International Centre of Excellence in Water Resources Management

<u>Invited</u>: The University of Adelaide's *<u>India-Australia Workshop on Research in Water Resources Engineering</u>* during February 12-15, 2007

<u>Acquainted</u>: ICE WaRM' activities in education, training, and encouraging international research collaboration through International Liaison Programme

<u>Awarded:</u> ICE WaRM's International Visits and Exchanges Programme Fellowship in March 2008

<u>Currently</u>: Research collaboration with University of Adelaide during May-July 2008 on Neural Networks for Water Resources Modelling and Management

Water Problems and Solutions: An Indian Perspective

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Outline

- Global Water Issues & Facts
- Integrated Water Management
- Technological Advancements
- Indian Water Resources
- Problems and Solutions
- Case Study - Rainwater Harvesting
- Conclusions

Water Issues

- ***Water Availability***
- Water Design
- ***Water Management***
- Water Quality
- Water Rights and Policies
- Impact of Climate Change
- More ….

Global Water Facts

- Total water – 1,386 Million Kilometer^3
- 97% in oceans & 1% on land is saline
- => only 35 MKm3 on land is fresh
- Of which 25 MKm3 is solid!!
- Only 10 MKm3 is fresh liquid water
- Availability has remained CONSTANT!!
- Water Demands are INCREASING!!

Source: Subramanya (2001)

Global Water Facts

What do we do?
Utilize existing WR efficiently!!
How?

Integrated Water Management

What is an Integrated Approach?

- Any system consists of several elements
- Each element is important for proper functioning of the system
- If one of the elements fails/does not function properly, the system will fail/not function properly
- In order to sustain a healthy system, an integrated approach capable of considering ALL elements together is required

Integrated Water Management

- Effective utilisation of water resources
- ***Technological advancements***
- Administrative support
- Social, legal, and political aspects
- ***Community education & participation***
- Proper co-ordination among stake-holders
- More ….

Technological Advancements

Technological Advancements

- Data Collection & Communication: SAR, LiDAR, Satellite, Automatic data-loggers, Telemetry, Off-shore techniques
- Database Management: GIS, AutoCAD, www
- Mathematical Modeling: ANNs, GAs, SVMs, DSS-Expert Systems, Mechanistic Models, Hybrid models, and Uncertainty analysis

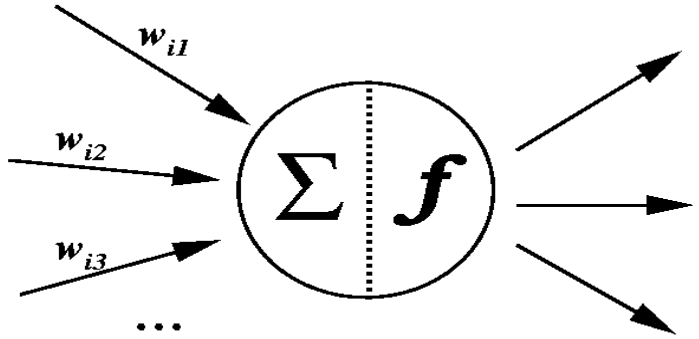
Artificial Neural Networks

An Artificial Neural Network (ANN) is a highly interconnected network of many simple processing units called neurons that are capable of simulating the functioning of a human brain.

Artificial Neuron

An Artificial Neuron is the basic building block of an ANN

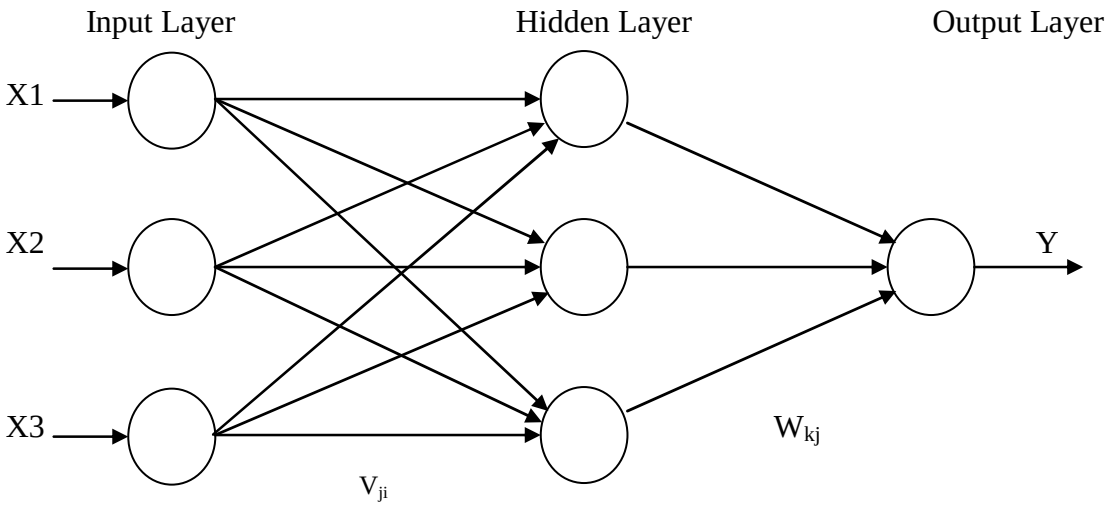
McCulloch and Pitts (1943) Artificial Neuron



$$y_i = f(net_i)$$

Artificial Neural Network

Feed-forward MLP



Genetic Algorithms

Genetic Algorithm (GA) is an optimization method/search technique based on the concept of natural selection inherent in evolution, which combines survival of the fittest with genetic operators abstracted from nature (Holland, 1975).

Genetic Algorithm

- A GA starts with an initial population of solutions
- A single solution = ‘natural chromosome’
- The population is evolved using three basic genetic operators: selection, crossover or mating, and mutation
- This evolution of population of solutions is continued from one generation to the next until desired accuracy of fitness function is achieved

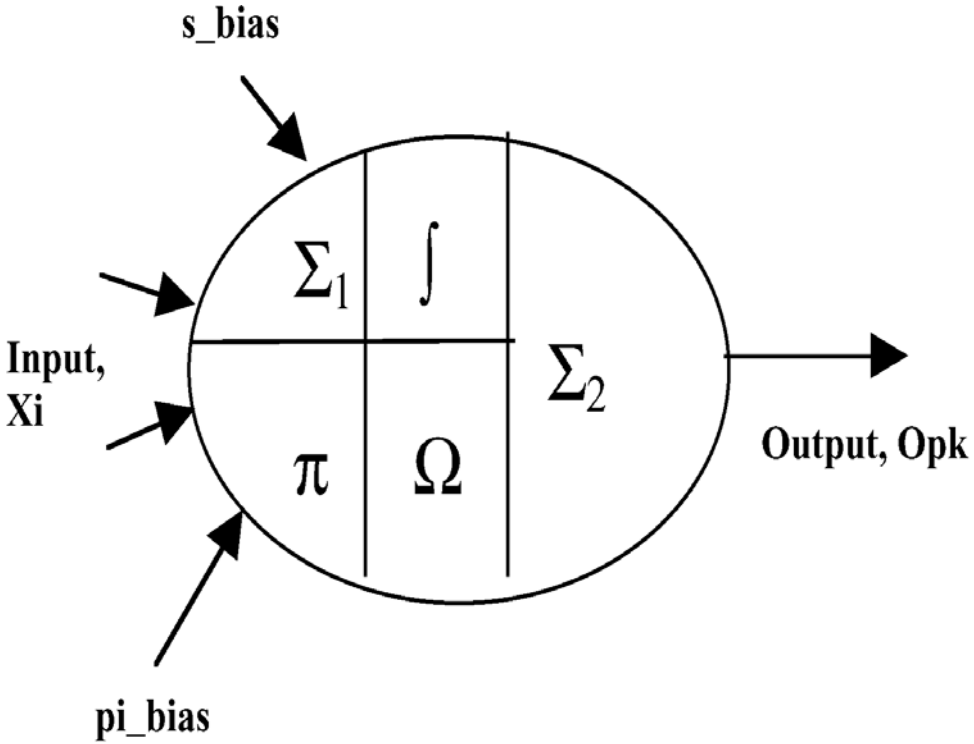
Technological Advancements

Research works carried out at IIT Kanpur, India

- ANNs: Rainfall-runoff modelling, municipal water demand modelling, groundwater pollution source identification, dam break flow modelling
- GAs: Design of irrigation channels, Determination of unit hydrograph, ANN training
- RS/GIS: Study channel migration of Ganga, Yamuna, Sharda, Ghaghra, & other rivers, Location of bridges and Floodplain management

Technological Advancements

Generalized Neuron proposed by Scientists at IIT Kanpur, India



Indian
Water Resources

India: General

- Geographical Area = 3.29 MKm2 (2.4%)
- Population = 1,027,015,247 (March 2001, 15%)
- Livestock = 500 M (20%)
- Highest Point = 8,611 m (Karakoram)
- Lowest Point = -2.2 m (Kuttanad, Kerala)
- Longest River = Brahmputra (2,900 km)
- Largest Lake = Chilka (Orissa, 1,165 Km2)

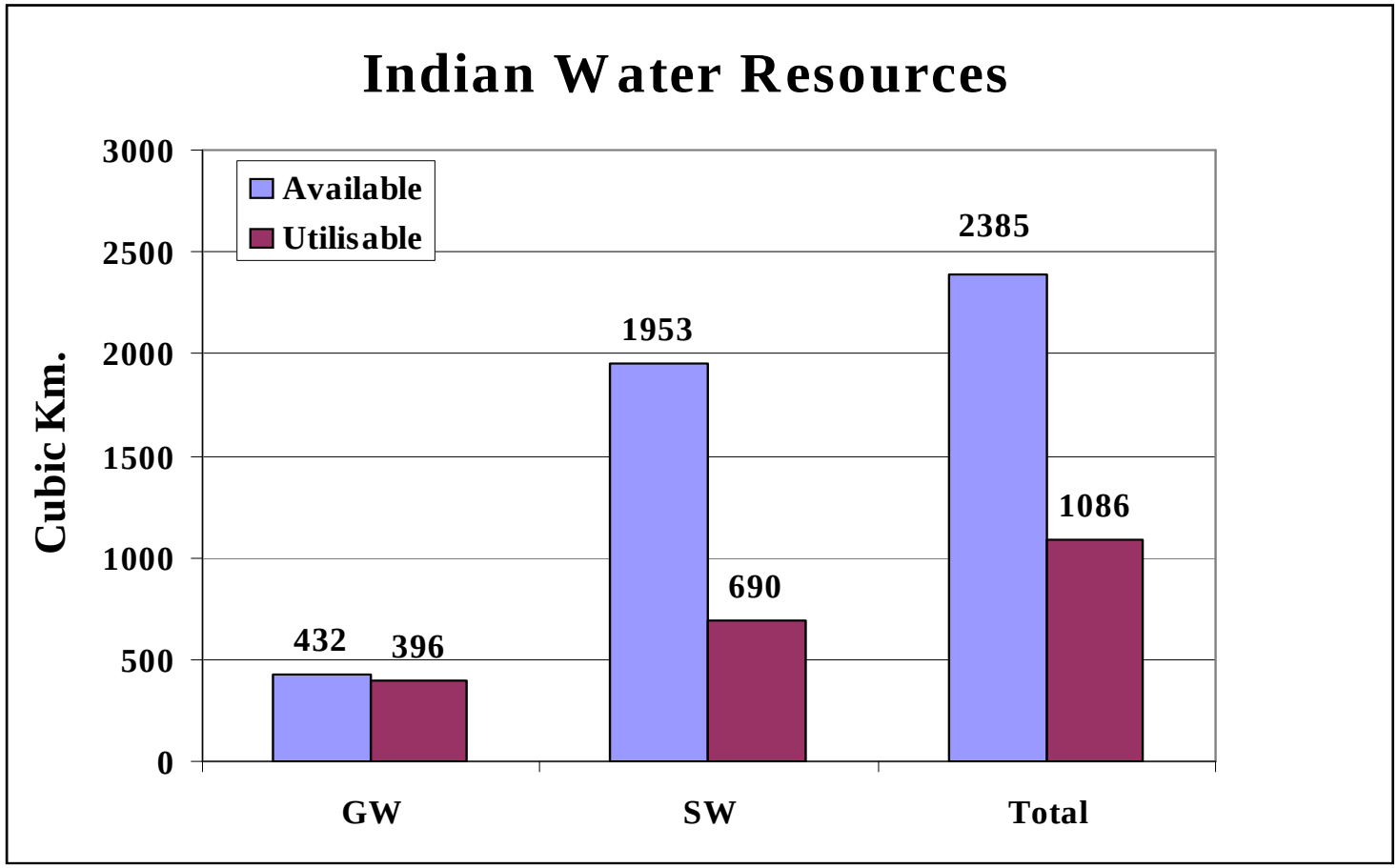
(Source: http://en.wikipedia.org/wiki/Geography_of_India)

Indian Water Resources

(Source: Ministry of Water Resources: http://www.wrmin.nic.in/)

Indian Water Resources

(Source: Ministry of Water Resources: http://www.wrmin.nic.in/)



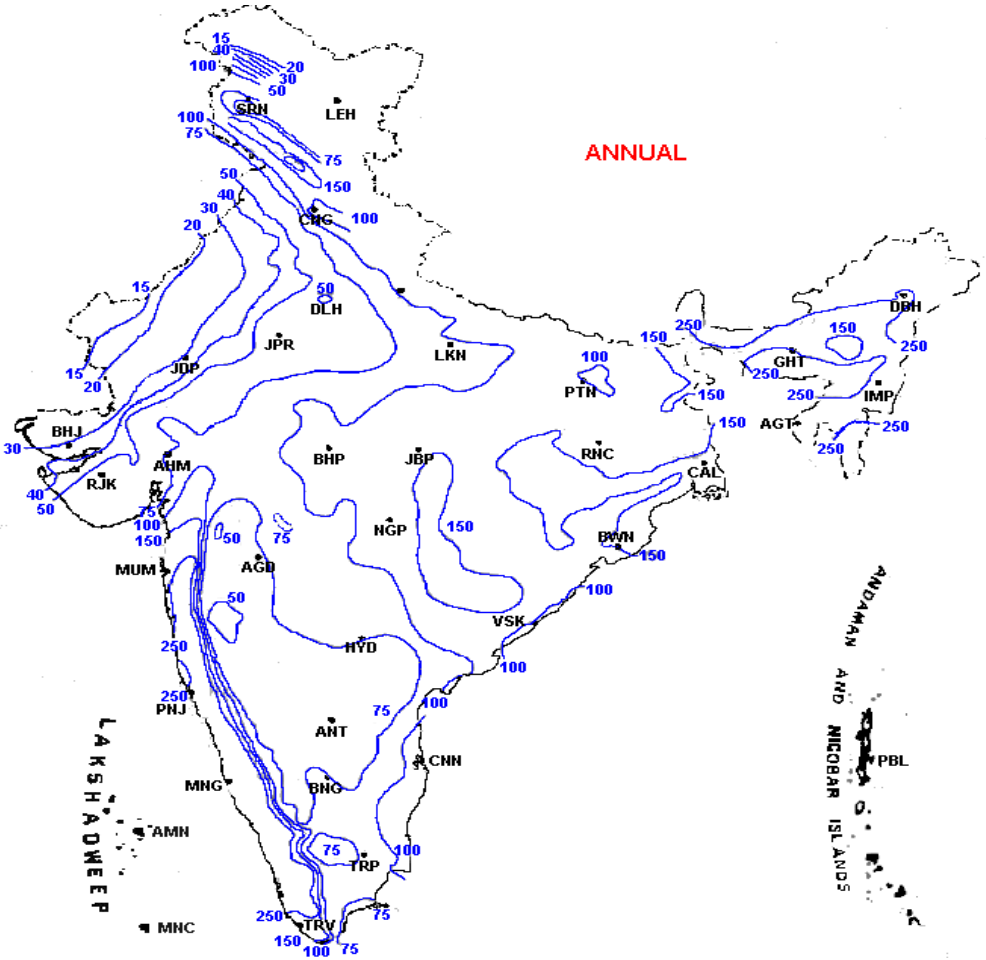
Successful Indian WR Projects

- Bhakhra Nangal Dam (Punjab)
- Hirakund Dam (Orissa)
- Damodar Valley (WB, Bihar)
- Nagarjun Sagar (AP)
- Rajasthan Canal (Raj.)
- Sardar Sarovar (Gujarat & Raj.)

Indian Water Problems: Spatial

- Water availability in India is highly uneven with respect to *Space*
- Highest Rainfall in the World at Mousinram, Cherapunji, Meghalaya AAR 11,430 mm)
- Jaisalmer, Rajasthan (AAR 150 mm)

Indian Water Problems: Spatial



Indian Water Problems: Spatial

The highly uneven spatial distribution of rainfall results in floods in one part of the country and droughts in the other at the same time.

Indian Water Problems: Spatial

Indian Water Problems: Spatial

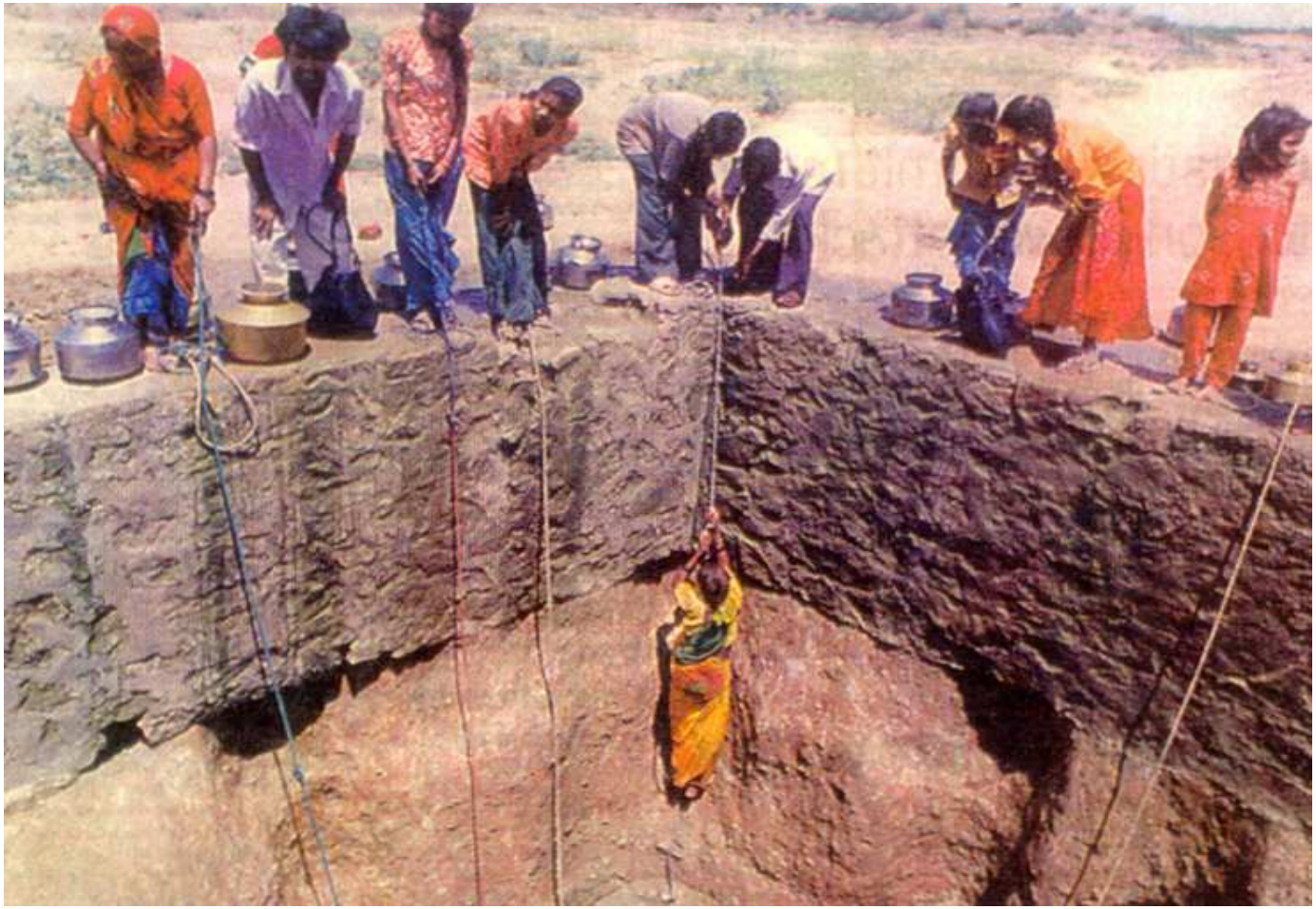
Indian Water Problems: Spatial

Times of India, 17 June, 2008 (Kolkata)

Indian Water Problems: Spatial

Indian Water Problems: Spatial

Indian Water Problems: Spatial



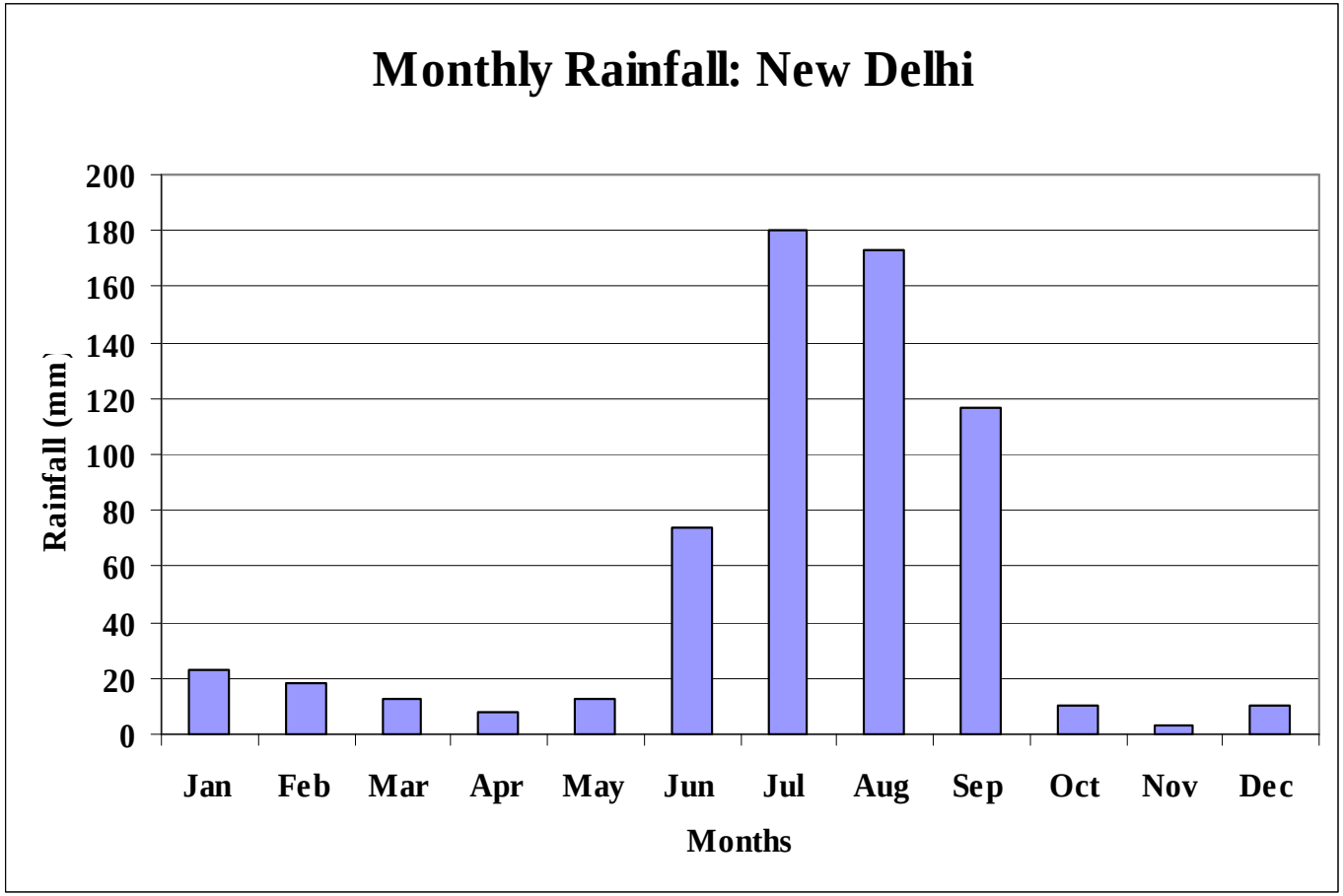
Indian Water Problems: Temporal

- Water availability in India is highly uneven with respect to *Time*
- Most of the rainfall in majority of the country is concentrated in monsoon season (June-September)
- We depend on rainfall for meeting most of our water requirements throughout the year

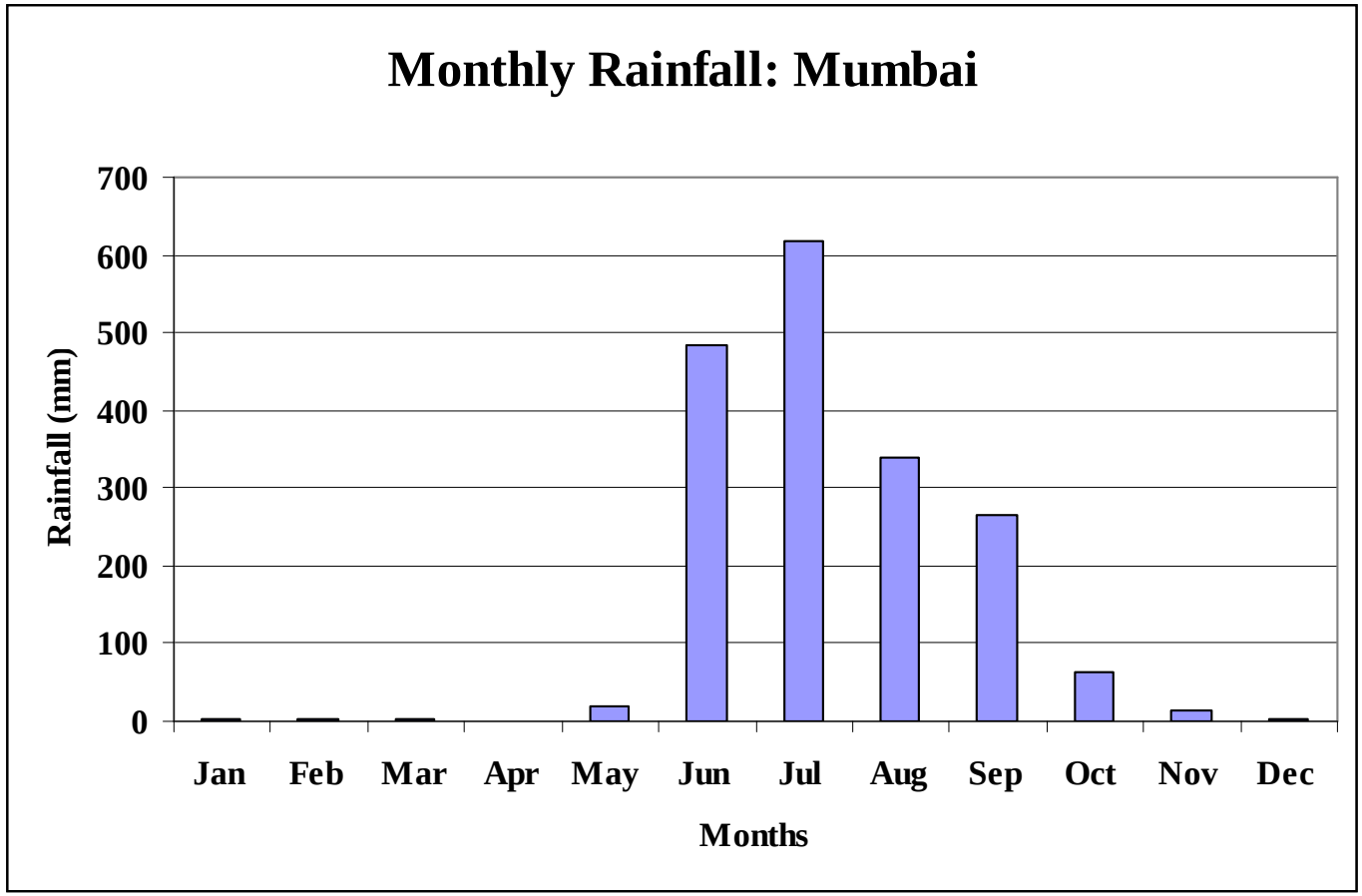
Indian Water Problems: Temporal

- India receives 50% of its annual rainfall in 15 days
- More than 90% of river flows occur in four monsoon months
- Cherapunji also suffers from shortage of water during non-rainy season almost every year

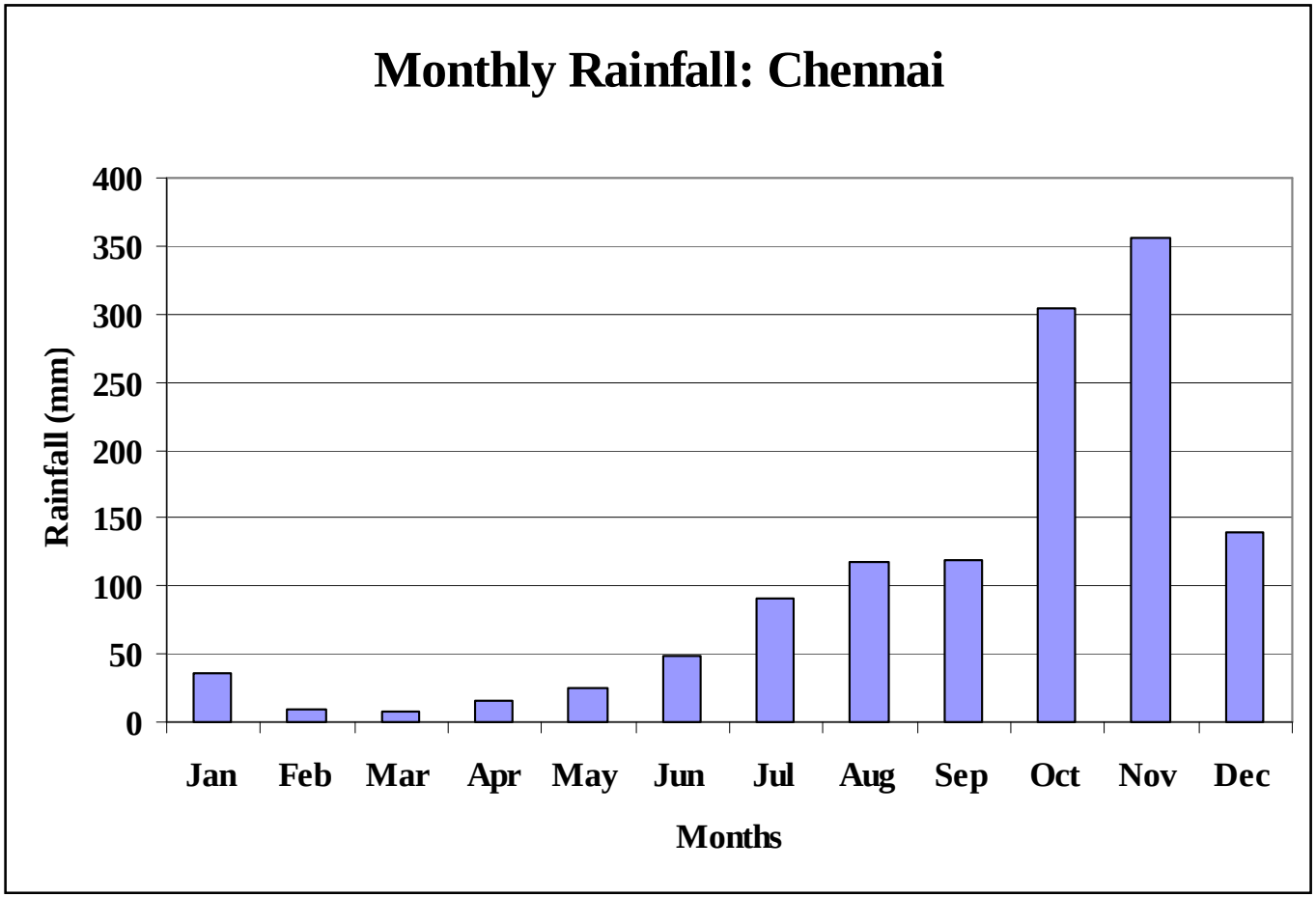
Indian Water Problems: Temporal



Indian Water Problems: Temporal



Indian Water Problems: Temporal



Indian Water Problems: Other

- Over-exploitation of GW: Falling GWTs, Reduction of base flows in rivers, Saltwater intrusion into coastal aquifers
- Improper irrigation practices: Water-logging, Salinity in soils, aquifers polluted by fertilizers
- Industrial pollution of major rivers

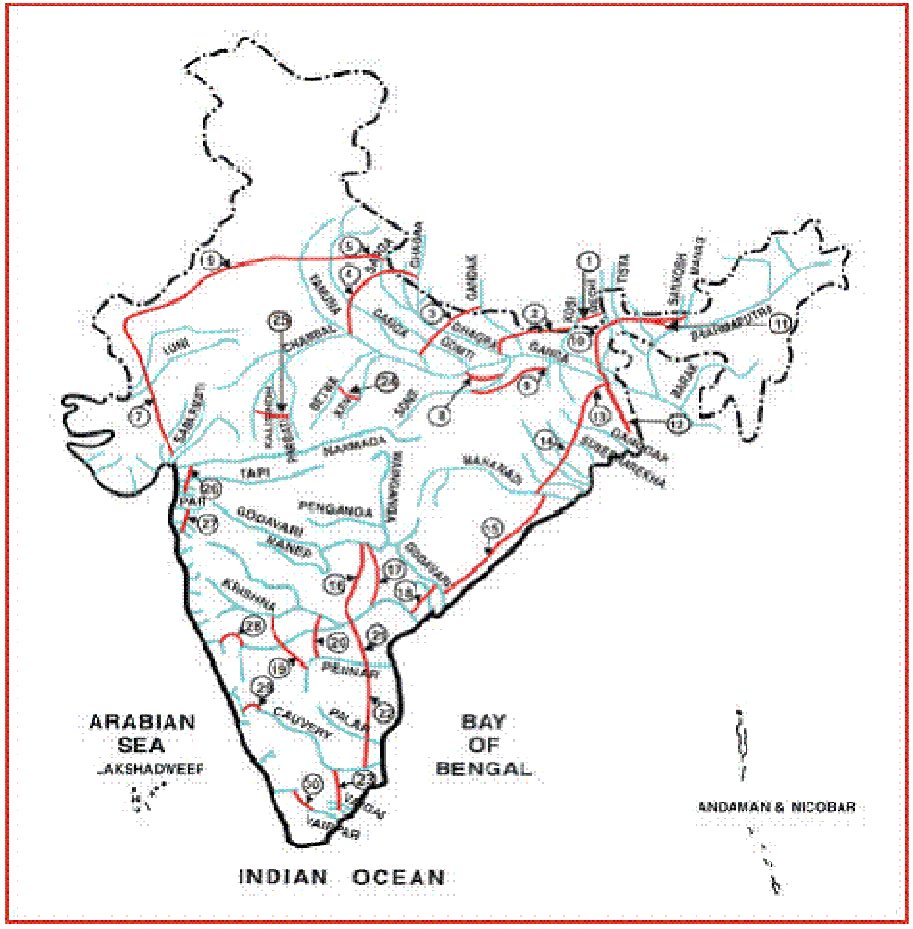
Possible Solutions

Solutions of water problems in India lie in its root causes

Space => Interlinking

Interlinking of Rivers in India

(Source: Ministry of Water Resources: http://www.wrmin.nic.in/)



Interlinking of Rivers in India

(Source: Ministry of Water Resources: http://www.wrmin.nic.in/)

HIMALAYAN COMPONENT

1. Kosi – Mechi
2. Kosi – Ghagra
3. Gandak – Ganga
4. Ghagra – Yamuna **
5. Sarda – Yamuna **
6. Yamuna – Rajasthan
7. Rajasthan – Sabarmati
8. Chunar- Sone Barrage
9. Sone Dam – Southern Tributaries of Ganga
10. Manas –Sankosh - Tista - Ganga
11. Jogighopa – Tista – Farakka (Alternate)
12. Farakka – Sunderbans
13. Ganga (Farakka) – Damodar – Subernarekha
14. Subernarekha – Mahanadi

PENINSULAR COMPONENT

15. Mahanadi (Manibhadra)–Godavari (Dowlaiswaram)*
16. Godavari (Inchampalli) – Krishna (Nagarjunasagar)*
17. Godavari (Inchampalli) – Krishna (Pulichintala) *
18. Godavari (Polavaram) – Krishna (Vijayawada) *
19. Krishna (Almatti) – Pennar *
20. Krishna (Srisailam) – Pennar *
21. Krishna (Nagarjunasagar) – Pennar (Somasila) *
22. Pennar (Somasila) – Cauvery (Grand Anicut) *
23. Cauvery (Kattalai) – Vaigai – Gundar *
24. Ken – Betwa *
25. Parbati – Kalisindh – Chambal *
26. Par – Tapi – Narmada *
27. Damanganga – Pinjal *
28. Bedti – Varda
29. Netravati – Hemavati@
30. Pamba – Achankovil – Vaippar *

*** FR Completed ** FR Completed for Indian portion**

Possible Solutions

Solutions of water problems in India lie in its root causes

Time => Rainwater Harvesting

Case Study:
Rainwater Harvesting

Rainwater Harvesting in India

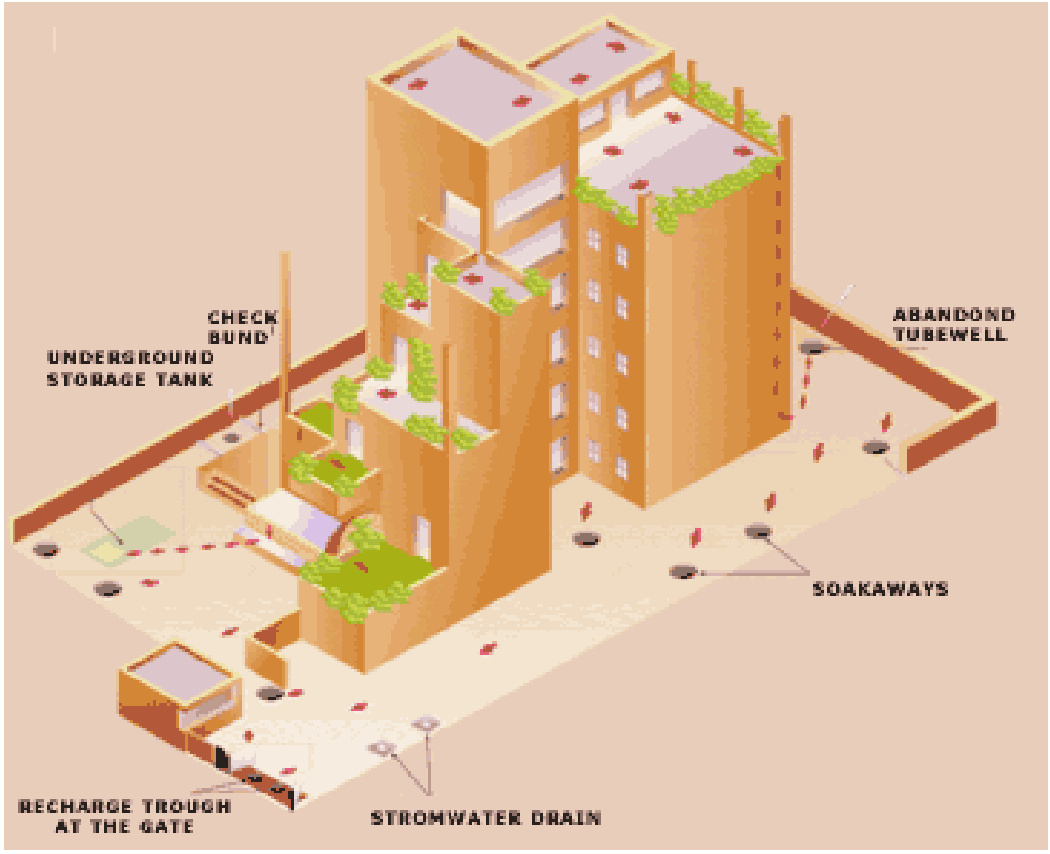
Efficient Rainwater Harvesting practices in northern states of Rajasthan and Gujarat and southern state of Tamil Nadu have resulted in increased water availability, agricultural production, and economic prosperity.

Rainwater Harvesting: Forms

Two Forms

- Rooftop RWH: suitable for large buildings in urban areas
- Community based RWH: suitable in both urban and rural areas

Rooftop RWH in India (CSE, New Delhi)



Rooftop RWH in India

Some states in India (UP & New Delhi) have enacted laws on mandatory RWH in buildings

Community Based Rainwater Harvesting

Community based RWH in India

What an integrated effort with community participation can do is demonstrated through a case study on RWH in Alwar, Rajasthan, India

RWH in Alwar, Rajasthan, India

- Alwar: NE Rajasthan
- Area 8,380 km2
- Population 2.3 M (1991)
- Most in Villages: Depends on Agriculture
- Annual Rainfall 600 mm
- 80% during June-September

RWH in Alwar, Rajasthan, India

- In 1985, Tarun Bharat Sangh (TBS) started construction of *Johads* in Thanagazi Tehsil in Alwar District, Rajasthan with the help of an NGO (CSE).
- A *Johad* is a rainwater harvesting structure (RWHS), which collects seasonal runoff and allows it to percolate.

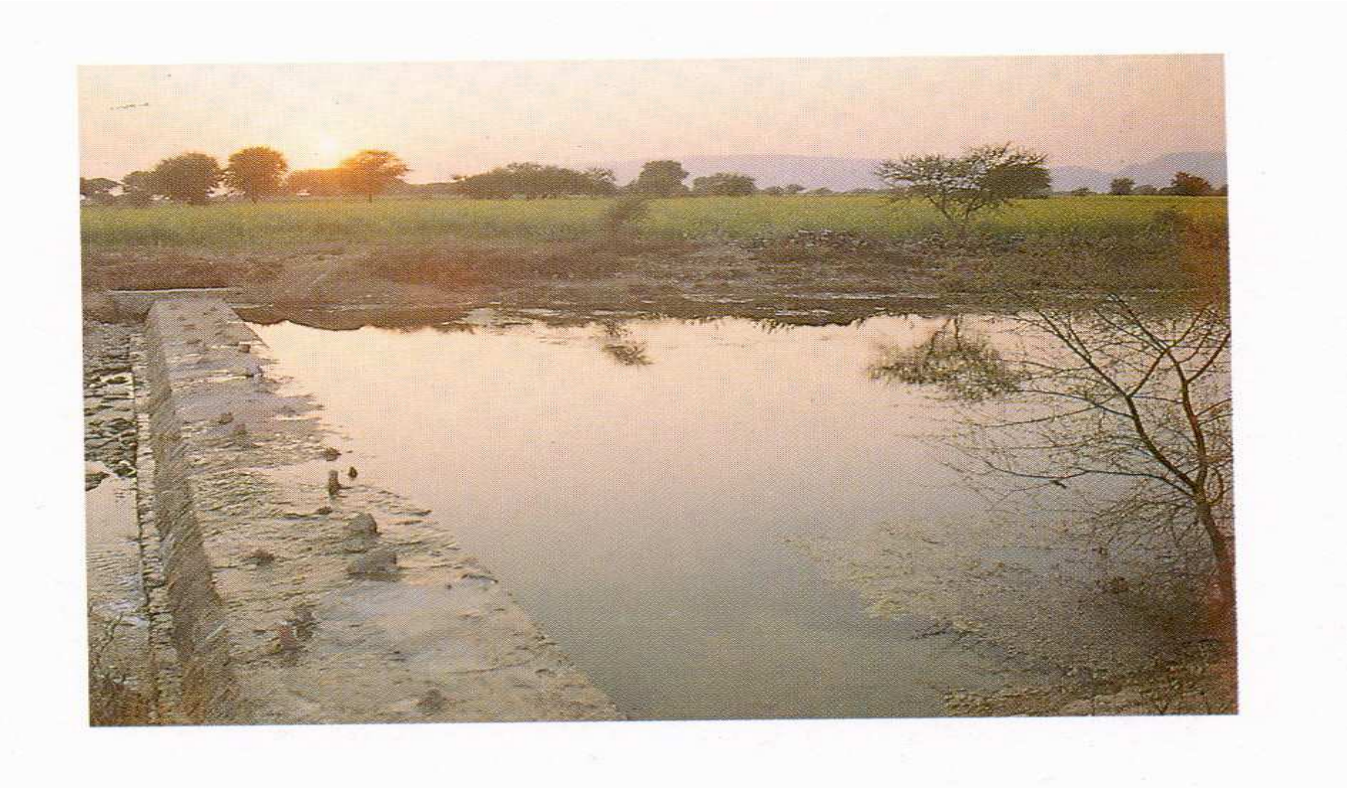
RWH in Alwar, Rajasthan, India

- A *Johad* can be constructed by building a barrier across an ephemeral stream or by excavating a pond at a natural depression.
- Water collected in a *Johad* can be used for drinking, agriculture, groundwater recharge, and supporting cattle farming.

RWH in Alwar, Rajasthan, India

A Typical Johad

RWH in Alwar, Rajasthan, India



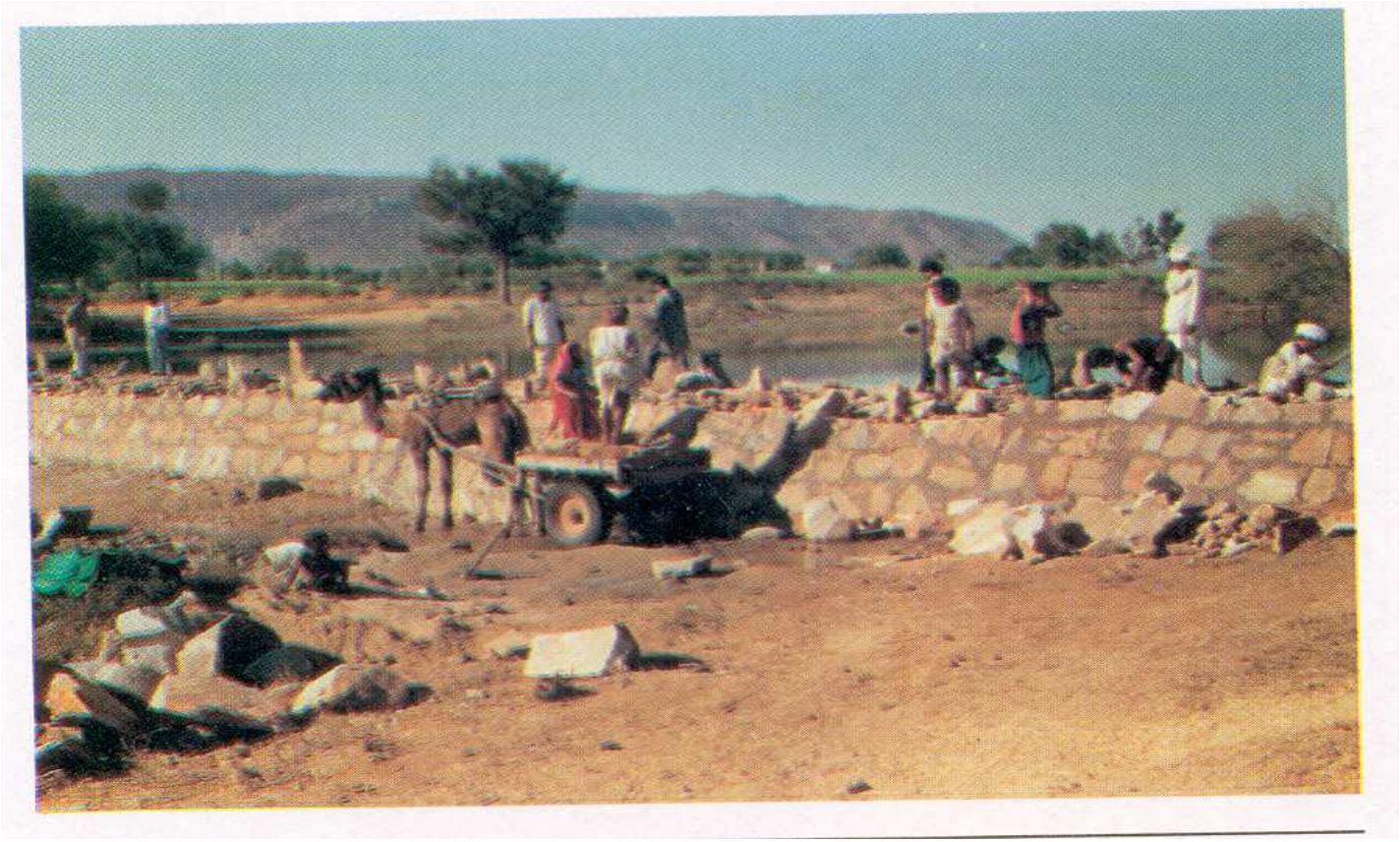
A Typical Johad

RWH in Alwar, Rajasthan, India

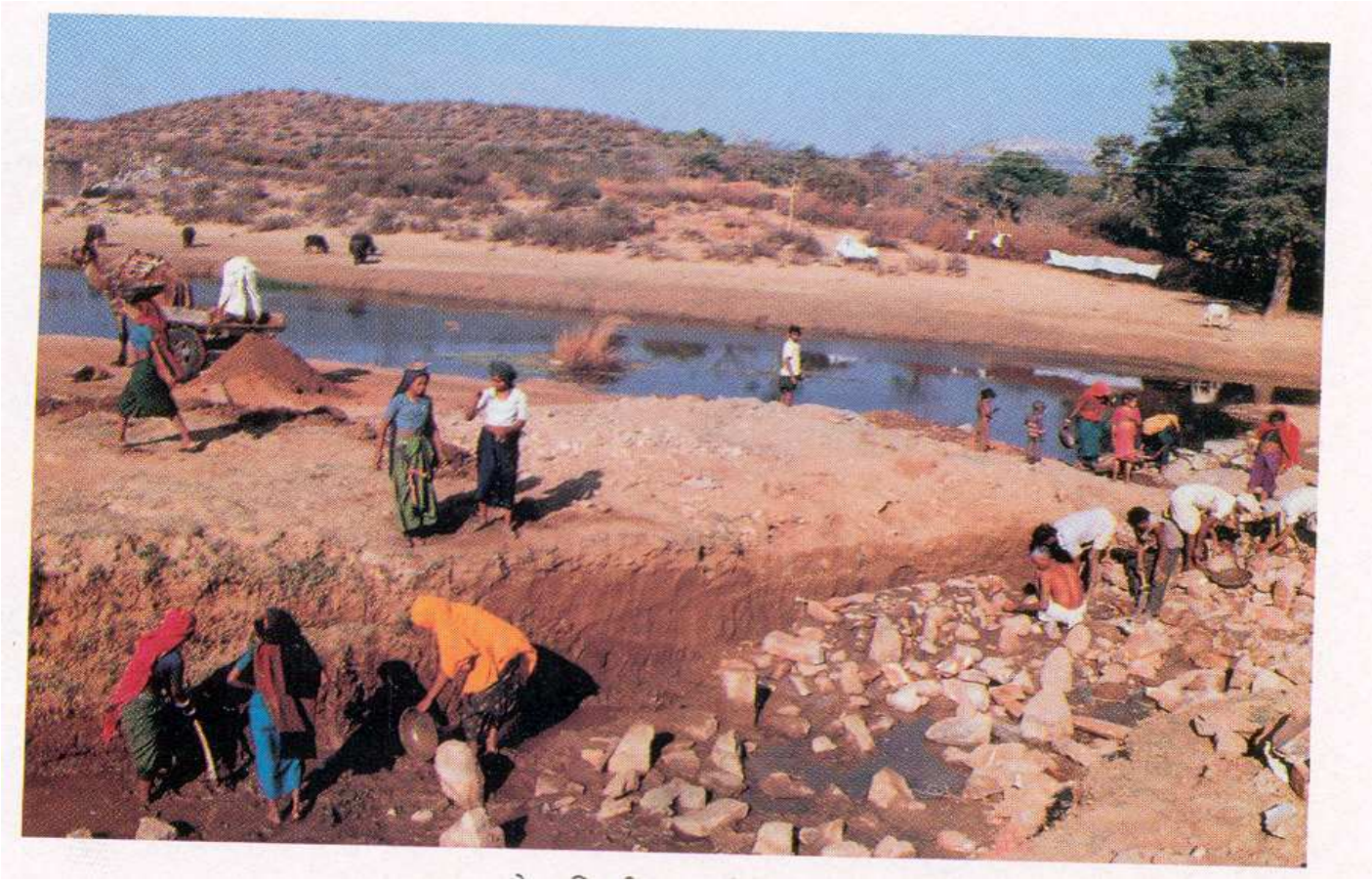
- **How they did it?**
  - Preparation of maps
  - Determining Storage Capacity
  - Designing the structure
  - Constructing the RWHS (Johads)
  - 70% of the costs met through local material and free labour through ***community participation***

RWH in Alwar, Rajasthan, India

RWH in Alwar, Rajasthan, India



RWH in Alwar, Rajasthan, India



RWH in Alwar, Rajasthan, India

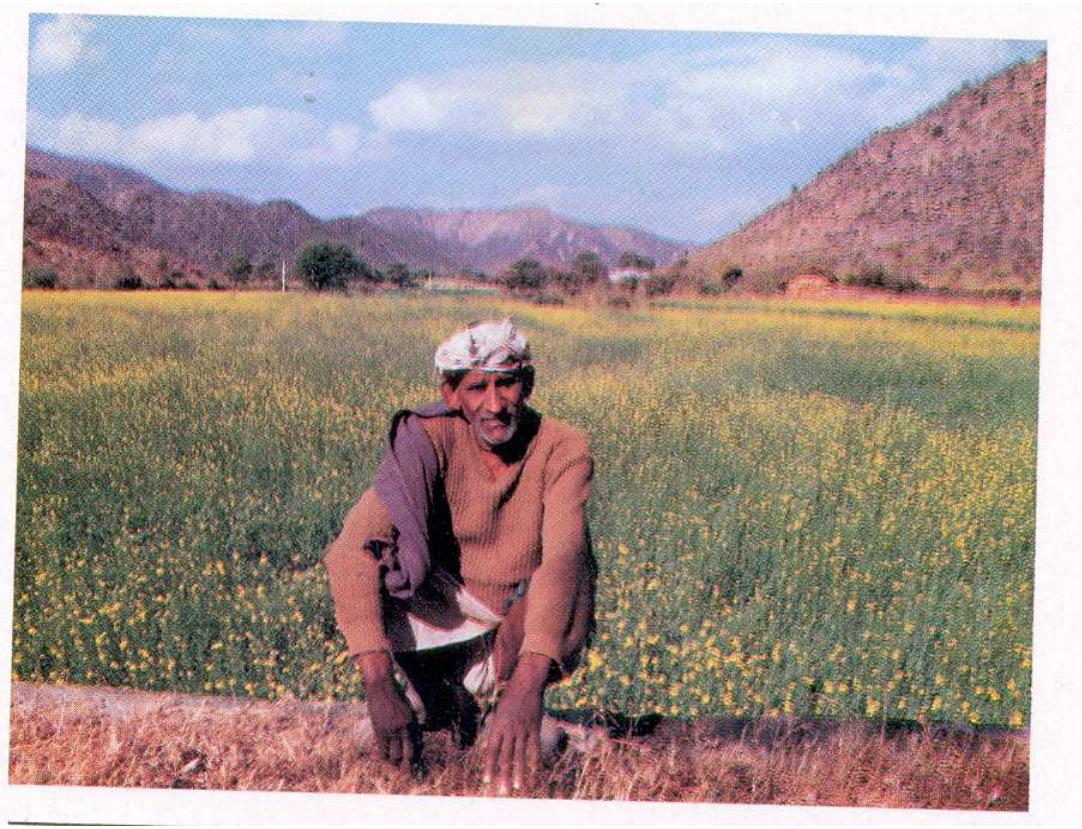
By 1997, The Tarun Bharat Sangh with the help of the local villagers in Alwar, Rajasthan, India completed construction of about 3000 *Johads* in about 650 Villages

RWH in Alwar, Rajasthan, India

A village before construction of Johads in Alwar, Rajasthan, India

RWH in Alwar, Rajasthan, India

Same village after construction of Johads in Alwar, Rajasthan, India



RWH in Alwar, Rajasthan, India

Benefits from Johads

- Sustained water availability for agriculture
- Drinking water for cattle
- TWO crops in a year instead of ONE
- Increases in crop-yields for the farmers
- Increased Overall Agricultural Productions
- More land brought under cultivation
- Increased fodder → Increased milk production
- Benefits multiplied
- Per Capita Income increased manifolds

RWH in Alwar, Rajasthan, India

Benefits from Johads

- Drinking water wells don't dry anymore
- Women didn't need to fetch water from distances
- Migration of male folks to cities stopped
- Reversal of flow of population to villages started
- Economic and social well-being, and prosperity in the region

RWH in Alwar, Rajasthan, India

Pleasant Surprises/Additional Benefits!!

- Many Ephemeral Streams → Perennial

  Arvari, Ruparel, Sarsa, Bhagani-Tildeh, and Jahajwali

- Overall Increase in GWT in the region
- Forestation in upper catchment increased
- Ecological balance restored

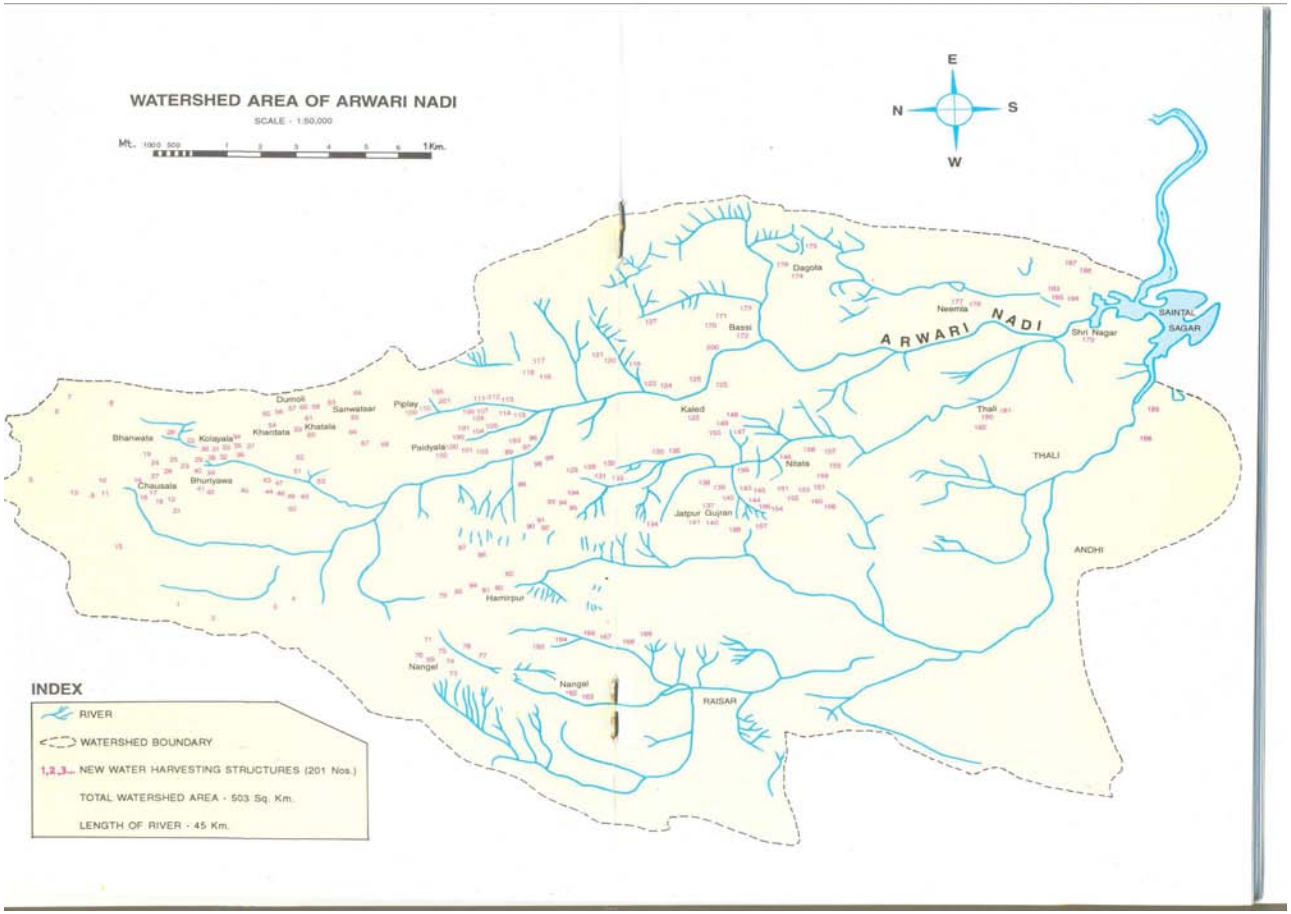
RWH in Alwar, Rajasthan, India

Example of Arvari River Basin (ARB)

- Drainage Area = 503 km2
- Length of River = 45 km
- No. of RWHS (1986-1997) = 238

(Source, Patel, 1997)

The Arvari River Basin



RWH in Alwar, Rajasthan, India

Gradual Increase of GWT in ARB was as follows:

- Johad construction started in 1986
- In 1990, river flowed till October
- In 1991, river flowed till January next year
- In 1992, river flowed till February next year
- In 1993, river flowed till March next year
- In 1994, river flowed till April next year
- In 1995, river became PERENNIAL!

(Source Mahapatra, 1999)

RWH in Alwar, Rajasthan, India

This remarkable feat of re-engineering the hydrological balance of the region, increased prosperity, and restoration of its ecology was achieved through people's sustained effort with little technical support, over a period of about ten years.

Mr. Rajendra Singh, President, Tarun Bharat Sangh
(P. O. – Kishengarh, Alwar, Rajasthan, INDIA)
Winner, Ramon Magsaysay Award (2001)
(Asia's version of the Nobel Prize)

RWH in Alwar, Rajasthan, India

Mr. Singh is internationally recognised for making dry rivers and ponds run with water in the Alwar district of Rajasthan. His pioneering work of building small RWHSs to trap rain water and recharge ground water earned him the Magsaysay Award for the year 2001.

RWH in Alwar, Rajasthan, India

People change history, we change geography.

-- Rajendra Singh

Conclusions

- Water is essential for all kinds of lives on earth
- Water related problems are increasing by the day globally
- Indian scenario of water problems is worse due to large spatio-temporal variations in water availability
- It is difficult to solve water problems but not impossible!!

Conclusions

- Finally, for a complete and sustainable solution to water problems, integrated approach involving the use of technological advancements, optimal management of existing water resources, political will, administrative support, citizen's education, people's participation, social and legal support, effective co-ordination among various agencies involved, and competitive and healthy practices are needed!!

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Thank you for listening!!