Course: HYDROINFORMATICS

IIIT-H, Spring, 2024

Faculty: Dr. Shaik Rehana, Associate Professor

Lab for Spatial Informatics (LSI), IIIT Hyderabad,

Email: rehana.s@iiit.ac.in

Format of the Course

Project-type format

- Students will work individually or in a small group
- Projects include data processing, development of data driven algorithms, etc.
- Classes will provide brief basic back ground about the problem
- Student will be working on data-intensive research topics and project environments
- Create basic programs for exploring the data processing to retrieve the information

Expectations of Students

- Class discipline – multidisciplinary
- Ready to learn/participate
- Turn off or keep silent all electronic devices
- Laptops are allowed during the class task and tutorial hours (When it is offline)

Prerequisite Course / Knowledge

General awareness about the water and climate related problems and computational programming skills to develop tools for an effective water resources management. Statistical and Mathematical Basics is expected (not necessary)

“Common Sense”

Goals

- ✓ To understand and manage water in natural and built environments
- ✓ Principles and operation of Hydroinformatics in water management with the application of information technology
- ✓ Study, design, development, and deployment of hardware and software systems for hydrologic data collection, distribution, interpretation, and analysis

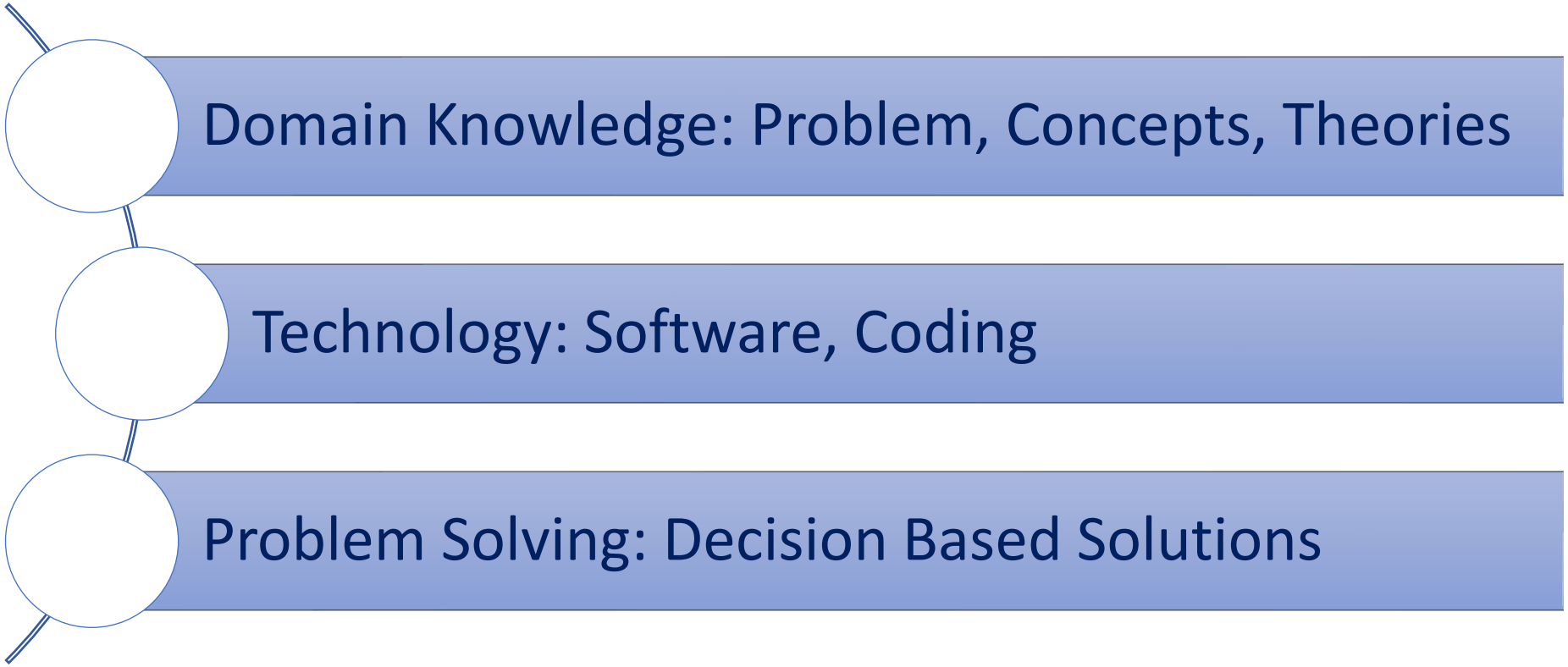
- **Useful to**
  - Computer Engineering - Programming, Data-Driven Algorithms, Statistics, Probabilities, etc.
  - Civil Engineering - Hydrology

  Programmes
  - Computer Science Extension…
  - Lab for Spatial Informatics (LSI)
  - Building Science (BSD)
  - Computer Aided Structural Engineering (CASE)
  - Others, who are interested to learn the applications of GIS and Remote Sensing

End of the Course

- Understanding Water Related Issues
- How to use and process various formats of spatio-temporal data
- How to use the processed data in solving climate related problems
- Water quantity and quality related problems

Overview of Hydroinformatics



Hydroinformatics

Hydroinformatics is a branch of informatics which concentrates on the application of information and communications technologies in addressing serious problems of the equitable and efficient use of water for many different purposes.

Hydroinformatics includes the concepts of real-time monitoring, data analysis, artificial intelligence and Machine Learning and Internet of Things to monitor, manage and conserve water for the maximum benefit of mankind

Deals with the Problems Related to

Hydraulics, Hydrology, Environmental, and

Water Resources Engineering

More on…

Hydraulics: Fluid Mechanics, deals with the flow of liquids (water) in pipes, rivers, dams, etc.

Hydrology: Science of water, deals with the occurrence, circulation, and distribution of water of the earth and the earth's atmosphere

Environmental Engineering: Supply of water, disposal of wastewater, control of pollution and protecting the quality of environment of air, water, and land resources.

Water Resources Engineering: Quantitative study of hydrologic cycle – distribution and circulation of water linking the earth's atmosphere, land and oceans.

Example: Flood Management of a city

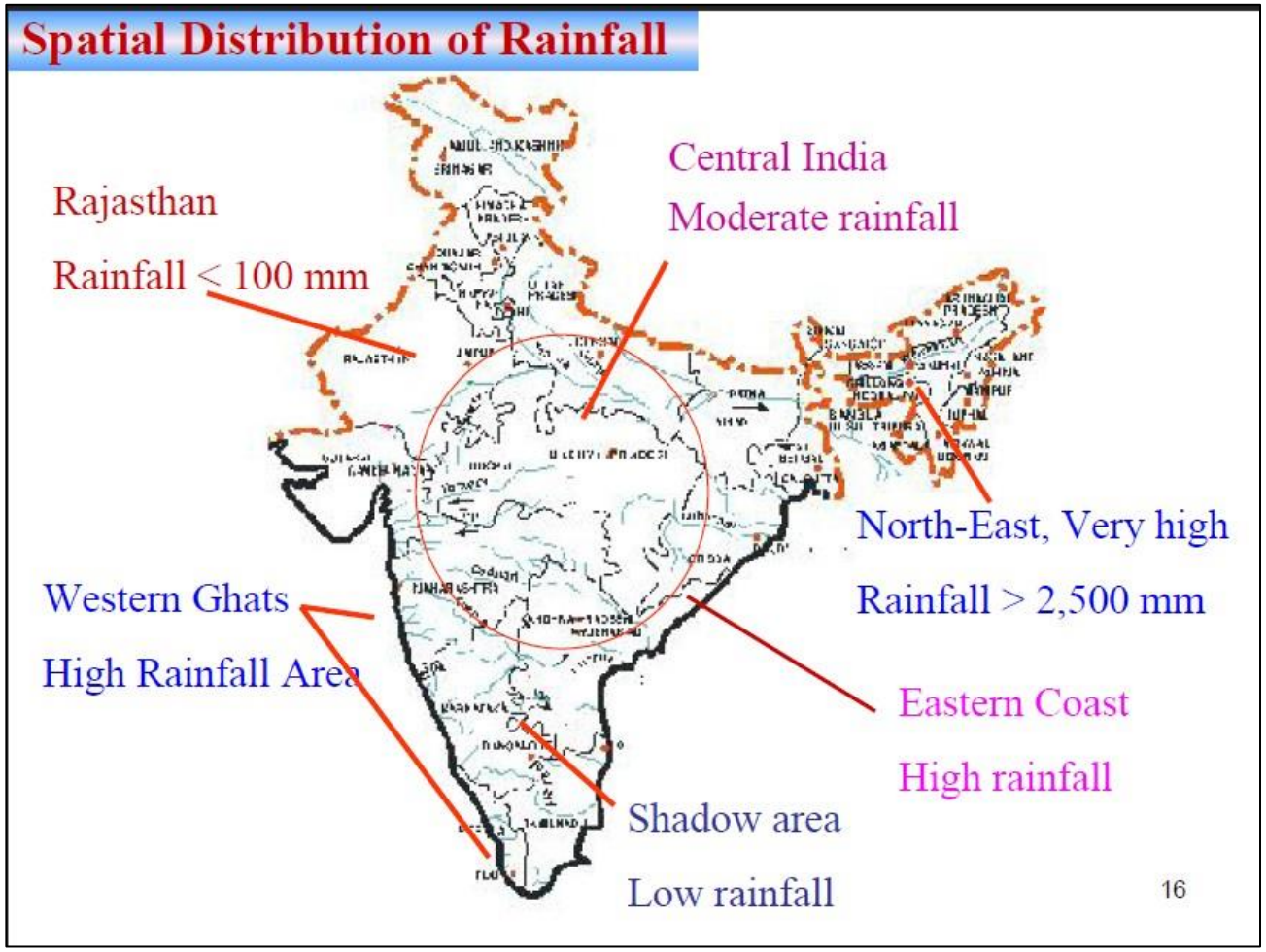
Water is an Integral Part of Life

- From Greek hudōr water

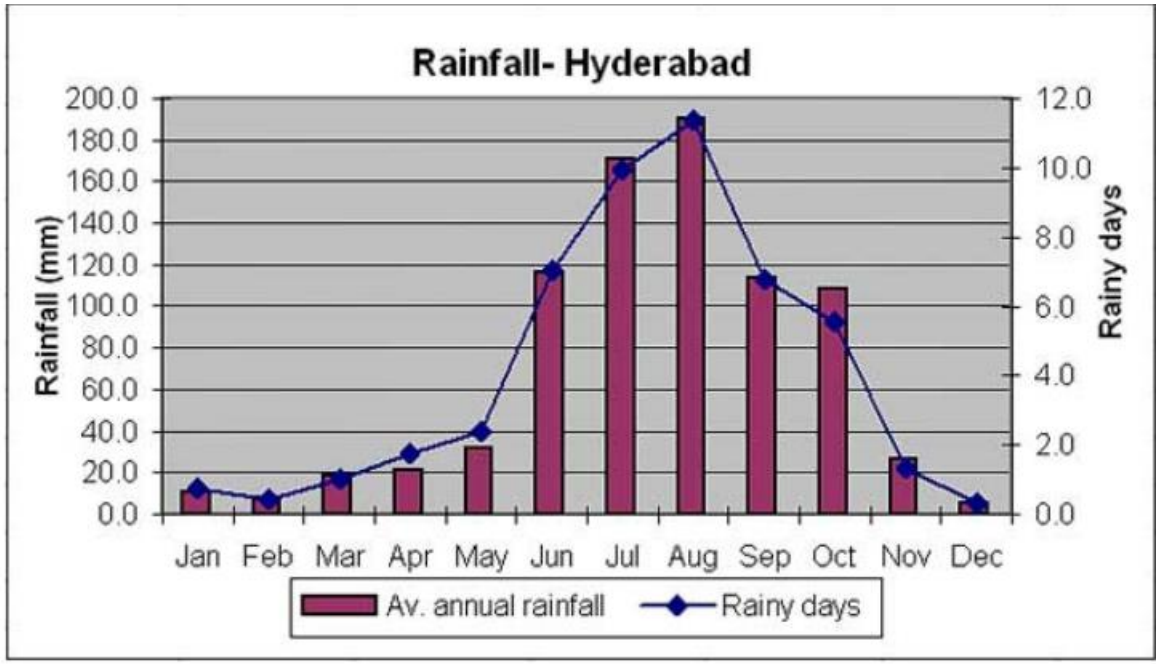
What is the Problem?

- Water is not distributed as we might wish

Rainfall - Spatial Variability over India



https://qsstudy.com/variability-rainfall-indian-monsoon/


Rainfall- Hyderabad
Rainfall (mm)
200.0
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Rainy days
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Av. annual rainfall
Rainy days

What is the Problem?

- There is often too much or too little

Water Related Disasters - Flood

What is the Problem?

- There is often too much or too little

Water Related Disasters - Drought

What is the Problem?

- What exists is too polluted or too expensive

Water Related Disasters - Quality

What is the Problem?

- Water situation is likely to further deteriorate as a result of urbanizations and global climate changes

Water Related Disasters

- ✓ Most disasters are water-related
- ✓ Floods, landslides, storms, heat waves, wildfires, extreme cold, droughts and waterborne disease outbreaks are all becoming more frequent and more intense, mainly due to **Climate Change**
- ✓ Around 74% of all natural disasters between 2001 and 2018 were water-related and during the past 20 years, the total number of deaths caused only by floods and droughts exceeded 1, 66,000, while floods and droughts affected over three billion people
- ✓ The impacts of disasters are exacerbated by urbanization and degradation of natural environments.

Source: https://www.unwater.org/water-facts/water-and-disasters

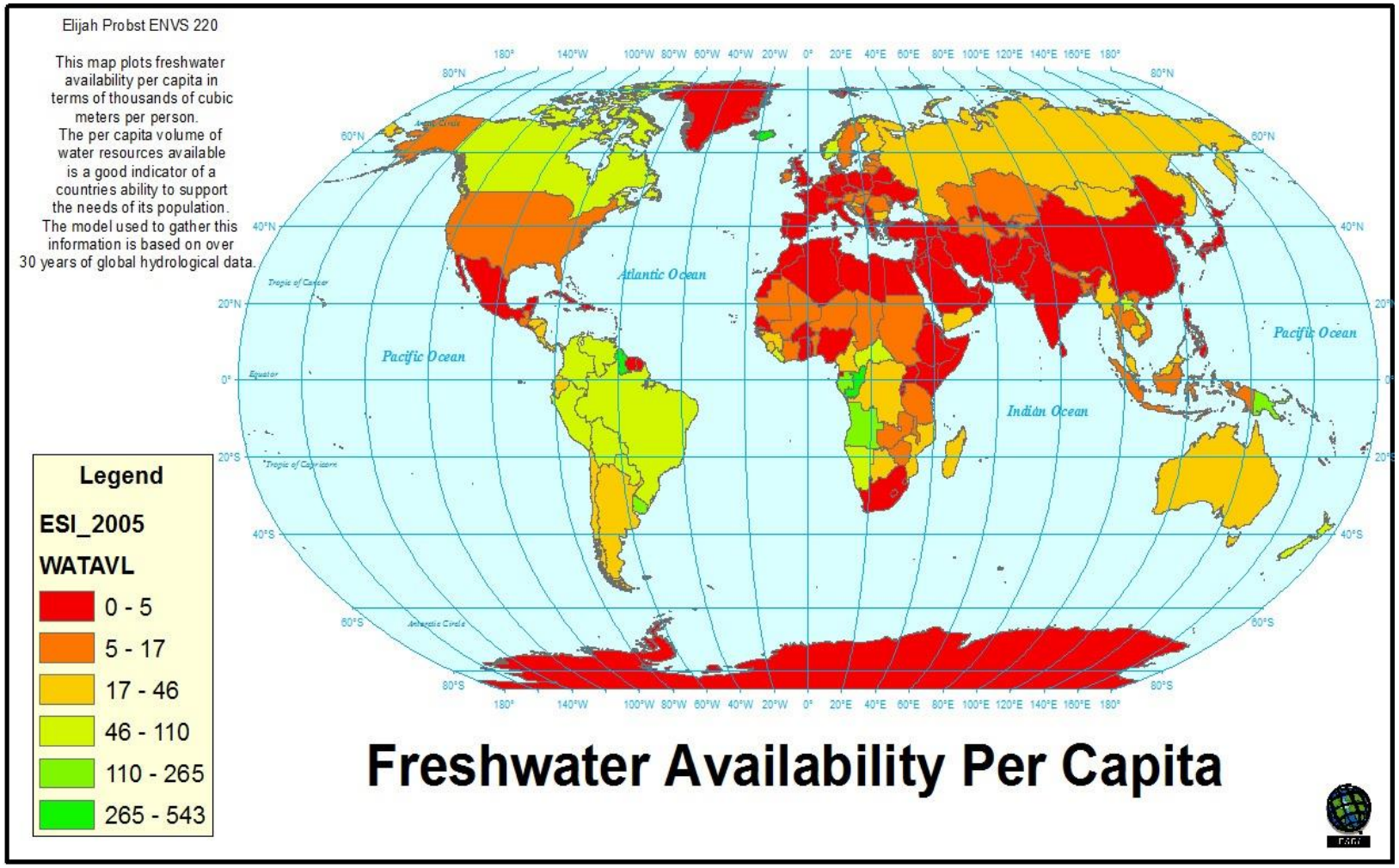
Introduction

- Water is one of the most important inputs of economic development.

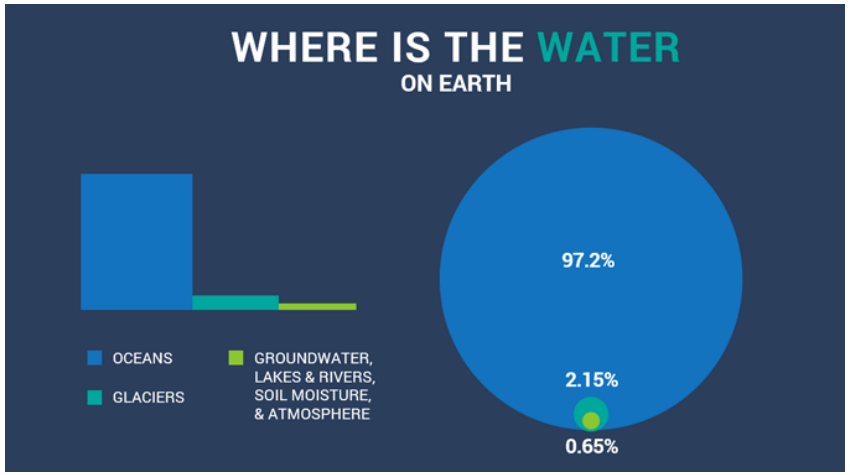
Water Around the World		
Too Little	Too Much	Too Polluted

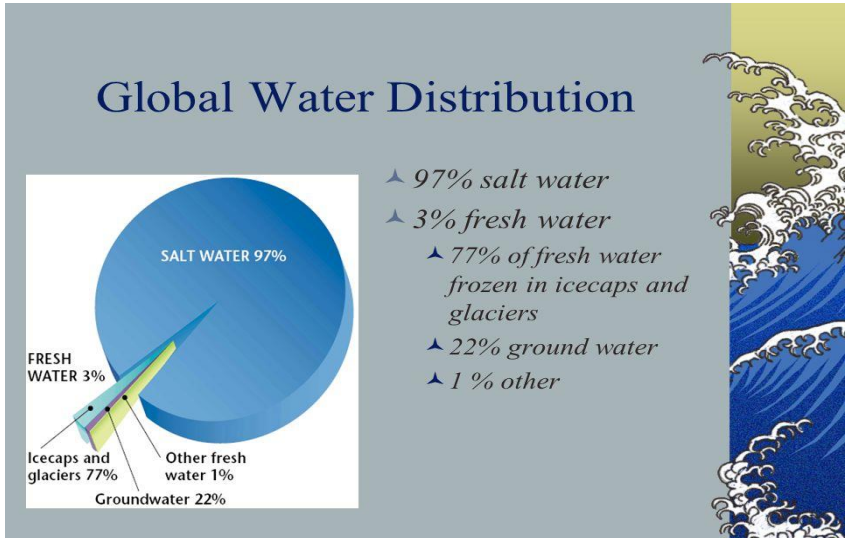
Water Resources (Rivers, ponds, lakes, reservoir, etc.)		
Beautiful	Disaster	Prosperous

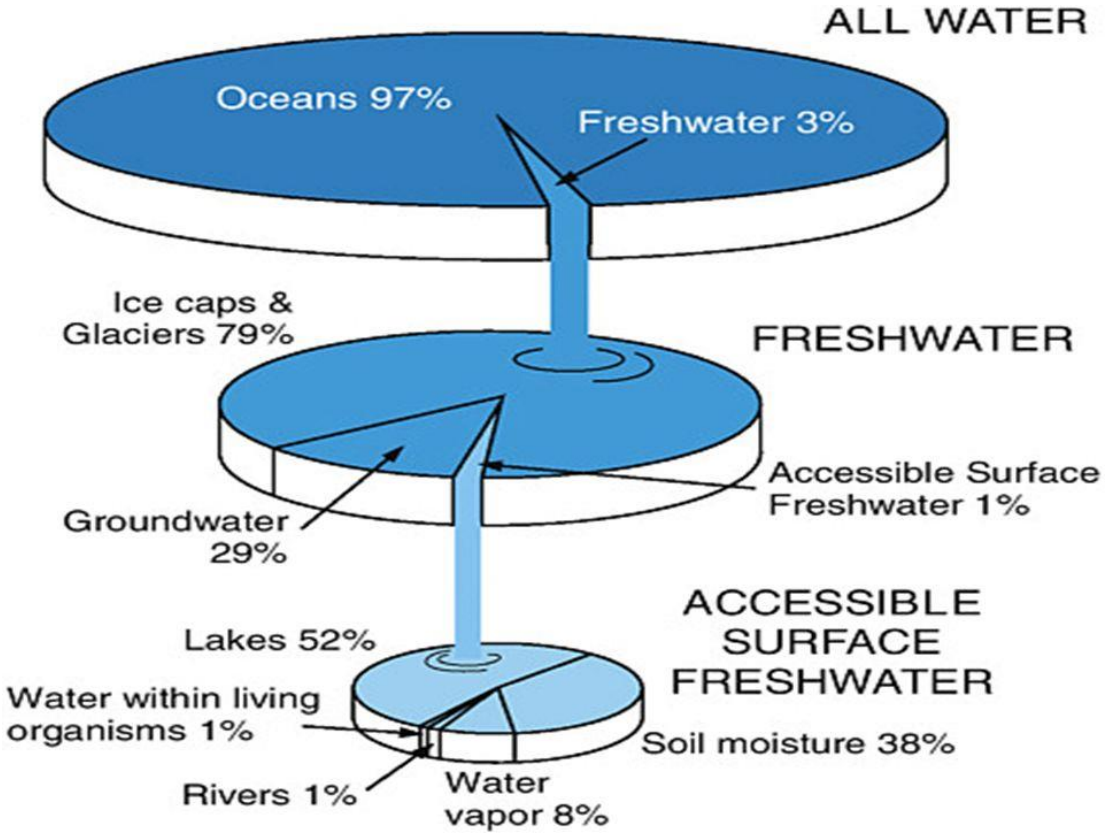
- Earth **“the water planet"**
- A world with plentiful water



Global Water Distribution on Earth

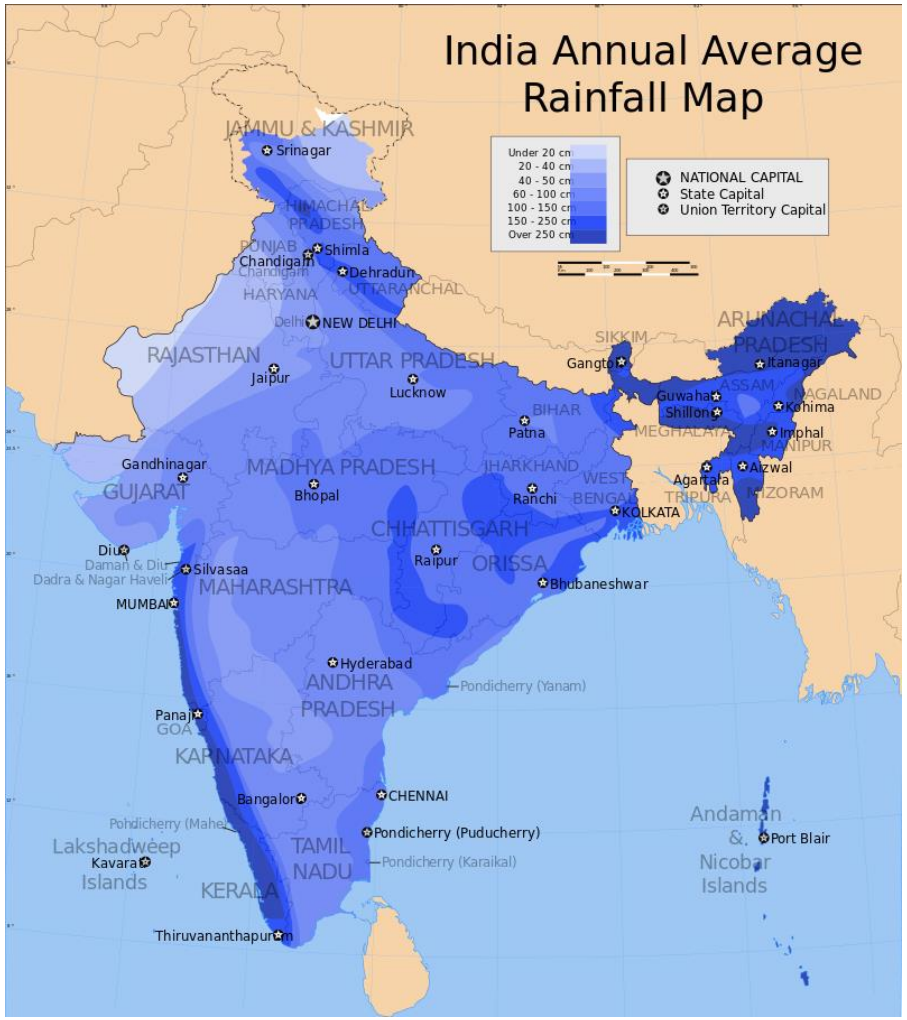






River Water Quantity and Quality in India

- India is rich in water resources, being endowed with a network of rivers and blessed with snow cover in the Himalayan range that can meet a variety of water requirements of the country.
- However, with the rapid increase in the population of the country and the need to meet the increasing demands of irrigation, human and industrial consumption, the available water resources in many parts of the country are getting depleted and the water quality has deteriorated.
- Indian rivers are polluted due to the discharge of untreated sewage and industrial effluents (Bhardwaj, 2005)



River Water Quantity and Quality in India

- India has large regional mismatches between water availability and demands, with increasing withdrawals from surface and subsurface sources rising to unsustainable conditions.
- India is an agriculture-dominated country and about 70% of the population's employment and economy depends on agriculture sector.
- The timely supply of irrigation water with sufficient quantity is challenging given the spatial and temporal mismatches of river water availabilities, increasing drinking and industrial water demands under population growth and pressure to increase crop yields.
- The determination of optimal water allocations for various sectors to fulfill various demands is of primary interest for most of the reservoirs of India.
- Tremendous population growth, rapid urbanization, alterations in agricultural patterns, unplanned growth of industries and failure of maintaining the environmental standards are the major causes for poor river water quality systems in India.

Water Security of India

- More than 600 million people are facing acute water shortages
- India's 70% of the people depend on agricultural profession for their livelihood
- Fresh water availability is important for assessing climate adaptation to ensure water and food security, agricultural water management and socioeconomic development.
- Understanding the water balance components at global and continental is of important for a sustainable water resources management (Vörösmarty et al., 2015)

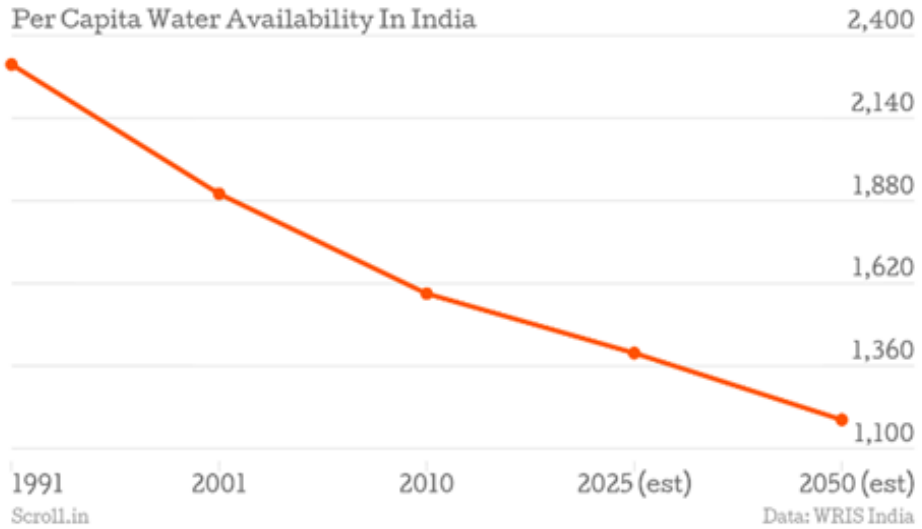


Figure 1: Per Capita Water Availibilty in India (Source: WRIS)

A population becomes "water stressed" when water levels fall to 1,700 cubic metres per capita, and "water scarce" when water levels fall to less than 1,000 cubic metres per capita. Source: http://www.futuredirections.org.au/publication/drought-water-security-india/

INTERNATIONAL INSTITUTE OF INFORMATION TECHNOLOGY
HYDERABAD

WATER RESOURCES

- Water resource, any of the entire range of natural waters that occur on the Earth, regardless of their state (i.e., **vapour, liquid, or solid**) and that are of potential use to humans.

- Waters of the oceans, rivers, and lakes; other available water resources include groundwater and deep subsurface waters and glaciers and permanent snowfields.

❖ **Surface Sources**

✓ Ponds and lakes

✓ **Streams and rivers**

✓ Storage resources (reservoirs)

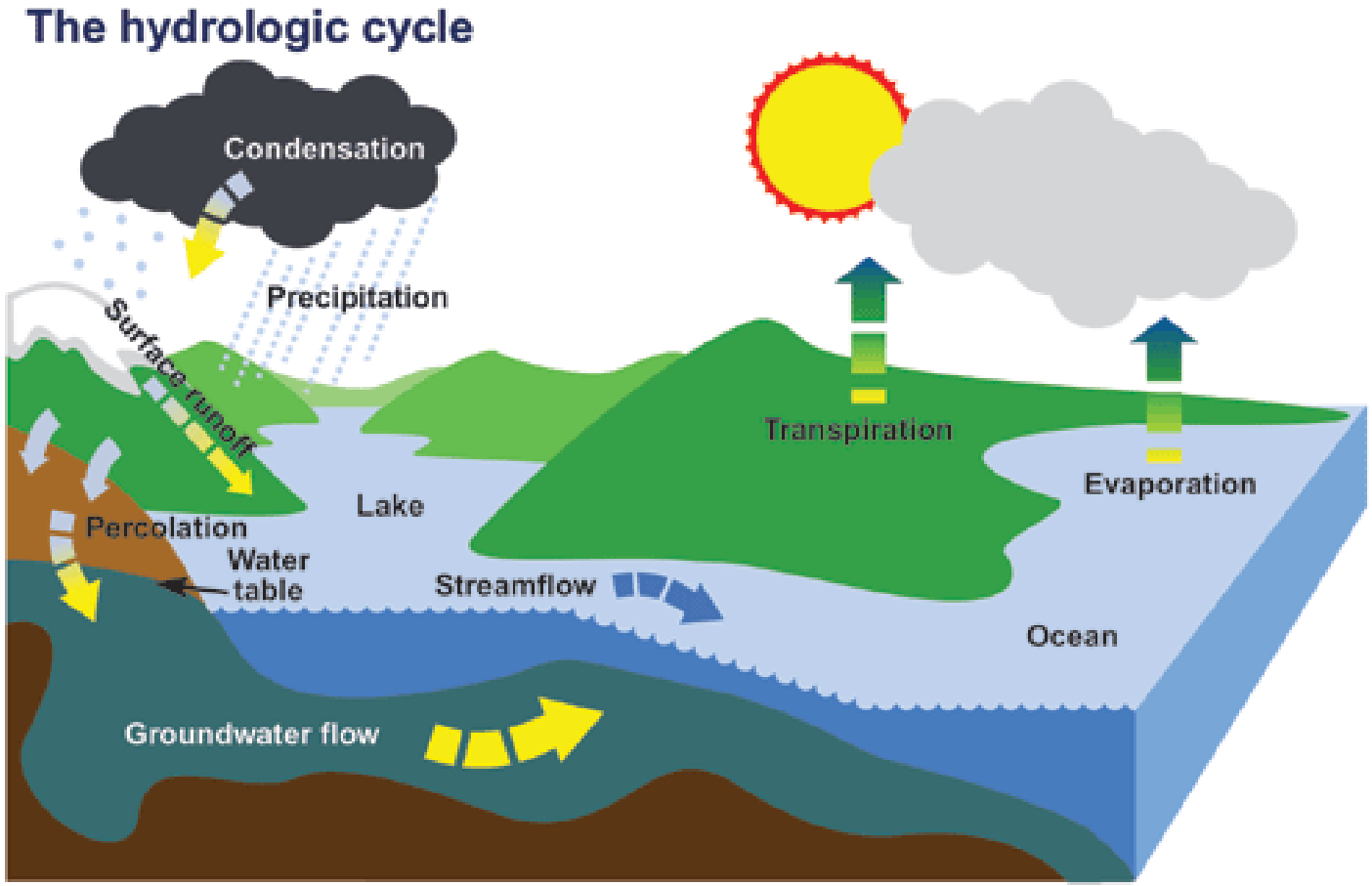
❖ **Subsurface or underground sources**

✓ Springs

✓ Wells

sources-of-water

Hydrological Cycle



At what scale we work ?

Every where water is available….

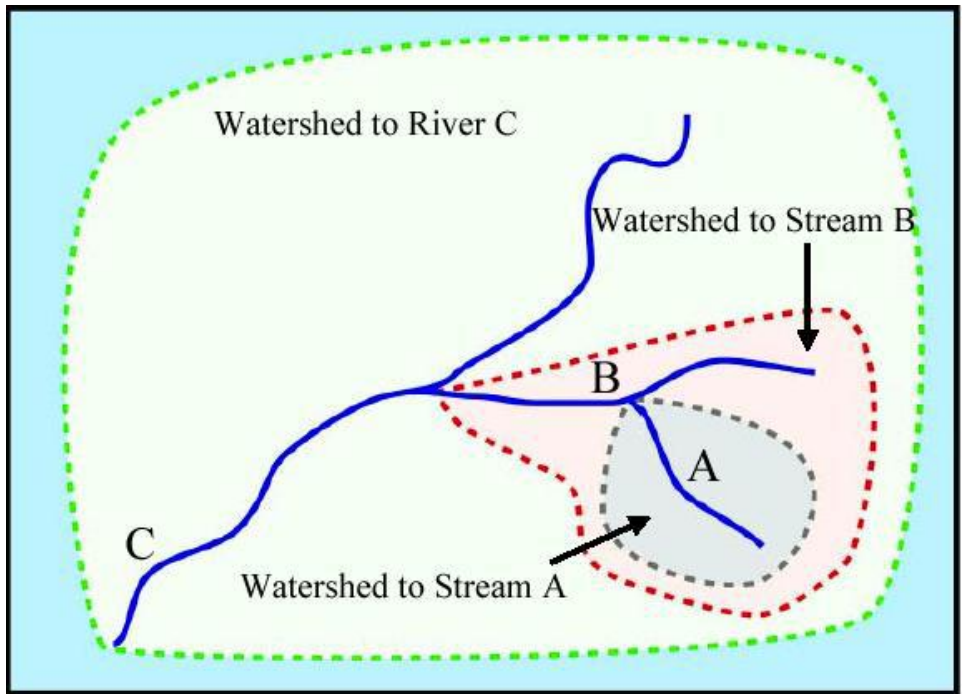
Question: Where to study ?

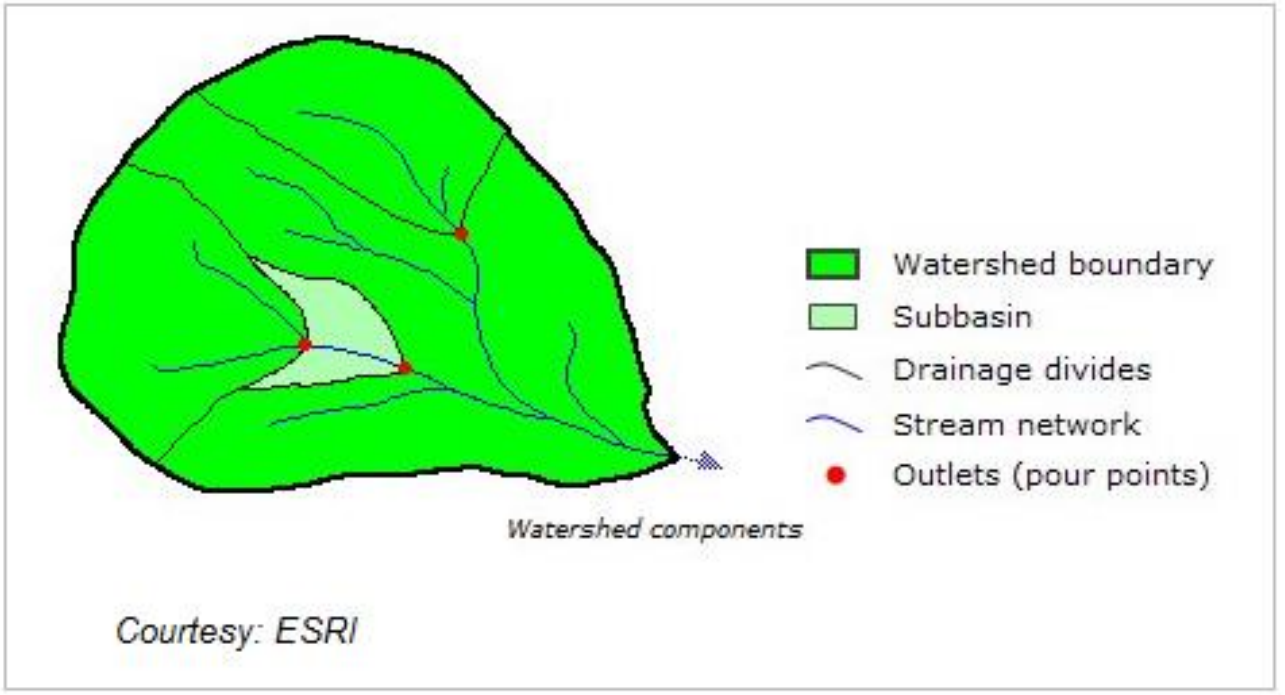
Answer: River Basin, city, country, catchment, global, region, etc.

What to study ?

Quantities, flows volumes, depths, quality using parameters, etc.

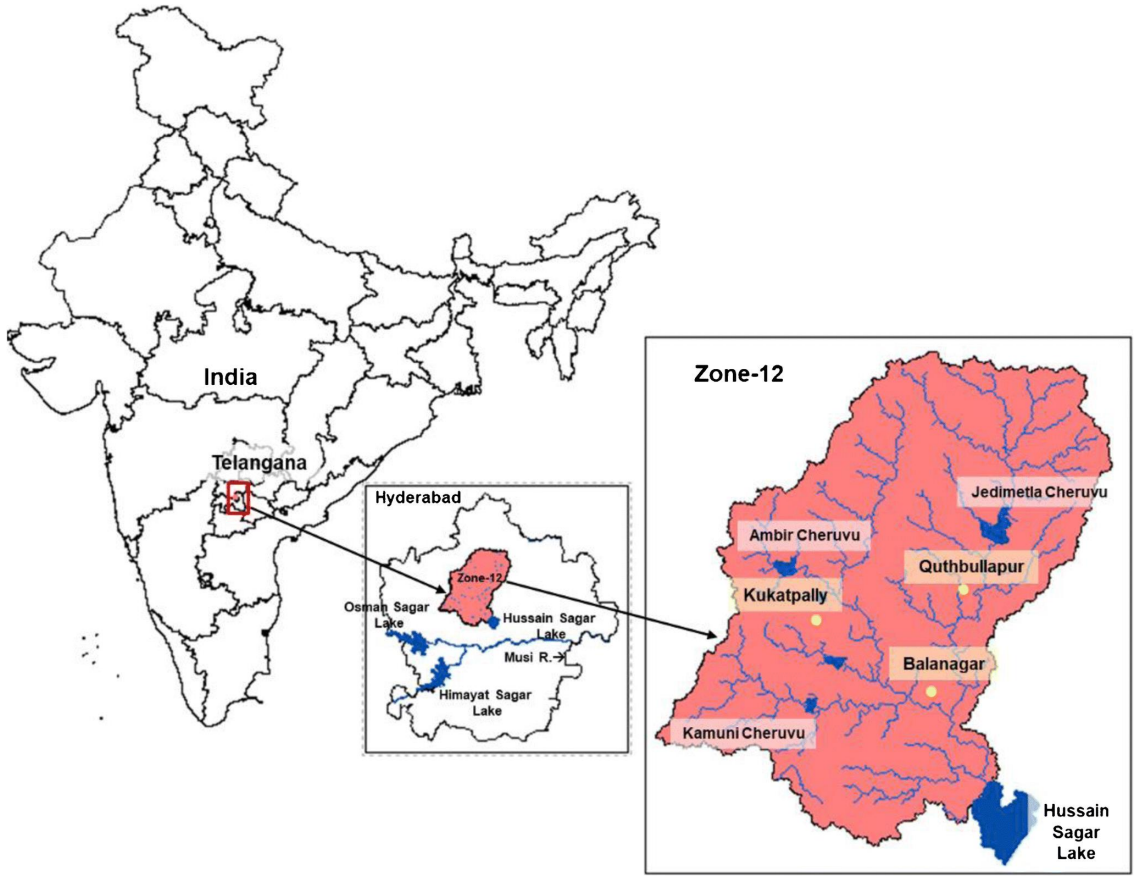
More About Watershed ..

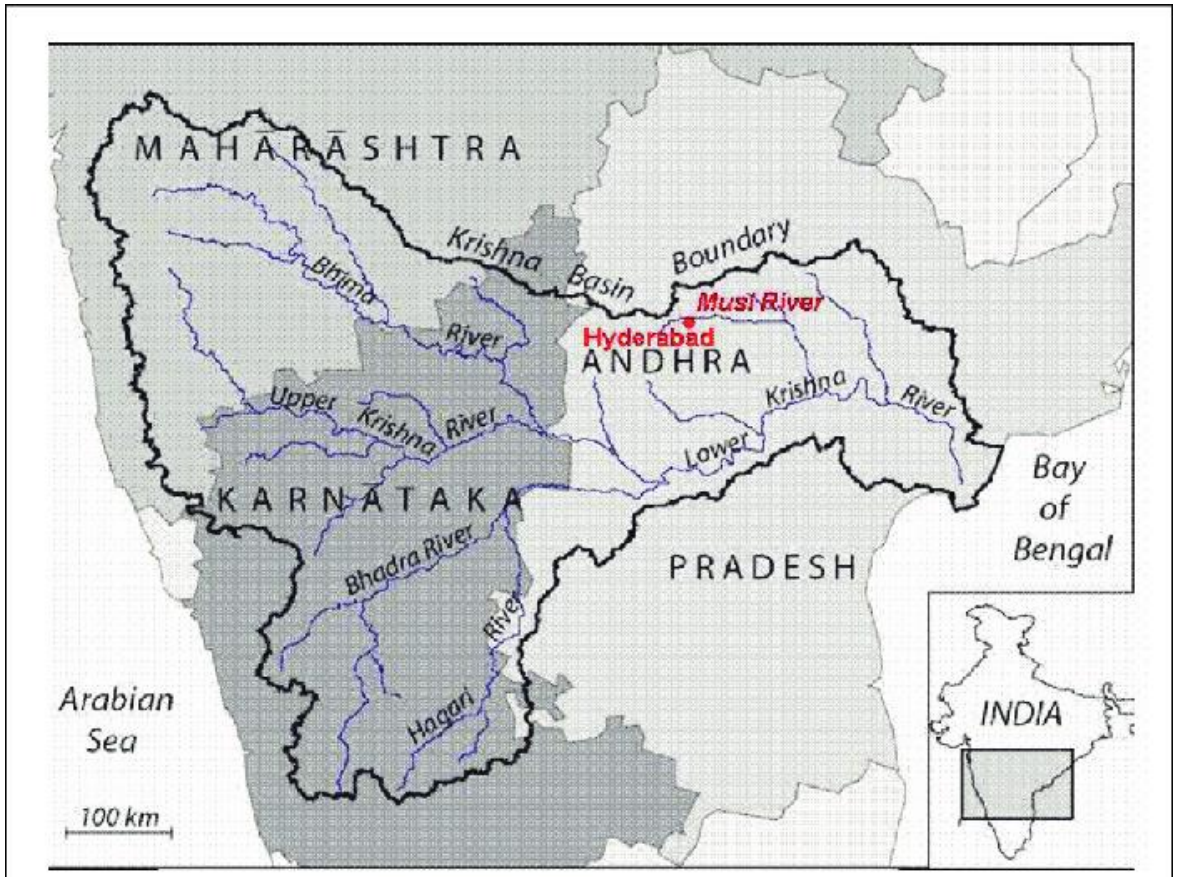




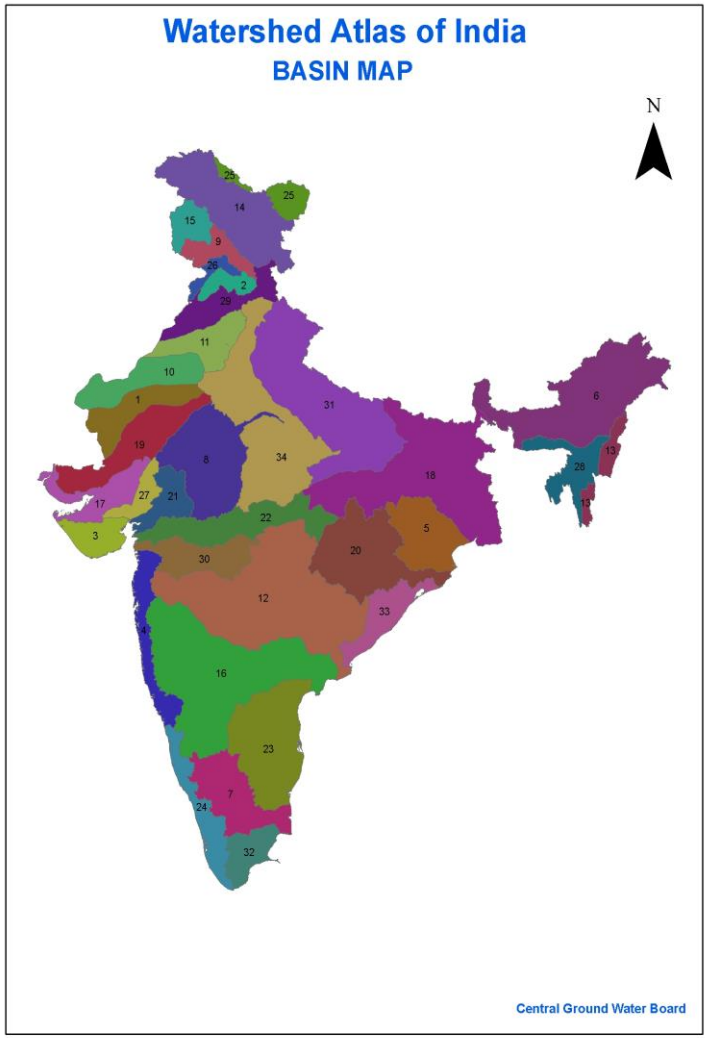
- Area contributing
- Smaller watersheds make up larger watershed

Spatial Scales of Water Resources Systems





Spatial Scales of Water Resources Systems



Map Reference No	BASIN
1.	BARMER
2.	BEAS
3.	BHADAR
4.	BHATSOL (RIVERS FROM SHERAVATI TO TAPI FLOWING INTO ARABIAN SEA)
5.	BRAHMANI (MAHANADI TO DAMODAR)
6.	BRAHMPUTRA
7.	CAUVERY
8.	CHAMBAL
9.	CHENAB
10.	CHURU
11.	GHAGHAR
12.	GODAVARI
13.	IMPHAL
14.	INDUS
15.	JHELUM
16.	KRISHNA
17.	KUTCH
18.	LOWER GANGA
19.	LUNI
20.	MAHANADI

Map Reference No	BASIN
20.	MAHANADI
21.	MAHI
22.	NARMADA
23.	PENNAR (CAUVERY TO KRISHNA)
24.	PERIYAR (RIVERS FROM KANYAKUMARI TO SHARAVATI FLOWING INTO ARABIAN SEA)
25.	QURA-QUSH
26.	RAVI
27.	SABARMATI
28.	SURMA (DRAINAGE FLOWING INTO BANGLADESH)
29.	SUTLEJ
30.	TAPI
31.	UPPER GANGA
32.	VAIPPAR (KANYAKUMARI TO CAUVERY)
33.	VAMSADHARA (GODAVARI TO MAHANADI)
34.	YAMUNA

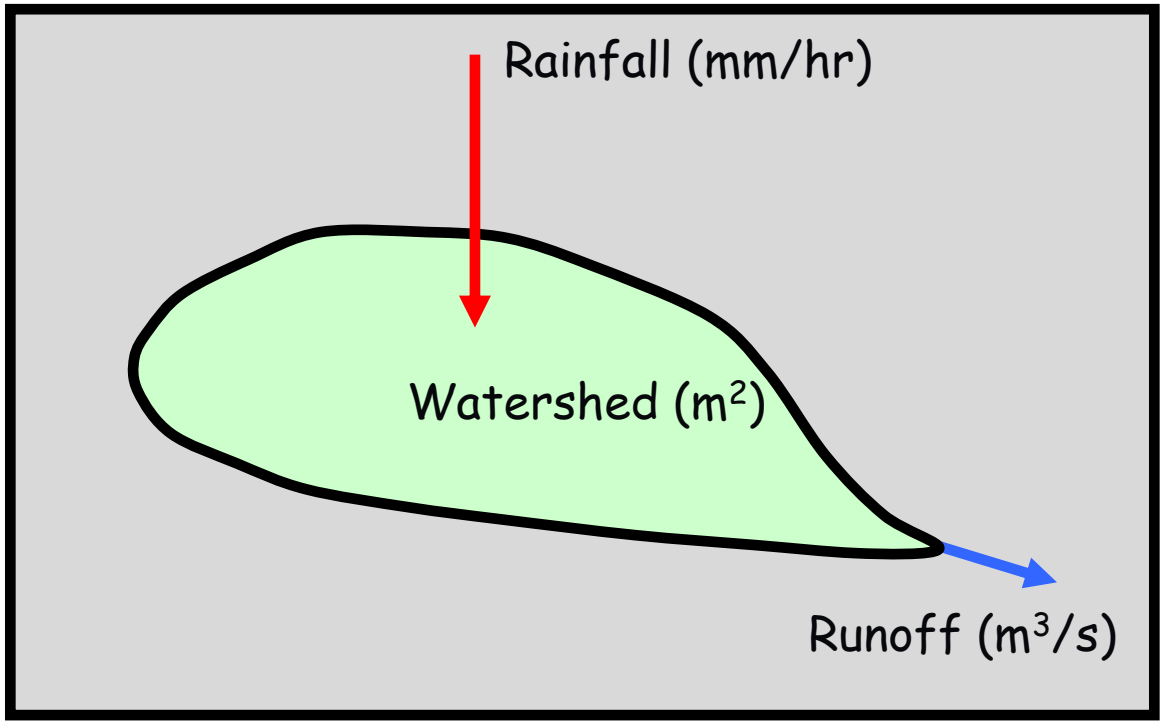
How to Characterize Water ?

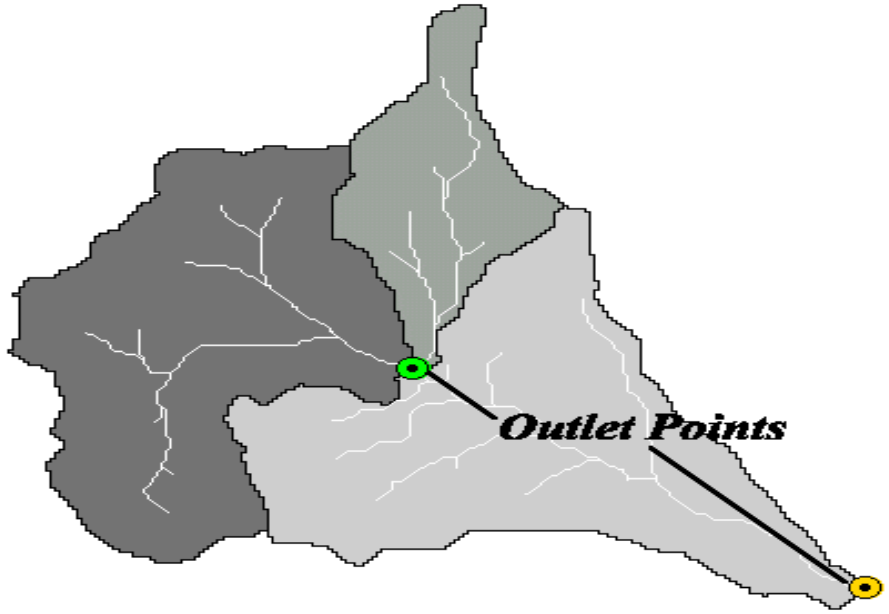
- Water Quantity
- Water Quality

What is Water Quantity ?

- A reservoir contains 2 Mm^3 of water
- The flow in the river is 15 m^3/s
- The water flow in the pipe is 20 lit/s
- Water quantity is defined by a single parameter - Water mass

Spatial Scales of Water Resources Systems





Watersheds also known as catchments or drainage basins are aerial hydrologic units that contribute to rainfall-runoff dynamics defined at a point known as pour point or outlet (for a stream, lake or landscape depression).

How to Estimate the Water Quantity ?

- Ex: Water is flowing through a pipe with a velocity of 30 m/s. Area of pipe = 10 m^2

Volume of water flowing through pipe in a given time ?

Volume of water flowing per unit time, Q = V A = 30 X 10 = 300 m^3/s

- Ex: A river flow has velocity of 20 m/s. What is the river flow ?

- Ex: A circular pipe with flow velocity as 10 cm/s, what is the flow through the pipe ?

- A catchment with an area of 1750 Km^2 received 1250 mm of precipitation. Calculate the total runoff occurred in the year (in m3)

- A catchment with an area of 1750 Km^2 received 1250 mm of precipitation. Calculate the total rainfall occurred in the year (in m3)

- Sol: Area of the catchment = 1750 Km^2 = 1750 X 10^6 m^2
- Precipitation received = 1250 mm = 1.25 m
- Total annual precipitation = 1.25 X 1750X10^6 = 2187.5 X 10^6 m^3

What is Water Quality ?

- Water quality determines the '**goodness**' of water for particular purposes (Drinking, Irrigation, Industrial, Outdoor Bathing (Holy dips), etc.)

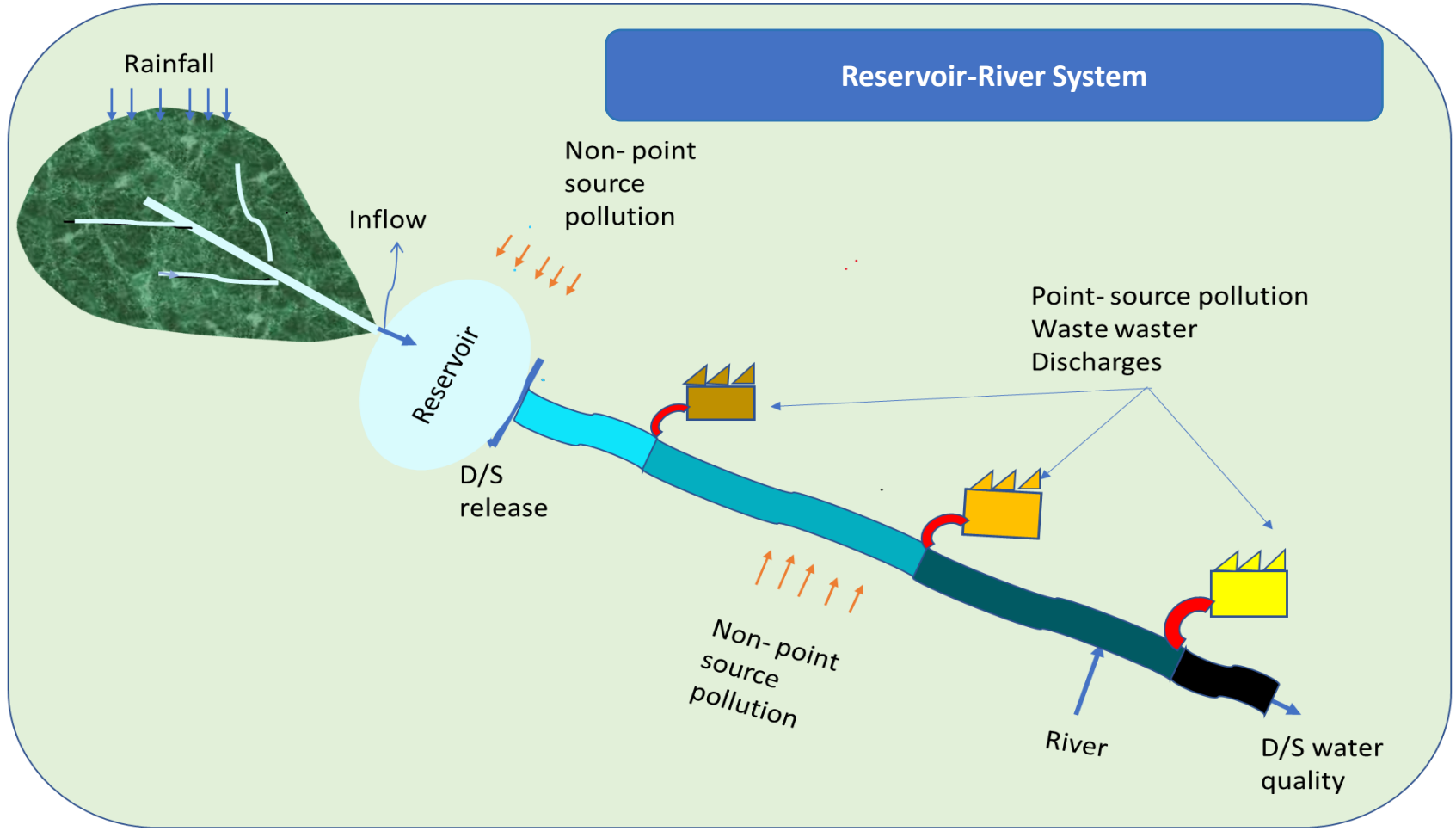
- Pure liquid water is colorless, tasteless, and odorless and solely consists of H_2O molecules.

What is Water Quality ?

- Quality may be good for coolant industry, but is it good enough for drinking ?
- Water looks good for irrigating some crops, but suitable for livestock, fish culture ?
- Water is a universal solvent, it picks up a lot !
- Water quality is a function of anything and everything the water might have picked up during its journey from clouds to the earth to the waterbody: in dissolved, colloidal, or suspended form

How to Measure the Water Quality

Understanding the Water Resources Systems


Reservoir-River System
Rainfall
Inflow
Non- point source pollution
Reservoir
D/S release
Point- source pollution
Waste waster Discharges
Non- point source pollution
River
D/S water quality

Hydroinformatics

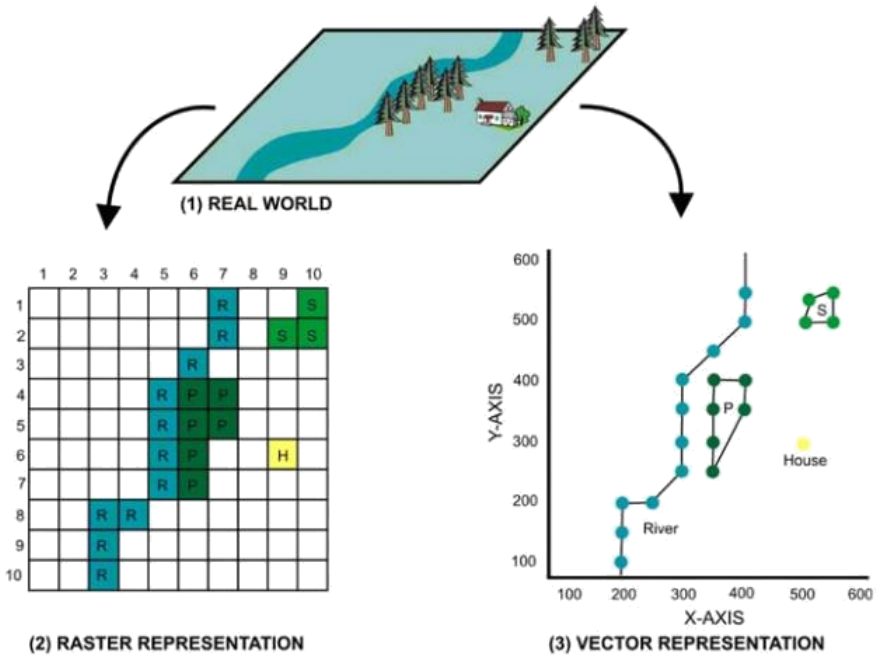
To understand and manage water in natural and built environments

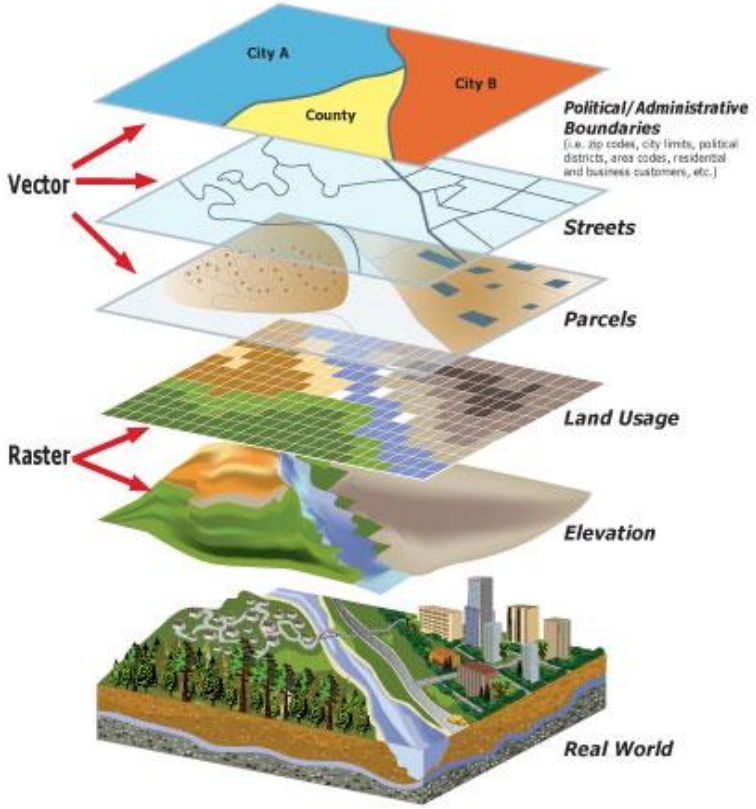
Natural and Built-up Systems

- Water-related problems are quite complex due to the interrelationships between water-related environment, social and business factors
- Data sources
  - Natural dimension
  - Social dimension
  - Business dimension

- **Natural dimension:**
  - Understanding the water cycle, Spatio-temporal distribution of water and interaction of water and the environment
  - Water-related data:
    - Measurement of precipitation
    - River flow
    - Water quality
    - Soil moisture
    - Soil characteristics
    - Ground water condition
    - Air temperature
    - Humidity
    - Solar flux

Scaling of a Water Resources System

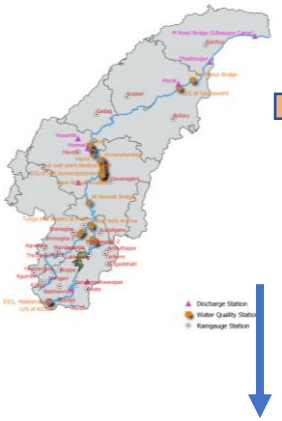




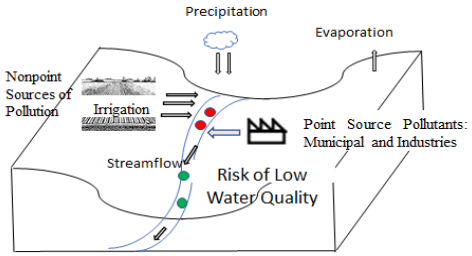
- The real world can only be depicted in a GIS through the use of models that define **phenomena in a manner that computer systems can interpret**, as well perform meaningful analysis.
- There are two fundamental approaches to the representation of the spatial component of geographic information:
  - **Vector Model** (Points, Lines, Polygons)
  - **Raster Model** (Surfaces)

Types of Data

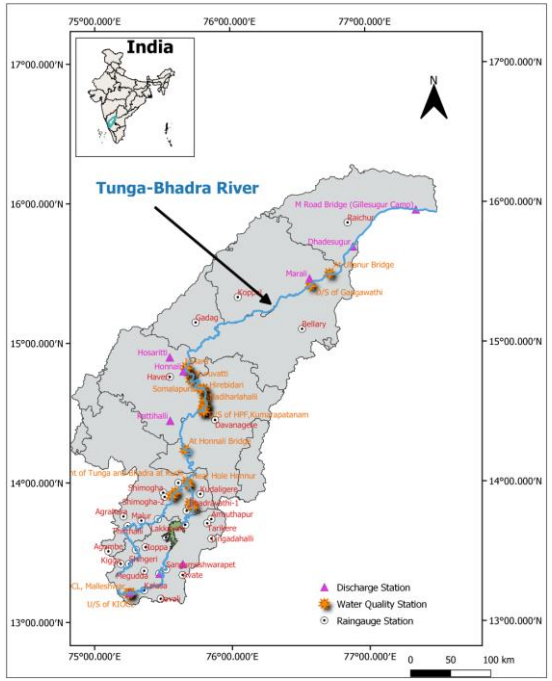
Hydro-climatic and Water Quality Monitoring

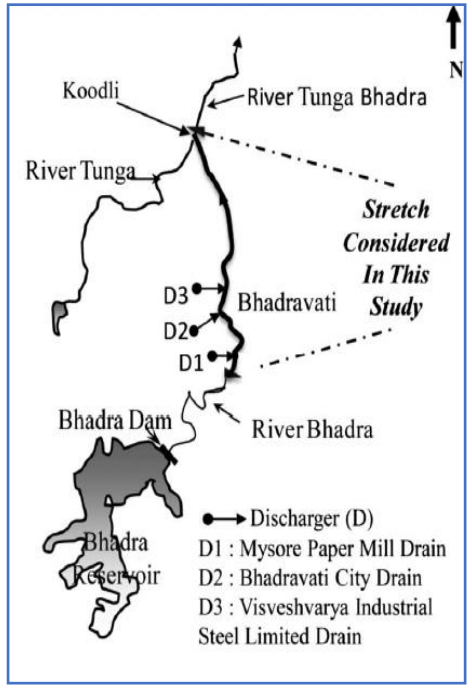


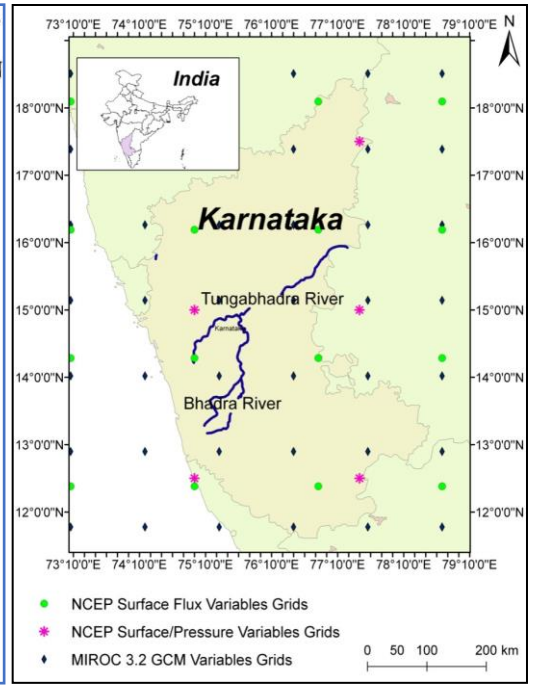
Water quantity and quality Assessment



Driving Factors







To Learn about Data

- Types of data
  - Spatial resolution
  - Temporal variability
- Dimension of data
  - 1D, 2D, 3D, 4D
- Point and gridded data
- Vector, Raster and Image data

More about Data

- Meteorological, hydrological, climatological, experiment and simulation data sets
- Data storage file formats and standards
- Web based data and access using web services
- Integration of data (e.g. hydro-climate)
- Various forms of data (e.g. grd, NetCDF)
  - Scalar data values on a regular rectangular grid, either in (x, y) or (longitude, latitude) space.
  - NetCDF (Network Common Data Form) for array-oriented scientifics geo-gridded data sets

Rainfall Data

- Temporal - hourly, daily, monthly, annual

- Seasonal –

    - Winter Season - January – February
    - Pre Monsoon Season - March – May
    - Southwest Monsoon Season - June - September
    - Northeast Monsoon Season - October – December

To learn about Data processing

- Changing spatial and temporal scales
  - Spatial interpolation and pooling – basin scale, zonal scale, point scale etc.
  - Temporal aggregation – annual, monthly, daily etc.
  - Climate data processing - downscaling and upscaling etc.
  - To use the processed data in simulations, hydraulic and hydrology water based models.
  - Data visualization and interpretation

To learn about Tools

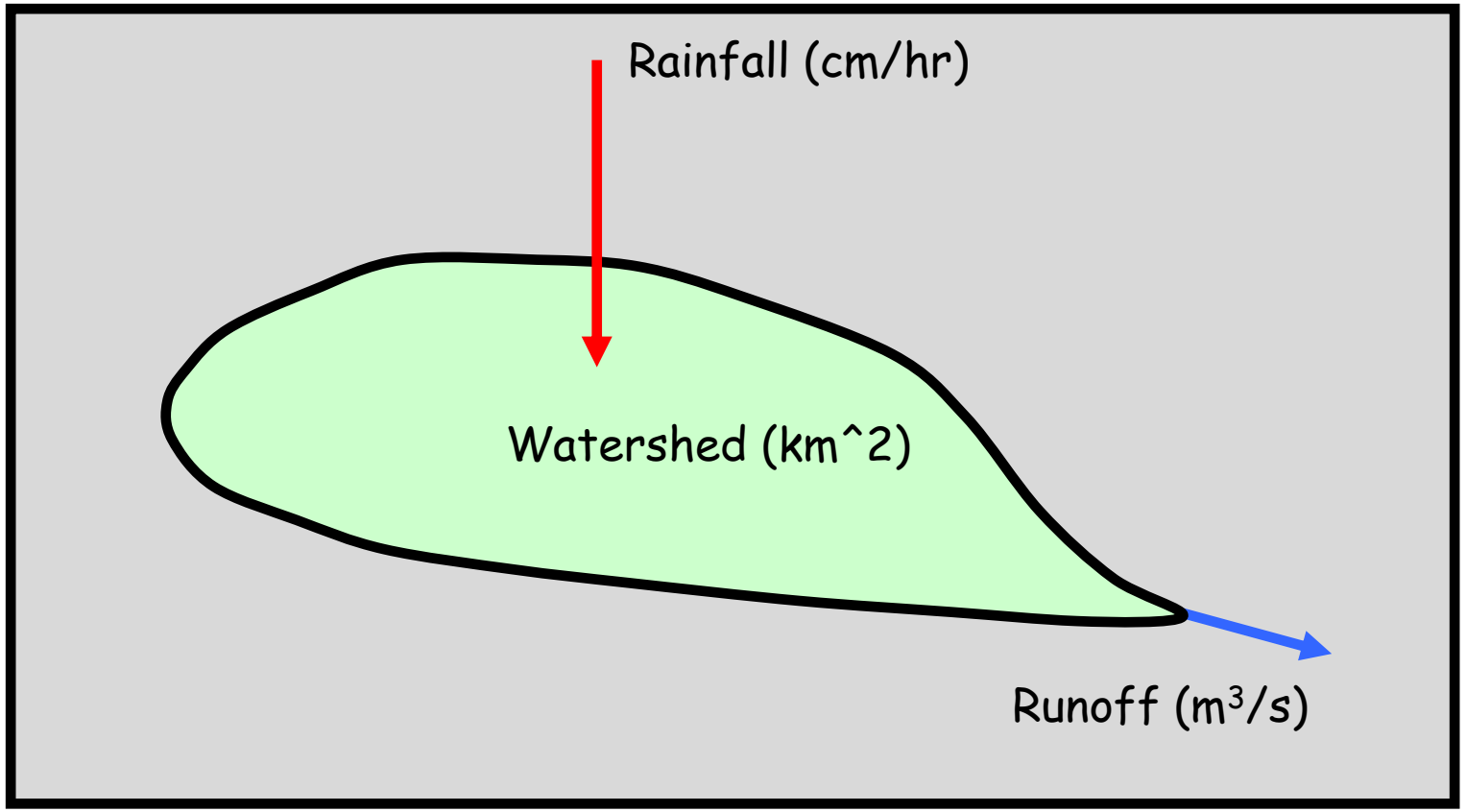
- Geographic Information Systems
- Remote Sensing
- Predictive Models
- Statistical Methods
- Uncertainty Analysis
- Decision Making Tools
- Optimization Methods

Soft Computation

- QGIS
- MATLAB
- Python
- Any programming language
- Data driven algorithms

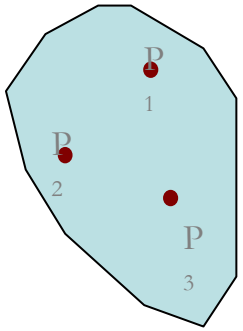
Scale of Water Resources Systems

Watershed/Basin/Catchment



Flow, Streamflow, Runoff, Inflows, Yield = f(Rainfall, Watershed hydrologic properties)

Point Data and Gridded Data

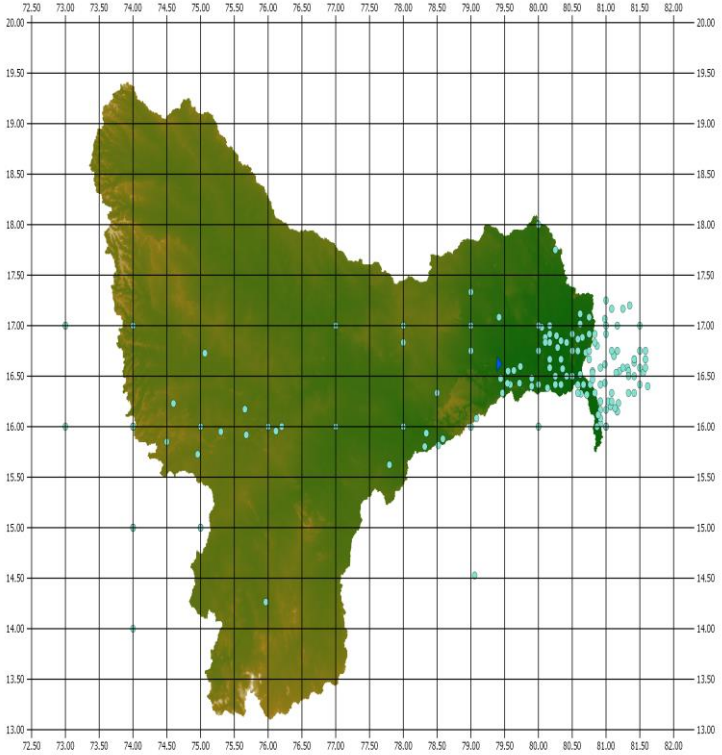


Example

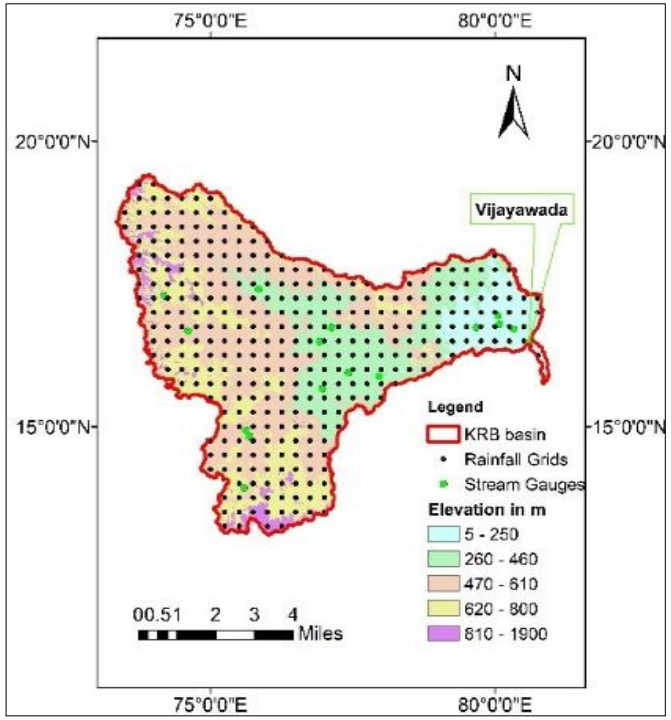
$P_1 = 10$ mm

$P_2 = 20$ mm

$P_3 = 30$ mm



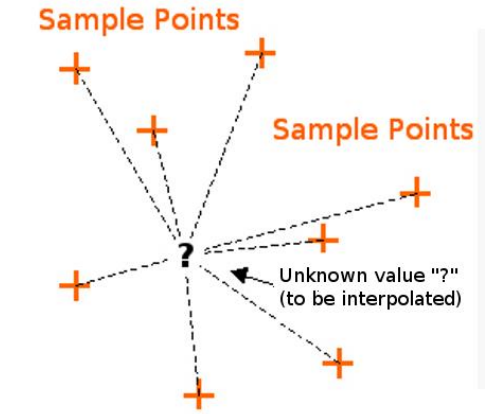
Rainfall stations superimposed on Krishna River Basin

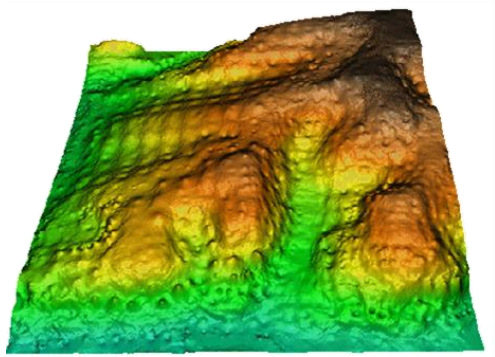


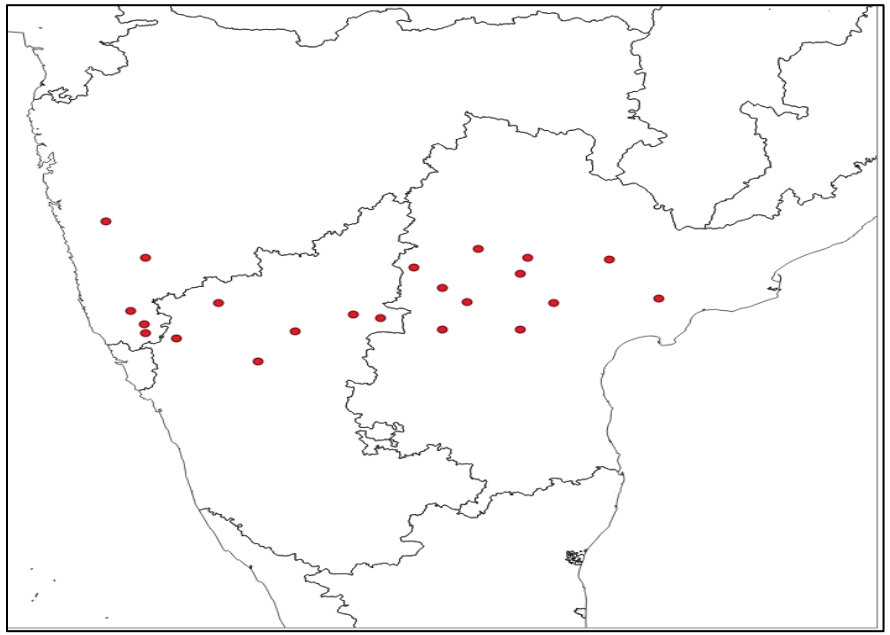
Rainfall Gridded data superimposed on Krishna River Basin

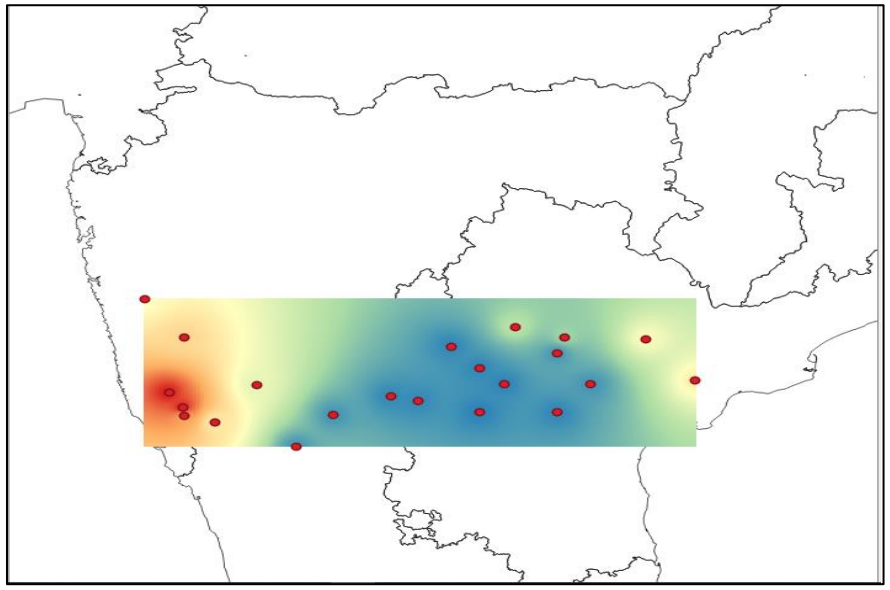
Spatial Interpolation

- Calculating an unknown value from a set of points with known values that are distributed across an area.
- Spatial interpolation is the prediction of values at un-sampled locations from measurements made at control points within the same area









More about the tasks

- Creating data visualizations
- Writing and executing computer code to computationally intensive tasks
- Transforming file systems, databases using programming languages, etc.
- Organize the data supporting to water-based systems

Problems to Solve

- High performance computing algorithms can be used to design short and long term adaptive measures and alternatives for combatting floods, droughts, heatwaves, water quality, agriculture, climate change and human influences.

- Data driven and machine learning algorithms for simulating complex and uncertain water systems under the lack of knowledge of exact mechanistic processes involved