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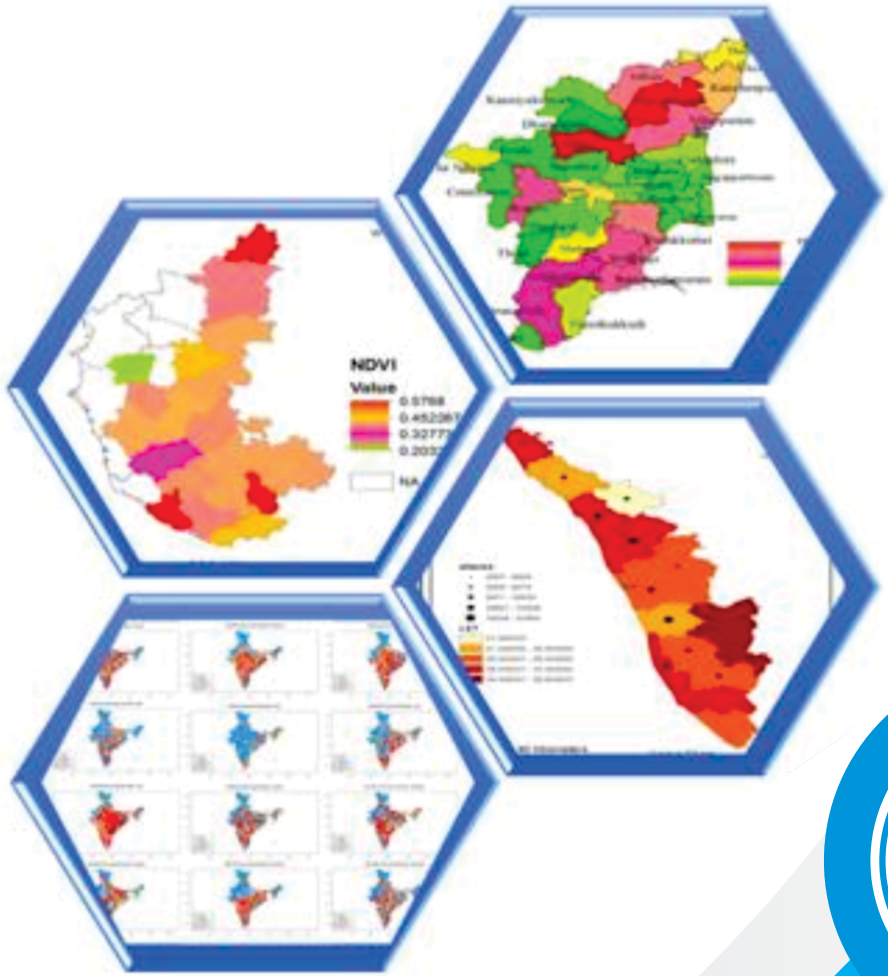
ICAR-National Institute of Veterinary Epidemiology & Disease Informatics (NIVEDI)
National Innovations on Climate Resilient Agriculture (NICRA) Consolidate Report

Period : February 2015 to March 2019



NICRA

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Front page: Maps prepared under NICRA project
Back page: ICAR NIVEDI institute image

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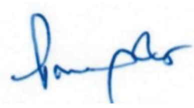
I am happy to know that this institute has prepared the consolidated report of the work done under NICRA project from the inception to 31st March 2019. In the recent past there are reports on the climate change and their influence on the livestock disease occurrence mainly on the vector borne diseases. Further, the analysis of weather and remote sensing data will help in geographical surveillance of livestock diseases and their influence on disease occurrence. Environmental condition prevailing in the world is indistinguishably linked to human and animal health. Environment favors transmission of pathogens to the susceptible host and to cause the disease. Hence it is important to study the environmental parameters that influence the occurrence of the diseases which can be extracted from various sources. This ICAR NIVEDI consolidated report under National Innovation in Climate Resilient Agriculture (NICRA) project emphasizes on the various achievements accomplished under NICRA project during 2015-2019. Vector maps were designed and weather parameters studied for a period of 10 years to study the livestock disease occurrence patterns. The livestock disease risk maps have been prepared for the vector borne parasitic diseases of livestock which will help the policy makers in making the informed decisions on control and prevention of these diseases.

The information on remote sensing and disease-climate modeling has been generated under this project will also help in better correlation of vector borne disease occurrence and its relation to the climate change. I am appreciating the significant contributions made by NICRA project team of scientists, senior research fellows and project assistants for preparing this consolidated report with salient achievements under this project.



(Parimal Roy)

CONTENTS

PREFACE

The environmental variables are very crucial in determining the epidemiology and transmission pattern of infectious diseases and analyzing these variables will enhance the accuracy of disease prediction that ultimately helps to implement timely and effective control measures. The emergence of Remote sensing satellites provided a wide array of environmental variables at different spatial and temporal scales which created an avenue to increase our understanding about the correlation between diseases and a variety of environmental/climatic variables. Remote sensing offers the ability to observe and collect data for large area as relatively quickly, and is an important source of data for Geographical Information System (GIS). The generation of remote sensing data manually is a difficult task since it demands handling of huge data that require more time, manpower, storage space etc. The extraction of these variables from the remote sensing data products and databases are made easy by the use of software like R, an open source software available to all the researchers. R is designed for statistical computing, with thousands of packages that contain the implementations of almost every available statistical method. R is an integrated suite of software facilities for data management, calculation and graphical display.

This manual state the importance of understanding the climate variables influencing the livestock disease incidence and the change in the climate profoundly alters disease dynamics. Climate-disease models and risk maps to predict the disease occurrence are developed using R software.

This manual will help the researchers in the field of climate change studies and its relationship to livestock diseases and animal health. We thank the Deputy Director General (AS), ICAR, New Delhi and our Director for their support and encouragement in bringing out this manual. The editors thank the National Innovations in Climate Resilient Agriculture (NICRA) project for providing funds and support in preparing this manual.

K. P. Suresh
P. Krishnamoorthy
Siju Susan Jacob

National Innovations on Climate Resilient Agriculture (NICRA)

NICRA Project Team from ICAR NIVEDI

Phase I- From 24th February 2015 to 31st March 2017

- Principal Investigator (Earlier)
  1. Dr. B.R. Shome, Principal Scientist

- Co-Principal Investigators
  1. Dr. K.P. Suresh, Principal Scientist
  2. Dr. P. Krishnamoorthy, Scientist

Phase II- From 1st April 2017 to 31st March 2019

- Principal Investigator (Present) -
  1. Dr. K.P. Suresh, Principal Scientist

- Co-Principal Investigators
  1. Dr. P. Krishnamoorthy, Senior Scientist
  2. Dr. Siju Susan Jacob, Scientist

Details of Research staffs worked under this project

Name of Staff	Area of Specialization	From	To
Senior Research Fellows			
Dr. Ashwini M.	Masters in Veterinary Science	15-12-2017	29-07-2018
Mr. Sudhagar S.	Masters in Biotechnology	23-10-2017	24-09-2018
Mr. Kiran Kumar	Masters of Computer Applications	1-01-2018	1-07-2019
Ms. Rashmi R. Kurli	Masters of Technology in Industrial Biotechnology	28-11-2018	16-09-2019
Mr. Dharshan H. V	Masters of Computer Applications	31-08-2019	Till date
Mrs. Shinduja R.	Masters of Technology in Biotechnology	22-10-2019	Till date
Young Professional II			
Mr. Mainak Mondal	B.E Biotechnology	24-05-2018	23-08-2019
Project Assistants			
Mr. Nithin Kumar	B.com	19-11-2018	31-07-2019
Ms. Amulya R. L	M. Sc in Agricultural Biotechnology	14-10-2019	14-11-2019

Introduction (Highlight importance of climate change and its relevance to the project activities under NICRA)

The burden of infectious diseases of livestock is alarmingly increasing. As the scientific evidence of climate change is unequivocal, the challenge of reducing the incidence and transmission of infection diseases in livestock is a growing concern especially in developing countries. As it is envisaged that climate change is profoundly modulating the survivability and transmissibility of pathogens, the situation of emergence of new species or strains of pathogen with increased virulence and shift in the geographic distribution of diseases especially vector borne diseases may be anticipated in the near future. A better understanding of disease incidence with respect to climatic variables is essentially required for speculating the future incidence trends with respect to climate change. In order to establish the link between climate change and infectious diseases, it demands (i) examining the evidence for association between climate variability and incidence of disease from recent past, (ii) determining early indicators of already emerging infectious diseases and (iii) use of above mentioned evidences to create predictive models to estimate future burden of infectious disease under projected climate change scenarios. In order to understand the effect of climate change on infectious diseases both statistical and mathematical models have imperative roles to play; statistical models generally use descriptive correlations between explanatory (climate change) and response (disease incidence) variables to predict the future trend. Such models may not be suitable for underpinning the biological mechanisms behind the predictive changes. On the other hand, mathematical models following a process-based approach by combining different environmental, epidemiological and biological process to formulate assumptions that characterize models. Further, model calibration and validation may provide reliable means to predict short term and long-term disease dynamics.

Brief Technical Program (activity wise)

PHASE I

Title: Livestock Disease Surveillance in relation to weather data and emergence of new Pathogen

Objectives

- Development of threshold levels of climate variables on incidence of livestock disease.
- Developing correlation index between the climate variables, risk factors and incidence of livestock diseases.
- To establish any phenotypic and molecular changes in isolates and identification of new circulating pathogens in these area under changing environment.
- To study the economic impact and strategies adopted by livestock farmers to climate change.

Technical Program

Objectives:

1. Development of threshold levels of climate variables on incidence of livestock disease

   Activity-1: Identifying the study area with homogenous regions with respect to climatic condition

   Activity-2: Observation and measurement of climatic variables in relation to occurrence of livestock diseases

   Activity-3: Development of threshold values like wetness index, vegetation index and temperature

2. Developing correlation index between the climate variables, risk factors and incidence of livestock diseases

   Activity-1: Measurement of risk factor and risk map for livestock disease for occurrence of livestock disease in selected regions

3. To establish any phenotypic and molecular changes in isolates and identification of new circulating pathogens in these area under changing environment

   Activity-1: Collection of clinical samples, epidemiological data from selected areas of disease outbreaks

   Activity-2: Isolation and molecular epidemiology of pathogens

   Activity-3: Diagnosis and characterization for endemic and new emerging livestock diseases using conventional and molecular approaches

4. To study the economic impact and strategies adopted by livestock farmers to climate change

Activity-1: Collection of primary and secondary data.

Methodology:

Climatic Change analysis

It was carried out for the following states- Assam, Karnataka, Tamil Nadu, West Bengal, Kerala and Telangana

Results:

- Ecological variables like presence of waterbodies, forest coverage, elevation/slope, land use/land cover pattern was collected.

[I] ASSAM

1. Modeling the Outbreak of FMD using Climatic Factors in State of Assam.

The NDVI mean value was found to range from 0.39 to 0.72 and mean LST range from 21. 05 to 32.55 as depicted in Tables below.

Assam DISTRICT	NDVI		LST		NDVI (1 month lag)		LST (1 month lag)	
	Mean	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Baksa	0.51	0.08	29.46	1.57	0.64	0.09	30.05	1.01
Barpeta	0.54	0.06	28.67	1.23	0.58	0.04	28.06	0.92
Bongaigaon	0.53	0.05	29.89	2.30	0.52	0.06	28.11	1.28
Cachar	0.46	0.04	26.70	0.41	0.58	0.09	26.86	0.32
Darrang	0.61	0.03	29.93	1.13	0.54	0.04	30.21	1.28
Dhubri	0.39	-	27.19	-	0.45	-	28.55	-
Dibrugarh	0.72	-	22.31	-	0.55	-	26.27	-
Goalpara	0.52	0.02	30.31	0.51	0.57	0.02	31.34	0.69
Golaghat	0.42	0.02	23.77	1.07	0.60	0.04	22.88	0.78
Jorhat	0.46	0.04	28.24	2.06	0.55	0.01	27.34	2.58
Kamrup	0.51	0.03	26.78	0.54	0.54	0.03	26.65	0.61
Kamrup Rural	0.69	-	32.55	-	0.68	-	29.93	-
KarbiAnglong	0.50	0.00	26.28	0.57	0.57	0.05	23.68	0.59
Karimganj	0.56	0.03	26.16	0.15	0.60	0.00	26.44	0.13
Lakhimpur	0.49	-	21.05	-	0.75	-	23.81	
Morigaon	0.58	0.04	29.79	0.39	0.59	0.05	31.23	1.09
Nagaon	0.43	0.07	26.24	1.44	0.50	0.08	26.69	1.22
Nalbari	0.66	0.03	28.51	1.01	0.69	0.01	28.41	0.92
Sibsagar	0.40	0.14	29.79	1.04	0.58	0.18	22.84	0.37
Sonitpur	0.40	0.05	23.25	1.40	0.48	0.05	21.64	0.47
Tinsukia	0.47	-	31.23	-	0.49	-	26.63	-

Table 1.1 Mean Threshold values of climatic variables for FMD Outbreaks in the districts of Assam state (2005-2010).

Assam DISTRICT	NDVI		LST		NDVI (1 month lag)		LST (1 month lag)	
	Mean	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Barpeta	0.56	0.04	27.03	0.69	0.54	0.01	26.24	1.70
Bokakhat	0.72	-	32.13	-	0.72	-	32.13	-
Bongaigaon	0.47	0.04	22.12	1.02	0.56	0.05	25.25	0.49
Darrang	0.54	0.07	27.52	0.57	0.57	0.07	26.44	1.45
Dhemaji	0.71	0.05	24.94	1.29	0.76	0.07	26.77	0.30
Dhubri	0.58	0.11	27.56	2.15	0.53	0.10	25.69	4.02
Goalpara	0.40	-	30.65	-	0.43	-	26.03	-
Golaghat	0.34	0.15	28.03	0.98	0.35	0.15	26.51	2.30
Jorhat	0.62	0.03	27.49	0.81	0.53	0.03	28.21	0.83
Jorhat west	0.45	-	27.89	-	0.43	-	24.01	-
Kamrup	0.53	0.02	27.69	0.80	0.54	0.03	27.30	0.59
Kamrup (Rural)	0.50	0.07	31.25	2.60	0.57	0.06	30.62	1.51
Karbi- Anglong	0.47	0.10	33.29	1.82	0.40	0.06	27.81	2.20
Karimgang	0.53	-	30.19	-	0.59	-	30.19	-
Lakhimpur	0.66	0.00	26.11	2.06	0.70	0.05	26.73	0.80
Morigaon	0.54	0.02	32.81	0.32	0.40	0.03	30.27	0.42
Nalbari	0.50	0.05	29.12	2.52	0.45	0.02	27.30	3.03
Sivasagar	0.69	0.04	23.86	1.39	0.74	0.05	25.48	0.88
Sonitpur	0.60	0.04	27.61	1.22	0.58	0.06	26.60	0.99
Tinsukia	0.55	0.05	23.92	3.04	0.57	0.04	23.57	0.79
Udalguri	0.45	0.06	21.84	0.03	0.45	0.06	22.85	0.22

Table 1.2 Mean Threshold values of climatic variables for FMD Outbreaks in the districts of Assam state (2011-2015).

Risk Map for FMD

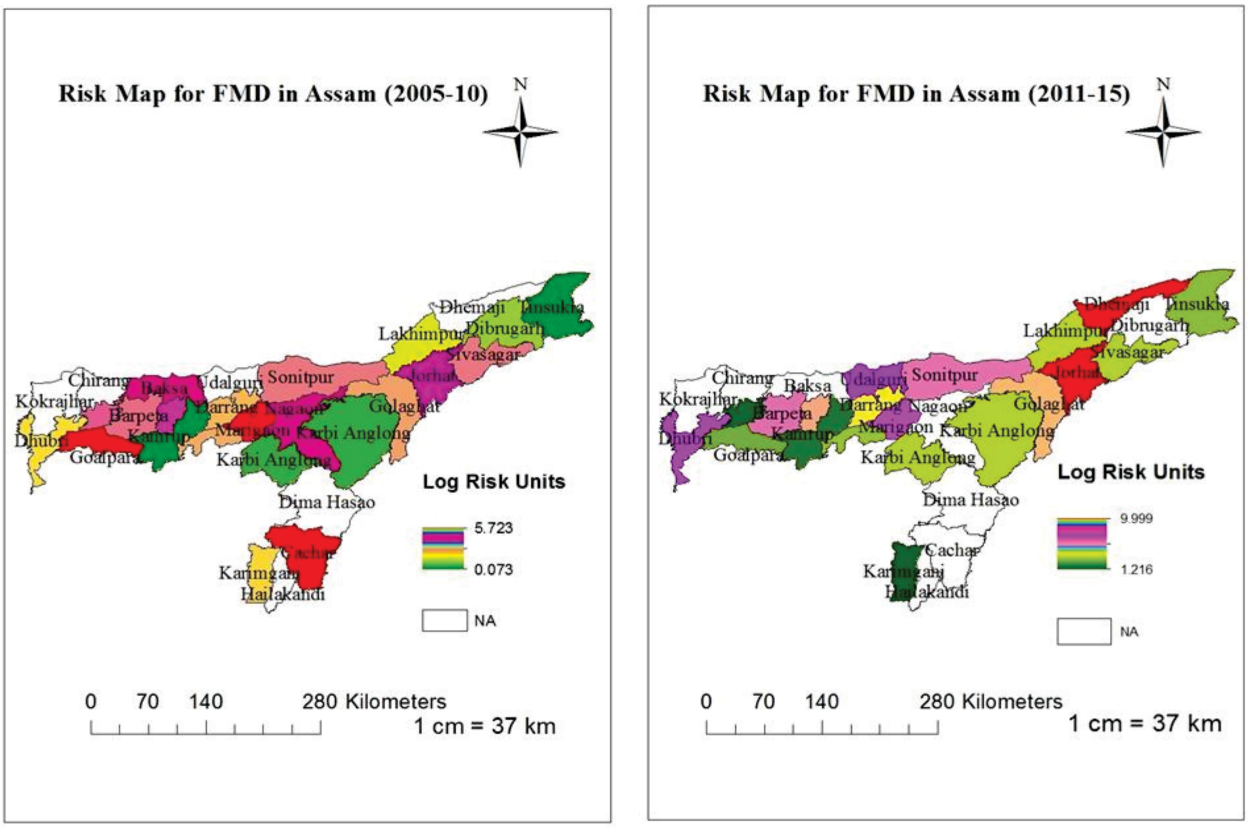


Fig 1.1: The risk map for FMD in Assam region.

[II] KARNATAKA

2. Development of Climate-Anthrax Relationship Models in order to understand the epidemiology of the Disease Data on Anthrax Outbreak in Karnataka State during the year 2000 - 2014.

To develop Climate-Anthrax relationship models in order to understand the epidemiology of the disease Data on Anthrax outbreak in Karnataka state during the year 2000 to 2014 was collected from department of Animal Husbandry and Veterinary Services, Government of Karnataka. A total of 337 Anthrax outbreak data in Karnataka state from the year 2000-2014 at village level has been extracted from Department of Animal Husbandry, Karnataka. Subsequently data on latitude / longitude has been generated.

Development of threshold levels of climate variables on incidence of livestock disease

Normalized Difference Vegetation Index (NDVI) (the numerical indicator that uses the visible and near-infrared bands of the electromagnetic spectrum, and is adopted to analyses remote sensing measurements and assess whether the target being observed contains live green vegetation or not) and Land Surface Temperature (LST) were accordingly measured using MODIS with overall average of 0.426 (NDVI) and 33.03 (LST). In the risk factor domain, the amount of rainfall, atmospheric temperature (min, max), soil type, soil nutrients and water resources were also collected retrospectively. Further, remote sensed variables like Normalized Difference Vegetative Index (NDVI) and Land surface temperature (LST) were collected using Moderate Resolution Imaging spectro-radiometer tools (MODIS Tools).

Risk maps during 2006-10 and 2011-15 was developed using Poisson regression model to understand the risk intensity patterns during quinquinneal period. The variables used for preparing PPR risk maps for Karnataka and Tamil Nadu are livestock population, rainfall, NDVI and LST. Risk pattern shifted from Gulbarga to Yadgir and Kolar during quinquinneal period.

The data on minimum temperature, maximum temperature, rainfall and humidity were collected from twenty-five Automatic weather stations located throughout India under NICRA project for the period January 2009 to December 2015 (seven years). Data obtained from five stations namely Anantapur, Bengaluru, Bijapur were analyzed for determining the pattern of change in weather parameters. There was not much variation in the minimum and maximum temperature, relative humidity in the five centers. However, the rainfall showed huge variation between the years over the period of seven years.

2.A Normalized difference vegetation index (NDVI):

For the date of outbreak, MODIS (Moderate Resolution Imaging Spectroradiometer) - NDVI image has been extracted from REVERB. The image was provided as an input in ERDAS Imagine. The pixel values were converted to index value (NDVI image X 0.0001) Subsequently from image the latitude and longitude reading was noted. Based on this latitude and longitude, the NDVI value was obtained. Classification of low to high vegetation was made based on vegetation index. We considered water as a negative value, 0-0.1 was considered as rock, soil and barren land. 0.2- 0.4 was taken as low vegetation, 0.41-0.6 as moderate and 0.6-0.8 as high vegetation (Fig. 1).

2.B Land Surface Temperature (LST):

For the date of outbreak, MODIS (Moderate Resolution Imaging Spectroradiometer)- LST image has been extracted from REVERB. The image was provided as an input in ERDAS Imagine. The pixel values (Kelvin format) were converted to centigrade (LST image X 0.002- 273.15 Kelvin). Subsequently from image the latitude and longitude reading was noted. Based on this latitude and longitude, the LST value was obtained (Fig. 2).

2.C Normalized Difference Wet Index (NDWI):

For the date of outbreak, LANDSAT-8 image has been extracted from Earth Explorer. The image was provided as an input in ERDAS Imagine. Subsequently model was constructed for NDWI calculation using (BAND 3-BAND5)/ (BAND3 + BAND 5). The results were obtained between -1 to +1. Subsequently from image the latitude and longitude reading was noted. Based on this latitude and longitude, the NDWI value was obtained we considered positive value as water and zero and negative value as soil and terrestrial vegetation (Fig. 3).

2.D Normalized Difference Moisture Index (NDMI):

For the date of outbreak, LANDSAT-8 image has been extracted from Earth Explorer. The image was provided as an input in ERDAS Imagine. Subsequently model was constructed for NDMI calculation using (BAND 5-BAND6)/ (BAND5 + BAND 6). The results were obtained between -1 to +1. Subsequently from image the latitude and longitude reading was noted. Based on this latitude and longitude, the NDMI value was obtained. Wetlands and other vegetated areas with high levels of moisture and barren area, deserts appear as low levels of moisture (Fig 4).

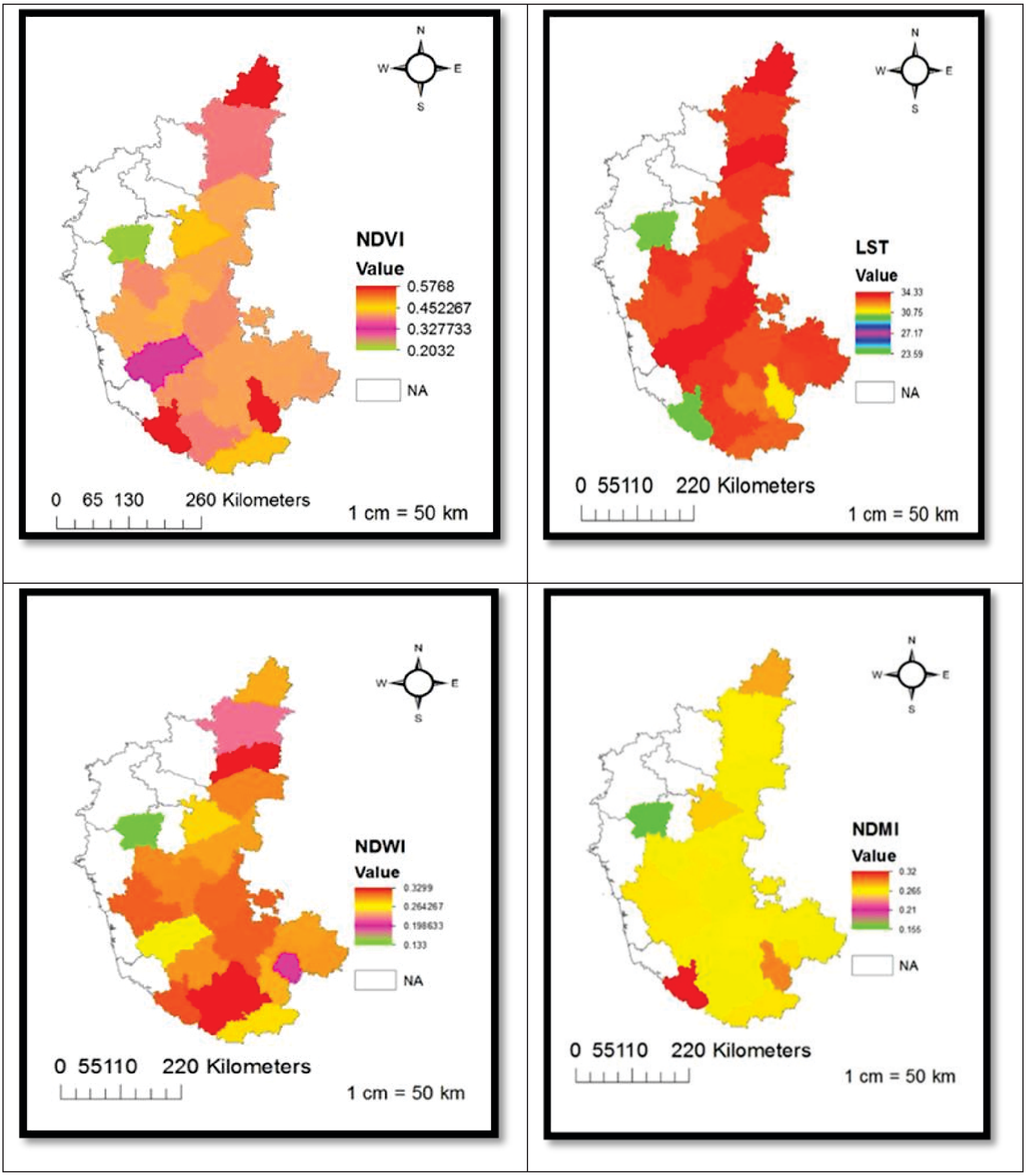


Fig 2.1: Maps showing the NDVI, LST, NAWI & NDMI of Karnataka region.

Table 2.1: Outbreak results and average LST, NDWI, NDMI and NDVI.

ST_NM	District	Outbreak results	Climate variables (RS data)			
			LST	NDWI	NDMI	NDVI
Karnataka	Kodagu	1	25.93	0.312	0.320	0.577
Karnataka	Ramanagara	8	31.03	0.286	0.297	0.523
Karnataka	Dharwad	1	23.59	0.133	0.155	0.203
Karnataka	Koppal	6	32.74	0.276	0.279	0.464
Karnataka	Mandya	13	32.42	0.330	0.270	0.424
Karnataka	Bangalore	6	32.98	0.256	0.276	0.422
Karnataka	Chamrajnagar	5	32.64	0.274	0.275	0.464
Karnataka	Shimoga	9	32.90	0.308	0.275	0.426
Karnataka	Tumkur	23	32.91	0.309	0.273	0.423
Karnataka	Davanagere	65	32.91	0.299	0.274	0.432
Karnataka	Gulbarga	10	33.09	0.259	0.273	0.405
Karnataka	Bellary	47	33.10	0.292	0.271	0.425
Karnataka	Chikkaballapura	263	33.15	0.291	0.271	0.424
Karnataka	Bangalore Rural	107	33.04	0.292	0.270	0.425
Karnataka	Mysore	3	33.14	0.324	0.269	0.406
Karnataka	Hassan	21	33.23	0.295	0.271	0.417
Karnataka	Haveri	6	33.21	0.297	0.270	0.413
Karnataka	Raichur	11	33.17	0.299	0.270	0.426
Karnataka	Kolar	59	33.13	0.293	0.269	0.419
Karnataka	Chikmagalur	1	34.01	0.265	0.274	0.364
Karnataka	Bidar	1	34.33	0.287	0.289	0.525
Karnataka	Chitradurga	29	33.49	0.306	0.269	0.413
Karnataka	Yadgir	2	33.94	0.327	0.273	0.404

Poisson Model:

$$log(outbreaks)= 0.9033-0.1091(NDVI) -0.0140(LST) -0.0001(NDWI) +1.2369 (NDMI)$$

Or

$$Outbreak=Exp\{0.9033-0.1091(NDVI) -0.0140(LST) -0.0001(NDWI) +1.2369 (NDMI)\}$$

The risk maps for Anthrax and PPR disease in Karnataka was prepared and given in the figures below.

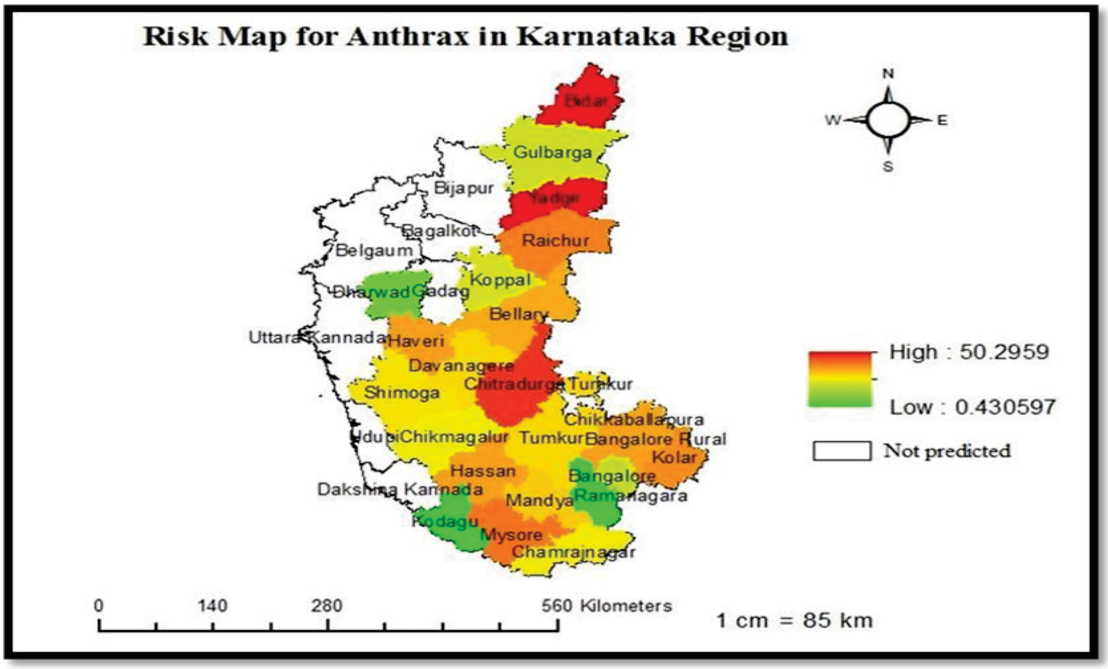


Fig. 2.2 Risk map for Anthrax in Karnataka Region.

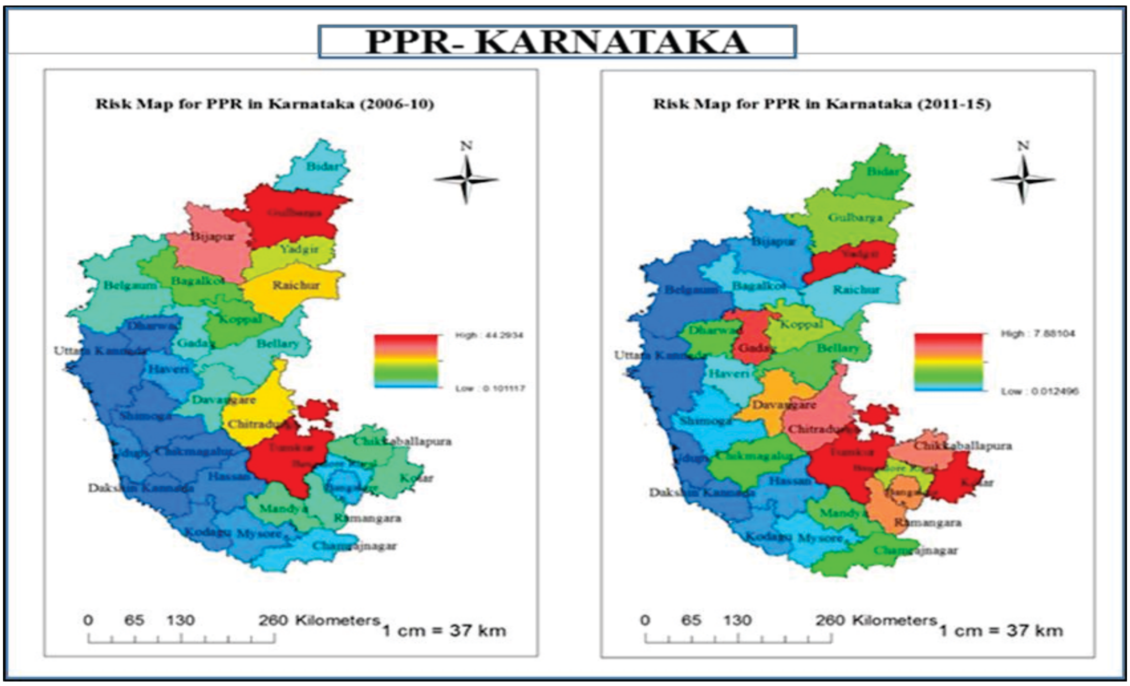


Fig2.3: Risk map of PPR in Karnataka region.

[III] TAMIL NADU

3. BIO-CLIMATOGRAPH ANALYSIS

Bio-climatographic analysis showed there was relationship between rainfall and livestock disease outbreaks for all the livestock diseases outbreaks.

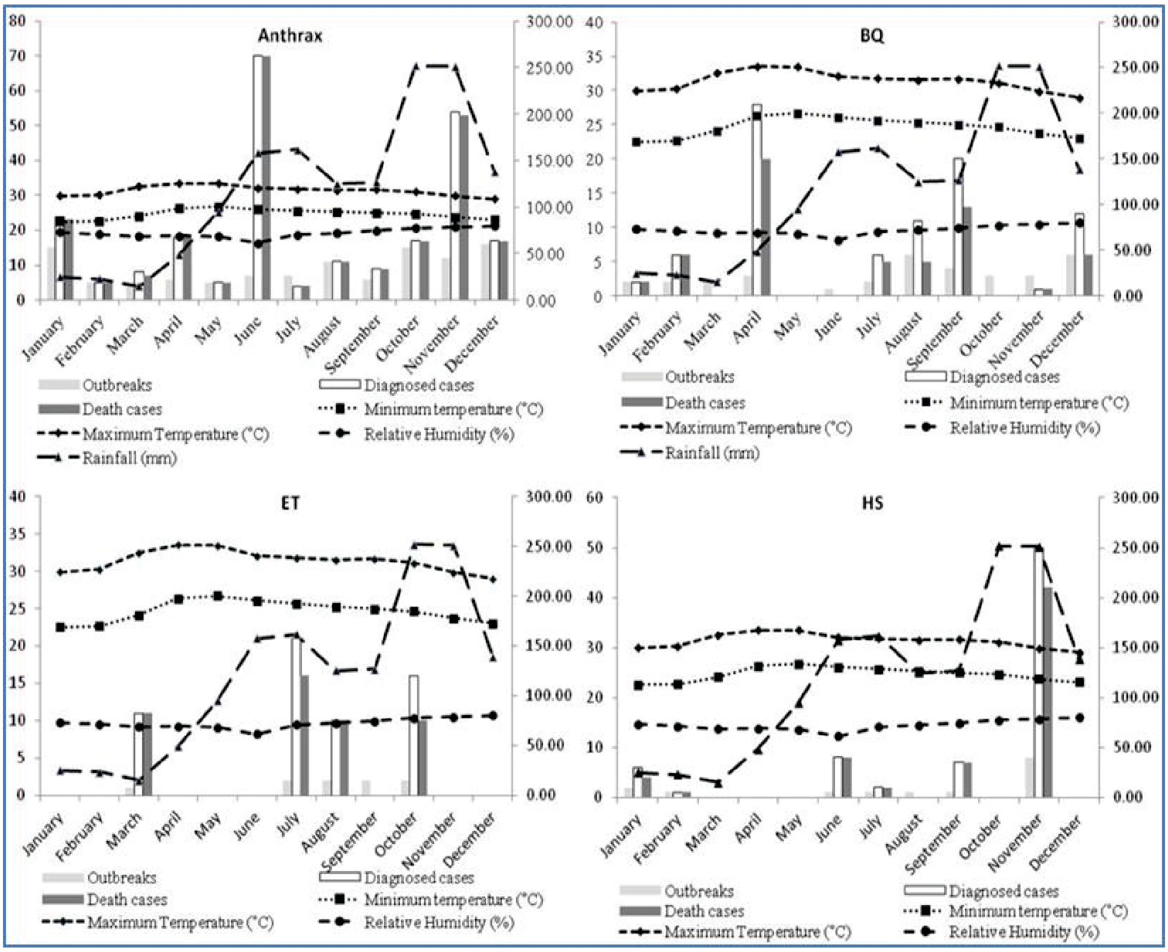


Fig 3.1: Bio-climatographs of bacterial diseases occurred in Tamil Nadu

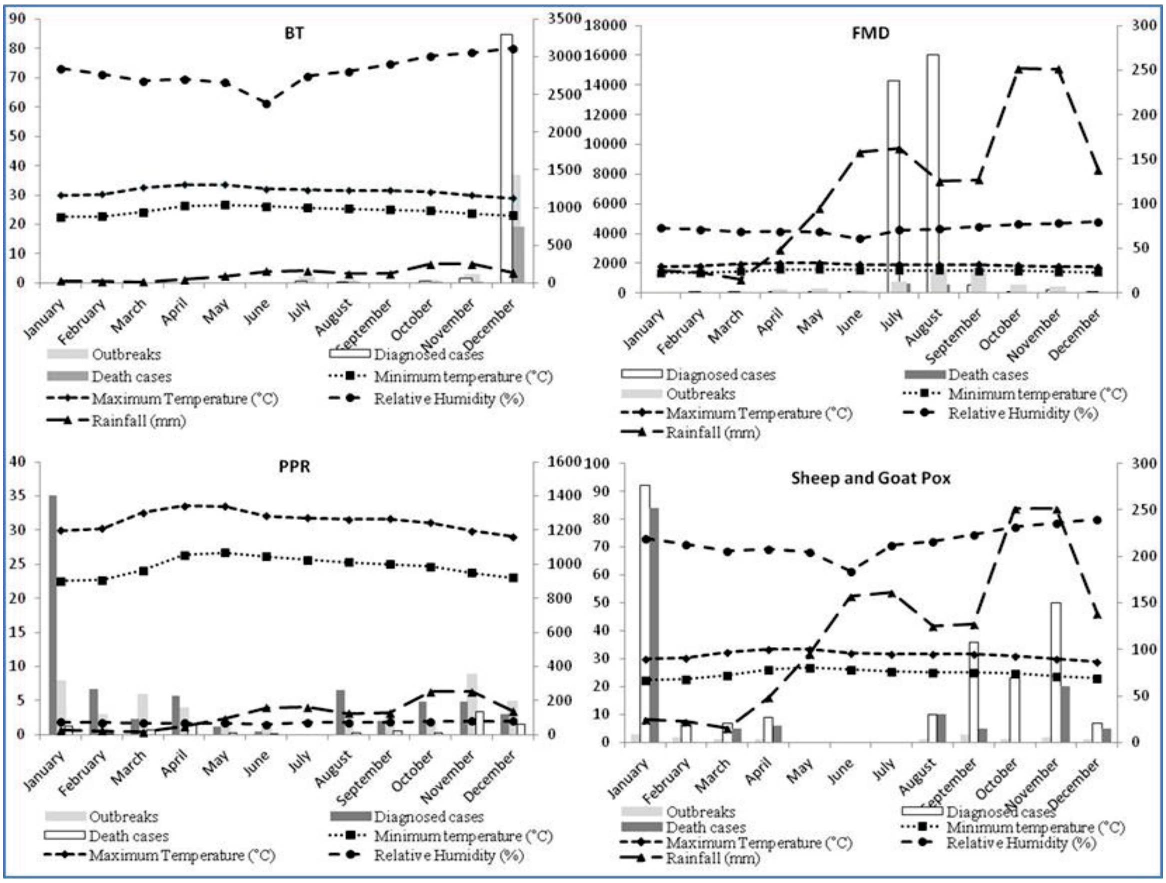


Fig 3.2: Bio-climatographs of viral diseases occurred in Tamil Nadu

3.1 EPIDEMIOLOGICAL ANALYSIS

The of eight livestock diseases was undertaken for Tamil Nadu state in India. Spatio-temporal data (2002-14) on outbreaks, diagnosed cases, death cases were collected and analyzed for season wise, zone wise and with weather parameters. Cumulative outbreaks revealed Anthrax(109) was high followed by Foot and mouth disease[FMD](99), Peste des petits ruminants[PPR](45), Bluetongue[BT](44), Black quarter[BQ](34), Haemorrhagic septicemia[HS](15), Sheep and Goat pox(15) and Enterotoxaemia[ET](9). Season wise analysis revealed highest number of outbreaks were during North east monsoon for all the diseases. Agro climatic zone and cluster analyses revealed that highest number of outbreaks occurred in North eastern and South zones. Bio-climatograph analysis showed there was relationship between rainfall and livestock disease outbreaks for all the diseases. It could be concluded that disease prevalence was high in Northeastern and South zone of Tamil Nadu and during north-east monsoon. Further, preventive vaccinations against anthrax, FMD, PPR have to be initiated in two zones before monsoon to mitigate the livestock diseases in Tamil Nadu state of India.

Risk Map of PPR in Tamil Nadu State during 2006-10 & 2011-15

The variables used for preparing PPR risk maps for Karnataka and Tamil Nadu are livestock population, rainfall, NDVI and LST. Further, in Tamil Nadu there was Government scheme for distribution of Sheep and Goats to the farmers and might have increased the occurrence of PPR outbreaks over the years.

Risk maps of PPR disease in Karnataka and Tamil Nadu showed risk intensity decreased by six times in Karnataka and increased by three times in Tamil Nadu. There is a need to control PPR.

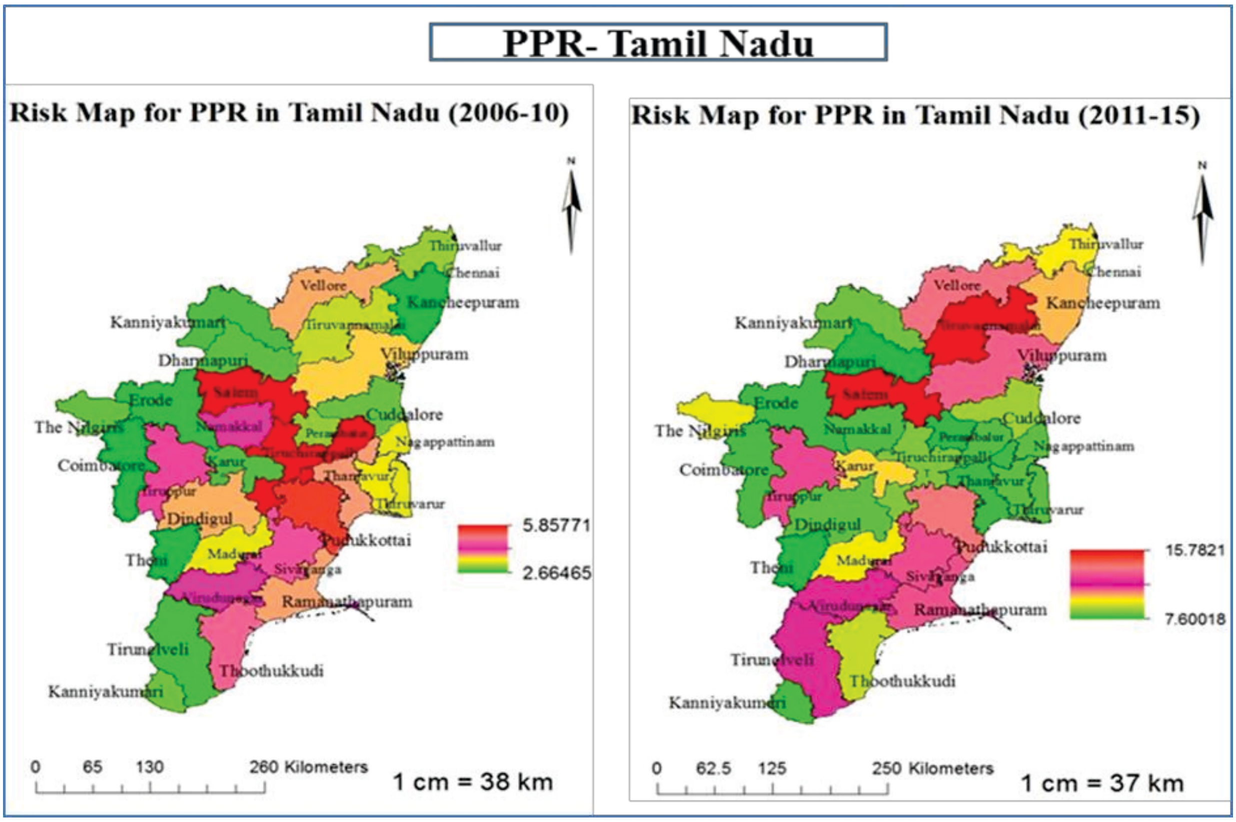


Fig 3.2.1: Risk map of PPR in Tamil Nadu region.

3.2 Intensity Maps were generated to know relationship of LST/NDVI and disease occurrence in the states of TELANGANA.

VIRAL DISEASES IN TELANGANA

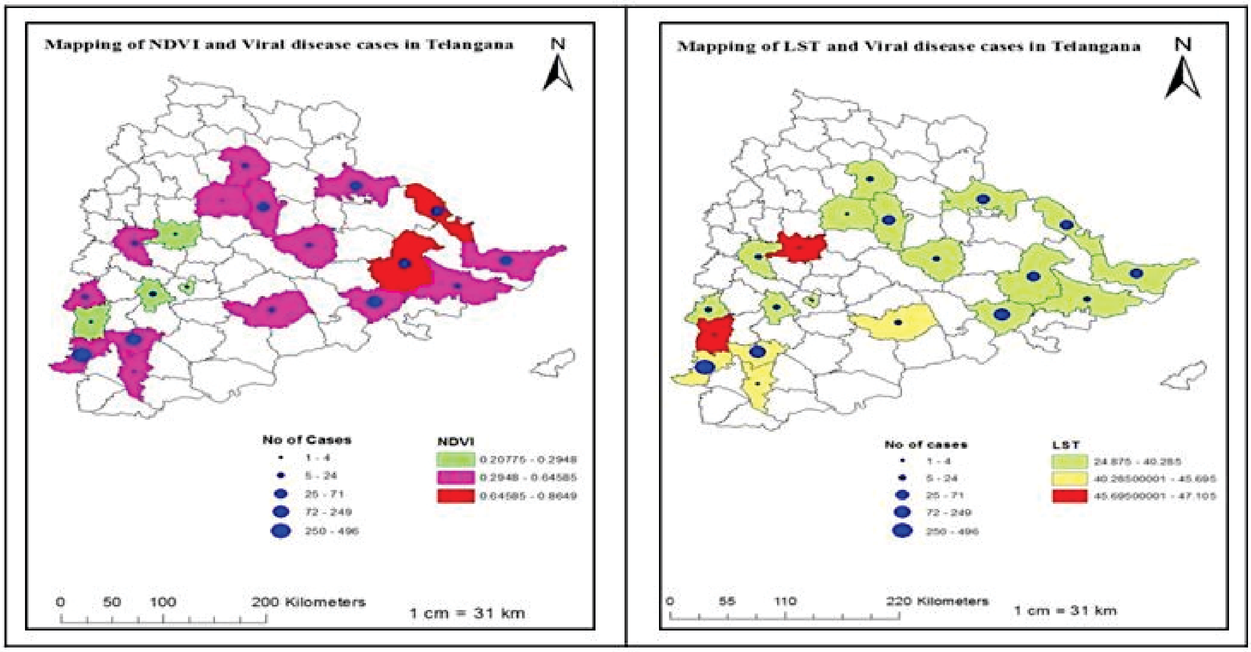


Fig 3.3.1: Intensity Maps for LST and NDVI of Viral diseases in Telangana.

BACTERIAL DISEASES IN TELANGANA

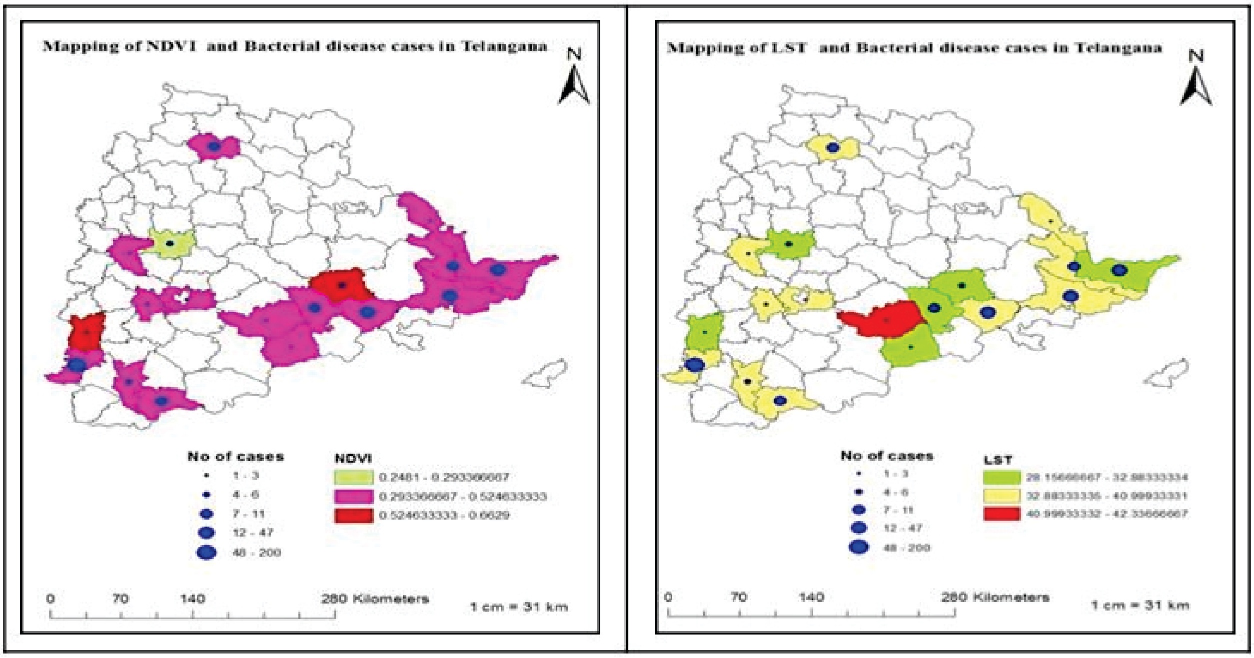


Fig 3.3.2: Intensity Maps for LST and NDVI of bacterial diseases in Telangana.

4. Modeling the outbreak of Parasitic Diseases using climatic factors in state of West Bengal

A total of 1622 cases reported for parasitic diseases (viz., Anaplasmosis, Theileriosis, Babesiosis and Trypanosomiasis) covering 262 villages in districts of West Bengal during 2009-2015 was linked to different climatic variables viz., NDVI, LST, Wind speed, Sea Level Pressure, Precipitation of Water, Relative, humidity, Temperature and Elevation. NDVI is correlating with positively with Wind speed, sea level pressure, R. Humidity, and precipitation. Similarly, LST is shown to correlate positively with R. humidity, air temperature, precipitation (Table 2).

		On time		Lag 1 month		Lag 2 month	
	Essential Climate Variable (ECV)	**r value**	**P value**	**r value**	**P value**	**r value**	**P value**
NDVI	**Wind speed**	0.10	0.11	-0.03	0.59	-0.03	0.68
	Sea level pressure	0.02	0.74	0.00	0.97	-0.08	0.20
	Precipitation of Water	-0.09	0.12	-0.01	0.92	0.10	0.10
	R. humidity	0.28	<0.0001	0.28	<0.000	0.33	<0.0001
	Temperature	-0.24	<0.0001	-0.22	<0.000	-0.06	0.35
	Pressure	-0.24	<0.0001	-0.20	0.00	-0.05	0.44
	Precipitation	0.00	0.90	0.08	0.19	0.15	0.01
LST	**Wind speed**	0.43	<0.0001	0.39	<0.0001	0.29	<0.0001
	Sea level pressure	0.04	0.56	0.01	0.85	-0.05	0.46
	Precipitation of Water	0.34	<0.0001	0.33	<0.000	0.49	<0.0001
	R. humidity	0.12	0.08	0.14	0.04	0.27	<0.0001
	Temperature	0.33	<0.0001	0.37	<0.000	0.41	<0.0001
	Pressure	-0.07	0.28	-0.03	0.70	-0.03	0.70
	Precipitation	0.41	<0.0001	0.37	<0.0001	0.51	<0.0001

Table 4.1: Correlation (NDVI vs. ECV and LST vs. ECV).

It was seen that the vegetation index, an integral part of land moisture, the temperature, rainfall etc to be significantly and positively associated with disease incidence and showing more significant association in two month lag of NDVI. The mean range of NDVI is 0.51, 0.52 and 0.53 respectively for lag2 month, lag 1month and current conditions respectively. Land surface temperature (LST) is negatively and significantly associated with disease incidence and mean of LST ranging from 23-24 °C. The risk map for parasitic diseases in districts of West Bengal is depicted in Fig 5. The climatic variables were found to range as depicted below.

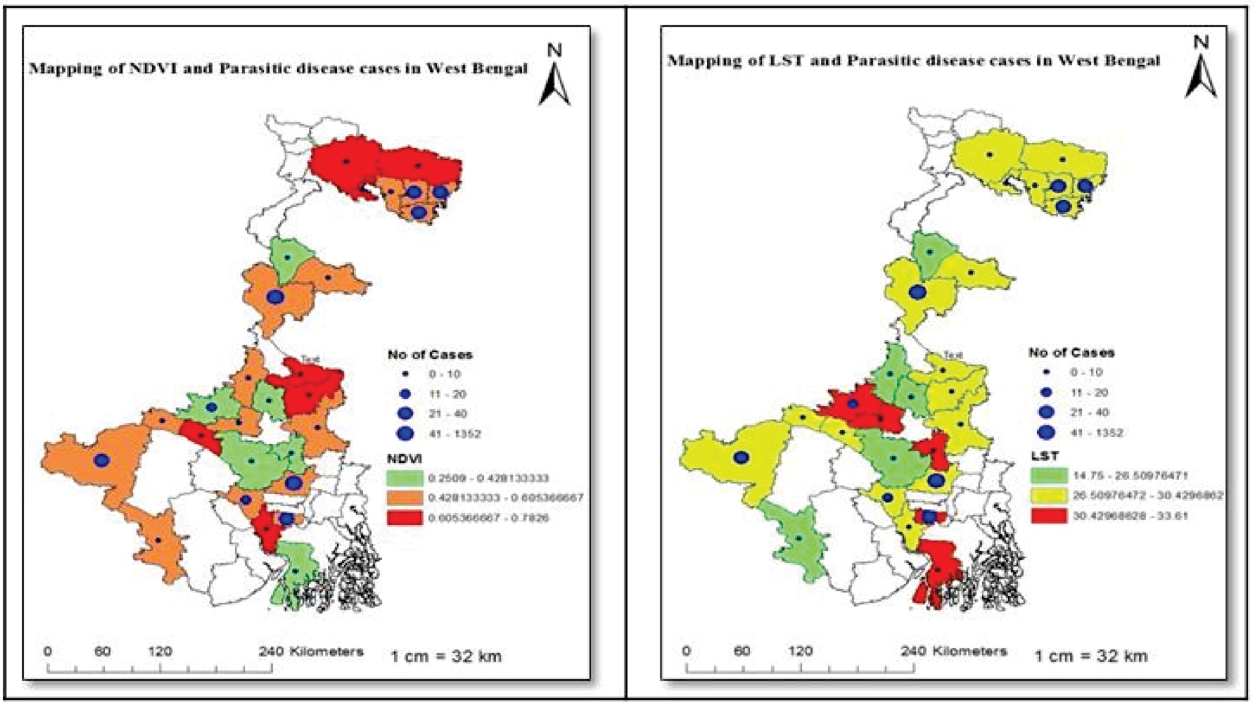


Fig 4.1: Mapping of NDVI and Parasitic diseases in West Bengal.

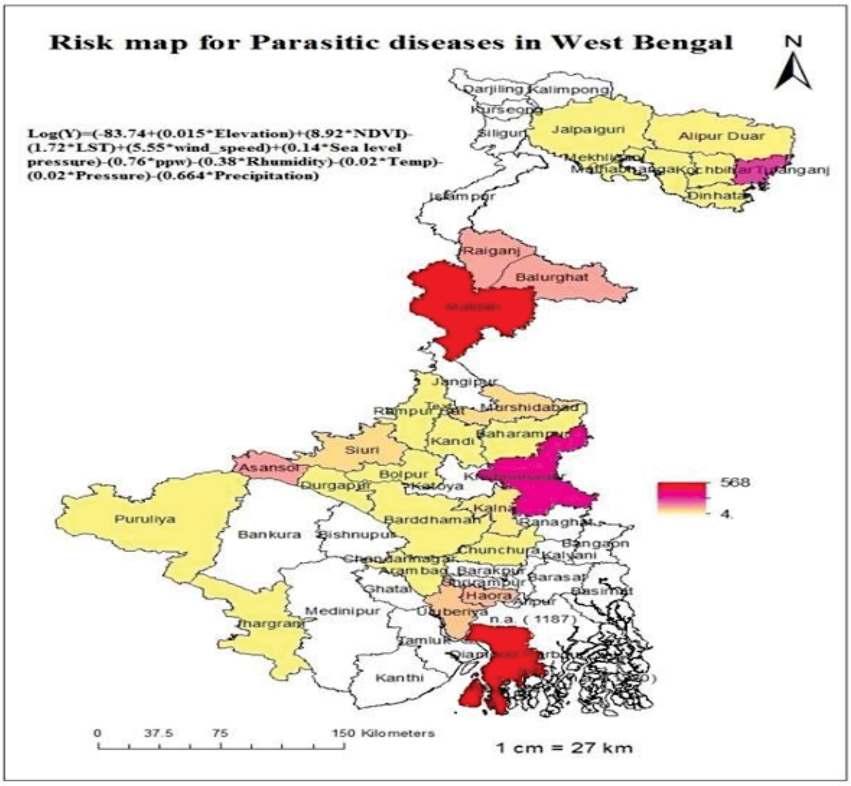


Fig 4.2: Risk map of parasitic diseases in West Bengal.

The table for Continuous variable information is as below.

Continuous Variable Information				
Variables	**Minimum**	**Maximum**	**Mean**	**SD**
NDVI	0.00	0.75	0.48	0.14
NDVI 1 M lag	0.25	0.78	0.51	0.13
NDVI 2 M lag	0.23	0.84	0.52	0.14
LST	14.41	43.93	29.31	4.86
LST 1 M lag	18.37	42.13	28.61	4.38
LST 2 M lag	20.19	38.09	27.43	4.04
Wind Speed	1.45	25.15	8.49	4.73
Wind speed 1 M lag	1.38	23.29	7.78	3.71
Wind speed 2 M lag	1.45	18.21	7.73	3.68
Sea level pressure	0.00	1018.89	973.29	185.66
Sea level pressure 1M lag	0.00	1018.73	974.71	185.92
Sea level pressure 2M lag	0.00	1018.89	990.44	132.48
Perceptible Water	4.77	65.42	31.13	15.60
Perceptible Water 1M lag	4.33	62.13	27.11	13.60
Perceptible Water 2M lag	4.09	65.42	25.80	13.54
R humidity	37.02	98.58	64.27	19.22
R humidity 1M lag	33.87	98.93	60.28	18.41
R humidity 1M lag	30.69	97.39	60.19	18.79
Temperature	-	32.60	24.62	7.46
Temperature 1M lag	-	31.90	23.97	7.95
Temperature 1M lag	-	32.60	22.95	7.94
Pressure	712.53	1034.69	976.55	99.22
Pressure 1M lag	713.31	1034.54	977.85	99.49
Pressure 2M lag	713.09	1034.69	979.01	99.97
Precipitation	0.00	13.06	3.56	3.48
Precipitation 1M lag	0.00	13.63	2.39	3.05
Precipitation 1M lag	0.00	9.78	2.16	2.73
Elevation	4.00	282.00	39.78	45.69

Table 4.2. Descriptive statistics of climate variables in West Bengal Parasitic Disease.

Modeling the outbreak of Bacterial Diseases using climatic factors in state of West Bengal

A total of 7176 cases reported for bacterial diseases covering 406 villages of districts of West Bengal during 2009-2015 was linked to different climatic variables viz., NDVI, LST, Wind speed, Sea Level Pressure, Precipitation of Water, Relative humidity, Temperature.

Continuous Variable Information				
Variables	**Minimum**	**Maximum**	**Mean**	**SD**
NDVI	0.04	0.83	0.53	0.14
NDVI 1 M lag	-0.01	0.86	0.53	0.14
NDVI 2 M lag	0.10	0.86	0.51	0.14
LST	20.17	41.65	28.99	3.73
LST 1 M lag	19.39	44.21	29.65	4.06
LST 2 M lag	9.51	41.73	29.68	4.61
Wind Speed	1.00	20.45	6.44	3.00
Wind speed 1 M lag	0.52	23.77	6.71	3.20
Wind speed 2 M lag	0.52	27.48	6.66	3.40
Sea level pressure	0.00	1018.73	961.72	207.47
Sea level pressure 1M lag	0.00	1018.03	1003.15	50.19
Sea level pressure 2M lag	0.00	1018.89	971.81	172.33
Perceptible Water	4.72	65.42	39.90	16.63
Perceptible Water 1M lag	4.45	66.14	40.96	15.90
Perceptible Water 2M lag	4.33	66.14	40.32	15.94
R humidity	25.34	97.12	75.07	19.56
R humidity 1M lag	30.69	98.29	74.53	19.72
R humidity 1M lag	30.69	98.60	71.91	20.81
Temperature	1.47	32.60	25.67	4.39
Temperature 1M lag	1.35	32.60	26.25	4.50
Temperature 1M lag	-	32.60	26.54	4.49
Pressure	715.12	1034.54	991.35	51.14
Pressure 1M lag	714.33	1033.77	990.75	51.00
Pressure 2M lag	713.87	1034.69	990.67	50.99
Precipitation	0.00	25.51	5.02	4.45
Precipitation 1M lag	0.00	17.33	5.12	4.17
Precipitation 1M lag	0.00	25.51	5.00	4.26
Elevation	-	284.00	42.64	55.77

Table 4.1.1. Descriptive statistics of climate variables in West Bengal

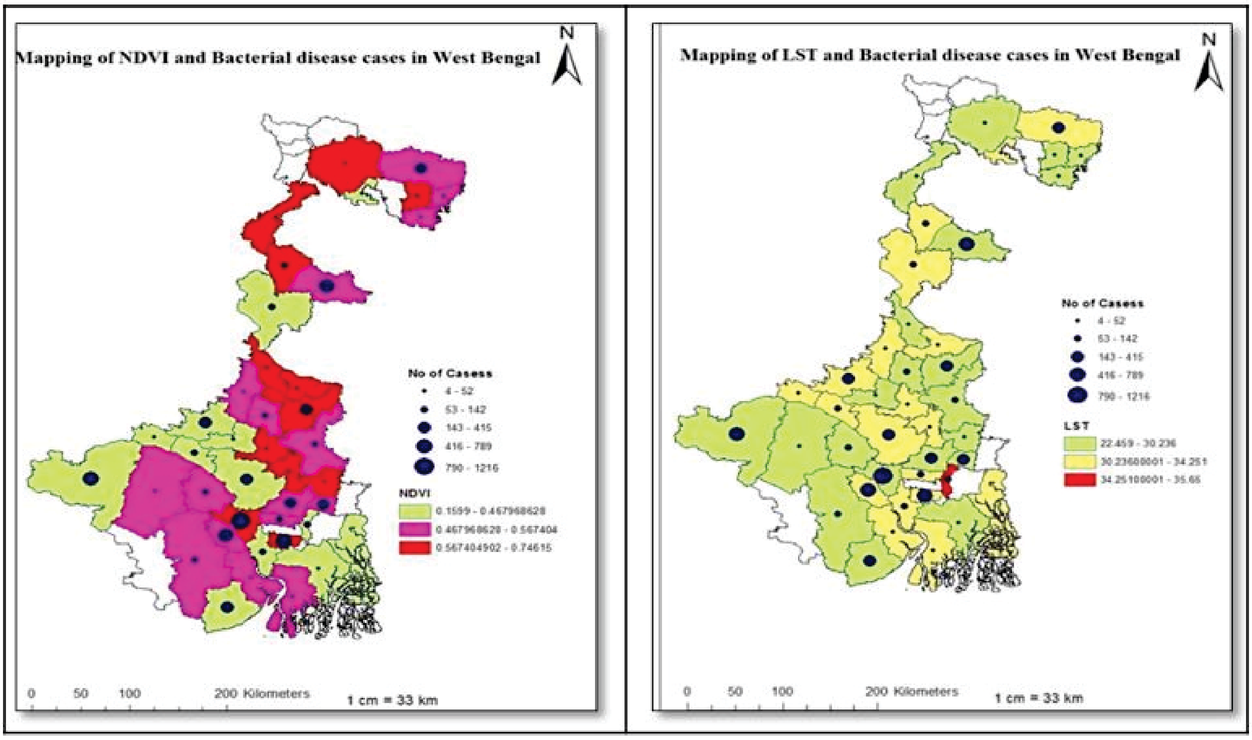


Fig 4.1.1. Mapping of NDVI and Bacterial diseases in West Bengal.

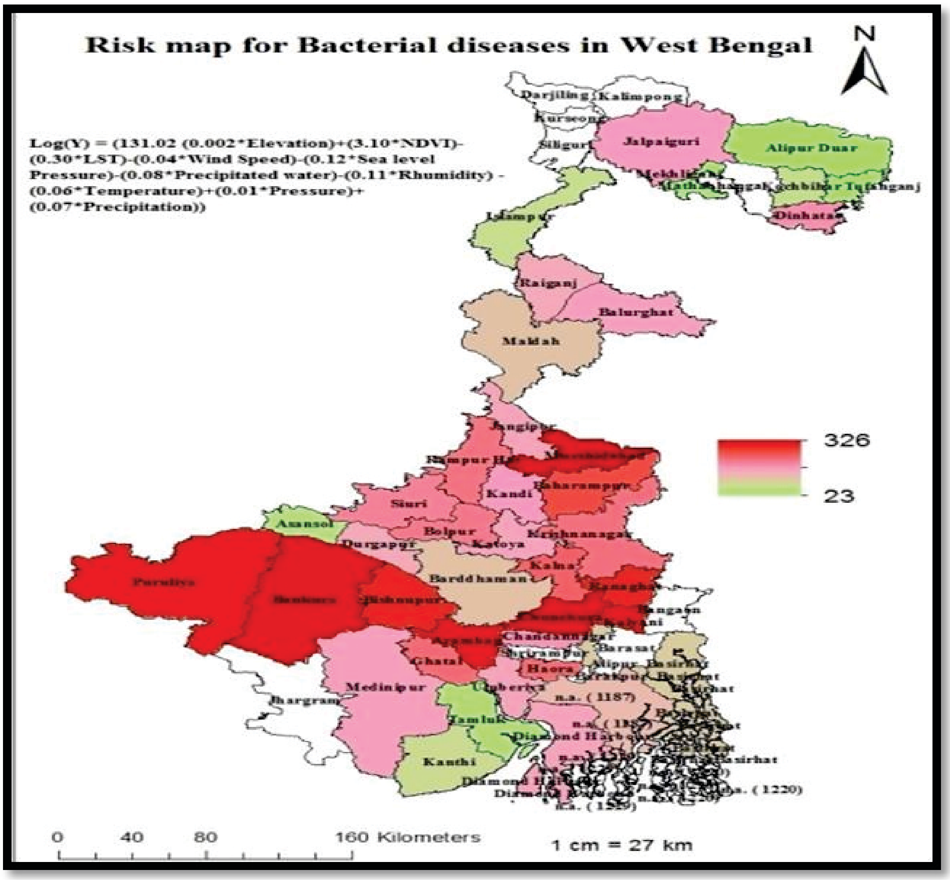


Fig 4.1.2: Risk map for bacterial disease in West Bengal.

4.1 Modelling the outbreak of Viral Diseases using climatic factors in state of West Bengal.

A total of 2,15,879 cases reported for viral diseases covering 1751 villages of districts of West Bengal during 2009-2015 was linked to different climatic variables viz., NDVI, LST, Wind speed, Sea Level Pressure, Precipitation of Water, R humidity, Temperature and Elevation. The correlation analysis of NDVI and LST with the other climatic variables. The climatic variables were found to range as depicted below.

Continuous Variable Information				
Variables	**Minimum**	**Maximum**	**Mean**	**SD**
NDVI	-0.07	0.90	0.51	0.14
NDVI 1 M lag	-0.04	0.92	0.51	0.14
NDVI 2 M lag	0.04	0.85	0.50	0.14
LST	-13.61	45.20	29.34	4.54
LST 1 M lag	10.63	44.24	29.18	4.41
LST 2 M lag	-17.67	45.10	29.07	4.31
Wind Speed	0.75	25.15	6.95	3.84
Wind speed 1 M lag	0.75	27.48	7.02	4.05
Wind speed 2 M lag	0.52	25.15	6.97	3.99
Sea level pressure	996.54	1018.89	1007.11	5.52
Sea level pressure 1M lag	996.54	1018.89	1006.97	5.59
Sea level pressure 2M lag	996.54	1018.89	1006.88	5.51
Perceptible Water	4.95	66.14	34.77	16.57
Perceptible Water 1M lag	3.78	66.14	34.67	16.82
Perceptible Water 2M lag	4.14	66.14	34.65	16.76
R humidity	24.46	99.33	69.86	21.58
R humidity 1M lag	28.76	99.33	69.48	21.87
R humidity 1M lag	22.01	99.33	69.11	21.82
Temperature	-	32.60	24.73	5.34
Temperature 1M lag	-	32.78	24.76	5.50
Temperature 1M lag	-	32.78	24.74	5.65
Pressure	712.53	1034.69	975.08	79.15
Pressure 1M lag	713.71	1034.69	975.00	79.20
Pressure 2M lag	712.53	1034.69	974.96	79.27

Precipitation	0.00	25.51	4.23	4.22
Precipitation 1M lag	0.00	16.99	4.26	4.35
Precipitation 1M lag	0.00	17.55	4.29	4.33
Elevation	-	2351.00	58.39	96.18

Table 4.2.1. Descriptive statistics of climate variables in West Bengal.

Parameter Estimates

Parameter	B	SE	95% Wald Confidence Interval		Hypothesis Test	
			Lower	Upper	Wald Chi-Square	Sig.
NDVI	2.82	0.22	2.40	3.24	171.87	<0.001
NDVI 1 M lag	4.84	0.22	4.40	5.28	467.44	<0.001
NDVI 2 M lag	1.49	0.18	1.13	1.85	64.82	<0.001
LST	-0.01	0.00	-0.01	-0.01	147.06	<0.001
LST 1 M lag	-0.02	0.00	-0.02	-0.02	298.90	<0.001
LST 2 M lag	-0.42	0.12	-0.66	-0.19	12.88	<0.001
Wind Speed	-0.01	0.00	-0.01	-0.01	217.28	<0.001
Wind speed 1 M lag	-0.01	0.00	-0.02	-0.01	192.71	<0.001
Wind speed 2 M lag	-0.02	0.00	-0.02	-0.02	352.58	<0.001
Sea level pressure	0.10	0.00	0.09	0.10	2089.11	<0.001
Sea level pressure 1M lag	-0.05	0.00	-0.05	-0.04	288.03	<0.001
Sea level pressure 2M lag	0.01	0.00	0.01	0.02	12.57	<0.001
Perceptible Water	-0.04	0.00	-0.04	-0.03	1643.74	<0.001
Perceptible Water 1M lag	0.00	0.00	0.00	0.01	24.06	<0.001
Perceptible Water 2M lag	-0.03	0.00	-0.03	-0.03	1448.83	<0.001
R humidity	0.03	0.00	0.03	0.04	3276.61	<0.001
R humidity 1M lag	-0.01	0.00	-0.01	-0.01	99.26	<0.001

R humidity 1M lag	0.03	0.00	0.03	0.04	3770.38	<0.001
Temperature	0.03	0.00	0.02	0.04	67.77	<0.001
Temperature 1M lag	0.08	0.00	0.07	0.09	585.65	<0.001
Temperature 1M lag	-0.05	0.00	-0.06	-0.05	413.43	<0.001
Pressure	-0.17	0.00	-0.17	-0.16	4370.55	<0.001
Pressure 1M lag	0.16	0.00	0.15	0.17	2334.08	<0.001
Pressure 2M lag	0.02	0.00	0.01	0.02	52.88	<0.001
Precipitation	-0.06	0.00	-0.06	-0.06	2596.28	<0.001
Precipitation 1M lag	0.08	0.00	0.08	0.08	5608.92	<0.001
Precipitation 1M lag	0.03	0.00	0.03	0.03	751.93	<0.001
Elevation	0.00	-	0.00	0.00	303.95	<0.001
NDVI * Temperature	0.06	0.01	0.05	0.07	143.76	<0.001
NDVI* Pressure	-0.01	0.00	-0.01	0.00	231.68	<0.001
NDVI 2M lag * Pressure 2M lag	0.00	0.00	0.00	0.00	80.16	<0.001
LST 2M lag* Sea level Pressure 2M lag	0.00	0.00	0.00	0.00	15.79	<0.001
NDVI 1M lag * Pressure_1M lag	-0.01	0.00	-0.01	-0.01	626.22	<0.001

Table 4.2.2. Model description for establishing the relationship between the viral disease and the climate variables in West Bengal.

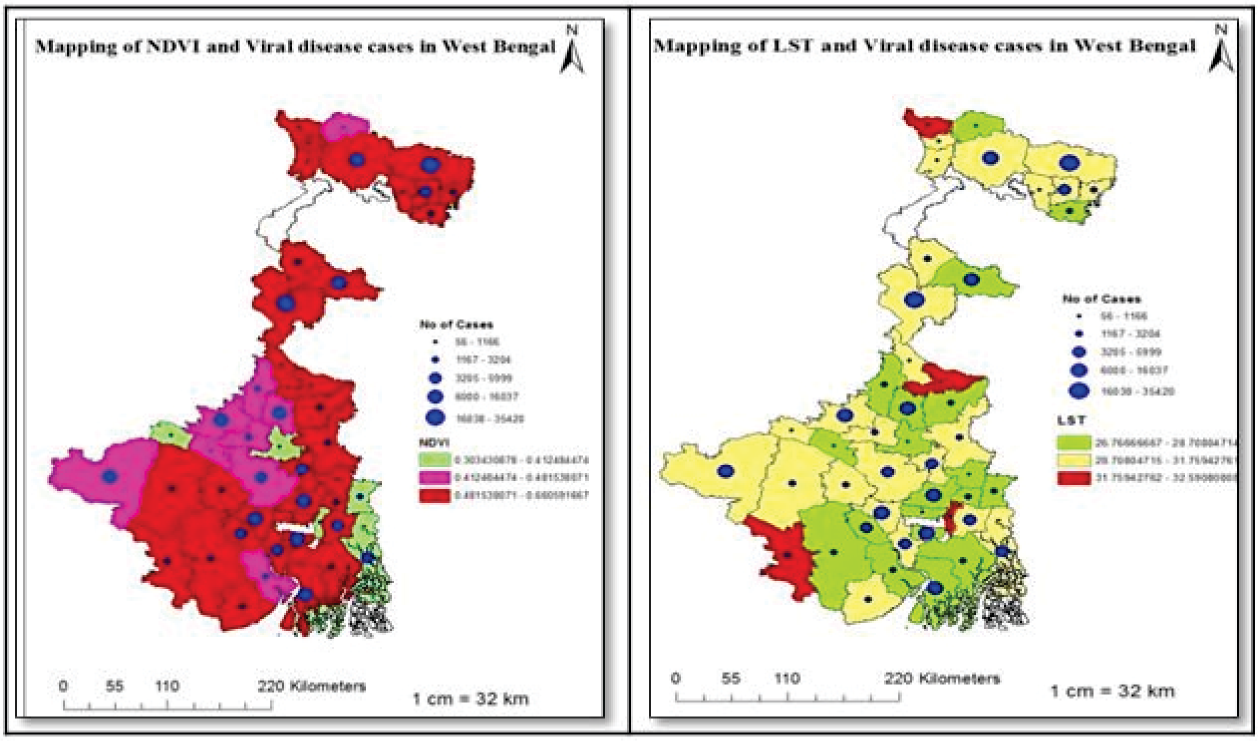


Fig 4.2.1. Mapping of NDVI and Viral diseases in West Bengal.

[V] KERALA

Climate-Parasitic relationship model were developed to understand in order the epidemiology of the disease. The occurrence of different parasitic diseases from 2001 to 2016 were retrieved from National Animal Disease Referral Expert System (NADRES database. A total of 14 parasitic disease outbreaks were observed in the state of Kerala. The disease-incidence data was processed to link the values of all the Meteorological & remote sensing data and was subjected to Poisson regression modeling to establish the climate-disease relationship model. The model suggested that, NDVI and rainfall in lag month are positively associated with higher incidence and LST and temperature in lag month were negatively associated with the incidence of parasitic diseases.

Henceforth, the study concludes that the environmental variables are very crucial to study the epidemiology of pathogen and disease prediction to implement timely control measures, also the result of this study is significant in respect of present scenario of global climate change.

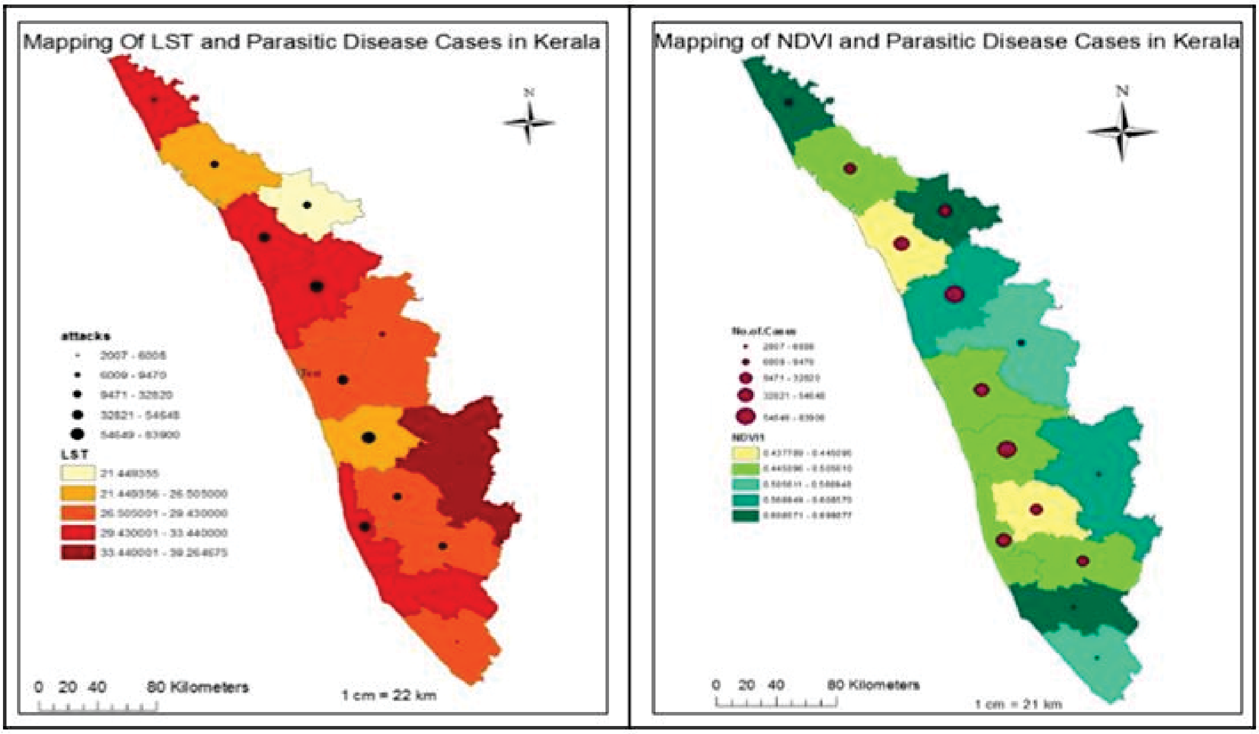


Fig 5.1. Mapping of NDVI and Parasitic diseases in Kerala.

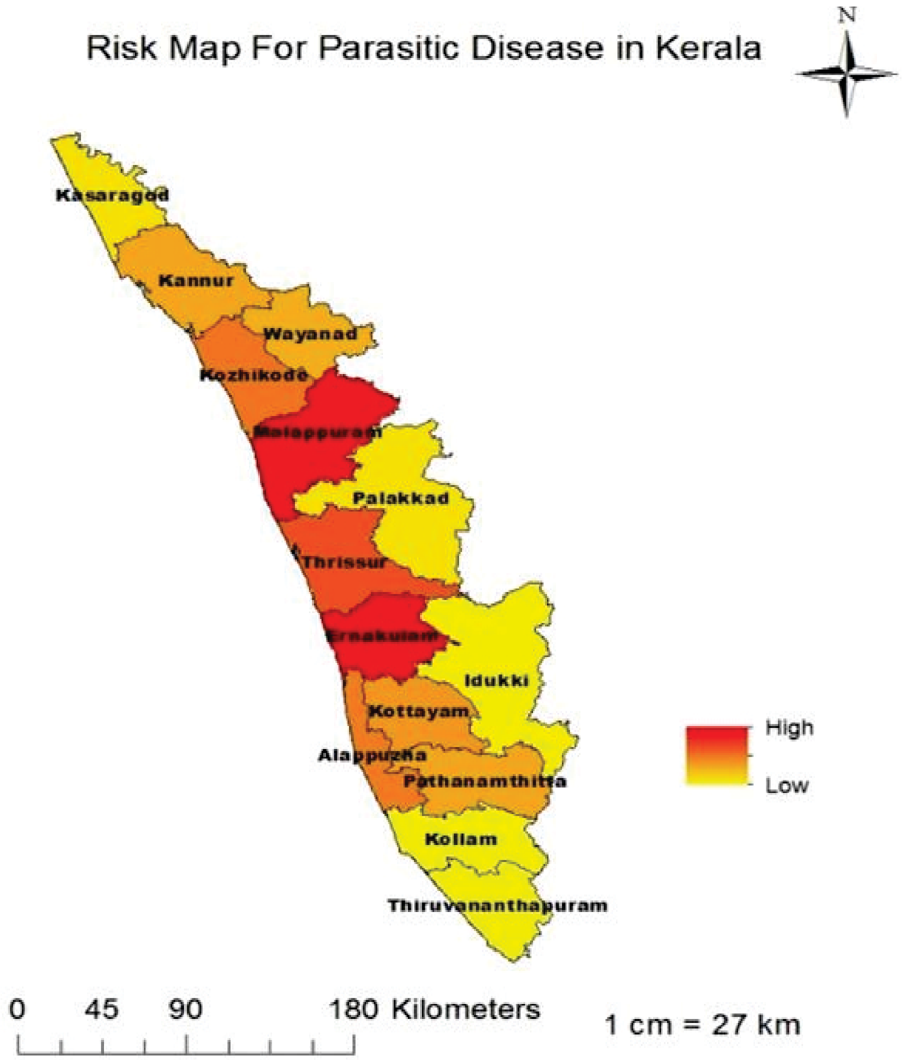


Fig 5.2. Risk Map of Parasitic diseases in Kerala.

[VI] RAJASTHAN

The occurrence of different parasitic diseases from 2001 to 2016 were retrieved from National Animal Disease Referral Expert System (NADRES database. A total of 9 parasitic disease outbreaks were observed in the state of Rajasthan during this period. The disease-incidence data was processed to link the values of all the Meteorological & remote sensing data and was subjected to Poisson regression modeling to establish the climate-disease relationship model. The model suggested that, NDVI and rainfall in lag month are positively associated with higher incidence and LST and temperature in lag month were negatively associated with the incidence of parasitic diseases.

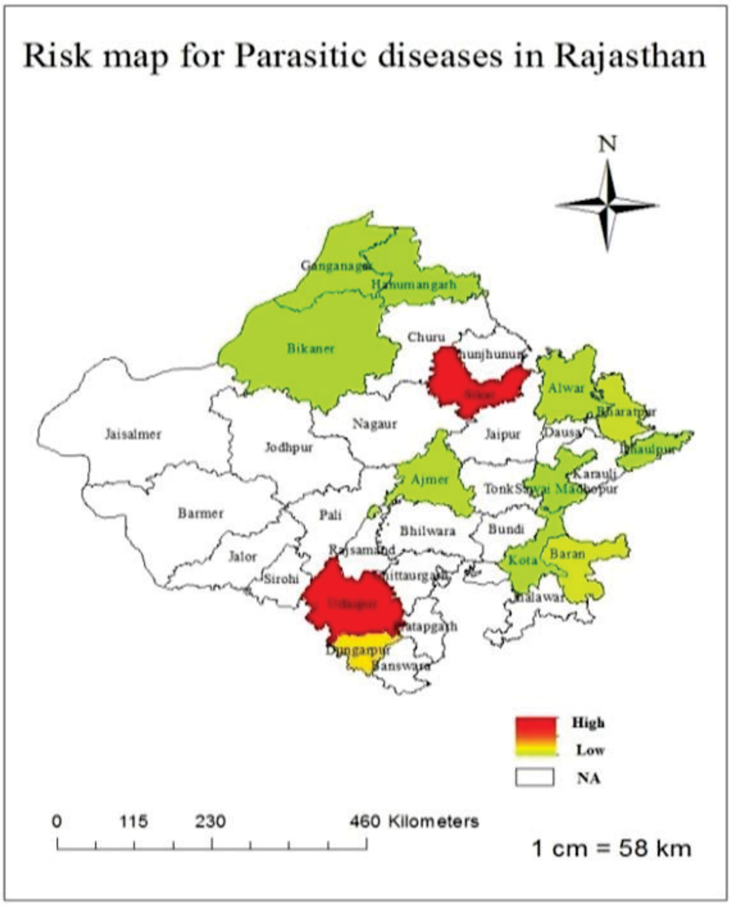
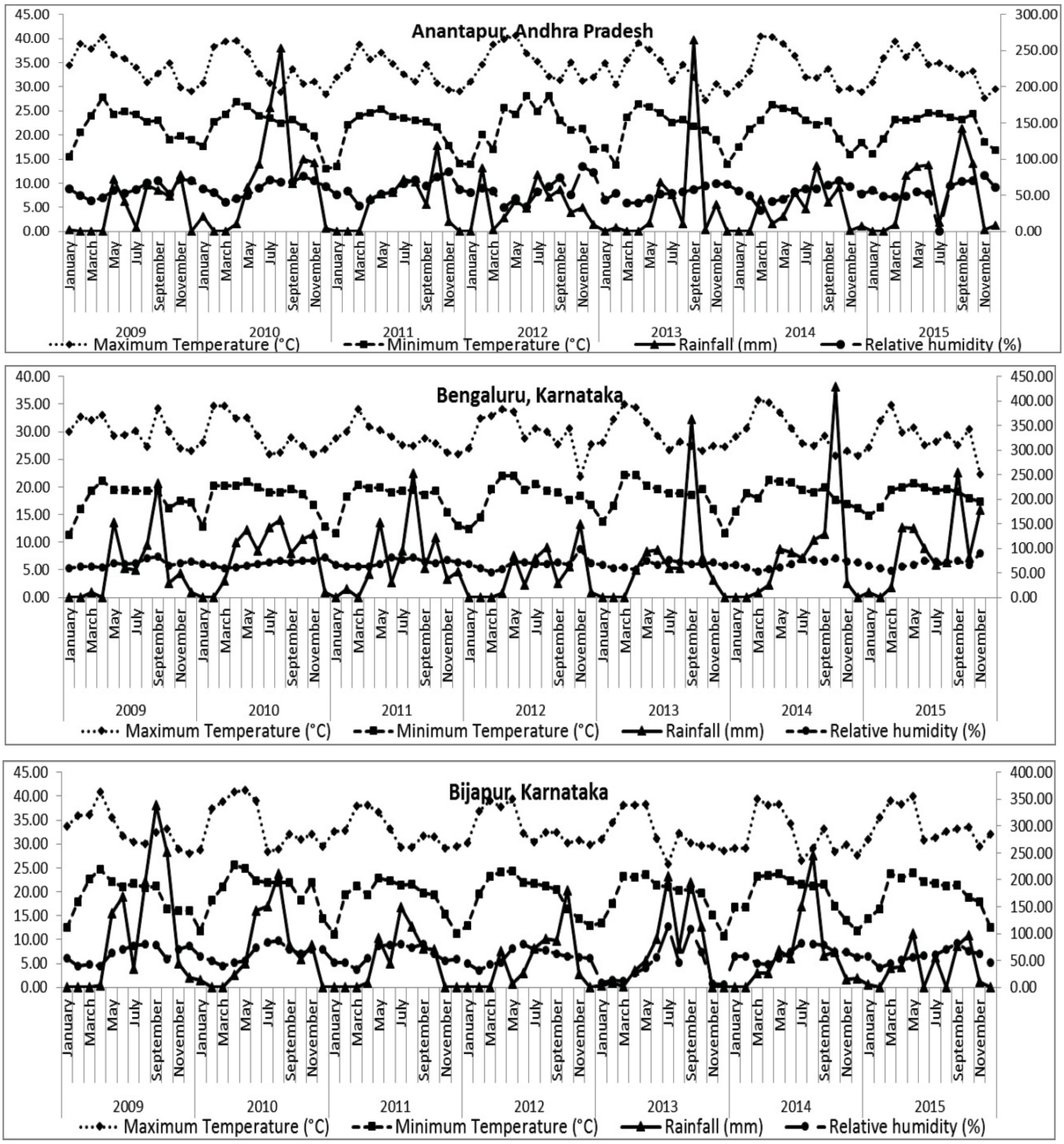


Fig 6.1. Risk Map of Parasitic diseases in Rajasthan.

The analysis results of the weather parameters obtained from five automatic weather stations in Anantapur, Bengaluru, Bijapur, Kovilpatti and Thirussur in southern India are depicted in graphical form (Fig. 8). The analysis of weather data indicated that there was not much change in minimum and maximum temperature and relative humidity over the years. However, the rainfall data showed huge variation between the years during the period studied. The Anantapur, Andhra Pradesh showed increased rainfall peak in 2010 and 2013 years. The peak rainfall was observed in 2013 and 2014



in Bengaluru and 2009 and 2014 in Bijapur, respectively in Karnataka state.

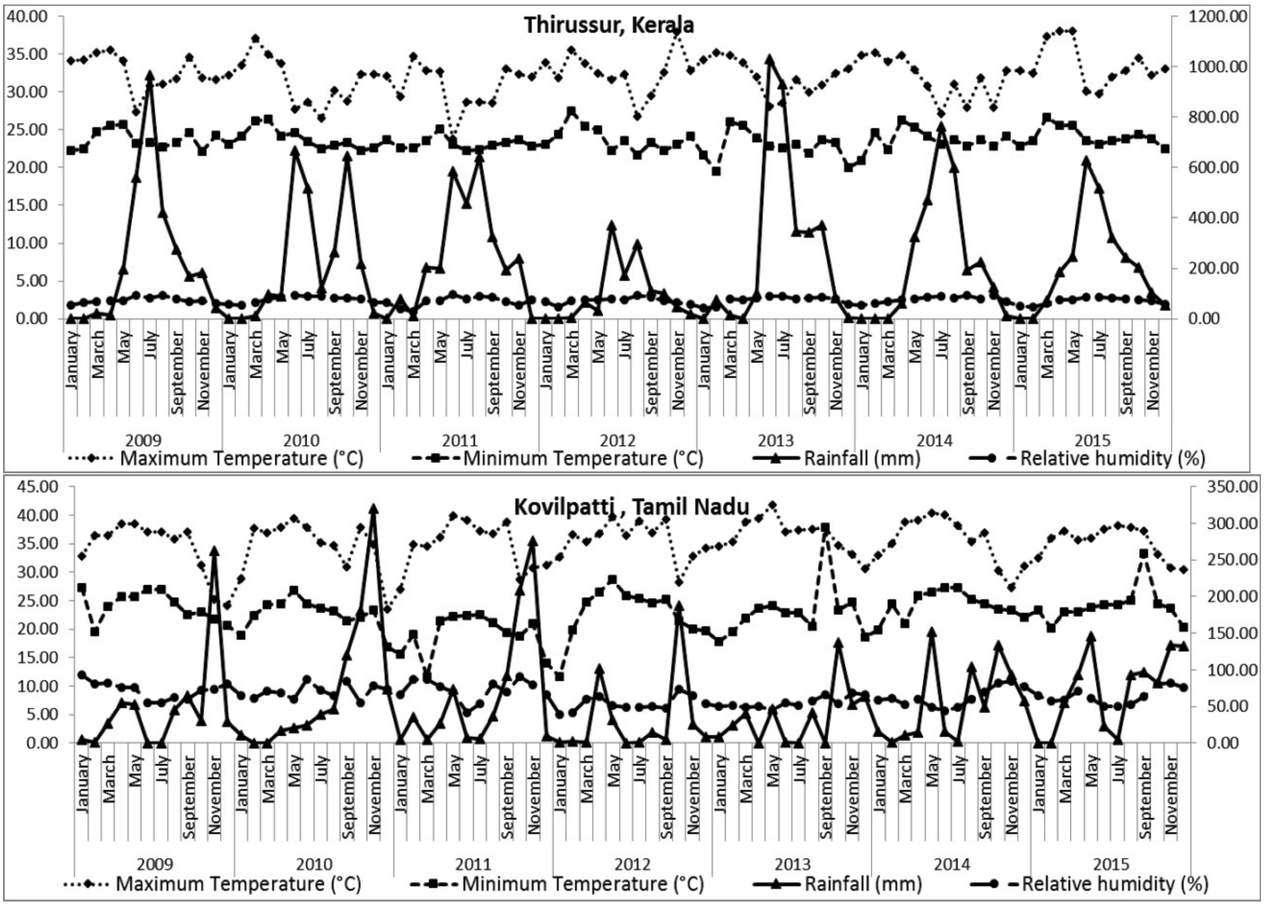


Fig. 6.2 Graphs showing the variation in weather parameters in five centers a) Anantapur b) Bengaluru c) Bijapur d) Kovilpatti e) Thirussur in past seven years

The Kovilpatti in Tamil Nadu showed peak rainfall occurring in 2009, 2010 and 2011, afterwards decrease in the rainfall was observed. There was two peak period of rainfall every year and this was due to the occurrence of rainfall during south west and north east monsoon seasons. The Thirussur, Kerala showed that the rainfall was maintained uniformly over the years but peak occurred in 2009 and 2013 years. The bio-climatograph of bacterial and viral diseases reported in Tamil Nadu are depicted in Fig 8a and 8b. The analysis indicated that there is relationship between the occurrence of livestock diseases and rainfall.

Extended spectrum beta lactamase producing multi drug resistant *E. coli* isolated from Subclinical Mastitis milk

GenBank: LWDC00000000.1 - *Escherichia coli* strain SCM-21, whole genome shotgun sequence. One *E. coli* strain isolated from subclinical case of mastitis, resistant to more than three antibiotics was detected as extended-spectrum beta-lactamase (ESBL) producers by screening test as per the Clinical and Laboratory Standards Institute (CLSI). CTX-M- and TEM-type beta-lactamase genes (blaCTX-M, blaTEM) were detected by polymerase chain reaction in the isolates. Whole Genome Sequencing showed that the *E. coli* harbored several metal resistance related genes in addition to the antibiotic resistance genes (Table 3).

The use of certain antibiotics, has led to an increase in MDR phenotypes associated with the overexpression of efflux pumps. In addition, the presence of naturally occurring heavy metals and the use of chemicals in agriculture can also induce the expression of efflux pumps in environmental strains leading to cross-resistance. Antibiotic sensitivity testing should be performed to preserve the efficacy of extended-spectrum cephalosporins for the treatment of bovine mastitis.

Table 5. Metal resistance genes identified by whole genome sequencing of *E. coli* strain SCM-21detected in Subclinical Mastitis

Function	**Subsystem**	Role
Cobalt-zinc-cadmium resistance protein CzcA; Cation efflux system protein CusA	Cobalt-zinc-cadmium resistance; Cobalt-zinc-cadmium resistance	Cation efflux system protein CusA
Cobalt-zinc-cadmium resistance protein	Cobalt-zinc-cadmium resistance	Cobalt-zinc-cadmium resistance protein
Arsenical pump-driving ATPase (EC 3.6.3.16)	Arsenic resistance; Stress related cluster	Arsenical pump-driving ATPase (EC 3.6.3.16)
Arsenical resistance operon repressor	Arsenic resistance	Arsenical resistance operon repressor
Sensor protein of zinc sigma-54-dependent two-component system	Zinc resistance	Zinc resistance-associated protein
Response regulator of zinc sigma-54-dependent two-component system	Zinc resistance	Sensor protein of zinc sigma-54-dependent two-component system

Multidrug resistant *Proteus mirabilis* carrying multiple efflux pumps detected in apparently healthy Pig fecal sample

GenBank: LWDB00000000.1 - *Proteus mirabilis* strain NIVEDI3-PG74, whole genome shotgun sequence. One *Proteus mirabilis* isolate from pig fecal sample was found to be resistant to multiple drugs. Whole genome sequencing allowed detailed view of the *Proteus mirabilis* core genome. The ResFinder web server (www.genomicepidemiology.org) was used to identify acquired antimicrobial resistance genes, using a threshold of 98.00% identity (ID). The multidrug resistant strain was found to possess genes for beta-lactamase including metallo beta-lactamase superfamily, tetracyclin resistance determinant efflux protein *tet*A, aminoglycoside adenyl-transferase conferring resistance to streptomycin and determinants imparting resistance to fluroquinolones (Table 4). Importantly the strain was found to possess 14 multidrug resistance efflux pumps besides carrying bacterial toxin colicin E2 and bacteriocin production cluster. The isolate was also found to carry *Inc*F plasmids, which allows mutations and recombination's, enabling it to evolve rapidly to adapt to the host environment.

The mechanisms by which bacteria evade the effects of antimicrobial agents are many, but in recent years it has become apparent that efflux is a significant means of resistance and probably explains the intrinsic resistance to numerous drugs. The current information generated is valuable in paving way to devise strategies for such emerging pathogens detected in livestock. Combining broad spectrum efflux pump inhibitors with current drugs that are pump substrates can recover clinically relevant activity of those compounds and thus may reduce the need for the discovery and development of new antimicrobial agents that are not pump substrates. Additional effort toward the identification, characterization and determination of the clinical utility of efflux pump inhibitors is warranted.

Table 6. Antimicrobial resistance genes identified by whole genome sequencing of pig fecal origin *Proteus mirabilis NIVEDI 3*

Sample resistance gene	Identity	Phenotype	Accession No.
dfrA17	100	Trimethoprim resistance	FJ460238
aadA5	100	Aminoglycoside resistance	AF137361
aac(6')-Ib	99.5	Aminoglycoside resistance	M21682
aac(6')Ib-cr	99.81	Fluoroquinolone and aminoglycoside resistance	EF636461
blaOXA-1	100	Beta-lactam resistance	J02967
catB3	100	Phenicol resistance	AJ009818
tet(J)	99.08	Tetracycline resistance	ACLE01000065
dfrA1	100	Trimethoprim resistance	X00926
aadA1	100	Aminoglycoside resistance	JQ480156
cat	98.17	Phenicol resistance	M11587

PHASE II

Title: Modeling the Effects of Climate Variability on Transmission of Vector-borne Livestock Diseases in India Using Remote Sensing and Geographical Information System

Objectives:

- To measure the potential influence of climate variability on temporal and spatial change in vector distribution and transmission patterns of vector–borne livestock diseases in India.
- Development of vector map and predictive risk map for control of vector-borne livestock diseases through climate-vector-pathogen relationship models.

Technical Program:

Development of climate-sensitive Decision support system to aid in decisions concerning the choice of appropriate livestock disease control strategies

a) Collection and identification of vectors.
b) Measurement of environmental variables (GRID based/ nearest IMD/AWS).
c) Measurement of remote sensing variables (Source: MODIS/LISS IV/Landsat 8).
d) Measurement of livestock and human activity.

Methodology:

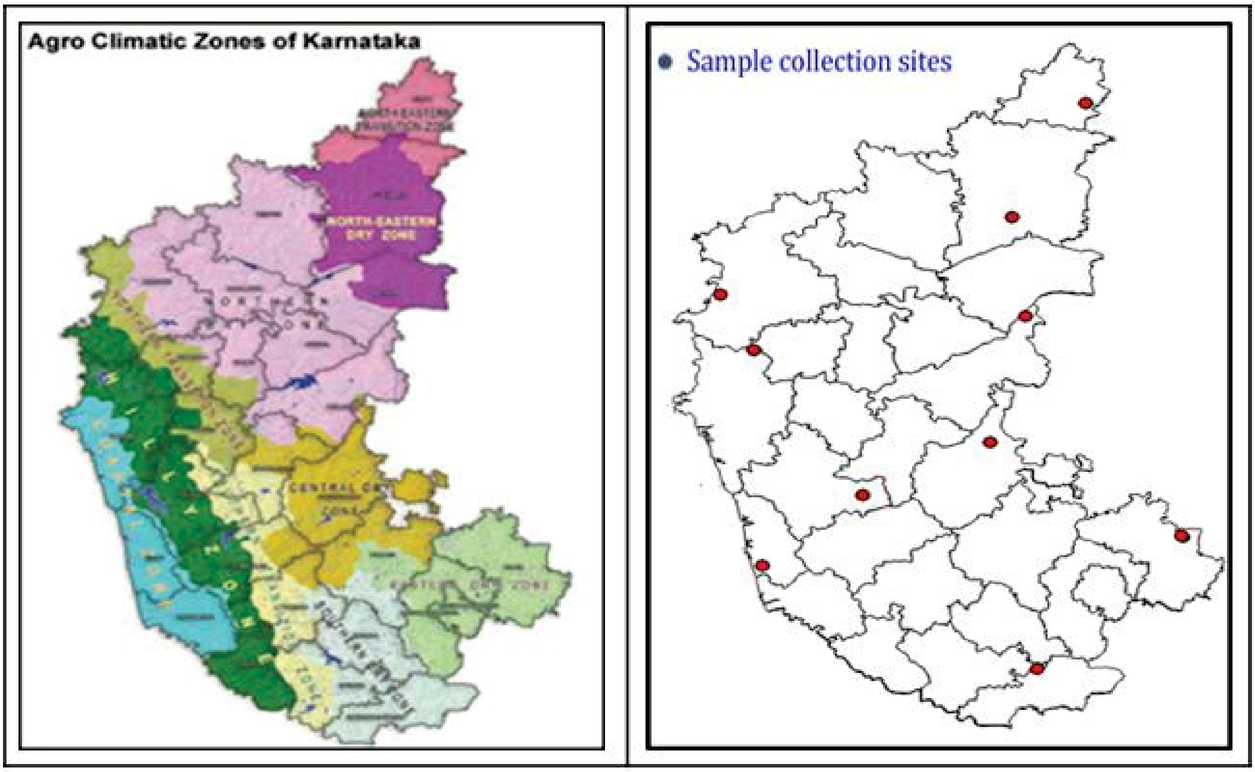
1. Monthwise, zone wise and bodysite wise prevalence of different tick genus namely *Rhiphicephalus sp, Haemophysalis sp, Hyaloma sp* and other species were obtained.
2. Systematic review and meta-analysis was done using the published literature and determined the pooled prevalence estimate of Anaplasmosis in India (10%) and World (32%).
3. Risk map was developed for Bluetongue disease for Karnataka and Tamilnadu states. Eleven model variants were used and evaluated by 3 methods, 'ROC': Relative Operating Characteristic, 'KAPPA': Cohen's Kappa (Heidke skill score) and 'TSS': True kill statistic (Hanssen and Kuipers discriminant, Peirce's skill score). The average score of best 3 model variants obtained by evaluation were used to generate the risk maps.
4. Tick samples were collected, processed and morphologically identified at genus level from 10 agroclimatic zones of Karnataka (September 2017 to September 2018) and Kerala (October 2017 to September 2018) states.

Summary of most significant achievements (outputs and outcomes, in bullet form) with relevant photos and illustrations

- Tick vector samples were collected from ten sites based on agroclimatic zones in Karnataka and Kerala states and determined the month-wise and zone-wise prevalence different genus of ticks. The body sites of tick prevalence indicted high quantity of ticks are residing in neck and dewlap region of the cattle.
- Risk maps were developed for Bluetongue disease for Karnataka and Tamil Nadu states by using various weather, remote sensing, anthropogenic variables. This will help the various stakeholders in planning the control and preventive measures for this disease. The Random forest model is identified as the best fit model after evaluation of eleven models for the preparing of Risk maps for Bluetongue disease based on three statistical parameters.

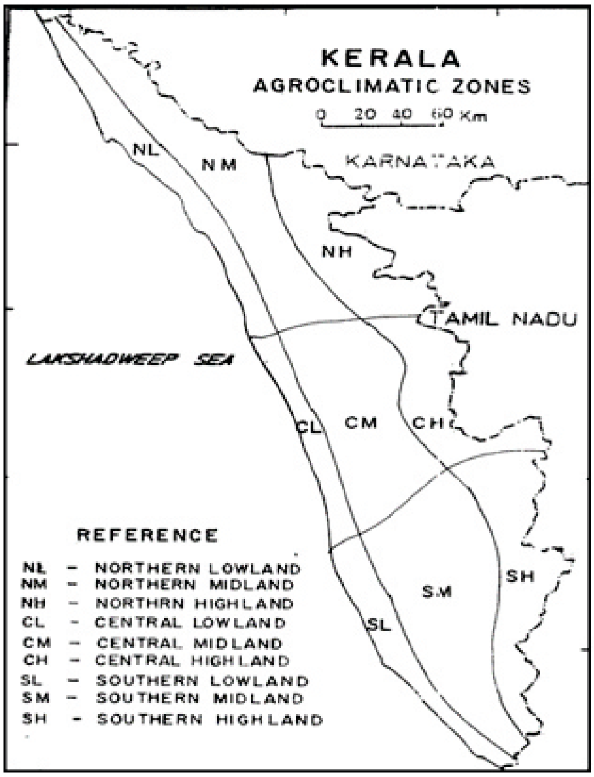
Results:

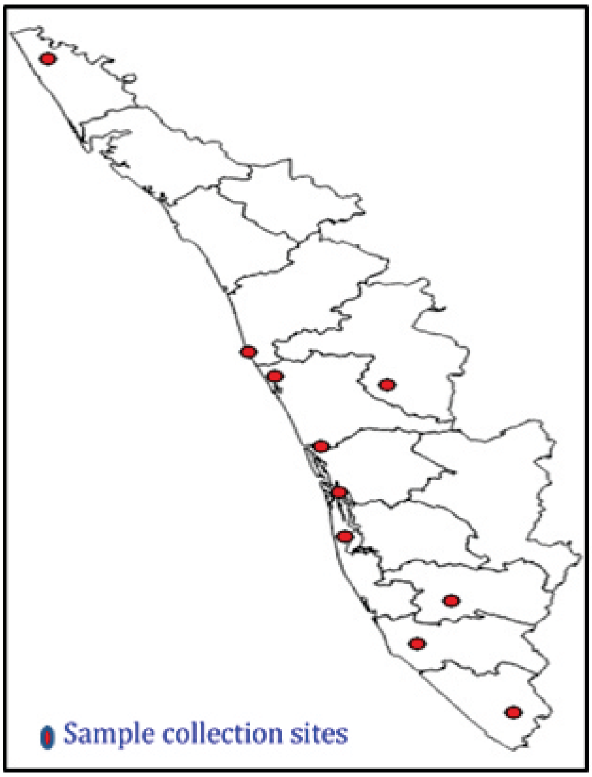
- Morphological identification was done.
- Grid based rainfall and temperature data collected for Karnataka.
- NDVI and LST variables were collected for two states.
- Livestock density was calculated for both states.



List of Zones & Districts selected for tick collection in Karnataka

No	Zones	District	Place of sampling
1	North Eastern Transition Zone	Bidar	Kamthana
2	North Eastern Dry Zone	Yadgir	Shahapura
3	Northern Dry Zone	Bellary	Shridargadda
4	Central Dry Zone	Chitradurga	Thalaku
5	Eastern Dry Zone	Kolar	Korukonapalli
6	Southern Dry Zone	Mandya	Ragibomanahalli
7	Southern Transition Zone	Shivamoga	Hosodi
8	Northern Transition Zone	Belgaum	Kadoli
9	Hilly Zone	U. Kannada	Tergaon
10	Coastal Zone	Udupi	Shirva

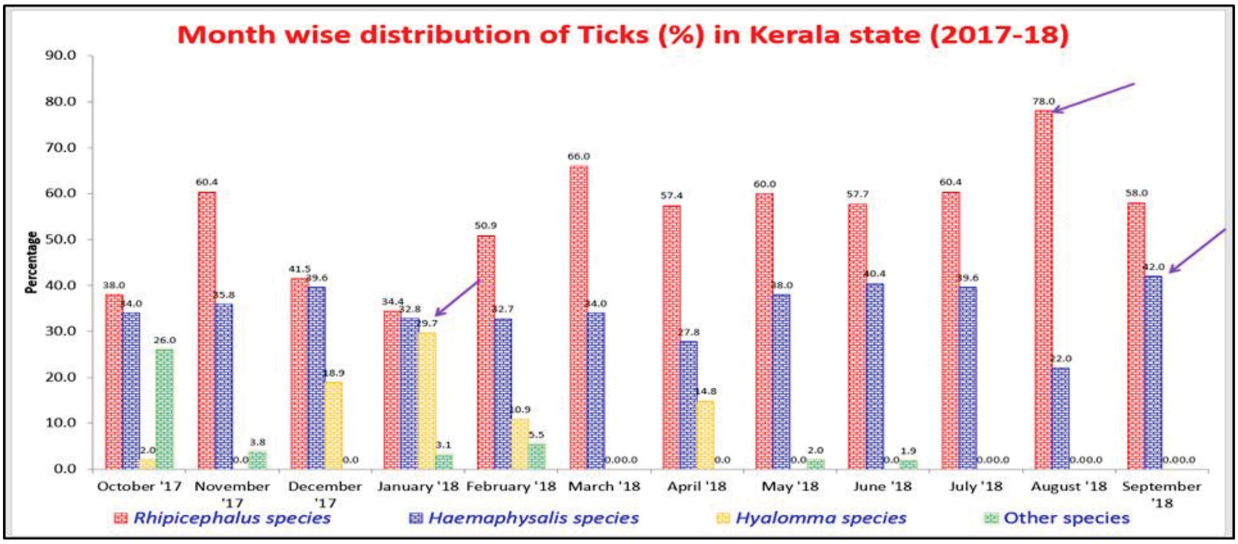




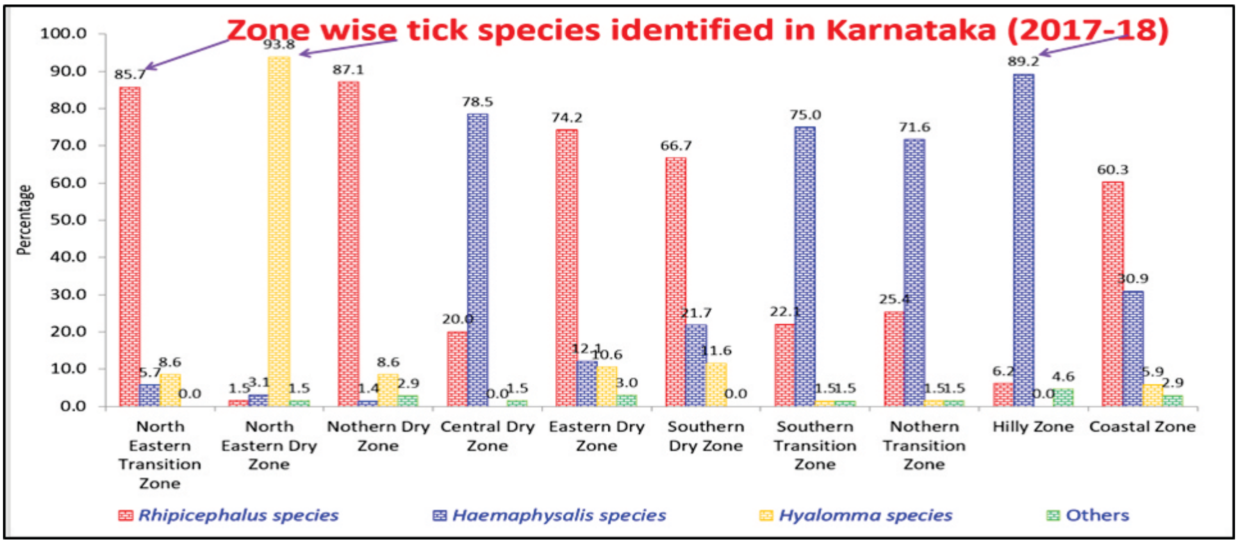
List of Zones & Districts selected for tick collection in Kerala

No.	**Zones with codes**	**District**	Place of sampling
1	Northern Low Land (K)	Kasargoad	Neerchal
2	Northern Mid Land (L)	Malappuram	Ponnai
3	Northern High Land (M)	Wayanad	Kottapadi
4	Central Low Land (N)	Thrissur	Panangad
5	Central Mid Land (O)	Ernakulam	Puthenvelikkara
6	Capital (P)	Trivandrum	Veeranakavu
7	Central High Land (Q)	Palakkad	Vandazhi
8	Southern Low Land (R)	Alapuzha	Kanjikkuzhi
9	Southern Mid Land (S)	Kollam	Elampalloor
10	Southern High Land (T)	Pathanamthitta	Pramadom

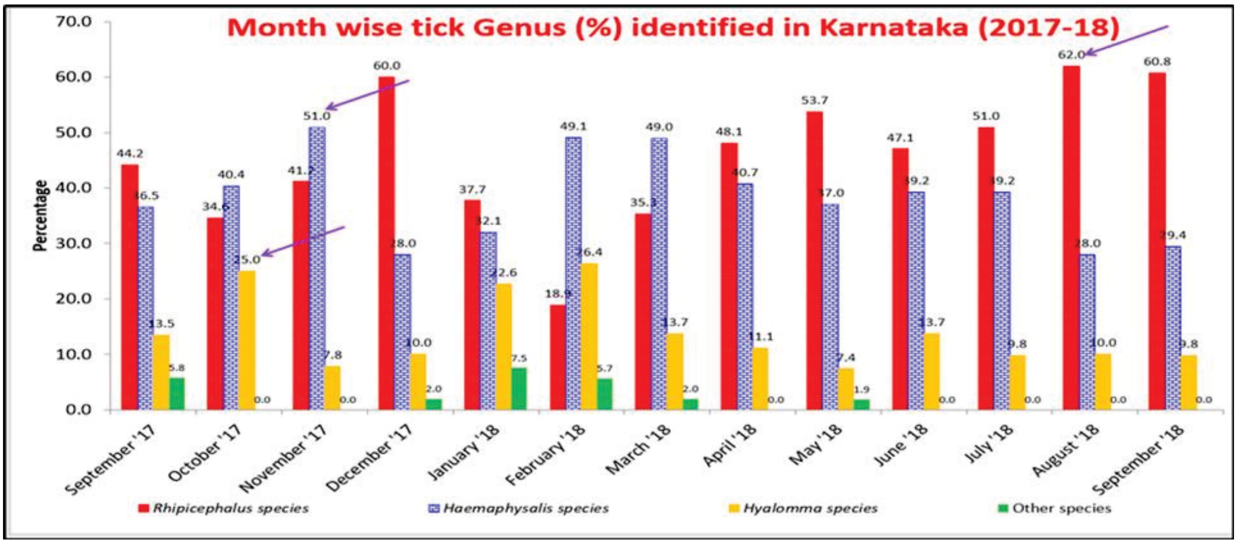
Sample collection



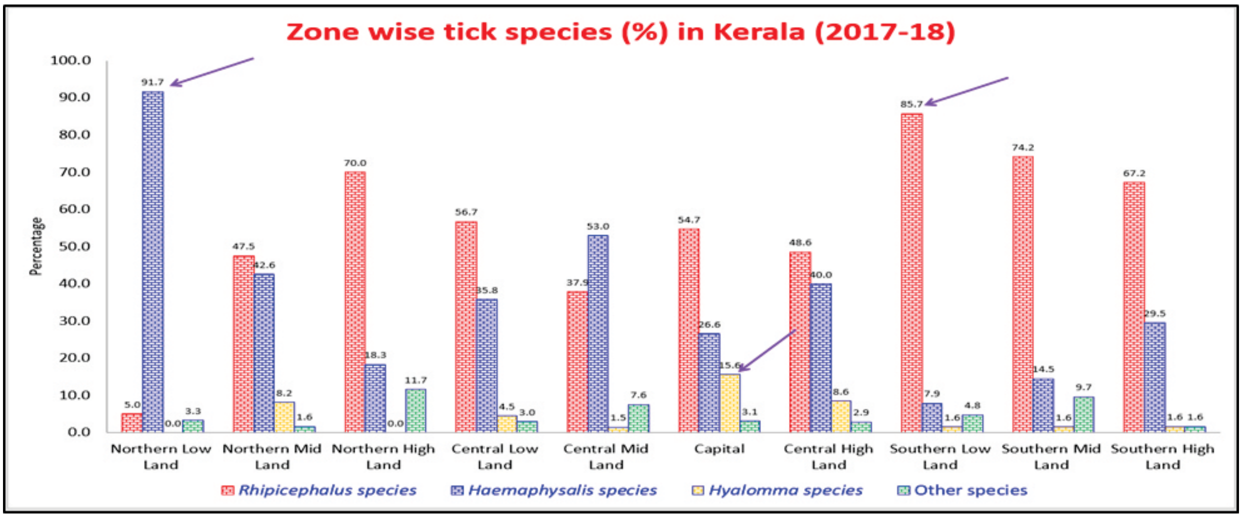
Month wise distribution of Ticks (%) in Kerala state (2017-18)
Percentage
October '17
November '17
December '17
January '18
February '18
March '18
April '18
May '18
June '18
July '18
August '18
September '18
Rhipicephalus species
Haemaphysalis species
Hyalomma species
Other species



Zone wise tick species identified in Karnataka (2017-18)
Percentage
North Eastern Transition Zone
North Eastern Dry Zone
Nothern Dry Zone
Central Dry Zone
Eastern Dry Zone
Southern Dry Zone
Southern Transition Zone
Nothern Transition Zone
Hilly Zone
Coastal Zone
Rhipicephalus species
Haemaphysalis species
Hyalomma species
Others

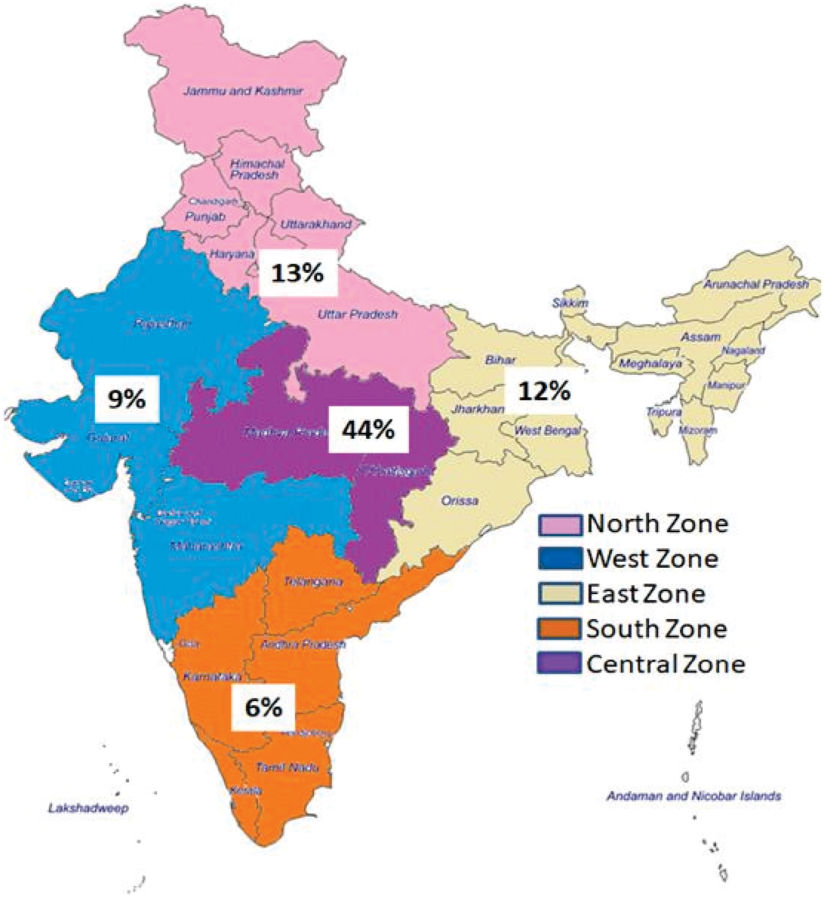


Month wise tick Genus (%) identified in Karnataka (2017-18)
Percentage
September '17
October '17
November '17
December '17
January '18
February '18
March '18
April '18
May '18
June '18
July '18
August '18
September '18
Rhipicephalus species
Haemaphysalis species
Hyalomma species
Other species



- Morphological and molecular identification of ticks based on the mitochondrial cytochrome oxidase subunit 1 gene
- Sequence analysis and submitted to GenBank for accession numbers.

Meta-analysis of prevalence of Anaplasmosis in India and world was done (Krishnamoorthy et al., 2019).



- Risk maps were developed for Bluetongue disease for Karnataka and Tamil Nadu states by using various weather, remote sensing, anthropogenic variables. This will help the various stakeholders in planning the control and preventive measures for this disease. The Random forest model is identified as the best fit model after evaluation of eleven models for the preparing of Risk maps for Bluetongue disease based on three statistical parameters.
- Space-Time Cluster Analysis of Bluetongue in Karnataka and Anaplasmosis in Kerala.
- Identification of significant risk parameters of VBDs by discriminant analysis and developing climate- pathogen-vector relationship model and projection of these results- Risk Map.

Evaluation results of best fit models (Bluetongue for Karnataka)

Evaluation	GLM	GAM	RF	GBM	NNET	MARS	FDA	CT	SVM	NB	ADA
KAPPA	0.41	0.41	0.743	0.491	0	0.452	0.513	0.688	0.552	-0.266	0.848
ROC	0.889	0.889	0.999	0.896	0.5	0.921	0.746	0.932	0.916	0.823	0.91
TSS	0.588	0.588	0.98	0.624	0	0.68	0.492	0.774	0.763	-0.315	0.821

Evaluation results of best fit models (Bluetongue for Tamil Nadu)

Evaluation	GLM	GAM	RF	GBM	NNET	MARS	FDA	CT	SVM	NB	ADA
KAPPA	0.41	0.41	0.743	0.491	0	0.452	0.513	0.688	0.552	-0.266	0.848
ROC	0.889	0.889	0.999	0.896	0.5	0.921	0.746	0.932	0.916	0.823	0.91
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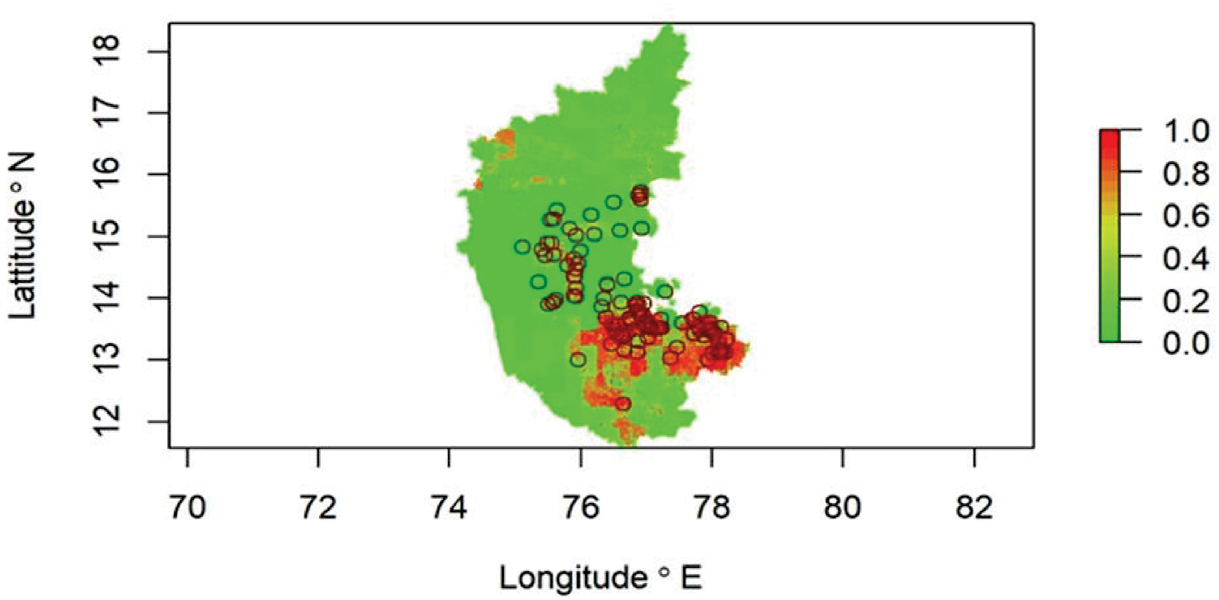
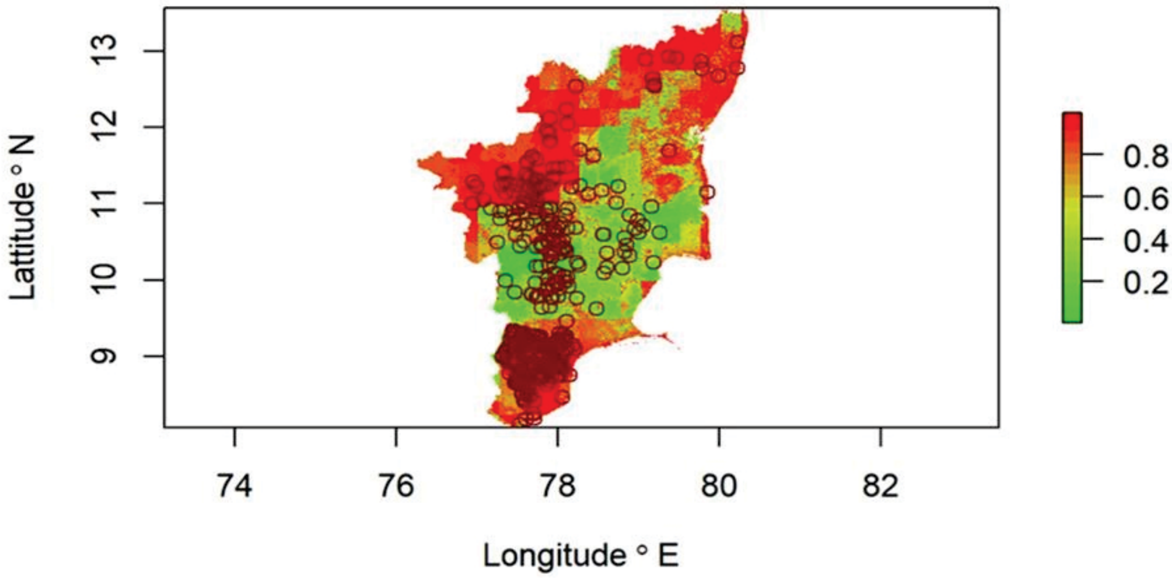
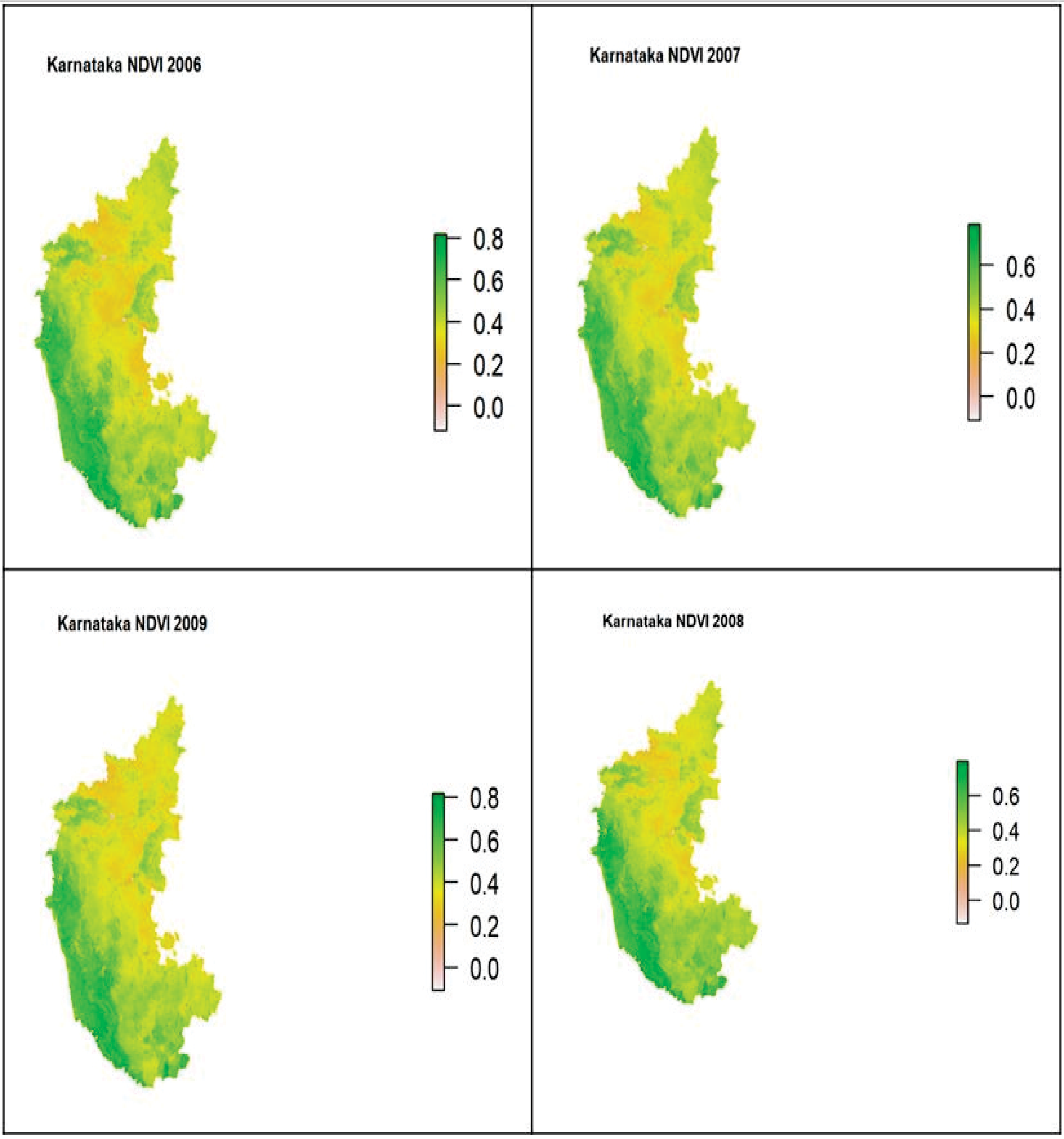




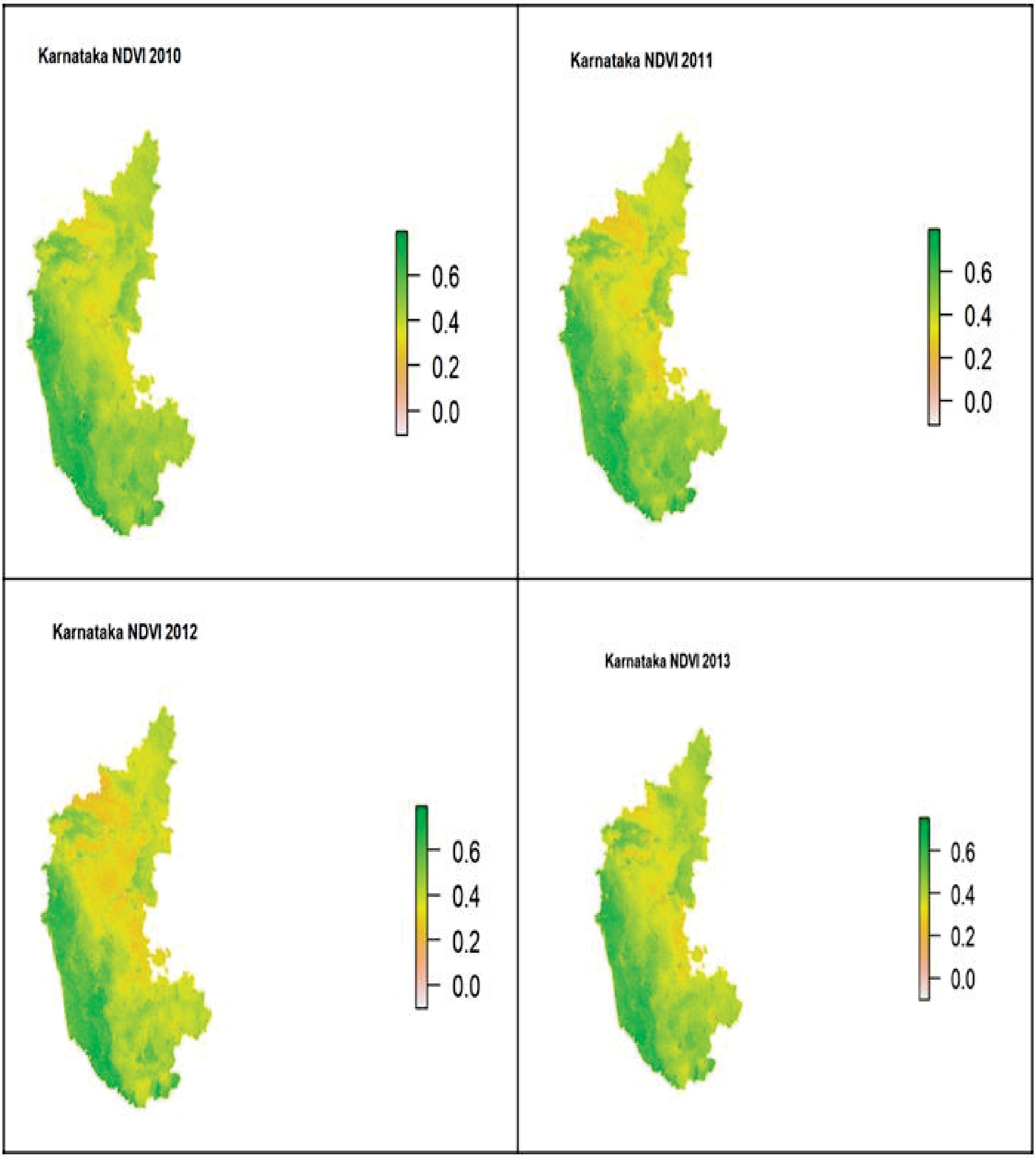
- Development of Climate Smart Models also helps to predict the occurrence of disease in advance for better management & control of Diseases. The risk maps play an important role in the guidance of interventional strategies, so as to develop system of cost-effective allocation of scarce resources.
- The risk ranges from 0 to 1, green indicating no or minor risk and red indicates high risk of the disease occurrence, dark red circles indicate outbreak locations of the disease.
- Periodic regression is used for the detection of seasonal and cyclical pattern in a time series data analysis. Seasonal variations are an important characteristic for disease occurrence. Most of the cyclical and seasonal variations of different types of data occur depending on the daily, monthly, yearly changes. Periodic regression is used to assess the significance of the risk factors for disease incidence or an outbreak as well as prediction and forecasting.

Climate Resilient Technologies/Products/varieties/germplasm lines/mapping population/genes/patents developed with brief description.

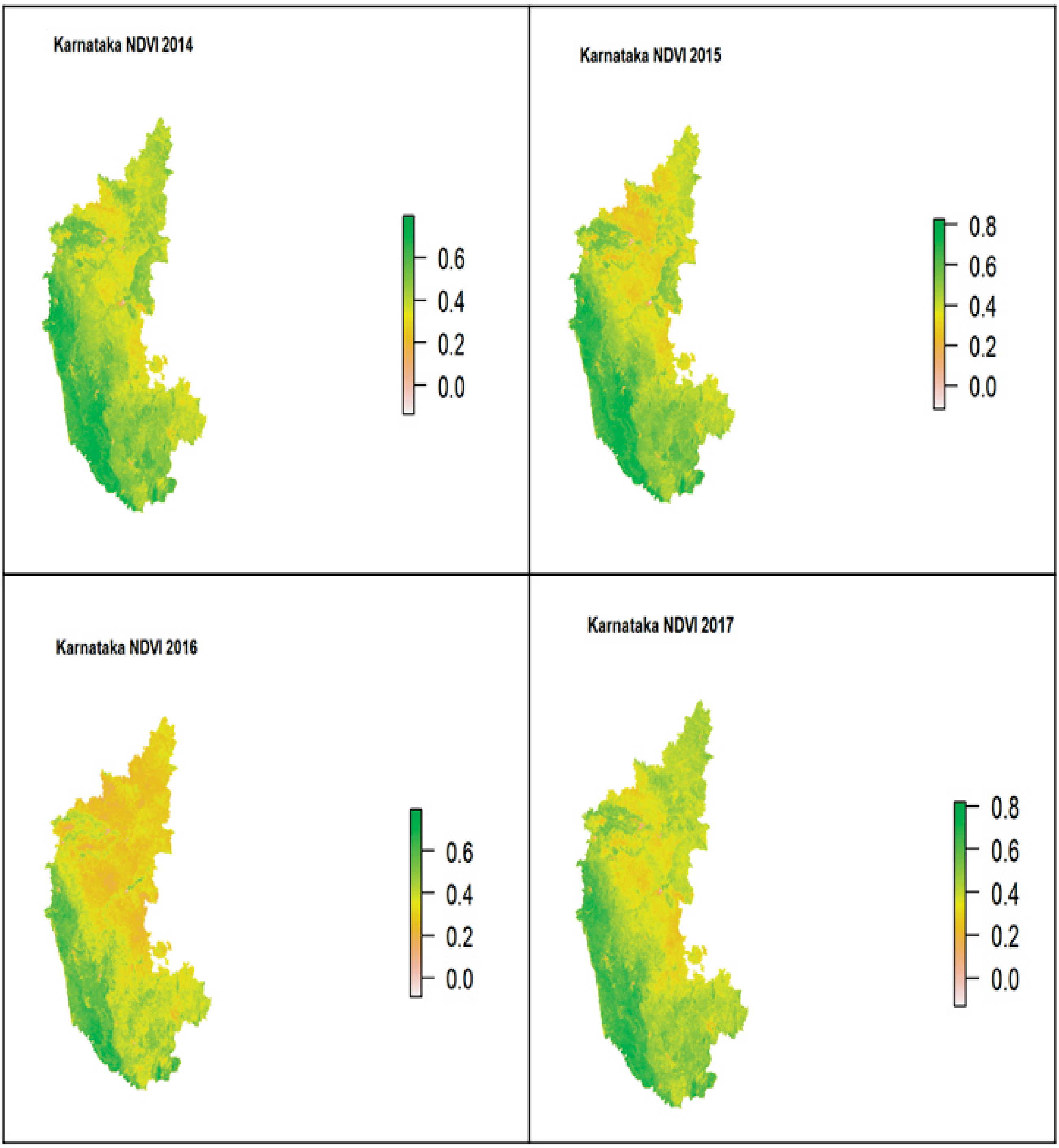
NDVI data for the period 2006-2007 for Karnataka



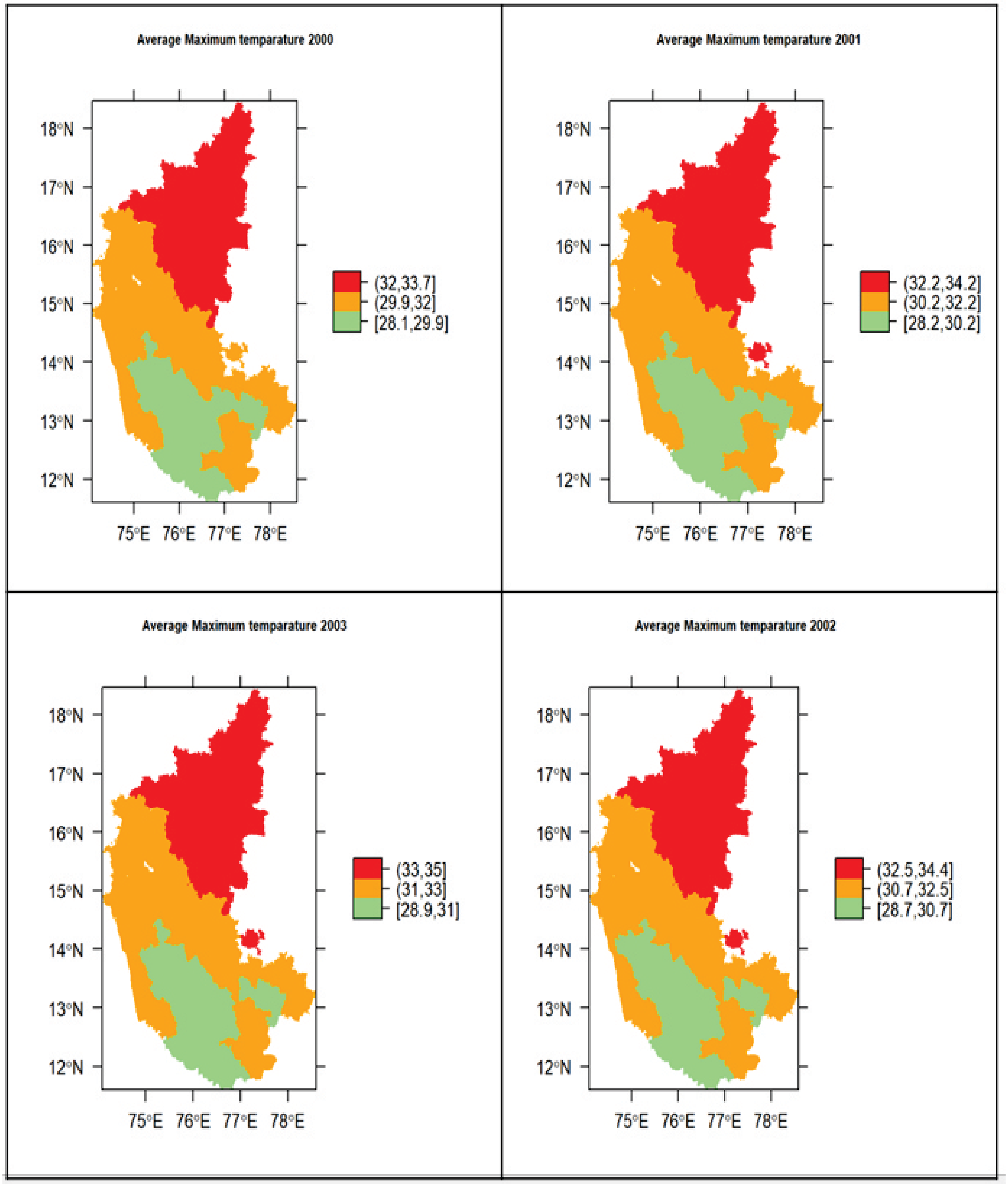
NDVI data for the period 2010-2013 for Karnataka



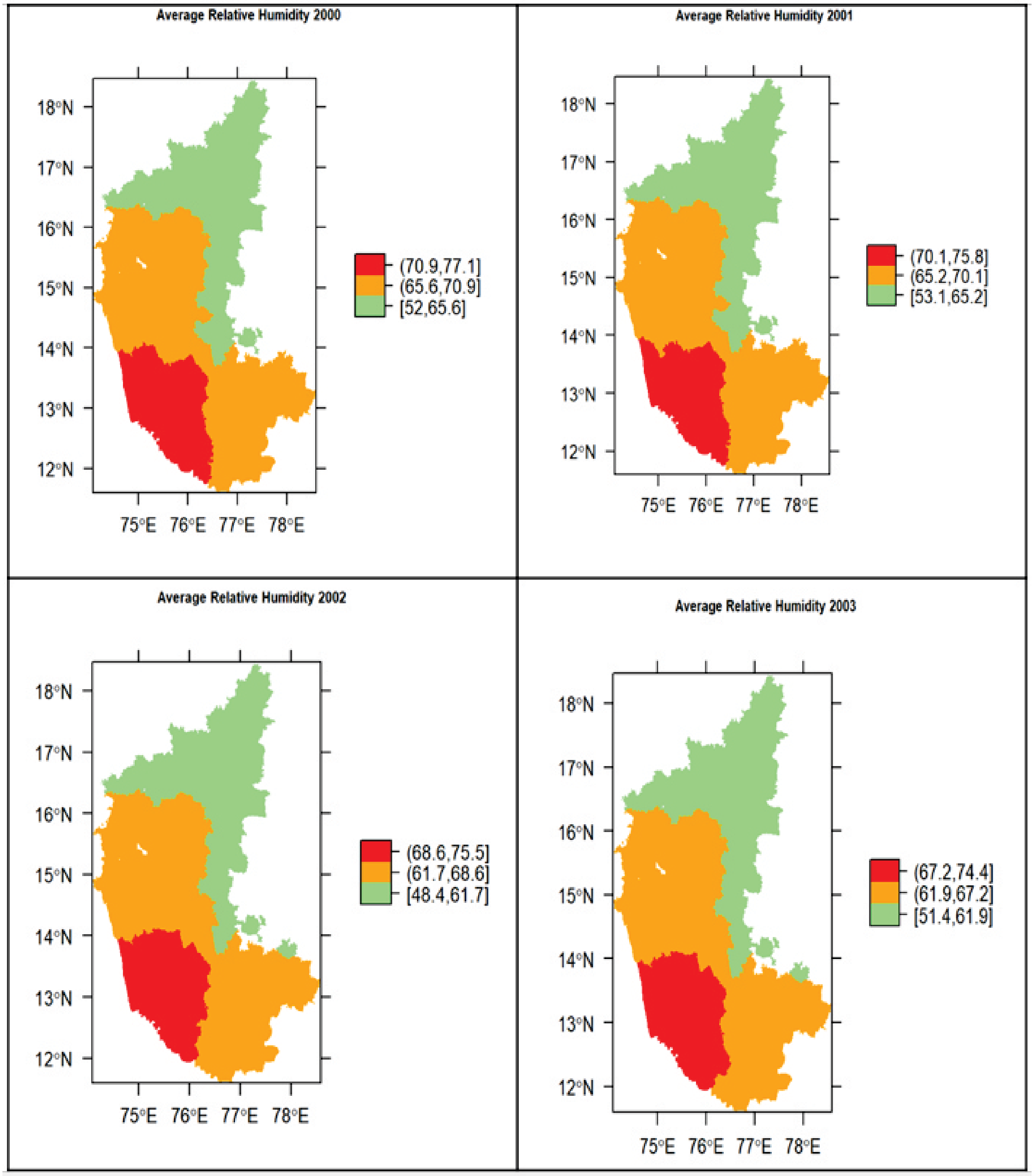
NDVI data for the period 2014-2017 for Karnataka



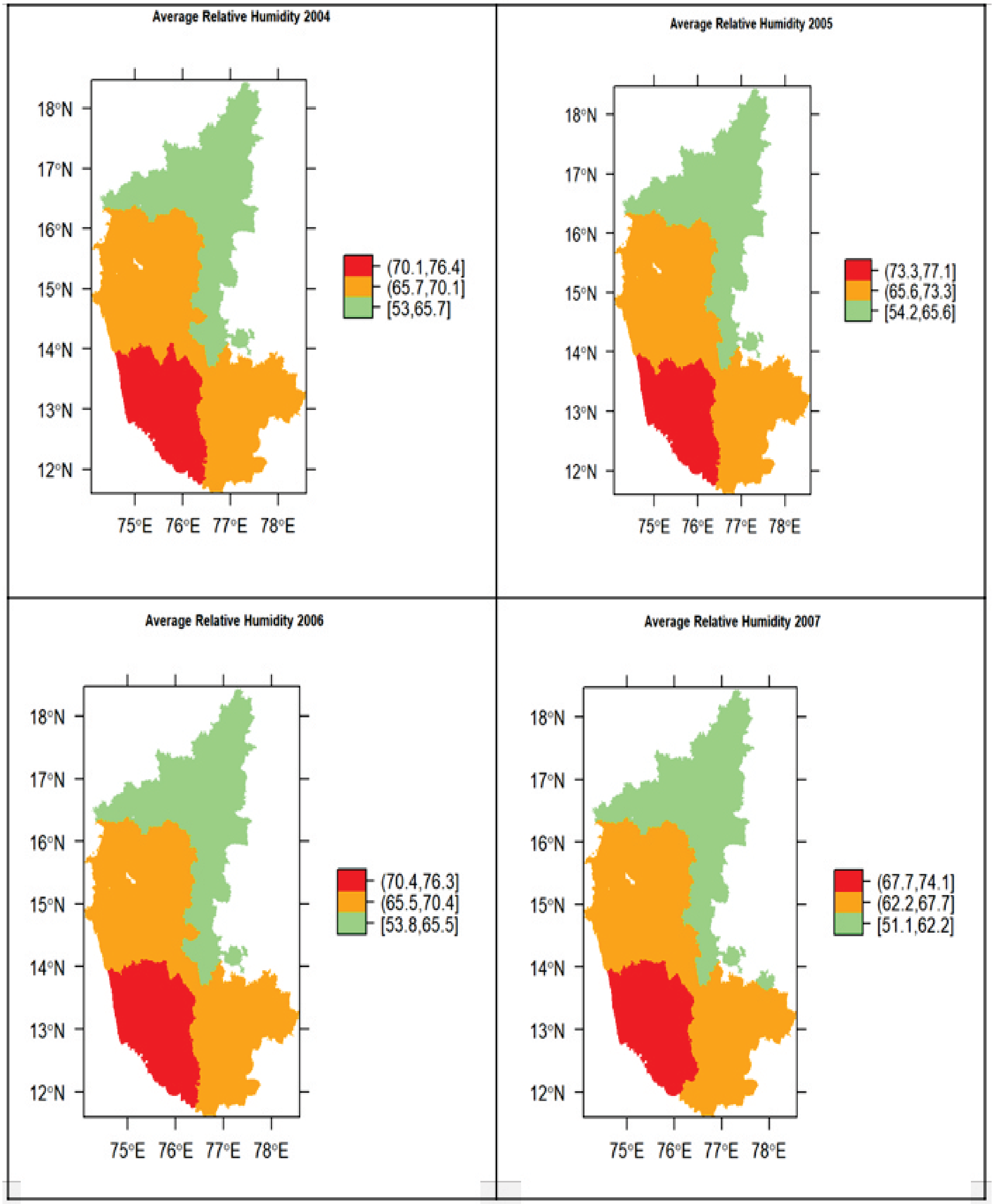
Average maximum temperature recorded in Karnataka during 2000-



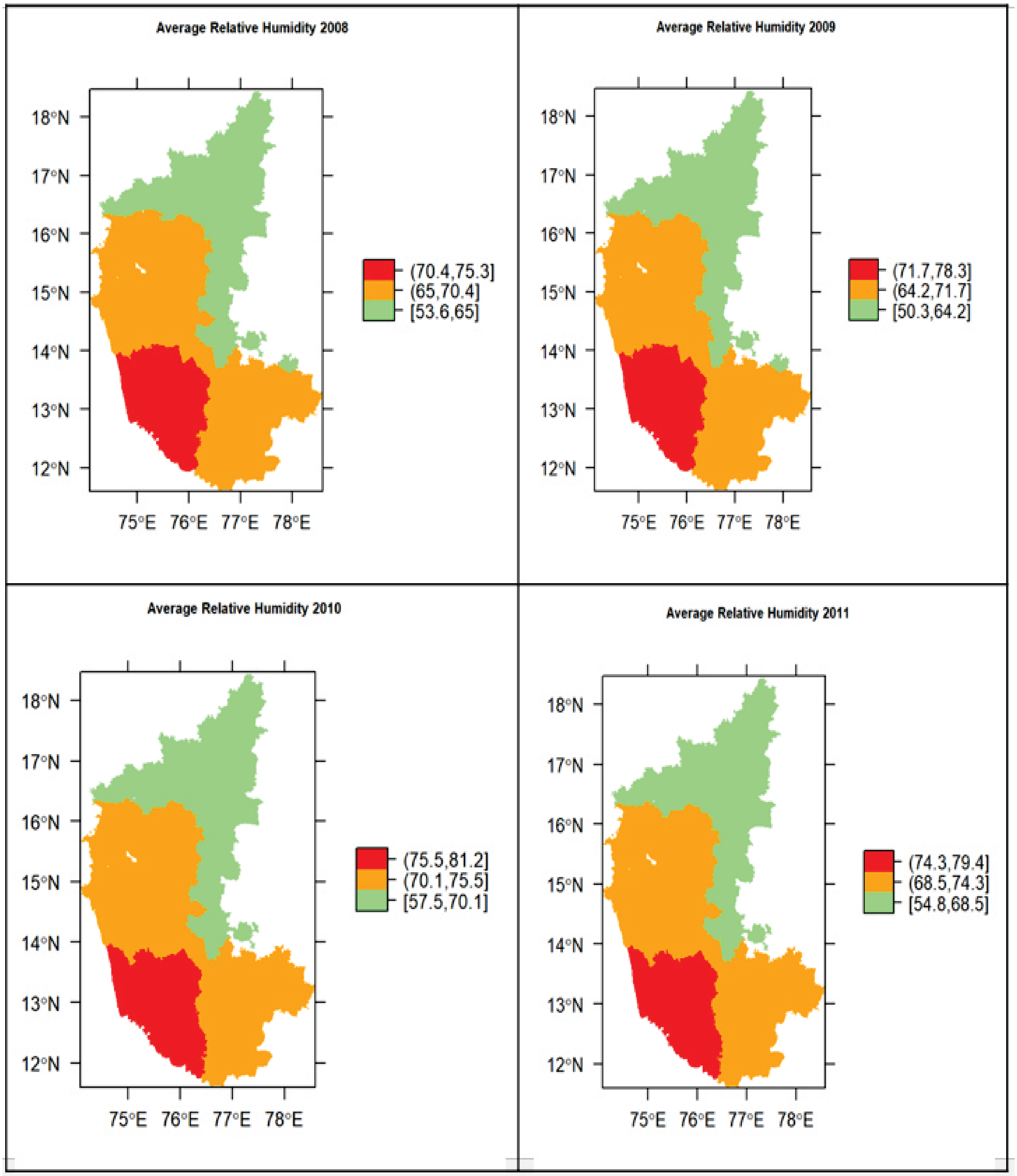
Average Relative Humidity in Karnataka 2000-2003



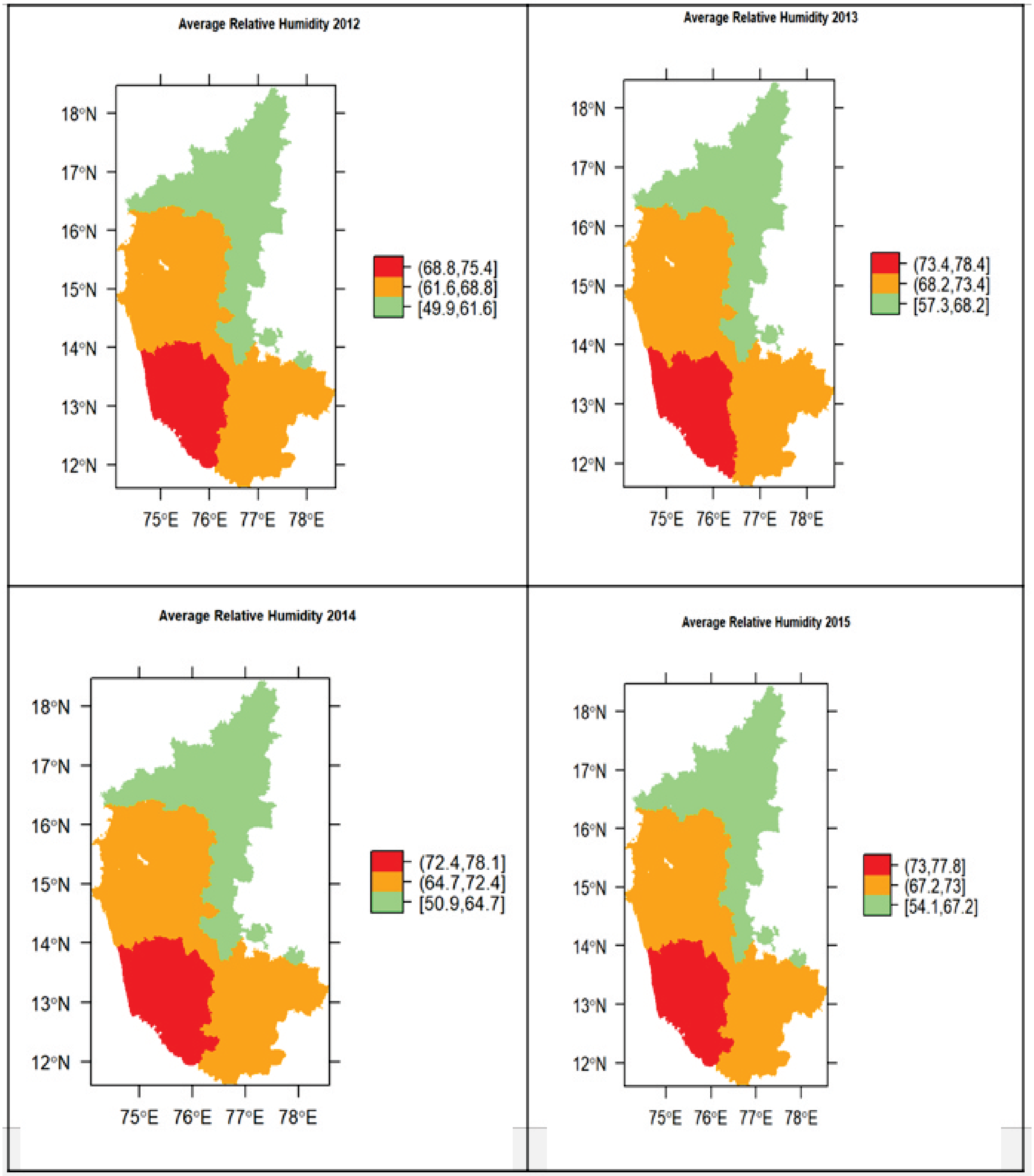
Average Relative Humidity in Karnataka 2004-2007



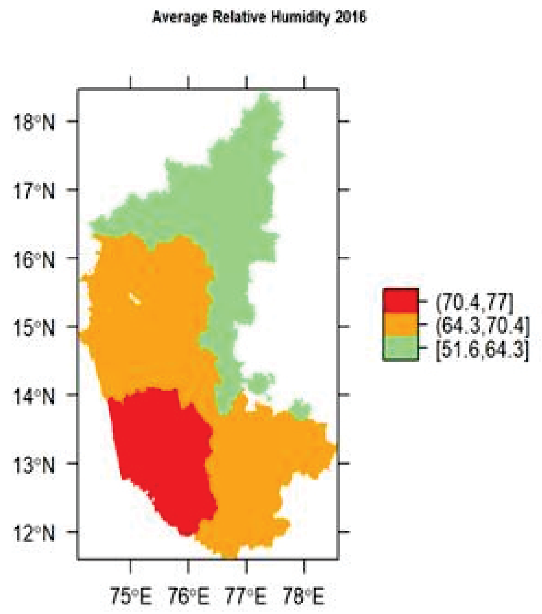
Average Relative Humidity in Karnataka 2008-2011

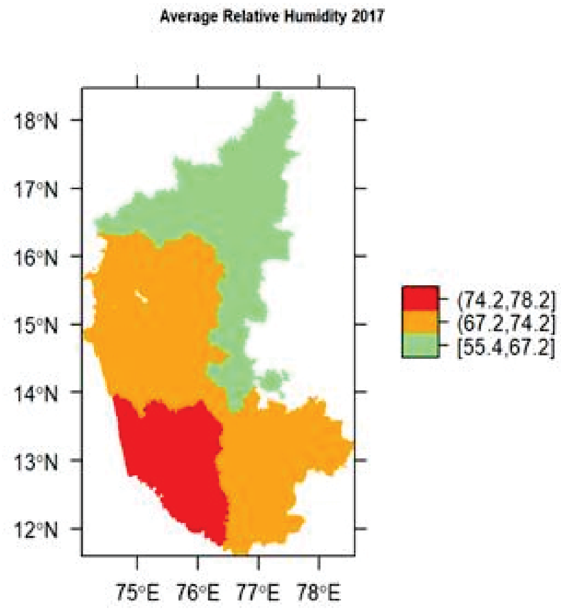


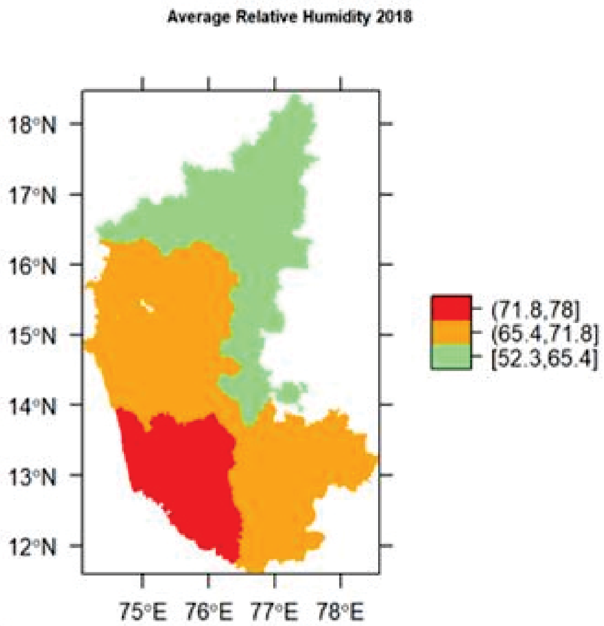
Average Relative Humidity in Karnataka 2012-2015



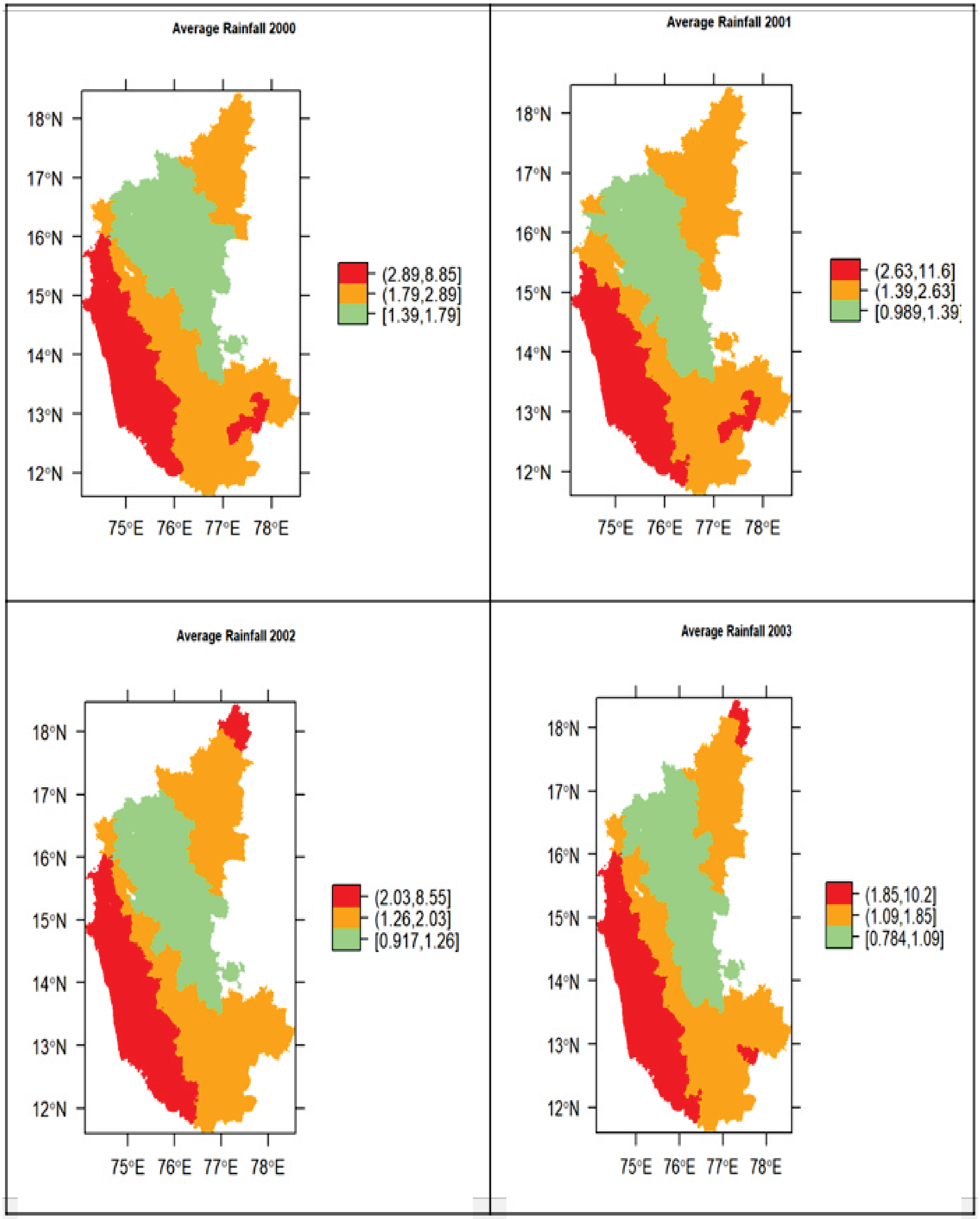
Average Relative Humidity in Karnataka 2016-2018



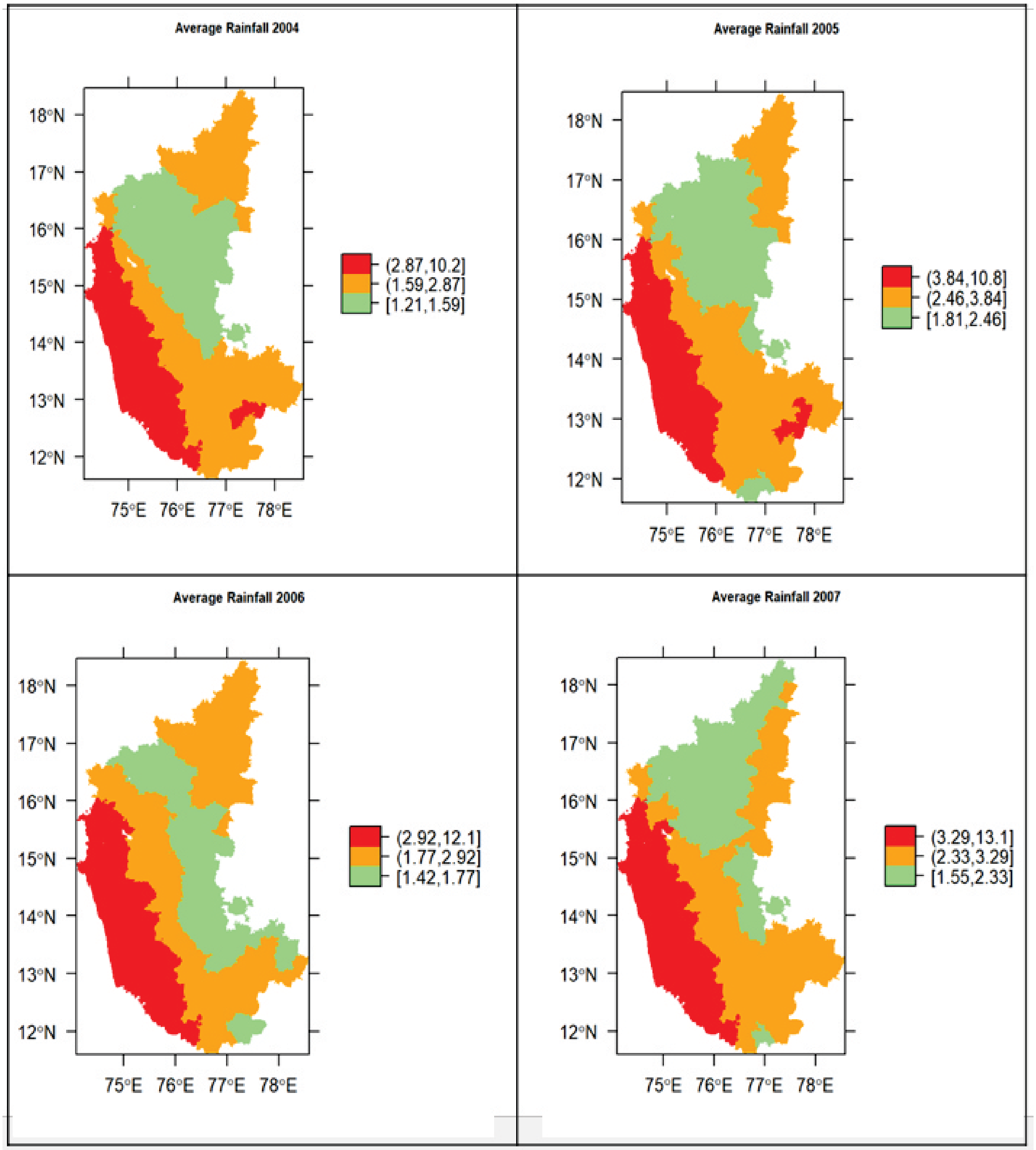




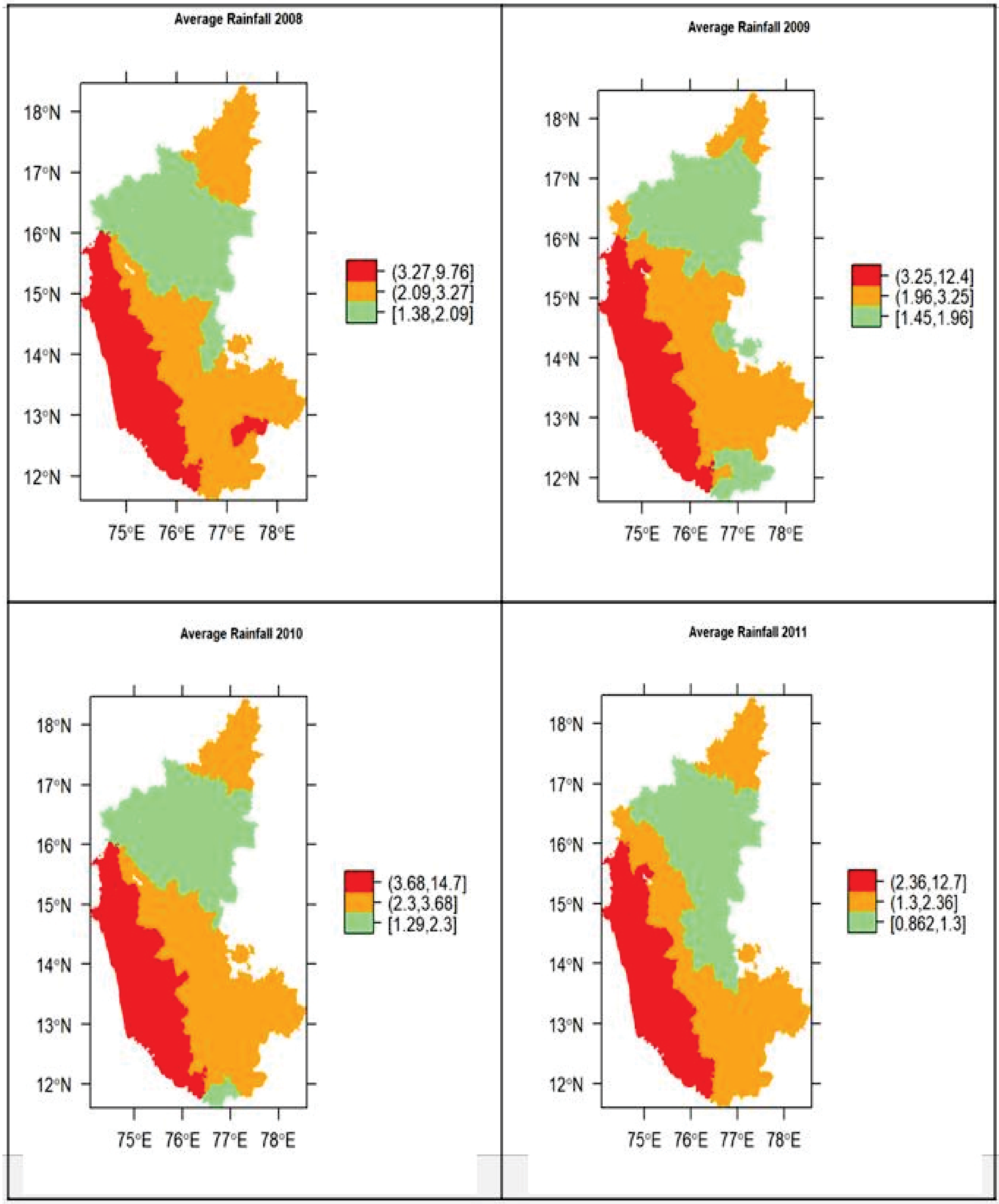
Average rainfall in Karnataka during 2000-2003



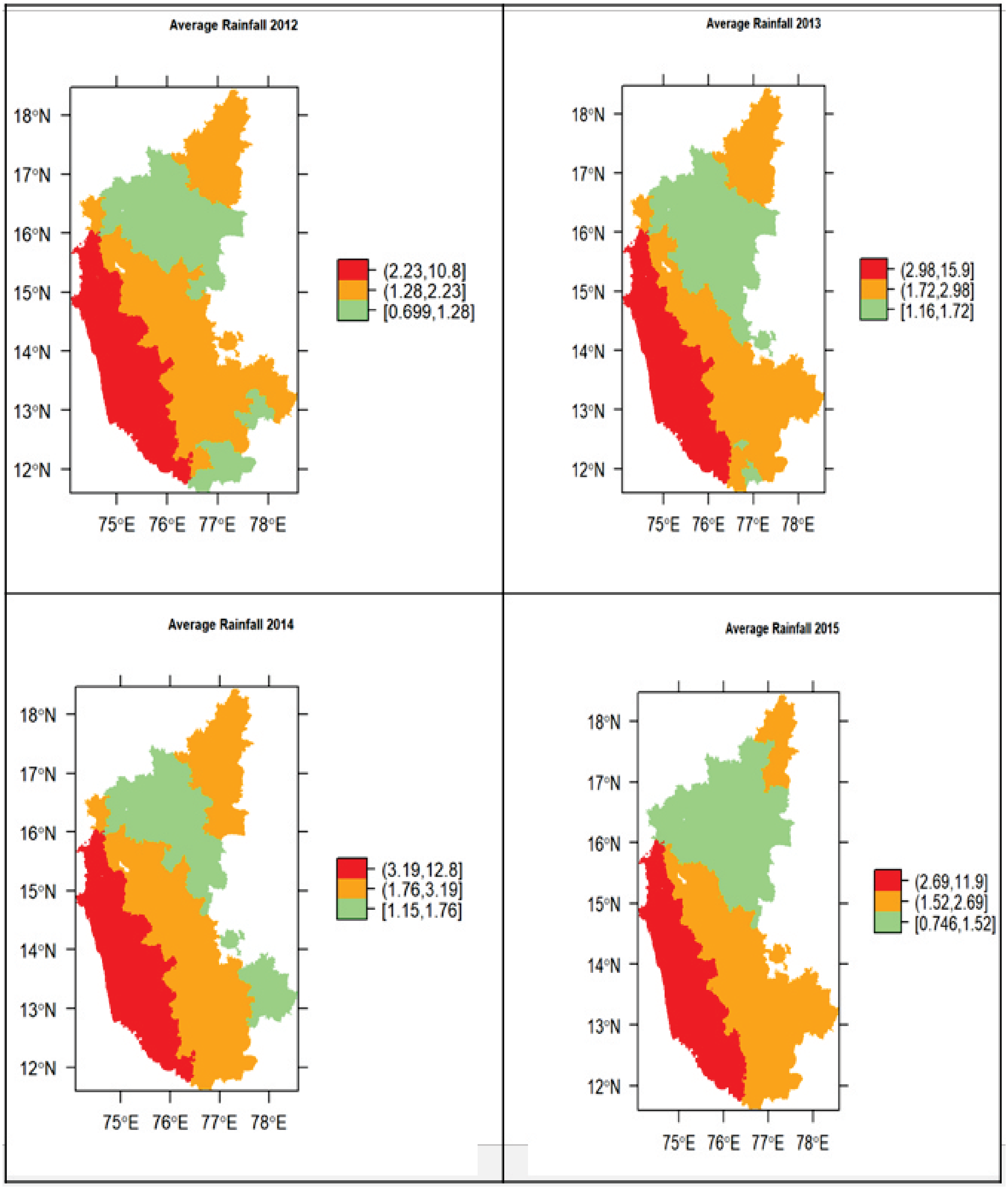
Average rainfall in Karnataka during 2004-2007



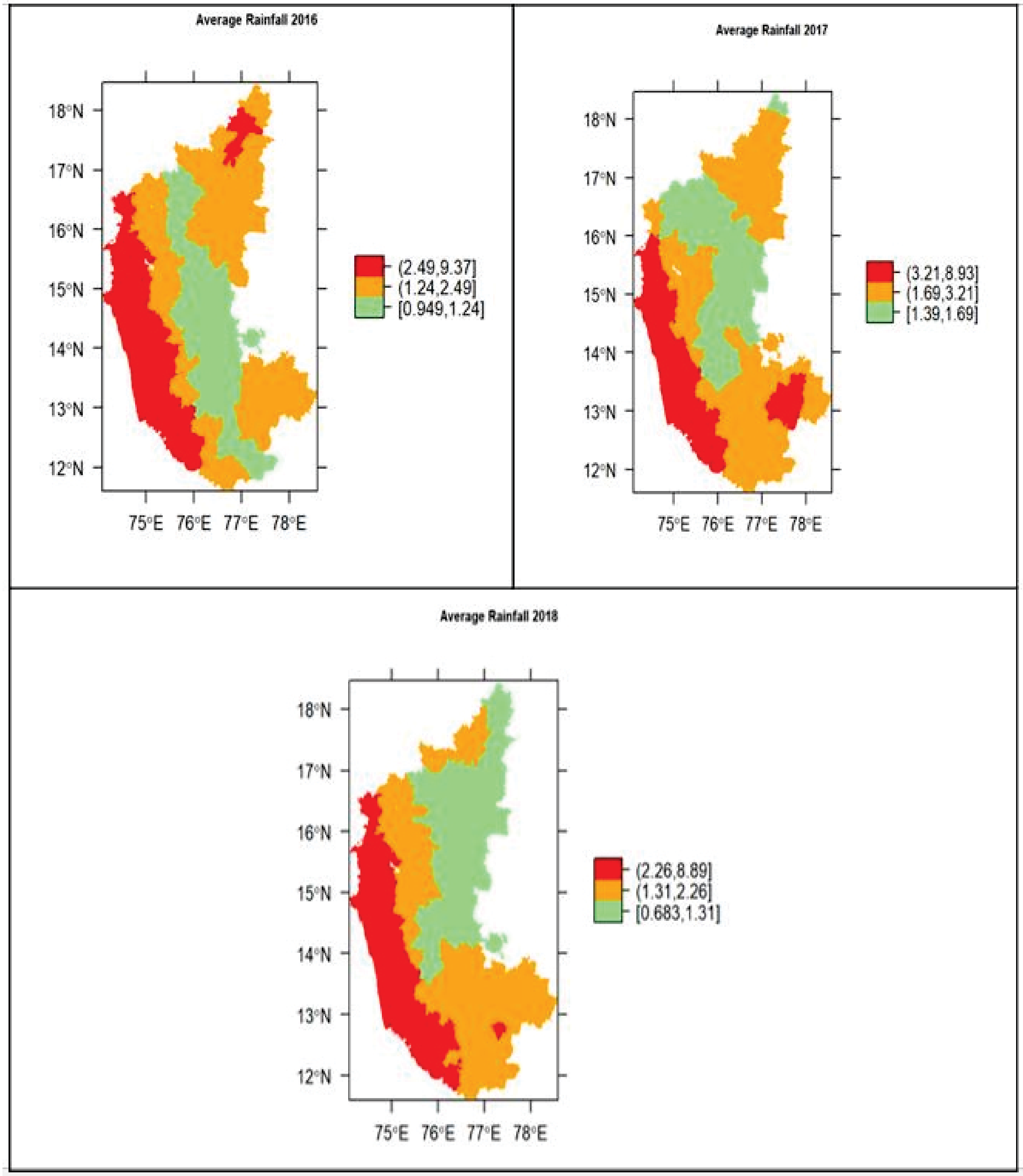
Average rainfall in Karnataka during 2008-2011



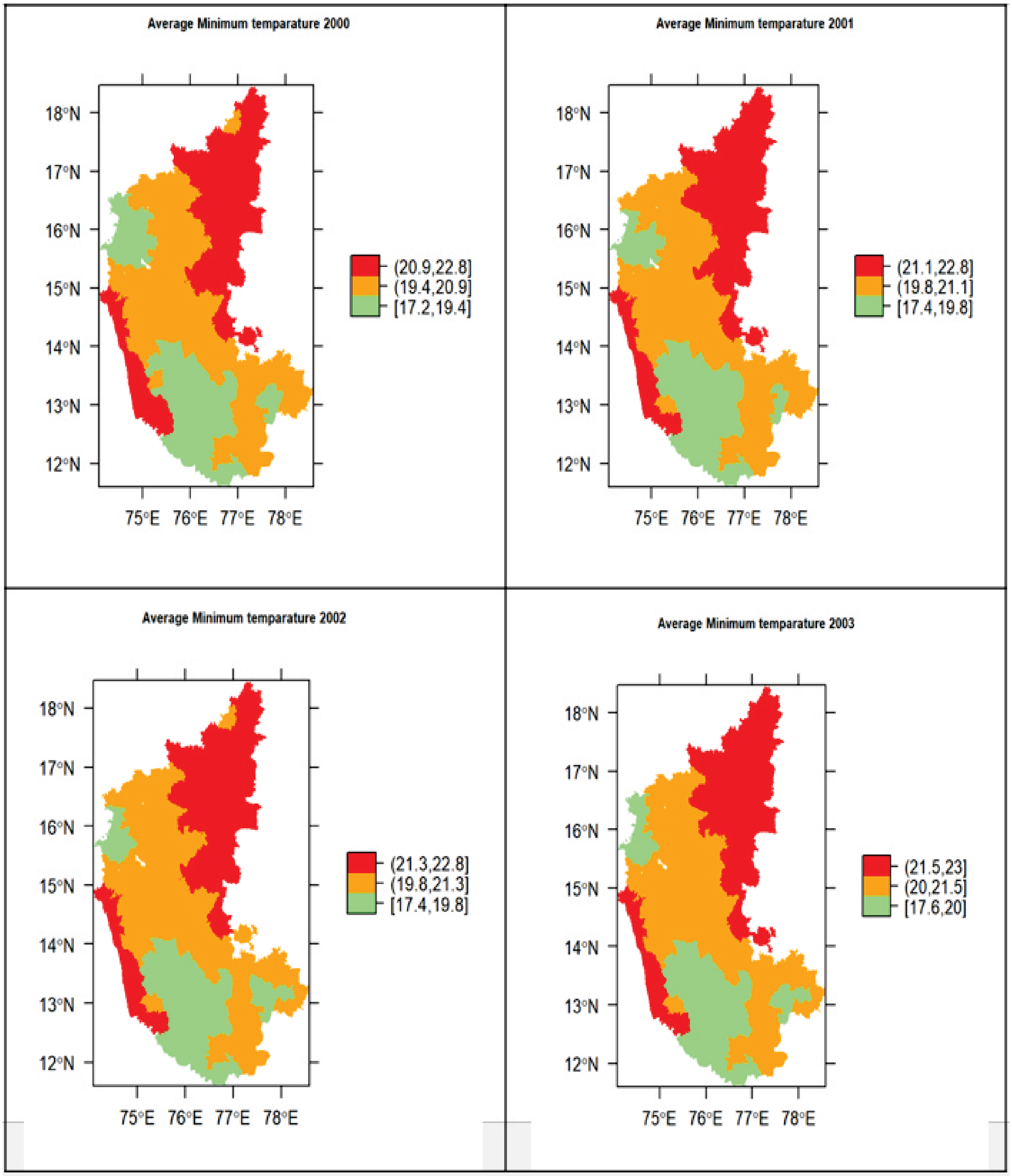
Average rainfall in Karnataka during 2012-2015



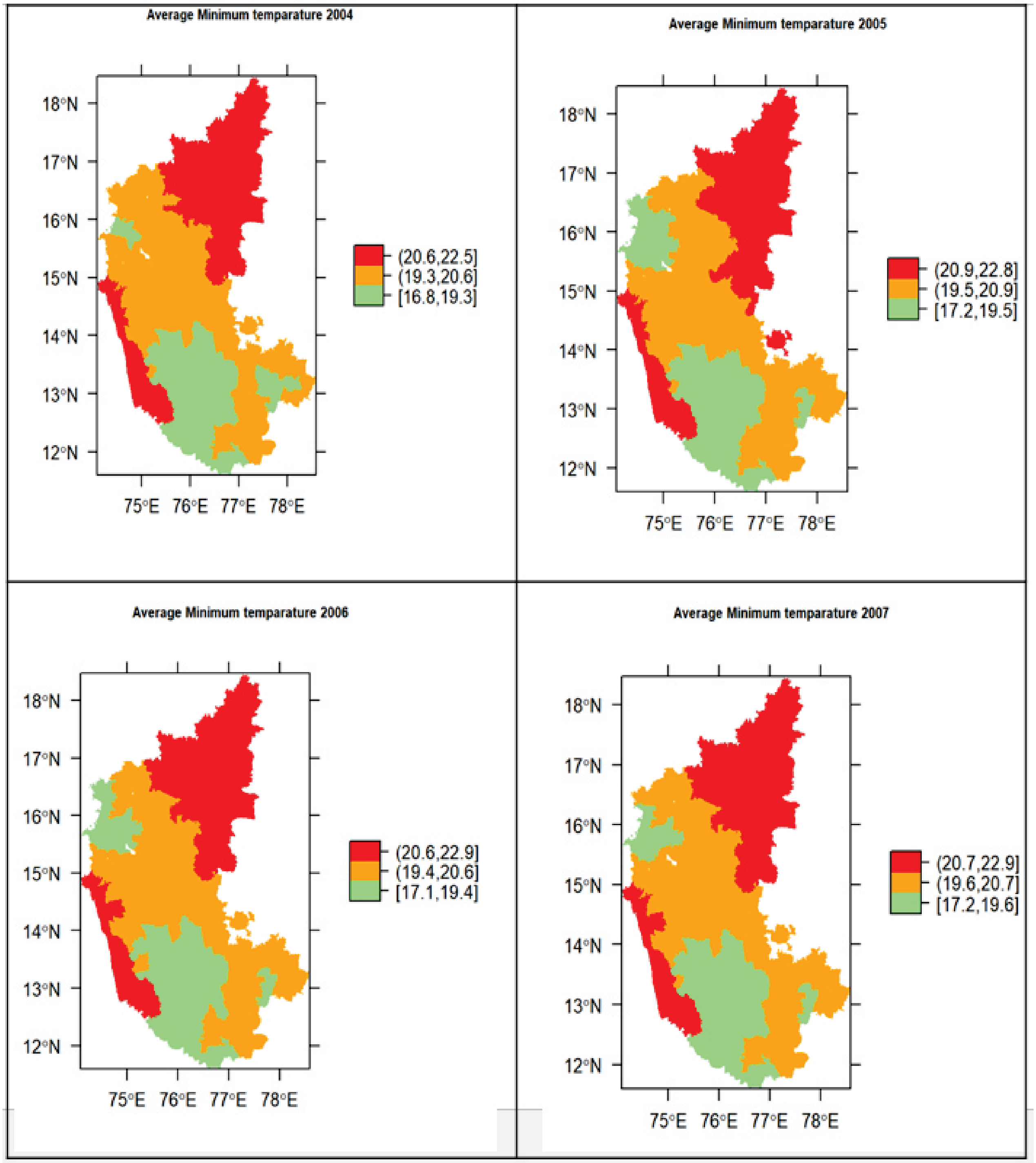
Average rainfall in Karnataka during 2016-2018



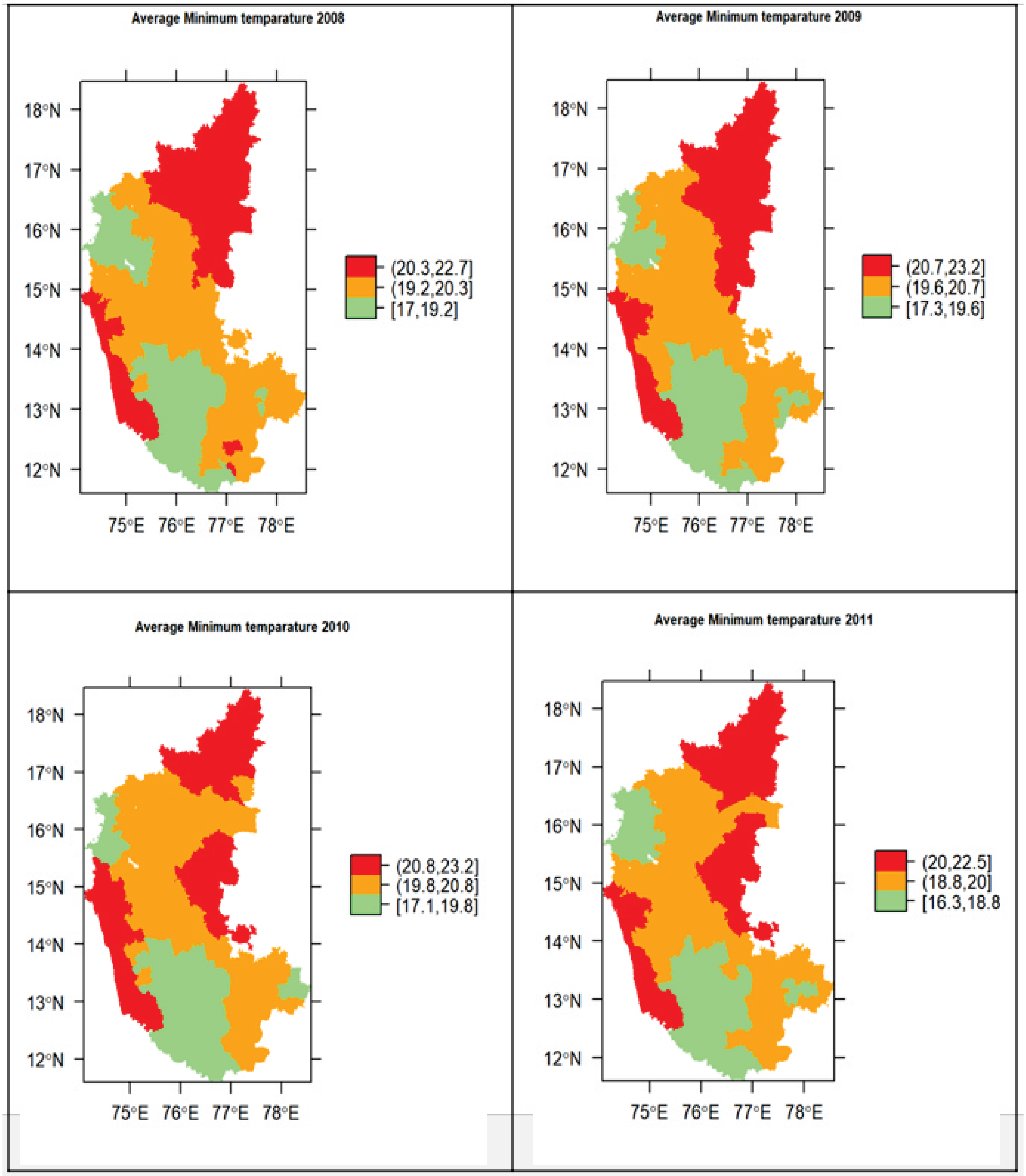
Average Minimum Temperatures recorded in Karnataka during 2000-2003



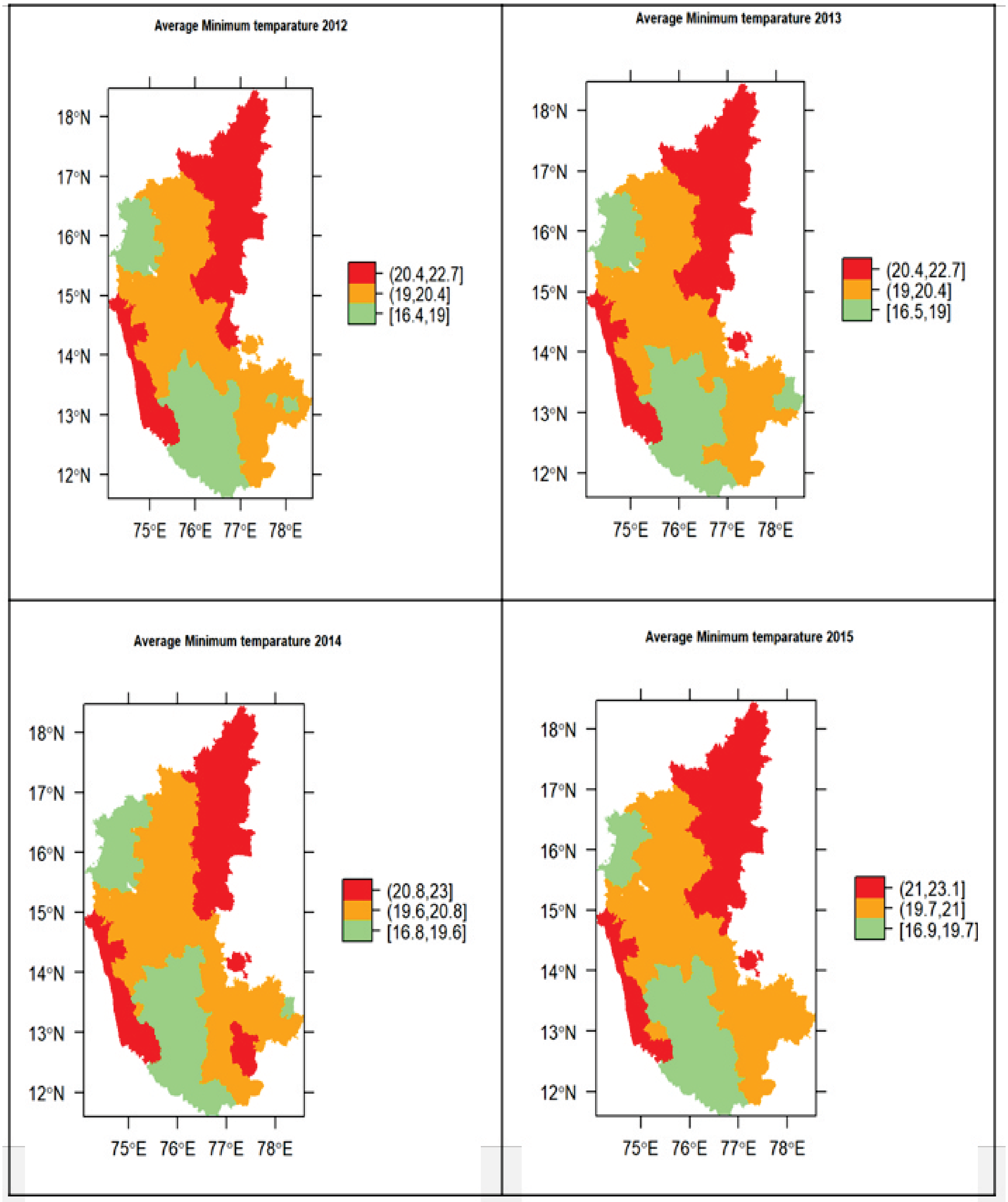
Average Minimum Temperatures recorded in Karnataka during 2004-2007



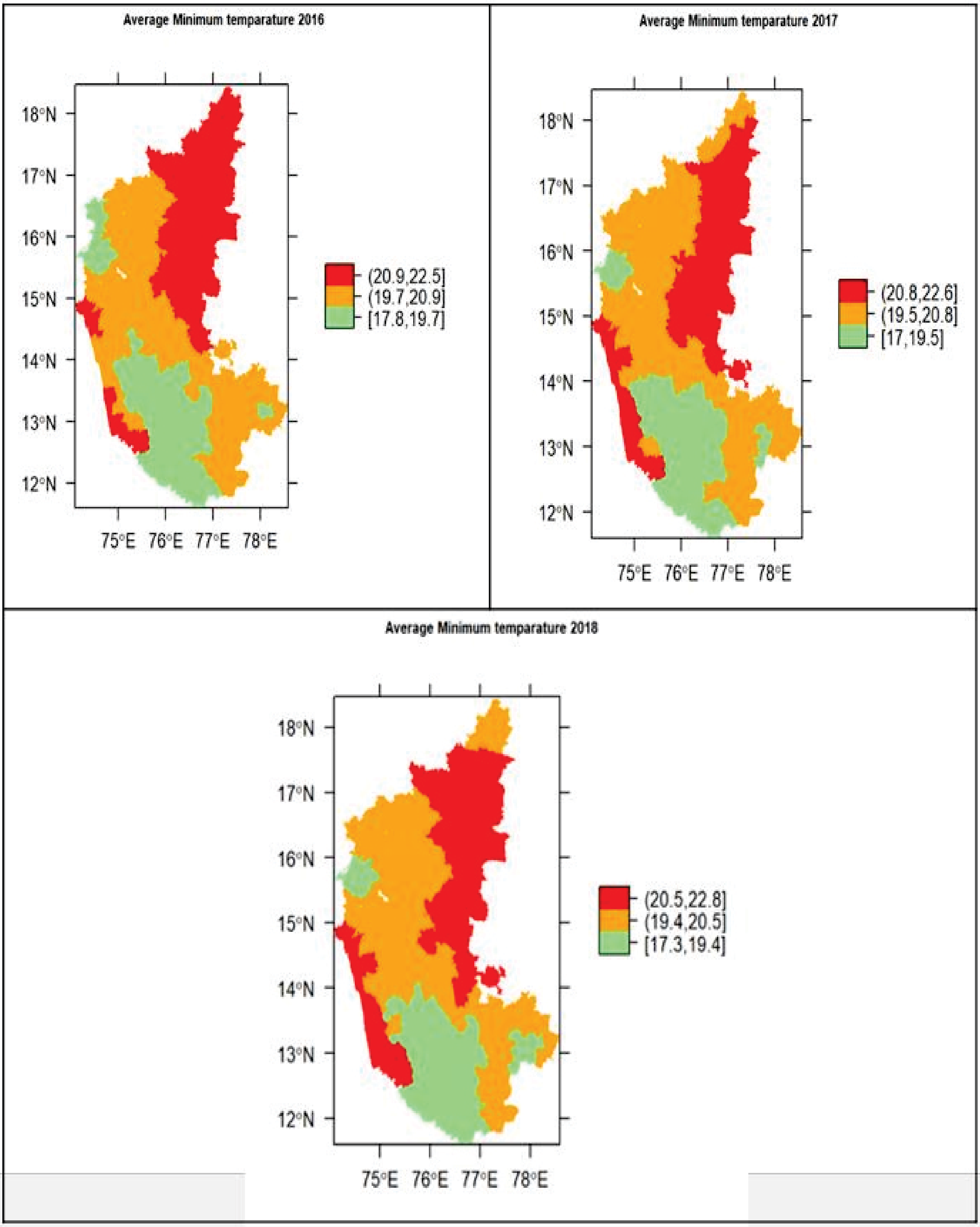
Average Minimum Temperatures recorded in Karnataka during 2008-2011



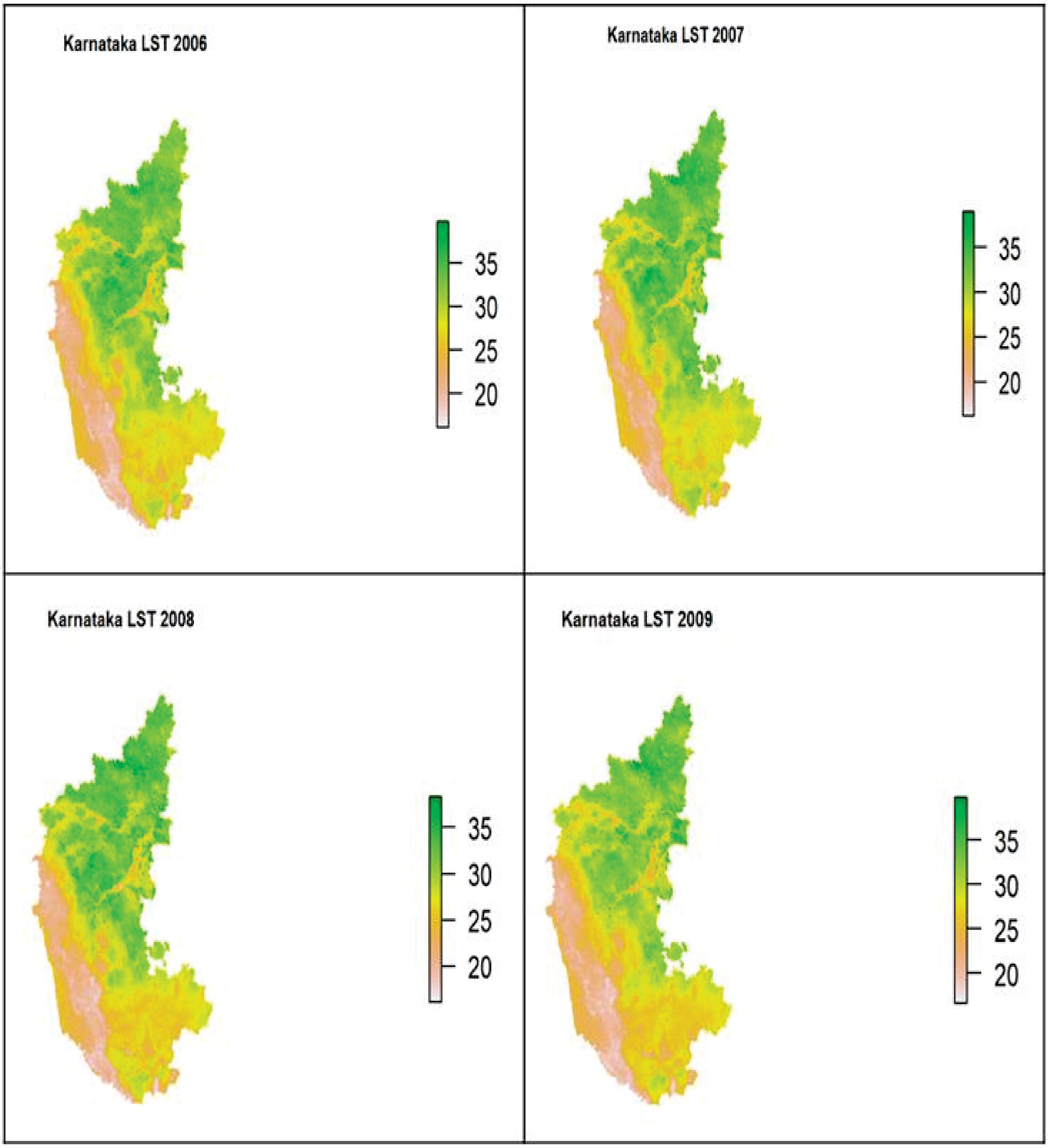
Average Minimum Temperatures recorded in Karnataka during 2012-2015



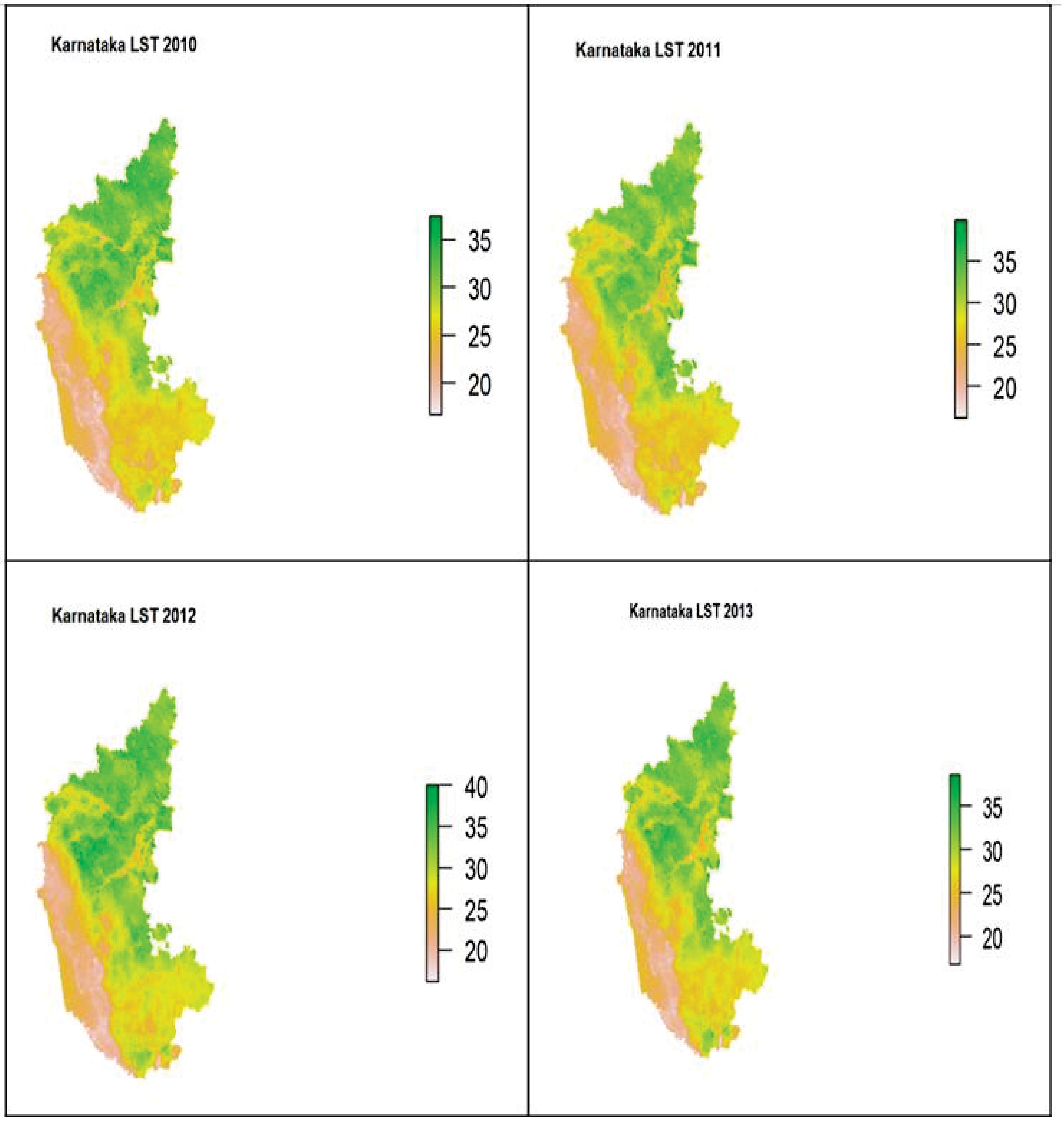
Average Minimum Temperatures recorded in Karnataka during 2016-2018



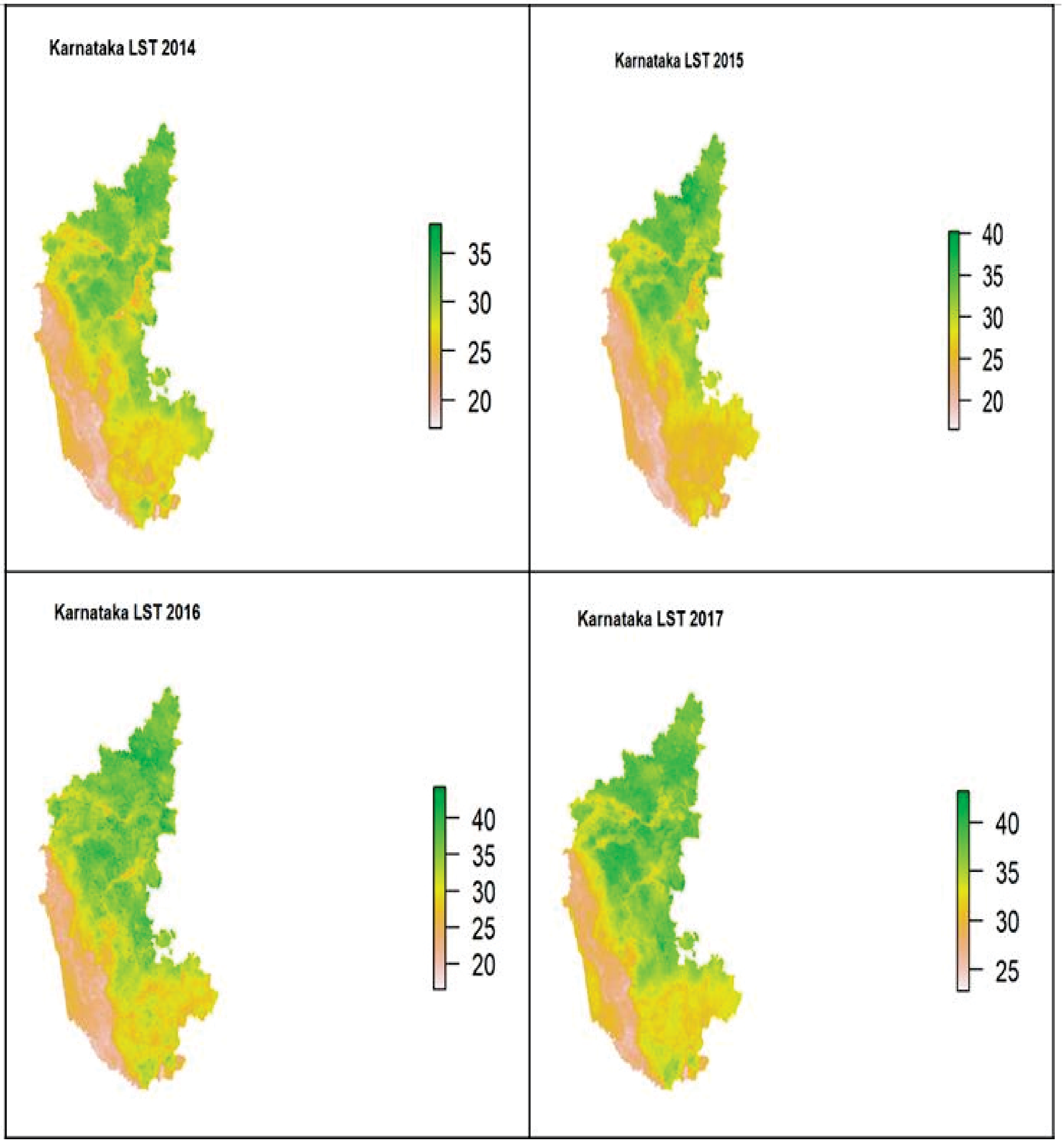
LST data for the period 2006-2009 for Karnataka



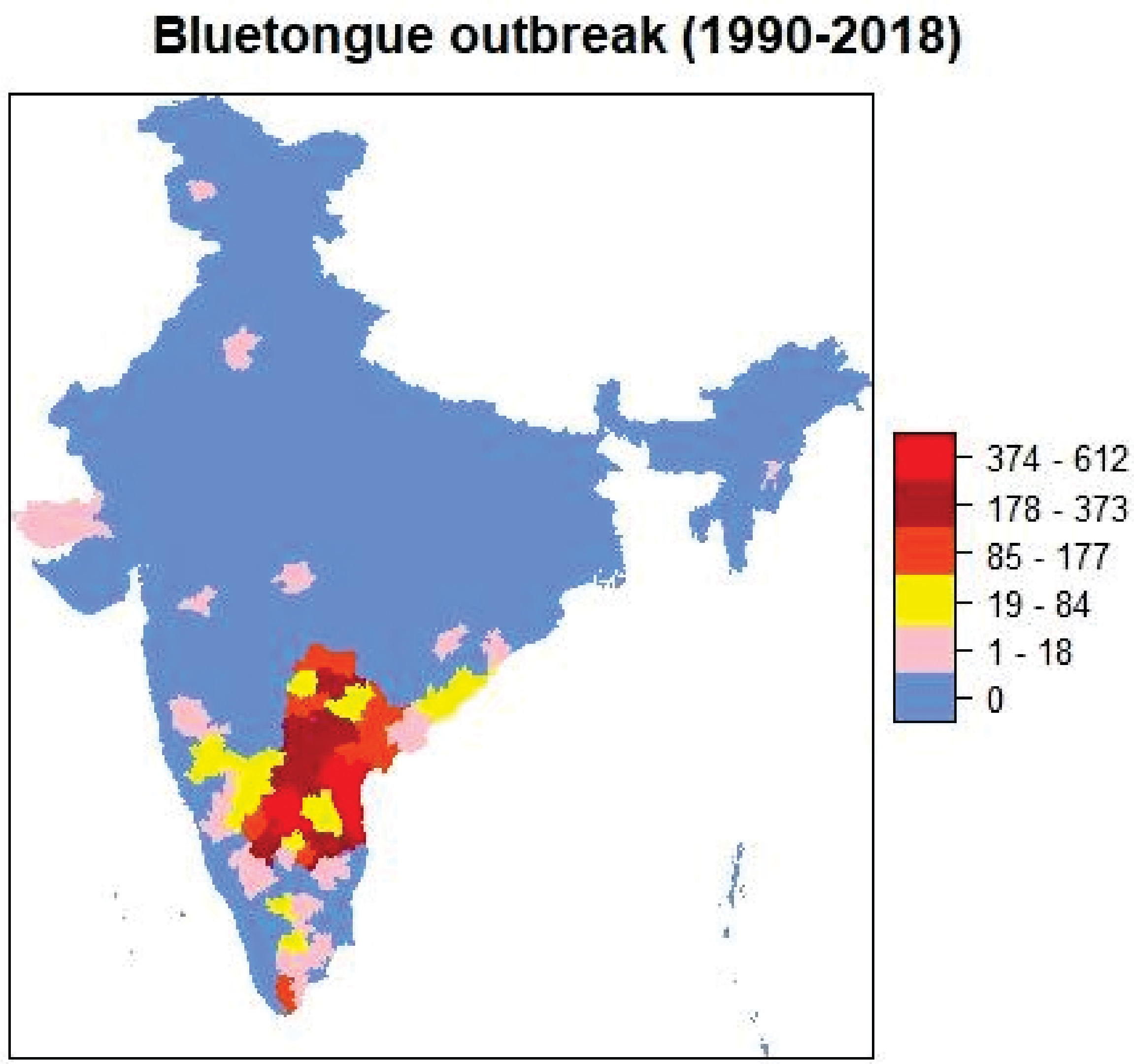
LST data for the period 2010-2013 for Karnataka



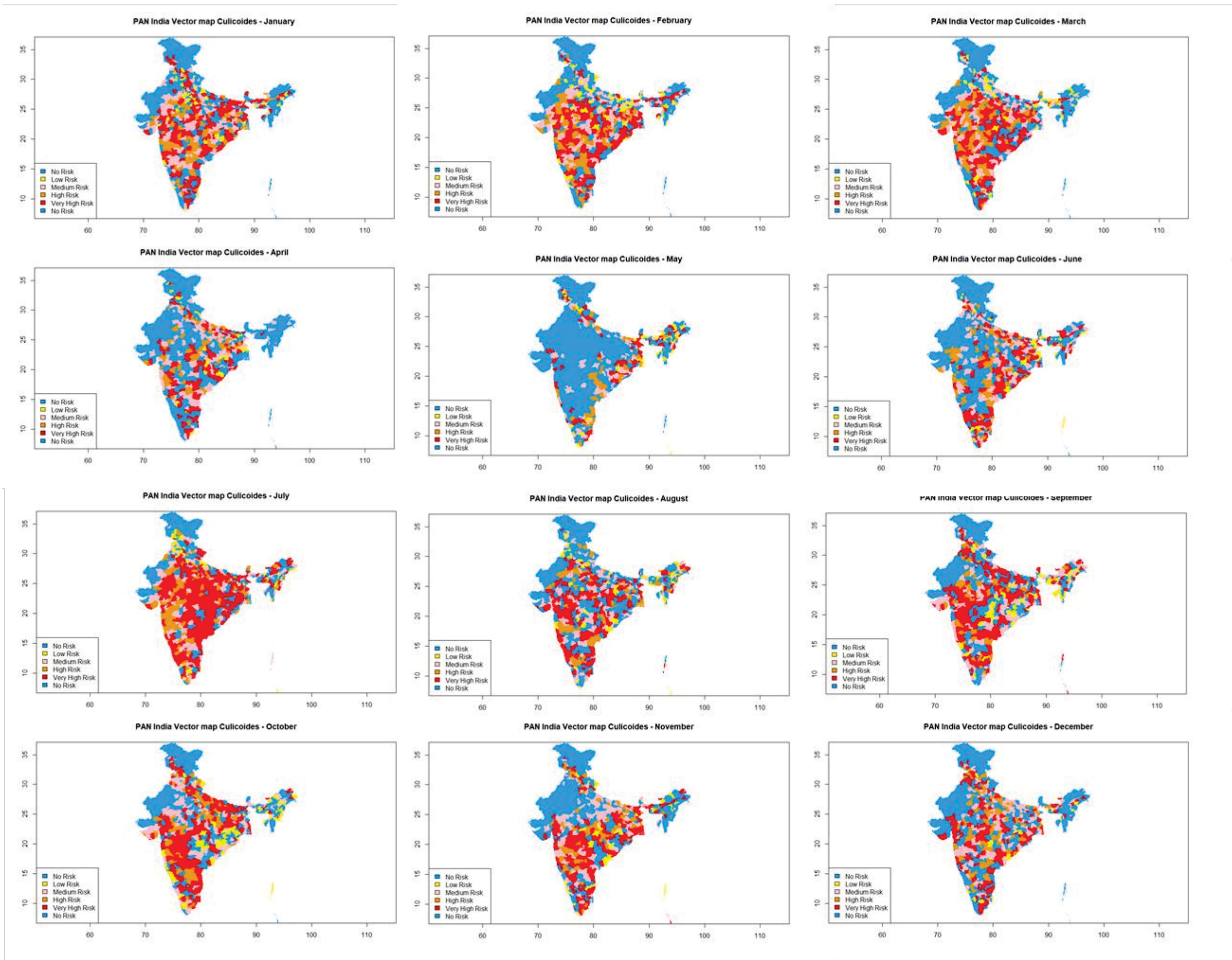
LST data for the period 2014-2017 for Karnataka



Bluetongue disease outbreak was cumulated and mapped from 1990-2018



Month-wise Bluetongue disease Vector (*Culicoides species*) map for India was developed to know the hotspots and spread of risk areas during different season



List of equipment's procured under NICRA project:

Sl. No	Name of the items	Quantity (No. s)
1.	Desktop Computer All in one system Make: Dell, Model: 5348	1
2.	Software & Antivirus (1) Ms Office Professional 2013 (2) Quick Heal total security antivirus (Single user 3 year validity)	1
3.	Electric Loop sterilizer without flame Make: Himedia, Model: LA832	1
4.	-20 Deep freeze Make: Vestfrost upright, Model: BFS345	1
5.	Electronic Balance Make: Sartorius Electronic, (Model BSA2235)	1
6.	Strontium 16gb metal (Pendrive)	5
7.	Laser jet colour Printer Make: HP, Model: Jet PRO MFP M227	1
8.	Laptop, MS-Office & antivirus software Make: Lenova yoga2, Model 59428504	1
9.	Audio visual equipment Make: Panasonic Model: W850	1
10.	Desktop computer for microscope	1
11.	Desktop computer	1
12.	Trinocular Head for microscope	1
13.	Digital camera for microscope for photography	1
14.	Digital camera for photography Make: Cannon DSLREOS600D, Model: W18.55	1
15.	Vertical Autoclave Make: Vestfrost Upright Deep Freezer, Model BSEA65	1
16.	Multi-channel Pipettee (Make: Omega) Singal channel 0.1ul-2ul Singal channel 0.5ul -10ul Singal channel 10ul-100ul Singal channel 20ul-200ul Singal channel 100ul-1000ul	1 each
17.	Screen Projector Make: Benq Projector, Model: MS506P	1
18.	Deep Freezer Make: Brand Elanpro, Model: EFS340	1

doubling farmers income through livestock health and production". 5-7th December 2017. College of Veterinary and Animal Science, Parbhani, Maharashtra, India. pp: 253-254.

11. Hamsapriaya S, Dheeraj R, Krishnamoorthy P, Parimal Roy and Suresh KP. 2018. Meta-analysis on prevalence of Extended spectrum beta lactamase (ESBL) producing pathogens in animals. In: XXXI Annual Convention of Indian Association of Veterinary Microbiologists, Immunologists and Specialists in Infectious Diseases. 29-31st January 2018 at College of Veterinary Science, SVVU, Tirupati, Andhra Pradesh, India. pp: 79.

Manual:

1. Technical Report- Climate data generation, mapping and climate-disease relation modelling using R". (2018). Compiled and edited by Suresh KP, Krishnamoorthy P, Siju SJ. pp: 1-36. http://krishi.icar.gov.in/jspui/handle/123456789/16703

GenBank Submissions:

1. GenBank: LWDC00000000.1 - Escherichia coli strain SCM-21
2. GenBank: LWDB00000000.1 - Proteus mirabilis strain NIVEDI 3-PG74
3. Sequence analysis based on mitochondrial cytochrome oxidase subunit 1 gene and identified the tick species with GenBank accession numbers

Sl. No	Isolate No.	Ticks Identified	GenBank Accession No.
1	NIVEDI_2019_PK01	*Rhipicephalus microplus*	MK736267
2	NIVEDI_2019_PK02	*Hyalomma excavatum*	MK736268
3	NIVEDI_2019_PK03	*Haemaphysalis bispinosa*	MK749746
4	NIVEDI_2019_PK04	*Rhipicephalus microplus*	MK749744
5	NIVEDI_2019_PK05	*Rhipicephalus microplus*	MK749745
6	NIVEDI_2019_PK06	*Rhipicephalus microplus*	MK789135
7	NIVEDI_2019_PK07	*Rhipicephalus microplus*	MK820033
8	NIVEDI_2019_PK08	*Haemaphysalis bispinosa*	MK820028
9	NIVEDI_2019_PK09	*Haemaphysalis bispinosa*	MK820029
10	NIVEDI_2019_PK10	*Haemaphysalis bispinosa*	MK820030
11	NIVEDI_2019_PK11	*Rhipicephalus sanguineus*	MK820031
12	NIVEDI_2019_PK12	*Haemaphysalis bispinosa*	MK820032
13	NIVEDI_2019_PK13	*Rhipicephalus microplus*	MK749747
14	NIVEDI_2019_PK14	*Rhipicephalus microplus*	MK749748
15	NIVEDI_2019_PK15	*Rhipicephalus microplus*	MK749749
16	NIVEDI_2019_PK16	*Rhipicephalus microplus*	MK749750

4. Krishnamoorthy P, Kanani A, Shah N, Shome BR, Suresh KP and Roy P. 2018. Spatial and temporal epidemiological analysis of ten livestock diseases of Gujarat state, India. In: Veterinary Pathology Congress 2018 and XXXV National symposium on Recent advances in Veterinary pathology and disease diagnosis for sustainable livestock and poultry production. 22-24th October 2018 at College of Veterinary Science and Animal Husbandry, Sardarkrushinagar, Gujarat, India. pp: 178.
5. Shinduja R., Shruthi C.R., Rashmi R. Kurli, Dheeraj R. and Suresh K.P. 2019.A systematic review and Meta-analysis on prevalence of parasitic diseases in animals of North eastern region, India. In: 28th National Congress of Veterinary Parasitology and National Symposium on Novel Technologies and strategies for sustainable control of parasitic diseases of Livestock, Poultry and Public health significance. 28th -30th January 2019 at College of veterinary science, Sri Venkateswara Veterinary University, Tirupati Andhra Pradesh, India
6. Rashmi R. Kurli., Dheeraj R., Siju Susan Jacob., P.Krishnamoorthy., D.Hemadri., K.P.Suresh. 2019. Suitability risk analysis of Bluetongue in Karnataka. In: "XIV Agricultural Science Congress at New Delhi from February 20-23, 2019 on the theme "Innovations for Agricultural Transformation" at New Delhi, India
7. Sridevi R, Krishnamoorthy P, Rashmi K, Dheeraj R, Patil SS and Suresh KP. 2018. Peste des Petits Ruminants: spatial risk mapping of Maharashtra by Bioclimatic variables. In: XXXI Annual Convention of Indian Association of Veterinary Microbiologists, Immunologists and Specialists in Infectious Diseases. 29-31st January 2018 at College of Veterinary Science, SVVU, Tirupati, Andhra Pradesh, India. pp: 221.
8. Krishnamoorthy P, Govindaraj G, Kanani A, Shah N, Shome BR and Roy P. 2017. Spatio-temporal epidemiological analysis of zoonotic diseases of livestock in Gujarat. In: National symposium on "Intersectoral approaches to combat zoonoses: strategies and challenges". 11-13th October 2017, College of Veterinary Science, Sri Venkateswara Veterinary University, Tirupati, Andhra Pradesh, India. pp: 248-249.
9. Krishnamoorthy P, Tatwarthy SB, Suryawanshi SN, Shome BR and Roy P. 2017. Spatio-temporal epidemiological analysis of livestock diseases of Maharashtra state. In: International conference on "Emerging horizons in diagnosis of animal and poultry diseases-towards sustainable production in Asian countries. 9-11th November 2017, Veterinary College, Bengaluru, Karnataka, India. pp: 60-61.
10. Hamsapriya S, Rashmi RK, Krishnamoorthy P, Suresh KP, Roy P. 2017. A systematic review and meta-analysis on prevalence of methicillin resistant Staphylococcus aureus in Animals. In: National conference on "Recent trends in Veterinary Immunology and biotechnology for

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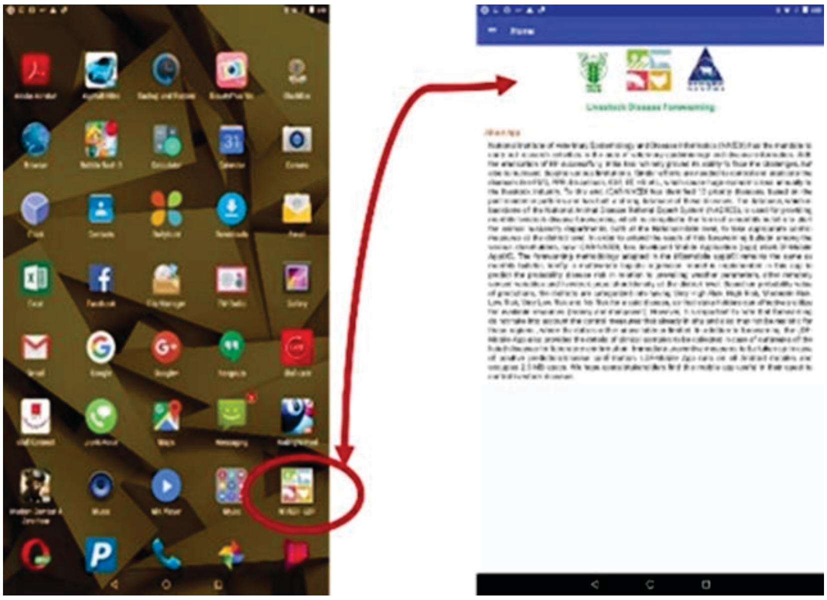
4	NIVEDI_2019_PK04	*Rhipicephalus microplus*	MK749744
5	NIVEDI_2019_PK05	*Rhipicephalus microplus*	MK749745
6	NIVEDI_2019_PK06	*Rhipicephalus microplus*	MK789135
7	NIVEDI_2019_PK07	*Rhipicephalus microplus*	MK820033
8	NIVEDI_2019_PK08	*Haemaphysalis bispinosa*	MK820028
9	NIVEDI_2019_PK09	*Haemaphysalis bispinosa*	MK820029
10	NIVEDI_2019_PK10	*Haemaphysalis bispinosa*	MK820030
11	NIVEDI_2019_PK11	*Rhipicephalus sanguineus*	MK820031
12	NIVEDI_2019_PK12	*Haemaphysalis bispinosa*	MK820032
13	NIVEDI_2019_PK13	*Rhipicephalus microplus*	MK749747
14	NIVEDI_2019_PK14	*Rhipicephalus microplus*	MK749748
15	NIVEDI_2019_PK15	*Rhipicephalus microplus*	MK749749
16	NIVEDI_2019_PK16	*Rhipicephalus microplus*	MK749750

LDF Mobile App



In order to extend the reach of this forewarning bulletin among the various stakeholders, ICAR - NIVEDI, has developed Mobile Application (app) “LDF-Mobile App”. The forewarning methodology adapted in the “mobile app” remains the same as monthly bulletin; briefly, a multivariate logistic regression model is implemented in this app to predict the probability disease risk in relation to prevailing weather parameters, other remotely sensed variables and livestock population/density at the district level. Based on probability value of predictions, the districts are categorized into having Very High Risk, High Risk, Moderate Risk, Low Risk, Very Low Risk and No Risk for a said disease, so that stake holders can effectively utilize the available resources (money and manpower). However, it is important to note that forewarning do not take into account the control measures that already in situ and also may not be realistic for those regions, where the data is either unavailable or limited.

Audit Utilization Certificates

Budget 2015-16

Name of the Institute: **ICAR – National Institute of Veterinary Epidemiology & Disease Informatics**

Ramagondanahalli, Yelahanka, Bangalore – 560 064, Karnataka.

Statement of Expenditure in respect of NICRA project for the year 2015-16

Title of the Project: Livestock Disease Surveillance in relation to weather data and emergence of new pathogens

Name of the PI: Dr. B.R. Shome, Principal Scientist

S. No.	Sub-Head	Amount Sanctioned for the year 2015-16	Expenditure incurred during the year 2015-16	Closing balance as on 31st March, 2016
A.	**Recurring Contingencies**			
1	Operational expenses (Labour, skilled staff, POL, Supplies etc.,) Contractual Services etc.,	2000000	1934547	65453
2	TA	200000	96093	103907
3	HRD			
	Sub – total A (1-3)	***2200000***	***2030640***	***169360***
B.	Non-Recurring			
4	Equipment			
5	Furniture			
6	Information Technology	250000	0	250000
7	Minor Works/Renovation			
8	Equipment costing less than Rs.5 lakhs	500000	100483	399517
	Sub – total (4-8)	***750000***	***100483***	***649517***
	Grand Total (A+B)	**2950000**	**2131123**	**818877**

11/4/16

Signature of Principal Investigator

डा. बि.आर. सोम, एम.वि.एस.सि.,पिएच.डा.,
Dr. B.R. SHOME, M.V.Sc.,Ph.D.,
प्रधान वैज्ञानिक/Principal Scientist
पी आई निकरा/PI-NICRA Project
भाकृअनुप-निवेदी/ICAR-NIVEDI
रामगोंडनहल्लि, बेंगलूरू-५६० ०६४
Ramagondanahalli, Bengaluru-560 064

11/4/16

Signature of Asstt. Finance & Accounts Officer

Asst. Finance & Accounts Officer
निवेदी / NIVEDI
बेंगलूरू-६४/Bengaluru-64

Budget 2016-17

Name of the Institute: ICAR-National Institute of Veterinary Epidemiology and Disease Informatics							
Statement of Expenditure in respect of NICRA project for the year 2016-17							
Title of the Project : National Initiative on Climate Rsilient Agriculture (NICRA)							
Name of the PI : DR. B. R. Shome, Principal Scientist							
Sl. No	Sub-Haed	Budget for 2016-17	Openinig balance as on 01.04. 2016	Receipts 2016-17	Expenditure incured during the year 2016-17	Refund during 2016-17	Balance as on 30.11.2016
A.	**Recurring Contingencies**						
1	Operational expenses (Labour, Skilled staff, POL, Supplies etc.,) Contractual Service etc.,	2600000	65453	1274517	1297330		42640
2	TA	200000	103907	100000	107116		96791
3	HRD	50000		25000			25000
	Sub-total A (1-3)	2850000	**169360**	**1399517**	**1404446**	**0**	**164431**
B.	**Non-Recuring**						0
4	Equipment						
5	Furniture						0
6	Information Technology		250000	-250000	0	0	0
7	Minor Works/Renovation						
8	Equipment Costing less than RS. 5 lakhs		399517	-399517	0	0	0
	Sub-total B (4-8)	0	**649517**	**-649517**			**0**
	Grand Total (A+B)	**2850000**	**818877**	**750000**	**1404446**	**0**	**164431**

Signature of Principal Investigator
Dr. B.R. SHOME, M.V.Sc.,Ph.D.,
Principal Scientist
PI-NICRA Project
ICAR-NIVEDI
Ramagondanahalli, Bengaluru-560 064

Signature of Finance & Accounts Officer/
Comptoller/Charterd-Accountant
Asst. Finance & Accounts Officer
NIVEDI
Bengaluru-64

Budget 2017-18

Name of the Institute: ICAR-National Institute of Veterinary Epidemiology and Disease Informatics

Statement of Expenditure in respect of NICRA project for the year 2017-18

Title of the Project: [illegible]

Name of the PI: [illegible]

(Rupees)

Sl No	Sub Head	Opening balance as on 1st April 2017	Released during 2017-18	Amount Released during 2017-18	Expenditure incurred 1st April 2017 to 31st March 2018	Closing balance as on 31st March 2018
A.	Recurring Contingencies	-	-	-	-	-
1	Operational expenses (RA/SRF's, Young Professionals, Labour, [illegible] POL, Supplies, Contractual Services etc.)	-	-	[illegible]	[illegible]	[illegible]
2	TA	-	-	[illegible]	[illegible]	[illegible]
3	HRD	-	-	-	-	-
	Subtotal of A (1-3)	-	-	[illegible]	[illegible]	[illegible]
B.	Non-Recurring				-	
1	Equipment	-	-	-	-	-
2	Furniture	-	-	-	-	-
3	Information Technology	[illegible]	[illegible]	-	-	-
4	Works	-	-	-	-	-
	Subtotal B (1-4)	[illegible]	[illegible]	-	-	-
	Grand total (A+B)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Signature of Principal Investigator

Signature of Finance & Accounts Officer / Comptroller / Chartered Accountant

Budget 2018-19

[illegible]

[illegible]

[illegible]

S.N.	Sub-Head	Opening balance as on 1st April 2018	RE sanctioned 2018-19	Amount Released during 2018-19	Expenditure incurred 2018-19	Refund if any	Closing balance as on 31st March, 2019
A.	Grants in Aid General (Recurring)						
1	Operational expenses (RA, SRF's, Young Professionals, Labour, skilled staff, POL, Supplies, Contractual Services etc.)	[illegible]	[illegible]	[illegible]	[illegible]	-	[illegible]
2	TA	[illegible]	[illegible]	[illegible]	[illegible]	-	[illegible]
3	HRD	-	-	-	-	-	-
4	SCSP Component	-	-	-	-	-	
	Sub-total of A (1-4)	[illegible]	[illegible]	[illegible]	[illegible]	-	[illegible]
B.	Grants for Creation of Capital Assets (Capital)						
5	Equipment	-	[illegible]	[illegible]	[illegible]	-	[illegible]
6	Furniture	-	-	-	-	-	-
7	Information Technology	-	[illegible]	[illegible]	[illegible]	-	[illegible]
8	Works	-	-	-	-	-	-
9	SCSP Component	-	-	-	-	-	-
	Sub-total B (5-9)	-	[illegible]	[illegible]	[illegible]	-	[illegible]
C.	Institutional Charges	-	-	-	-	-	-
	Grand Total (A+B+C)	[illegible]	[illegible]	[illegible]	[illegible]	-	[illegible]

Signature of Principal Investigator

[illegible]

Signature of Finance & Accounts Officer / Comptroller / Chartered Accountant

[illegible]