Spatial analysis for disease data and disease mapping

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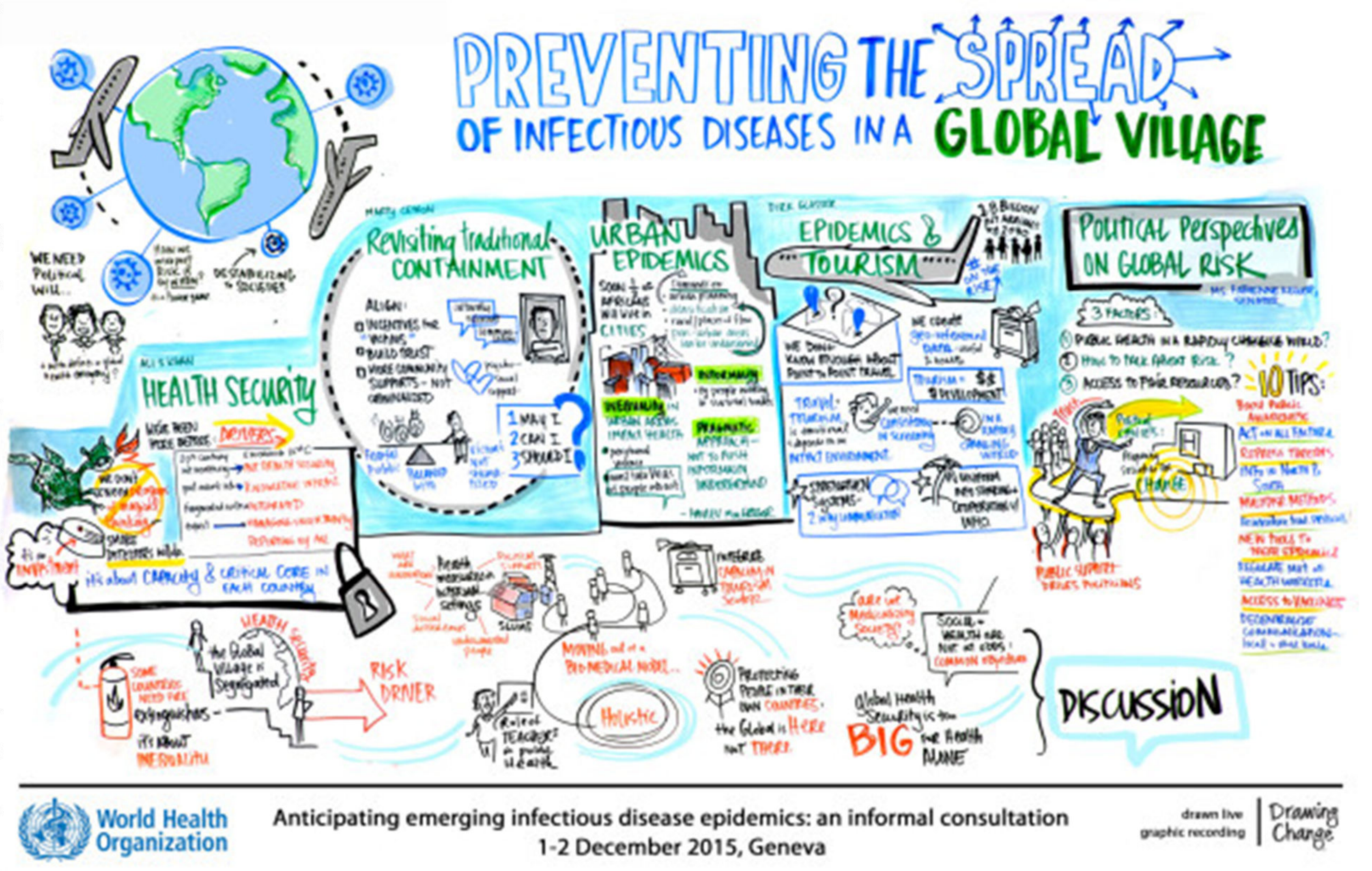
Sustainable Development Goals (SDGs)

www.unep.org/

The tale of infectious diseases

Few Numbers!

- 1400 species caus
humans
- 347 diseases – sus
  - ✓ Viable commer
diagnosis and
  - ✓ Include therapy
for clinicians
- 62 clinical significa
preventable diseas
  - o 19 as routine c
- Significant infectio
India – vector-born
  - o Malaria, Dengu
and Kala-azar



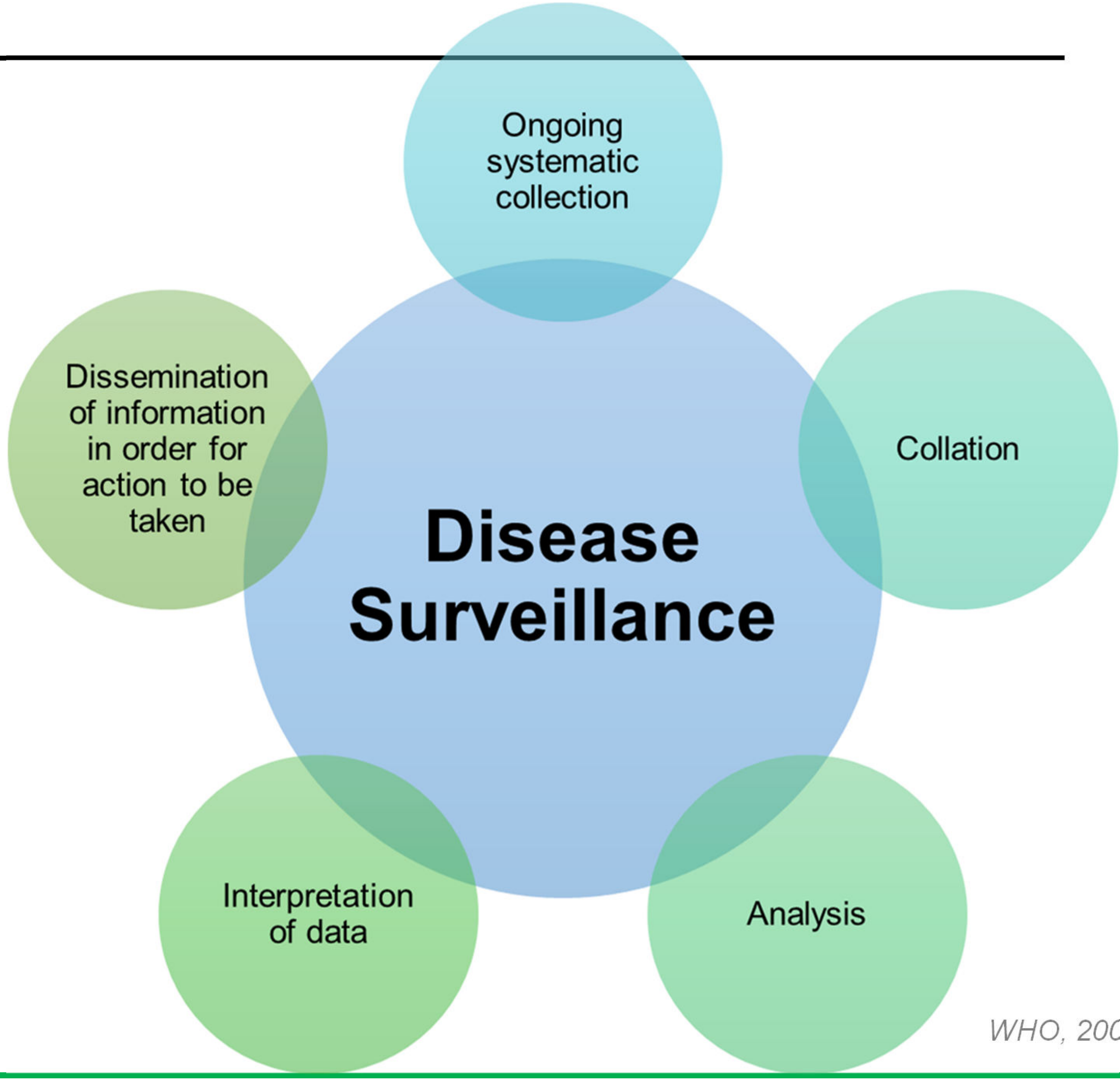
WHO, 2015

Hay et al., 2013; Milane & Alemu, 2018; NVBDCP

Disease Surveillance

Early detection of unusual health events - enable coordinated response and control activities

- ✓ travel restrictions, movement bans on animals, and distribution of prophylactics to susceptible members of the population *(Robertson et al., 2010)*

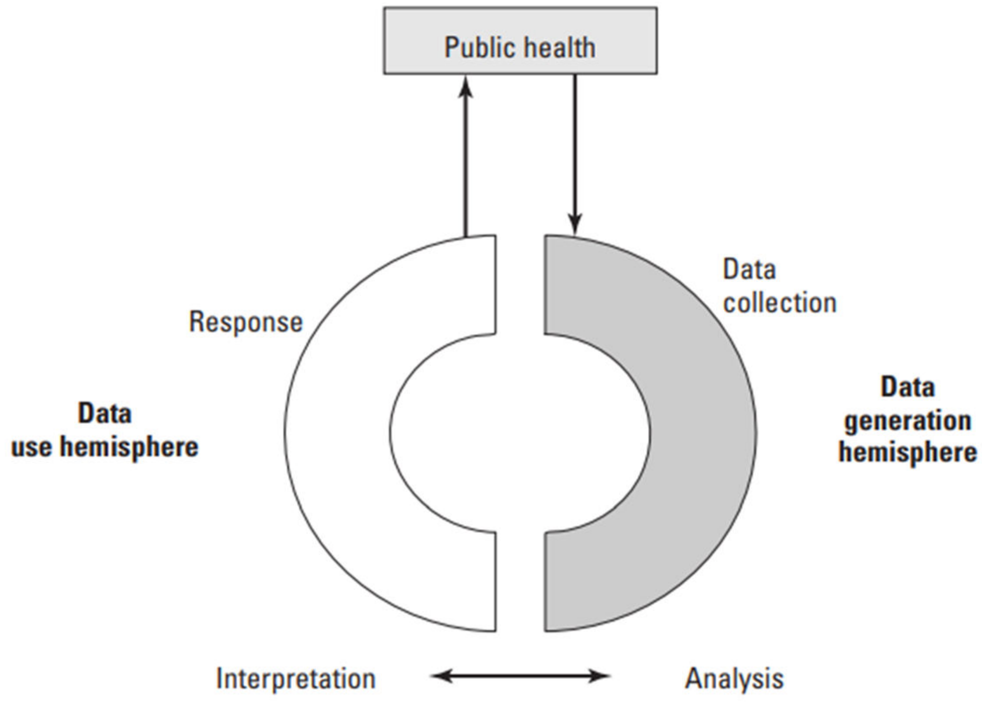


WHO, 2007

Disease Surveillance

The design of surveillance systems

- Surveillance systems could be designed – to meet public health objectives *(Robertson et al., 2010)*
    - Each system has different requirements – data, methodology + implementation
- The intended function of surveillance system – **Outbreak Detection + Disease Control** *(Foege et al., 1976; Nsubuga et al., 2006)*
- These systems – centered around **indicators** (measurable factor used by decision makers to estimate objectively the size of a health problem and monitor the processes, the products, or the effects of an intervention on the population) *(Nsubuga et al., 2006)*

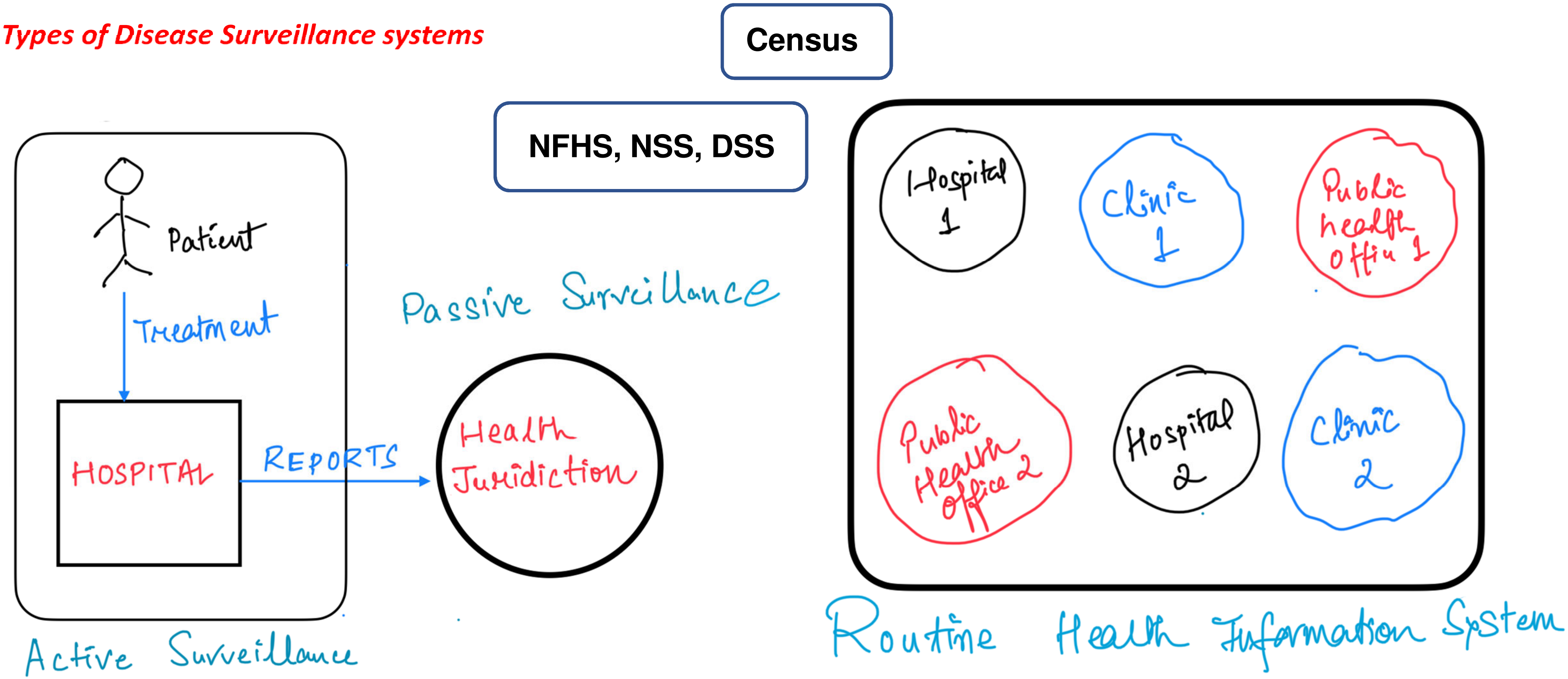


Surveillance & Response Conceptual Framework

Nsubuga et al., 2006

Disease Surveillance

Types of Disease Surveillance systems



Targeted health data collection system

Disease Surveillance

Method Selection of Disease Surveillance systems

- Method selection should consider system-specific factors indicative of the context under which they will be used (**Table 1**)
- Selection of statistical methods – impacted by design constraints from – scalability, data quality, and data volume *(Robertson et al., 2010)*
- Space-time disease surveillance tools addresses a certain set of objectives – broadly helps the policy makers *(Robertson & Nelson, 2014)*
- These tools – when combined with maps – provide the basis for public health interventions

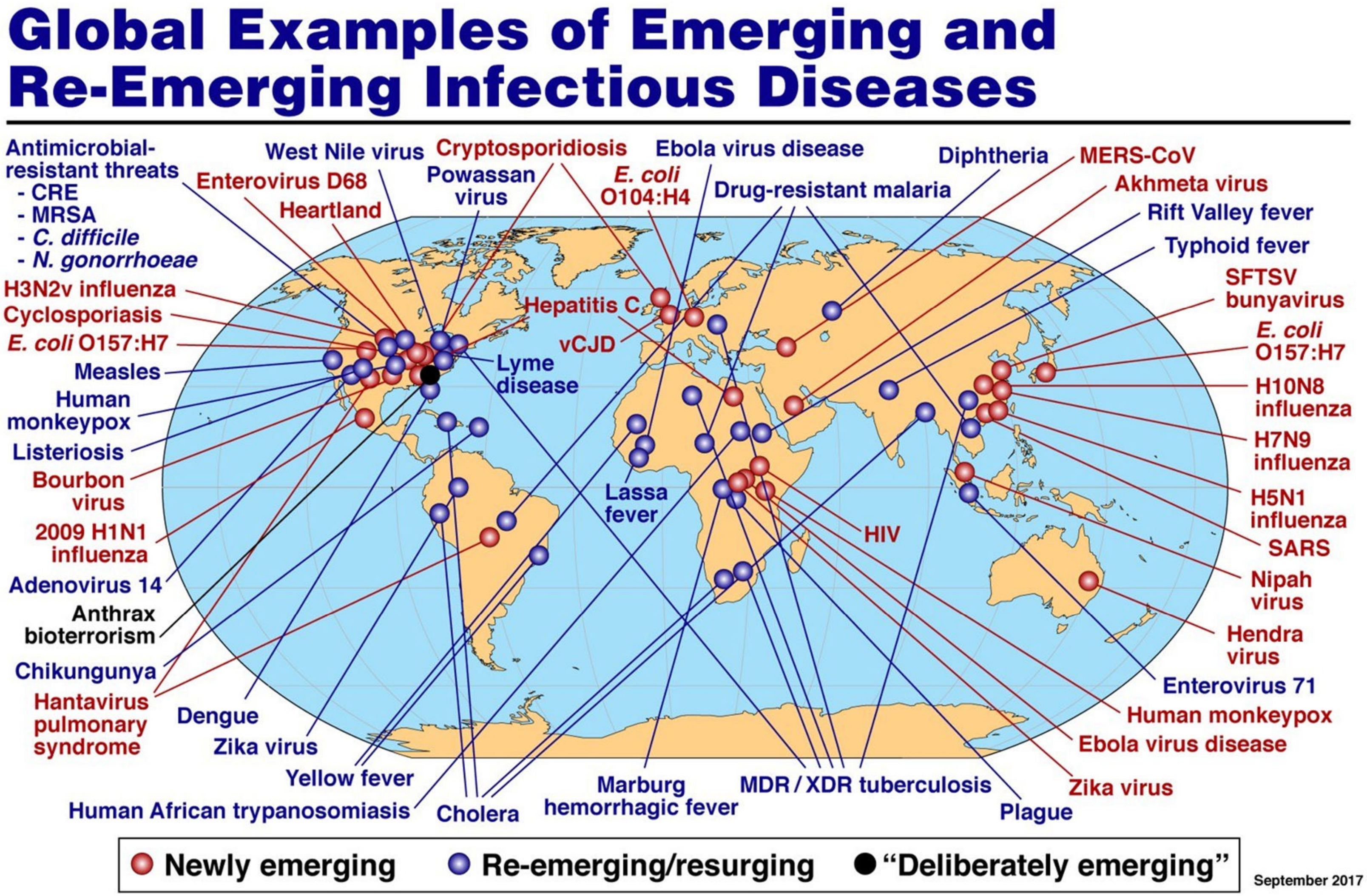
Factor	Description
Scale	The spatial and temporal extent of the system (e.g., local/regional/national/international)
Scope	The intended target of the system (e.g., single disease/multiple disease, single host/multiple host, known pathogens/unknown pathogens)
Function	The objective(s) of the systems (outbreak detection, outbreak characterization, outbreak control, case detection, situational awareness (Mandl et al., 2004; Buehler et al., 2004), bio-security and preparedness (Fearnley, 2008))
Disease characteristics	Is the pathogen infectious? Is this a chronic disease? How does it spread? What is known about the epidemiology of the pathogen?
Technical	The level of technological sophistication in the design of the system and its users (data type and quality, algorithm performance, computing infrastructure and/or reliability, user expertise)

Table 1: Contextual factors for evaluation of methods for space–time disease surveillance *(Robertson et al., 2010*

Disease surveillance

Why Mapping is an import

- Mapping precisely malaria transmissi
  - ✓ Central to the World Health C
  - ✓ Huge investme the data on dis
- Mapping – a primar epidemiology *(Hay et*
- Maps showing disea intensity
  - ✓ Immediate visua extent and mag health problem



Paules et al., 2017

Mapping in Disease Surveillance

Advantages of Mapping

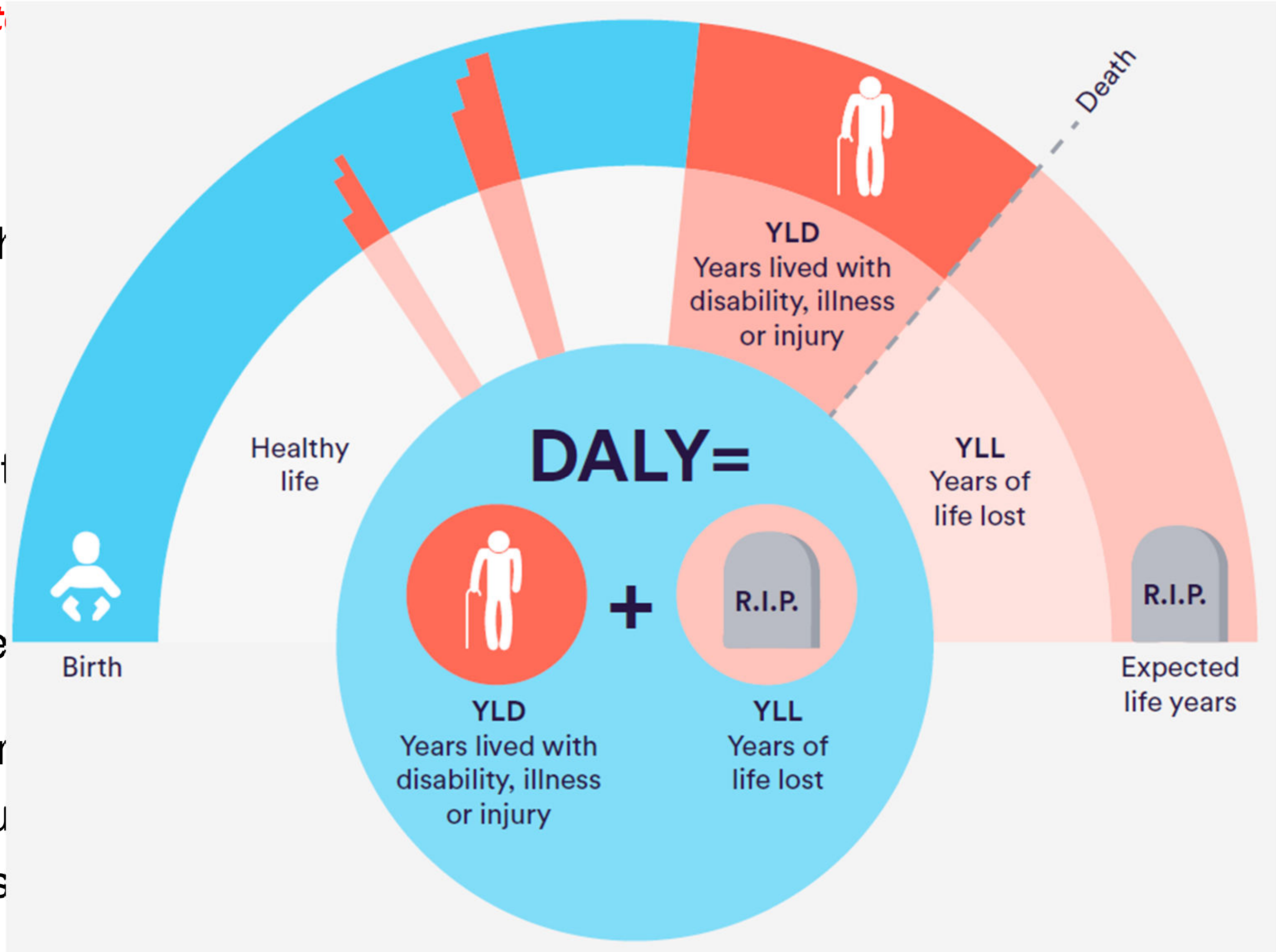
- Maps provide critical estimates of disease limits, transmission, and clinical burden
- Maps underpin surveillance systems + outbreak tracking
- Maps help to target resource allocation from macro to micro-scale
- Maps inform and form the basis of international guidelines
- Thus, maps provide essential evidence base for supporting progress towards global health commitments

Pigott et al., 2015

Prioritizing Infectious Disease Mapping

A generalized Method to map the disease out
deaths)

- Selection of disease for mapping
  - ✓ Any potential disease for which
    available
- Creating disease clusters
  - ✓ Identifying the regions/ hotspot
- Assessing disease burden
  - ✓ Through disability-adjusted life
- Assessing global/local health comr
  - ✓ Dissemination of Results throu
  - ✓ Formulating policy frameworks
    with targeted responses

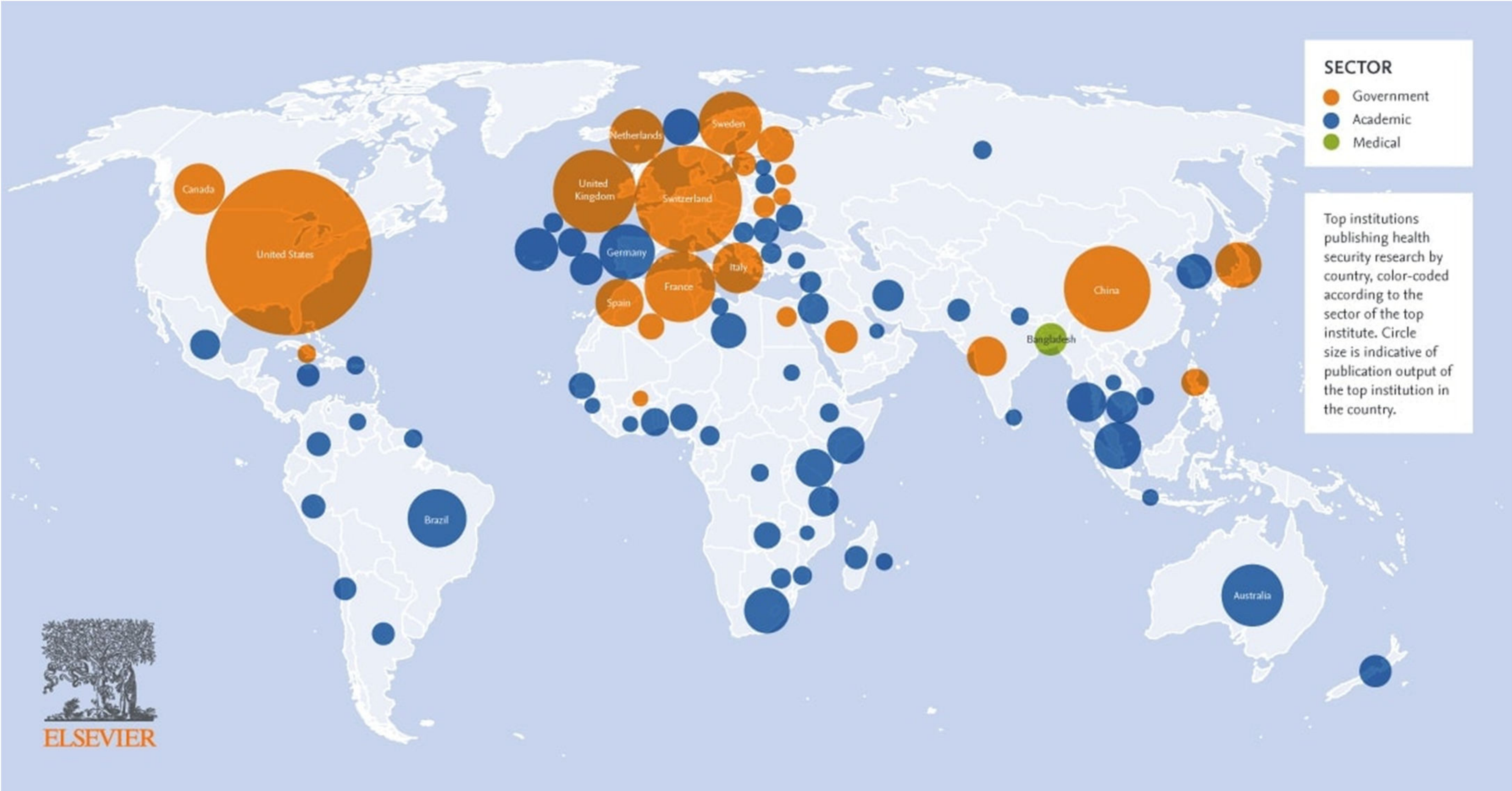


Pigott et al., 2015

https://vizhub.healthdata.org/gbd-compare/india

Global Mapping

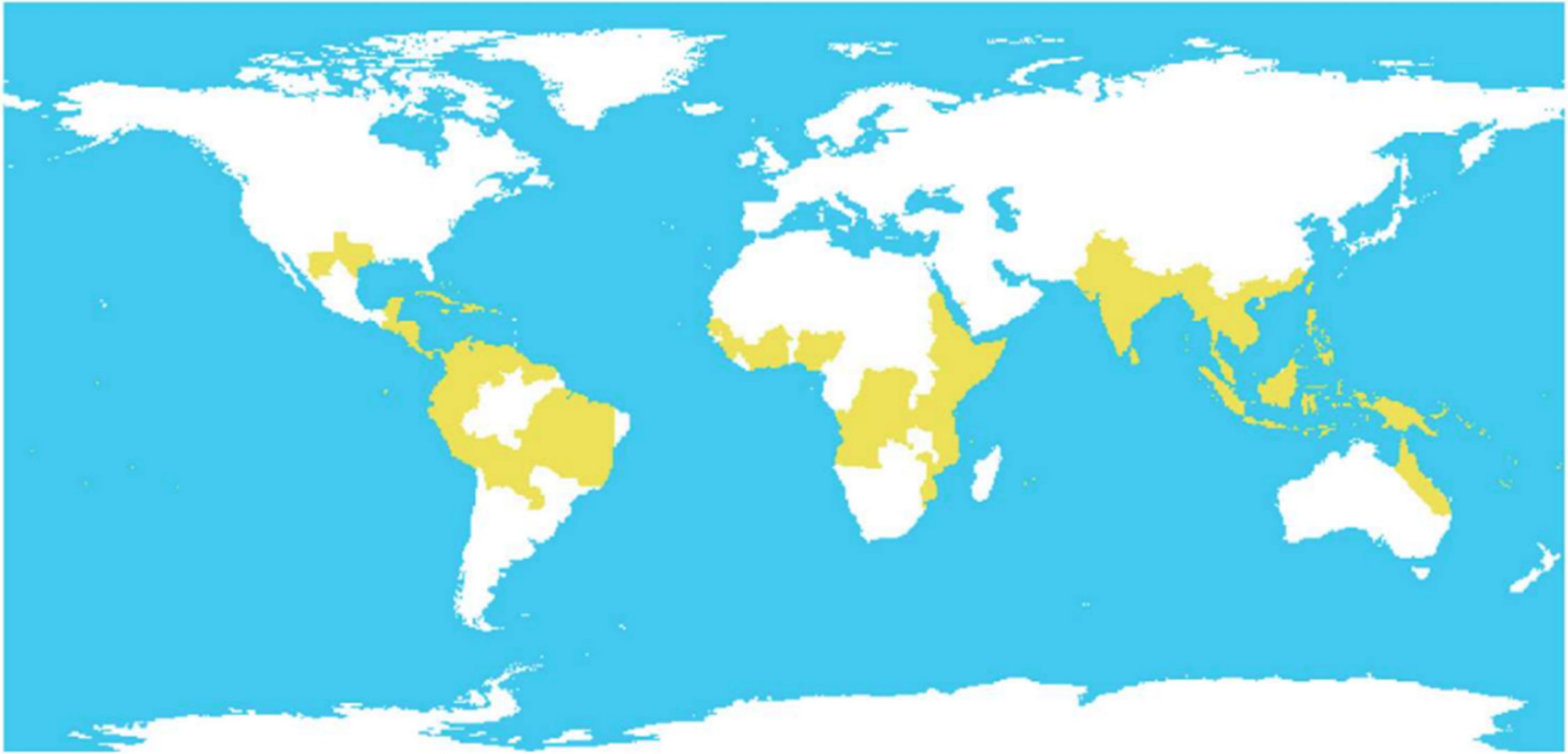
Global research trends in infectious disease



Elsevier, 2020

Global Mapping

Global distribution of Dengue between 1975 and 1996



The yellow areas indicate >1 outbreak between 1975 and 1996.

Hales et al., 2002

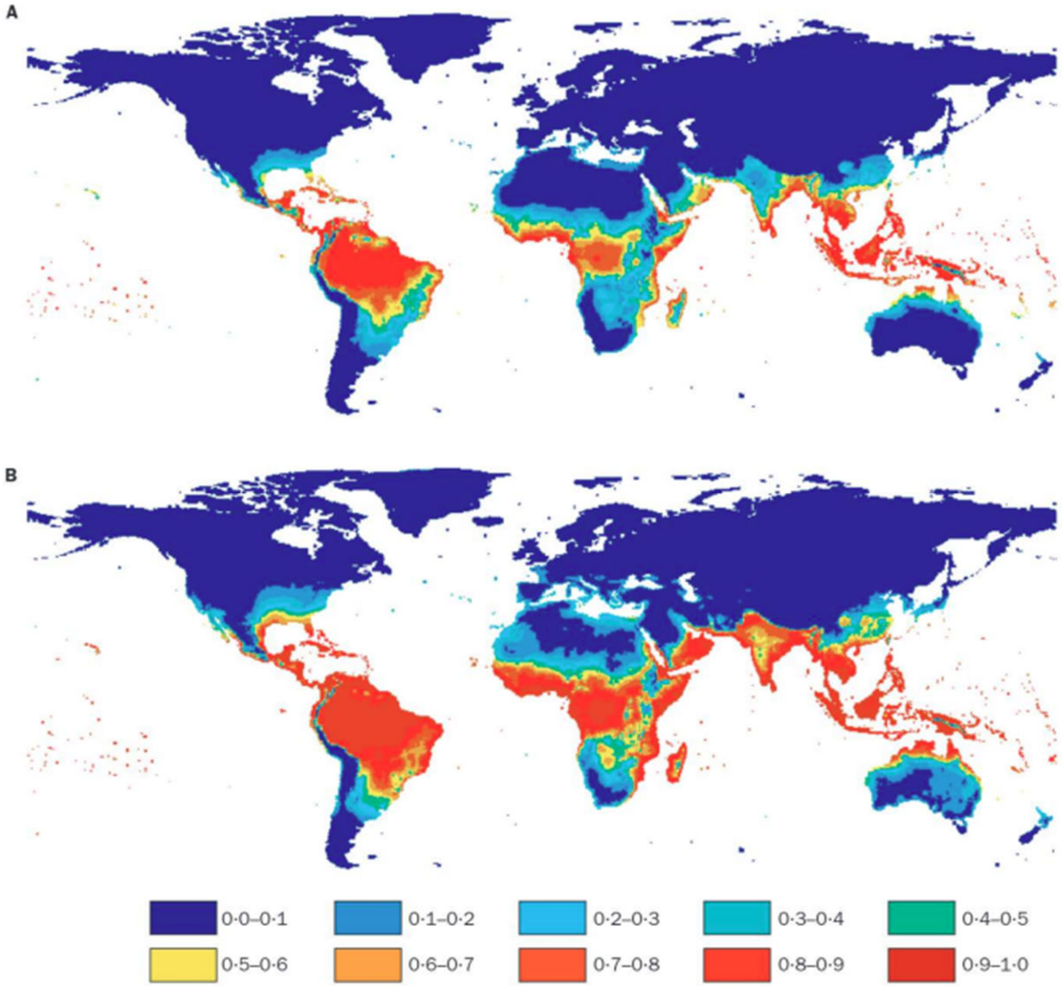
Global Mapping

Projected baseline population at risk in A. 1990 and B. 2085

- Logistic regression model constructed using
  - ✓ Vapour pressure as the predictor of dengue fever risk
  - ✓ Climate data from 1961 to 1990

- Forecasted geographical spread of dengue transmission based on climate projections for 2080-2100 using a global circulation model

- Colours – probability of dengue transmission



Hales et al., 2002

Global Mapping

NTDs in Latin America

- In Latin America ~195 million people live in poverty, a situation that increases the burden of some infectious diseases
- Neglected diseases often restricted to poor, marginalized sections of the population
- PAHO aimed to analyze the presence of selected diseases using geospatial techniques
- Five diseases at the first sub-national level (states) were mapped,
  - ✓ showing the presence of the disease (''hotspots'') and overlap of diseases (''major hotspots'')

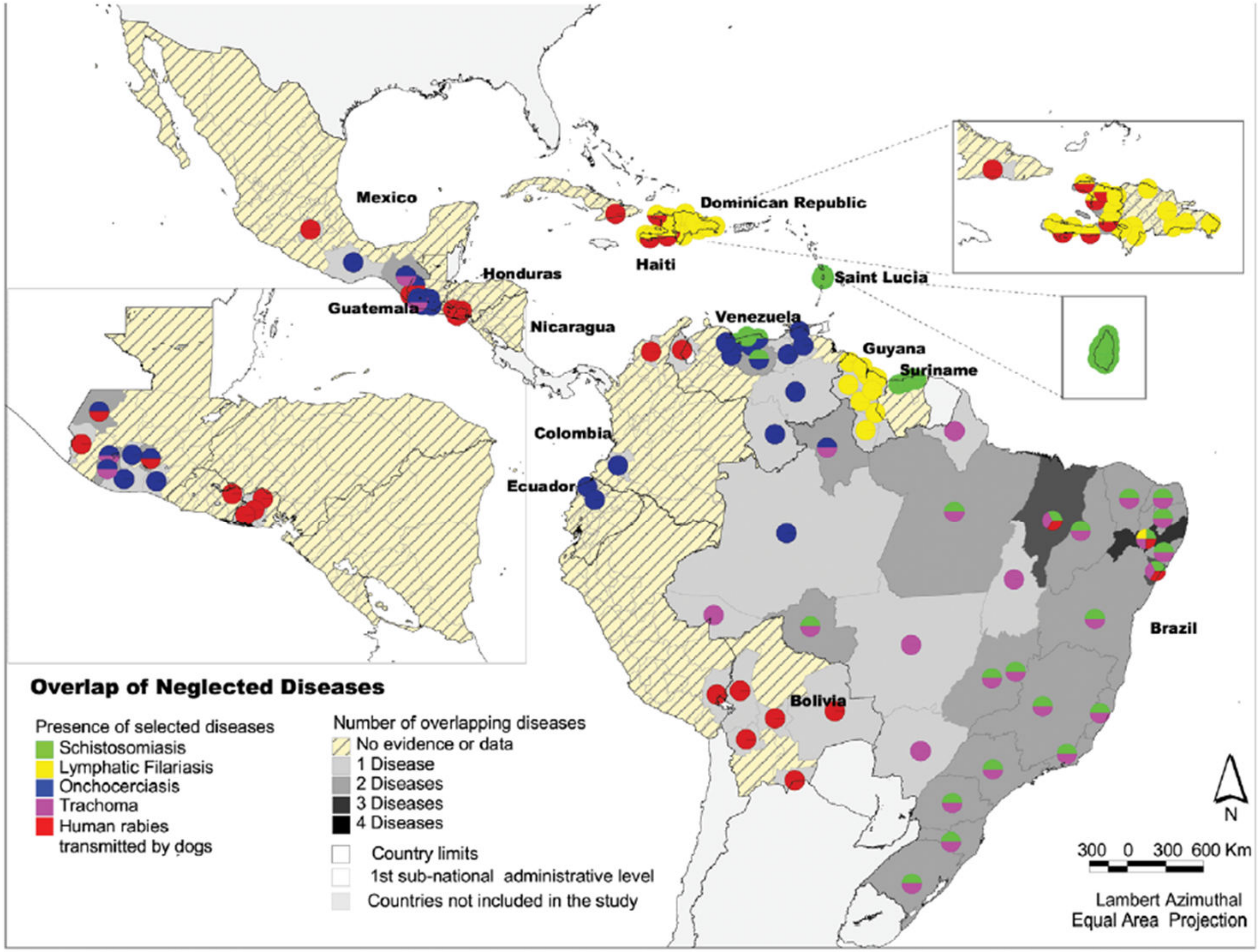


Figure 7. Overlapping diseases present in the country at the first subnational level, Latin America and the Caribbean. *Source:* PAHO, based on several sources.

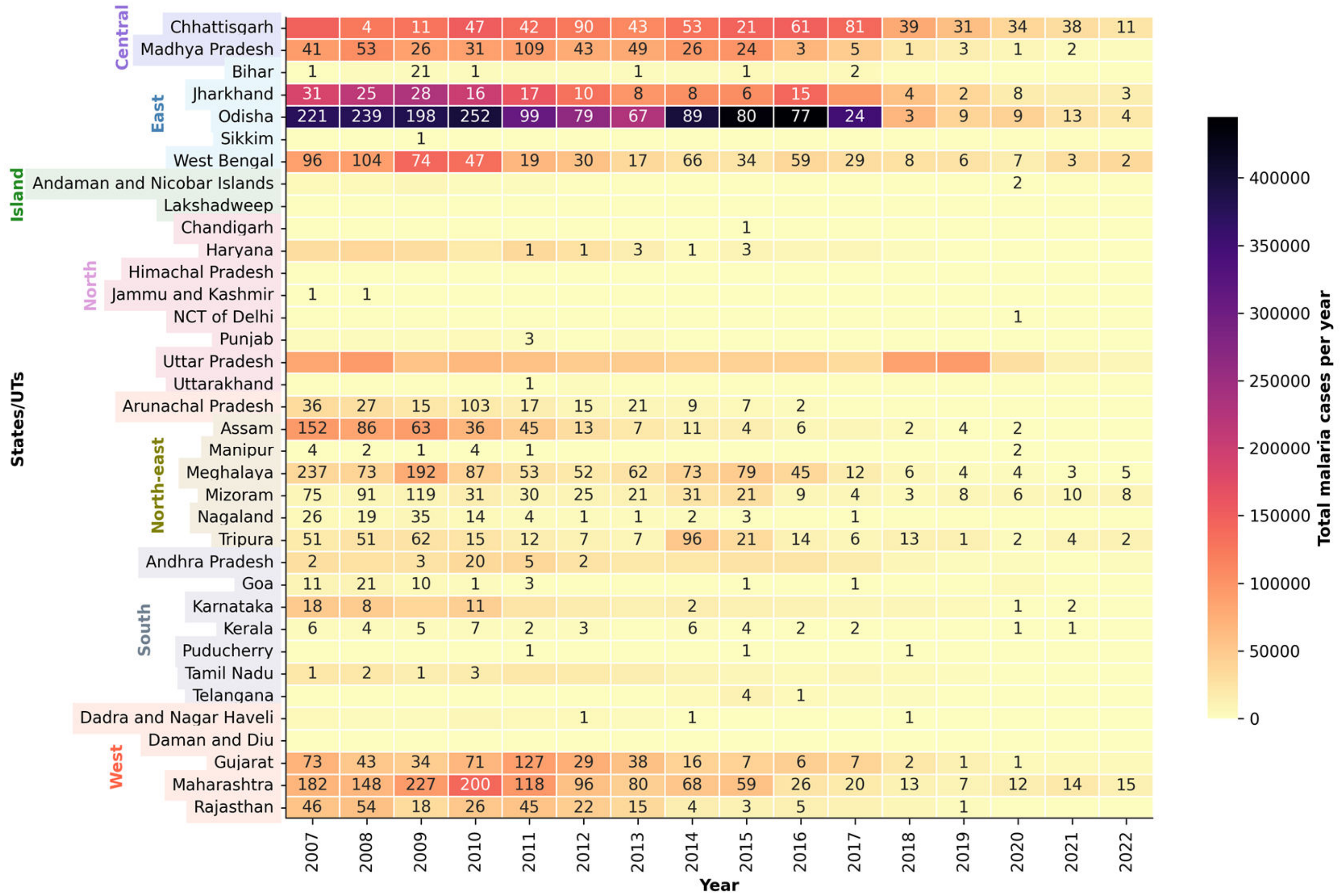
doi:10.1371/journal.pntd.0000964.g007

Schneider et al., 2011

Regional Mapping – India

Spatiotemporal distribution of Malaria

- Malaria in India is attributed to a total economic burden of $1.9 billion *(NVBDCP)*
- The health burden – also well-documented - with ≈15 million cases + case fatality rate of 544 deaths (per 1 million cases) reported across India between 2007 and 2022
- The cases are represented by the heatmap, while the numbers on each block denote deaths

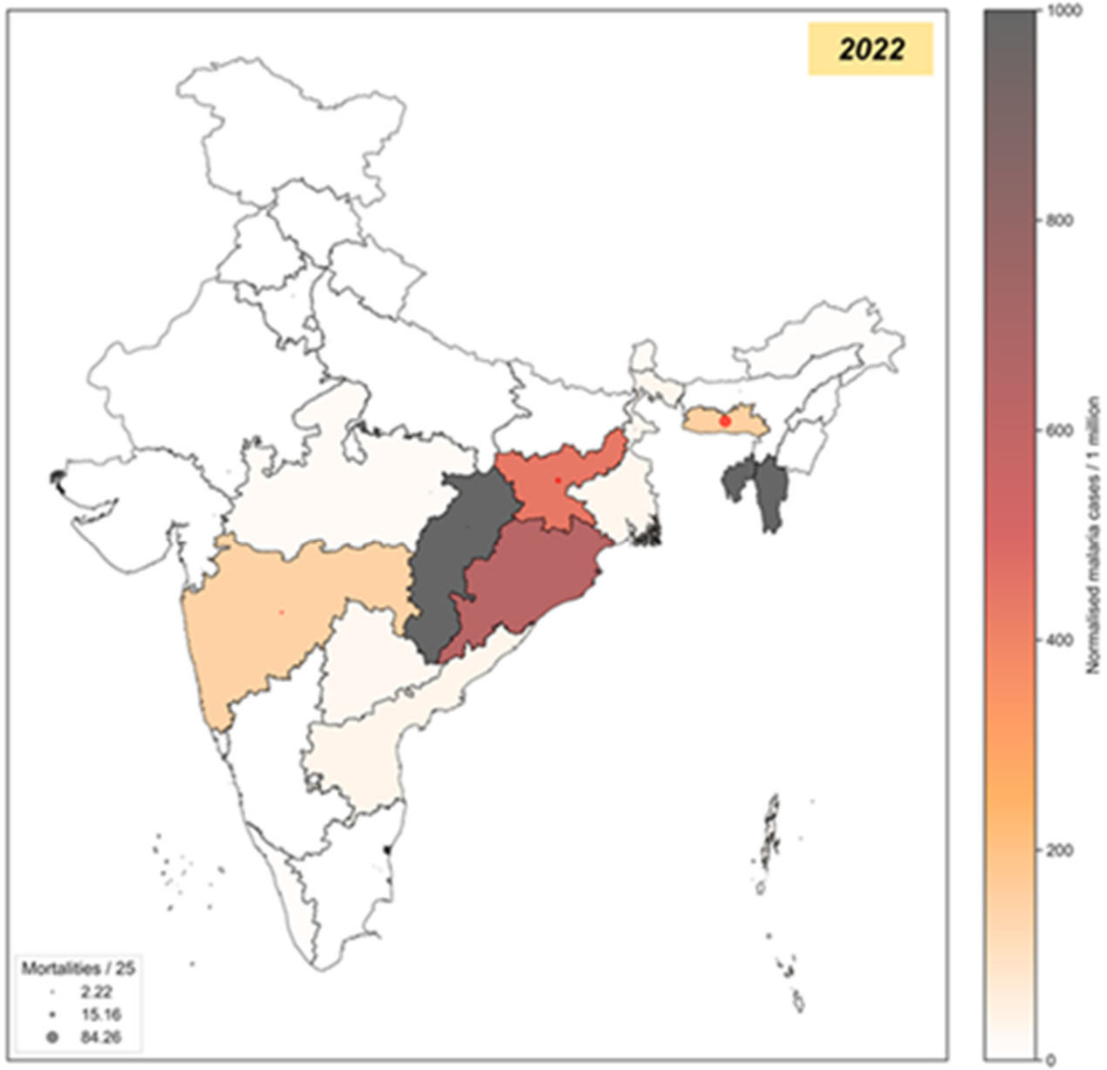


Sam et al., 2023 (ICUC 2023)

Regional Mapping – India

Spatial distribution of Malaria (2022)

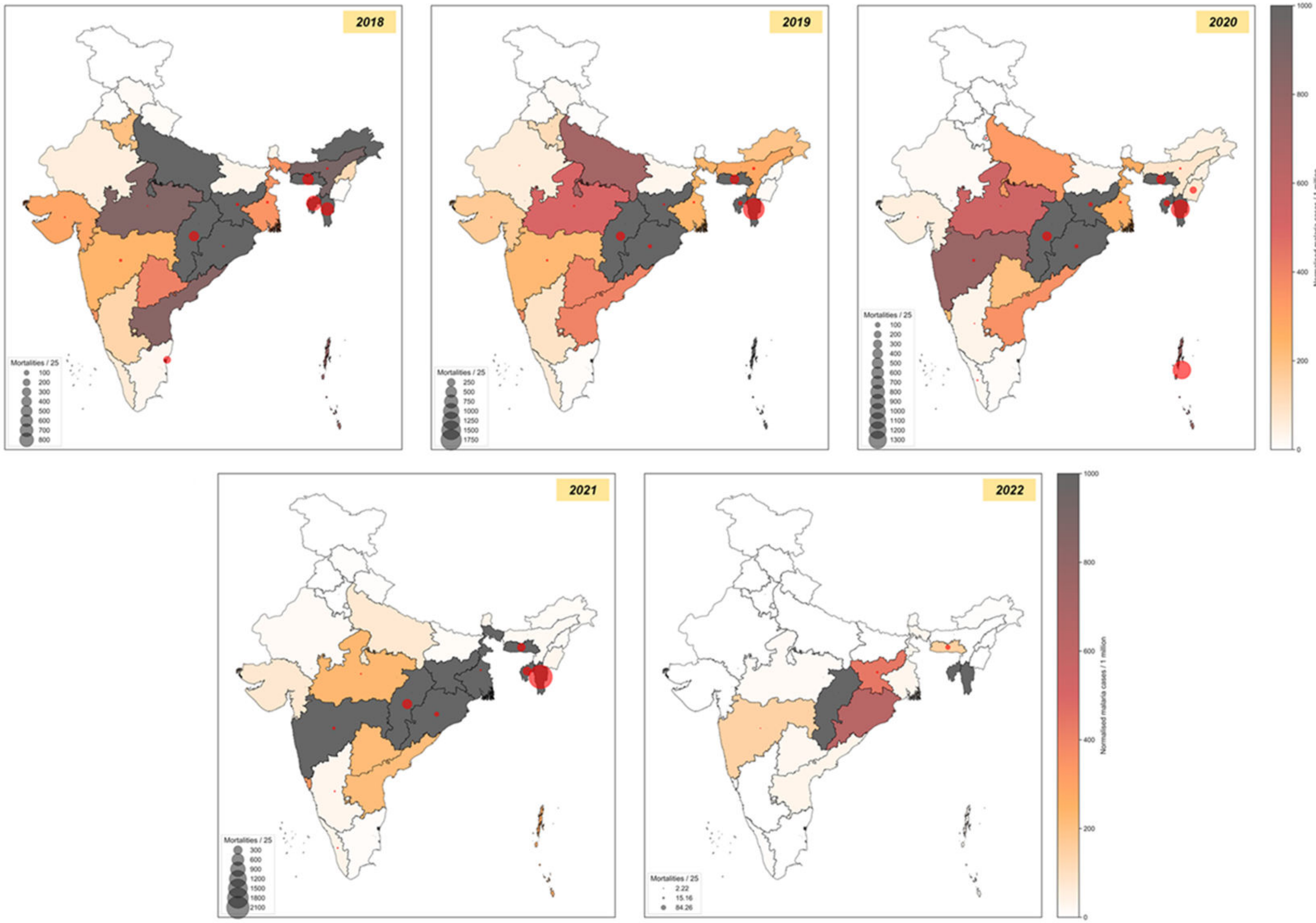
The colour bar represents the malaria cases per 10 million people, while the red dot represents the mortalities.



Regional Mapping – India

Spatiotemporal distribution of Malaria (2018-2022)

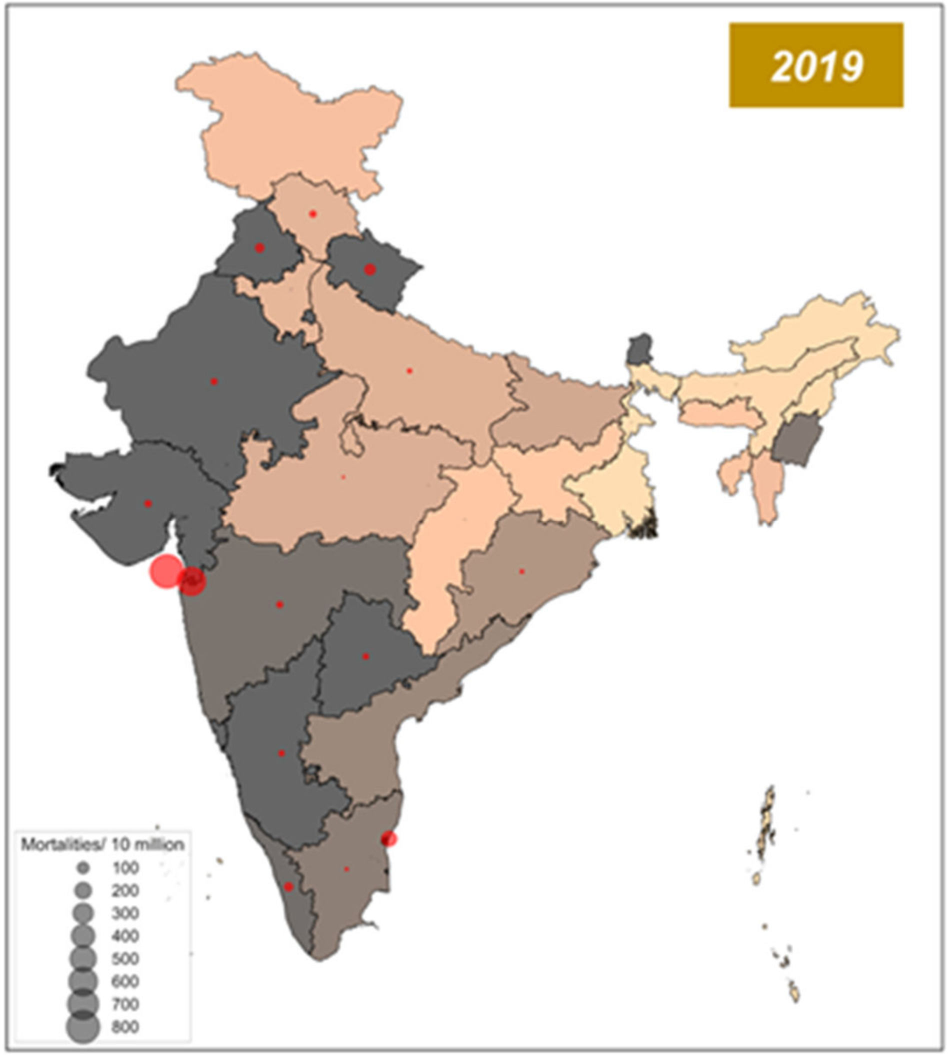
The colour bar represents the malaria cases per 10 million people, while the red dot represents the mortalities.



Regional Mapping – India

Spatiotemporal distribution of Dengue (2015-2022)

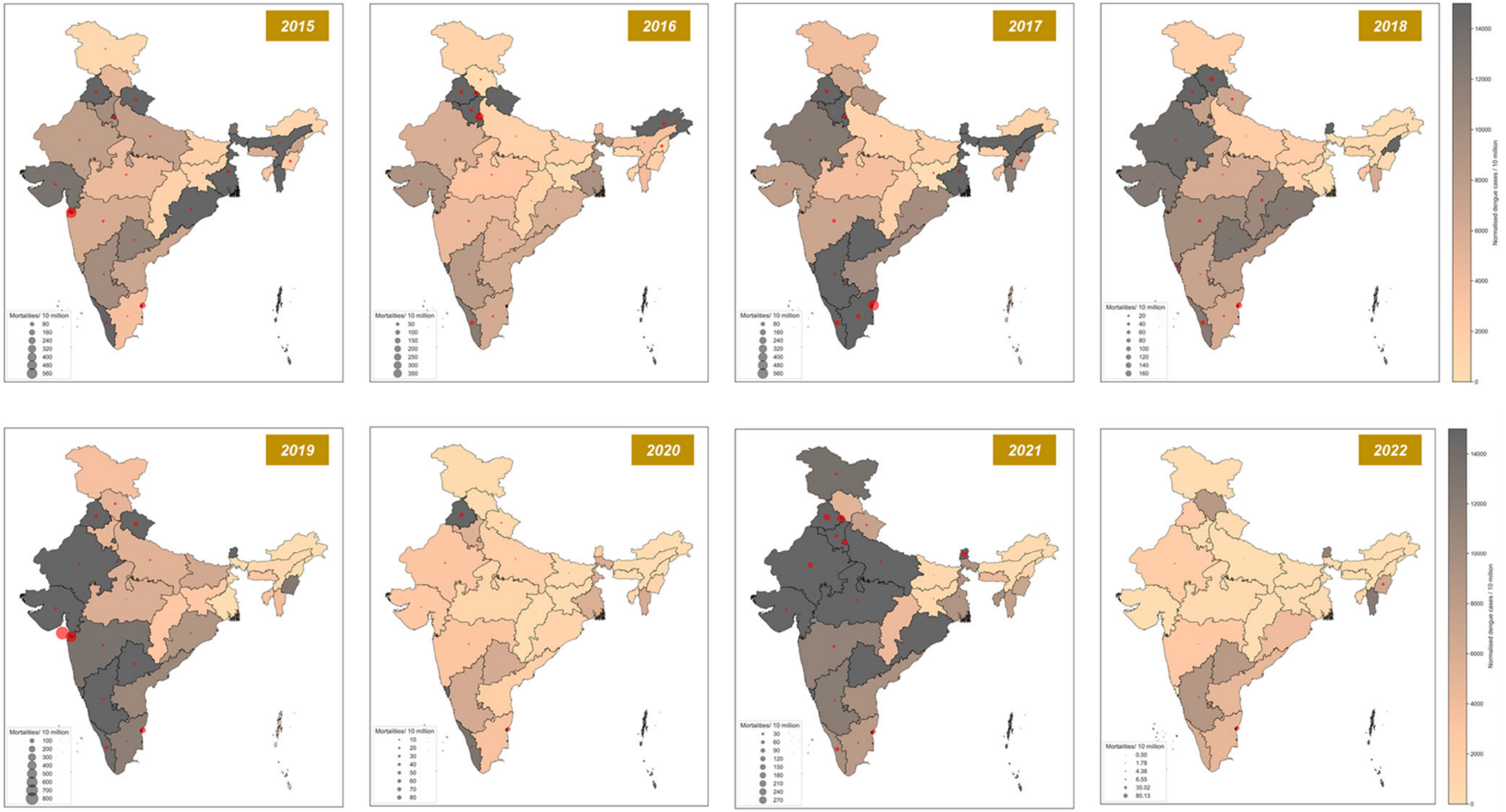
The colour bar represents the dengue cases per 10 million people, while the red dot represents the mortality



Regional Mapping – India

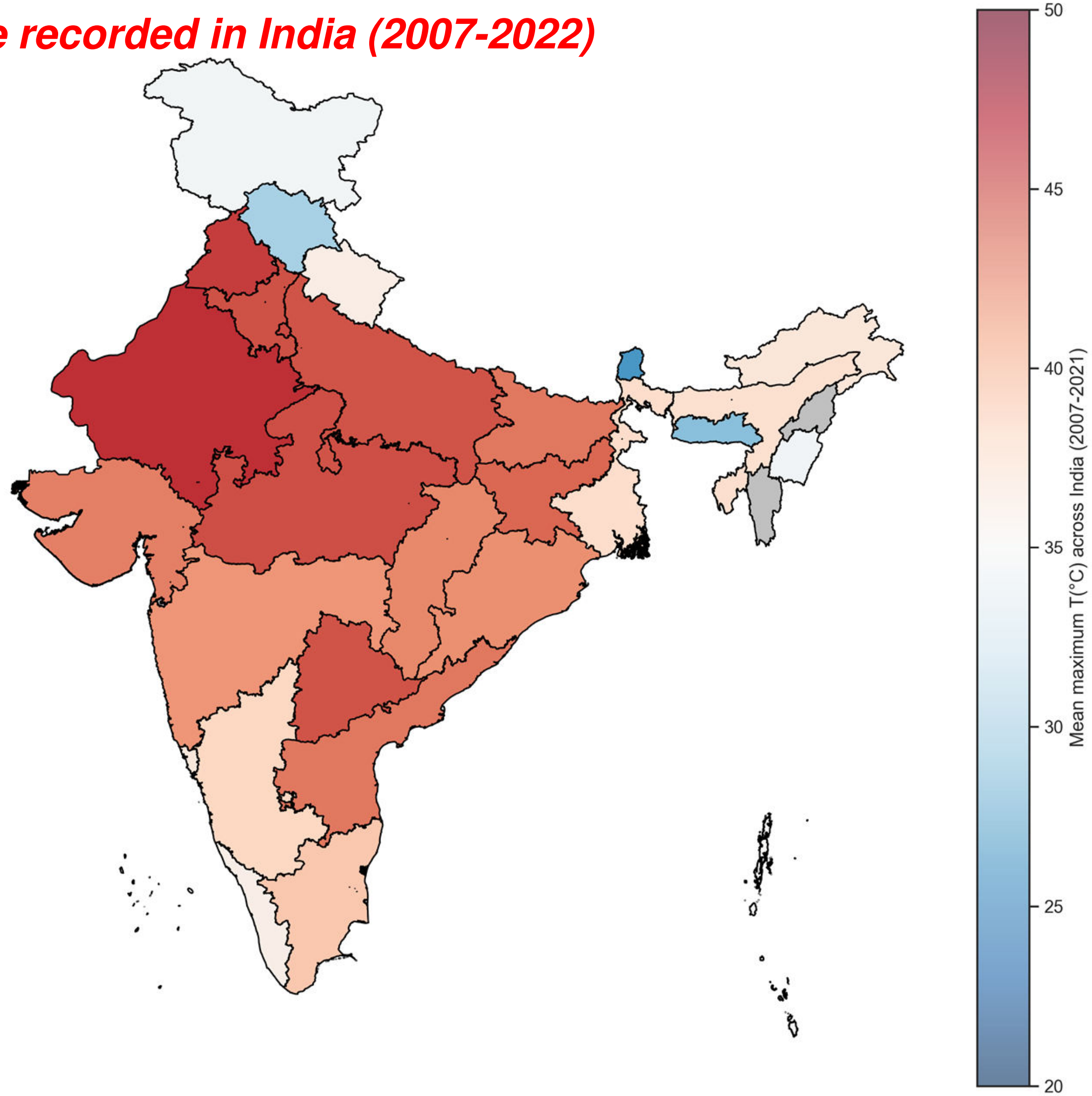
Spatiotemporal distribution of Dengue (2015-2022)

The colour bar represents the dengue cases per 10 million people, while the red dot represents the mortalities.



Regional Mapping – India

Spatial distribution of mean maximum temperature recorded in India (2007-2022)



Regional Mapping – India

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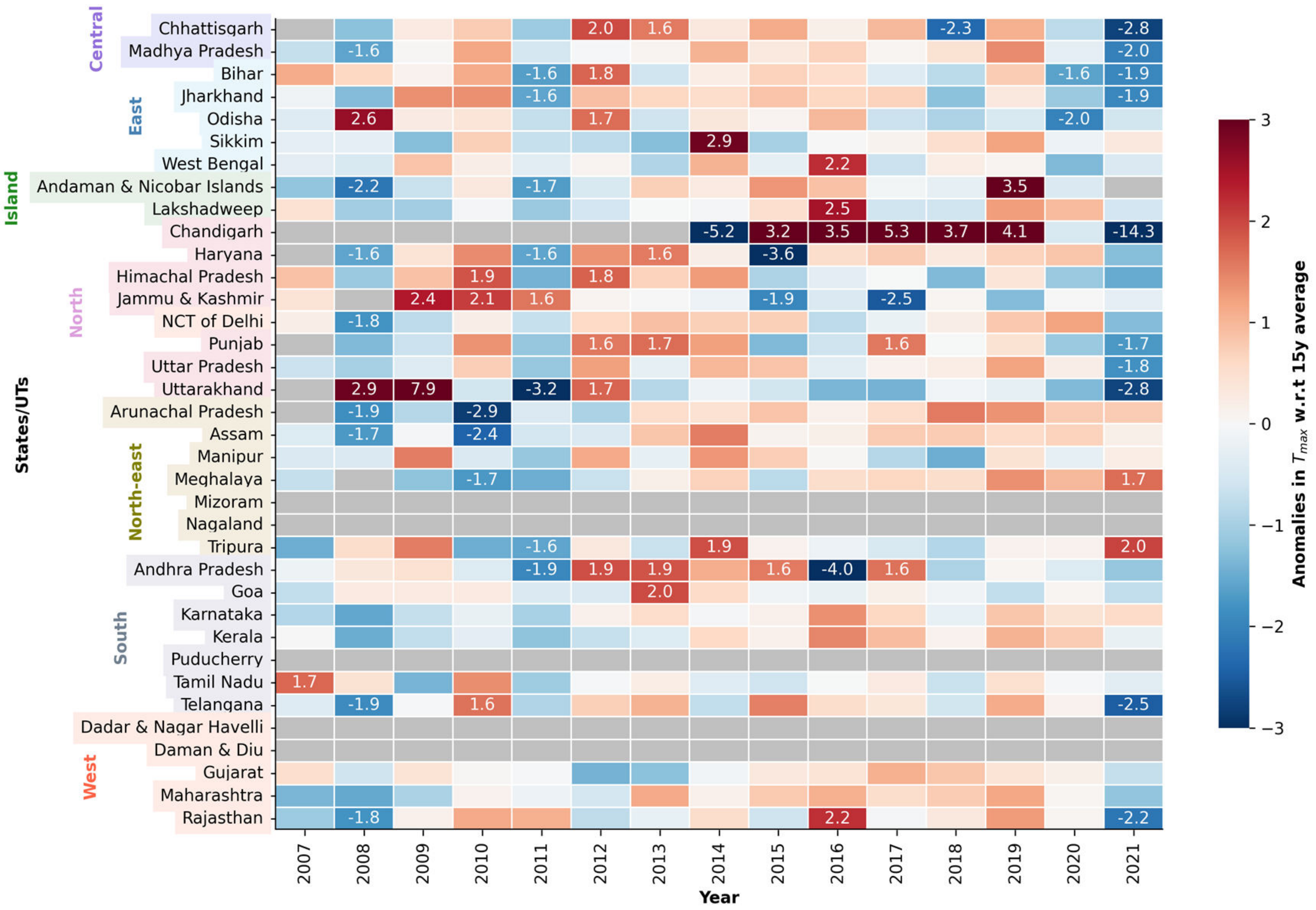
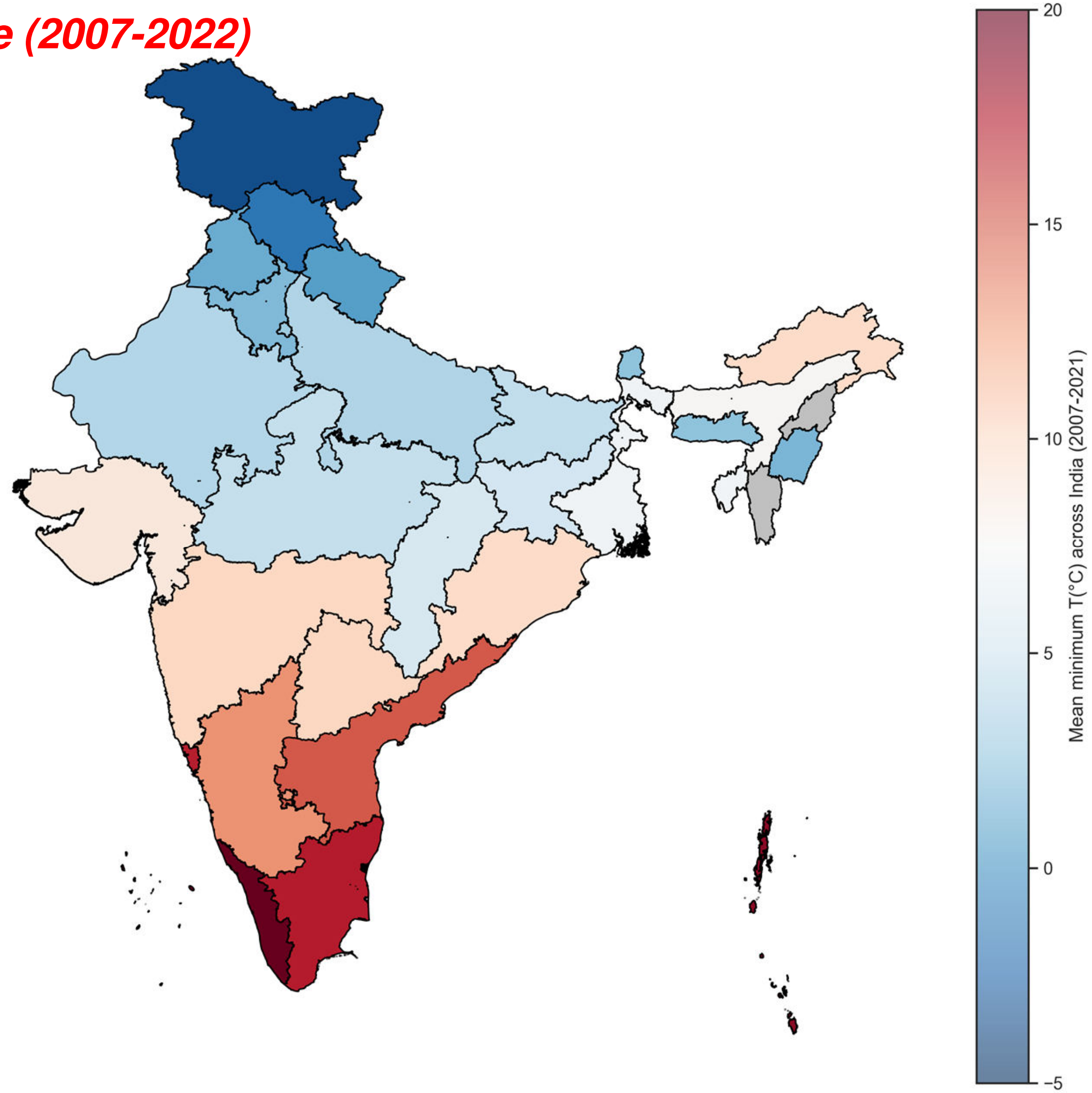


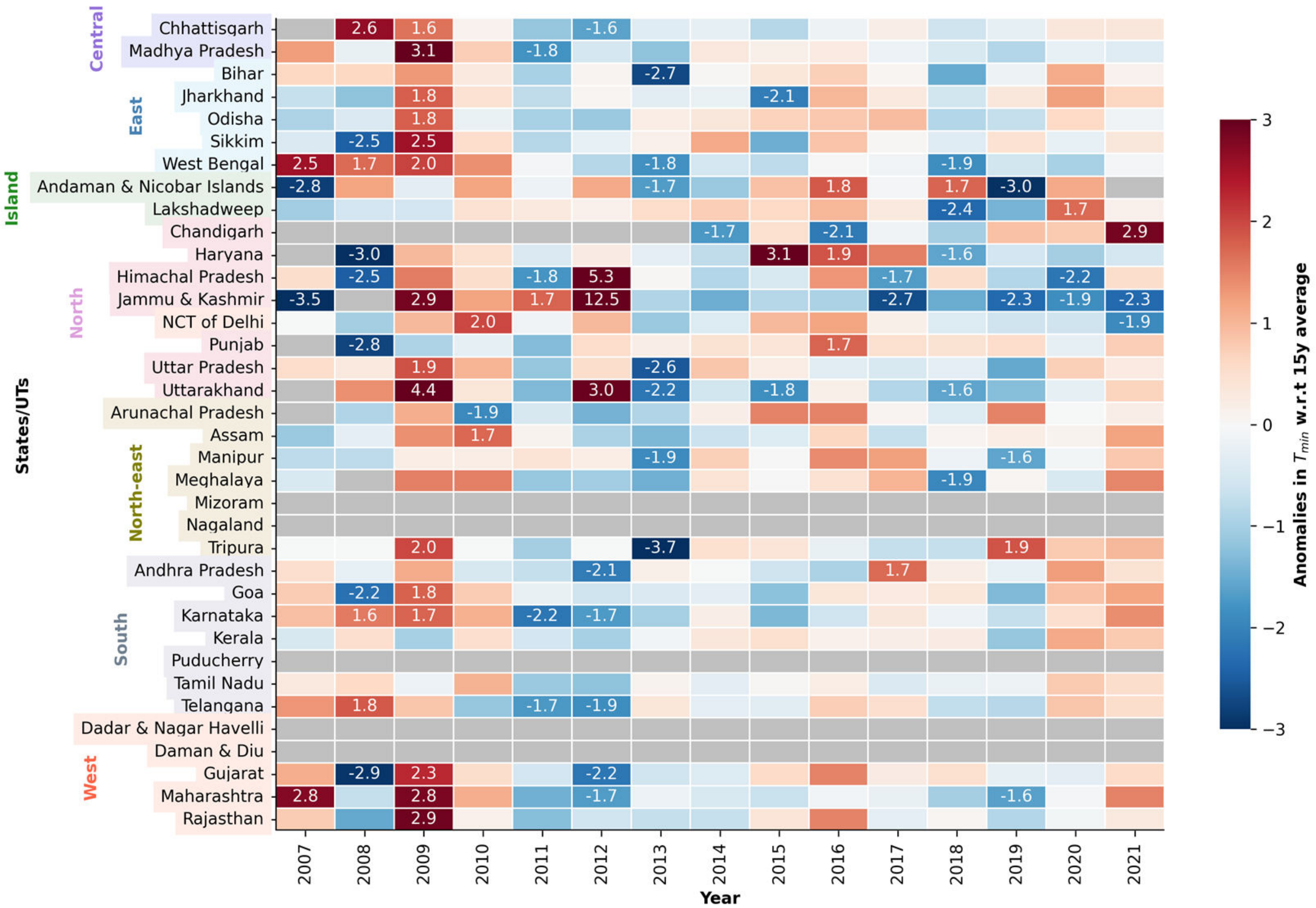
Regional Mapping – India

Spatial distribution of mean minimum temperature (2007-2022)



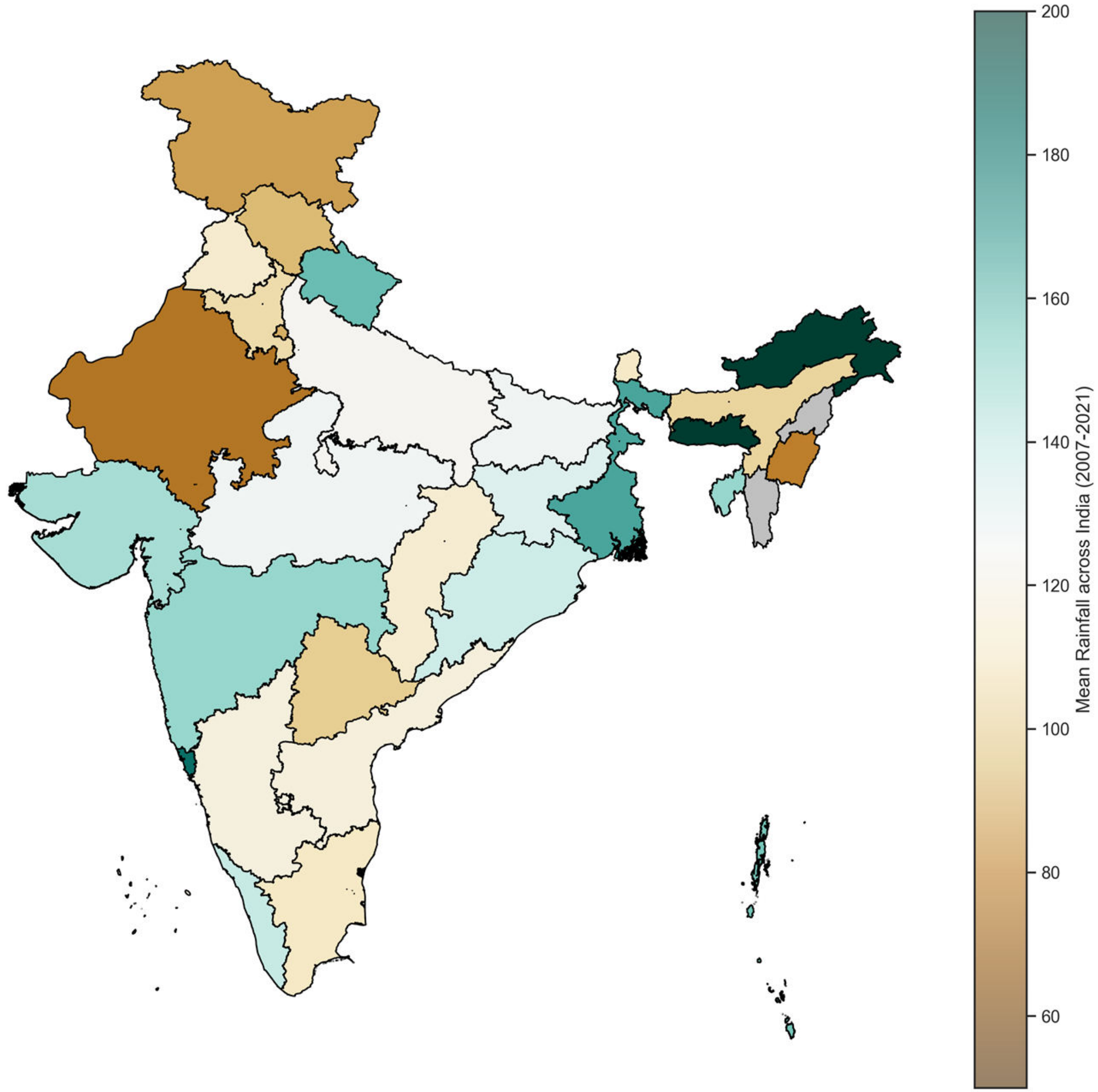
Regional Mapping – India

Spatiotemporal distribution of mean minimum temperature (2007-2022)



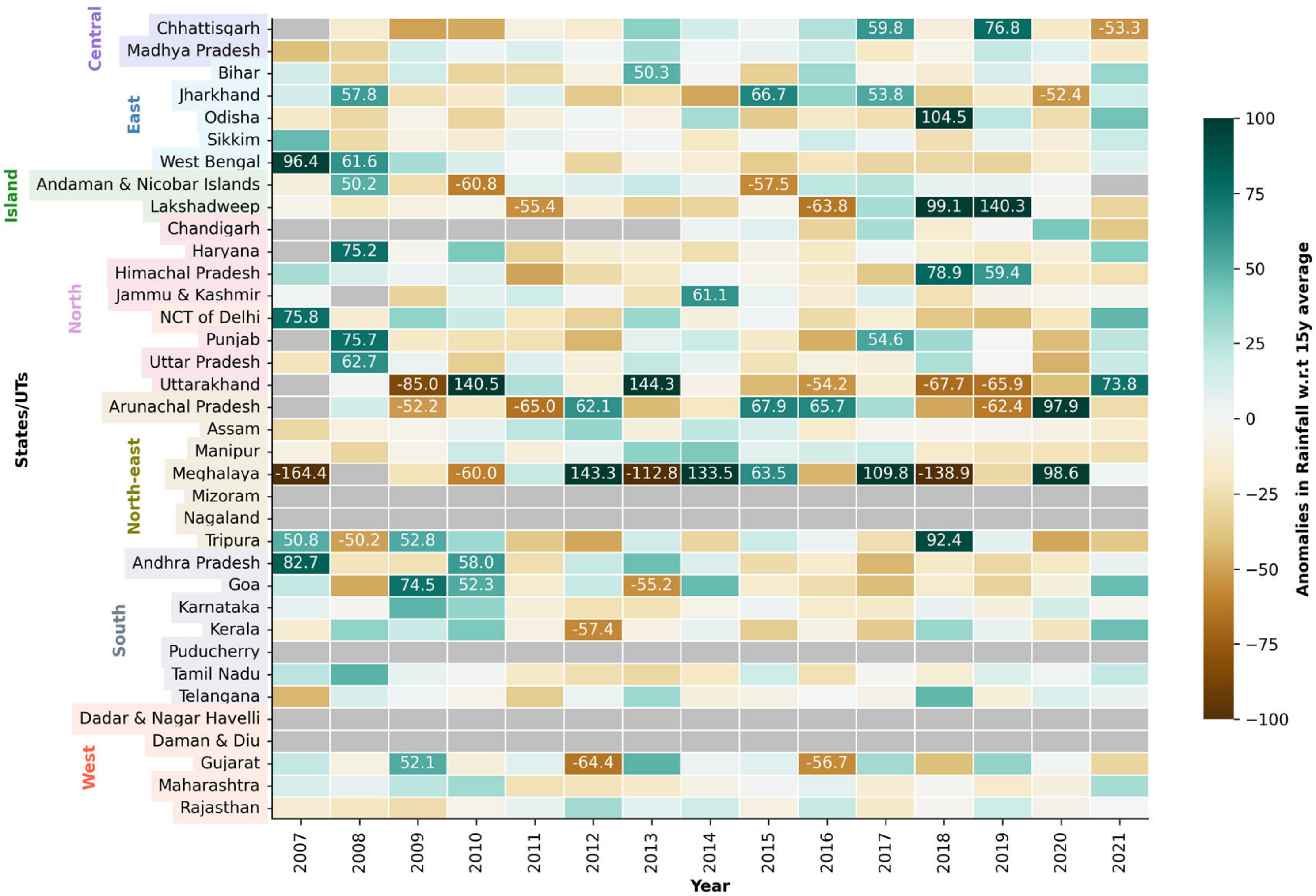
Regional Mapping – India

Spatial distribution of mean rainfall (2007-2022)



Regional Mapping – India

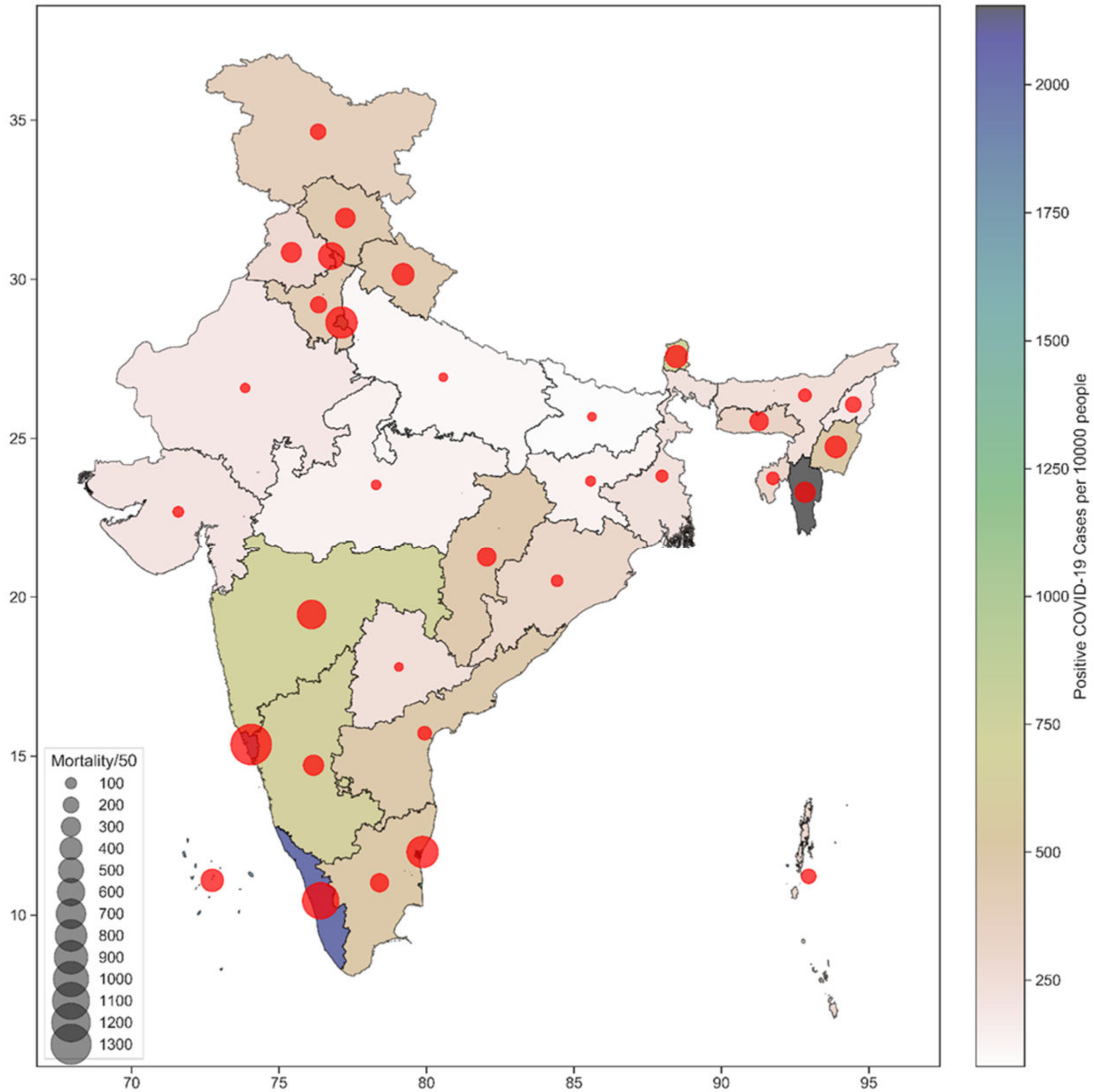
Spatiotemporal distribution of mean rainfall (2007-2022)



Regional Mapping – India

Spatiotemporal distribution of COVID-19

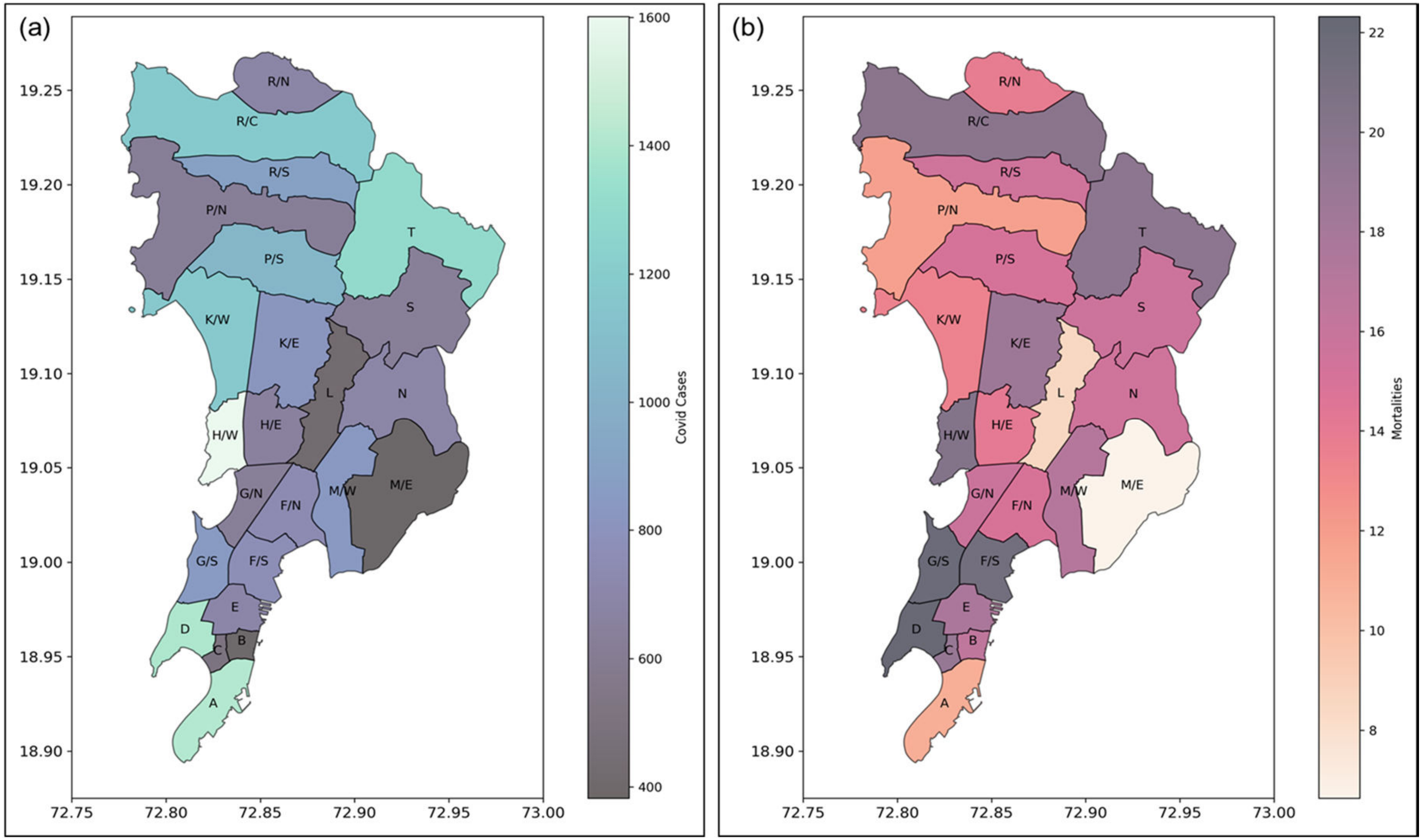
- Till 22nd August 2022, India reported a cumulative 44.3 million positive COVID cases, while the case fatality was 1.18%
- Maharashtra accounted for 18% of the country's cases and 28% of the case fatalities
- South India reported about 40% of the total cases
- West India – 24% of the cases + 32% of the deaths
- The densely populated regions of the northern plains reported the highest case fatalities (1.58 deaths per 100 cases)



Zonal Mapping – Mumbai

Spatiotemporal distribution of (a) normalized COVID-19 cases and (b) mortalities

- Mumbai reported a total of 10,32,563 positive cases till 05th April, 2022
- Overall case fatality was 1.9/ 100 cases: higher than the average observed for the whole country (1.2)
- Normalization for 10000 people



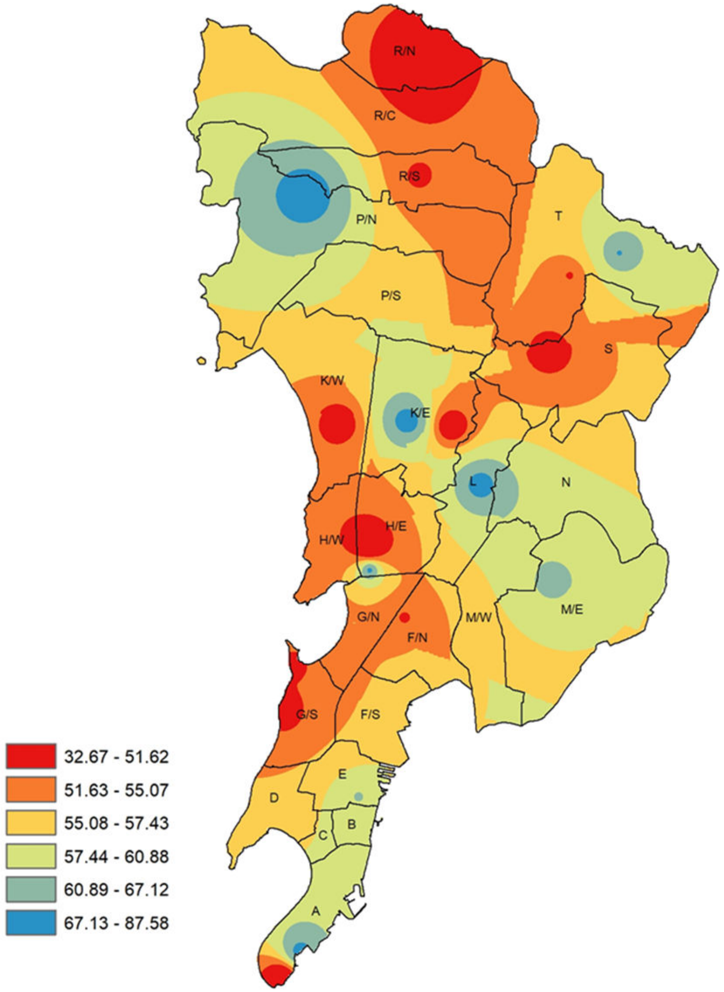
Sam et al., 2022 (ISEE 2022)

Zonal Mapping – Mumbai

Interpolated $PM_{2.5}$ distributions between 1st March 2020 and 5th

- Mumbai reported a mean 56.61 ± 4.77 $PM_{2.5}$ concentrations for the period
- Positive correlations observed between the normalised COVID-19 cases and the $PM_{2.5}$

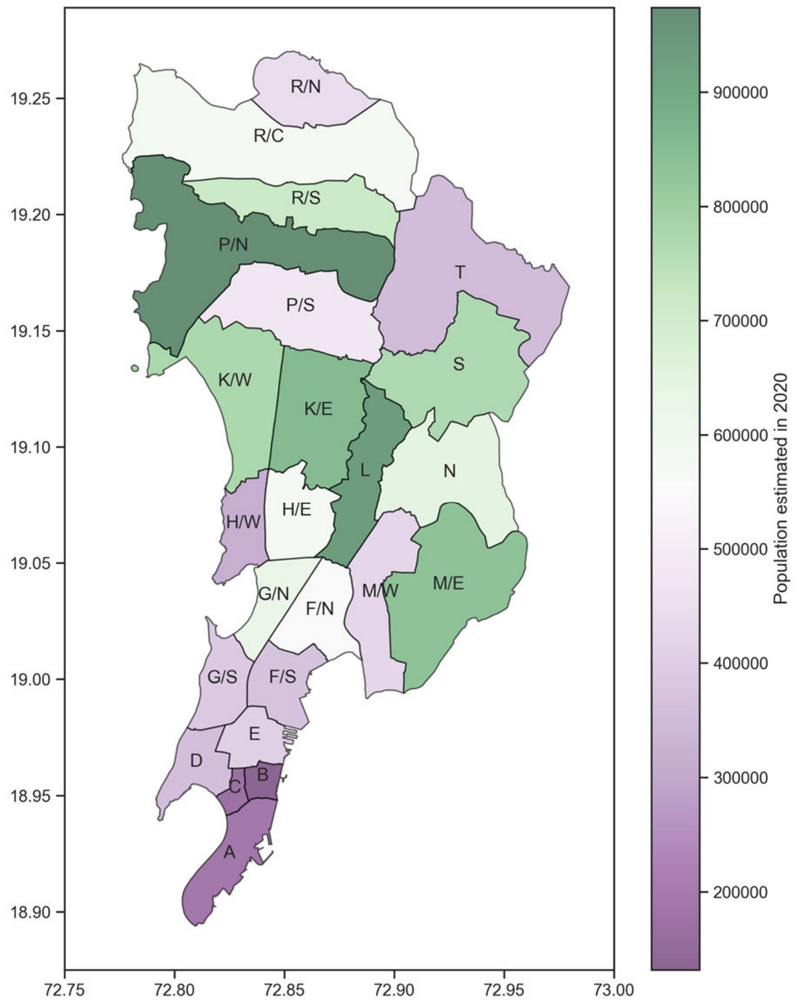
PM2.5 Concentrations



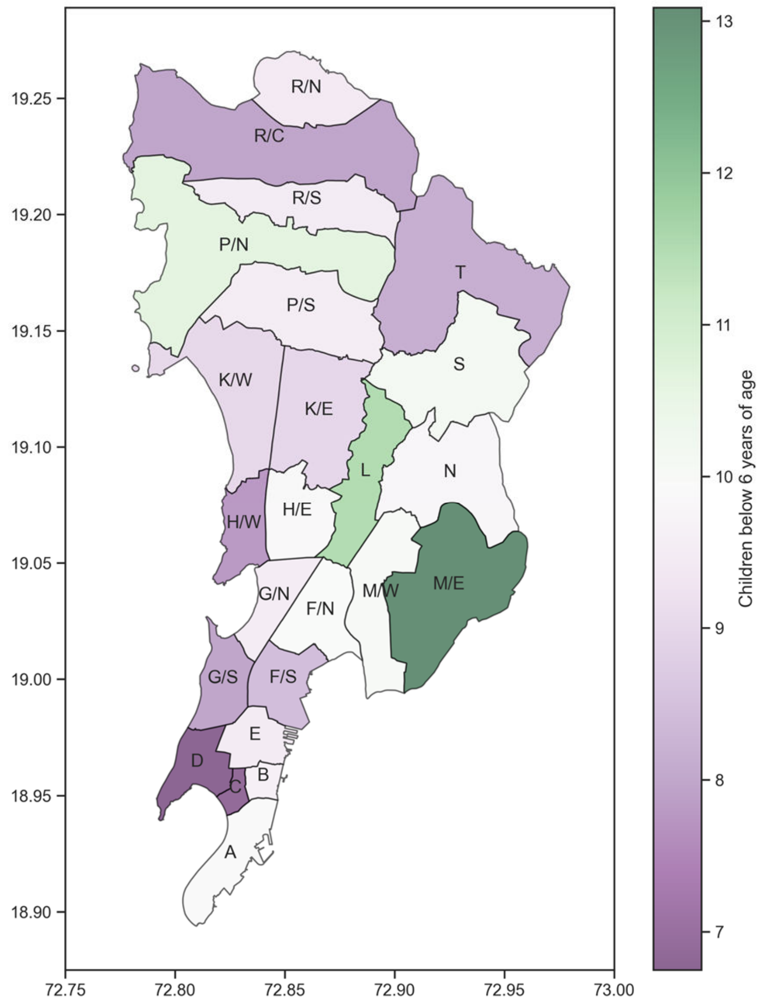
Sam et al., 2022 (ISEE 2022)

Zonal Mapping – Mumbai

Population estimated for 2020

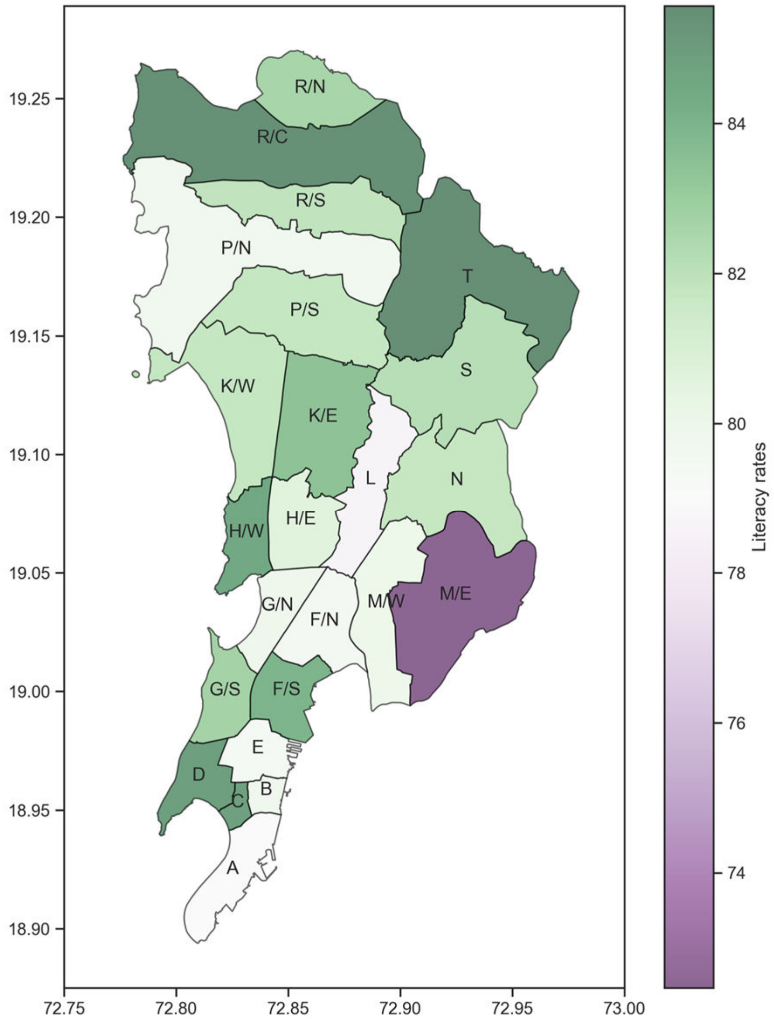


Population of Children below 6 years (2020)

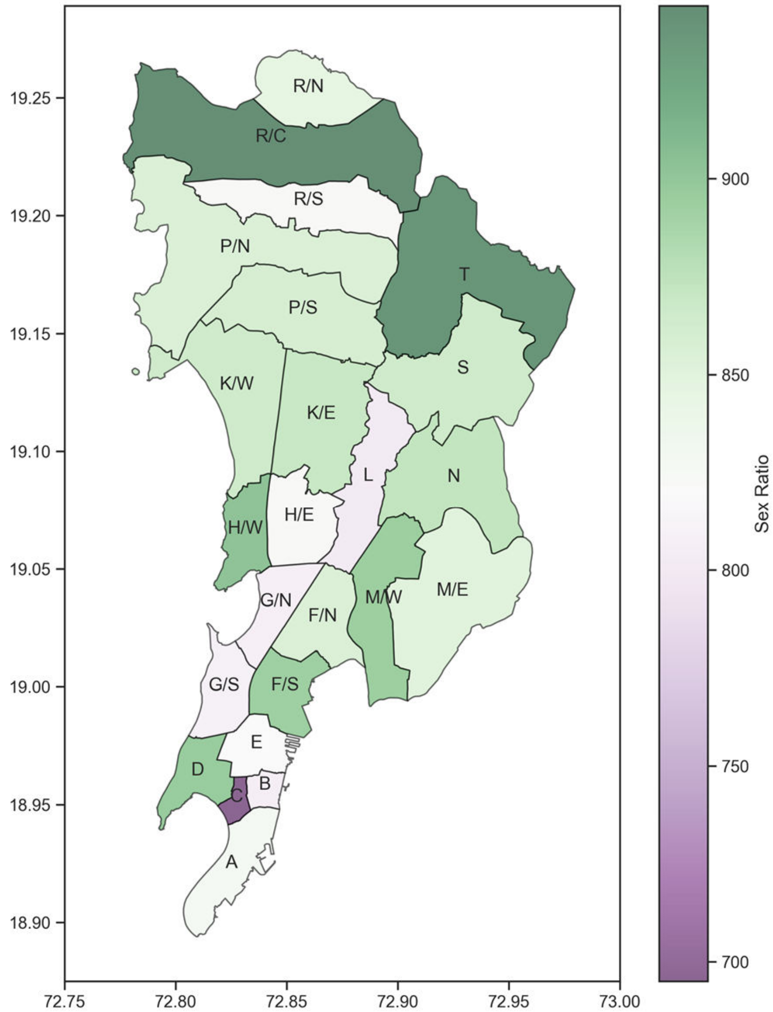


Zonal Mapping – Mumbai

Literacy rates



Gender Ratio



Summing up…

- Mapping in epidemiological is essential to **study** the distribution
- Mapping helps in **screening** and **detection** of hotspots
- May assist in the rapid identification of infectious disease outbreaks
- Outcomes from mapping helps in **designing policy frameworks**
- Designed policy frameworks help in **alleviating** disease-related outcomes
- **Long-term preparedness** can be achieved through early detection and mitigation with the help of mapping exercises