# Sustainable Watershed Management in Ganga river basin Using SWAT Model


**PRESENTED BY**

**Dr N K Tiwary, Professor, Water and Land Management Institute, Patna, Bihar, India**

**Sristi Singh, B.Tech, Computer Science**

# Introduction

- Rainfed areas constitute about two third of the total 142 million Hectare cultivated land in the country
- These rainfed areas contribute only 45% to the total food grains production whereas irrigated area which account for only one third of the cultivated area contribute 55% of the total food grains production .
- Very high priority has been accorded to the holistic and sustainable development of rainfed areas based on watershed approach.
- **Sustainable Watershed Management using modern technology is the only solution for the problem of food security.**

# What is a Watershed ?

- Watershed is a geo- hydrological area which drains through a common point into a stream or river. It is an ideal planning unit for conservation of soil , water & vegetation.
- A small watershed of a few hectares drains into a stream & forms part of a larger watershed, until the combined watersheds become a major river basin.
- Watershed Development projects are implemented on the basis of planning for Micro- Watersheds
- On an average a Micro-watershed has an area of around 500 – 700 Ha.
- Watershed management is a holistic approach aimed at overall development of its natural, human and animal resources.

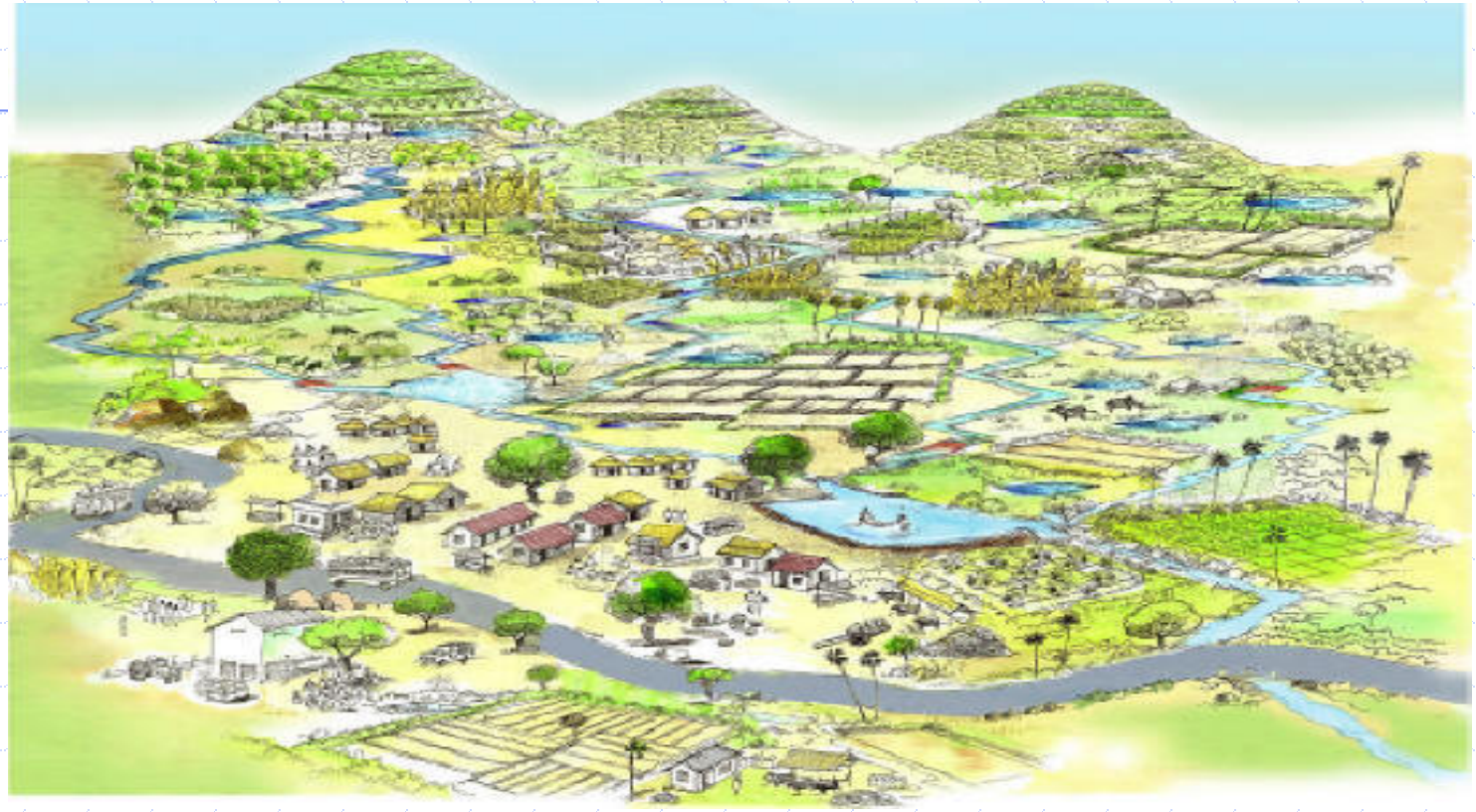
# Watershed as a hydrologic unit

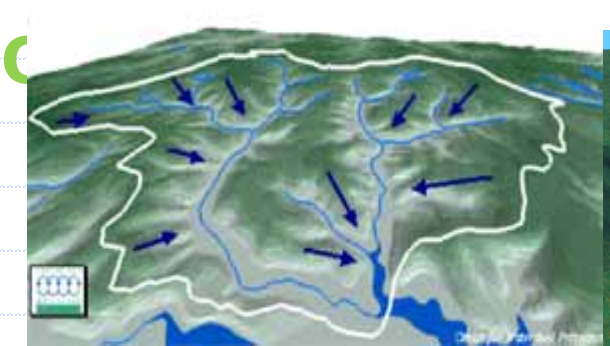
- Watershed as a hydrologic unit has been adopted for integrated development of any area. This is because of the fact that water is a basic element for survival of all the biological materials as well as non-biological activities.

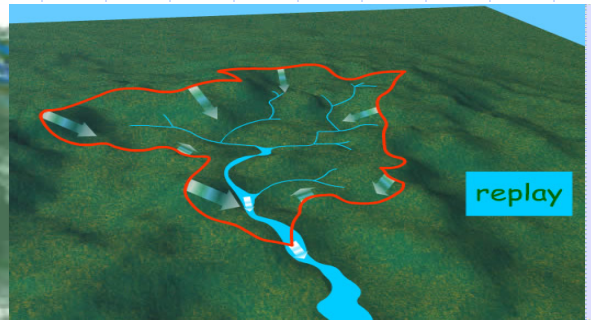
- Hence, it has been perceived that development will be sustainable only when planning is made around water availability, harvesting and its efficient utilization.

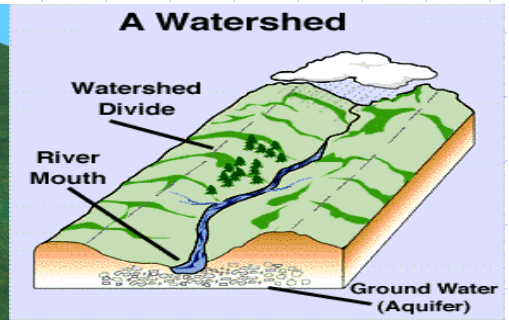
# A TYPICAL WATERSHED

# Watershed Management







# Integrated Watershed Management (IWM)

## Background

- Large water resources development projects in India have **adverse socio-economic and environmental consequences.**

- The failure of such projects, contributed to **indebtedness,** raising **economic pressure** and jeopardising future development.

- Indiscriminate **expansion of marginal lands** and **over-utilisation of existing water resources** for irrigation.

- Traditional **water harvesting systems** have suffered sever neglect.

- This type of development not only called into question
- the **adequacy of water resources schemes** but triggered the urgent
- search for more effective and appropriate management strategies.

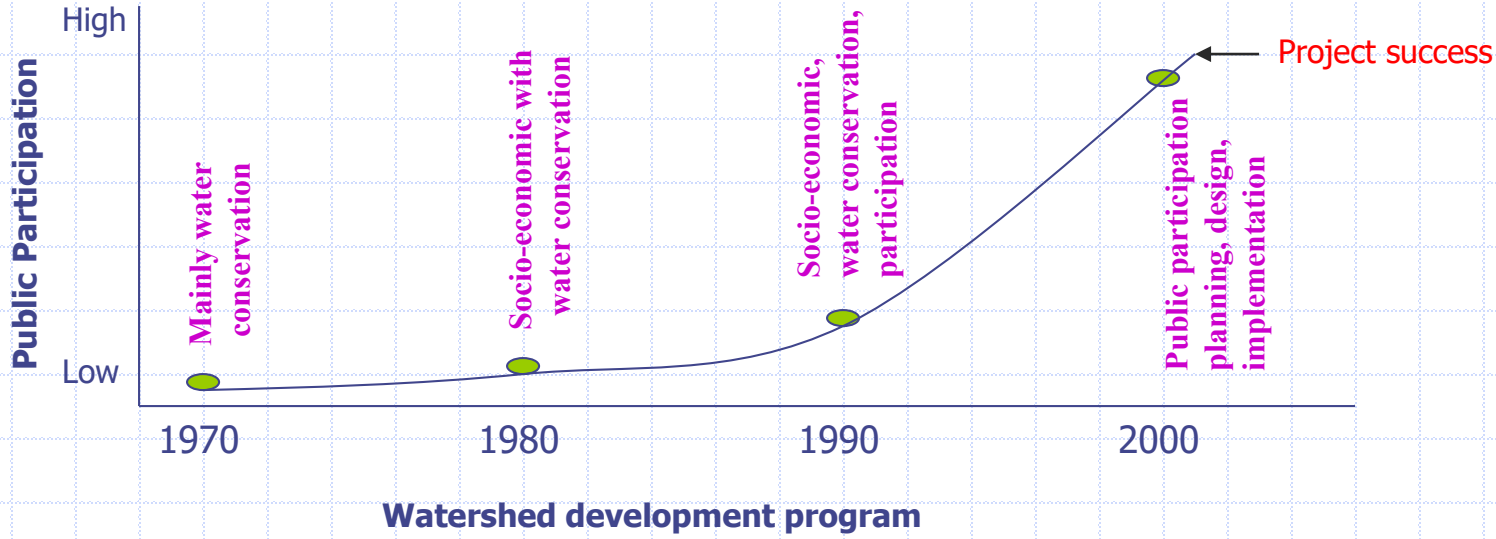
- Major response to follow "**Integrated Watershed Management Approach**".

## Sustainable Watershed Development and Management

- The four engineering and management tools for effective and sustainable development of water resources in semi-arid rural India: -
  - Appropriate technologies
  - Decentralised development system
  - Catchment based water resources planning
  - Management information system
- In past the efforts were more on the soil conservation and taking measures on the land where as we used to neglect the welfare of the land users.
- For sustainable watershed management there is need to integrate the social and economic development together with soil and water conservation

# Integrated Watershed Approach

**IWM is the process of planning and implementing water and natural resources ……. an emphasis on integrating the bio-physical, socio-economic and institutional aspects.**




**Social issues are addressed through involvement of women and minority.**

**Community led water users groups have led the implementation efforts.**

# Concepts and Principles of Integrated Watershed Management(IWM)

**Objectives:**

- Water has multiples uses and must be managed in an integrated way.
- Water should be managed at the lowest appropriate level.
- Water allocation should take account of the interests of all who are affected.
- Water should be recognised and treated as an economic good.

**Strategies:**

- A long term, viable sustainable future for basin stake holders.
- Equitable access to water resources for water users.
- The application of principles of demand management for efficient utilisation.
- Prevention of further environmental degradation (short term) and the restoration of degraded resources (long term). .

**Implementation Programs:**

- Comprise an overall strategy that clearly defines the management objectives, a delivery mechanisms and a monitoring schedule that evaluates program performance.
- Recognise that the development of water resources may require research, to assess the resource base through modelling and development of DSS, and to determine the linkage between water resources and the impacts on environment, socio-economy.
- Ensure that mechanisms and policies are established that enables long term support.

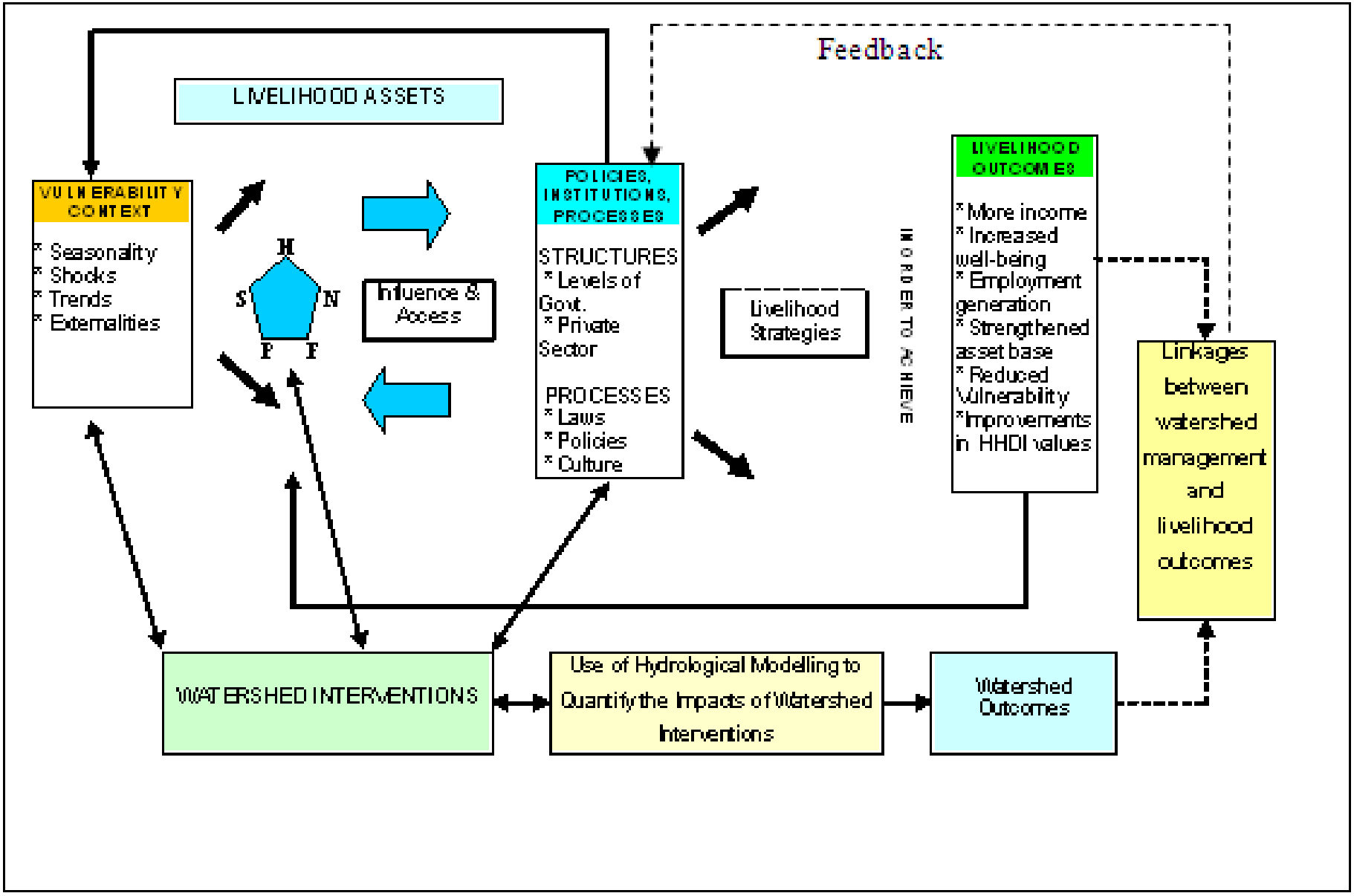



Figure 3.1 Watershed based sustainable livelihoods framework (Revised from DFID 2001)

# Objectives.....

- Ensuring judicious resource utilization without disturbing the ecological balance for sustaining livelihoods of local communities
- Soil and Water conservation or Land and water management is the means but sustainable production systems are the ends
- Use of Hydrological modeling to quantify the impacts of watershed interventions

# Watershed Development & Modelling

- Limited water resources,- more demand.

- **Watershed is the basic scientific unit.**
- **Need for proper planning and management.**
- **Integrated watershed development approach**
- **Digital revolution**
- **Recent advances in watershed modelling - use of computer models, remote sensing and GIS.**

# WATERSHED Development

- **Watershed Characteristics.**
- **Hydrology of watershed.**

| Watershed (ha) | Classification |
|---|---|
| 50,000-2,00,000 | Watershed |
| 10,000-50,000 | Sub-watershed |
| 1,000-10,000 | Milli- watershed |
| 100-1,000 | Micro-watershed |
| 10-100 | Mini-watershed |

# WATERSHED Development …

## Parameters of Watershed

- Size
- Shape
- Physiography
- Climate
- Drainage
- Land use
- Vegetation
- Geology and Soils
- Hydrology
- Hydrogeology
- Socioeconomics

# WATERSHED MODELLING …

**Watershed modelling steps**

1. Formulation
2. Calibration/verification
3. Application

**Watershed model constitutes**

1. Input function
2. Output function
3. Transform function

# WATERSHED MODELLING ...

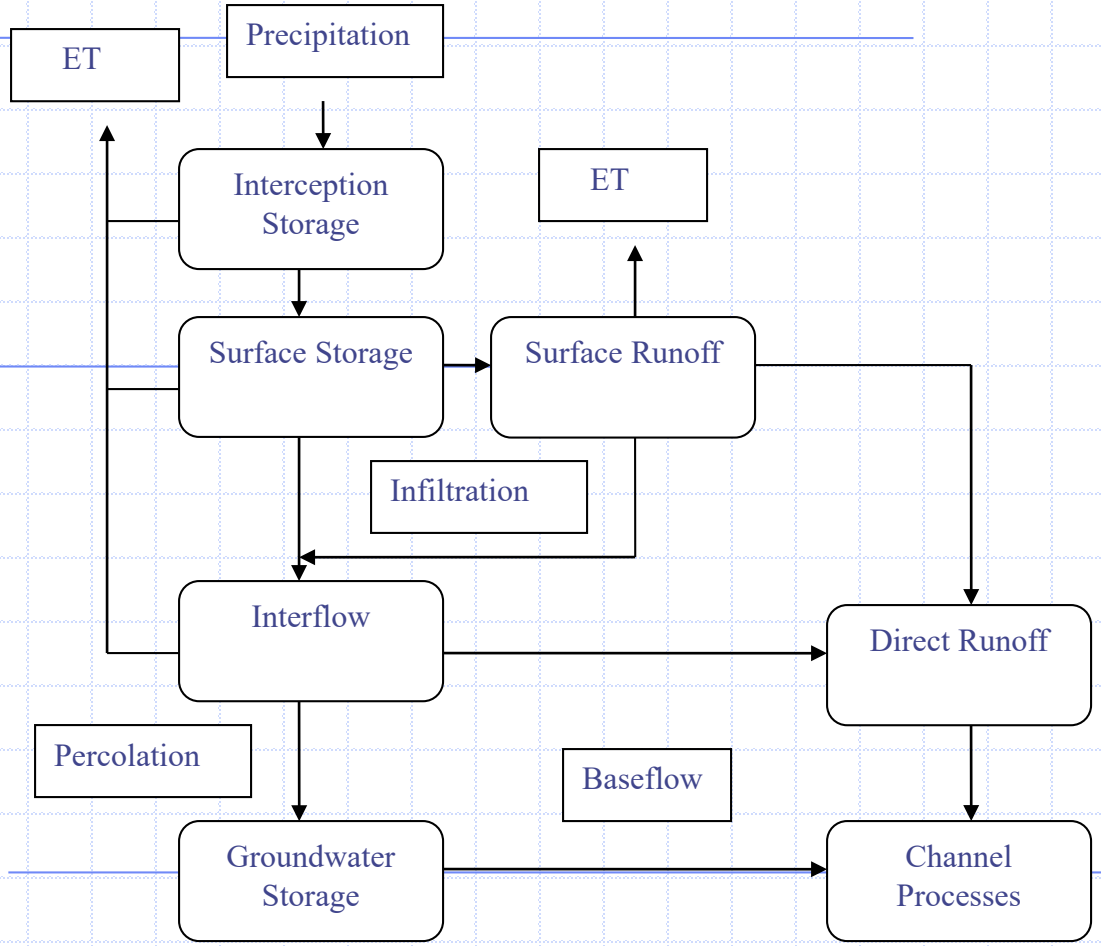



**Fig Flowchart of simple watershed model (McCuen, 1989)**

# WATERSHED MODELLING …

## General Classification of Models

**Broadly classified into three types**

***Black Box Models:*** **These models describe mathematically the relation between rainfall and surface runoff without describing the physical process by which they are related.**

**e.g. Unit Hydrograph approach**

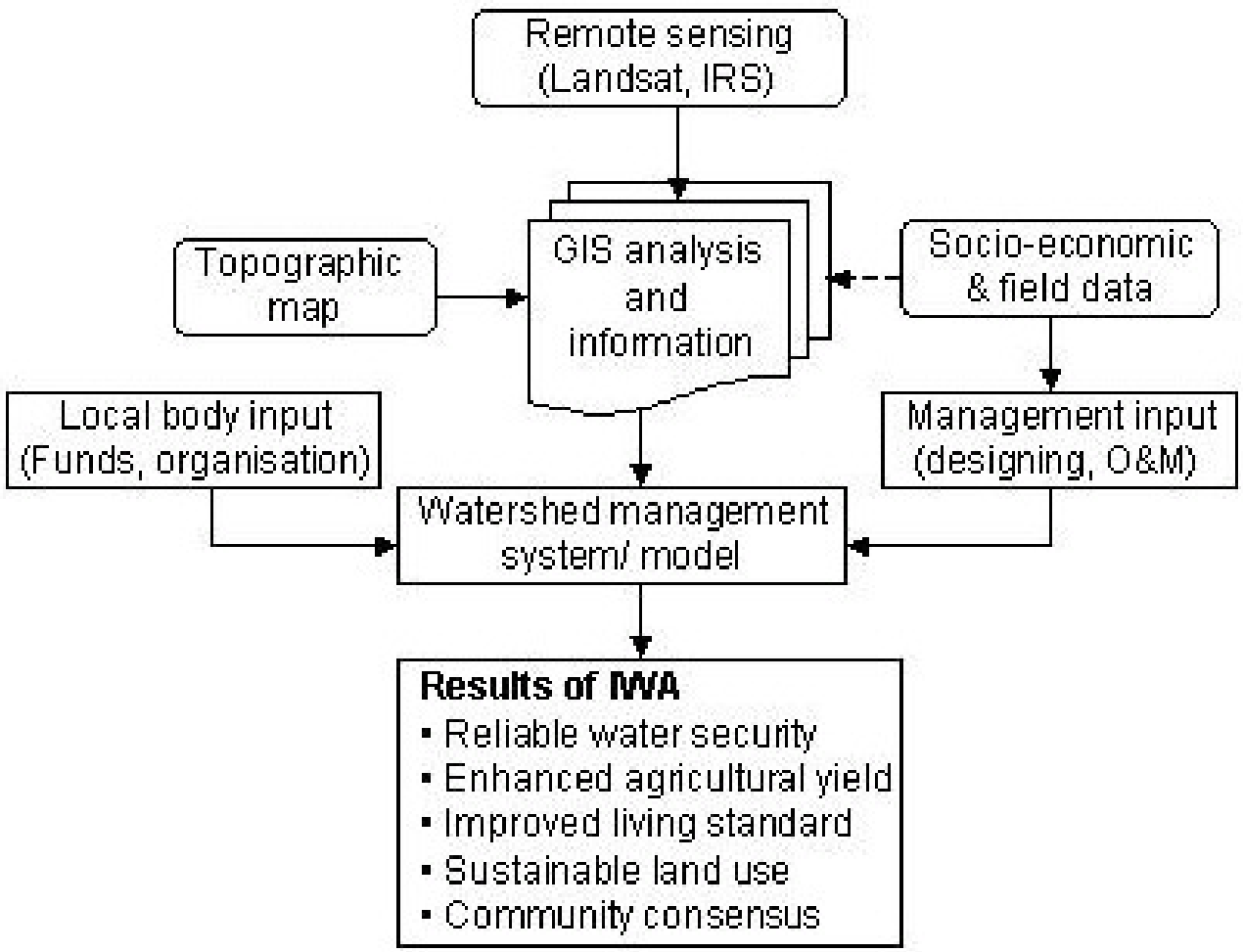
***Lumped models:***

**These models occupy an intermediate position between the distributed models and Black Box Models.** e.g. Stanford Watershed Model

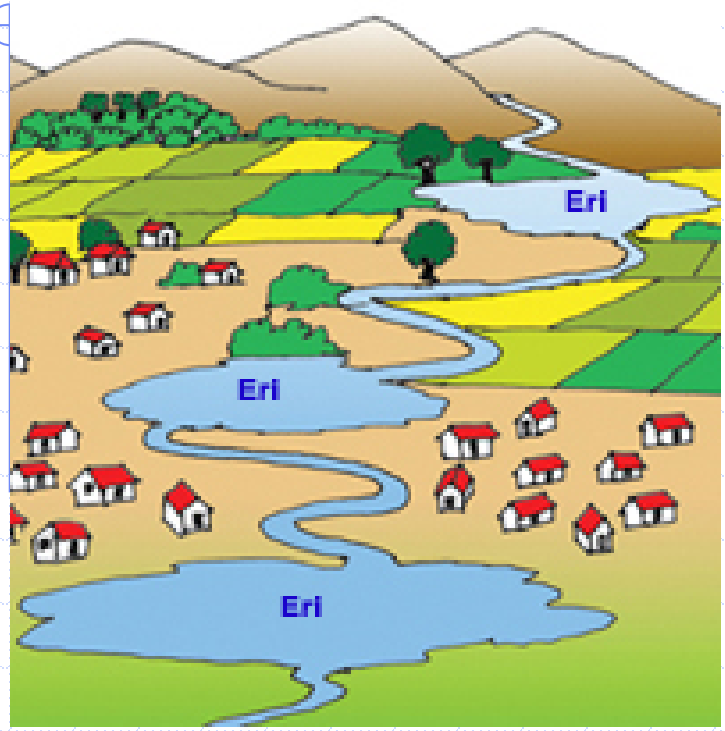
***Distributed Models:***

**These models are based on complex physical theory, i.e. based on the solution of unsteady flow equations (SWAT Model)**

# IWA – Modeling through Advanced Technologies



# Water Conservation & Harvesting





Total water management for sustainable development?.

# Water Conservation

- Important step for solutions to issues of water and environmental conservation is to change people's attitudes and habits
- Conserve water because it is right thing to do!.

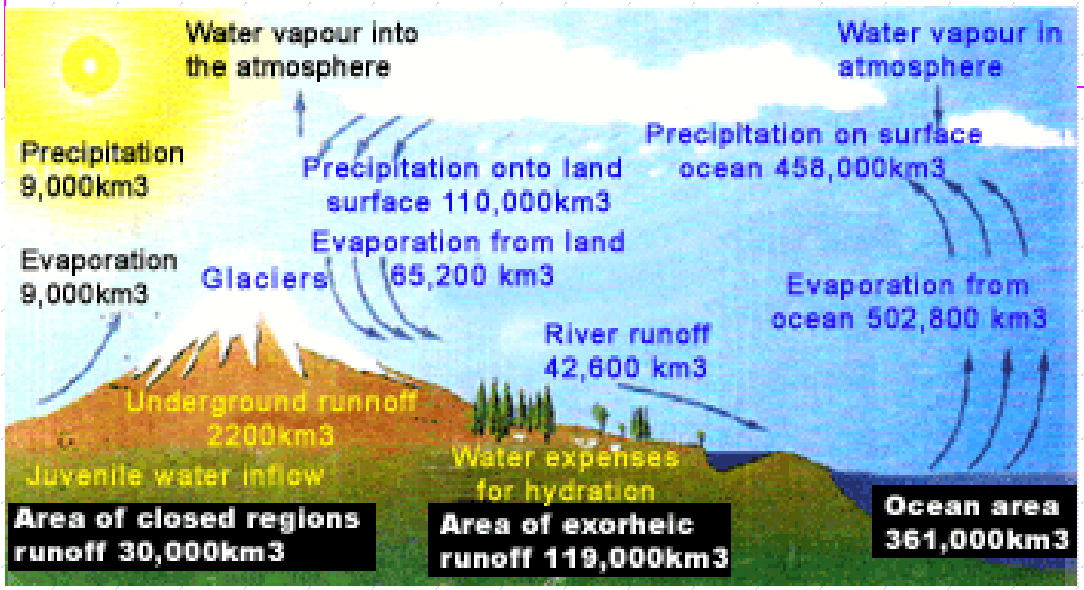
- **What you can do to conserve water**?
- Use only as much water as you require. Close the taps well after use. While brushing or other use, do not leave the tap running, open it only when you require it. See that there are no leaking taps.
- Use a washing machine that does not consume too much water. Do not leave the taps running while washing dishes and clothes.

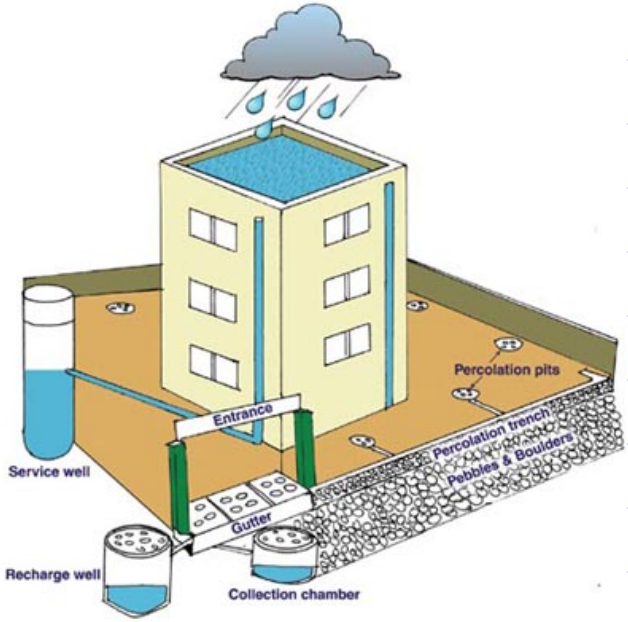
# Water Conservation…

- Install small shower heads to reduce the flow of the water. Water in which the vegetables & fruits have been washed - use to water the flowers & plants.
- At the end of the day if you have water left in your water bottle do not throw it away, pour it over some plants.
- Re-use water as much as possible
- Change in attitude & habits for water conservation
- Every drop counts!!!

# Rain Water Harvesting?.

- Rain Water Harvesting RWH- process of collecting, conveying & storing water from rainfall in an area – for beneficial use.
- Storage – in tanks, reservoirs, underground storage-groundwater
- Hydrological Cycle



# Rain Water Harvesting?.

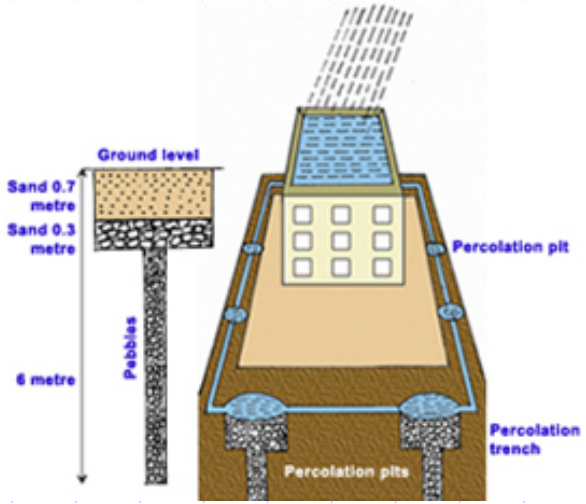
- RWH - yield copious amounts of water. For an average rainfall of 1,000mm, approximately four million litres of rainwater can be collected in a year in an acre of land (4,047 $m^2$), post-evaporation.

- As RWH - neither energy-intensive nor labour-intensive

- It can be a cost-effective alternative to other water-accruing methods.

- With the water table falling rapidly, & concrete surfaces and landfill dumps taking the place of water bodies, RWH is the most reliable solution for augmenting groundwater level to attain self-sufficiency

# RWH – Methodologies




- Roof Rain Water Harvesting
- Land based Rain Water Harvesting
- Watershed based Rain Water harvesting
  - For Urban & Industrial Environment –
    - Roof & Land based RWH
      - Public, Private, Office & Industrial buildings
      - Pavements, Lawns, Gardens & other open spaces

# Rain Water Harvesting– Advantages

1.Provides self-sufficiency to water supply

2.Reduces the cost for pumping of ground water

3.Provides high quality water, soft and low in minerals

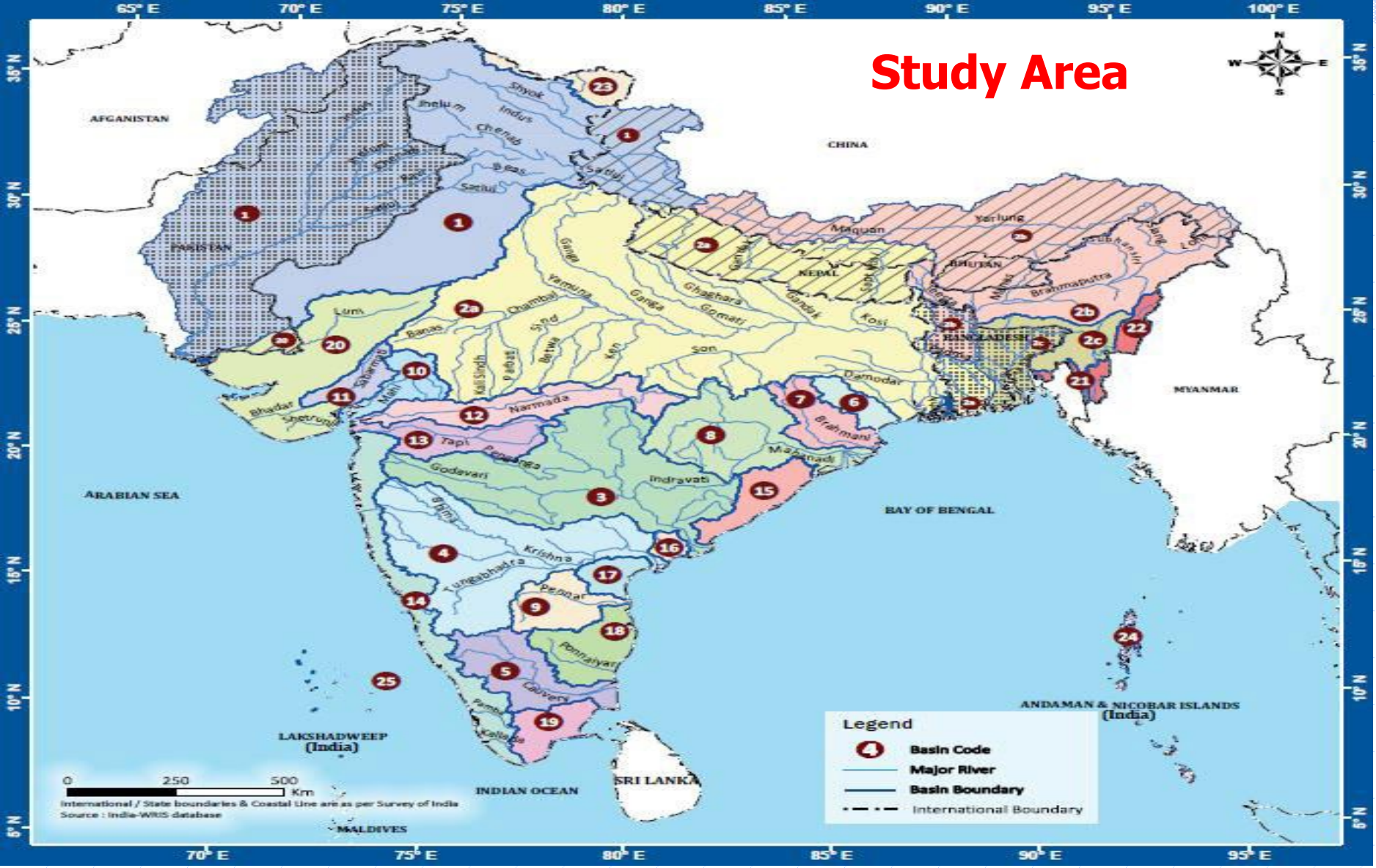
4.Improves the quality of ground water through dilution when recharged

5.Reduces soil erosion & flooding in urban areas

6.The rooftop rain water harvesting is less expensive & easy to construct, operate and maintain

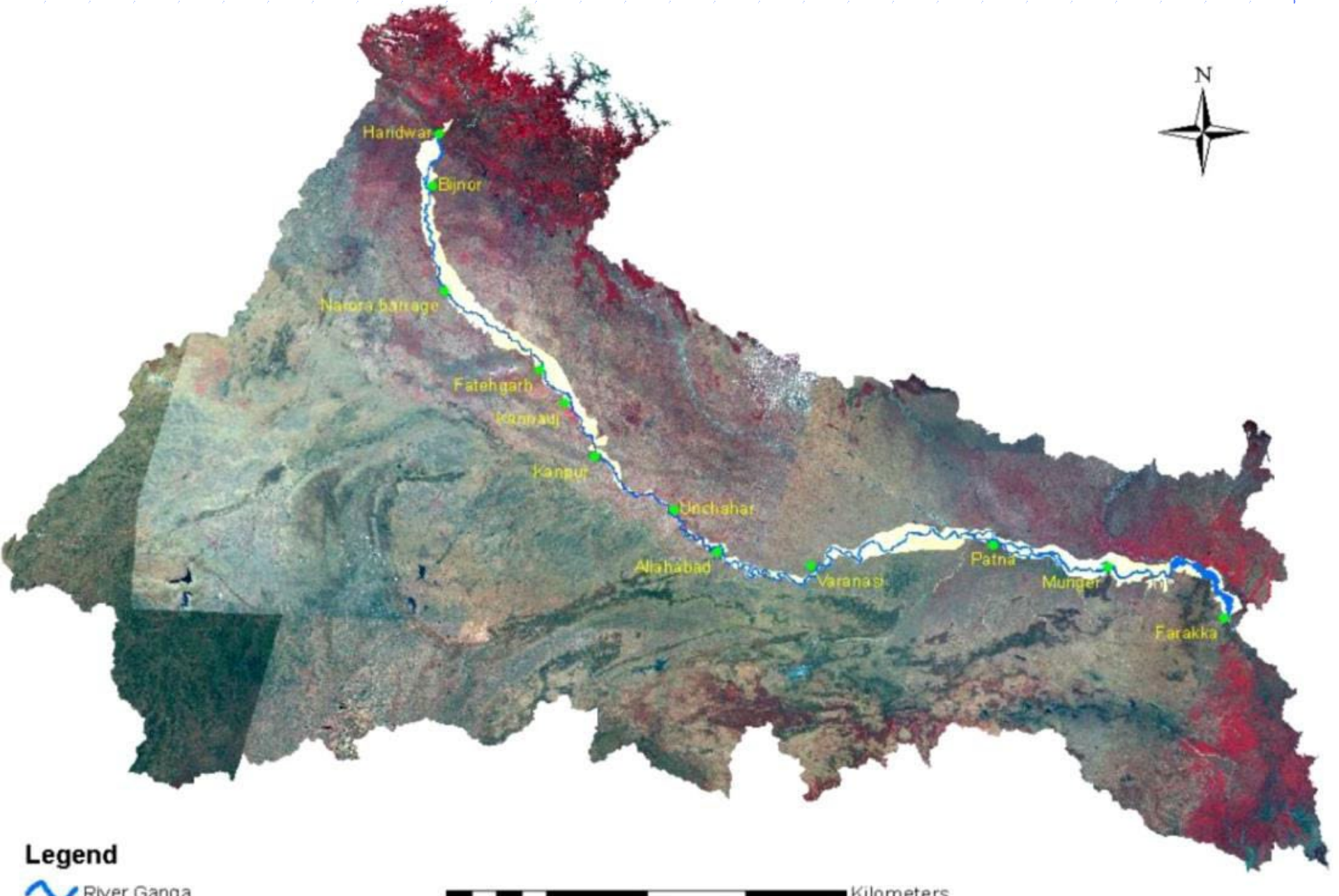
7. In desert, RWH only relief

8. In saline or coastal areas & Islands, rain water provides good quality water




**Main River Basins of India showing the Ganga River Basin (Yellow-region) [*India-WRIS, 2012*]**

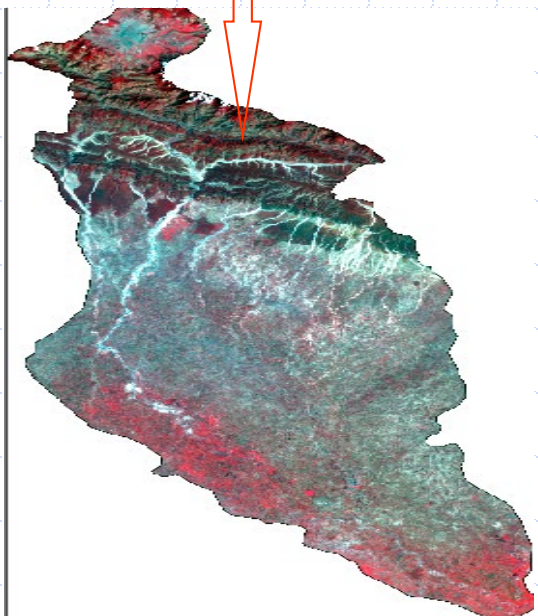
# Geomorphic Map of Ganga River Valley



# Catchment Area of Bagmati –a subwatershed of Ganga river basin = 1900 km$^2$

## Case Study





Salient features of Bagmati watershed

| | | |
|---|---|---|
| 1. | Total Drainage Area upto Hayaghat | 14,384 Sq Km |
| 2. | Drainage Area in Bihar | 6500 Sq Km |
| 3. | Population in Bihar | 55.30 Lakh |
| 4. | Mean annual flows | 2184.4 MCM |
| 5. | Average annual rainfall | 1255 mm |
| 6. | Total length of main river in Bihar | 394 Km |
| 7. | Cropped area in Bihar | 5362 Sq Km |
| 8. | Tributaries: Lalbakeya(R), Lakhandei(L), Darbhanga-Bagmati(L), Old kamla(L), Hasanpur Bagmati(R) | |

**Table 5.4** Landuse in the study area

| Sl No | Land use | Area in Sq Km | Percentage of Catchment area |
|---|---|---|---|
| 1. | Land under miscellaneous trees and groves | 273.91 | 4.21 |
| 2. | Fallow and waste land | | |
| I. | Current fallow | 417.13 | 7.17 |
| II. | Other follow | 505.15 | 8.1 |
| III. | Culturable waste | 76.91 | 1.11 |
| 3 | Net area under cultivation | 4318.52 | 66.44 |
| 4 | Barren land & permanent pastures | 106.43 | 1.64 |
| 5 | Area under non-agricultural use | 1295.84 | 19.94 |

# Simulation of Watershed Interventions through Modelling

- Integrated watershed management, typically involve interventions in order to bring about desirable changes. Interventions are in form of changes in landuse/covers like afforestation, development of pasture land, horticulture etc.; or alterations and additions to the landscape of watershed by creating structures like check dams, ponds etc.

- These watershed management activities affect the watershed hydrology (Calder 1999, Rao and Prasad 1997) especially with regard to water and sediment yields (Kothyari et al. 2002, Moehansyah et al. 2002, Bolton et al. 1991).

- Hydrological modelling can be used to measure the impact of watershed interventions on water and sediment yields.

# SIMULATING WATERSHED HYDROLOGY USING SWAT MODEL

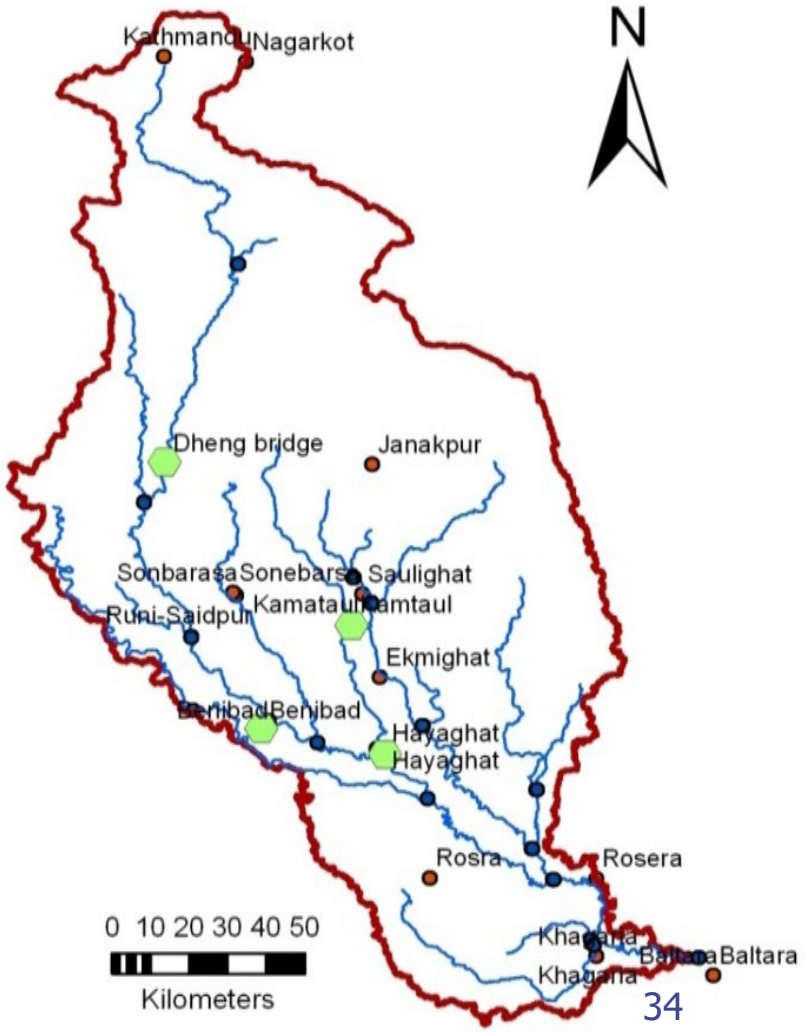
1. Resources Mapping using Geographical Information System
2. Assessment of water availability using SWAT MODEL
3. Developing Management Information System using web based water resource information system

# Results and Discussions

## Model Set up for Study Area - Bagmati river basin

- (1) DEM – SRTM (90 m resolution)
- (2) Landuse – Global USGS (2 M)
- (3) Soil – FAO Global soil (5 M)
- (4) Rain gauges /Temperature gauges – IMD
- (5)Stream Gauges – CWC
- (6) Rainfall data-
  IMD Data,
  Aphrodite Gridded rainfall data,
  real time rainfall data downloaded from websites

Gauge Stations and Stream Networks



# Watershed Delineation Steps

SRTM DEM

Mosaic or Masking if required

Burning with help of known watershed and river network

Fill Sinks

Direction

Flow Accumulation

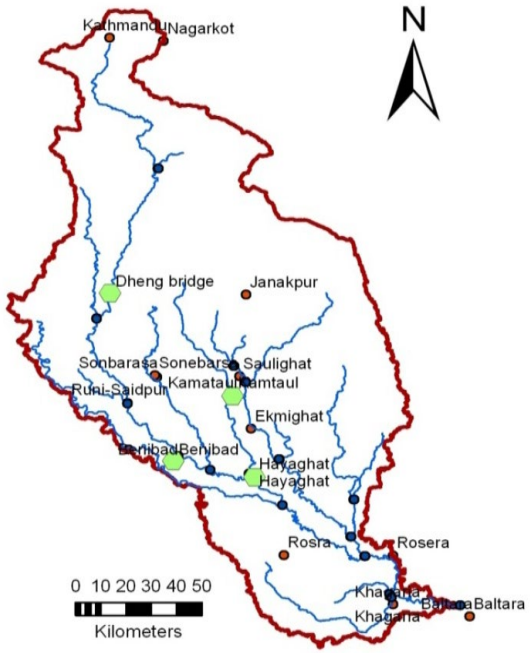
Network Extraction

Drainage Network Ordering

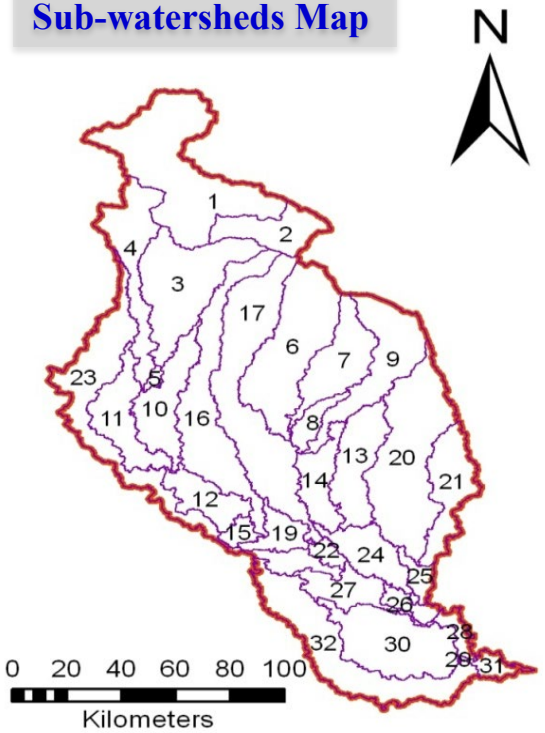
Catchment Extraction

Final Basin Boundary and Drainage map

**Stream Networks**



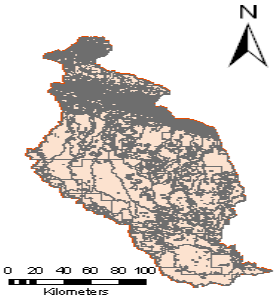

**Sub-watersheds Map**

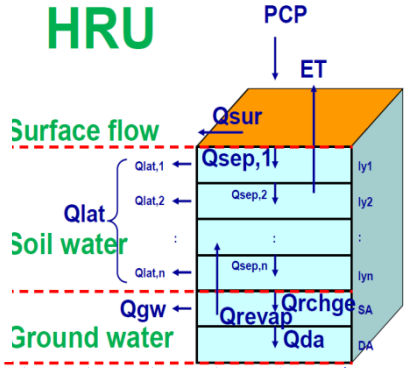


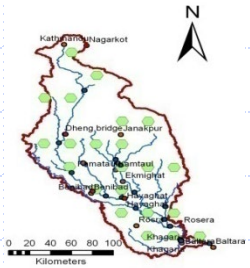
# Model Set up (In put Maps)

- Study area: Bagmati river basin, Bihar, India
- Watershed area: 1532353 ha. = 14384 km$^2$
- Total number of sub-watershed: 32 (threshold leve 30000 ha)
- Number of HRU formation: 206
- MULTIPLE HRUs LandUse/Soil/Slope OPTION :THRESHOLDS : 5 / 5 / 5 [%]
- Number of calibration points: 1 (Hayaghat)

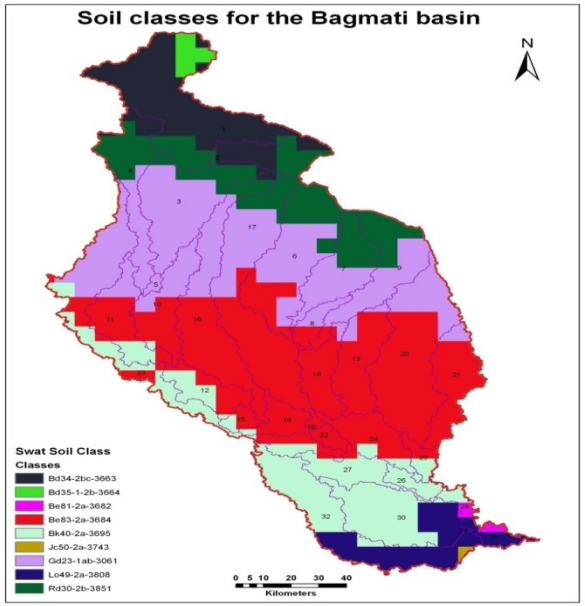
HRU Map



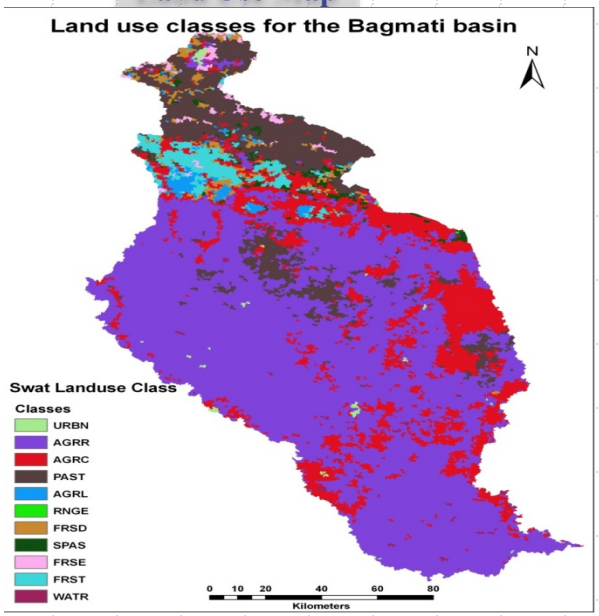



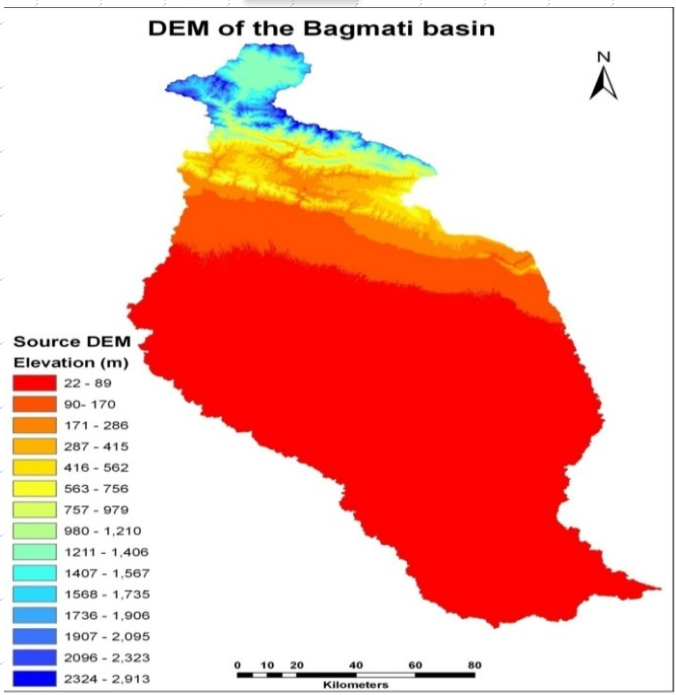

Soil type Map




Land Use Map




DEM



# Model Set up for study area

## Data sets used

- The SWAT model requires data on terrain, land use, soil, and weather for assessment of inflows and outflows of reaches. Following datasets have been used for setting up of the SWAT model:
- (1) DEM – SRTM (90 m resolution)
- (2) Landuse – Global USGS (2 M)
- (3) Soil – FAO Global soil (5 M)
- (4) Rain gauges /Temperature gauges – IMD

**Table 6.4**Details of landuse

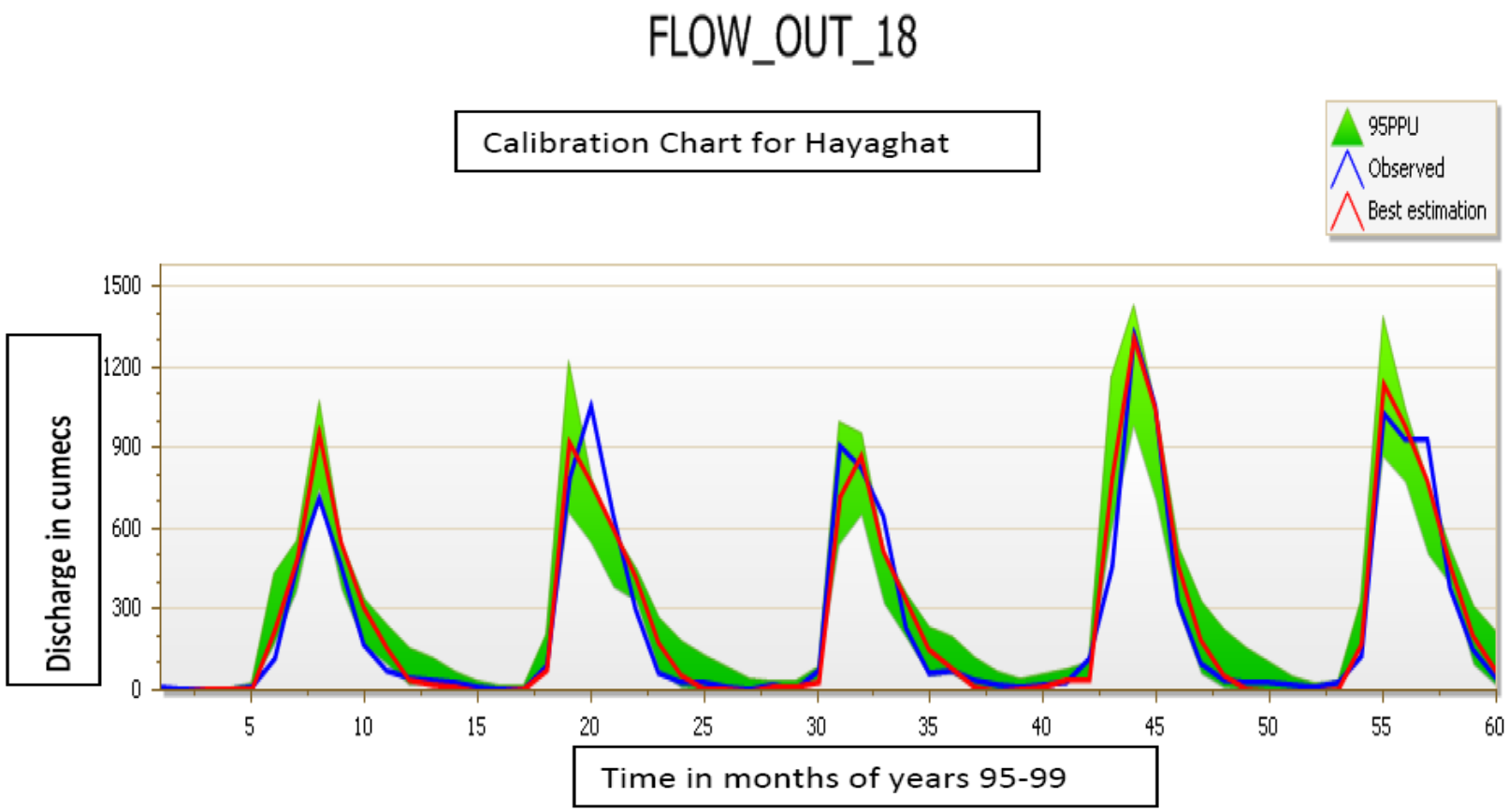
| NAME | GLB_LU | LANDUSE |
|---|---|---|
| URBN | URMD | Urban |
| AGRR | CRDY | Agricultural Land-Row Crop |
| AGRC | CRIR | Pasture |
| PAST | CRGR | Pasture |
| AGRL | CRWO | Agricultural Land-Generic |
| RNGE | GRAS | Range-Grasses |
| FRSD | SHRB | Forest-Deciduous |
| SPAS | SAVA | Summer Pasture |
| FRSE | FOEB | Forest-Evergreen |
| FRST | FOMI | Forest-Mixed |
| WATR | ICES | Ice/Water |

Table-6.2 Soil properties

# Soil Details

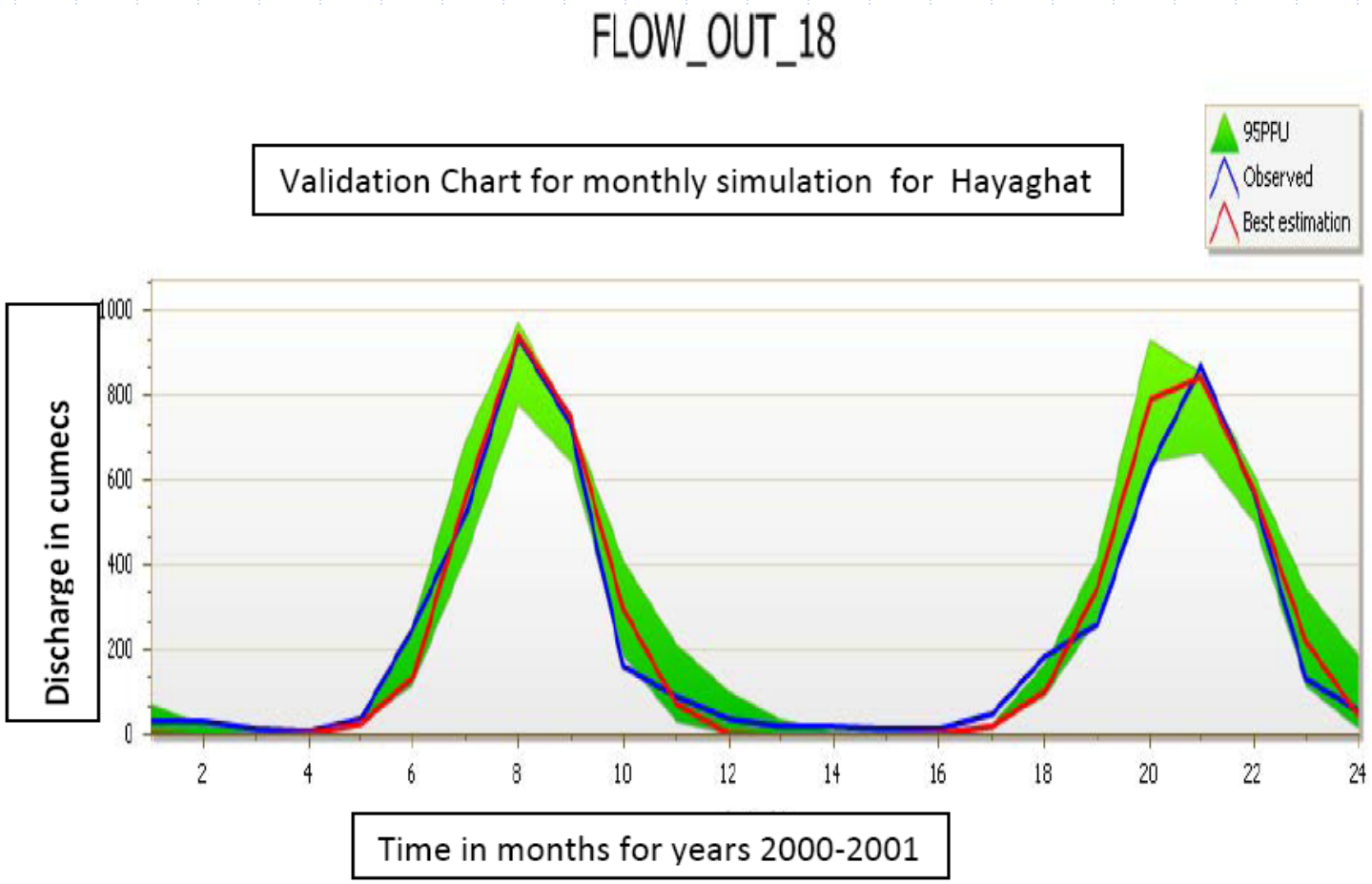
| SEQN | SNAM | NLAYERS | HYDGRP | TEXTURE | SOL_AWC1 | SOL_K1 | CLAY1 | SILT1 | SAND1 |
|---|---|---|---|---|---|---|---|---|---|
| 3663 | 3663 | 2 | C | LOAM | 0.117 | 35.65 | 24 | 35 | 42 |
| 3664 | 3664 | 2 | C | LOAM | 0.157 | 28.52 | 17 | 36 | 47 |
| 3682 | 3682 | 2 | D | LOAM | 0.175 | 7.77 | 24 | 36 | 40 |
| 3684 | 3684 | 2 | C | LOAM | 0.175 | 13.92 | 22 | 38 | 41 |
| 3695 | 3695 | 2 | C | LOAM | 0.175 | 14.96 | 20 | 40 | 40 |
| 3743 | 3743 | 2 | D | LOAM | 0 | 6.48 | 18 | 44 | 38 |
| 3761 | 3761 | 2 | C | LOAM | 0.175 | 24.73 | 20 | 34 | 46 |
| 3808 | 3808 | 2 | D | LOAM | 0.175 | 6.17 | 21 | 35 | 44 |
| 3851 | 3851 | 2 | D | CLAY_LOAM | 0.137 | 7.17 | 27 | 35 | 37 |

# Calibration - Output

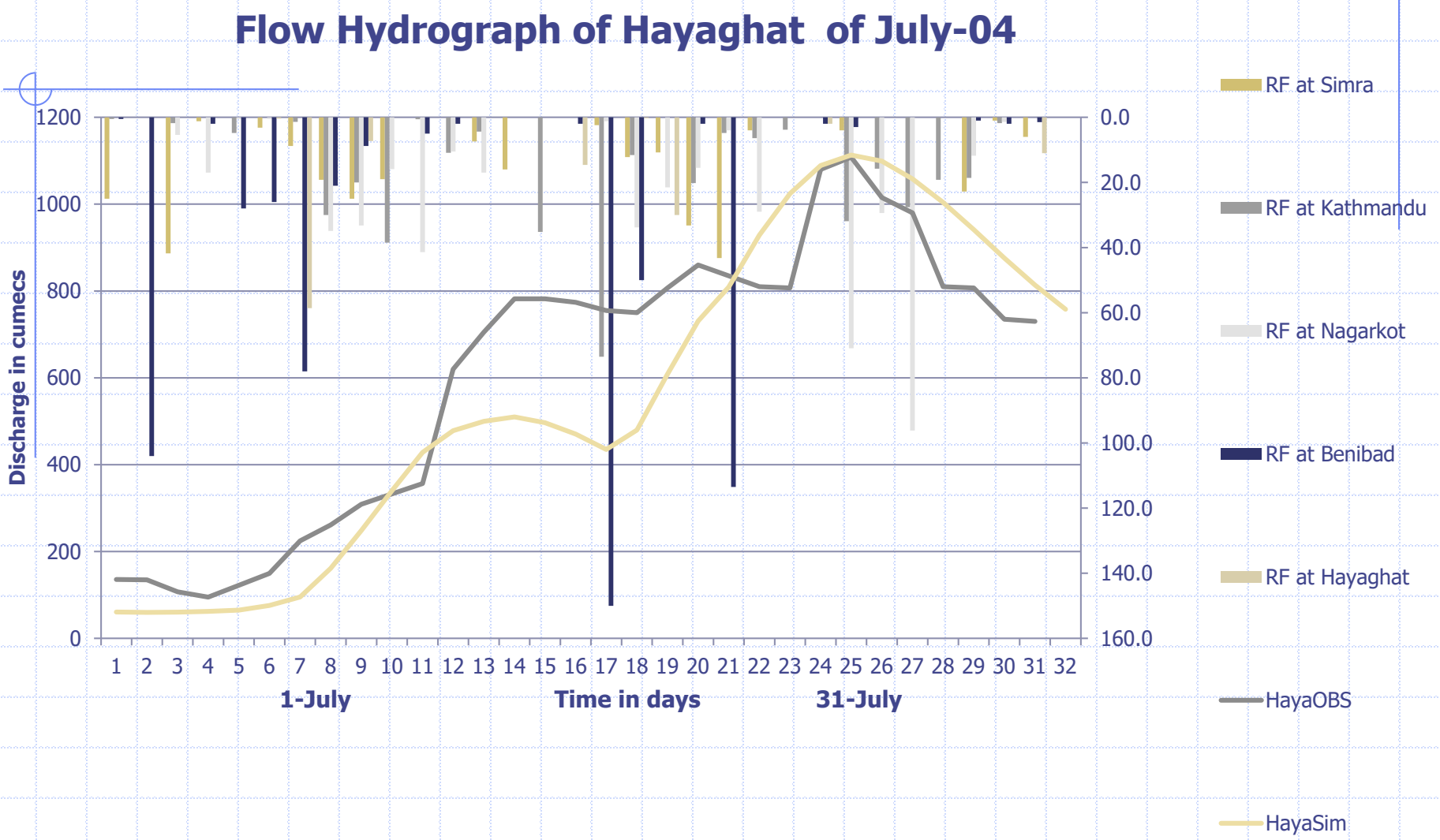



Discharge $m^3/s$

# Validation for monthly flow



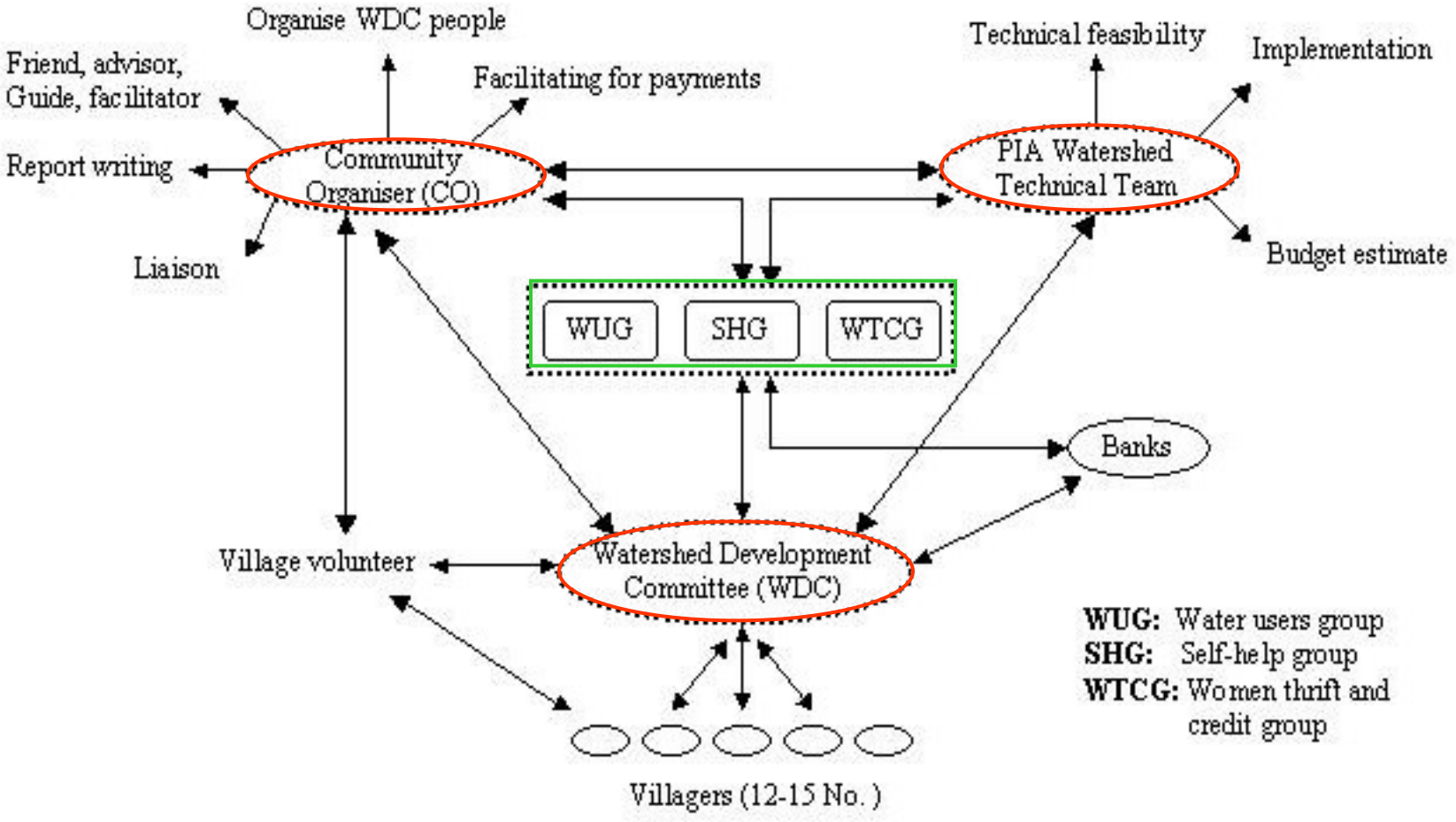
# Flow Hydrograph Daily Simulation



# Community participation and local capacity building

**Development of new village level institutions and local capacity building.**

**Operation & maintenance of structures, regulation of financial matters, and conflict resolution.**



## Discussion

Success interventions reside in integration of appropriate technical and managerial measures.

People's participation in the entire process are most important.

The benefits of water harvesting and water conservation definitely reached.

Thus, IWM approach may be characterised by

- Community management built on existing social structure,
- Project management drawn from village level organisations,
- Joint forest management with community participation,
- Self-help water user groups and community based banking institutions.

Limitation: 100% drought proofing for every water use can not be achieved.

## Concluding Remarks

**The integrated watershed management approach have the following major components:**

- **Promote sustainable economic development through optimum utilisation of natural resources and local capacity building.**

- **Restore ecological balance through community participation and cost affordable technologies for easy acceptance.**

- **Improving living conditions of the poorer through more equitable resources distribution and greater access to income generating activities by integrating watershed based sustainable livelihood framework.**

## Integrated Water Resources Development and Management ( IWRDM) is recommended for sustainable watershed management

Integration of -

- River basin resources- surface and ground.

- Demands - consumptive and non-consumptive, and supplies.

- Facilities - mega to micro.

- Human and eco-systems.

- S&T and engineering with social, economic, synergic needs.

END

THANK YOU