Climate Change Risk Assessment in the Indian Himalayan Region

Arunachal Pradesh

Prepared by State Climate Change Cell-Arunachal Pradesh.

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Supported by

Indian Institute of Technology Mandi, Indian Institute of Technology Guwahati ,CSTEP Bengaluru & Indian Institute of Science Bangalore

Funded by

Department of Science and Technology(DST), Ministry of Science and Technology,Govt.of India

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District level Climate Change Risk Profile of Arunachal Pradesh.

1. Introduction

State Profile

Arunachal Pradesh is located in the easternmost part of the Indian Himalayas. It stretches between 91°30'E-97°30'E longitude and 26°30'N-29°31'N latitude covering an area of 83,743 km^2. The State shares its boundary in the south with the neighboring states of Assam and Nagaland and an international border withTibet in the north,Myanmar in the east, and Bhutan in the west. The entire territory forms a complex hilly system with elevations ranging from 50m to 7,000m. The rivers Kameng, Subansiri, Siang,Lohit,and Tirap along with numerous rivulets flow through the state. The undulating topography and high rainfall pattern in the state have endowed it with the largest forest cover in India extending over 79.63 percent of its geographical area and making it one of the top global biodiversity hotspots.

Governance,Demography,andEconomy

The state of Arunachal Pradesh has 25 districts, 109 blocks, 5589 villages and 46 notified towns housing 1.38 million people. The average population density of the State is17 persons/sq. Km which ranges from a minimum of 1 person/km^2 to a maximum of 51 persons/km^2 (Census, Size, Growth Rate and Distribution of Population, 2011). Around23% of the total population resides in urban spaces and the rest 77% reside in rural areas.As Per the census 2011, about69% of its population is of tribal origin.

Advance estimates of Gross State Domestic Product (at current prices 2011-12 series) for 2019-20 of Arunachal Pradesh place it at Rs. 27036.64 Crore. Per capita,GSDP is estimated as Rs.1, 64,557 and per capita income as Rs. 1,49,798. Share of Gross Value Addition(GVA)by the primary,secondary,and tertiary sectors are 31.19%,25.71%,and 43.1%respectively estimated at current prices(Directorate of Economics and Statistics, GoAP, 2019-2020). The total population below the poverty line is pegged at 34.7%(Ministry of Agriculture & FarmersWelfare,2021).

Climate Profile

The climate in Arunachal Pradesh Can be classified as Tropical,subtropical,temperate, and alpine. The tropical climate extends over 80m to 900m above mean sea level(MetreaboveMeanSeaLevel-mamsl).It is characterized by high rainfall and humidity, and temperature ranging between 22-36ºC in summer and 10-25ºC in winter.Sub-tropical climate extends from 900-1800m mamsl with moderate rainfall and humidity and cool temperatures ranging between 15-30ºC in summer and 14-21ºC in winter. The Temperate climate extending from 1800m to 3500m above experiences less rainfall and cooler temperatures and here temperatures range between 0-22ºC. The alpine zone extending above 3500m amsl, experiences cool temperatures in the range of 0-20ºC along with snowfall.

Assessment of Temperature trends for the State made for the period 1980 and 2019 based on IMD gridded data indicates a rise in annual mean temperature by 0.015ºC per year,which translates to a rise in temperature by 0.59ºC in the last 40 years.The state onaveragereceives2543 mm of rainfall annually. Spatially the rainfall varies between a minimum of 1567 mm in the higher elevations to about 3266 mm in the foothill areas.Between June and September during the southwest monsoon period, the state receives 64 percent of its total rainfall. During the period 1980 and 2019, a significant decreasing trend in southwest monsoon rainfall (JJAS) and also in annual rainfall is observed, along with an increase in the number of dry days and a decrease in the number of rainy days.

Climate Change Projections

The Data sets have been generated by the Coordinated Regional Climate Downscaling Experiment (CORDEX) conducted for South Asia.The CORDEX South Asia dataset include dynamically downscaled climate change daily projections at 50 km x 50 km resolution using 3 RCMs with 17 ensemble members.For Arunachal Pradesh, the climate change projections have been derived from an ensemble average of 10 of these RCM outputs suitable for the Indian region.The future projections in this report are based on two standardized forcing scenarios called Representative Concentration Pathways (RCPs),namely RCP 4.5 (mid-range emissions) and RCP 8.5 (high-end emissions) scenarios. Each scenario is a time series of emissions and concentrations of the full suite of GHGs,aerosols, and chemically active gases, as well as Land use changes through the twenty-first century, characterized by the resulting Radiative Forcing in the year 2100. RCP 4.5 is an intermediate stabilization pathway that results in a Radiative Forcing of 4.5 W/m^2 in 2100and RCP 8.5 is a high-concentration pathway resulting in a Radiative Forcing of 8.5 W/m^2in 2100.

ObservedClimateTrends

Temperature:A State-level analysis

The analysis of temperature for the period 1980-2019 indicates a rising trend in annual average maximum and minimum temperature in Arunachal Pradesh. Over this period, the maximum temperature has increased annually at the rate of 0.034°C and the minimum temperature has increased at the rate of 0.017°C.The annual average Diurnal Temperature Range (DTR) also shows an increasing trend, the increase being 0.016°C per annum.

During 1980-2019, the annual average maximum temperature across the State was 29.02°C. It ranged from a minimum of 27.7°C recorded in 1992 to a maximum of 30.19°C,in2013.

The annual average minimum temperature during 1980-2019 was 18.73°C and it ranged from a minimum of 18.07°C to a maximum of 19.47°C. The highest average minimum temperature was recorded in the year 1999, and the most minimum in 2012.The annual average Diurnal Temperature Range (DTR) during 1980-2019 was 10.36°C and it ranged between 9.35°C - 12.54°C, the highest DTR being recorded in the year 1997 and the minimum 1990 (Source:SAPCC2.0)

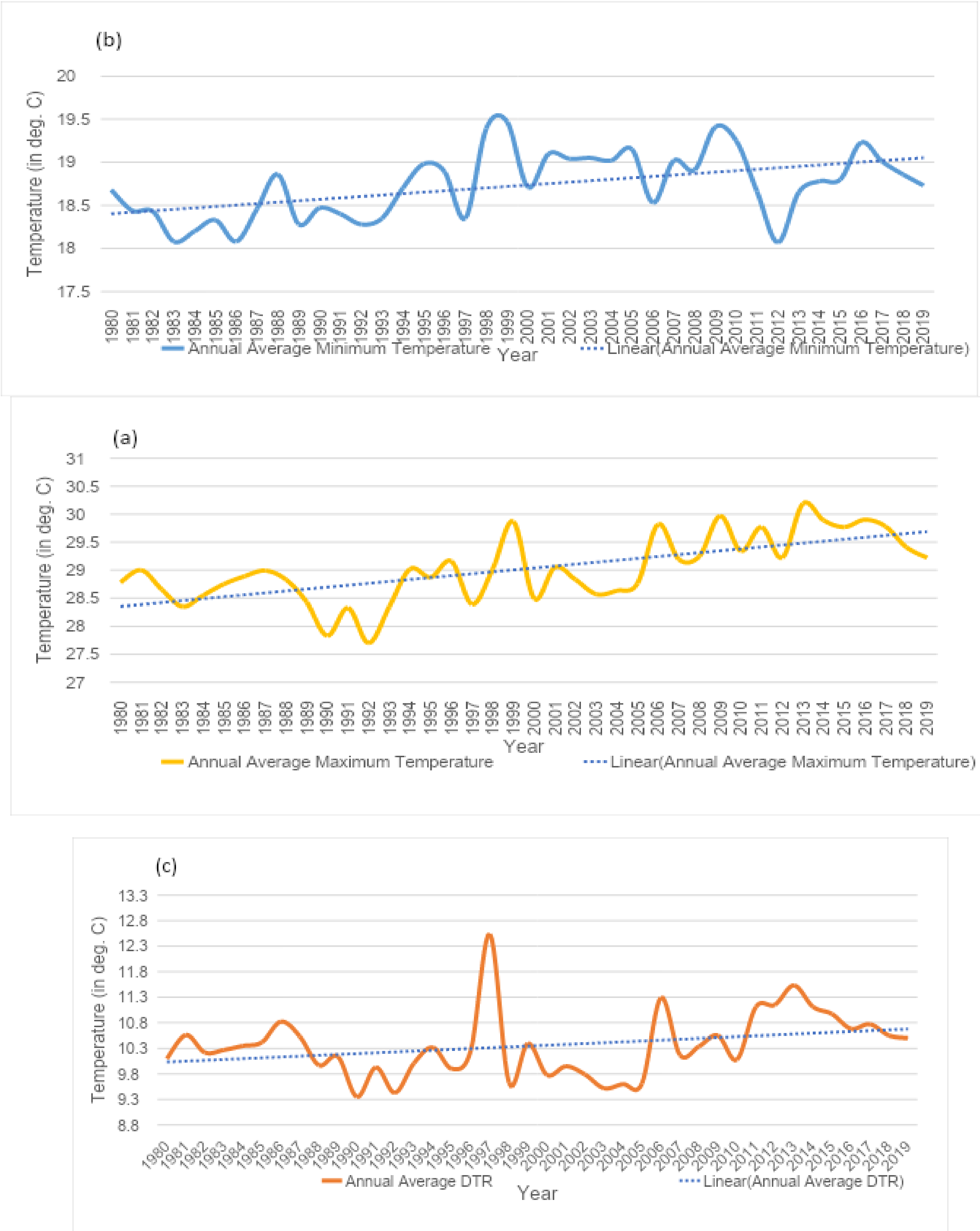
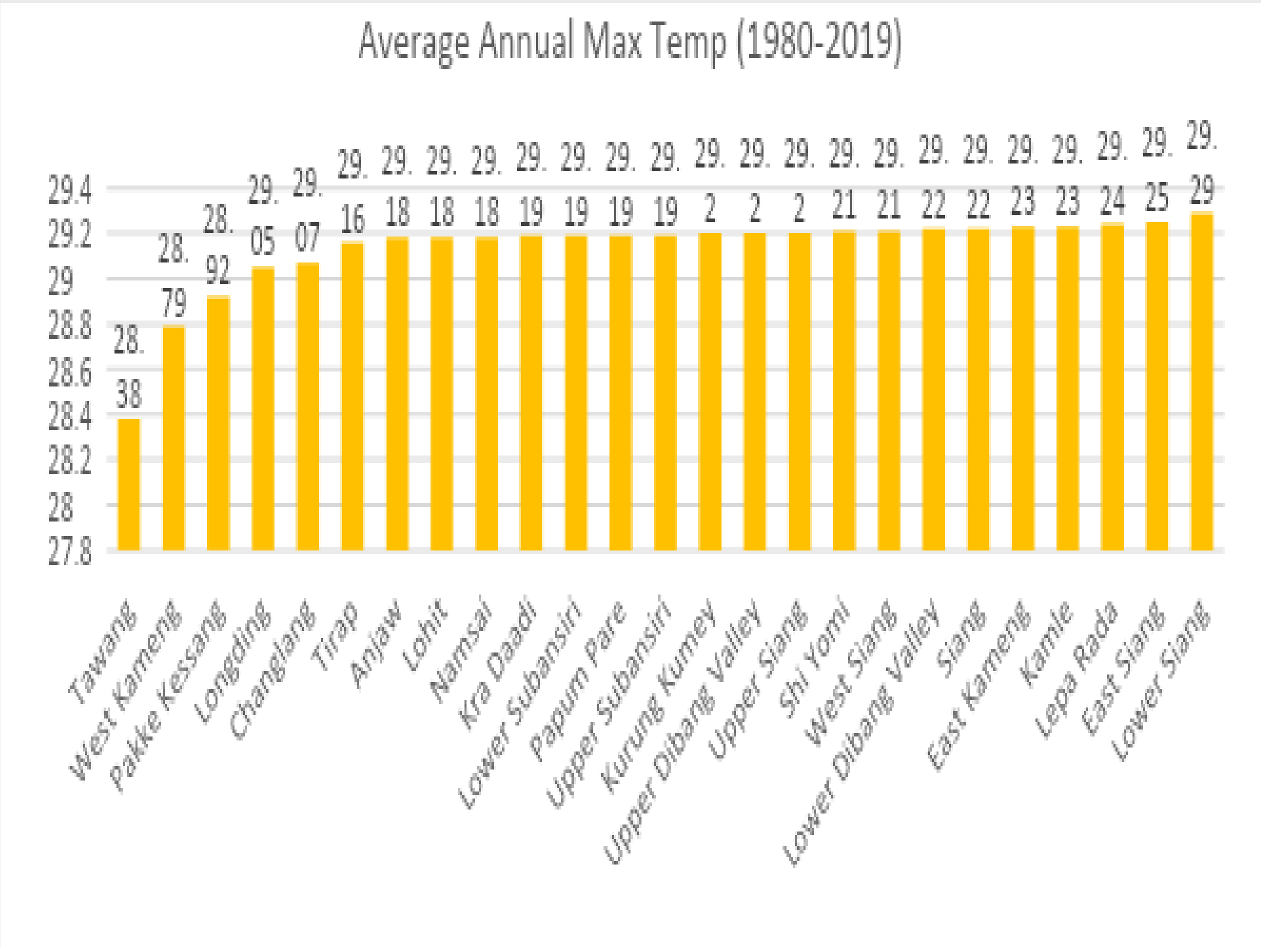


Figure:1.Trends(a)annual average maximum temperature,(b)minimum temperature and(c)diurnal temperature range in Arunachal Pradesh between 1980-2019(SAPCC 2.0)

Temperature:At District-level analysis

The district-level analysis of temperature carried out for the period 1980-2019 indicates that during this period the highest average maximum temperature was recorded for Lower Siang at 29.29°C at(SeeFigure)while the lowest average maximum temperature was recorded for Tawang(29.38°C).Ontheotherhand,the average minimum temperature during 1980-2019 was highest for KurungKumey at 19.02°C(SeeFigure),and minimum at Tawang at 18.35°C. The highest average DTR during this period was also recorded in theWest Siang district(11.03°C).



The district-level analysis also shows a consistently increasing trend across all districts for annual average maximum temperature, annual average minimum temperature as well as annual average DTR.It is worth noting that the trend is consistent with state-level analysis.

Figure:2.Distribution of annual average maximum and minimum temperature across districts between 1980-2019(Source:SAPCC 2.0)

Precipitation:A District-level analysis

A district-level analysis of rainfall for the period 1980-2019 indicates that West Siang District has received the highest annual rainfall followed by Upper Subansiri, Siang, ShiYomi, and Papum Pare as presented in the figure. It is important to note that there is a uniform decrease in annual rainfall in all districts between 1980 and 2019, however, there is one outlier district indicating an increase in rainfall namely Shi Yomi

(4.4352mm/yr).The highest amount of decrease in annual rainfall over the period 1980-2019 is seen inWest Kameng (37.44mm/yr)

As far as monsoon rainfall is concerned, all districts show a decrease in rainfall over the period except two districts ShiYomi(5.1mm/yr) and UpperSubansiri(0.16mm/yr).During the monsoon season between the period 1980-2019, Lower Subansiri received the highest rainfall(2353.48mm),followed by KraDaadi(2183.04mm) and Kamle(2137.17mm). District Changlang has received the lowest rainfall recorded at 870.19mm.The District-level analysis of mean annual and seasonal rainfall in Arunachal Pradesh During the period 1980-2019.

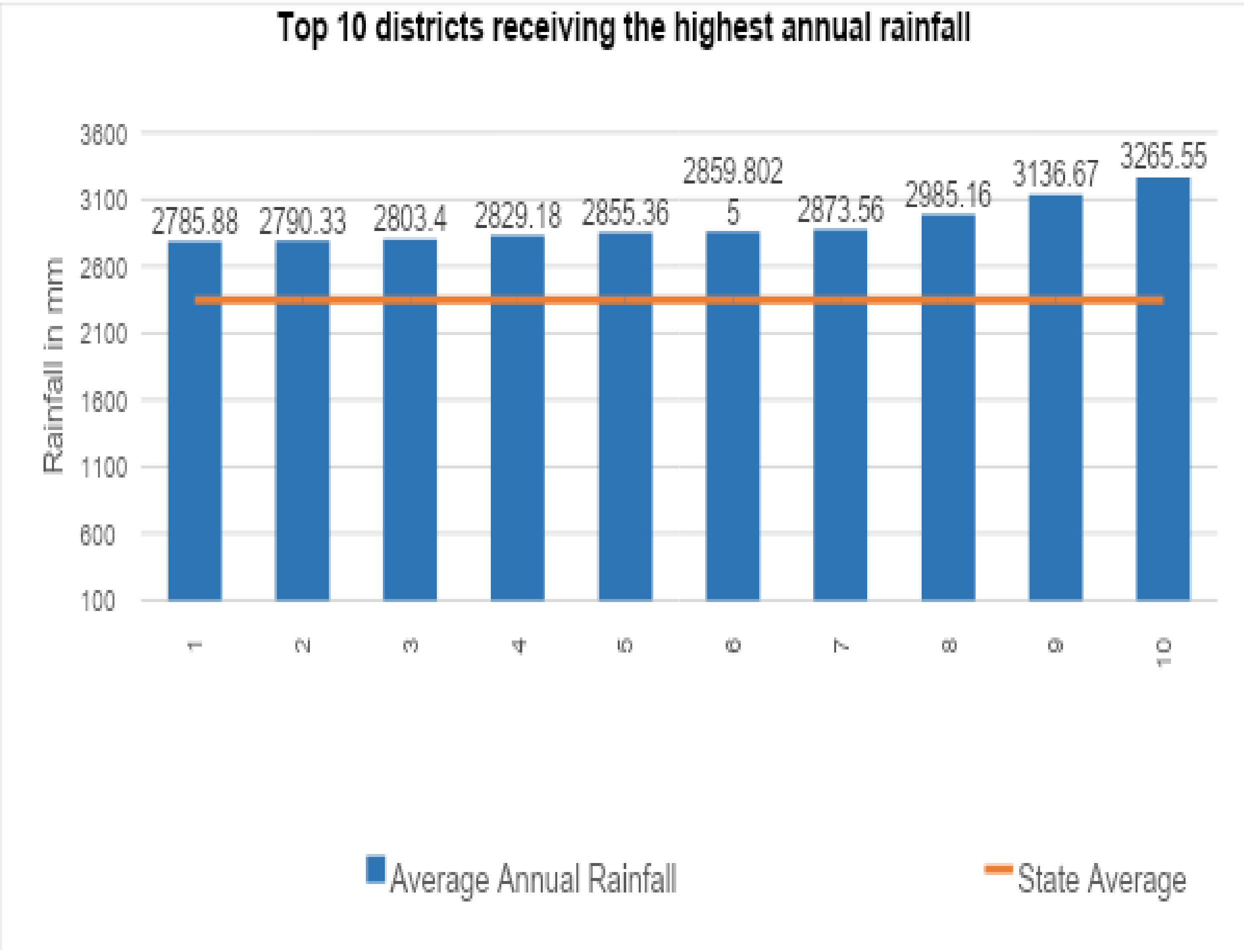


Figure3:Districts receiving the highest Annual Rainfallin Arunachal Pradesh between 1980 and 2019

a. Type of hazard that the state faces (Give some statistics on impacts on people,livelihood, sectors of infrastructure and the losses)

The IMD, annual reports for 2014, 2015, 2016, 2017, 2018, and 2019 show heavy rainfall events in the state of Arunachal Pradesh leading to floods, landslides/mudslides, and soil erosion. The state is also subjected to hailstorms, heavy snowfall, high-speed wind, and thunderstorms. According to the 2014 to 2019 IMD and also stated by (Ray et al.,2021) massive damages were done to the human and animal lives, infrastructure, and agriculture sector. About 5 deaths/million population is reported due to heavy rainfall and landslides in the state.The evaluation provided by the Indian Institute of Tropical Meteorology (IITM), Pune shown through the regional climate model (RCM- PRECIS),

In the current scenario of the state when urbanization is at its peak and several other factors like illegal earth cutting, land encroachment, shifting/jhum cultivation, etc., a forest fire is not a new subject to the state. With a total of 79.33 percent making it the second highest percentage of forest cover in the country as per the report of ISFR, 2019, and Forest Survey of India 2021, the state is at high risk of forest fires. As per the Forest Survey of India from the year 2001 to 2007, there has been a significant decline in the forest area in the state.

Climate Change Projections (**Temperature and Precipitation)**

The annual average maximum temperature in Arunachal Pradesh is likely to rise by 1.62°C and by 2.03°C by 2021-2050 under RCP4.5 and 8.5 scenarios respectively.By end-century, the annual average maximum temperature may rise up to 3.06°C and 6.61°Cunder RCP 4.5 and 8.5 scenarios respectively.The annual average minimum temperature in the state is projected to increase up to 1.31°C and 1.63°C for RCP4.5 and RCP8.5 respectively by 2021-2050.It may further rise upto 2.43°C to 4.27°C under RCP4.5 and 8.5 scenarios,respectively,by 2071-2100.

Annual average rainfall in Arunachal Pradesh is projected to decrease marginally, by 1.27per cent towards mid-century and increase about 2.80 per cent towards end-century under RCP4.5.ForRCP8.5 scenario annual precipitation is projected to increase marginally by Percent towards mid-century and 0.12 percent towards end-century map the seasonal rainfall projections for winter (January, February), summer (March, April, May), monsoon months(June,July,August,September)and post-monsoon(October,November,December).

The average annual maximum temperature during the baseline is recorded at 21.14°C. All the districts except Anjaw, Dibang Valley, Kurung Kumey, Tawang, Upper Siang andUpper Subansiri are expected to record higher maximum temperature between 2021-2050 under RCP 4.5 scenario than the annual average maximum temperature recorded during baseline.Under RCP8.5 scenario, Anjaw ,KurungKumey,UpperSiang and Upper Subansiri are also expected to record higher temperatures than the annual average temperature recorded during baseline.

The average annual minimum temperature during the baseline recorded 10.1°C.Between 2021-2050, all the districts are projected to record higher minimum temperature underRCP4.5and RCP8.5 scenario than the annual average minimum temperature recorded during baseline except for Anjaw, Dibang Valley, Kurung Kumey, Tawang,Upper Siang and Upper Subansiri.

climate change both ongoing and future climate change faced by the state:

Climate change is a fact(IPCC2007)and its impacts are not only apparent to the environment and ecosystem, but also the socio-economic and cultural life of people across the globe, though with spatially varied intensity. The impact of climate change is believed to be more prominent and extensive on mountains as they are among the most fragile environment sonearth(Sharmaetal.2009).

The mountains,besides having a rich repository of biodiversity and water,provide ecosystem services to the communities downstream (Hamilton 2000, Korner 2004, Viviroli & Weingartner 2004). They harbor some of the world's most endangered and endemic flora and fauna species as well as the home to traditional communities who are highly dependent on ecosystem services for their subsistence and livelihood(Kollmairetal.2005).Eastern Himalaya aprioristico-region and biologically rich 'hotspot' (WWF 2005).

Mountain ecosystems are likely to experience wide-ranging effects on the environment,biodiversity,agriculture,and socio-economic conditions under the influence of climate change (Beniston 2003). Climate Change, especially changes in the hydrological cycle due to differences in precipitation patterns,leads to a shift in river runoff and consequently affects the whole ecosystem downstream, including agricultural productivity and human livelihood.

Arunachal Pradesh is the largest hill state in the North Eastern Himalayan Region of India With a total geographical area of about 8.37 million hectares of land. It has rich biological as well as cultural diversity. The state is the custodian of 23.52% of total flowering plants of India (Hegde 2002), including around 4,500 species of angiosperm and 550 species of orchids; and is also regarded as nature's repository of medicinal plants (Haridasan1989),where around 500 medicinal plants were identified during the preliminary survey.Arunachal Pradesh possesses India's second-highest level of genetic resources (SECC 2011).The fauna diversity Includes 85 Species of mammals and 760 species of birds(S 2011).The region has been identified by the Indian Council of AgriculturalResearch(ICAR)as the center of rice germplasm while the National Bureau of Plant Genetic Resource (NBPGR) has highlighted the region as being rich in wild relatives of crop plants. It is the center of origin of citrus crops. The State is home to 26 major tribes and 110 sub-tribes (Srivastava 2009). Agriculture is the mainstay of the people of the State With around 85 percent of the population directly or indirectly depending on it for their livelihood and the sector accounts for 25% of the gross state domestic product (SAPCC2011). The difficult agro-climatic condition with undulating topography, poor soil quality,subsistence nature of agriculture, traditional nature of cultivation (Vol. 16 pp. 535-5392017p-ISSN:0972-6268 No.2 Nature Environment and Pollution Technology an International Quarterly Scientific Journal Original Research Papere-ISSN: 2395-3454Open Access 536 Rupankar Bhagawati et al. Vol. 16, No. 2, 2017 Nature Environment and Pollution Technology),in adequate investment capabilities and improper enterprise mix account for poor development of the sector in the State and hinders in achieving its full potential.These Factors Are Compounded By changes in precipitation patterns and temperature in recent decades due to climate change. Agriculture is most vulnerable to climate change due to its high dependence on climate and weather. There are very few documents available on the climate change of Arunachal Pradesh despite its strategic location influencing the activities of almost all the Northeastern States of India. The Current review gives a brief overview of the climate change scenario of Arunachal Pradesh and its impact on the agricultural productivity and the farming system of the State.

b. Mention about vulnerability assessment conducted earlier

Vulnerability Risk Assessment at District Level:

The district level Vulnerability Assessment was carried out as per the available secondary data for 16 districts of Arunachal Pradesh and with one Sector specific on Agriculture was done by State Climate Change Cell and later on for all important sectors including agriculture sector. Vulnerability Assessment was done during preparation Arunachal Pradesh PCC2.0by IORA,Ecological Solutions,Pvt.Ltd,which is India's pioneering Environmental advisory group.

- Vulnerability Risk Assessment and District Ranking mapped with data from covering sectors like forest,Agriculture Horticulture,AnimalHusbandry, Fishery,Water Resources,Health,Sustainable Habitat LandUse,Energy,Sustainable transport systems, Disaster Management forArunachal Pradesh.

- Objectives consideredforVulnerabilityAssessment:

  To Understand Problems And Their Underlying Causes.

  To Analyze The characteristics determined by physical, socio-economic and environmental factors.

  To Minimize The Risk Factors

- **Outreach conducting Vulnerability Assessment:**

  To give priority over districts based on vulnerability assessment.

  Finding tools for empowerment and mobilizing vulnerable communities.Tomapthevulnerabledistrictsforsensitizationandfurtherresearch.

The study uses an integrated approach where both biophysical as well socio-economic indicators are taken into consideration. The advantage of using an integrated approach is that they provide a comprehensive picture of who is vulnerable, and what are the factors leading to vulnerability (O'Brien et al. 2007).The scale of the study is at a district level as it will help in prioritizing the most vulnerable districts of the State to enable adaptation planning. The data collection process involves a tier 1 method, a top-down method and is largely based on secondary sources of data collected from various line departments in theState.

The vulnerability assessment conducted in the state covers the following sector viz.,

1. Agriculture
2. Water Resources
3. Forest
4. Urban Habitat
5. Rural Habitat
6. Energy
7. Human Health, and
8. Disaster Management

Agriculture

A total of fifteen indicators were considered to evaluate the agricultural vulnerability at the district level.

The Indicators are:

1) Yield Variability(Coefficient Of Variation,Tonne/Ha)
    - Crop (major cereals)
    - Fruits and vegetables
2) Percentage of net area irrigated to net sown area
3) Water Availability
4) Drainagedensity

5) Livestock per 1,000 rural population

6) Percentage of landless marginal and small farmers

7) Percentage of area under water bodies

8) Groundwater availability

9) Crop diversity

10) Value Of Horticulture Output(perennial)/Value of Agricultural output.

11) Fair price shops/1000 population.

12) Road density

13) Diversity index of main source of income for rural HHs

14) Average person days/households employed and MGNREGA

15) No.of NRM works/1000 Ha(MGNREGA)

TheAgricultureVulnerabilityAssessments for the districts of Arunachal Pradesh reflects Kurung Kumey as the most vulnerable district while Lohit is the least vulnerable district in Arunachal Pradesh. Similarly, districts such as Upper Subansiri (0.67), Anjaw(0.65), Tirap(0.64), Dibang Valley(0.63), West Siang(0.63) West Kameng(0.63) and UpperSiang(0.61)fallsunderhighvulnerablewitharespective agricultural vulnerable index.Various underlying factors are determining the Agricultural vulnerability of these districts.For instance, in Kurung Kumey factors such as low drainage density, high percentage of landless, marginal and small farmers, low ground water availability, less no of livestock,poor connectivity etc have contributed to the agricultural vulnerability the district.Similarly, poor irrigation facilities, low variation in food grain crop yield, low drainage density, high percentage of marginal and landless farmers, poor connectivity, less number of workdays under MGNREGA etc., have contributed significantly to the Agricultural Vulnerability of the districts. For instance, average road density is below 0.50 sq km in each of the districts in Arunachal Pradesh. This had led to poor access to markets to sell their produce.This is presented in the graph & map below.

Table: Agriculture Vulnerability Index Ranks of Districts ofArunachal Pradesh

Name of the Districts	**Agriculture VulnerabilityIndex(VI)**	**Rank**

Anjaw	0.65	3
Changlang	0.54	9
Dibang Valley	0.63	5
East kameng	0.56	8
East siang	0.47	12
Kurung Kumey	0.74	1
Lohit	0.41	14
Lower Dibang Valley	0.45	13
Lower Subansiri	0.50	11
Papum Pare	0.52	10
Tawang	0.57	7
Tirap	0.64	4
Upper Siang	0.61	6
Upper Subansiri	0.67	11
West Kameng	0.63	5
West Siang	0.63	5

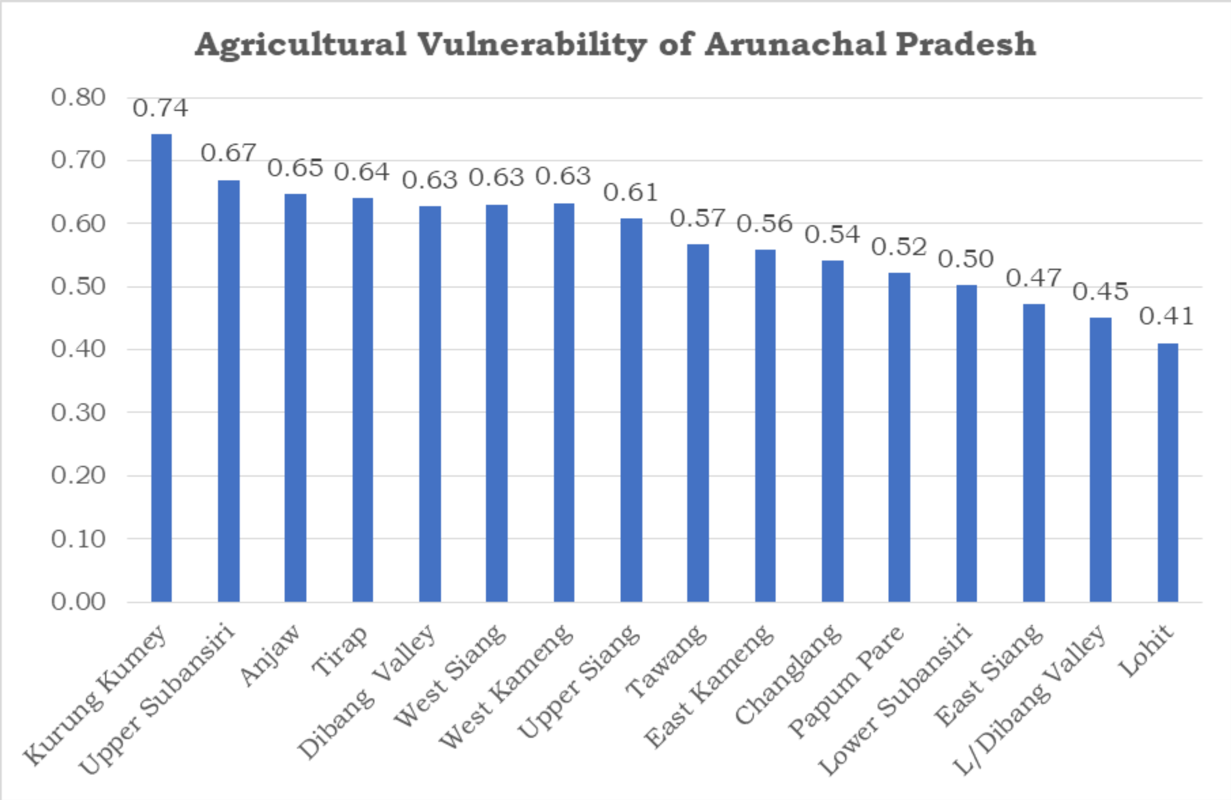


Figure4:Graph representing Agricultural Vulnerability of Districts ArunanchalPradesh

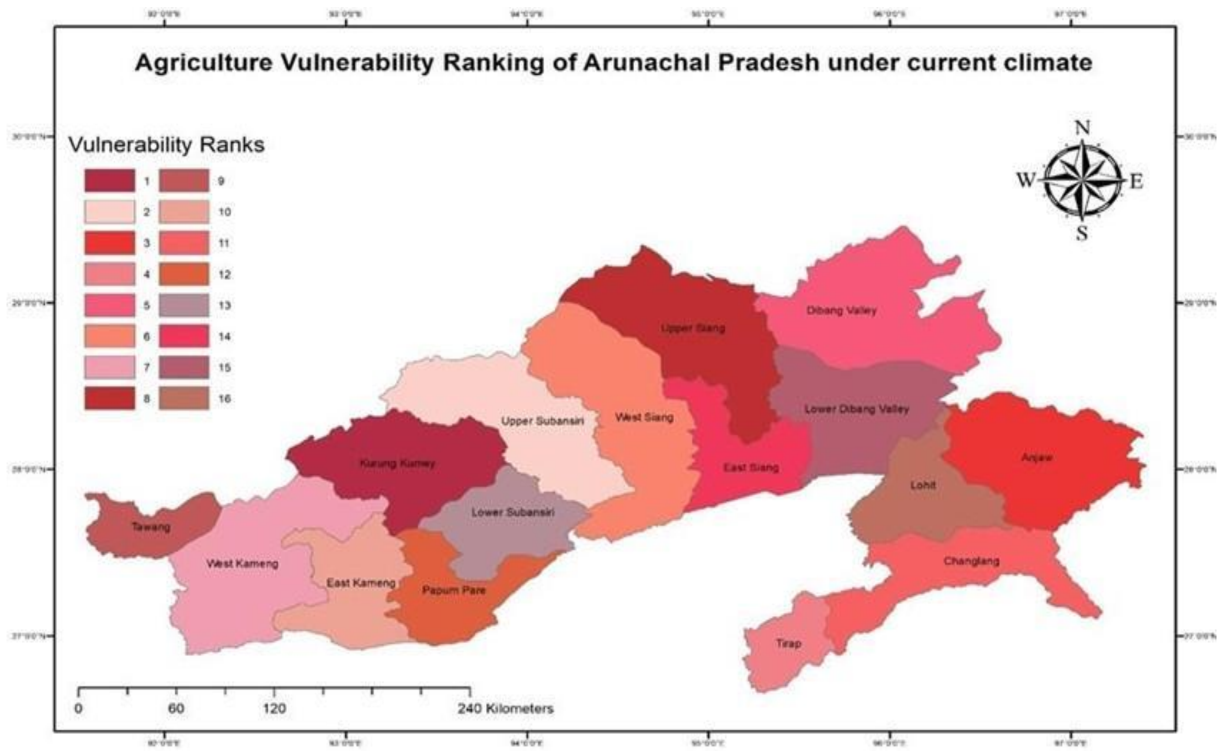


Figure:Map showing districts ranked based on Agricultural Vulnerability of Arunachal Pradesh.

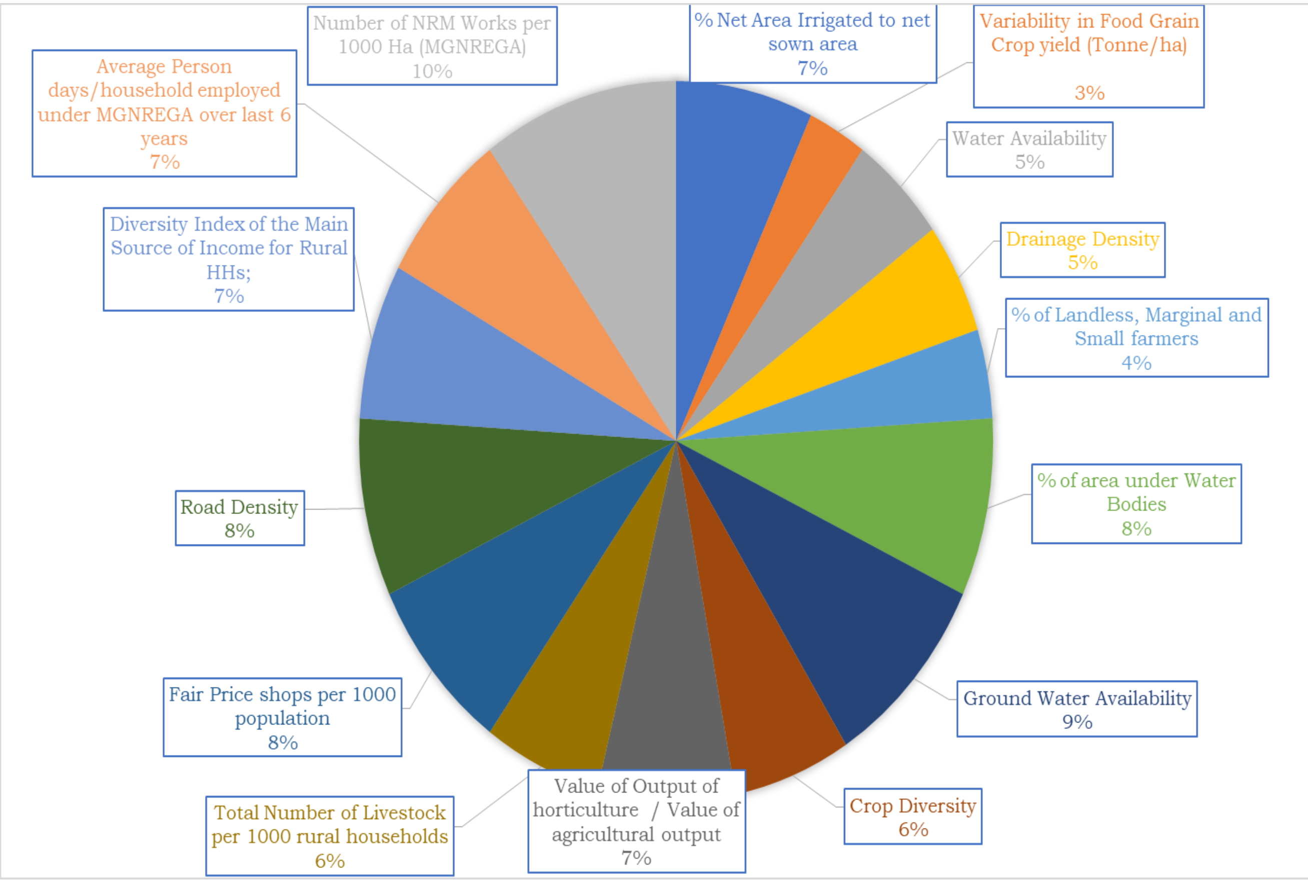


Figure 5: Major Drivers contributing to Agriculture vulnerability at the district level in Arunachal Pradesh

Major drivers of vulnerability for the districts in different vulnerability classes are presented in **Water Resources.**

A total of eight indicators were considered to assess water vulnerability at the district level.All the indicators were used for the computation of water vulnerability index (WVI). The List of the indicators selected is:

1) Stage of Groundwater Extraction (2017)

2) Percentage of Households having tap connection within premises (as of date)
3) Percentage Of Total Minor Irrigation Schemes In Use(2013-14),weighted by the percentage of irrigation potential utilized
4) PercentageofWaterconservationassetscreatedunderMGNREGS(2015-19)
5) Water Stress
6) Percentage change in wetland area (2015 over 2005)
7) Forest Canopy Density (Forest CoverArea)
8) Percent area under Irrigation

Out of the sixteen districts, one district (Upper Subansiri) was ranked as having very-high vulnerability; 4 districts(Tirap,Tawang,Lower Subansiri West Kameng)were ranked as highly vulnerable; Papum Pare, Kurung Kumey, East Siang, Dibang Valley & Anja Were ranked as having moderate vulnerability; Changlang, West Siang,East Kameng & Upper Subansiri districts were ranked as having low vulnerability and the remaining two districts(LowerDibangValley&Lohit)were ranked as having very-low vulnerability.

Major drivers of vulnerability for the districts' indifferent vulnerability classes represented the table below.

Table: Driversofwatervulnerabilityforthedistrictsindifferentvulnerabilityclasses

Vulnerability Class	Districts	Major Drivers of vulnerability
Very High	Upper Subansiri	1. Poor development of groundwater resources 2. Fewer water tap connections 3. Low Forest Canopy Density
High	Tirap, Tawang, Lower Subansiri,West Kameng	1. Poor development of groundwater resources 2. Fewer water tap connections 3. Fewer water conservation assets created under MGNREGS
Moderate	Papum Pare, KurungKumey,EastSiang, DibangValley,Anjaw	1. High water stress 2. Poor development of groundwater resources 3. Fewer water conservation assets created under MGNREGS
Low	Changlang,West Siang,East Kameng, Upper Siang	1. High water stress 2. Decreasing wetland area
Very Low	Lower DibangValley,Lohit	1. High water stress 2. Decreasing wetland area

Forest

The Five indicators were considered to assess forest vulnerability at the district level.

Access To Forests Resources:

1) Percentage change in forest area (2017-2019)
2) Forest area (in ha)/1,000 (SC/ST) rural population

3) Productivity of forests (value of forest produce extracted/ha of forest area)
4) Percentage of HH using firewood for cooking
5) Percentage of forests on slopes >30 degrees

Since only five indicators were considered,all indicators were used for the computation Forest Vulnerability Index (FVI).

Out of the Sixteen districts, Tirap was ranked as having very-high vulnerability;Upper Subansiri,West Siang Upper Siang Were ranked as Highly vulnerable; East Kameng West Kameng,DibangValley&Lower DibangValley,Tawang,East Siang, Changlang,Kurung Kumey & Lower Subansiri were ranked as having moderate vulnerability;Lohit & Anjaw were ranked as having low vulnerability and Papum Pare Was Ranked as having very-low vulnerability.

Major drivers of vulnerability for the districts in different vulnerability classes are presented in the figure.

Table:Driversofforestvulnerabilityforthedistrictsindifferentvulnerabilityclasses

Vulnerability Class	Districts	Major Drivers
Very High	Tirap	1. Reduction in forest area, 2. Low per capita availability of forest resources, 3. High dependence on firewood for cooking, 4. Low productivity of forests
High	Upper Subansiri, West Siang,Upper Siang	1. Low productivity of forests, 2. High percentage of forests on slopes >30°, 3. High dependence on firewood for cooking, 4. Reduction in forest area
Moderate	East Kameng West Kameng,DibangValley&LowerDibangValley,Tawang,EastSiang,Changlang	1. Low productivity of forests, 2. Reduction in forest area
Low	Kurung Kumey & Lower Subansiri,Lohit & Anjaw	1. Low productivity of forests, 2. High dependence on firewood for cooking
Very Low	PapumPare	Low Per Capita Availability Of Forest Resources

Urban Habitat

A total of eleven indicators were considered to assess vulnerability of urban habitats at the district level.In addition,the indicator Access to basic amenities has five sub-indicators:‘Sanitation,Electricity,DrinkingWater,Housing & Cooking Fuel’.Thelists of indicators are:

1) Population density
2) Percentage of urban households at risk to damage by wind, flood and earthquakes
3) Percentage of urban population who are multidimensionally poor in each district
4) Access To Basic Amenities(Sanitation,Electricity,DrinkingWater,Housing Cooking Fuel)
5) Percentage of households with kitchen inside the house and use of cleanfuel for cooking
6) UrbanLiteracy (secondary school and above)
7) Access to an alternate employment source (MGNREGS)
8) Women participation in the labourforce(urban)
9) Dependency ratio

10) Access To Functional Healthcare Facilities(Number of Sub-centers,PHCs,CHCs,Sub-divisional hospital, District Hospital)
11) Prioritization of natural resource management works under MGNREGS

Out of the 16 districts, 2 districts (Lower Dibang Valley, Papum Pare) were ranked as having very-high vulnerability; Anjaw, Kurung Kumey were ranked as highly vulnerable;Tirap, Lower Subansiri, Changlang, Lohit were ranked as having moderate vulnerability;East Siang, West Siang, Upper Subansiri, East Kameng, Upper Siang, Dibang Valley were ranked as having low vulnerability and finally Tawang, West Kameng were ranked as having very-low vulnerability. Major drivers of vulnerability for the districts in different vulnerability classes are presented in the table below.

Table:Drivers of vulnerability of urban habitat for district in different vulnerability classes

Vulnerability Class	**Districts**	**Major Drivers**
Very High	Lower DibangValley,Papum Pare	1. High Percentage Of Households At risk to damage by wind, flood and earthquakes 2. High dependency ratio 3.High Percentage Of Urban Population who are multidimensionally poor in each district
High	East Siang,Anjaw,Kurung Kumey	1. High Percentage Of Households At risk to damage by wind, flood and earthquakes 2. High Percentage Of Urban Population who are multidimensionally poor in each district 3. High dependency ratio

Moderate	Tirap,Lower Subansiri, Changlang, Lohit	1. High population density 2.High Percentage Of Urban Population who are multidimensionally poor in each district 3. High percentage of households at risk to damage by wind, flood and earthquakes
Low	East Siang,West Siang,Upper Subansiri,EastKameng,Uppersiang,DibangValley	1. High dependency ratio 2. High percentage of households at risk to damage by wind, flood and earthquakes 3. Low Access To An Alternate Employment source (MGNREGS)

Vulnerability Class	Districts	Major Drivers
Very Low	Tawang,WestKameng	1. High Percentage of Households At risk to damage by wind, flood and earthquakes 2. High dependency ratio 3. High Percentage Of Urban Population who are multidimensionally poor in each district 4. High population density

Rural Habitat

A total of twelve indicators were considered to assess vulnerability of rural habitats at the district level. In addition, the indicator 'Access to basic amenities' has four sub-indicators:Sanitation,Electricity,DrinkingWater & Cooking Fuel'.The Indicators Are:

1) Proportion of total Population living in rural areas
2) Percentage of rural households at risk to damage by wind, flood and earthquakes
3) Percentage of rural population who are multidimensionally poor in each district
4) Access To Basic Amenities(sanitation,electricity,drinking water cooking fuel)
5) Percentage of households with kitchens inside the house and use of cleanfuel for cooking.
6) RuralLiteracy (secondary school and above)
7) Access to an alternate employment source (MGNREGS)
8) Womenparticipationinthelabourforce(rural)
9) Dependency ratio
10) Access to functional health care facilities
11) Prioritization of natural resource management works under MGNREGS
12) HousecompletedunderPMAY-G(%of the target)

Out Of The 16 Districts,4 districts(Kurung Kumey,Tawang,Upper Subansiri,Upper Siang)were ranked as having very-high vulnerability; West Kameng, Tirap & Changlang were ranked as highly vulnerable; West Siang, East Kameng & Papum Pare were ranked ashavin moderate vulnerability;LowerDibangValley,Anjaw,DibangValley,LowerSubansiri & Lohit were ranked as having low vulnerability and finally East Siang was ranked as having very-low vulnerability.

Majordriversofvulnerabilityforthedistrictsindifferentvulnerabilityclassesarepresentedin theTable.

Table:Drivers of vulnerability of rural habitats for districts in different vulnerability class

Vulnerability Class	Districts	Major Drivers
Very High	KurungKumey,Tawang, Upper Subansiri, Upper Siang	1. HighproportionoftotalPopulationliving in rural areas 2. High percentage of households at risk to damage by wind,floods and earthquakes

Vulnerability Class	**Districts**	**Major Drivers**
		3. High Percentage of Rural Population who are multidimensionally poor in each district 4. High Dependency ratio
High	West kamen Tirap,Changlang	1. High proportion of total Population living in rural areas 2. High percentage of households at risk damaged by wind,floods and earthquakes 3. High Percentage of rural population who are multidimensionally poor in each district
Moderate	West Siang,East Kameng,Papum Pare	1. High Proportion of total Population living in rural areas 2. High Percentage of rural population who are multidimensionally poor in each district 2. High percentage of households at risk to damage by wind,floods and earthquakes
Low	Lower Dibang Valley,Anjaw, Dibang Valley,Lower Subansiri,Lohit	1. High Proportion of total Populationliving in rural areas 2. High Percentage of rural population who are multidimensionally poor in each district 3. High percentage of households at risk to damage by wind,floods and earthquakes 4. High dependency ratio

Very Low	East Siang	1. Low Prioritization Of Natural Resource Management works under MGNREGA 2. Low Rural Literacy (Secondary School and above) 3. Low access to an alternate employment source (MGNREGS)

Energy

Four indicators were considered to assess energy vulnerability at the district level, and all four were used for the computation of Energy Vulnerability Index (EVI). The selected indicators are:

1) Numberofrenewableenergyunitsperkm^2
2) Access to clean cooking fuels
3) Access to electricity
4) Percentage of households with Solar Home Systems

Out of the 16 districts, Changlang was ranked as having very-high vulnerability; Tirap,Kurung Kumey, Lower Subansiri, Upper Subansiri & Upper Siang were ranked as highly vulnerable; Anjaw, East Siang, Lohit & East Kameng were ranked as having moderate vulnerability; West kameng, Papum Pare & Lower Dibang Valley were ranked as having low vulnerability and West Siang,Tawang & Dibang Valley were ranked as having very-low vulnerability.Major Drivers of vulnerability for the district indifferent vulnerability classes are presented in the table below.

Table:Drivers of energy vulnerability for the district indifferent vulnerability classes

Vulnerability Class	Districts	Major Drivers
Very High	Changlang	1. Low percentage of households withSolar Home Systems, 2. Poor Access To Electricity, 3. Poor access to clean cooking fuels 4. Low Uptake Of Renewable Energy Sources
High	Tirap,Kurung Key,Lower Subansiri,Upper Subansiri & Upper Siang	1. Low percentage of households withSolar Home Systems, 2. Poor access to clean cooking fuels, 3. Low Uptake Of Renewable Energy Sources
Moderate	Anjaw,East Siang,Lohit East Kameng	1. Low percentage of households withSolar Home Systems, 2. Poor access to clean cooking fuels, 3. Poor access to electricity
Low	Westkameng,PapumPare& LowerDibangValley	1. Low percentage of households with Solar Home Systems, 2. Poor access to electricity
Very Low	WestSiang,Tawang & DibangValley	1.Poor Access To Electricity

Human Health

A total of thirteen indicators were considered to assess the vulnerability the healthsector at the district level.The selected indicators are:

1) Access To Functional Healthcare Facilities(NumberofSub-centers,PHCs,CHCs,Sub-divisional hospital, District Hospital)
2) Totalphysicians,nurses and midwives per 10,000 population
3) Infant Mortality Rate (IMR)
4) Households with any usual member covered by a health scheme or health insurance(%)
5) Disease Incidence

- Enteric fever
- Bacillary Dysentery
- Acute Diarrhoeal Disease
- MalariaIncidence

6) Literacy
7) Percentage of Population <6 and >60 years of age
8) Percentage of households at risk to damage by wind, flood and earthquakes
9) Percentage of population who are multidimensionally poor in each district
10) Access To Basic Amenities(safe drinking water,sanitation,and wastewater drainage)
11) Percentageofhouseholdswithkitchensinsidethehouseanduseofcleanfuelsforcooking
12) Nutritional Health among Infants and Women

- Percentage of children having anemia (age between 6 to 59 months)
- % of women with BMI <18.5 (total thin)
- % of women with BMI ≥25.0(overweight or obese)

13) Population density

Out of the 16 Districts,Tirap,Tawang,East Kameng,Lohit,were ranked as having very-high vulnerability;Changlang, Kurung Kumey were ranked as highly vulnerable;Papum Pare, Anjaw were ranked as having moderate vulnerability; Dibang Valley, Lower Dibang Valley, West Kameng, Upper Siang, Upper Subansiri were ranked as having low vulnerability and East Siang,West Siang,LowerSubansiriwererankedashaving very-low vulnerability.
Major drivers of vulnerability for the districts in different vulnerability classes represented in the table below.

Table:Drivers of health vulnerability for the districts in different vulnerability classes

Vulnerability Class	Districts	Major Drivers of vulnerability
Very High	Tirap, Tawang,East Kameng,Lohit	1. High population density 2. Less households with any usual Member Covered by a health scheme or health insurance(%) 3. Low literacy 4. High Percentage Of Households at Risk To Damage by wind, flood and earthquakes 5. Low number of physicians,nurses and midwives per 10,000 population

High	Changlang,KurungKumey	1. High population density 2. Less households with any usual Member Covered by a health scheme or health insurance(%) 3. Low literacy 4. High percentage of Population<6 and>60 years of age 5. Low number of physicians,nurses and midwives per 10,000 population
Moderate	Papum Pare, Anjaw	1. High population density 2. Less Households with any usual Member Covered by a health scheme or health insurance(%)

		3. Low literacy 4. High Percentage Of Households At Risk To Damage by wind, flood and earthquakes 5. Low Access To Basic Amenities(safe drinking water,sanitation and wastewater drainage)
Low	DibangValley, Lower DibangValley, WestKameng, UpperSiang, UpperSubansiri	1.Less Number Of Functional Health Centres(Total ofSub-centers,PHCs,CHCs,Sub-divisional hospital, District Hospital) 2. Less households with any usual Member Covered by a health scheme or health insurance(%) 3. Low literacy 4. High Percentage Of Households At Risk To Damage by wind, flood and earthquakes 5. Low access to basic amenities (safe drinking water,sanitation and wastewater drainage
Very Low	East Siang,West Siang, Lower Subansiri	1. Low Access To Basic Amenities(safe drinking water,sanitation and wastewater drainage) 2. High population density

Disaster Management

A total of nine indicators were considered to assess the vulnerability the disaster management sector at the district level.The list of indicators selected is:

1) Health Insurance coverage
2) Access to an alternate employment source (MGNREGS)
3) Percentage Of Households Atrisktodamagebywind,extreme rainfall and earthquakes
4) Literacy
5) Percentage of Population <6 and >60 years of age
6) Percentage of rural households below the poverty line
7) Access To Basic Amenities(Cooking Fuel,drinking water,sanitation,electricity and housing)
8) Percentage arable land on slopes >30 degrees

9) Percentage forest land on slopes >30 degrees

Out of the 16 districts, West kameng, West Siang, Dibang Valley, Tawang were ranked as having very-high vulnerability; Lohit, East Siang were ranked as highly vulnerable; UpperSiang, Lower Dibang valley, Kurung Kumey, Changlang were ranked as having moderate vulnerability; Tirap, Upper Subansiri were ranked as having low vulnerability and Papum Pare,East Kameng,Lower Subansiri,Anjaw Were Ranked as Having Very-low vulnerability.

Major drivers of vulnerability for the districts in different vulnerability classes are presented in theTable below.

Table:Drivers of disaster management vulnerability for the districts indifferent vulnerability classes

Vulnerability Class	**Districts**	**MajorDrivers of vulnerability**
Very high	Westkameng,West Siang,DibangValley,Tawang	1. Low access to electricity 2. Low Access To Drinking Water, sanitation and housing 3. High percentage of rural households below the poverty line
High	Lohit, East Siang	1. Low Access To Drinking Water And Sanitation 2. High percentage of arable land on slopes>30 degrees
Moderate	Upper Siang, Lower Dibang valley, Kurung Kumay ,Changlang	1. Percentage Of Households At Risk to damage by wind,extreme rainfall and earthquakes 2. High percentage of rural households below the poverty line

Low	Tirap,Upper Subansiri	1. Percentage of households at risk to damage by wind, extreme rainfall and earthquakes 2. Low access to electricity 3. Low literacy rate
Very low	Papum Pare,East Kameng, Lower Subansiri,Anjaw	1. Low access to Health Insurance 2. Low access to cooking fuel 3. Low access to electricity

Inherent,CompositeVulnerability

The composite vulnerability index (CVI) broadly captures the inherent vulnerability of districts.Table below provides the list of indicators selected for the computation of Cumulative Vulnerability Index(CVI).

Table:Indicators

Sector	**Indicator**
Agriculture	Crop Yield Variability
Water Resources	Water Stress
Forests	Percentage Change In Forest Area(2017-2019)
Habitats	Access To Basic Amenities(Cooking Fuel,sanitation,drinking water,housing)
Energy	Access To Electricity
Human Health	Access to functional healthcare facilities (Number ofSub-centers,PHCs,CHCs,Sub-divisional hospital,DistrictHospital)
Disaster Management	Percentage Of Households At Risk To Damage By Wind, extreme rainfall and earthquakes

Out of the 16 districts, Lower Subansiri, Dibang Valley were ranked as having very-high inherent vulnerability; Papum Pare, Tawang were ranked as highly vulnerable; Kurung Kumey, Upper Siang, East Siang, West Kameng, Lower Dibang, West Siang were ranked as having moderate vulnerability; Upper Subansiri, Anjaw, Lohit, Changlang were ranked as having low vulnerability and the remaining 3 districts(Tirap, East Kameng) were ranked as having very-low vulnerability. Major drivers of vulnerability for the districts in different vulnerability classes are presented in Table.

Table:Drivers of inherent, composite vulnerability for the districts in different vulnerability classes

Vulnerability Class	Districts	Major Drivers of vulnerability
Very High	Lower Subansiri, DibangValley	1. High percentage of households at risk to damage by wind, extreme rainfall and earthquakes 2. Low access to electricity 3. High crop yield variability
High	Papum Pare,Tawang	1. High percentage change in forest area 2. High percentage of households at risk to damage by wind, extreme rainfall and earthquakes 3. Low access to functional healthcare facilities (Number of Sub-centres, PHCs,CHCs, Sub-divisional hospital, District Hospital)
Moderate	Kurung Kumey, Upper Siang, East Siang, West Kameng, Lower Dibang,WestSiang	1. High percentage change in forest area 2. Low access to sanitation and drinking water 3. High water stress
Low	Upper Subansiri, Anjaw,Lohit, Changlang	1. High water stress 2. Low access to drinking water
Very Low	Tirap,East Kameng	1. Low access to electricity 2. Low access to sanitation 3. High water stress

Risk Assessment incorporating Climatic Hazards and Exposure to assist state governments. Climate risk assessments identify the likelihood of future climate hazards and their potential impacts on communities. This is fundamental for informing the prioritization of climate action and investment in adaptation.

Agriculture and horticulture are one of the very foundations of the state of Arunachal Pradesh in terms of essential opportunities and economic development.According to Nimasow,Chozom,Nimasow Tsering, 2014; Sharma & Saikia, 2021, the state has witnessed variability in rainfall and temperature causing severe effects in the agriculture production. The majority of the districts are under rain fed cultivation area which directly makes it vulnerable resulting in negative impact on the livelihood of farming communities in the state. Due to the increasing population and extreme pressure of urbanisation to caterto a large population in the state many environmental implications can be seen. The fact that the state lies in the Seismic zone V region along with the fast degrading environment in the modern age many risks can be faced by the state (SDMP, 2019). Due to the volatility of the current environmental situation there is a need for a proactive, sustainable and multi-pronged approach to manage disasters. An approach which would be much more climate resilient and environment friendly.Annual average rainfall of 2500-3000mm combined with the state's prevailing hydro-meteorological,geomorphologic and topological features,rampant diminishing forests cover and increasing stress due to human activities has meant that landslides and floods and flash floods are a recurring occurrence. The state has to come up with a better and efficient environmental policy to tackle the crisis. Increasing floods and rise in temperature has affected the production oftemperate fruits native to the state like apple and kiwi. Climate change has the potential torisktheonlyprimeeconomiccatalystsuchasagricultureofthestate.Sincea largemajority of the population depends on farming in underdeveloped states like Arunachal,this sector also faces the wrath of climate change and environmental crisis. With the 2653 surface water bodies present in the state which roughly covers an area of 1,55,728 ha(ISRO, National Wetland Atlas: Arunachal Pradesh, 2009), the state of Arunachal is still described as a low water stress state because the withdrawal and the supply ratio is low(Luo,Krishnan, & Sen, 2018). Due to the decreasing rainfall it is now evident that the development would take its due course in the increasing of the water demand in the future.A comparison of water management indices between base year (2015-16) and reference year(2017-

18)forArunachalPradeshhoweverrevealsthatby2018,66%of urban households had metered water supply with an established water pricing structure. This indicator is important to ensure the improvement of water sustainability and to establish infrastructure which encourages the efficacy of water usage.While the immense anthropogenic pressure is continuing there are also shifts in the climatic conditions and change in the landscape of the state. The state is also declared as extremely fire prone, which is 209.30 km^2 (ISFR, 2021). This calls for the immediate shift of focus towards the management of Forest fires and the decreasing of pressure on natural forests such as implementation of fuel-wood conservation programmes, expansion of protected areas,scientific removal of invasive species,restoration,creation or enhancement of wetlands,promoting agroforestry etc.inthestate.Climate has significant influence the distribution, structure and ecology of forests. Several climate vegetation studies across the globe have shown that certain climatic regimes are associated with particular plant functional types (Thornthwaite, 1948; Ravindranath, Joshi, Sukumar, & Saxena, 2005). It is to be kept in mind that the various aspects covered are aligned with the objectives of the state's Sustainable Development Goals Vision document which clearly states about the importance of promoting and implementing various techniques to achieve sustainable management.Factors Linehalt Deforestation,restoration degraded forests and increase. afforestation and reforestation,ensure conservation,restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, combat desertification and conservation of mountain ecosystems including biodiversity.

2. Risk Assessment Framework

What Is Risk And Why Risk Assessment?

The Intergovernmental Panelon Climate Change(2014,2022)[1,2]defined risk in the context of climate change as the impact arising from the“dynamic interactions between climate-related hazards with the exposure and vulnerability of the affected human or ecological system the hazards".Hazards,exposure,and vulnerability may each be subject to uncertainty terms magnitude,likelihood of occurrence and each may change over time and space due to socioeconomic development, adaptation responses and human decision-making (Figure 6). Assessing potential climate risk at the current time as well as in the future, therefore, requires an understanding of all three components: hazard,exposure,vulnerability and is essential for any currentand/or future adaptation planning.In this report, the state Arunachal Pradesh presents the district/block level climate change related risk profile with respect to wide-spread hazards - flood and drought.

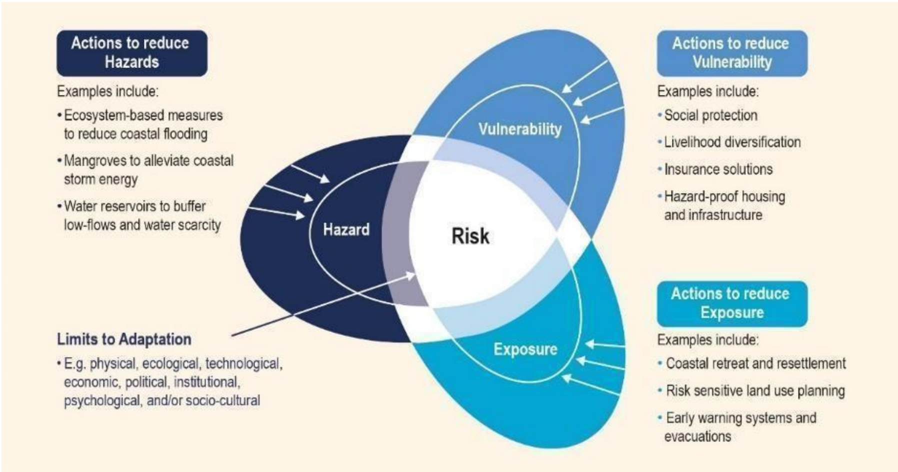


Figure6:IPCCRiskFramework(IPCC,2014)[2]

HowisRiskAssessmentdifferentfromVulnerabilityAssessment?

[1] IPCC 2014 Summary for policymakers In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field,C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B.Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge,United Kingdom New York,NY,USA,pp.1-32.

[2]IPCC,2022,TechnicalSummary:Impacts,AdaptationandVulnerability.ContributionofWorkingGroupIItotheSixthAssessmentReportoftheIntergovernmentalPanelonClimateChange[H.-O.Pörtner,D.C.Roberts,M.Tignor,E.S.Poloczanska,K.Mintenbeck, A.Alegría,M.Craig,S.Langsdorf,S.Löschke,V.Möller,A.Okem,B.Rama(eds.)].Cambridge University Press,Cambridge,UK and New York,NY,USA,pp.37–118,doi:10.1017/9781009325844.002.

Previously the states in the Indian Himalayan Regions carried out vulnerability assessments as a first step of this project. While vulnerability assessment is an integral part of climate risk assessment, the latter has two more components in it –

hazard assessment and exposure assessment . While climate hazard and hazard specific exposure contributed to the climate change risk, vulnerability of a system can be present irrespective of whether any hazard is in place or not. Moreover, reduction in the probability of any climate hazardcould be an outcome of long-term mitigation goals and risk could be reduced throughreductioninexposureonlyinthemediumtolongterm,reduction in vulnerability is possible through policy interventions in the short to medium term. Thus, one may say that addressing vulnerability is the entry point for the policy makers to reduce climate change risk, but climate change risk reduction finally also requires reduction in the probability of hazard and exposure.

Riskassessmentundercurrentclimateandfutureclimatescenarios

Risk assessment could be conducted under two scenarios depending on the objective of the assessment. This is determined by access to historical data, model-based climate change projections, resources, and technical capacity available.

- **Current Risk or Risk Assessment Based On Historical Climate Trends:** It is possible to assess the current risk for a given hazard or a set of hazards in a given region consisting of communities, ecosystems, and production systems. Risk could be assessed based on historical trends for a given hazard such as drought or flood,considering the frequency and intensity of the hazard occurrence based on observed data for the past 30 or 50 years. A first step towards adaptation to future climate change is considered to the reduction in vulnerability and exposure to present climate variability

- **Future Risk or Risk Assessment under projected climate change scenario:**Climatic Parameters Suchash Temperature,rainfall,storms,cyclones,etc.,are projected to be more severe and frequent in the coming years and decades. Climate Change projections are available from global circulation models at a higher spatial scale and from CORDEX models (0.5 x 0.5 deg) for finer spatial scale. Further,climate change projections could be considered under multiple Representative Concentration Pathways (RCPs), ranging from 2.6 to 8.5 or Shared SocioeconomicPathways (SSPs), ranging from 1.9 to 8.5. Risk in the context of climate change could also be considered for different future periodssuchas2020-2050or2070-2100.

3. Methodology Of RiskAssessment(6pages)

Asper IPCC in the Fifth Assessment Report (IPCC 2014), severity of the impacts of extreme and non-extreme weather and climate events depends strongly on the level of vulnerability and exposure to these events.Therefore,study of the nature of vulnerability and extent of exposure are critical to manage the risk and enhance resilience.The Vulnerability of a system is one of three components of risk.

Risk=F(Hazard,Exposure,Vulnerability)

Hazard: Hazard usually refers to climate-related physical events or trends or their physical impacts.This may not always be an extreme weather phenomenon but could be atrende.g., dry spells, wet days, etc., derived from climate trends.

Exposure: Exposure refers to the inventory of elements in an area in which hazard events may occur (Cardona, 1990; UNISDR, 2004, 2009b). Hence, if population and economic resources were not located in (exposed to) potentially dangerous settings, no problem of disaster risk would exist.

However, it is possible that a certain area is exposed but not vulnerable. In fact, when we consider developing resilient infrastructure or systems, their vulnerability may be reduced.It means either their sensitivity to certain levels of hazards or exposures have reduced, their adaptive capacity has increased or both. Therefore, vulnerability has two elements(sensitivity and adaptive capacity)

Vulnerability=F(Sensitivity,AdaptiveCapacity)

Vulnerability profiles can be constructed that take into consideration sources of environmental, social, and economic marginality (Wisner, 2003). Socio-economic systems further have bearing the adaptive capacity.Similarly,environmental factors are affected by biophysical systems. Holistic perspectives on vulnerability aim to go beyond technical modeling approaches.It attempts to embrace wider comprehensive explanation of vulnerability. These approaches differentiate exposure, susceptibility (i.e.,sensitivity)and societal response capacities as causes or factors of vulnerability.

IPCC defines:

Vulnerability as, “the propensity or predisposition to be adversely affected”. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt”.

Sensitivity is, “the degree to which a system or species is affected, either adversely or beneficially by climate variability or change”. The effect may be direct (e.g., change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea level rise). Sensitivity refers to those factors that directly affect the consequences of a hazard. Sensitivity may include physical attributes of a system (e.g., house-type, soil type,irrigation type, cropping intensity, etc.),

Adaptive capacity is, “the ability of systems, institutions, humans, and other organisms to adjust to potential damage,to take advantage of opportunities,autoresponder consequences, arising out of climatic or anthropogenic causes.

The risk management framework adopted by the IPCC in the Fifth Assessment Report(IPCC 2014) depicts the interaction of hazard, exposure and vulnerability resulting in risk within the overall climatic and non-climatic physical and socio-political environment.

Conducting vulnerability assessment Exposure Index is a multi-step exercise and requires identification of a clear set of goals and objectives which will determine the type of vulnerability assessment,scale,tier,indicators,and methods to be adopted.BothVulnerability& ExposureAssessment follow the same steps.

As the objective of this study is to identify, rank and prioritize the most vulnerable districts for each of the specified sectors in the State of Arunachal Pradesh under current climate,an integrated vulnerability assessment using a tier 1 method that quantifies indicators using secondary sources of information at the district level, has been employed.

AVulnerabilityIndex (VI), which is a metric that characterizes the vulnerability of a system, has been used. Values of VIs will lie between 0 and 1, where 0 stands for lowest vulnerability and 1 for highest vulnerability. Arrangement of the assessed VI values in decreasing or increasing orders allows for ranking of districts respective to sectoral and composite vulnerability. It must be noted that the vulnerability index value only provides a sense of quantified status of vulnerability and remains largely conceptual in its utility, as this value does not have any stand-alone practical significance.

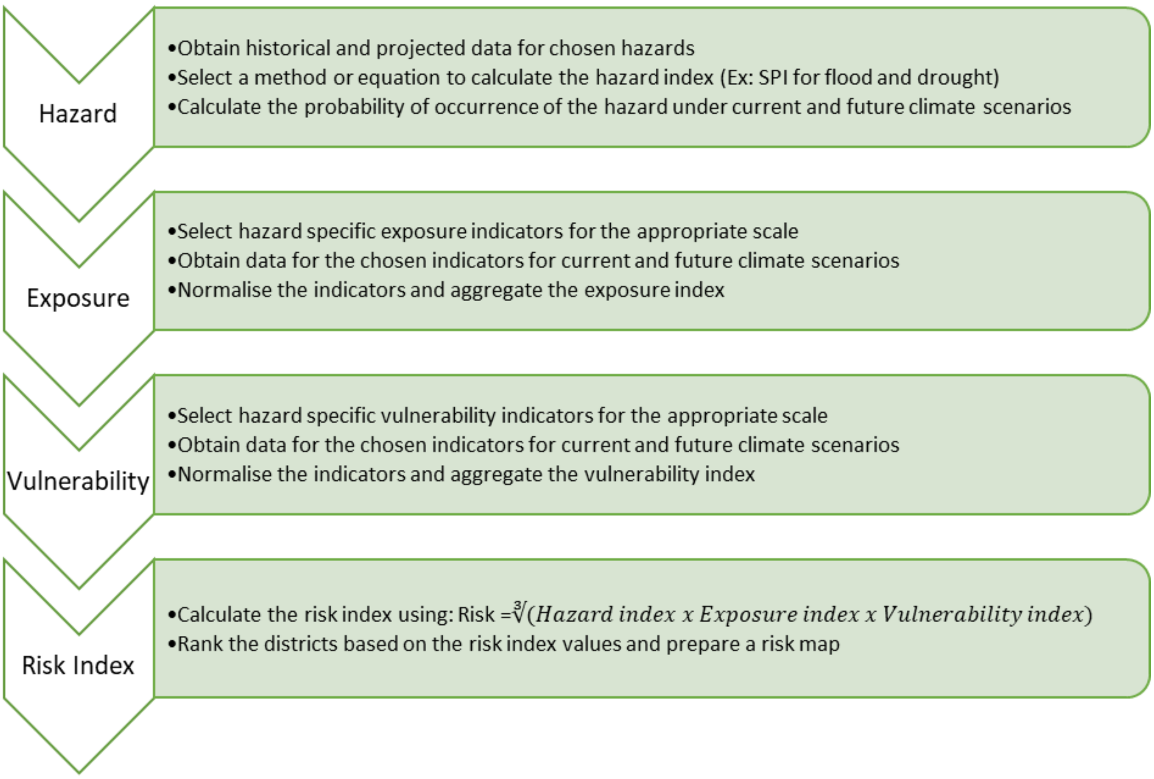


Figure:7.Steps compute risk\indices

Hazard Assessment

According to IPCC AR6, WG2 (2022)[3], hazard is defined as "the potential occurrence of anaturalorhuman-induced physical eventor trend that may cause loss of life, injury or other health impacts, as well as damage and loss to property, infrastructure, livelihoods,service provision, ecosystems and environmental resources". Hazard could be a climatic event such as heat stress, high intensity rainfall event or deficit rainfall. Hazard could also be an impact of a climatic hazardous event leading to floods, droughts, and landslides.

The Focus Of The Current assessment is on two predominant hazards—droughts and floods, due to the large-scale socio-economic impacts in India.

Flood: IPCC (2012)[4] defines flood as 'the overflowing of the normal confines of a stream or other bodies of water, or the accumulation of water over areas that are not normally submerged'.Meteorological floods can be caused by unusually heavy rain and same has been considered in this assessment to calculate the flood hazard indicator.

Drought: IPCC (2012)[5] defines meteorological drought as "a period of abnormally dry weather long enough to cause serious hydrological imbalance".The Indian Meteorological Department (IMD) declares drought in an area when the rainfall deficiency is ≥ 26% of its long-term normal. It is further classified into moderate and severe drought depending upon whether the deficiency is between 26 to50%ormorethan50% respectively.

3.1.1.HazardIndexforWetnessanddryness

One of the commonly used methods and index for dryness is the Standard PrecipitationIndex (SPI) (Mckee, 1993)[5]. SPI is based on probability of observed precipitation for any timescale.The Probability Of Observation is transformed into an Index. Data used to compute SPI for historical and future time periods are IMD gridded data (1969 - 2019) andCMIP5-15CORDEXmodelensemble(2030-2080)data(underbothRCP4.5andRCP
8.5 scenarios) for monthly rainfall in a 25x25 square km resolution (Risk assessments under the future climate would be carried out at a later stage).

The SPI is calculated from the historical precipitation record at a weather station, where precipitation accumulation over a period of time is compared to the same period of time throughout the historical record for that location. Since SPI is normalized, both wetter and drier climates can be represented – wetter for floods and drier for droughts.

[3] IPCC, 2022, Technical Summary: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth AssessmentReportoftheIntergovernmentalPanelonClimateChange[H.-O.Pörtner,D.C.Roberts,M.Tignor,E.S.Poloczanska,K.Mintenbeck, A.Alegría,M.Craig,S.Langsdorf,S.Löschke,V.Möller,A.Okem,B.Rama(eds.)].Cambridge University Press,Cambridge,UK and New York,NY,USA,pp.37–118,doi:10.1017/9781009325844.002.

[4] Seneviratne, S.I., N. Nicholls, D. Easterling, C.M. Goodess, S. Kanae, J. Kossin, Y. Luo, J. Marengo, K. McInnes, M. Rahimi, M.Reichstein,A.Sorteberg,C.Vera,andX.Zhang,2012:Changesin climate extremes and their impacts on the natural physicalenvironment.In:ManagingtheRisksofExtremeEventsandDisasterstoAdvanceClimateChangeAdaptation[Field,C.B.,V.Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley(eds.)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press,Cambridge,UK,and New York,NY,USA,pp.109-230.

[5] McKee, T.B., N.J. Doesken and J. Kleist, 1993: The relationship of drought frequency and duration to time scale. In: Proceedings of the Eighth Conference on Applied Climatology, Anaheim, California,17–22 January 1993. Boston, American Meteorological Society,179–184.

SPI for drought floods expressed as an index for different levels of severity of roughtor flood as given inTable 1.

Table:1.Classification SPI values

SPIVALUE	CLASSIFICATION
≥2.0	Extremely Wet
1.5to 1.99	Severely Wet
1.0to 1.49	Moderately Wet
-0.99to 0.99	Near Normal
-1.0to-1.49	Moderately Dry
-1.5to-1.99	Severely Dry
-2andless	Extremely Dry

Hazard-SpecificExposureAssessment

“Exposure” is “the presence of people, livelihoods, species or ecosystems, environmental functions, services and resources, infrastructure or economic, social or cultural assets in place and settings that could be adversely affected” (IPCC 2014)[6]. If population and economic resources were not located in (exposed to) potentially dangerous settings, the risk is less. Thus, Exposure can also be defined as the presence of the vulnerable system at a location where hazard occurs, therefore hazard can also be considered as the cofactor of the exposure. For the present analysis, the current climate exposure is considered.

Indicatorsofhazard-specificexposure

Given flood and drought hazards are considered, one of the most important indicators of exposure for both types of hazards is population density,which gives an idea of the presence of exposed population in the hazard prone area. Other than that, proportion of land under agricultural use (extent of exposed livelihoods that is most affected by climate hazards) and proportion of land with slope>30 degree (presence of any infrastructure in areas with highs lope are likely to face greater damage if there are climate hazards)are also considered to be the indicators of exposure.

One factor to consider while delineating indicators representing vulnerability or exposure is whether the indicator can be influenced or altered by policies in the short to medium term or not. If yes, we consider that to be a vulnerability indicator, if not then an exposure indicator. Clearly, relocating populations from disaster-prone areas, shifting of livelihoods from primary to secondary sector or relocating infrastructure from the high slope area—cannot be achieved through policy interventions in the short to medium term and hence are considered as exposure indicators.The Description Of Indicators,rationale for inclusion, their functional relationship with exposure, data source and the year of data are provided in Table 2.

[6] IPCC 2014 Summary for policymakers In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and SectoralAspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change ed C BFieldetal(Cambridge)(CambridgeUniversityPress)(Cambridge,UnitedKingdomandNewYork,NY,USA)pp1–32.

Table: 2.IndicatorsconsideredforExposure[7]

Indicators	Rationale For Selection	Functional Relationship With Exposure	Datasource	Year for which the data is applicable
Population Density(population per square km)	This indicates the population exposed to drought and flood in the given geographical area.More Population Exposed To Anyevent,more vulnerable the system will be and thus there will be high risk	Positive	Census 2011	2011
% land with slope>30⁰	The steep topography feature implies lack of availability of flat and difficulty in access, likely to be adversely affected during floods, landslides,etc.Also,infrastructure on the slopes are likely to be impacted more by the hazards. Therefore,if more area is exposed more will be the risk to population and infrastructure in the sloped area.	Positive	State Remote sensing and GIS Application Centre, ASTER GDEM 30m, CARTODEM 10mNRSC, AMSTERDAM (30m)	2018 to 2021
% land under agricultural use	Higher exposure the land under agriculture use to the hazard such as flood,drought,more will be the risk of low food production	Positive	Report on Agriculture Census, http://agricoop.nic.in/aagriculture contingency	2015-16 to 2021

'Vulnerability' is an 'internal property of a system' (IPCC-AR5, 2014)[8]. It represents the"Propensity or predisposition of the system to be adversely affected". Vulnerability of the natural ecosystem or socio-economic system is assessed as a function of its sensitivity (S)and its lack of adaptive capacity (AC). Sensitivity is defined as the "susceptibility to harmfrom the first-order impact of a hazard/stressor on the system". Adaptive capacity refers to"the ability or potential of a system to respond successfully to climate variability and change".For example,high prevalence of waterborne -borne diseases in a geographical location would reflect high sensitivity in anticipation of a flood (hazard), and if further, the area lacks public healthcare systems, that would imply a low adaptive capacity, adding to the vulnerability. Thus, vulnerability is a positive function of sensitivity (S) and a negative function of the adaptive capacity (AC) of a system. The higher the sensitivity, the higher will be the vulnerability,and the lower the adaptive capacity,the higher will be the vulnerability.Vulnerability is multidimensional and context-specificandisassessed

[7]Note that this may not be the final set of indicators.

Independently of hazard and exposure.However,hazard-specific and integrated vulnerability assessments are essential for adaptation planning.

Indicators of hazard-specific vulnerability

Invulnerability Assessment,we have indicators of different types(i.e.,biophysical,socio-economic,and institutional).Table3 presents the selected indicators under sensitivity and adaptive capacity,the rationale for considering these indicators, and the data sources.

Table3:Indicators of sensitivity and adaptive capacity,the rationale for inclusion,and data sources

Indicator	Rationale For Selection	Dimension	Datasource
%BPL Population **(BPL)**	People With Extremely Low Incomes Are Among The Most vulnerable. They have little to no financial capital,so they have the least capacity to adapt to the impacts of climate risk(O'Brien,et.al.,2008).	Sensitivity (Positive)	Statistical abstract of AP,2021.
Share of horticulture in agriculture**(Horticulture)**	Horticulture Treesarehardy And More Resilient Climate variations compared to agricultural crops. They Provide alternative income sources to agriculture. Once Established they are far less sensitive to the impacts of climate risks,particularly rainfall variability and droughts(IHAP,2019).	Adaptive Capacity (Negative)	Statisticalabstract ofAP,2021.
Forest area/1000 population**(FA)**	Forests are an important source of alternative livelihood and food through the extraction of non-timber forest products(NTFPs).	Adaptive Capacity(Negative)	Forest Survey of India,2021;Census of India,2011
Road Density**(RD)**	Under extreme weather events, the role of transport becomes crucial. The indicator focuses on accessibility and connectivity and provides the idea of the overall development region.	Adaptive Capacity(Negative)	Ministry of Road Transport and Highway Research. Wing,GOI.
Total Number Of Live **stocks** per1000 rural households	Livestocks are an important source of alternative livelihood.	Sensitivity (Positive)	Statistical abstract ofAP,2021.

Normalization of Exposure andVulnerability Indicators

Indicators considered for exposure and vulnerability are measured or expressed in different units and cannot be compared. Therefore, indicators are to be normalized. Normalization Serves Two purposes: i) It makes the indicators dimension-less, and comparable across districts,andii)It is the cardinal's positioning of indicator values that would range between 0 and 1 across districts.

Normalization is based on the indicator’s functional relationship with exposure vulnerability(Equations 1 and 2).

- **Case1**:For Positively Related Indicators,i.e.,where exposure vulnerability increases with the increase in the value of the indicator, the following formula is used:

$$\text{Normalized value} = \frac{Actualindicatorvalue - Minimumindicatorvalue}{Maximumindicatorvalue - Minimumindicatorvalue} \quad (1)$$

- **Case 2**: For negatively related indicators, i.e., where the vulnerability decrease with increase in the value of the indicator, the following formula is used:

$$\text{Normalized value} = \frac{Maximumindicatorvalue - Actualindicatorvalue}{Maximumindicatorvalue - Minimumindicatorvalue} \quad (2)$$

Applying the above equations, the normalized values of each indicator (for both exposure and vulnerability) for all the districts can be calculated. Post-normalisation, the exposure index or vulnerability index is calculated as an arithmetic mean of normalized value for the respective indicators. Taking arithmetic means also implies assigning equal weights to all indicators. Note, previous exercises show that there is rarely any difference in results based on equal indicators/PCA-based indicators.

AggregationofHazard,Exposure,Vulnerability:RiskIndex/Mapping

The hazard-specific risk index is calculated based on the geometric mean of the specific Hazard Index(HI), Exposure Index(EI) andVulnerability Index(VI)(equation 3).

$Risk\ Index = \sqrt{\quad}$ ……………………………………………………………………..…. (3)

Once the risk index is calculated,districts are ranked based on their index values and presented through risk maps.

4. District-level Risk Assessment Results for Arunachal Pradesh.

Table4: Summary of precipitation data for the state of Arunachal Pradesh(inmm)

District	YearlyArithmeticMean (1970-2019)	YearlyStandardDeviation (1970-2019)	Max (1970-2019)	Min (1970-2019)
Anjaw	0.074	0.84	2.2	-1.54
Changlang	-0.0003	1.00	4.22	-4.08
Dibangvalley	0.0481	0.91	3.3	-1.54

East Kameng	0.0008	1.00	2.95	-4.28
East Siang	0.000	1.00	3.26	-4.39
Kamle	-0.0001	1.00	3.63	–4.1
KraDaadi	0.0481	0.91	3.38	-1.54
Kurung kumey	0.0013	1.00	2.32	-3.69
Leparada	-0.0001	1.00	3.59	-4.16
Lohit	0.0010	1.00	2.56	-4.79
Longding	0.0015	1.00	3.12	-5.7
Lower Dibang Valley	-0.0012	1.00	2.93	-3.57
LowerSiang	0.0001	1.00	3.46	-4.36
Lower Subansiri	0.0009	1.00	3.25	-4.31
Namsai	-0.0002	1.00	3.27	-4.44
PakkeK essang	0.0013	1.00	2.61	-4.42
Papumpare	0.0019	1.00	2.13	-4.52
Shiyomi	0.0864	0.85	2.82	-1.39
Siang	0.0005	1.00	3.24	-3.19
Tawang	0.0013	1.00	2.66	-3.02
Tirap	0.0014	1.00	2.93	-5.45
Upper Siang	0.0283	0.94	3.49	-2.05
Upper Subansiri	0.0013	1.00	2.32	-3.69

West Kameng	0.0014	1.00	2.87	-3.79
West Siang	0.0008	1.00	3.52	-4.33

Table5:Types of occurrences of Wetness in the State of Arunachal Pradesh (1970-2019)

District	Col (A)	Col (B)	Col (C)	Col (D)	Col(E)
	No. of Wetness events (moderate)	**No. of Wetness events (severe)**	**No. of Wetness events (extreme)**	**Probability of Severe To Extreme Wetness events=** **(Col B + Col C)/595**	**Rank**
Anjaw	56	19	5	0.0403	11
Changlang	53	15	15	0.0504	10
DibangValley	45	27	14	0.0689	5
East Kameng	65	26	14	0.0672	6
East Siang	36	21	22	0.0723	4
Kamle	65	15	18	0.0555	9
KraDaadi	45	27	14	0.0689	5
KurungKume y	67	25	8	0.0555	9
Leparada	60	18	18	0.0650	8
Lohit	51	34	10	0.0739	3
Longding	64	15	15	0.0504	10
Lower DibangValley	56	34	17	0.0857	1
LowerSiang	47	19	22	0.0689	5
Lower Subansiri	59	23	10	0.0555	9
Namsai	43	20	21	0.0689	5

PakkeKessang	48	31	9	0.0672	6
PapumPare	55	19	5	0.0403	11
ShiYomi	75	15	6	0.0353	12
Siang	53	25	13	0.0639	7
Tawang	68	24	9	0.0555	9
Tirap	58	21	17	0.0639	7
Upper Siang	49	19	17	0.0605	8
Upper Subansiri	67	25	8	0.0555	9
WestKameng	37	38	12	0.0840	2
WestSiang	45	23	13	0.0605	8

Table6:Types of occurrences of Dryness in the state of Arunachal Pradesh(1970-2019)

District	(Col. A)	Col. (B)	Col. (C)	Col. (D)	Col. (E)
	No. of Dry ness events(moderate)	No. of Dryness events(severe)	No. of Dry ness events(extreme)	ProbabilityofseveretoextremelyDrynessevents =(Col B + Col C)/595	Rank
Anjaw	73	18	0	0.0303	16
Changlang	47	23	12	0.0588	7
Dibangvalley	58	22	0	0.0370	15
East Kameng	64	20	11	0.0521	11
East Siang	61	29	6	0.0588	7
Kamle	61	22	12	0.0571	8

KraDaadi	58	22	0	0.0370	15
Kurung Kumey	40	17	22	0.0655	4
Leparada	59	21	10	0.0521	11
Lohit	54	23	13	0.0605	6
Longding	46	18	14	0.0538	10
Lower DibangValley	79	18	5	0.0387	14
LowerSiang	47	15	15	0.0504	12
Lower Subansiri	48	14	19	0.0555	9
Namsai	62	24	4	0.0471	13
Pakke Kessang	35	22	19	0.0689	3
PapumPare	25	17	25	0.0706	2
ShiYomi	51	0	0	0.000	17
Siang	67	17	16	0.0555	9
Tawang	51	12	26	0.0639	5
Tirap	43	22	13	0.0588	7
Upper Siang	40	23	12	0.0588	7
Upper Subansiri	40	17	22	0.0655	4
WestKameng	48	40	8	0.0807	1
WestSiang	56	23	15	0.0639	5

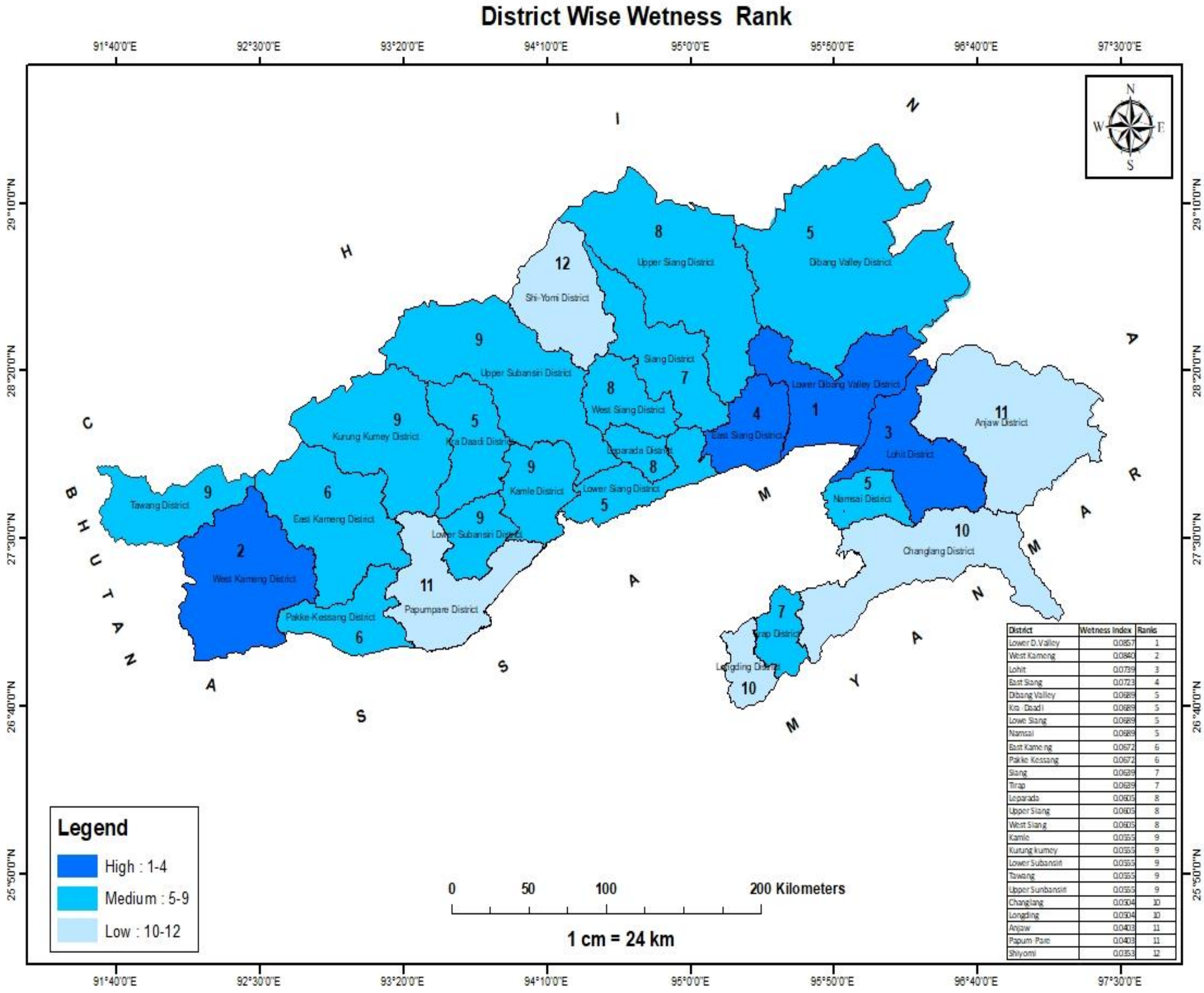


Figure 8: District wise Wetness Ranking map on a scale High to low (Top -Bottom) (1970-2019)

The Wetness index has been derived from the meteorological precipitation data from 1970 to 2019 using SPI generator & classified accordingly for 25 districts of Arunachal Pradesh. The highest probability of wetness events districts of Arunachal Pradesh are , lower Dibang Valley followed by West Kameng and Lohit respectively as shown in the above map, and whereas, Shi Yomi, Papumpare and Anjaw the least wet districts of Arunachal Pradesh followed Changlang & Longding . Further the districts have been categorized into three (3) categories viz., High for 1-4 ranks, Medium for 5-9 ranks & Low for 10-12 ranks.

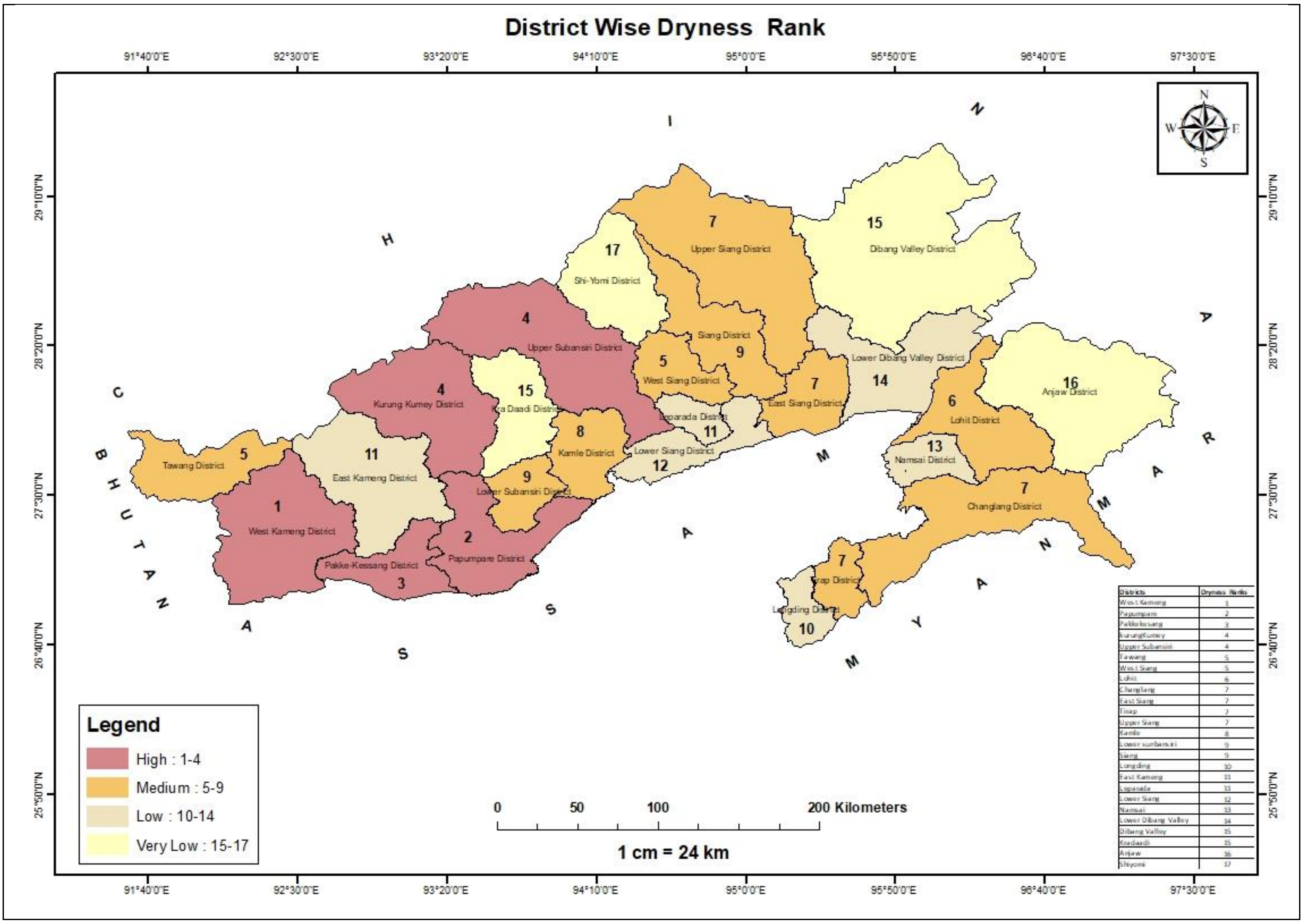


Figure9: Map showing dryness in the districts of state Arunachal Pradesh (1970-2019)

Based on Dryness Index Value, the 25 districts of Arunachal Pradesh have been categorized into four (4) categories viz., for High: 1-4 ranks, Medium: 5-9 ranks , Low: 10-14 & Very Low 15-17 ranks as shown in above map.

The highest probability of dryness events districts of Arunachal pradesh are, West Kameng, Papum-Pare & Pakke Kesang, Kurung Kumey and Upper Subansiri. The medium probability of dryness events are in the districts of West Siang, Tawang, Lohit, Changlang, East Siang,Siang, Lower Subansiri, Kamle, Tirap & Upper Siang (Map 3). Anjaw, Kra Daadi, Dibang Valley, Lower Dibang Valley, Shi Yomi, etc are the least dry districts.

Table7:District-wise actual values (AVs),normalized values (NVs) of indicators and the Exposure Index (EI)

District	Population Density		%Land With Slope >30°		Land under agricultural use		Exposure Index(EI)	Rank
	AV	NV	AV	NV	AV	NV		
Anjaw	3.4	0.05	93.93	0.93	1.4	0.05	0.34	13
Changlang	31.8	0.62	56.37	0.40	9.4	1.00	0.67	2
DibangValley/Upper D.Valley	0.9	0.00	85.73	0.81	1.0	0.00	0.27	14
East Kameng	19.0	0.36	99.18	1.00	5.0	0.48	0.61	3
East Siang	27.5	0.53	52.10	0.34	6.3	0.63	0.50	5
KurungKumey	15.2	0.29	94.90	0.94	2.3	0.16	0.46	8

Lohit	28.0	0.54	27.51	0.00	2.2	0.14	0.23	15
Lower Dibang Valley	13.9	0.26	64.08	0.51	3.2	0.27	0.35	12
Lower Subansiri	23.7	0.45	47.01	0.27	4.8	0.45	0.39	10
Papum Pare	51.0	1.00	66.20	0.54	5.5	0.53	0.69	1
Tawang	23.0	0.44	87.57	0.84	2.0	0.12	0.47	7
Tirap	47.4	0.93	50.51	0.32	4.7	0.44	0.56	4
Upper Siang	5.4	0.09	89.89	0.87	2.4	0.16	0.37	11
Upper Subansiri	11.9	0.22	76.28	0.68	6.0	0.60	0.50	6
West Kameng	11.3	0.21	56.37	0.40	1.6	0.07	0.23	16
West Siang	13.5	0.25	73.01	0.63	4.5	0.41	0.43	9

Figure10 :Ranking of the districts of the state Arunachal Pradesh based on exposure indicators (a) Population Density (b) % Land with Slope > 30° (c) Land under agricultural use

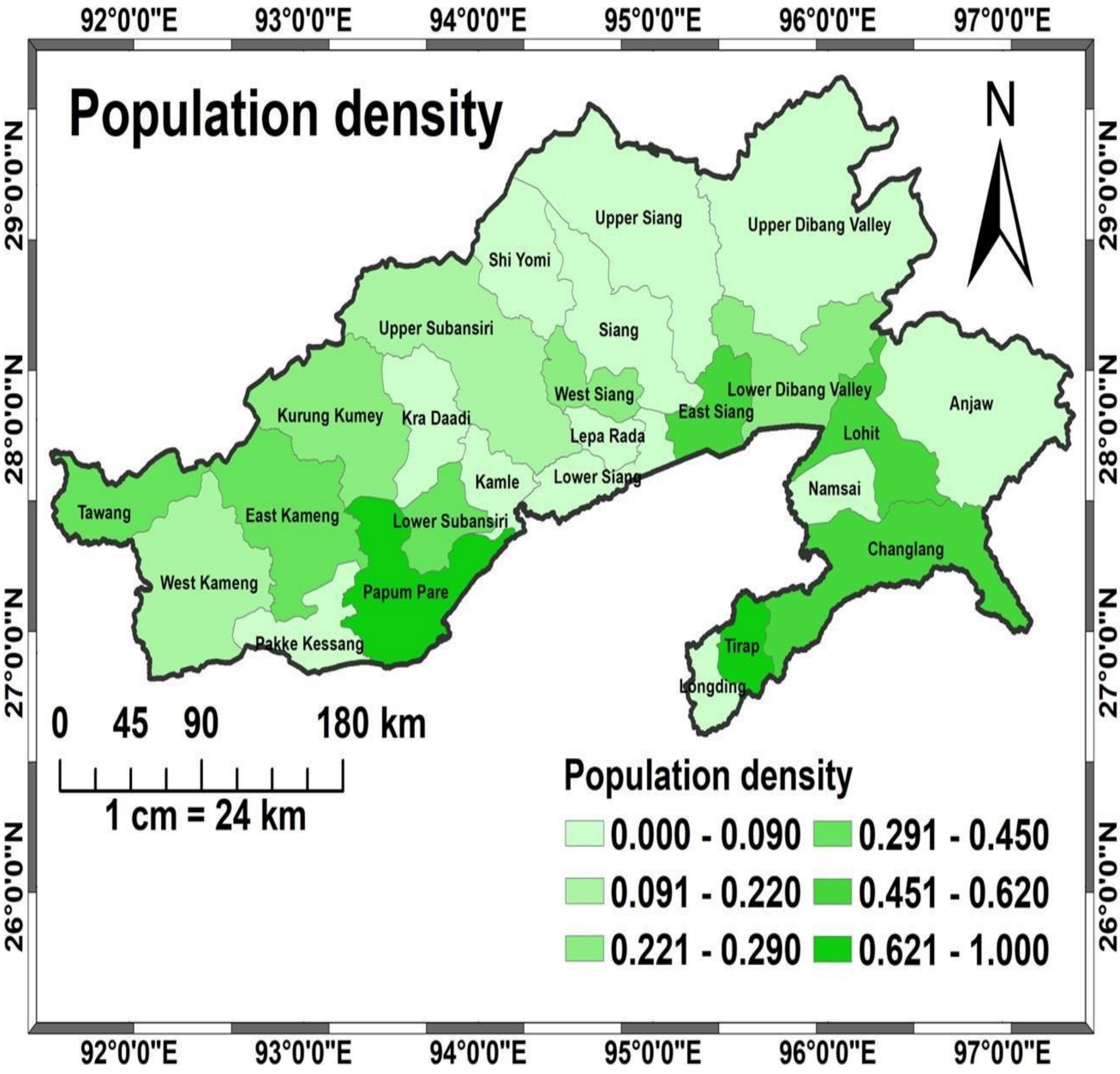


Figure 10a: Population Density map of Districts of AP(Census2011)

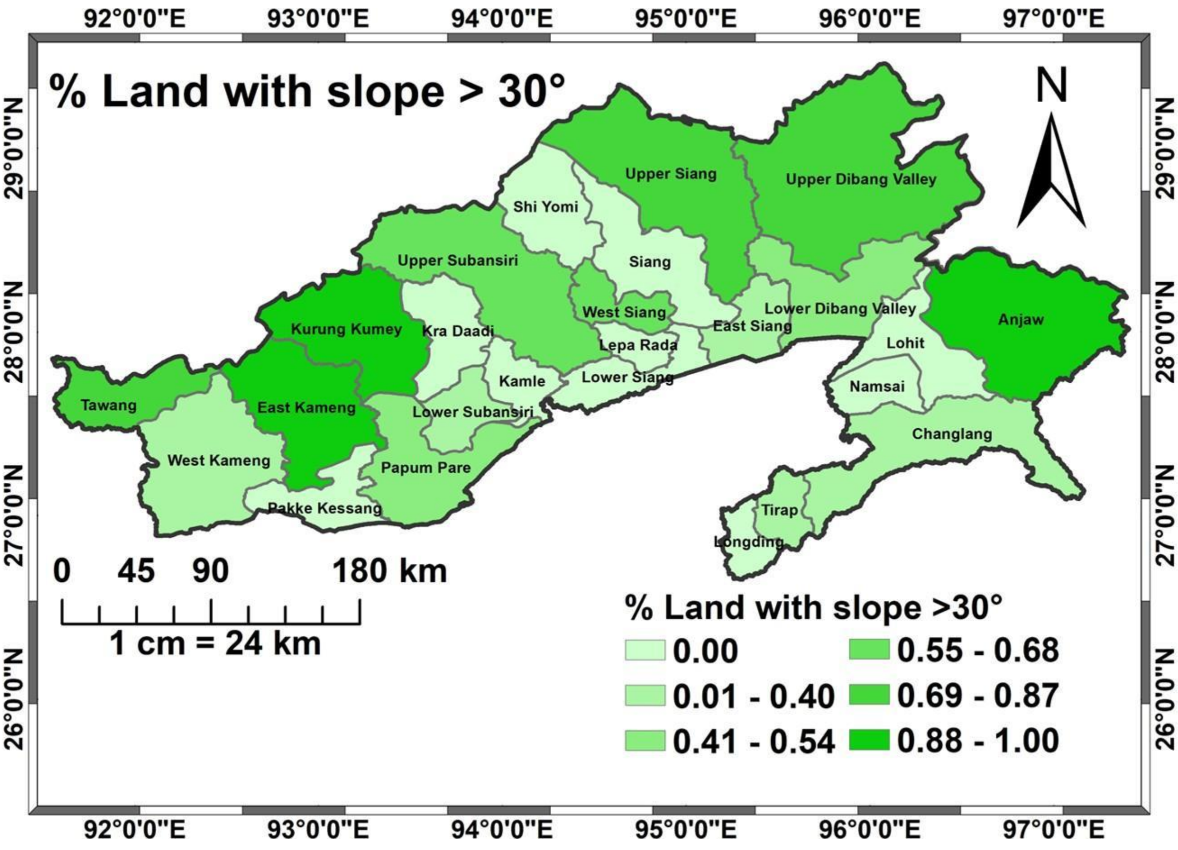


Figure 10b: Percentage of land under slope greater than 30

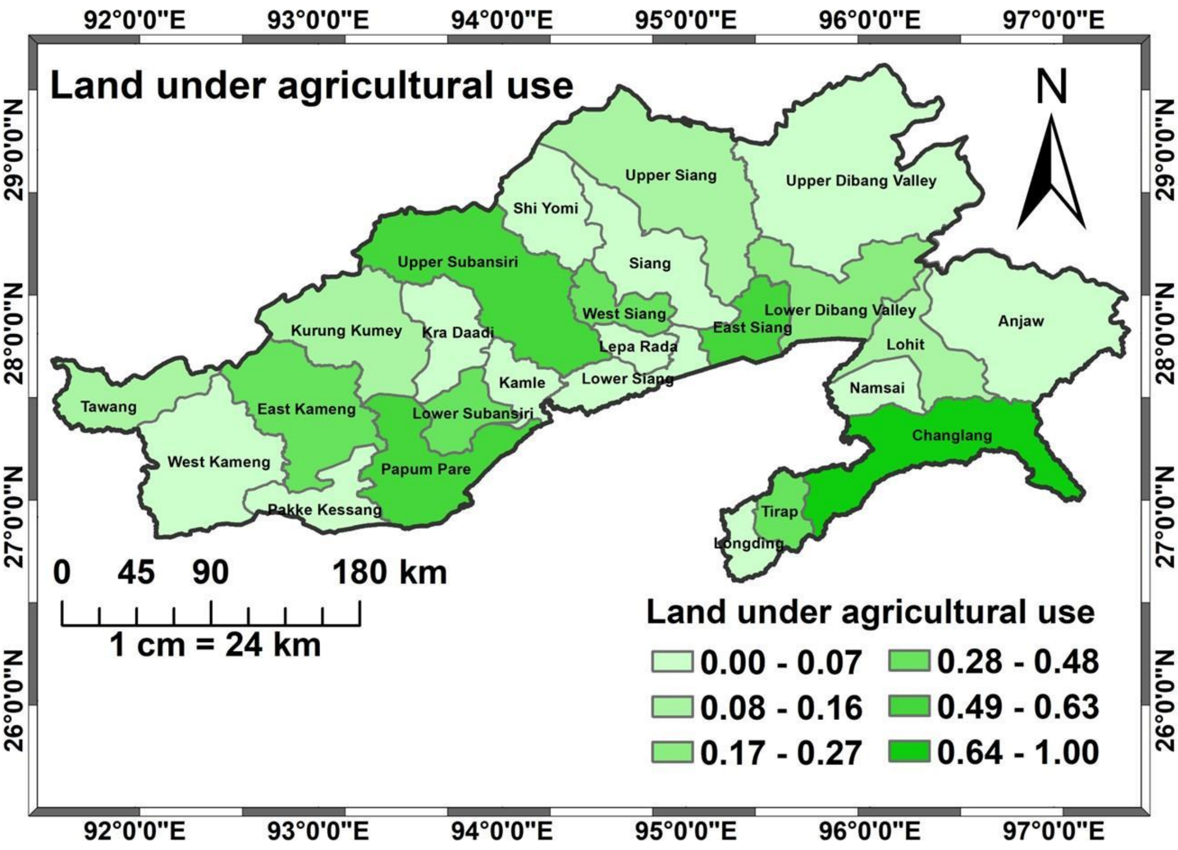


Figure 10 c: Map showing land under Agriculture use of districts of Arunachal Pradesh.

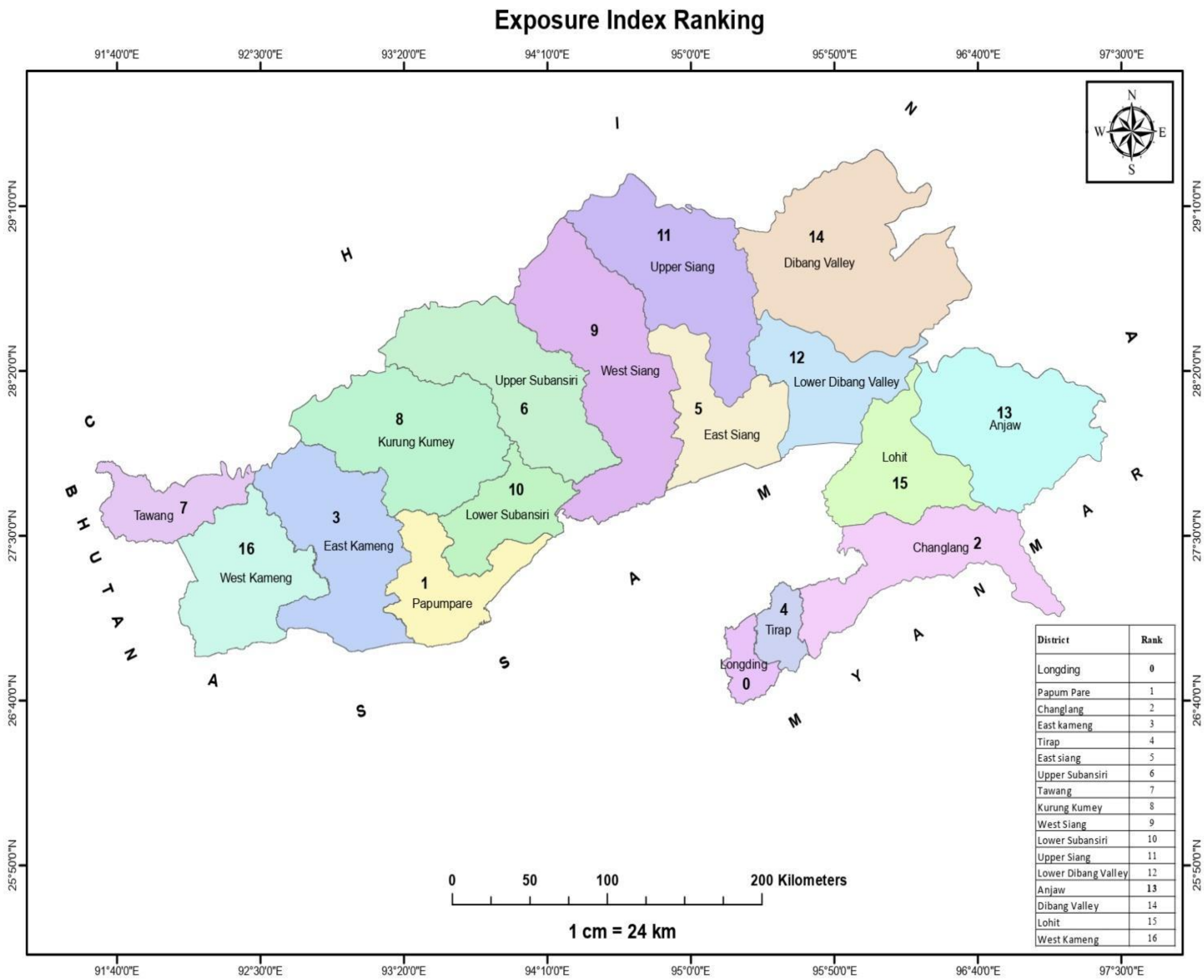


Figure 11: Map showing composite Exposure Index of districts of Arunachal Pradesh.

Due to limited data for the entire districts of the state, the Census of 2011, were considered and out of the total twenty five,

Sixteen districts were selected for the assessment. Papum Pare and Tirap districts are the most densely populated districts in the state. Dibang Valley is the least densely populated district. East Kameng, Kurung Kumey and Anjaw district has the highest percentage of land with slopes greater than 30°. Changlang and East Siang districts have the largest area under agricultural use.The Exposure Index is highest for the districts of Papum Pare, Changlang, East Kameng, Tirap and East Siang (Map 6). Exposure Index is least for the districts of West Kameng, Lohit, Dibang Valley, Anjaw, and Lower Dibang Valley.

Table8: District-wise actual values (AVs) ,normalized values (NVs) of indicators and the Vulnerability Index (VI)

District	**BPL**		**Horticulture**		**FA**		**Livestock**		**RD**		**VI& Ranks**	
	AV	**NV**	**AV**	**NV**	**AV**	**NV**	**AV**	**NV**	**AV**	**NV**	VI	Ranks
Anjaw	63	0.00	0.29	0.94	1272.43	0.88	65	0.83	0.08	0.93	0.716	5
Changlang	66	0.38	1.29	0.00	21.22	1.00	124	0.62	0.19	0.75	0.548	12
Dibang Valley	64	0.13	0.37	0.87	10168.73	0.00	61	0.84	0.04	1.00	0.567	11
East kameng	66	0.38	0.23	1.00	93.31	0.99	200	0.35	0.2	0.73	0.689	6
East Siang	66	0.38	0.85	0.42	36.60	1.00	266	0.11	0.16	0.80	0.540	13
Kurung Kumey	71	1.00	0.95	0.32	56.31	1.00	40	0.91	0.12	0.87	0.820	1
Lohit	63	0.00	1.25	0.04	26.85	1.00	297	0.00	0.17	0.78	0.364	15
LowerDibangValley	65	0.25	0.84	0.42	222.76	0.98	213	0.30	0.11	0.88	0.567	10
Lower Subansiri	66	0.38	0.75	0.51	69.25	0.99	291	0.02	0.19	0.75	0.530	14
Papum Pare	68	0.63	0.33	0.91	11.10	1.00	117	0.64	0.19	0.75	0.784	3
Tawang	64	0.13	0.88	0.39	86.96	0.99	219	0.28	0.64	0.00	0.356	16
Tirap	65	0.25	0.67	0.58	15.43	1.00	16	1.00	0.57	0.12	0.590	9
Upper Siang	68	0.63	0.37	0.87	528.26	0.95	163	0.48	0.13	0.85	0.754	4
Upper Subansiri	65	0.25	0.69	0.57	100.98	0.99	150	0.52	0.15	0.82	0.629	7
West Kameng	65	0.25	0.91	0.36	81.99	0.99	115	0.65	0.21	0.72	0.593	8
West Siang	67	0.50	0.25	0.98	66.04	0.99	77	0.78	0.15	0.82	0.815	2

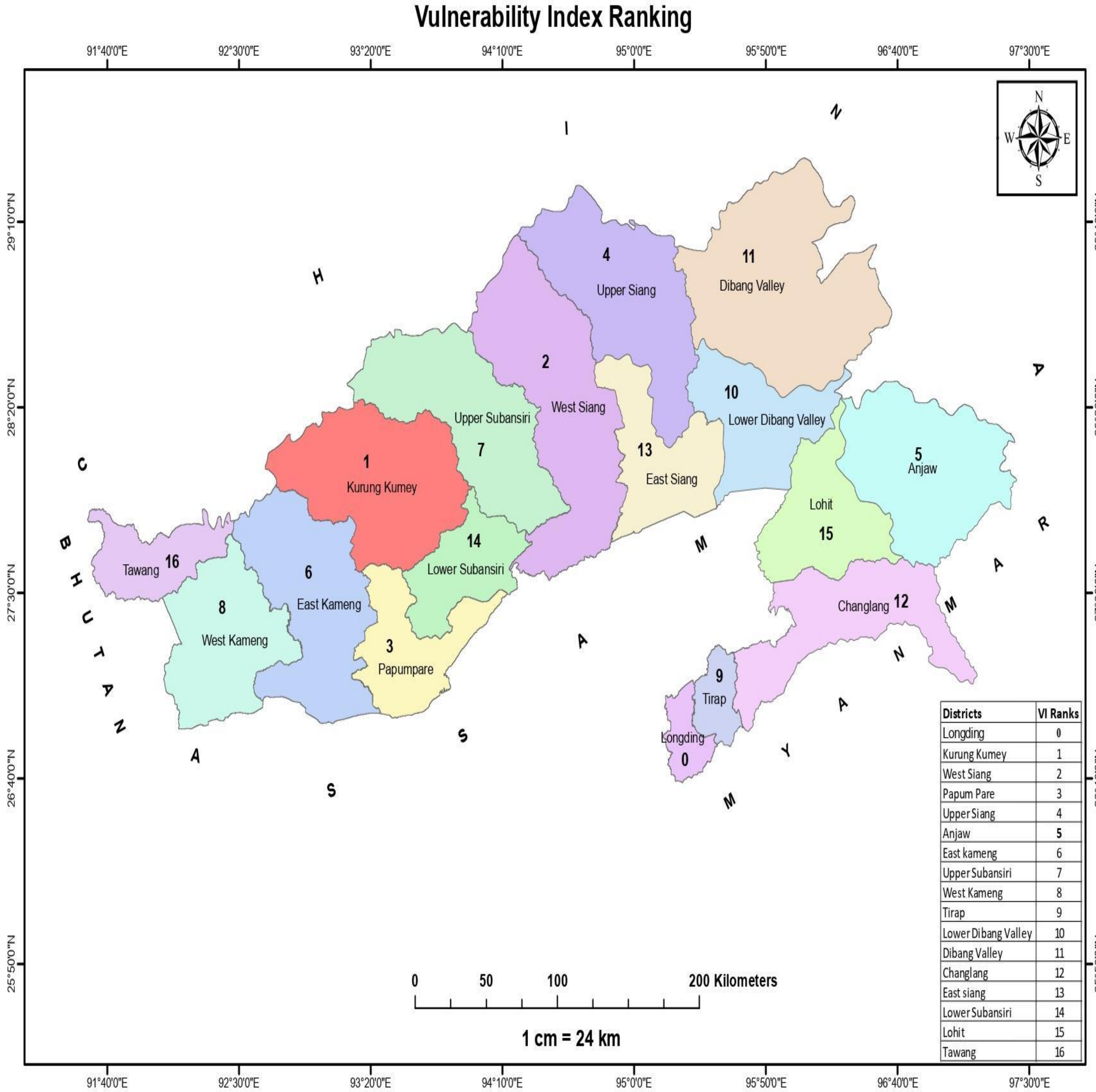


Figure 12: Map showing Vulnerability Index Ranks of districts of the state Arunachal Pradesh.

Highest percentage of BPL is found in the district of Kurung Kumey and the least is in Anjaw and Lohit districts. It is least in the district of East Kameng. The Forest area cover per thousand rural population is highest in Dibang valley and least in Papum Pare district. The livestock population per 1000 rural households is highest for

Lohit, East Siang, Lower Subansiri, and Lower Dibang Valley districts. The highest road density is found in the Tawang district and least in Dibang valley. Further, the derived Vulnerability index was found to be highest for Kurung Kumey with vulnerability index value 0.820, followed by West Siang with 0.815 , Papum Pare with 0.784 and Upper Siang with 0.754.Whereas, Lohit and Tawang districts were found to have the least Vulnerability Index.

Table 9: Wetness and Dryness-specific Risk Index values and corresponding ranks of districts in Arunachal Pradesh.

District	**Wetness Index**	**Dryness Index**	VI	EI	**Wetness Risk Index**	***Wetness Risk Rank***	**Dryness Risk Index**	***DrynessRisk Rank***
Anjaw	0.04	0.03	0.72	0.34	0.214	10	0.194	9
Changlang	0.05	0.06	0.55	0.67	0.264	5	0.281	2
Dibangvalley	0.07	0.04	0.57	0.27	0.221	9	0.183	10
East Kameng	0.07	0.05	0.69	0.61	0.309	1	0.276	4
East Siang	0.07	0.06	0.54	0.5	0.266	4	0.253	6
Kurung Kumey	0.06	0.07	0.82	0.46	0.283	2	0.298	1
Lohit	0.07	0.06	0.36	0.23	0.180	11	0.171	11
LowerDibangValley	0.09	0.04	0.57	0.35	0.262	6	0.200	8
Lower Subansiri	0.06	0.06	0.53	0.39	0.231	8	0.231	7

PapumPare	0.04	0.07	0.07	0.69	0.125	14	0.150	12
Tawang	0.06	0.06	0.06	0.47	0.119	15	0.122	14
Tirap	0.06	0.06	0.06	0.56	0.126	13	0.126	15
Upper Siang	0.06	0.06	0.75	0.37	0.255	7	0.255	5
Upper Subansiri	0.06	0.07	0.07	0.5	0.128	12	0.135	13
WestKameng	0.08	0.08	0.08	0.23	0.050	16	0.050	16
WestSiang	0.06	0.06	0.82	0.43	0.277	3	0.277	3

(HI: Hazard Index, I:Vulnerability Index, EI:Exposure Index)

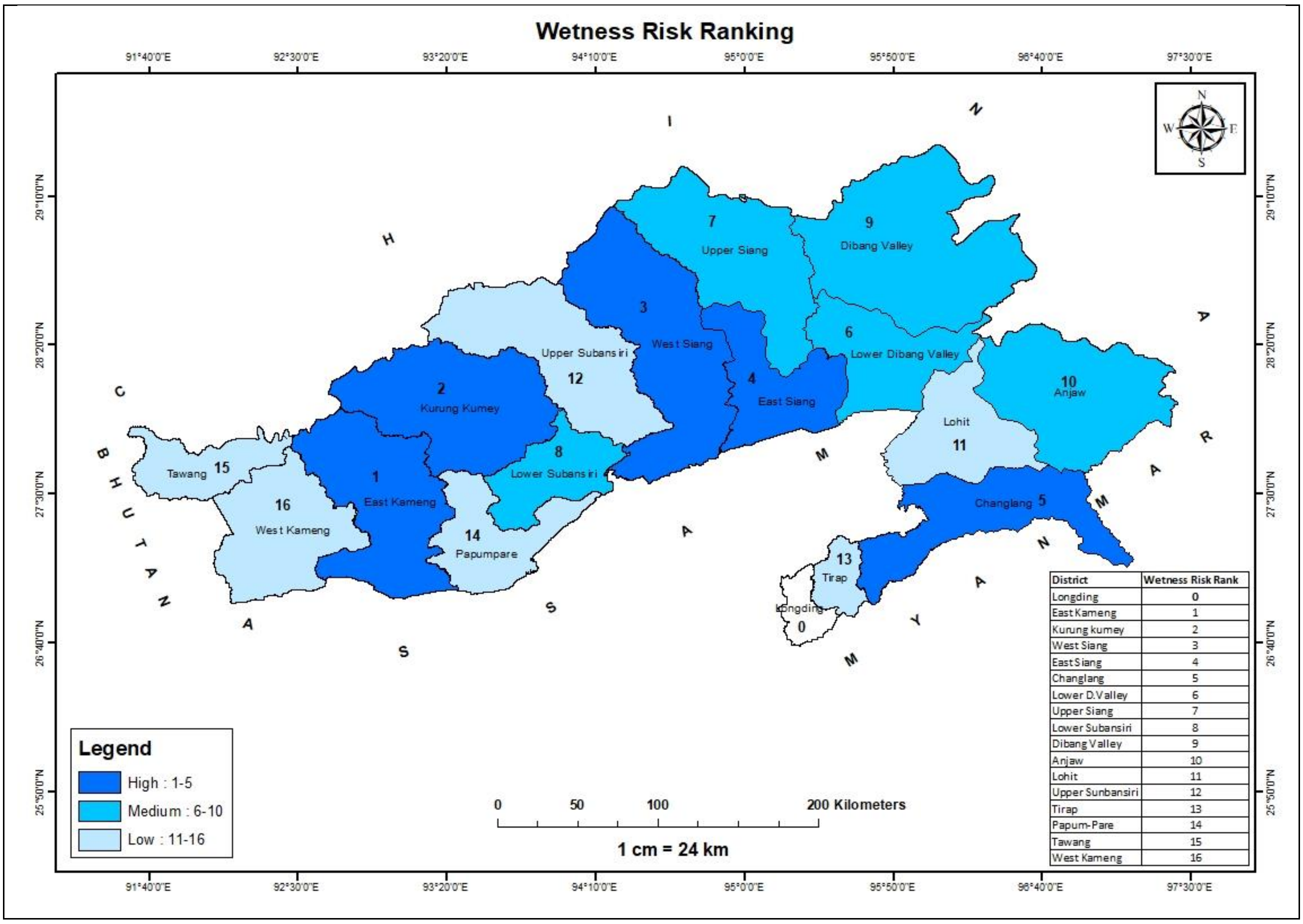


Figure 13: Distribution of districts based onWet Risk Index on a risk scale of Lowto High

Based on Wetness Risk index value, the districts of Arunachal Pradesh have been divided into three (3) categories which have been shown clearly in above map.The categories are:- High:1-5 ranks , Medium:6-10 ranks ,and for low:11-16 ranks, and for Longding district shown as zero(0) rank due to non availability of data.

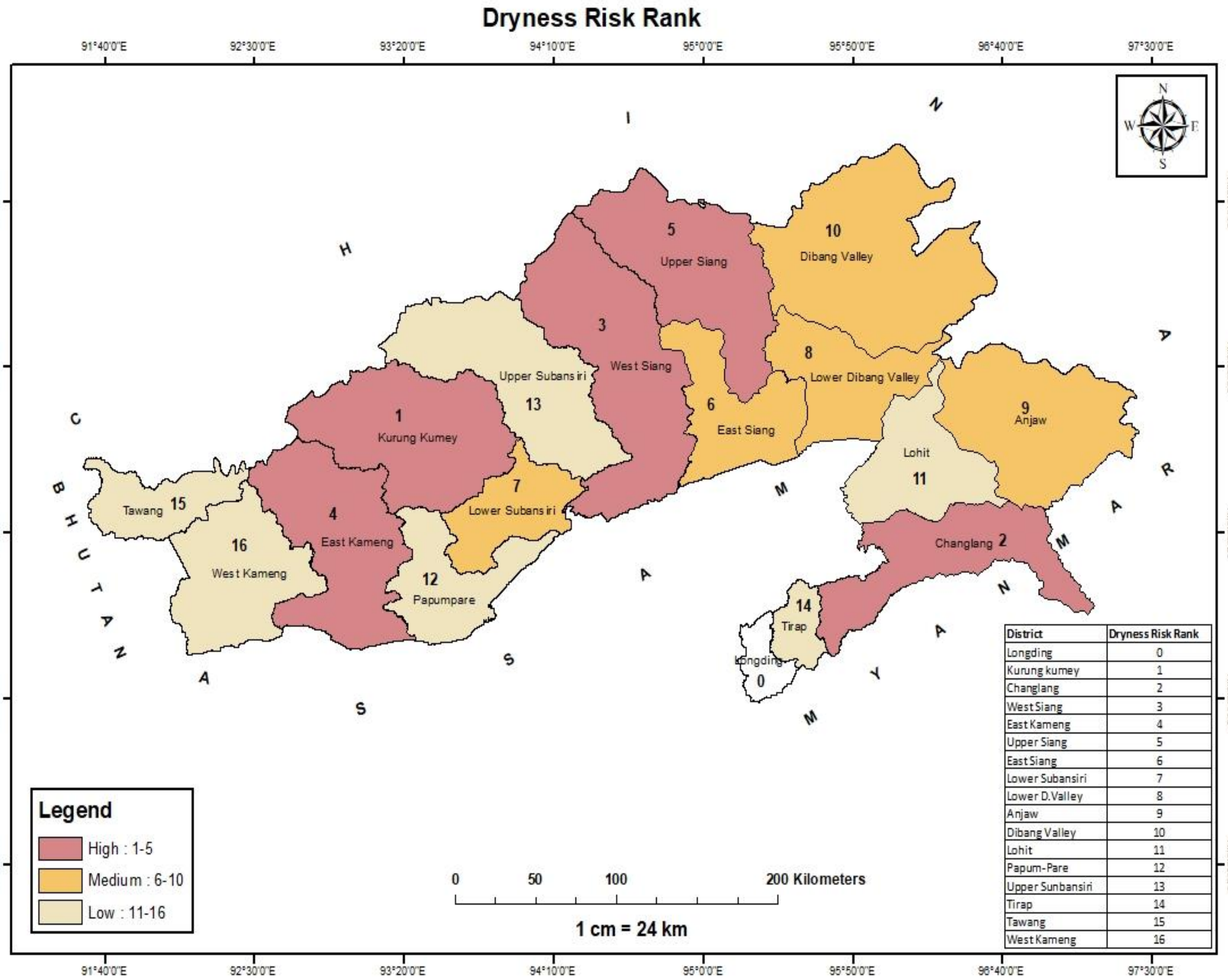


Figure14:Distribution of districts based on Dryness Risk Index on a risk scale Low to High

Based on Dryness index value , the districts of Arunachal Pradesh have been divided into three(3) category as shown clearly in above map, as for High:1-5 ranks , Medium:6-10 ranks ,and for low:11-16 ranks, and for Longding district shown as zero(0) rank due to non availability of data.

The Index for Wetness and Dryness, Vulnerability Index (VI) and Exposure Index (EI) of all the 16 districts of the state Arunachal Pradesh have been identified to further derive the Wetness and Dryness Risk Index ranks (Table 9). East Kameng has been identified as the highest Wetness risk district of Arunachal Pradesh followed by Kurung Kumey & West Siang. Whereas, West Kameng,Tawang and Papum Pare are the least wet districts.

Similarly,based on the Dryness Risk Index, Kurung Kumey district has the highest dryness risk rank followed by Changlang & West Siang,whereas West Kameng, Tawang & Tirap districts are the least dryness districts of Arunachal Pradesh.

least dryness risk is in the Drivers of ClimateRisk

Biophysical Drivers

Climate change threatens biodiversity directly by influencing biophysical variables that drive species' geographic distributions and indirectly through socio-economic changes that influence land use patterns, driven by global consumption, production and climate.Physical risk drivers are changes in both weather and climate that impact economies. They Can be categorized as acute risks, which are related to extreme weather events, or chronic risks associated with gradual shifts in climate. These drivers may appear with a significant time lag, and the frequency and severity of each type of risk may also vary considerably and become increasingly difficult to predict. While human activity and decisions affect exposure to physical climate risks, the location, timing and magnitude of specific physical events cannot be controlled.

In this study, some of the biophysical drivers considered for determining EI are percentage of land with slope greater than 30^0, percentage of land under agricultural use,share of horticulture in agriculture,forest area/1000 population,road density etc.Horticulture, forest cover and road density have negative adaptive capacity with respect to vulnerability index.

The steep topography feature implies lack of availability of flat and difficulty in access, likely to be adversely affected during floods, landslides, etc. Also, infrastructure ontheslopesislikelytobeimpactedmorebythe hazards. Therefore, if more area is exposed more will be the risk to population and infrastructure in the sloped area. Majority of the districts in the state of Arunachal Pradesh have a high percentage of land with slopesgreaterthan30^0.ThismakesthestateofArunachalPradeshmorepronetoriskofexposure.East Kameng and Kurungkumey districts have the highest percentage of landwith slopes greater than 30°. Both the districts fall under top ten districts prone to risk of exposure(Table 7).

Higher exposure of the land under agriculture use to the hazard such as flood,drought, more will be the risk of low food production. Changlang and East Siang districts have the largest area under agricultural use. Both the districts fall under top five districts prone to risk of exposure (Table7).

Horticulture trees are hardy and more resilient to climate variations compared to agricultural crops.They Provide alternative income sources to Agriculture.Once Established they are far less sensitive to the impacts of climate risks, particularly rainfall variability and droughts (IHAP, 2019). The share of horticulture produce with respect toagricultureproduceishighestforChanglangandLohitdistrict.Therefore,thesetwodistrictsareleastpronetovulnerabilityrisk.Whereas,the share of horticulture produce with respect to agriculture produce is least in the district of East Kameng making it more prone to risk of vulnerability (Table8).

Forests are an important source of alternative livelihood and food through the extraction of non-timber forest products.Under Extreme Weather Events,the role of transport becomes crucial.The indicator focuses on accessibility and connectivity and provides the idea of the overall development region.The Forest area cover per thousand rural populations is highest in Dibang valley and least in Papum Pare district.Dibang valley district is therefore least vulnerable and PapumPare district being one of the most vulnerable districts (Table 8).

Under extreme weather events, the role of transport becomes crucial. The indicator focuses on accessibility and connectivity and provides the idea of the overall development of a region. The highest road density is found in the Tawang district and least in Dibangvalley. Tawang district is comparatively less vulnerable than Dibang Valley district (Table8).

Socio-economic drivers

The socio-economic drivers considered in this study are population density, percentage ofBPL and livestock population per 1000 rural households. Population density has a positive relation with respect to exposure index. Percentage of BPL and livestock population per1000 rural households also has positive sensitivity to vulnerability index.

More population is exposed to any event, the more vulnerable the system will be and thus there will be high risk. Papumpare and Tirap districts are the most densely populated districts in the state.Both Districts Therefore Fall under top five districts prone to exposure risk (Table 7). Whereas, Dibang Valley is the least densely populated district andis therefore least prone to exposure risk.

People with extremely low incomes are among the most vulnerable. They have little to no financial capital, so they have the least capacity to adapt to the impacts of climate risk(O'Brien,et.al. 2008).HighestpercentageofBPLisfoundinthedistrictofKurungKumey and the least is in Anjaw and Lohit districts. Kurung Kumey is therefore most prone to vulnerability whereas Lohit Is the least vulnerable district (Table8).

Live stocks are an important source of alternative livelihood and have a positive sensitivity to vulnerability index. The livestock population per 1000 rural households is highest forLohit, East Siang, and Lower Diabng Valley districts.

These districts are least vulnerable districts (shown in Table).

5. ApplicationofRiskIndexandMapsattheDistrictlevel

Risk indexing is a useful and powerful tool that can provide valuable information the risks associated with climate change for identifying for sectoral level vulnerabilityAssessmentof the districts for taking up steps for responsive action.Risk Indexing ,Risk Assessments & Mapping at the district level based on available secondary data provide an opportunity to have a systematic and comprehensive perspective of the climate change risks that can be prioritized on an urgent basis and for appropriate adaptation measures that can be provided for efficient management for future.Creating a risk map forces organizations/govts etc., to identify the risks that could threaten the man and their possible impact and likelihood. The vulnerability ranking can clarify priorities to help them get ahead of issues before they threaten organization's operations, creating a risk map also facilitates interdepartmental dialogues about issues of climate change risk. It forces greater collaboration between the risk function and other departments within an organization as they must all work together to identify,prioritize and visualize risks.Such,a risk map can help visualize how risks in one part of the organization/sector can affect the other.

Thus, climate risk assessment, indexing & mapping is the foundation tool for effective climate risk management for identification of any important sectors within the block/district or state. A risk map also adds precision to an organization's risk assessment strategy and identifies gaps in an organization's risk management processes.

By identifying risk and assessing the magnitude of impacts on people, assets, value chains,infrastructure, settlements, and ecosystems, climate risk assessment informs decision makers on possible options for action. Thus, vulnerability and risk assessment for a given region of interest is a critical first step in addressing climate change,through development and implementation of adaptation resilience policies,programmes and projects. Following are the advantages of risk indexing & mapping:

- ❖ Prioritizing and allocating resources
- ❖ Identifying the need for more refined risk assessments
- ❖ Encouraging community-level risk communication and engagement
- ❖ Educating homeowners and renters
- ❖ Informing long-term community recovery

- support collaboration between the organization's risk function and other functional departments, which have greater visibility into risk due to the riskmap;
- developing riskmaps can help organizations demonstrate a comprehensive,well-aligned risk management strategy to insurance companies gain more favorable premiums;
- encourage shared strategic decision-making on risk issues;
- effectively focus on improving risk management and risk governance;

State Govt.Departments For Prioritizing Adaptation

TheIntergovernmentalPanelonClimateChange(IPCC)define adaptations adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities' (McCarthy etal., 2001, p.982). Adaptation may be technological, behavioral, financial, institutional or informational in nature, and occur in a variety of forms, including anticipatory, passive,reactive, proactive, autonomous, spontaneous or planned/purposeful (Carter et al., 1994;Smith, 1997; Smit et al., 2000; Fankhauser et al., 1999; Smith and Lenhart, 1996; Smit etal.,2000).In addition,Tompkinsetal.(2010,p.630)haveclassifiedadaptationactionsas
a)Building Adaptive Capacity-where activities may include research,planning,networking, awareness raising, training and advocacy; b) implementing adaptation, and c)developing supportive legislative and policy frameworks.

There is increasing recognition that organizations, particularly in key infrastructure sectors,are potentially vulnerable to climate change and extreme weather events, and require organizational responses to ensure they are resilient and adaptive.However,detailed evidence of how adaptation is facilitated, implemented and reported, particularly through legislative mechanisms slacking.The United Kingdom Climate ChangeAct(2008),introduced the Adaptation Reporting Power, enabling the Government to direct so-called reporting authorities to report their climate change risks and adaptation plans. We describe the authors' unique role and experience supporting the Department for Environment, Food and Rural Affairs(Defra)during the Adaptation Reporting Power's first round.An Evaluation Framework,used to review the adaptation reports,is presented alongside evidence on how the process provides new insights into adaptation activities and triggered organizational change in 78% of reporting authorities, including the embedding of climate risk and adaptation issues.The role of legislative mechanism sandisk-basedapproachesin driving and delivering adaptation is discussed alongside future research needs, including the development of organizational maturity models to determine resilient and well adapting organizations.TheAdaptation Reporting Power Process Provides Basis For Similar Initiatives in other countries, although a clear engagement strategy to ensure buy-in to the process and research on its long-term legacy, including the potential merits of voluntary approaches, is required.

For Project Adaptation Development

An adaptation project can result in a variety of outputs, including sartorial and integrated policy analysis and implementation. A typical adaptation project will identify adaptation strategies, policies, and measures aimed at different levels of society for different spatial and temporal scales.

The adaptation policies and measures that play an important role that influence the ability to successfully cope with climate variability, including the effectiveness of those policies and measures understanding the adaptations in place to cope with current climate risks is necessary to inform the development of adaptations to manage future climate risks that the system possesses,be it any sector of any region. The output from this activity forms a preliminary adaptation baseline that describes the policies and measures in place to reduce vulnerability.This involves identifying the autonomous and planned adaptations currently implemented to address climate risks in the priority system, including the level at which these have been implemented (national, regional and community level), their effectiveness and any barriers to their implementation. Also, it will help identify institutions that can support implementation adaptation policies and measures. This evaluation will facilitate proper ways of understanding the past,how policies and measures in place could be improved, and what strategies, policies and measures might be necessary in the future can be prioritized according to need as per the assessment findings in various sectors for all districts / blocks and state as a whole.

By this, the state can take a broad perspective and include relevant policies and measures that were designed to address other problems that are relevant to climate change risks.

The present vulnerability RiskAssessment methodology provides guidance on conducting an assessment of adaptive responses to historic climate risks, and on developing the relationship between current climate risks and adaptive responses that can be used to calculate future climate risks that would help the user to define adaptation strategies, policies and measures relevant to the climate risks in system which need urgent attention.

Donors

The Project for Strengthening of State Climate Change Centre/Cell -Arunachal PradeshunderNational Mission for Sustaining the Himalayan Ecosystem(NMSHE) is being supported by the Department of Science & Technology, Ministry Of Science & Technology, Govt.ofIndia.

Developmentoftargetedadaptationstrategiesandpractices

Based on consultations with stakeholders and experts three strategies were evolved to deal with strategic knowledge management in the state. Across the three strategies, a total of 16 actions are proposed to be implemented till 2030.

All proposed actions under the aforementioned strategies are further categorized into classes based on their type of climate actions i.e., adaptation centric, mitigation centric or both. Similarly the nature of actions is classified into Implementation, Policy, Research and Capacity Building focused.

With improved knowledge management in decision making and resilience will be increased.Hence,out of 14 actions proposed in the strategic knowledge management sector 94%are adaptation centric.Considering the importance of research for Mainstreaming innovation 38 percent of action areas are research focused.

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