CE 311: Hydrology & Water Resources Engineering

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CE 311: Hydrology & Water Resources Engineering (3-0-0)

Course objectives: To develop technical skills for modelling and quantifying hydrological processes. Development of research capabilities so that the students completing the course shall be capable of pursuing further works on water management, integrated water resources management, urban water management, flood control, managing climate change impacts on the water cycle, canal design, etc.

Syllabus: Surface water hydrology - hydrologic cycle, rainfall and its measurement, mean rainfall, runoff; Flow measurements; Infiltration losses; Storm hydrology; Unit Hydrograph; Storm hydrograph; Reservoir planning - Investigations, life of reservoir; Flood estimation and routing, flood forecasting; Surface and sub-surface drainage, water logging, remedial measures, drainage of land; Ground water hydrology - Introduction, types of aquifers, wells, well yield; Soil-Water-Plant relationships, crop water requirement; Layout of canal system; Types and methods of irrigation.

Expected outcome: The students shall be able to formulate hydrological processes in mathematical terms; be able to work with and recognize the limitations of hydrological data; be able to employ mathematical and computational techniques to solve real life hydrological problems.

Text and reference books

Texts:

1. V.T. Chow, D.R. Maidment, and L.W. Mays, Applied Hydrology, McGraw Hill, 1998.
2. V.P. Singh, Elementary Hydrology, Prentice Hall, 1993.

References:

1. H.M. Raghunath, Hydrology – Principles, Analysis and Design, Wiley Eastern Ltd., 1986.
2. 2. A.M. Michael, Irrigation – Theory and Practice, Vikas Publishing House, 1987.
3. 3. D.K. Todd, Groundwater Hydrology, John Wiley & Sons, 1993.
4. 4. K. Linsley, Water Resources Engineering, McGraw Hill, 1995.
5. 5. S.K. Garg, Irrigation Engineering and Hydraulic Structures, Khanna Publishers, 1992.
6. 6. H.P. Ritzema (Editor-in-Chief), Drainage Principles and Applications, ILRI Publication 16, 1994.

NPTEL course on Groundwater Hydrology

Assessment

• Assignment	: 15
• Quiz	: 15
• Mid semester exam	: 30
• End semester exam	: 40

Hydrology

"Hydrology is the science that treats the waters of the earth, their occurrence, circulation and distribution, their chemical and physical properties, and their reaction with their environment, including their relation to living things. The domain of hydrology embraces the full life history of water on the earth"

What hydrologists do:

Assessment	: availability of water
Water use	: water withdrawal and instream uses
Water Control	: flood and drought mitigation
Pollution Control	: point and nonpoint sources

Prehistoric times

HOMER (800 BC)

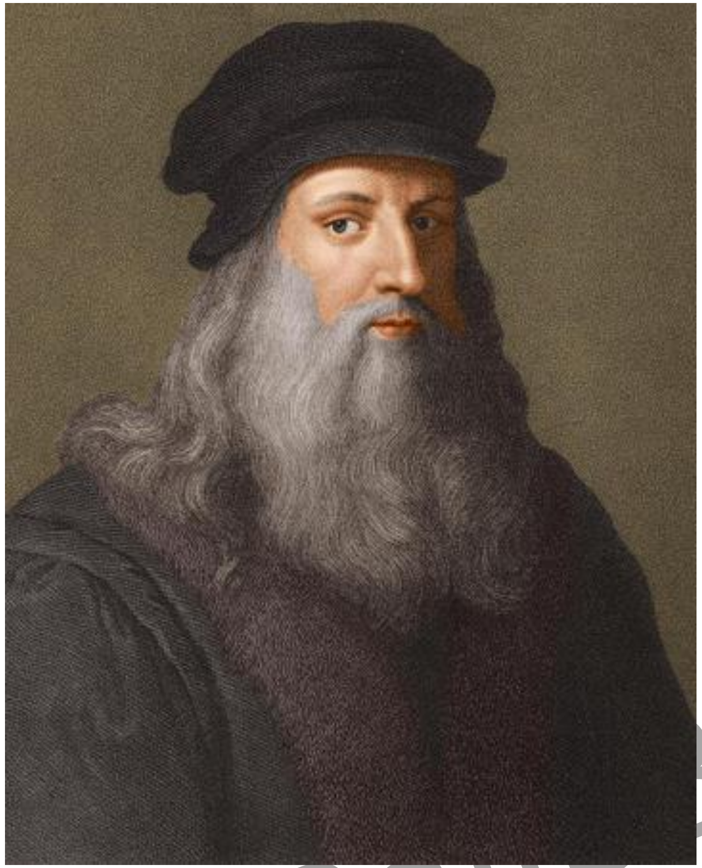
- It was thought that the land mass floated on a body of water, and the water in rivers and lakes has its origin under the earth.
- Examples of this belief can be found in the works of HOMER.

Anaxagoras (460 BC)

The idea that the water cycle is a closed cycle can be found in the works of Anaxagoras of Clazomenae (460 BC) and Diogenes of Apollonia (460 BC).

Plato and Aristotle speculated about the percolation of water through the ground as part of the water cycle

Plato (390 BC) and Aristotle (350 BC)



Leonardo Da Vinci (1500)

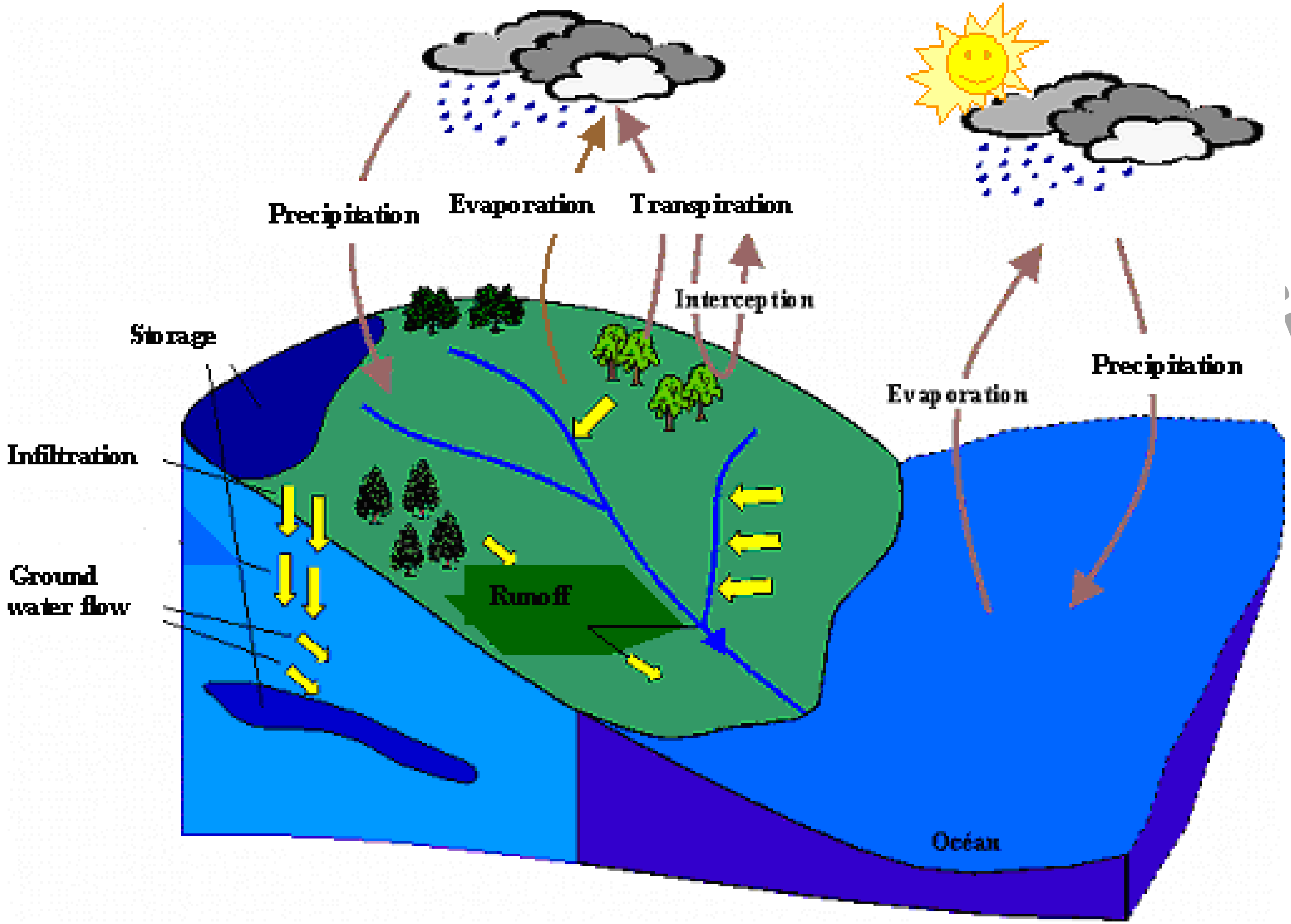
Up to the time of the Renaissance (14th to the 17th century), it was thought that precipitation alone was not sufficient to feed rivers, for a complete water cycle, It was believed that underground water pushing upwards from the oceans were the main contributors to river water. Bartholomew of England held this view (1240 AC), as did Leonardo da Vinci (1500 AC) and Athanasius Kircher (1644 AC).

Bernard Palissy (1580) first told that rainfall alone is sufficient for the maintenance of rivers

Hydrology in ancient India

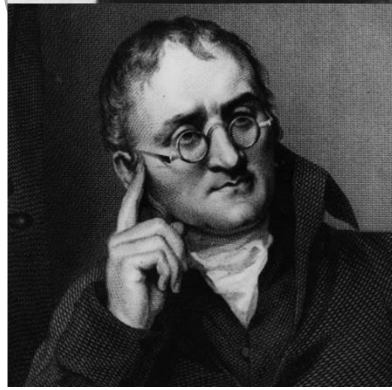
- Natural entities and forces, such as Sun, Earth, Rivers, Ocean, Wind, Water, etc. have been worshipped in India as Gods since time immemorial. Perhaps it is not a sheer coincidence that the King of these Gods is Indra, the God of Rain.
- This shows that the ancient Indians were aware of the importance of rain and other hydrologic variables for the society.
- The ancient Indian literature contains numerous references to hydrology and a reading of it suggests that those people knew the basic concepts of hydrological processes and measurements.
- Important concepts of modern hydrology are scattered in various verses of Vedas, Puranas, Meghmala, Mahabharat, Mayurchitraka, Vrhat Sanhita and other ancient Indian works.

Hydrologic Cycle

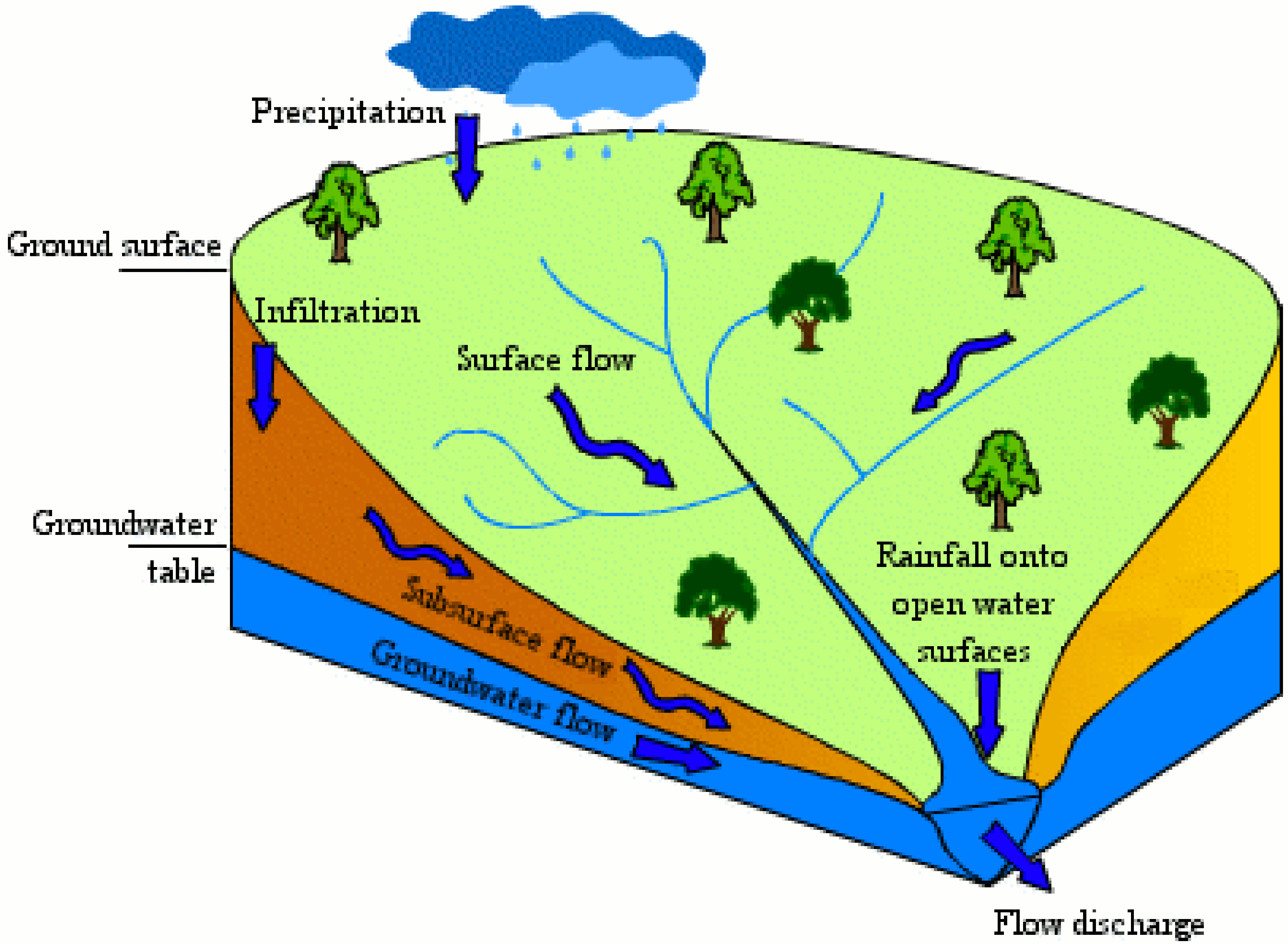


Henry Darcy

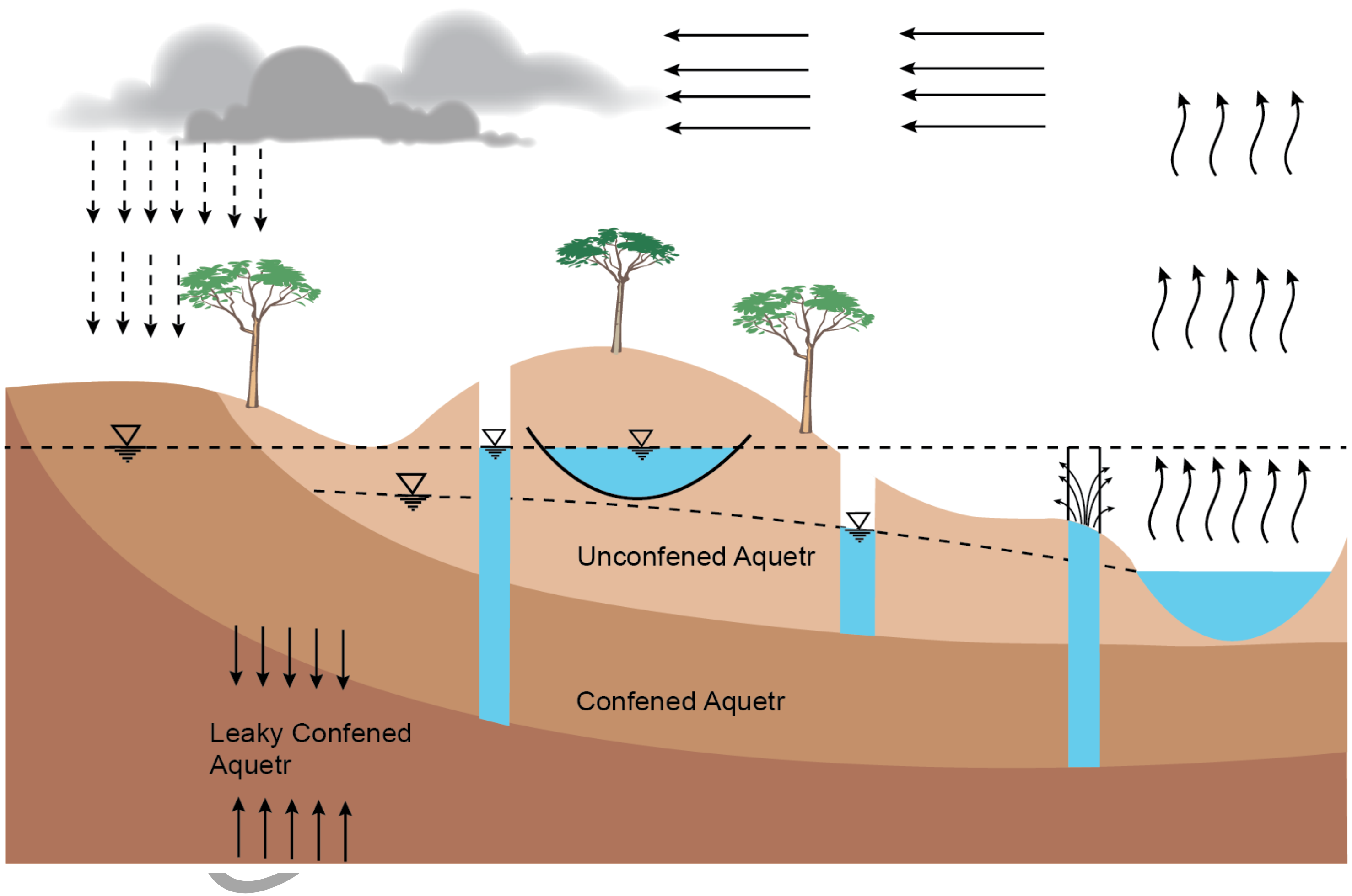
Dalton

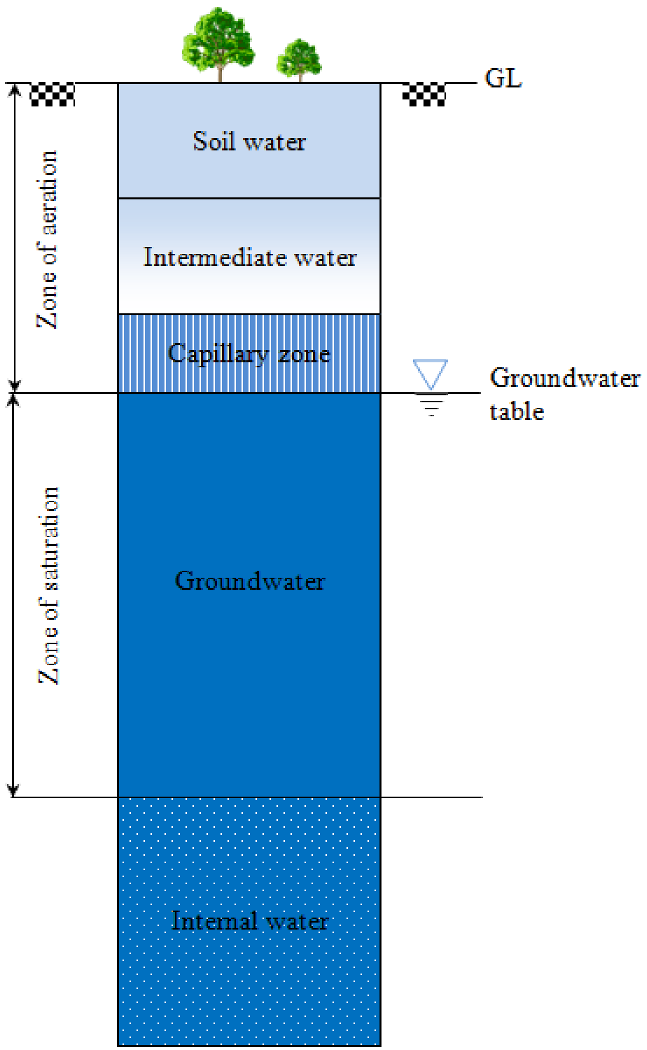


Horton

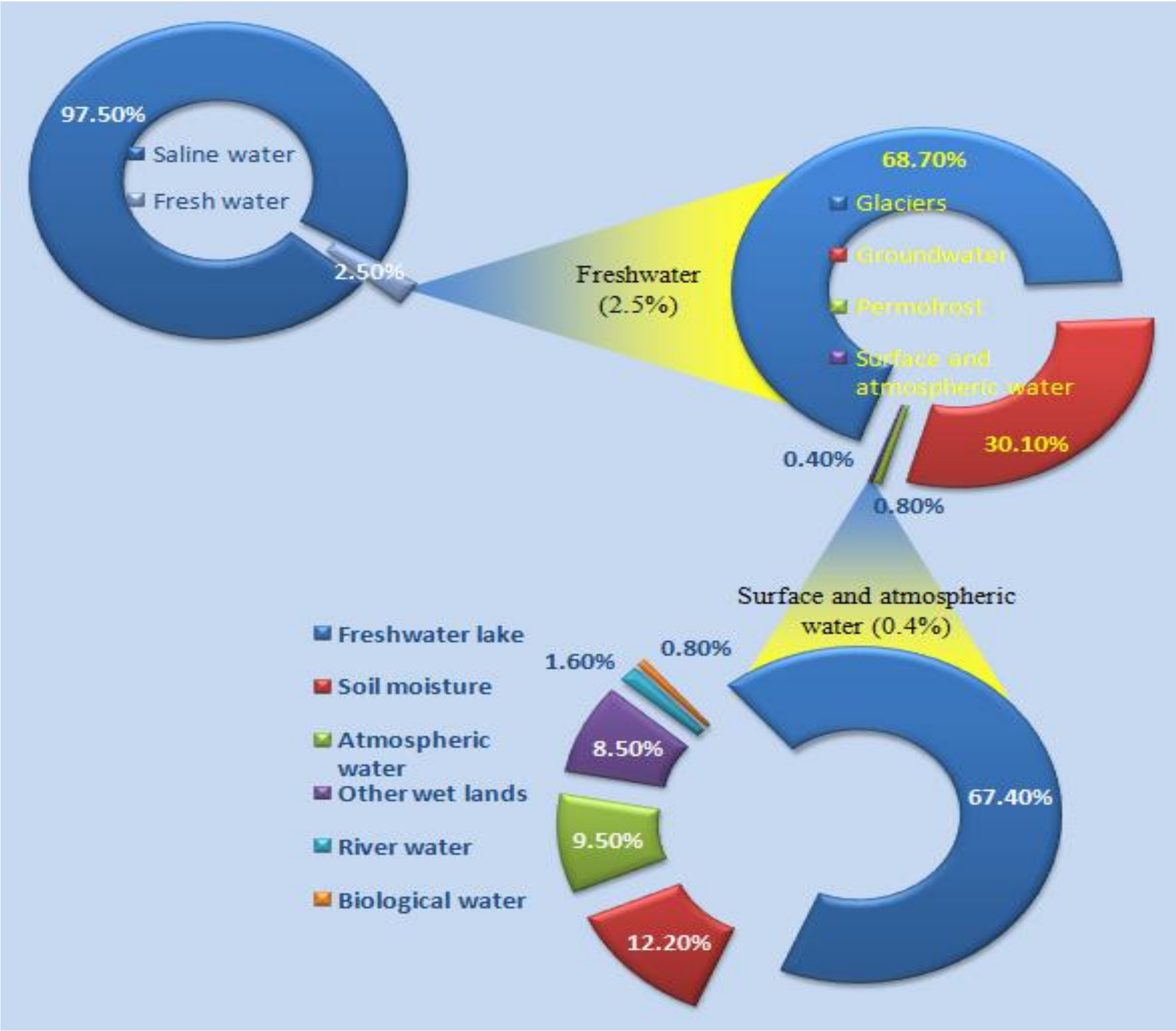


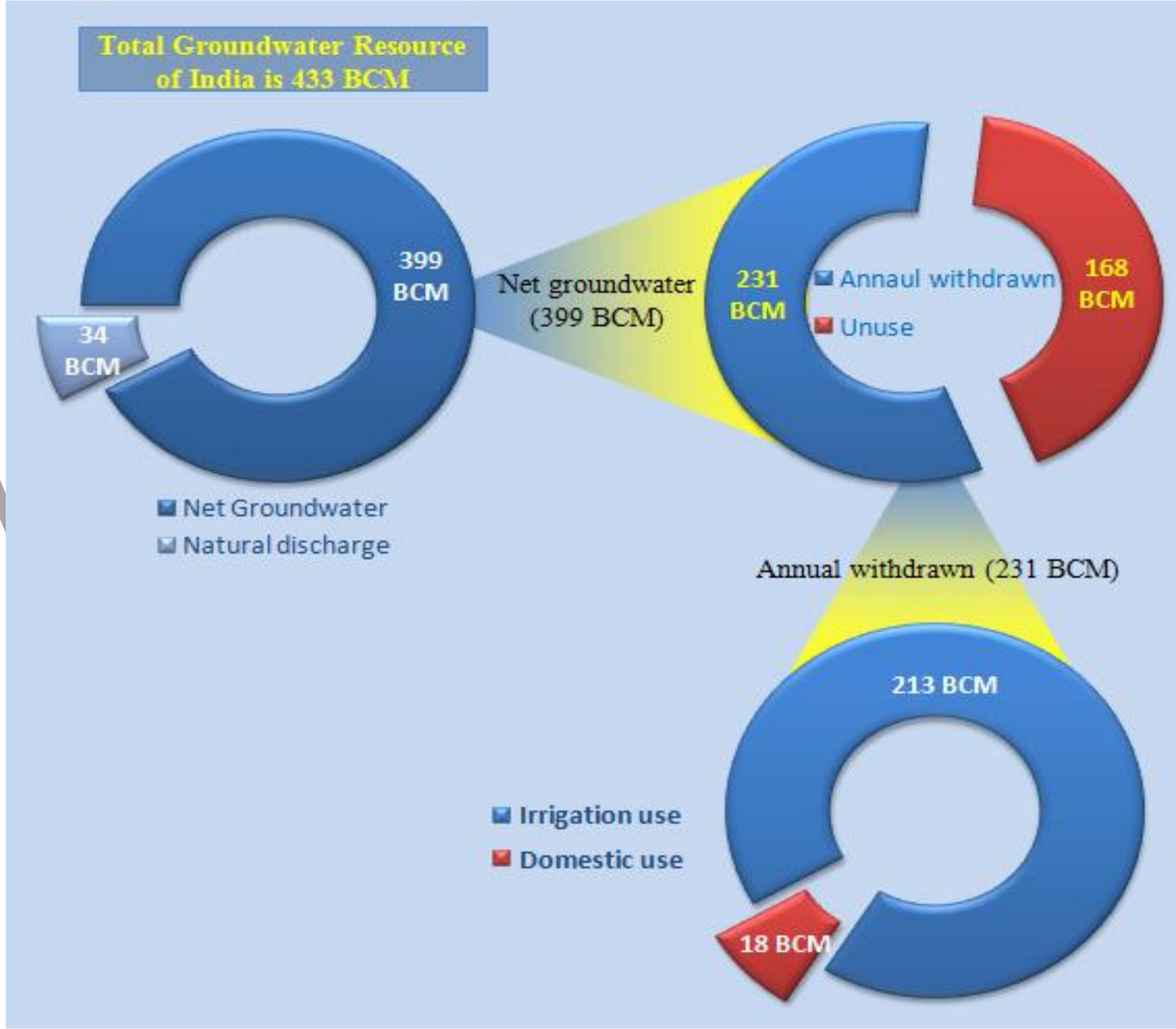
Precipitation
Ground surface
Infiltration
Surface flow
Groundwater table
Subsurface flow
Groundwater flow
Rainfall onto open water surfaces
Flow discharge


Unconfened Aquetr
Confened Aquetr
Leaky Confened
Aquetr

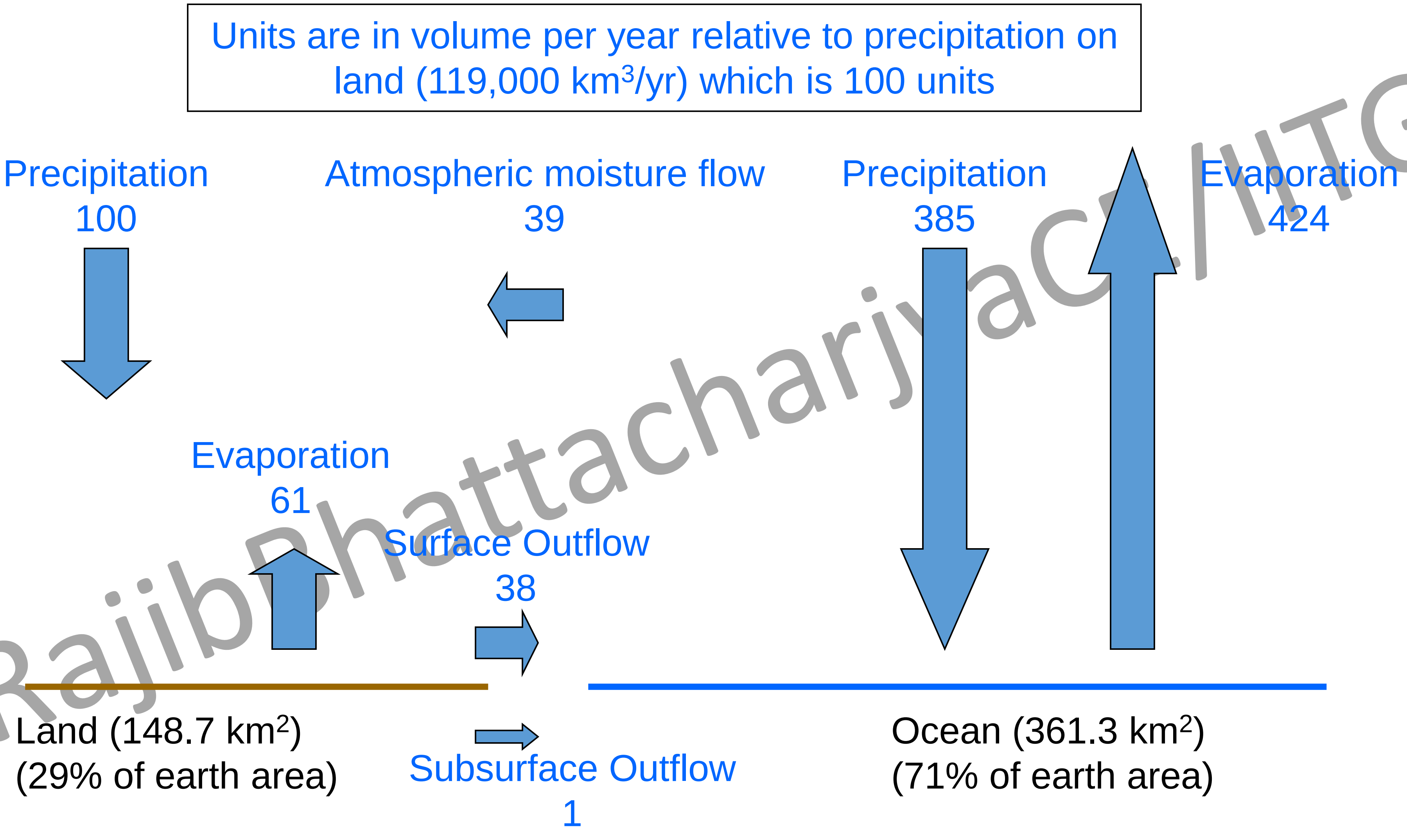

GL
Soil water
Intermediate water
Capillary zone
Groundwater
table
Groundwater
Internal water
Zone of aeration
Zone of saturation

Global distribution of water

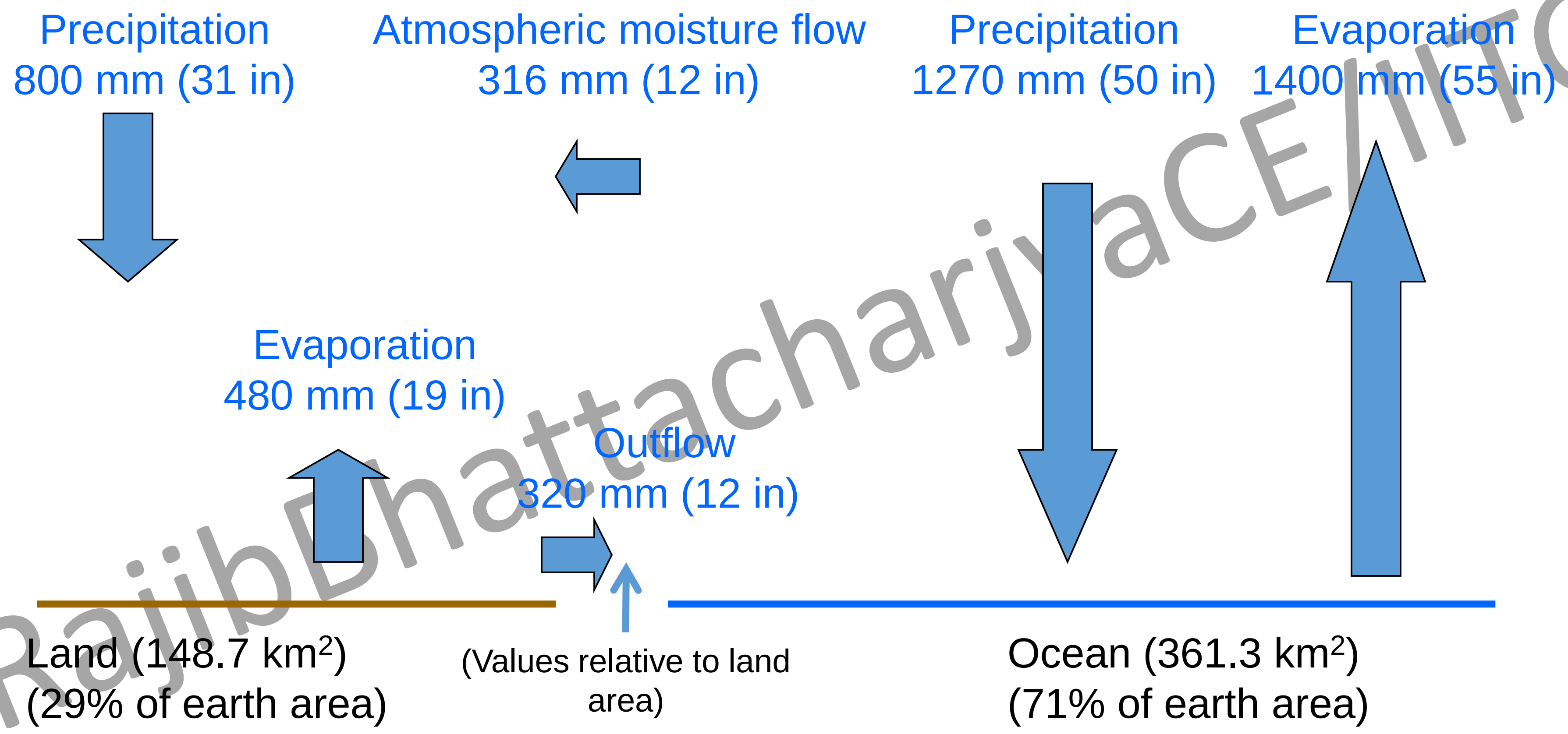




Global water balance (volumetric)



Global water balance



Applied Hydrology, Table 1.1.2, p.5

Residence Time

Residence time:

Average travel time for water to pass through a subsystem of the hydrologic cycle

$$T_r = \frac{S}{Q}$$ (Storage/flow rate)

Residence time of global atmospheric moisture

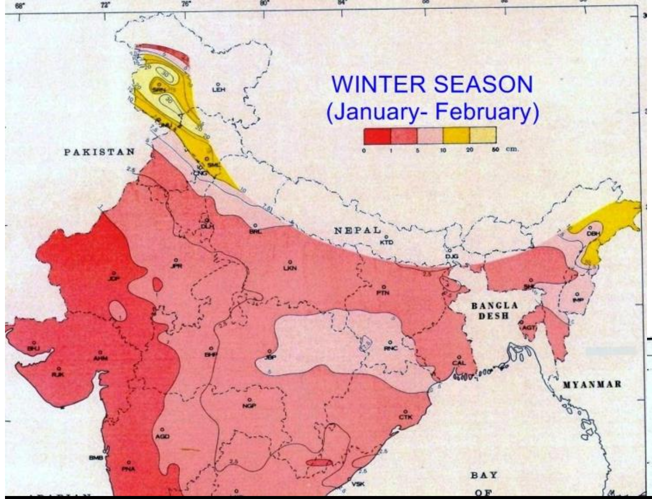
Volume (storage) of atmospheric water: 12,900 km^3

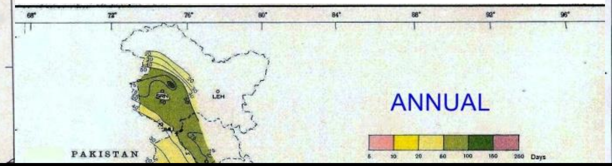
Flow rate of moisture from the atmosphere as precipitation = 577,000 km^3/yr

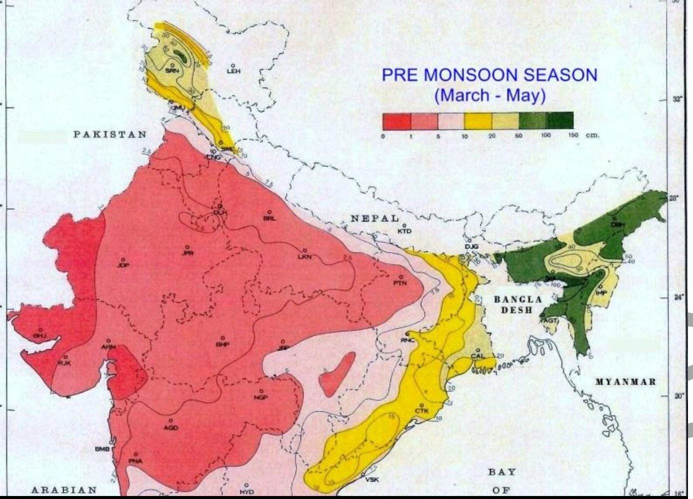
T_r= 12,900/577,000 = 0.022 yr = **8.2 days**

One reason why weather cannot be forecast accurately more than a few days ahead

Challenges before the country

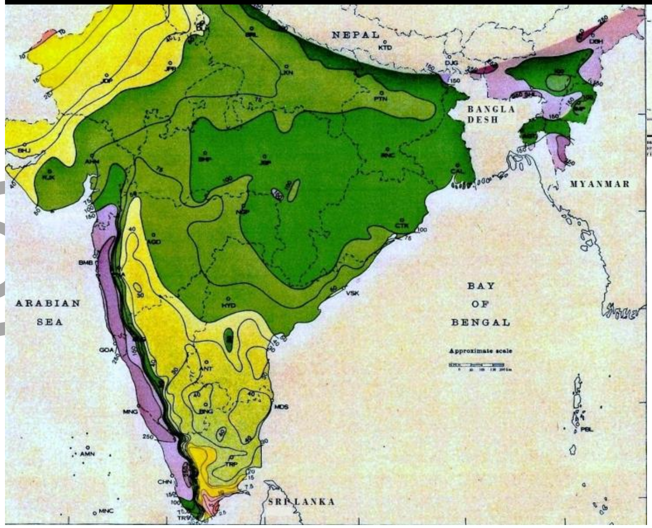


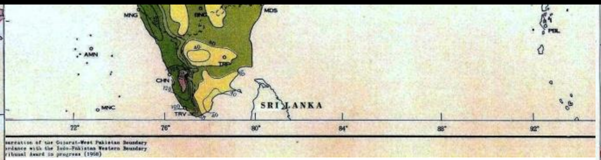


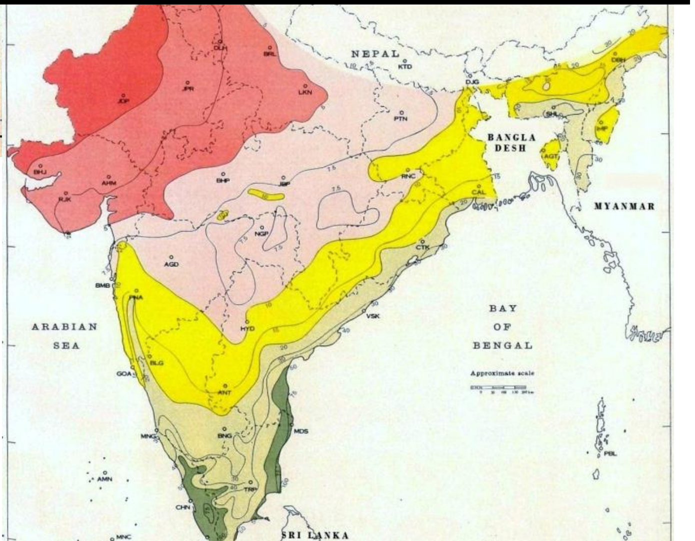


Thar desert: Average annual rainfall is less than 13 cm, while at Cherrapunji in the North-East it is as high as 1080 cm.

North-East India is getting about 180 days rainfall in a year, on the other hand, the number of rainy days in Rajasthan is around 20 days

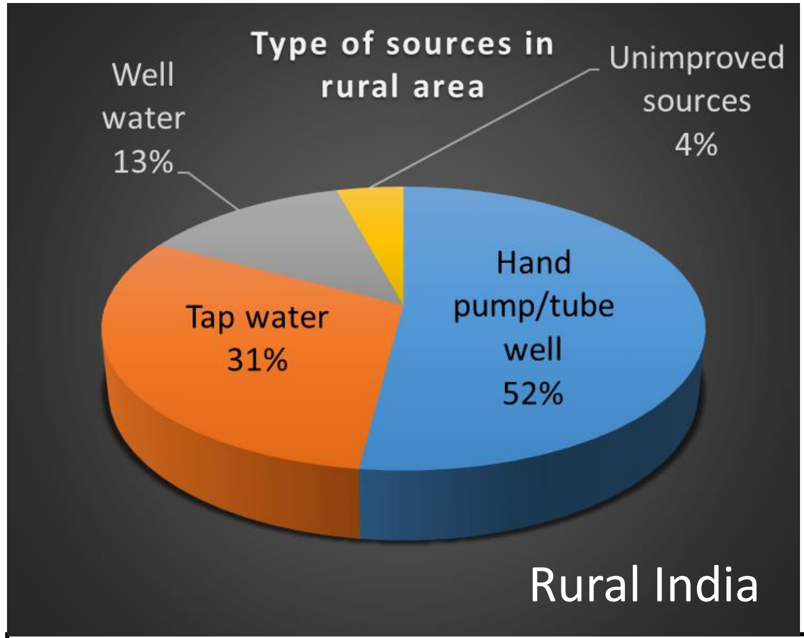




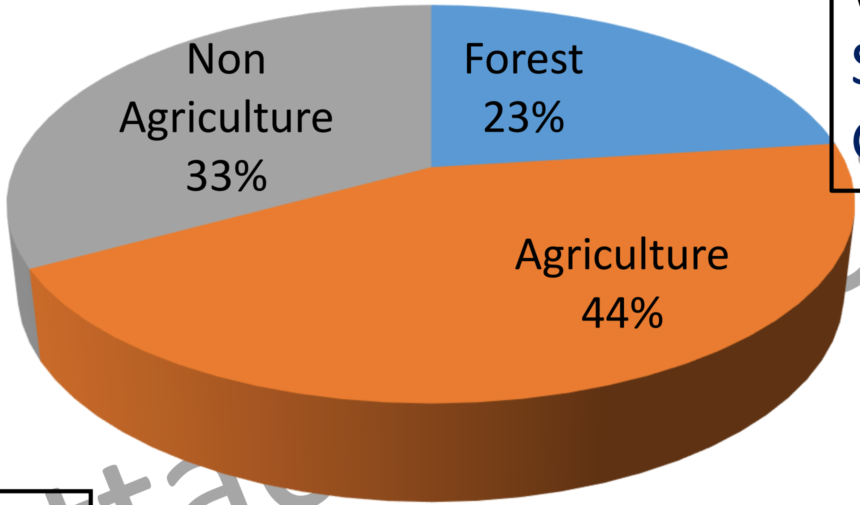


Source: IMD, India

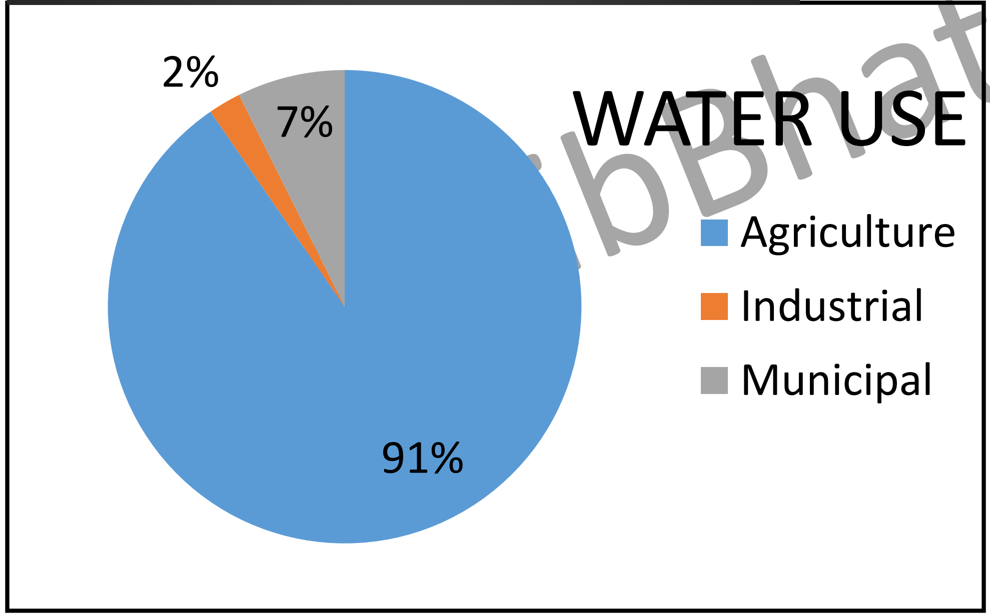
Challenges before the country

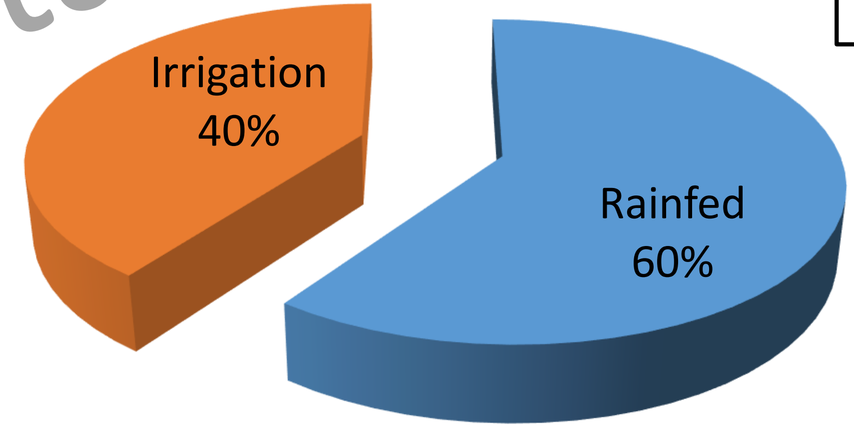


AREA DISTRIBUTION



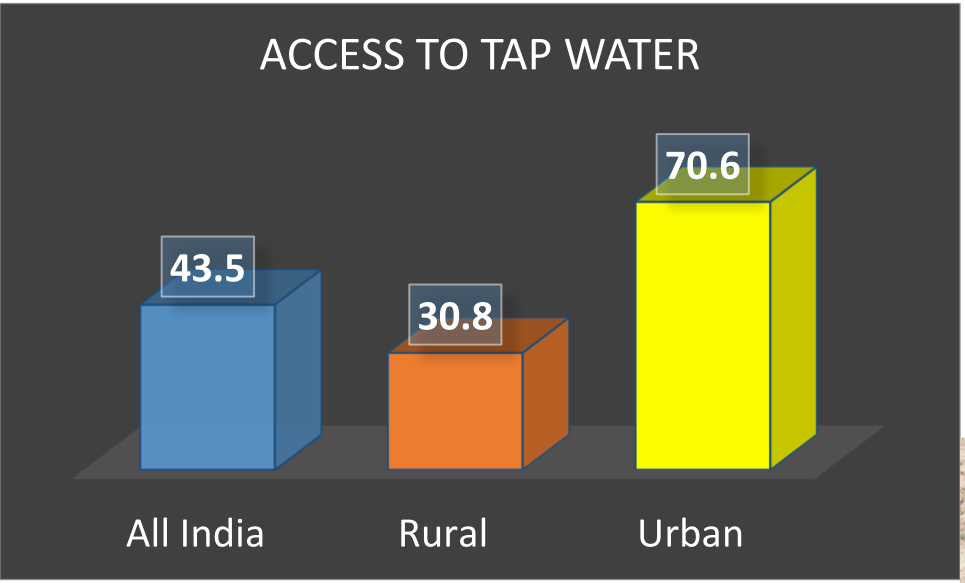
Amount of renewable water resources
Surface Water: 1869 BCM
Groundwater: 396 BCM

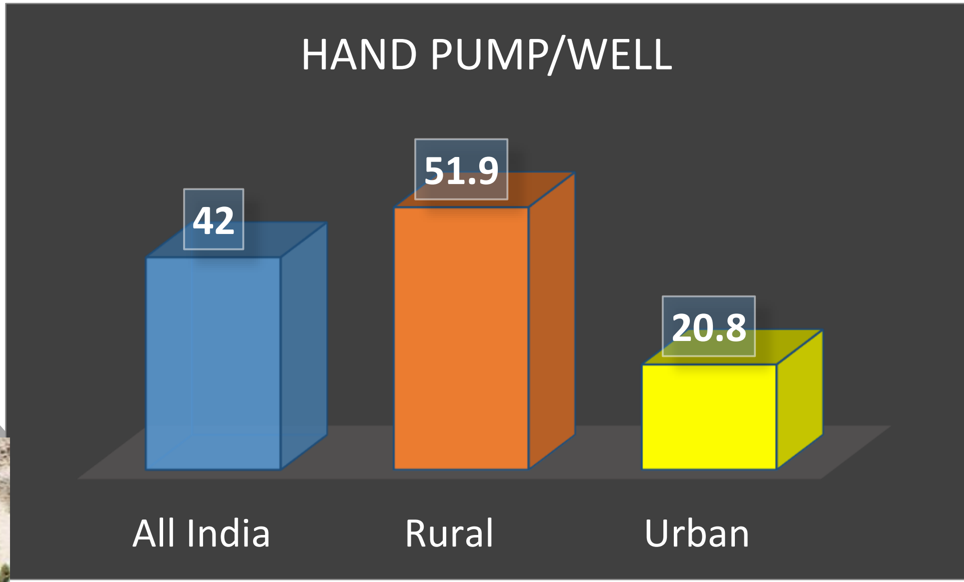


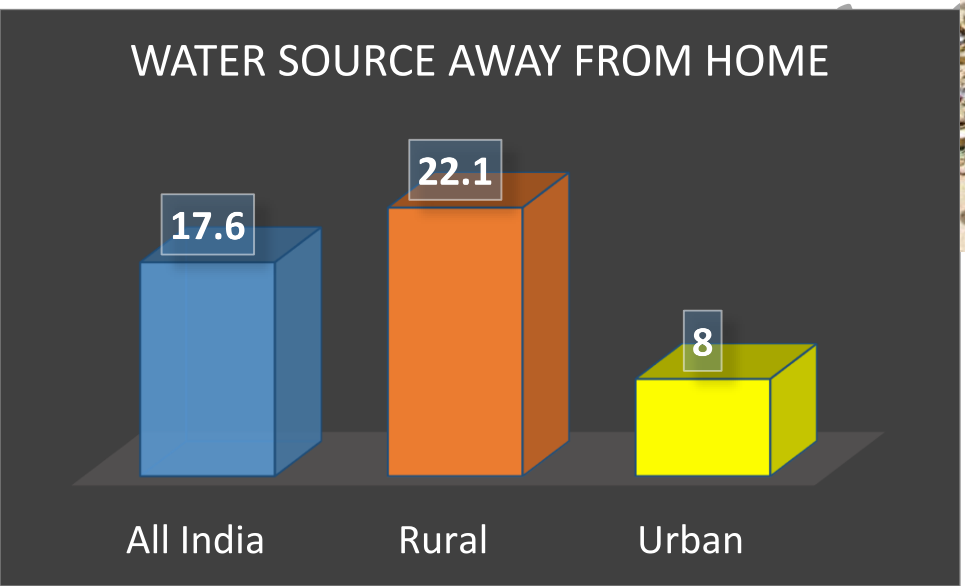


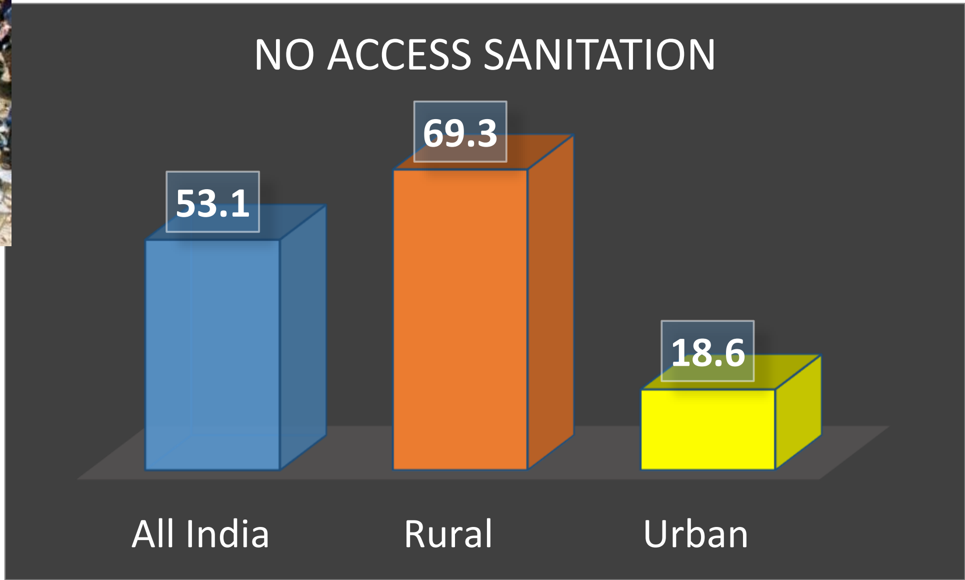
Pressure on water
1582 m^3/yr/capita

Challenges before the country

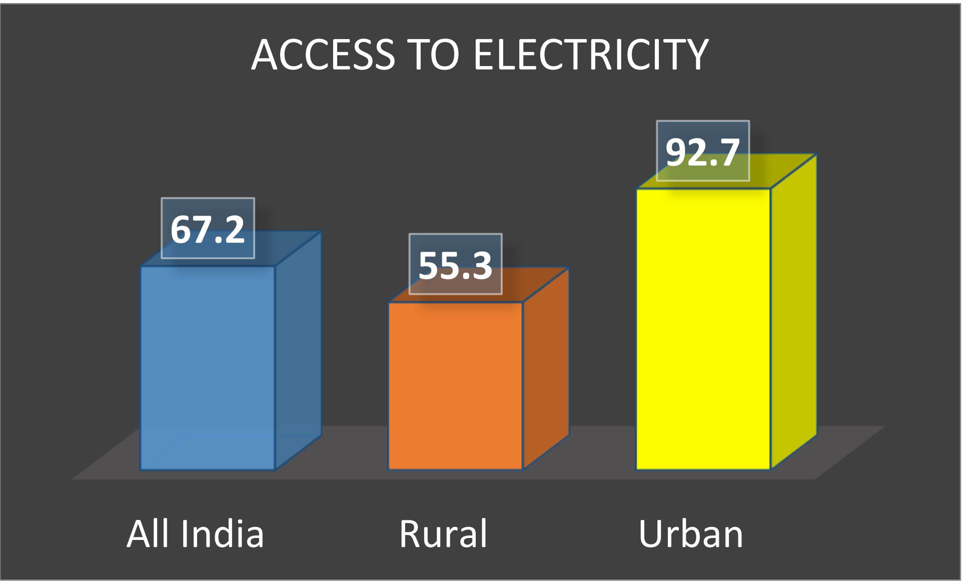


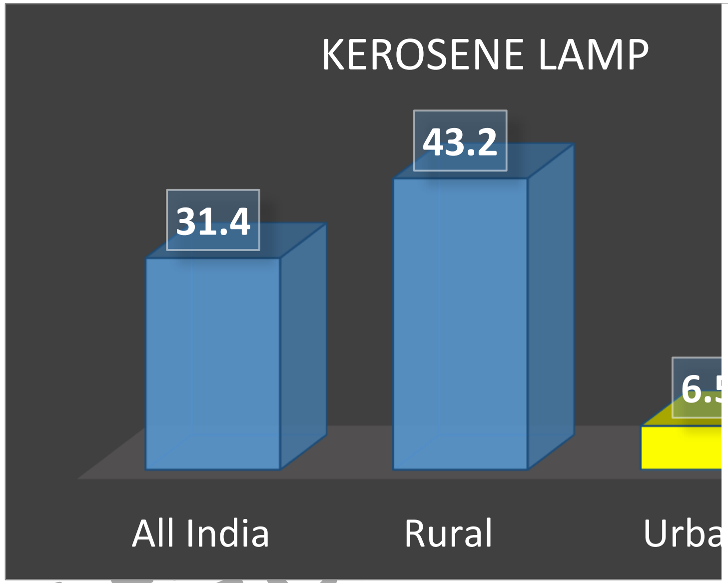


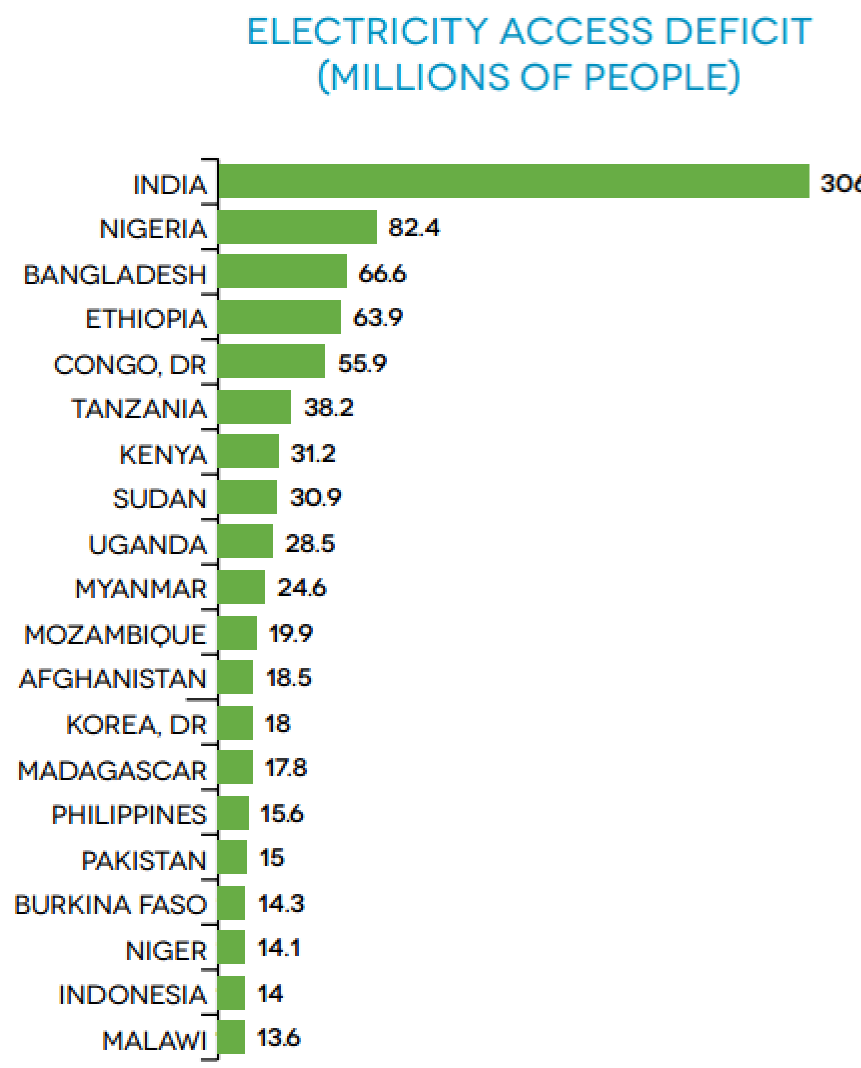


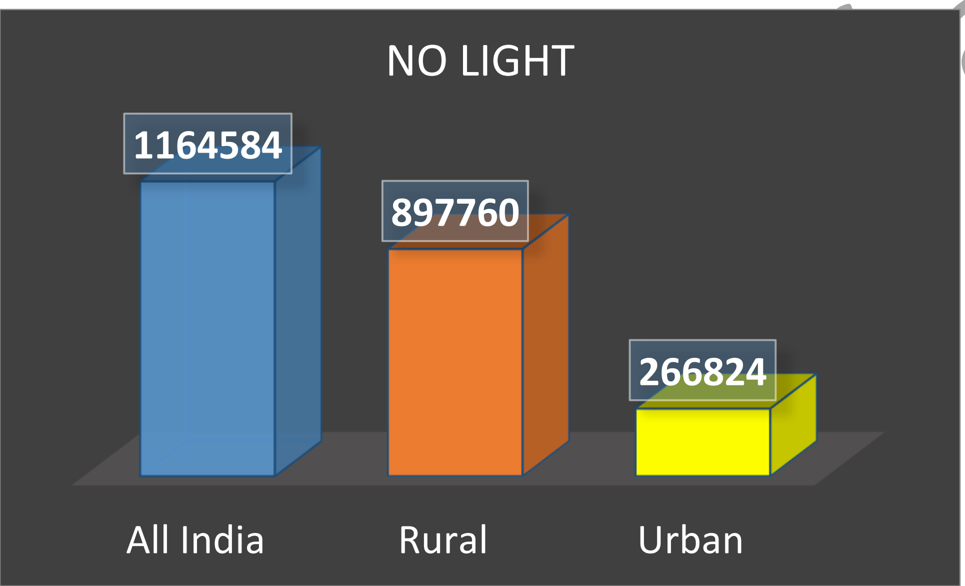


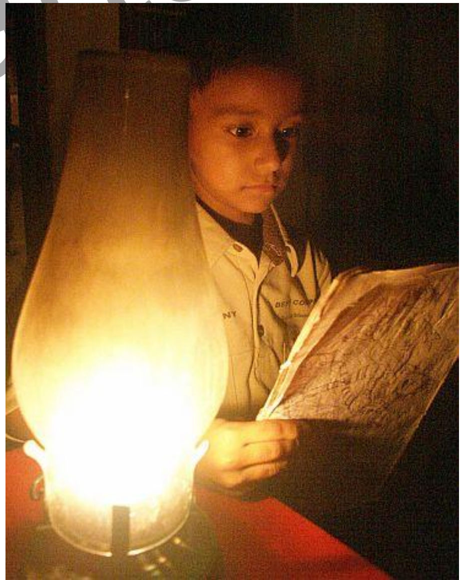
Challenges before the country



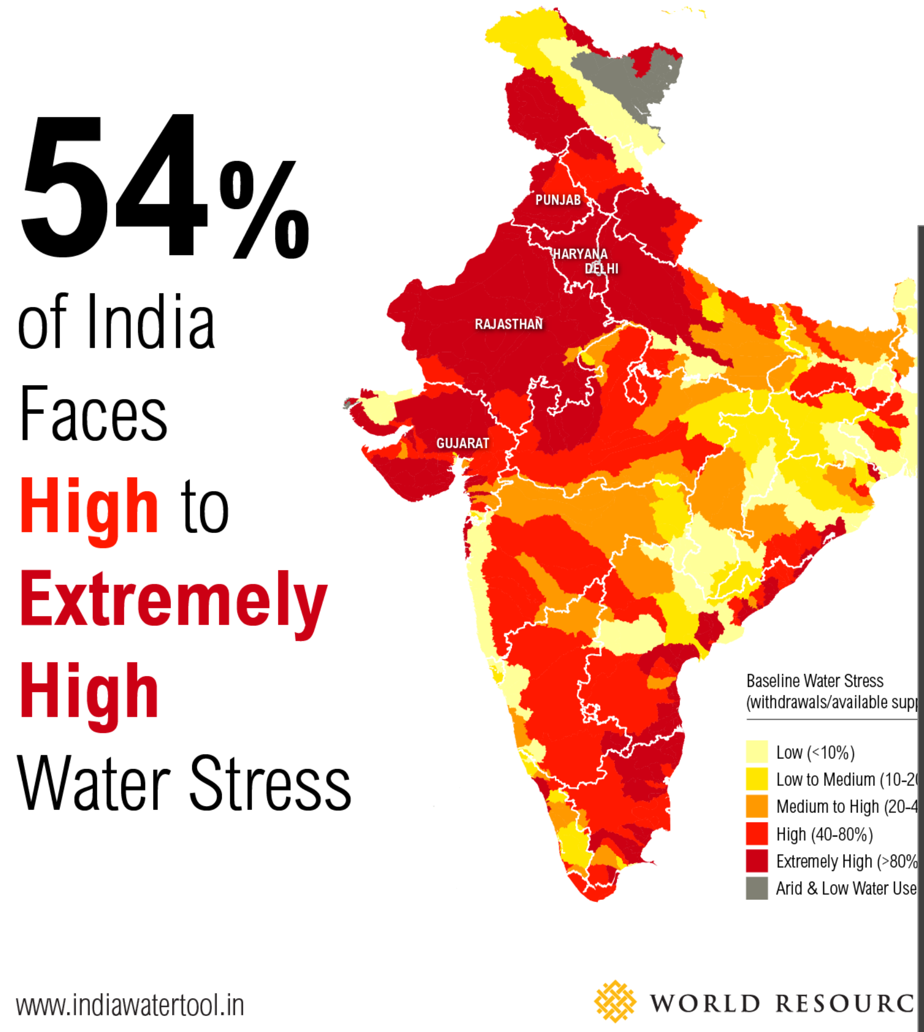


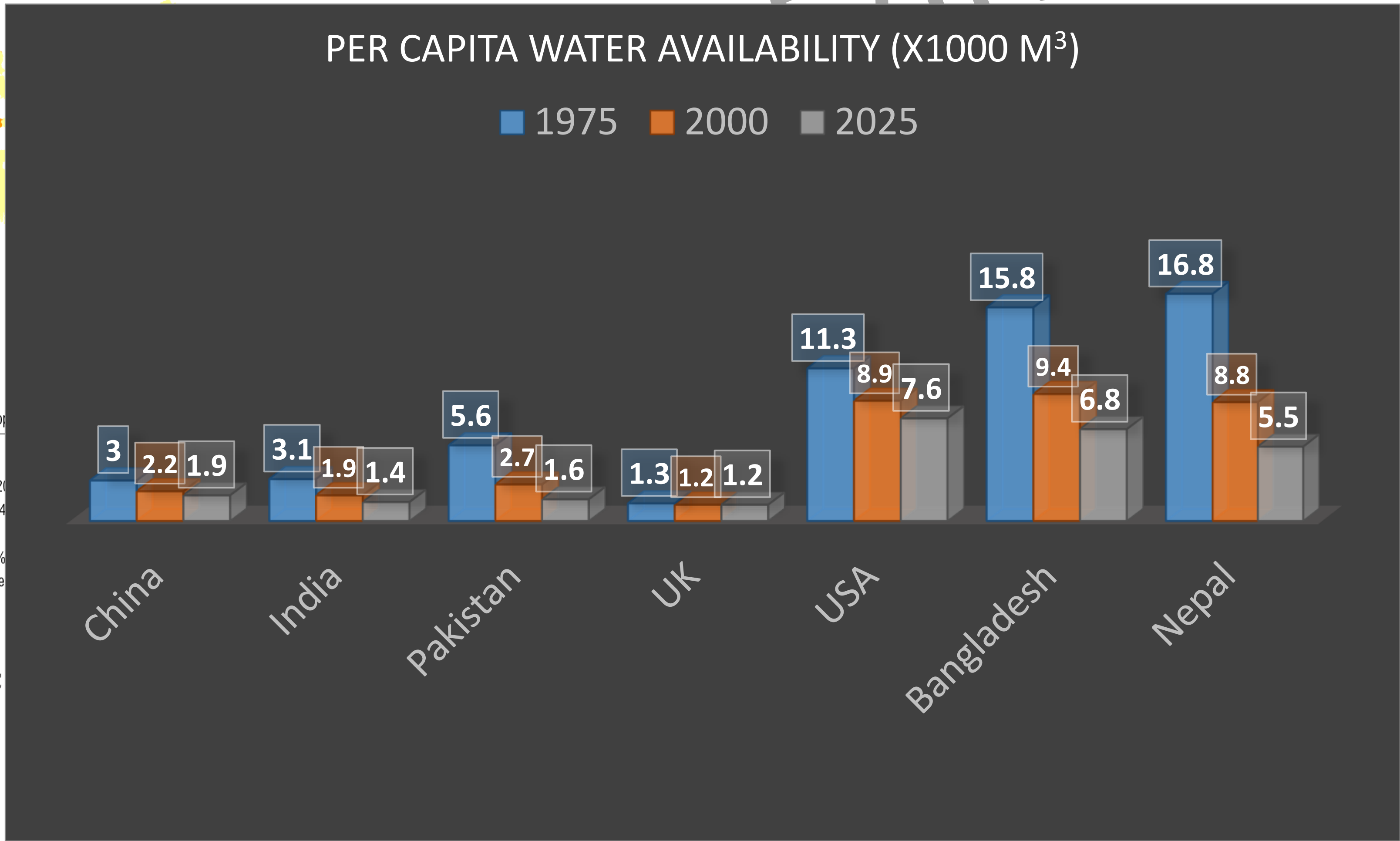




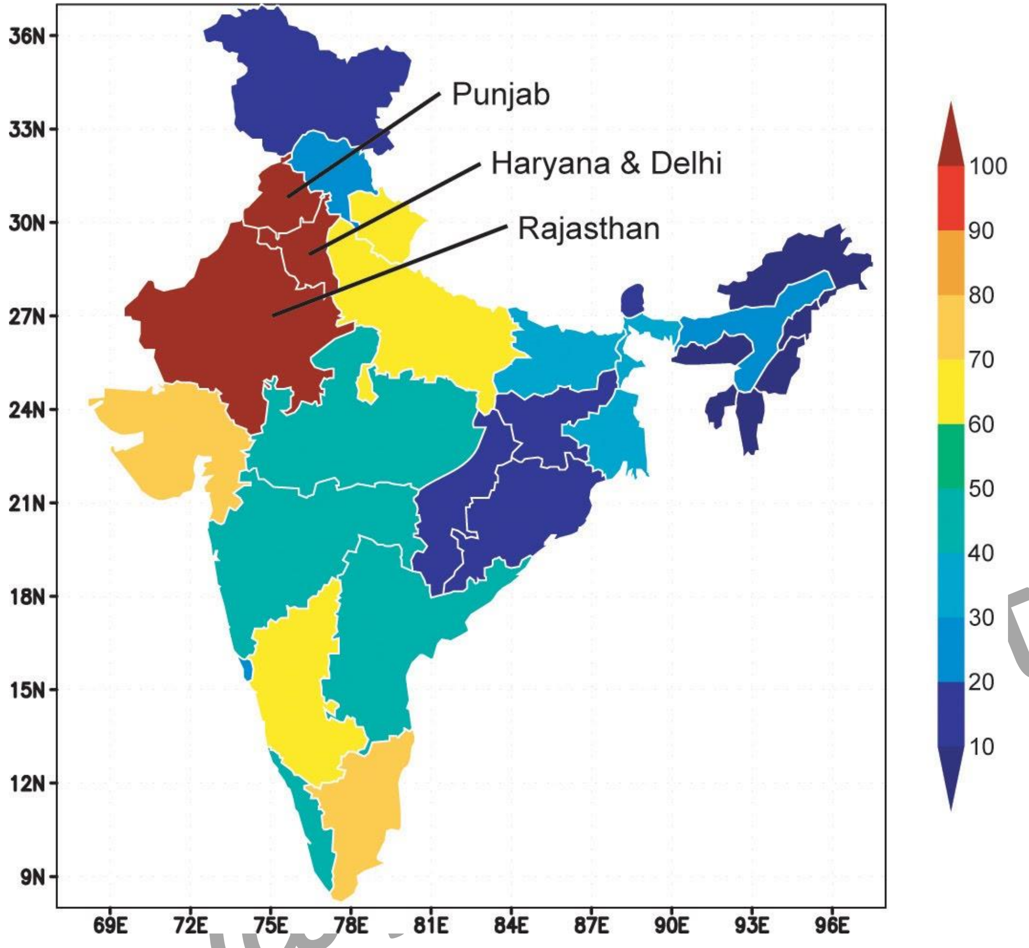


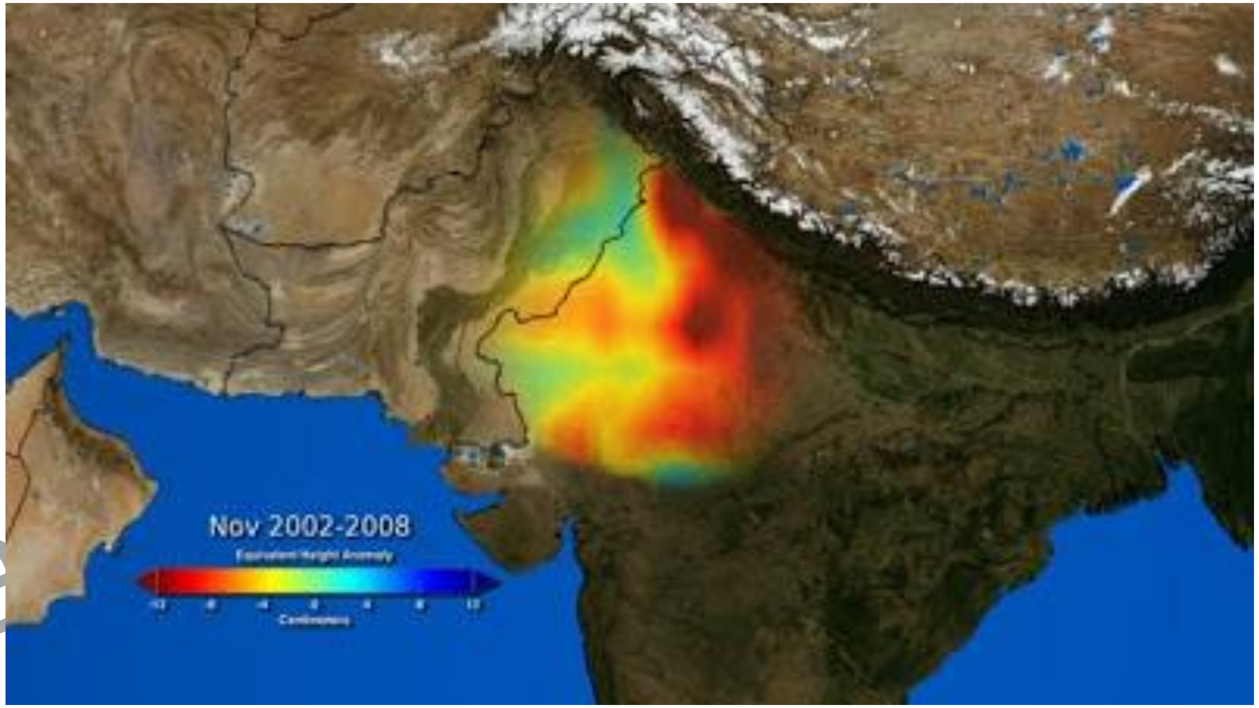
Challenges before the country





Challenges before the country



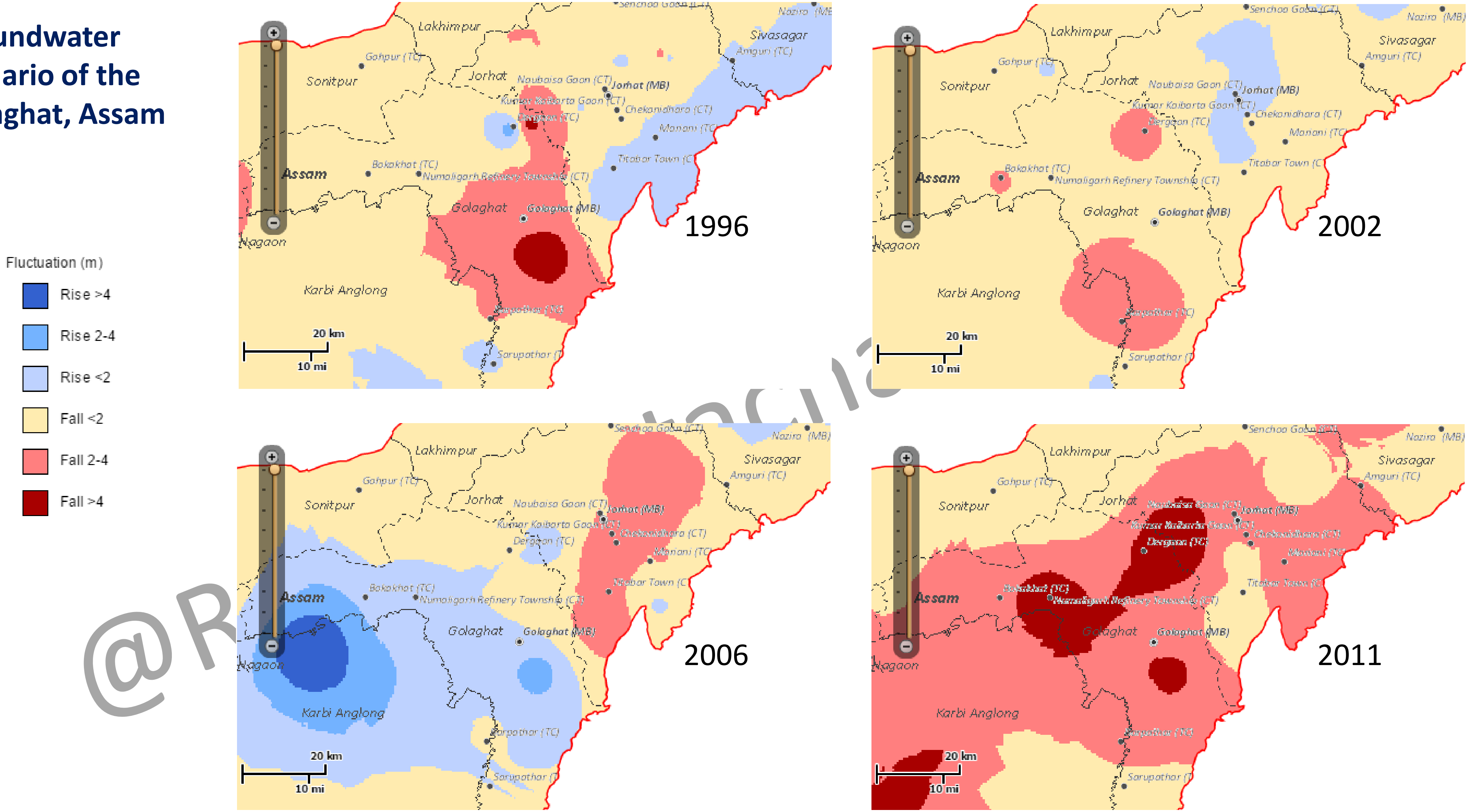


- ✓ *A study shows that the estimated rate of depletion of water table in northwestern India is 33 centimeters per year*

- ✓ More than 26 cubic miles of groundwater disappeared from aquifers in areas of Haryana, Punjab, Rajasthan and the nation's capitol territory of Delhi, between 2002 and 2008.
- ✓ This is enough water to fill Lake Mead, the largest manmade reservoir in the United States, three times.

Challenges before the country

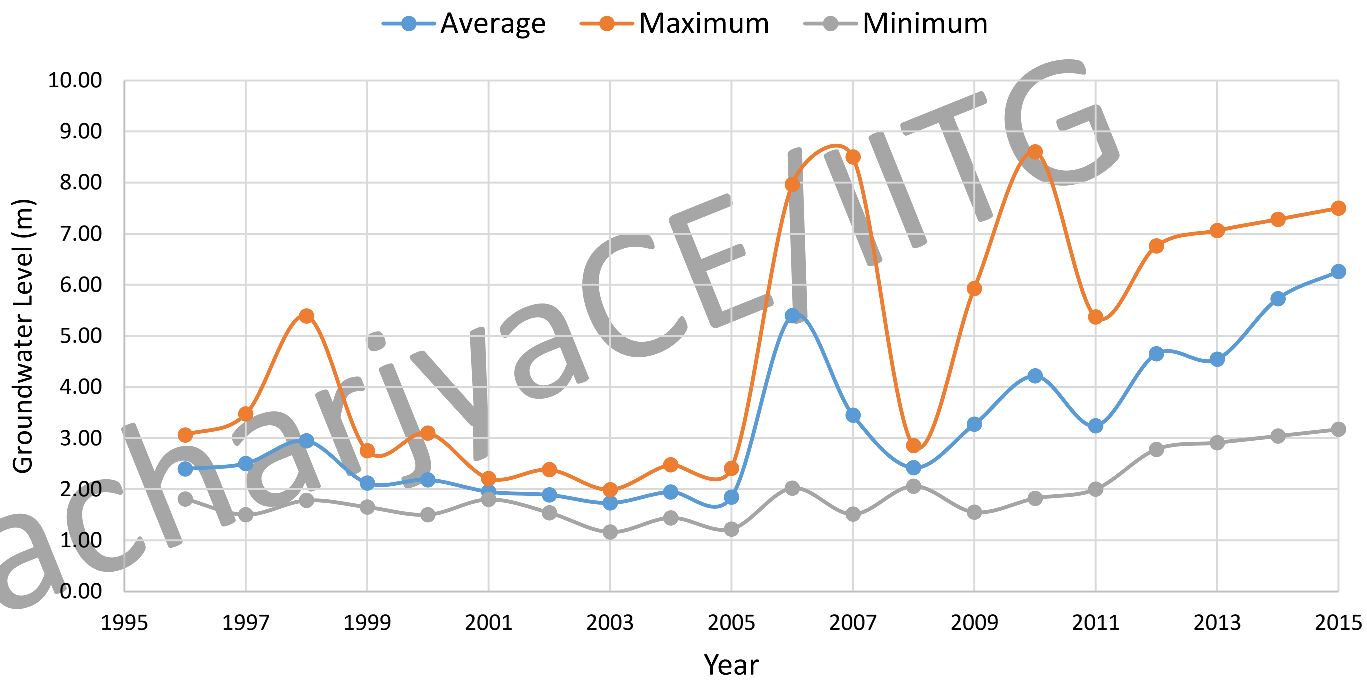
Groundwater scenario of the Golaghat, Assam



Challenges before the country

Groundwater scenario in Guwahati

- ✓ Depletion of average GL between 1996 and 2015 is 3.86 m (12.66 ft.)
- ✓ Maximum depletion of GL between 1996 and 2015 is 4.44 m (14.67 ft.)
- ✓ Minimum depletion of GL between 1996 and 2015 is 1.36 m (4.46 ft.)

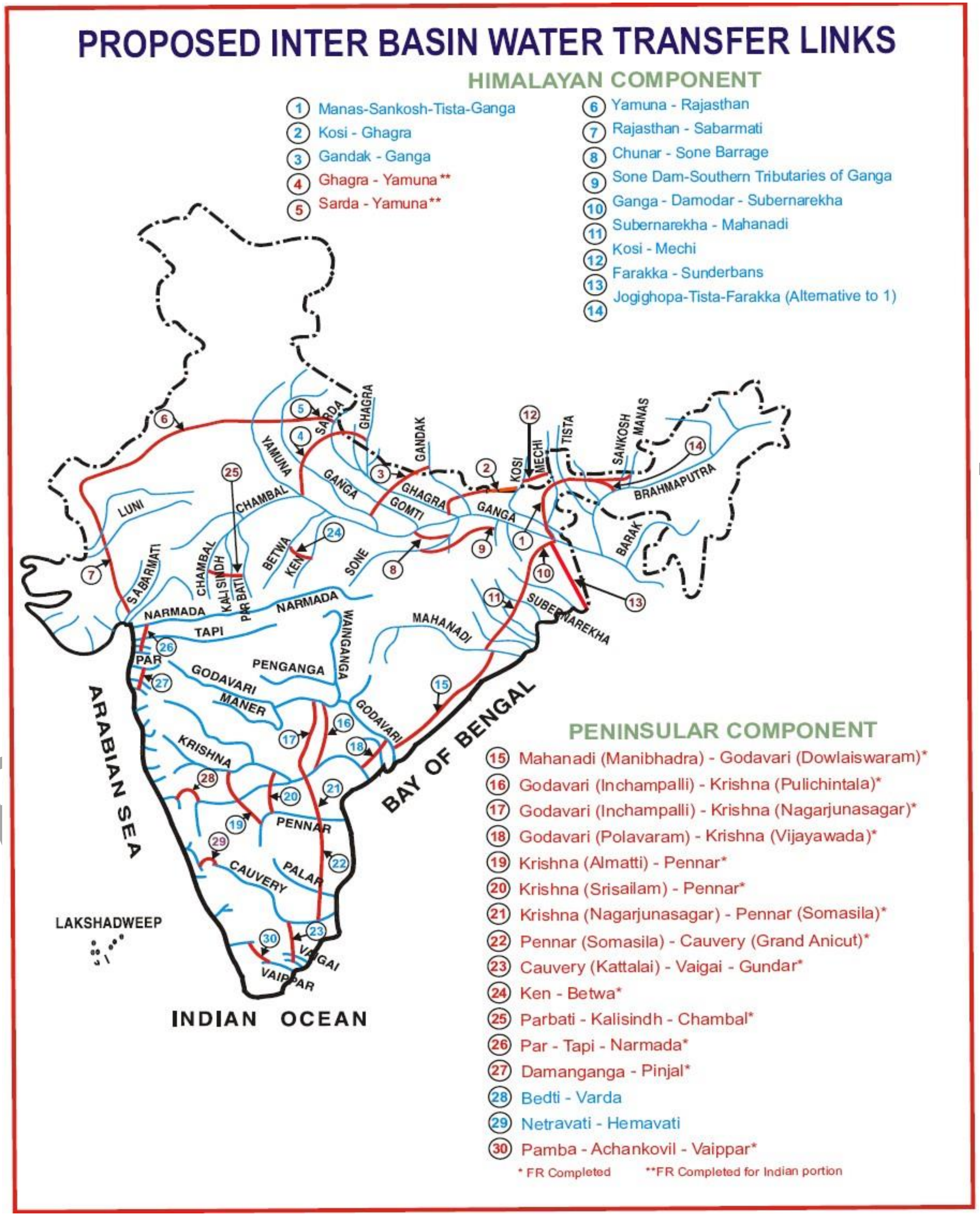


Water level at Zoo Nagangi, Guwahati

Average depletion per year is 20.31 cm

This is alarming!

River Linking Project

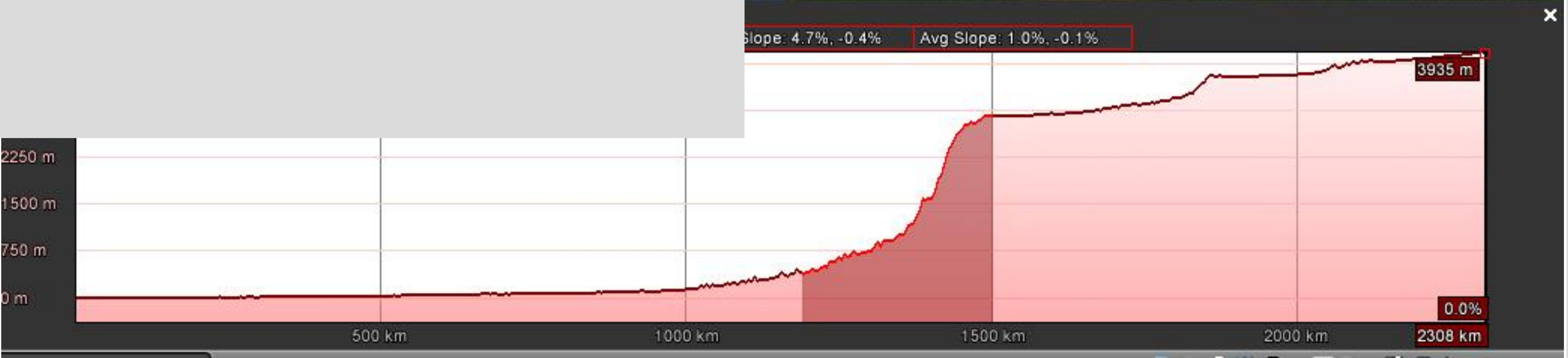


Potential hydro-power project sites

MEGA HYDRO ELECTRIC PROJECT AT GREAT BEND

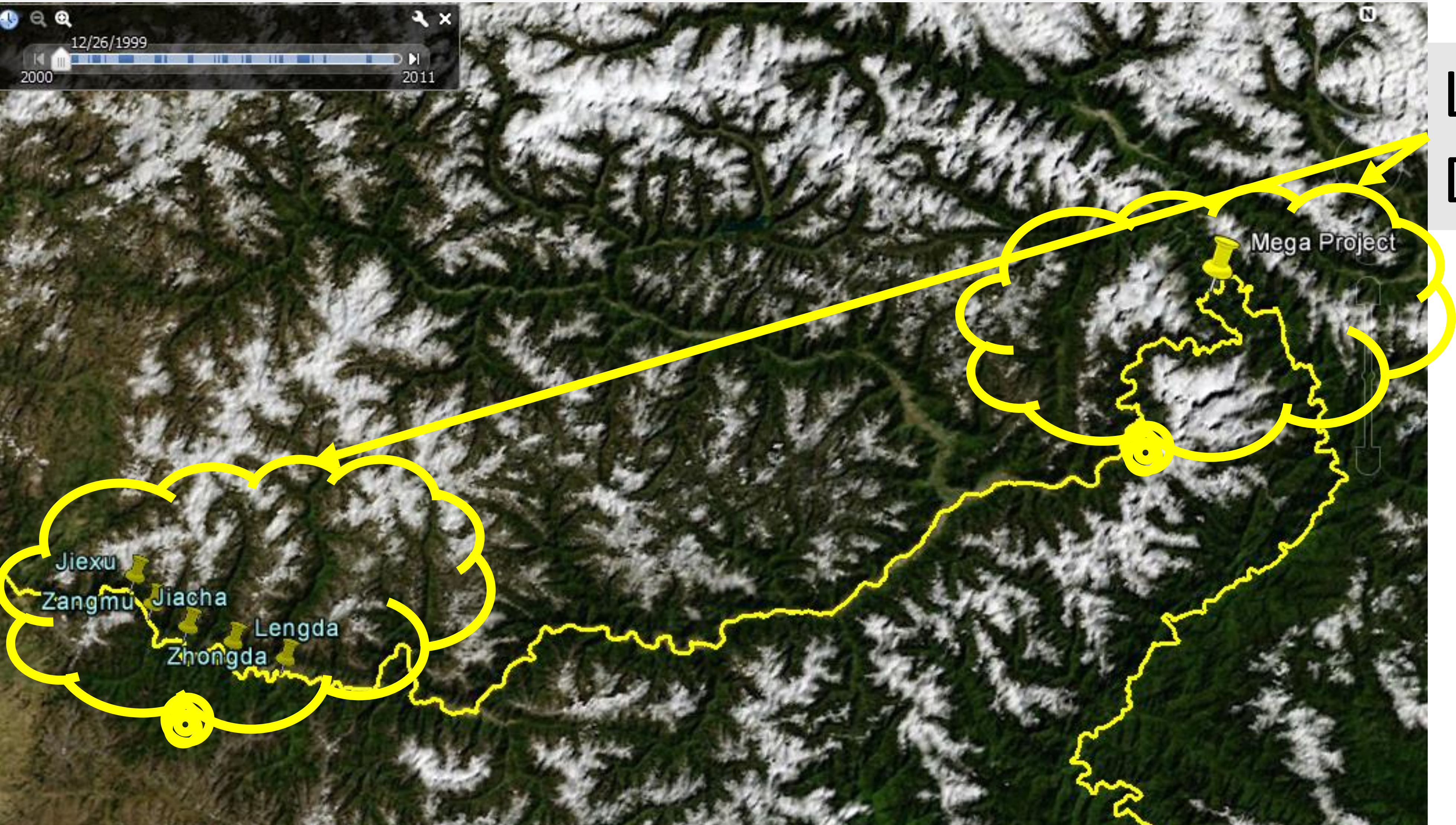
- Mega project with huge storage
- can store Water for longer period
- Installed capacity of 40,000 MW, almost double the Three gorge project

GREAT BEND



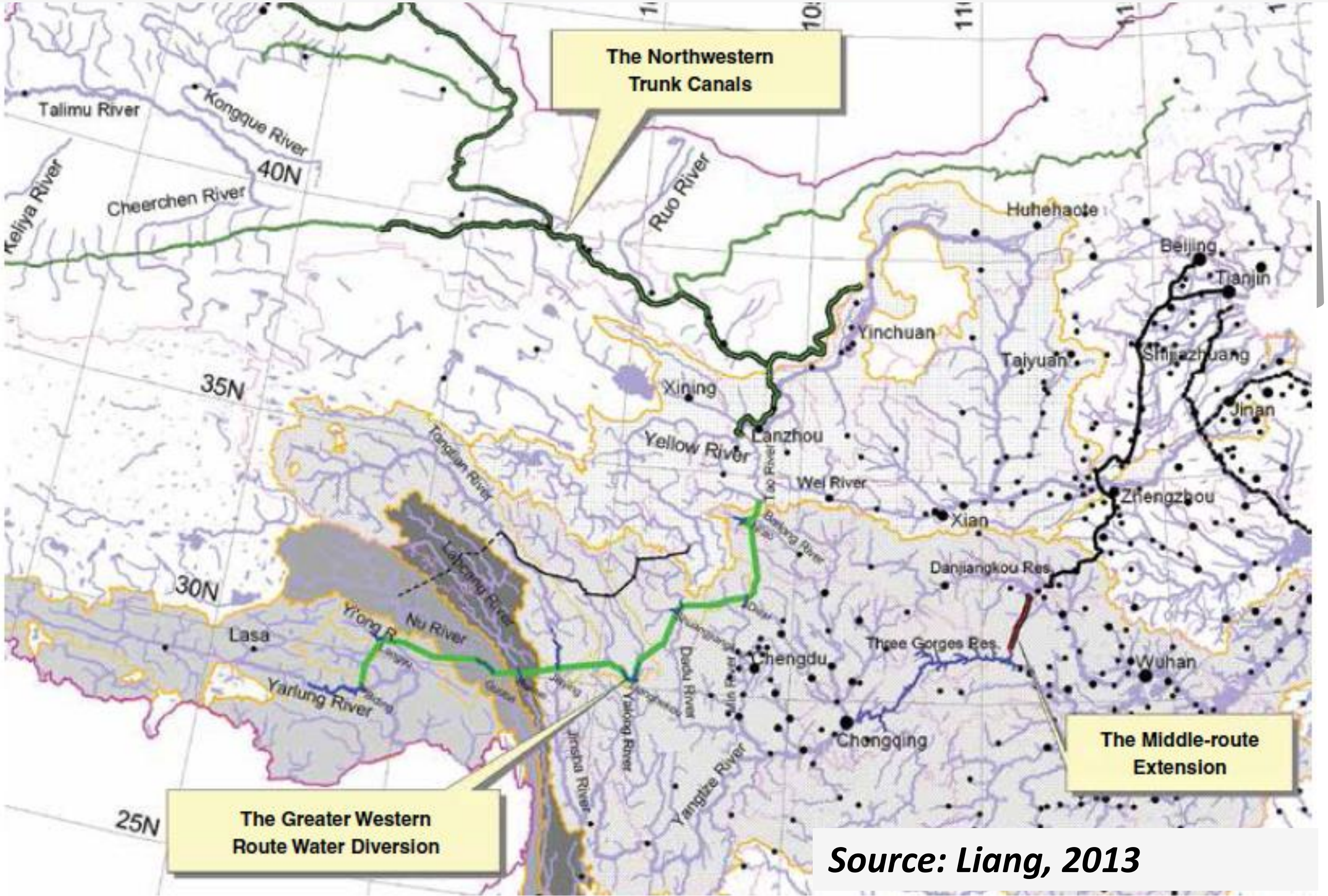
Elevation difference between two ends of the red line is around 2299 m

Dams on Yarlung Tsangpo



LOCATIONS of DAMS

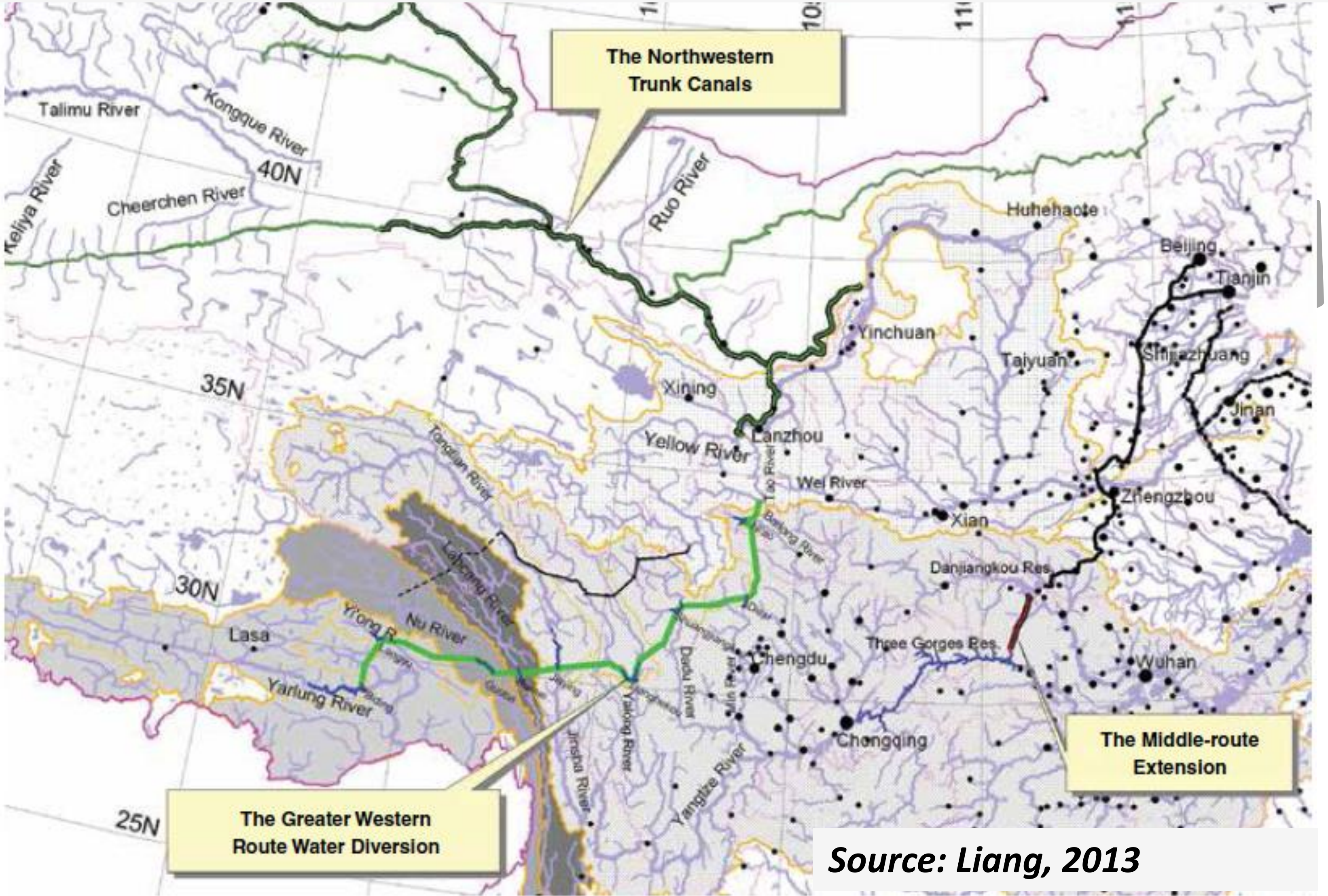
Water Diversion Project of China



Source: Liang, 2013

- Can divert 57 BCM water

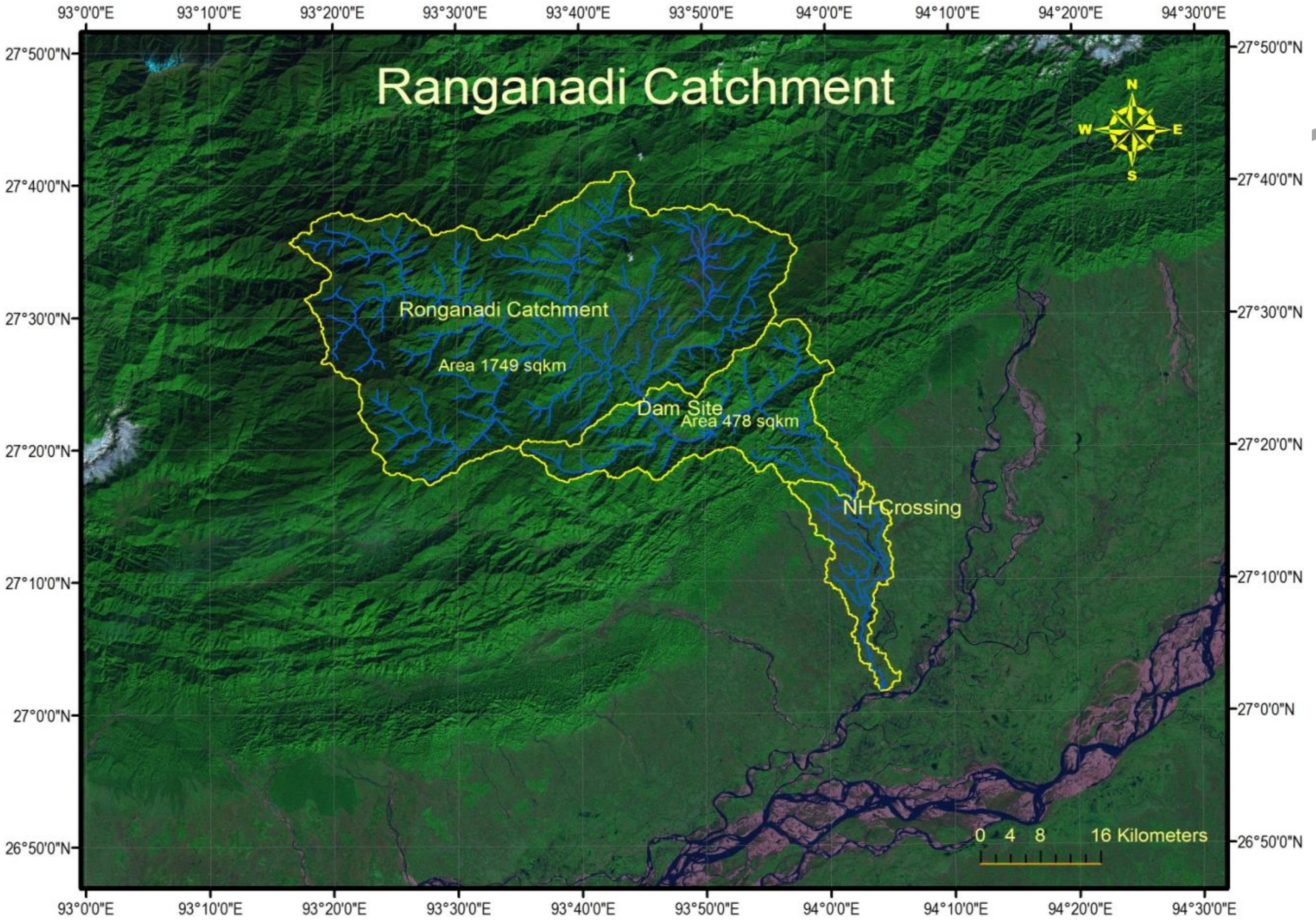
Water Diversion Project of China



Source: Liang, 2013

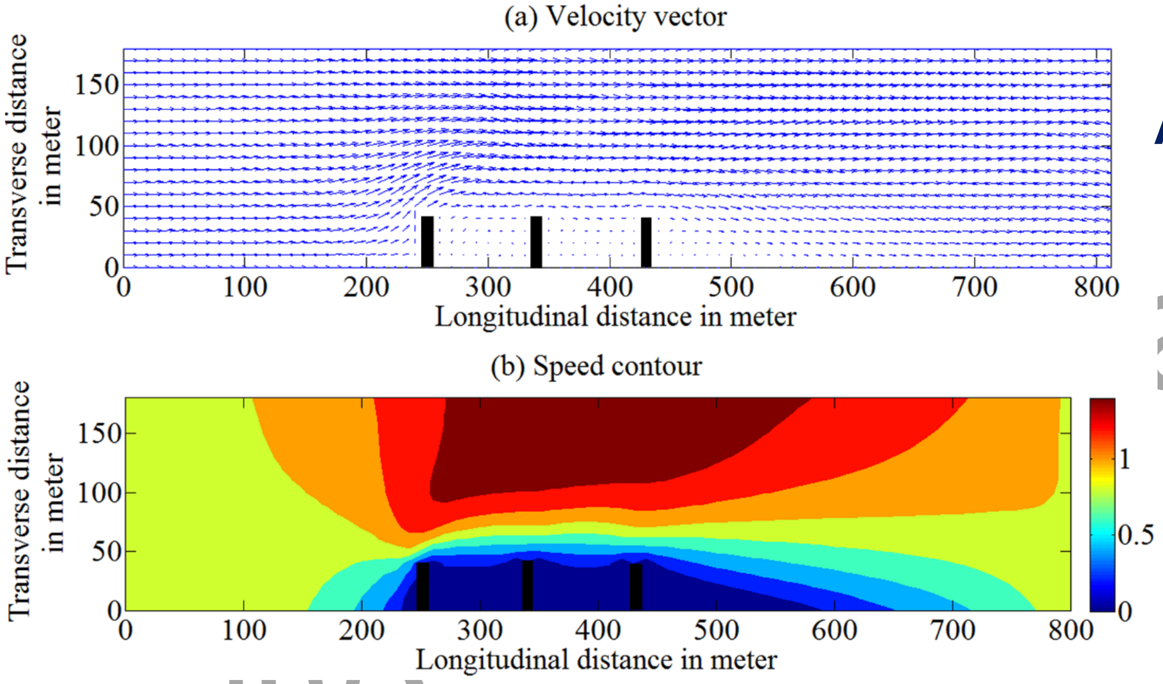
- three ways to implement the project
  - Only hydropower generation
  - Divert water during monsoon
  - Divert water throughout the year

DOWNSTREAM IMPACT ANALYSIS

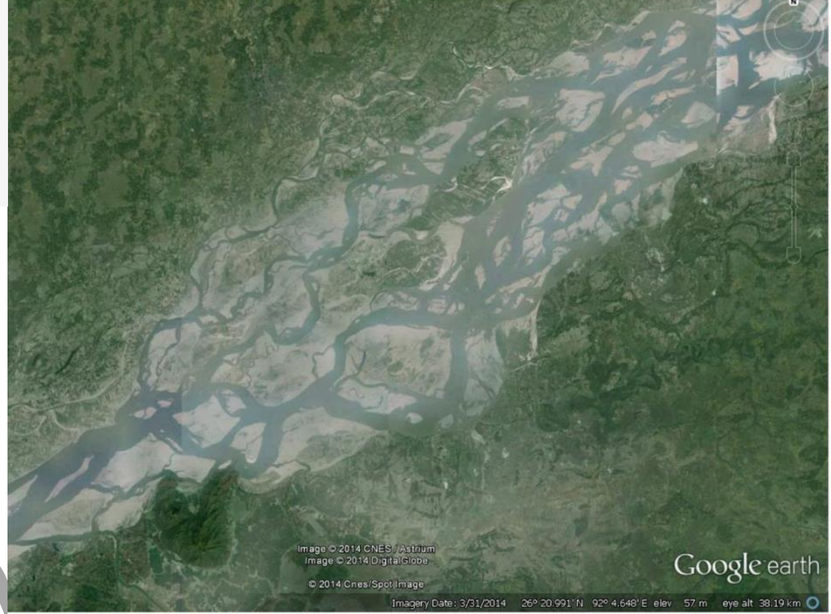


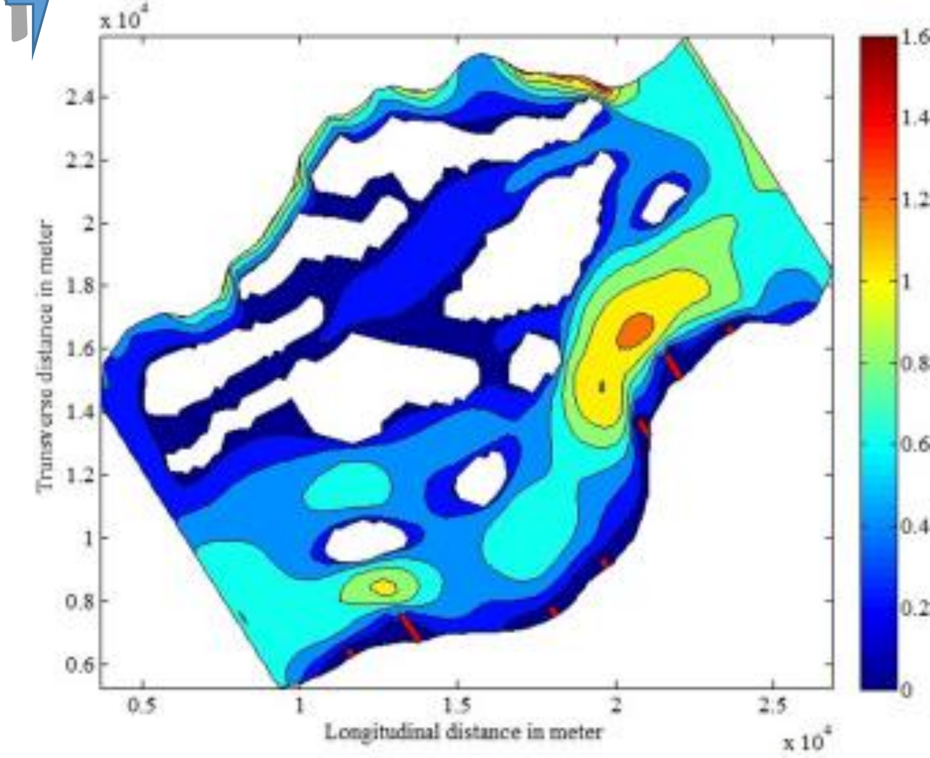
RIVER MODLING AND MANAGEMENT SYSTEM

Simulation-optimization based model to find obtain cost effective combination of river training works



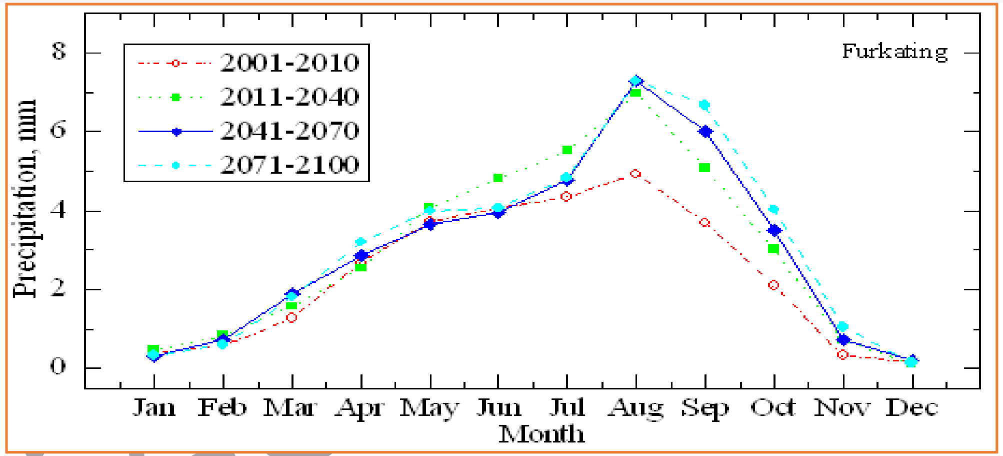
Applied on River Brahmaputra

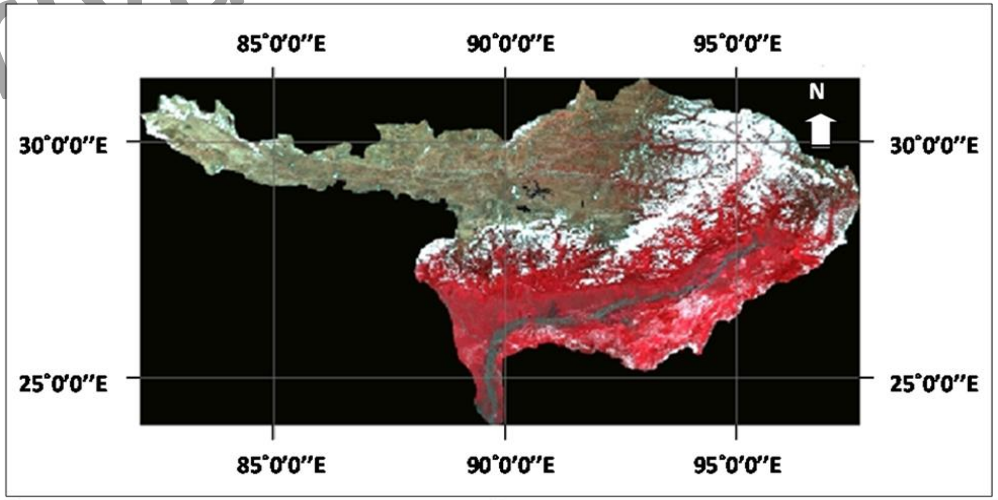


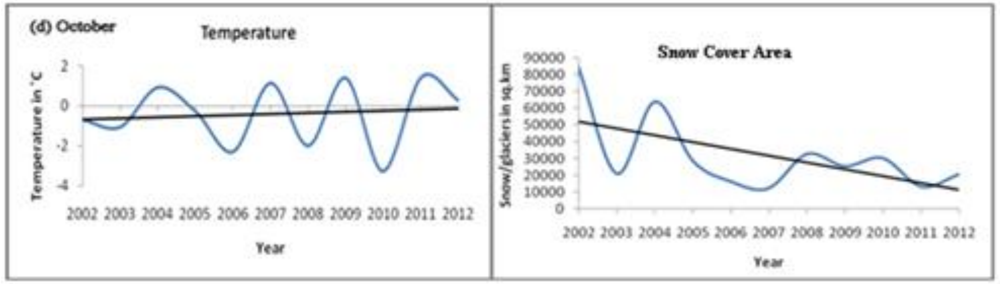


Impact of climate change

- ✓ Climate change may have significant impact on flow of river Brahmaputra
- ✓ Monsoon flow of the river may increase by twenty percent in future
- ✓ Lean period flow may decrease by fifteen to twenty percent
- ✓ Number of dry day may increase in future
- ✓ Temperature increase by 0.5   to 1.0 degree
- ✓ Shifting of Monsoon
- ✓ Reduction in Himalayan glacier/snow cover







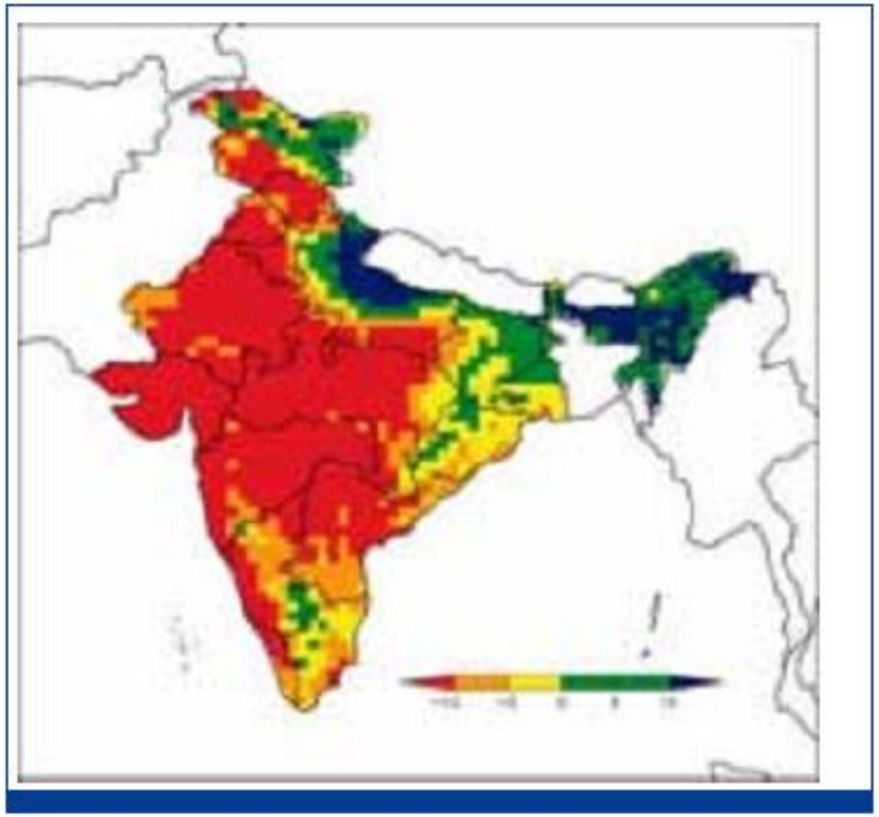


Figure 3.14: Projections of mean incremental annual number of rainy days for the period 2041-2060, based on the regional climate model HadRM2.

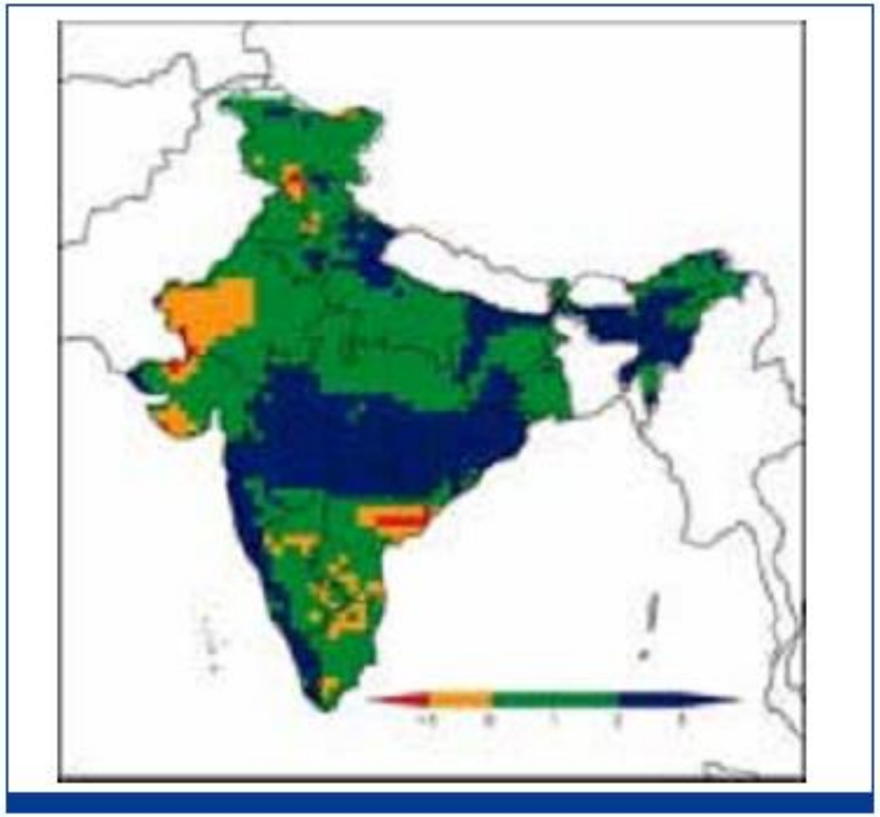


Figure 3.15: Projections of mean incremental rainy day intensity (mm/day) for the period 2041-2060, based on the regional climate model HadRM2.

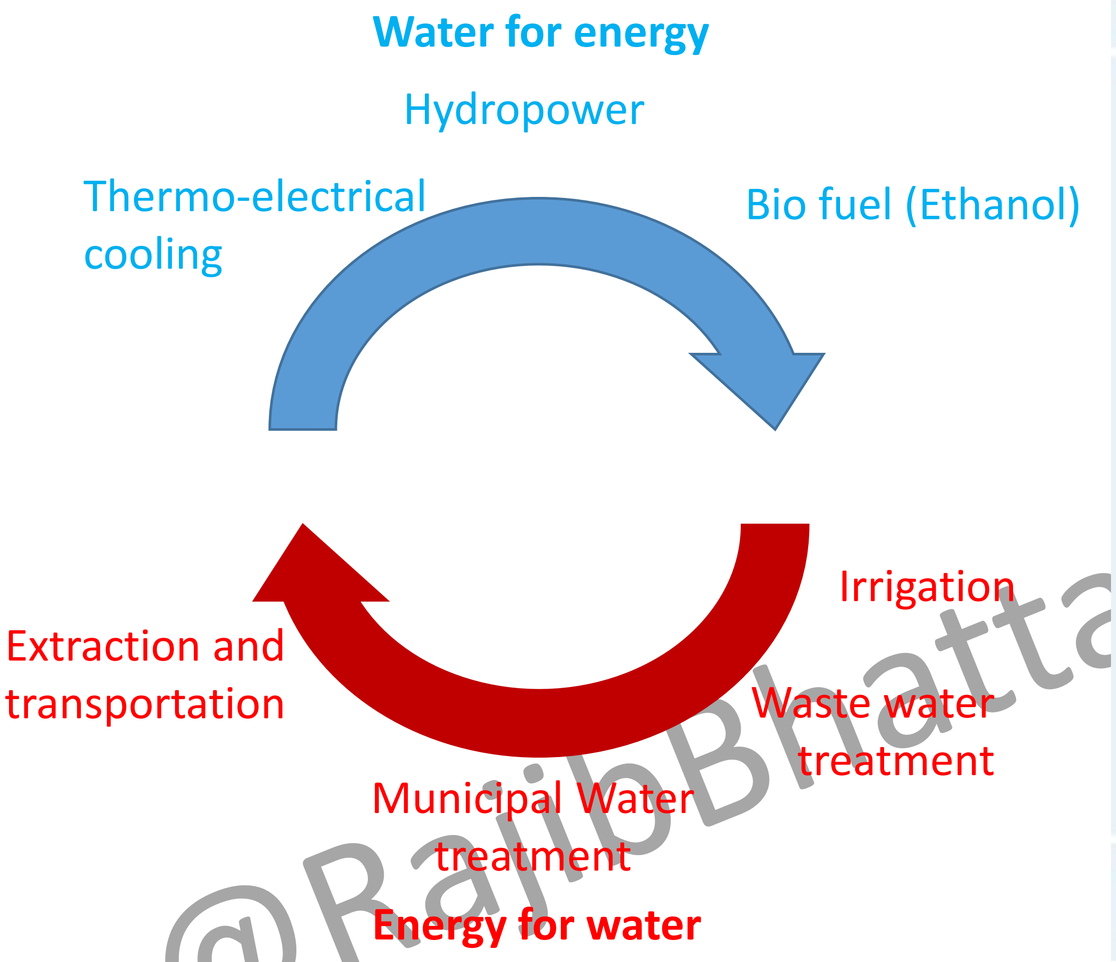
Source: India's 1st communication to UNFCC

Impact of climate change

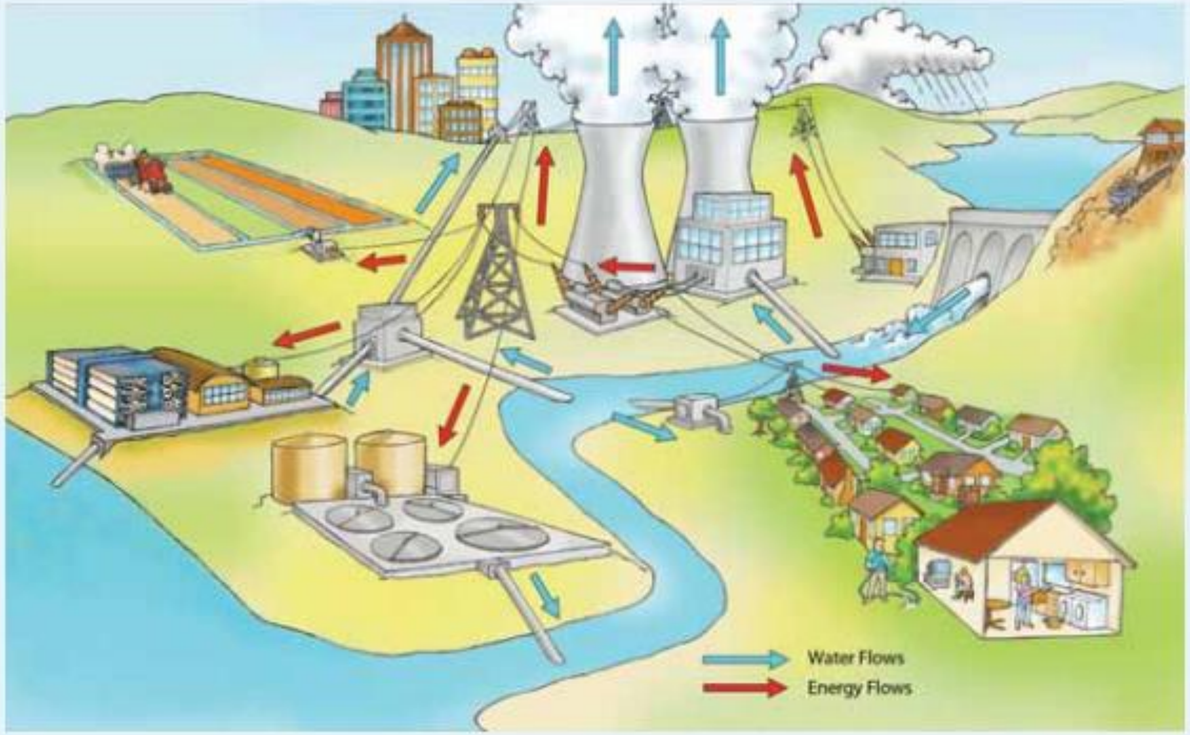
- **Agriculture**
  - 10-40% loss in crop production in India
  - India could lose 4-5 million tons wheat production with every degree rise temperature
  - Up to 50% reduction in maize yields
  - Rise in coconut yields
  - Reduction in apple production
- **Forest**
  - Net Primary Productivity is projected to increase by 68.8% and 51.2% under the A2 and B2 scenarios, respectively
  - 39% of forest are likely to undergo vegetation type change under the A2 scenario and 34% under the B2 scenario
- **Human health**
  - Higher mortality from heat stress and vector/water-borne diseases
  - Expanded transmission window for malaria

Water Energy Nexus and Virtual water

Water Energy Nexus



The energy–water nexus



Note: Energy flows are shown in red and water flows are shown in blue. As shown in the residential community, electricity and water are both used for different purposes.
Source: Courtesy of EPRI (prepared by EPRI for a US DOE Report to Congress in 2006).

Water Energy Nexus

We use energy for water

Source	Approx. Energy (kWh/Mgal)
Surface water	1400
Groundwater	1800
Seawater	9780-16500

We use energy for wastewater treatment

Treatment Type	Approx. Energy (kWh/Mgal)
Trickling filter	955
Activated sludge	1300
Advanced treatment without Nitrification	1500
Advanced treatment with Nitrification	1900

We use energy to reclaimed water

Source	Energy (kWh/Mgal)
Reclaimed water	1514-3785

Virtual water and its trade

Q. How much water is needed to make a cup of tea?

Ans. 27 litre per cup for 250ml

Q. How much water is needed to make a cup of coffee?

Ans. 132 litre per cup of 125 ml

Virtual water and its trade

1 glass of Milk

200 L

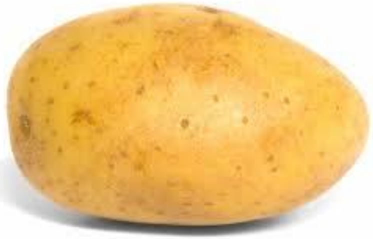
1 Apple

70 L

1 Orange

50 L

1 Potato



25 L

1 Pizza

1259 L

1 L of Bio-diesel (soybean)

11397 L

1 Kg of Rice

2497 L

1 Kg Chocolate

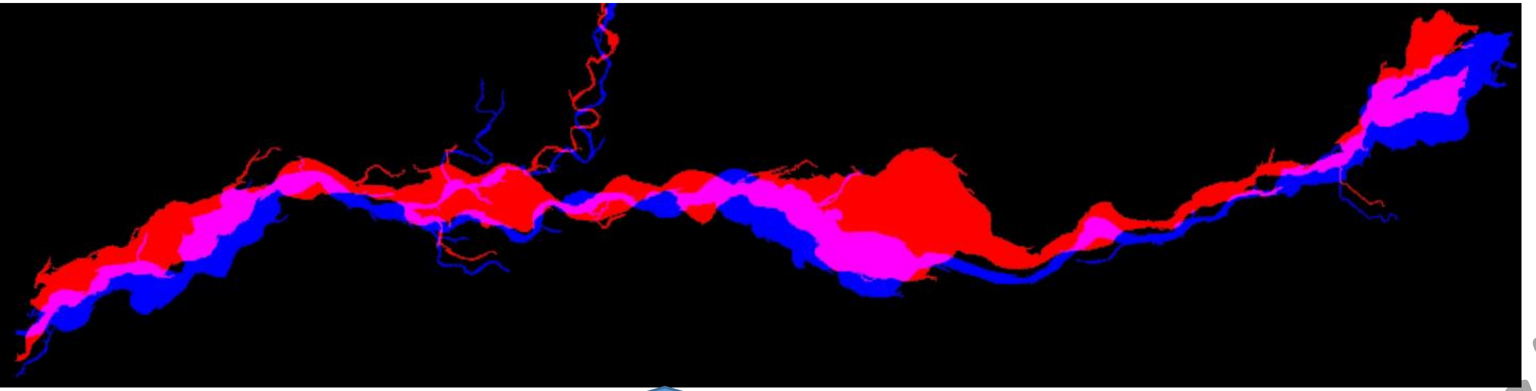
1259 L

Flow of virtual water by the tea industry

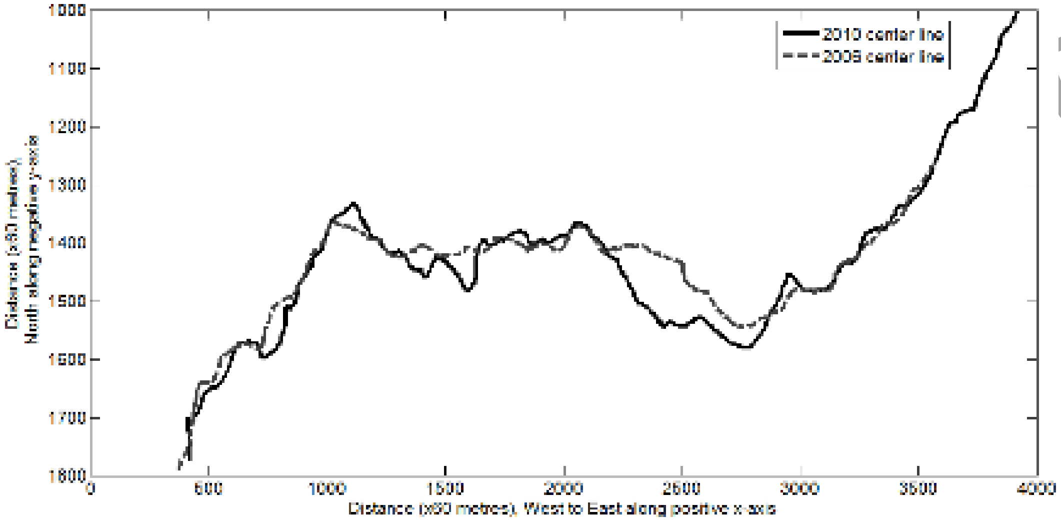
Country	Tea (MKG)		Water (ML)		Water (MCM)	
	14-15	13-14	14-15	13-14	14-15	13-14
Russian Fed	39.14	38.62	346780	342173	347	342
Ukraine	2.56	2.21	22682	19581	23	20
Kazakhstan	11.46	10.26	101536	90904	102	91
Other CIS	0.68	1.7	6025	15062	6	15
Total CIS	**53.84**	**52.79**	**477022**	**467719**	**477**	**468**
United Kingdom	**18.58**	**17.64**	**164619**	**156290**	**165**	**156**
Iran	**17.53**	**22.9**	**155316**	**202894**	**155**	**203**
Pakistan	**15.01**	**19.92**	**132989**	**176491**	**133**	**176**
U.A.E	**13.95**	**23.33**	**123597**	**206704**	**124**	**207**
U.S.A	**13.54**	**14.09**	**119964**	**124837**	**120**	**125**
Egypt (ARE)	**7.54**	**7.45**	**66804**	**66007**	**67**	**66**
Germany	**7.05**	**7.77**	**62463**	**68842**	**62**	**69**
Bangladesh	**5.01**	**13.94**	**44389**	**123508**	**44**	**124**
Poland	3.94	4.72	34908	41819	35	42
Japan	3.15	3.61	27909	31985	28	32
Australia	3.1	3.16	27466	27998	27	28
Saudi Arabia	3.03	2.63	26846	23302	27	23
China	3.01	4.14	26669	36680	27	37
Sri Lanka	2.88	1.55	25517	13733	26	14
Netherlands	2.78	3.26	24631	28884	25	29
Ireland	2.06	2.21	18252	19581	18	20
Afghanistan	1.95	2.46	17277	21796	17	22
Kenya	1.62	2.69	14353	23833	14	24
Canada	1.48	1.24	13113	10986	13	11
Singapore	0.4	0.34	3544	3012	4	3
Other countries	16.36	13.92	144950	123331	145	123
Total	**197.81**	**225.76**	**17,52,597**	**20,00,234**	**1,753**	**2,000**

Flow of virtual water by the tea industry

RIVER MONITORING SYSTEM

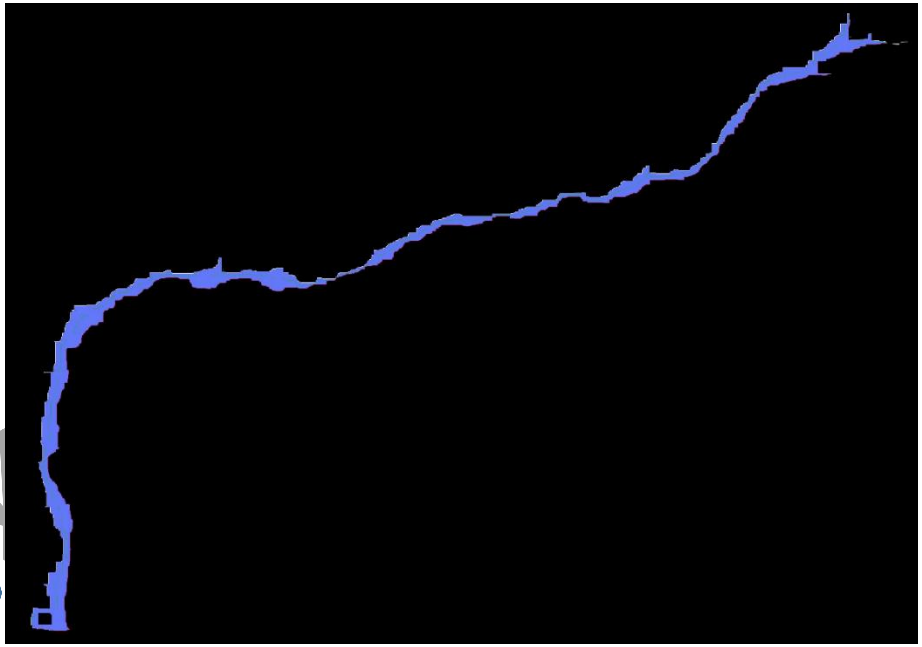


River migration study

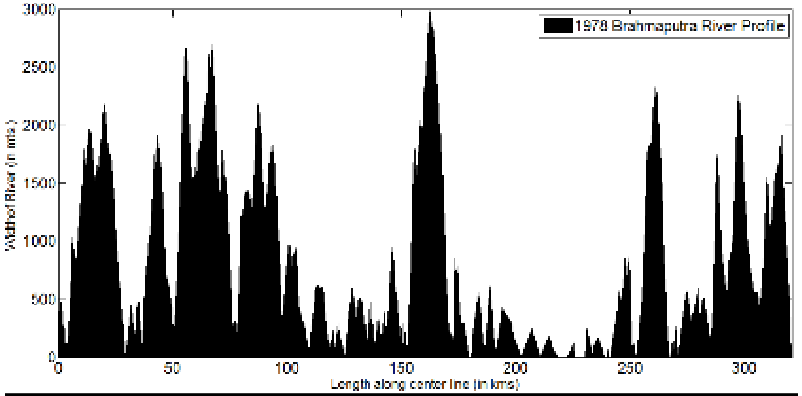


Centerline migration study

Delineation of Floodplain



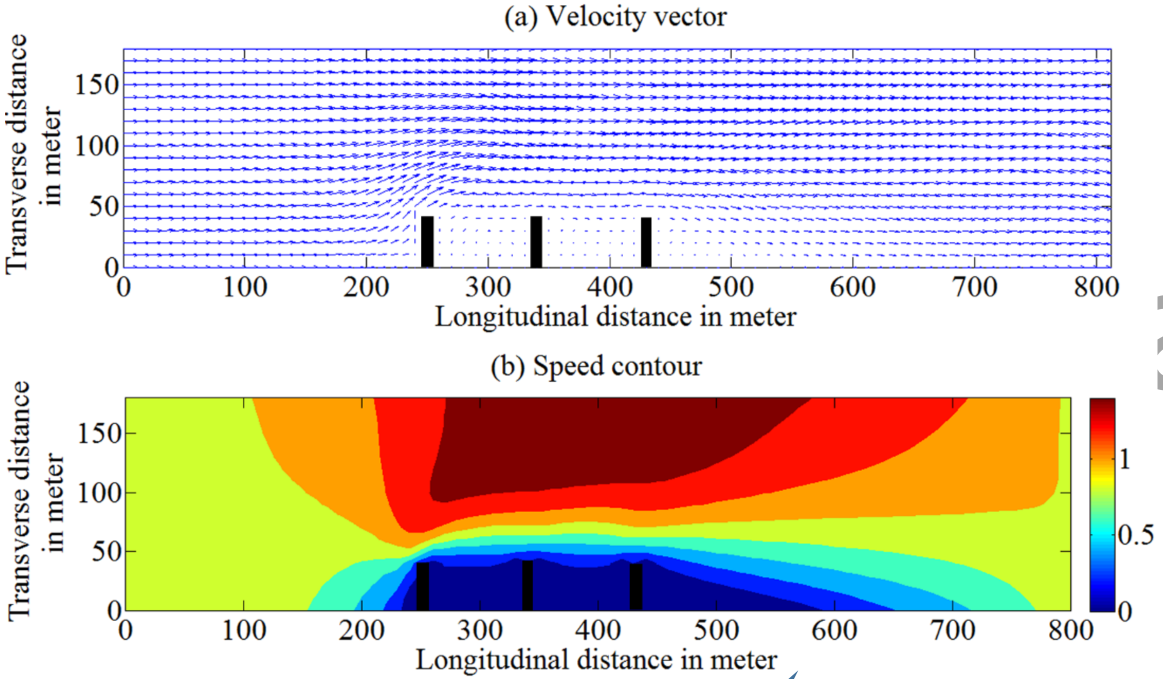
Determination river width



Dey Aveedibya, and **Bhattacharjya Rajib Kumar** (2013), "Monitoring River Center Line and Width - A Study on River Brahmaputra", *Journal of the Indian Society of Remote Sensing*, 42(2),475-482.

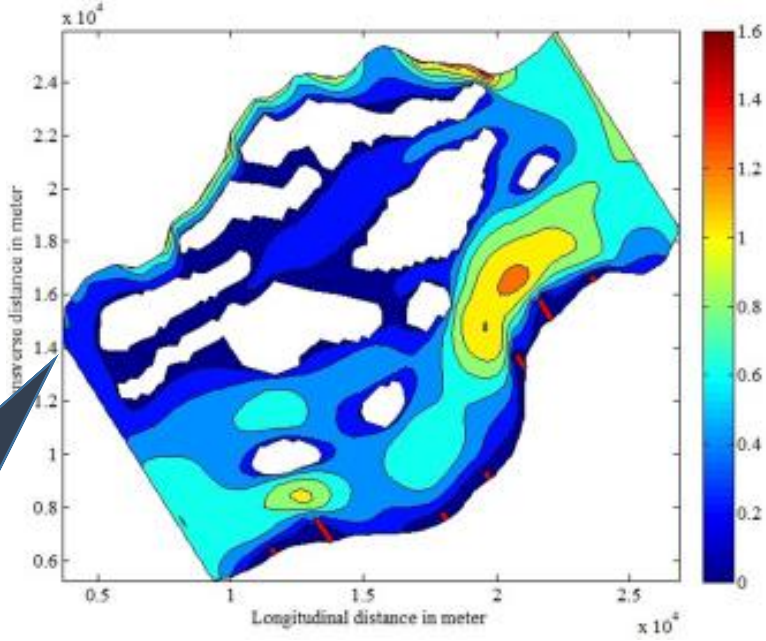
RIVER MODLING AND MANAGEMENT SYSTEM

Simulation-optimization based model to obtain cost effective combination of river training works



Kalita H.M., Sarma A.K., and Bhattacharjya R.K, ***Evaluation of Optimal River Training Work using GA Based Linked Simulation Optimization Approach***, WARM, 2014

Applied on River Brahmaputra



Kalita H.M., Bhattacharjya R.K and Sarma, A,K. **Linked simulation optimization model for evaluation of optimal bank protection measures** (Under review)

THANKS