	872	49
17 BIDAR	90 AURAD	63	701	116	879	48
	91 BIDAR	82	748	131	961	55
	92 BHALKI	75	678	117	870	52
	93 BASAVAKALYAN	72	648	102	821	49
	94 HUMNABAD	75	656	117	848	50
18 BELAGAVI	95 ATHANI	77	323	136	536	36
	96 BAILHONGAL	129	669	166	964	50
	97 BELAGAVI	157	1169	179	1504	79
	98 CHIKKODI	94	403	149	645	51
	99 GOKAK	108	322	141	572	37
	100 HUKKERI	133	470	169	773	48
	101 KHANAPUR	115	1669	176	1960	88
	102 RAMDURG	96	324	141	561	38
	103 RAIBAGH	76	307	125	508	38
	104 SOUNDATTI	115	359	150	624	40
19 BAGALKOTE	105 BADAMI	94	373	153	620	40
	106 BAGALKOTE	80	310	143	533	38
	107 BILGI	87	358	152	596	39
	108 HUNGUND	97	395	146	638	43
	109 JAMKHANDI	74	334	141	549	38
	110 MUDHOL	84	304	129	516	37
20 VIJAYAPURA	111 BASAVANABAGEWADI	84	397	151	631	40
	112 BIJAPUR	85	421	155	660	40
	113 INDI	62	452	123	637	38
	114 MUDDEBIHAL	89	389	155	633	40
	115 SINDGI	62	470	125	657	39
21 GADAGA	116 GADAGA	120	383	169	671	44
	117 MUNDARGI	108	321	153	581	38
	118 NARAGUNDA	111	361	160	632	39
	119 RONA	98	418	150	666	44
	120 SHIRAHATTI	125	399	177	701	47
22 HAVERI	121 BYADGI	116	428	144	689	57
	122 HANAGAL	125	727	180	1032	71
	123 HAVERI	134	447	169	751	59
	124 HIREKERUR	117	499	174	790	66
	125 RANIBENNUR	127	332	165	625	46
	126 SAVANUR	138	419	161	718	54
	127 SHIGGAON	137	546	170	852	63
23 DHARWADA	128 DHARWADA	144	593	167	904	61
	129 HUBLI	141	421	163	725	57
	130 KALGHATGI	144	719	167	1029	73
	131 KUNDGOL	143	427	160	729	52
	132 NAVALGUND	135	354	145	634	42

<i>Sl. No.</i>	<i>District</i>	<i>Sl. No.</i>	<i>Taluk</i>	<i>Pre-Monsoon</i>	<i>South West Monsoon</i>	<i>North East Monsoon</i>	<i>Annual</i>	<i>No. of Rainy days</i>
24	SHIVAMOGGA	133	BHADRAVATHI	122	540	198	859	68
		134	HOSANAGAR	164	2650	227	3041	99
		135	SAGAR	156	2462	200	2818	98
		136	SHIKARIPUR	147	665	179	990	72
		137	SHIVAMOGGA	134	646	200	980	67
		138	SORAB	123	1482	177	1783	83
		139	TIRTHAHALLI	158	3180	219	3556	103
25	HASSANA	140	ALUR	183	790	216	1189	73
		141	ARKALGUD	169	485	206	860	65
		142	ARASIKERE	154	316	218	688	47
		143	BELUR	209	827	236	1273	68
		144	CHANNARAYA-PATNA	146	287	212	645	47
		145	HASSAN	177	442	222	841	63
		146	HOLENARASIPUR	185	318	223	726	53
		147	SAKALESHPUR	204	1882	260	2346	104
26	CHIKMAGALURU	148	CHIKMAGALUR	209	908	225	1341	68
		149	KADUR	130	306	205	641	45
		150	KOPPA	217	2604	243	3064	111
		151	MUDIGERE	231	2558	287	3077	115
		152	NARASIMHA-RAJAPUR	174	1503	210	1886	94
		153	SRINGERI	209	3570	288	4067	116
		154	TARIKERE	123	496	187	806	68
27	KODAGU	155	MADIKERI	331	3395	353	4079	125
		156	SOMWARPET	213	1743	254	2211	105
		157	VIRAJPET	253	1810	254	2317	113
28	DAKSHINA KANNADA	158	BELTANGADI	239	3727	374	4339	126
		159	BANTWAL	229	3400	337	3967	120
		160	MANGALORE	233	3268	301	3802	116
		161	PUTTUR	228	3332	388	3948	124
		162	SULYA	229	3188	395	3811	129
29	UDUPI	163	KARKALA	232	4416	403	5051	129
		164	KUNDAPUR	176	4014	240	4430	114
		165	UDUPI	212	3557	270	4039	116
30	UTTARA KANNADA	166	ANKOLA	155	3137	217	3509	107
		167	BHATKAL	184	3773	279	4235	113
		168	HALIYAL	142	1550	181	1873	82
		169	HONNAVAR	159	3247	237	3644	110
		170	KARWAR	155	2860	206	3220	103
		171	KUMTA	156	3175	221	3552	110
		172	MUNDGOD	138	1220	197	1555	85
		173	SIDDAPUR	113	2531	191	2835	101
		174	SIRSI	110	2081	189	2379	98
		175	SUPA	120	2229	177	2525	94
		176	YELLAPUR	109	2499	184	2792	98

