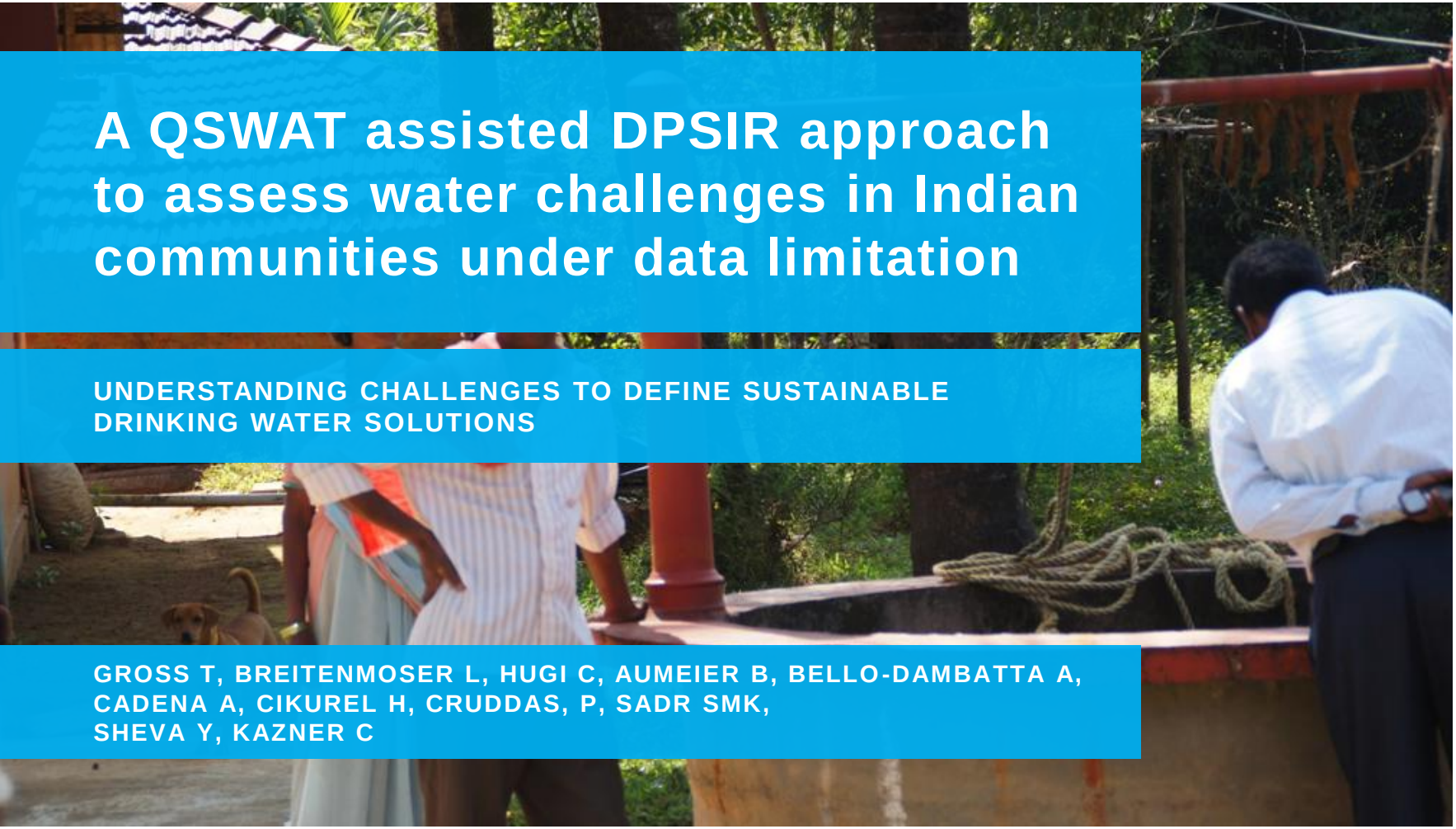
University of Applied Sciences and Arts Northwestern Switzerland
School of Life Sciences



# A QSWAT assisted DPSIR approach to assess water challenges in Indian communities under data limitation

## UNDERSTANDING CHALLENGES TO DEFINE SUSTAINABLE DRINKING WATER SOLUTIONS

GROSS T, BREITENMOSER L, HUGI C, AUMEIER B, BELLO-DAMBATTA A, CADENA A, CIKUREL H, CRUDDAS, P, SADR SMK, SHEVA Y, KAZNER C

# OVERVIEW

1. Background
   - Developments influencing water resources in India
   - Urban *vs.* rural drinking water situation
   - Institutional set-up of Indian water sector
2. Methodology
   - DPSIR at riverbasin and community scale
   - Riverbasin modelling with QSWAT
   - Two case sites in Karnataka
3. Results
   - QSWAT model set-up and verification
   - Water situation analysis
   - Implications for drinking water
4. Conclusions and outlook

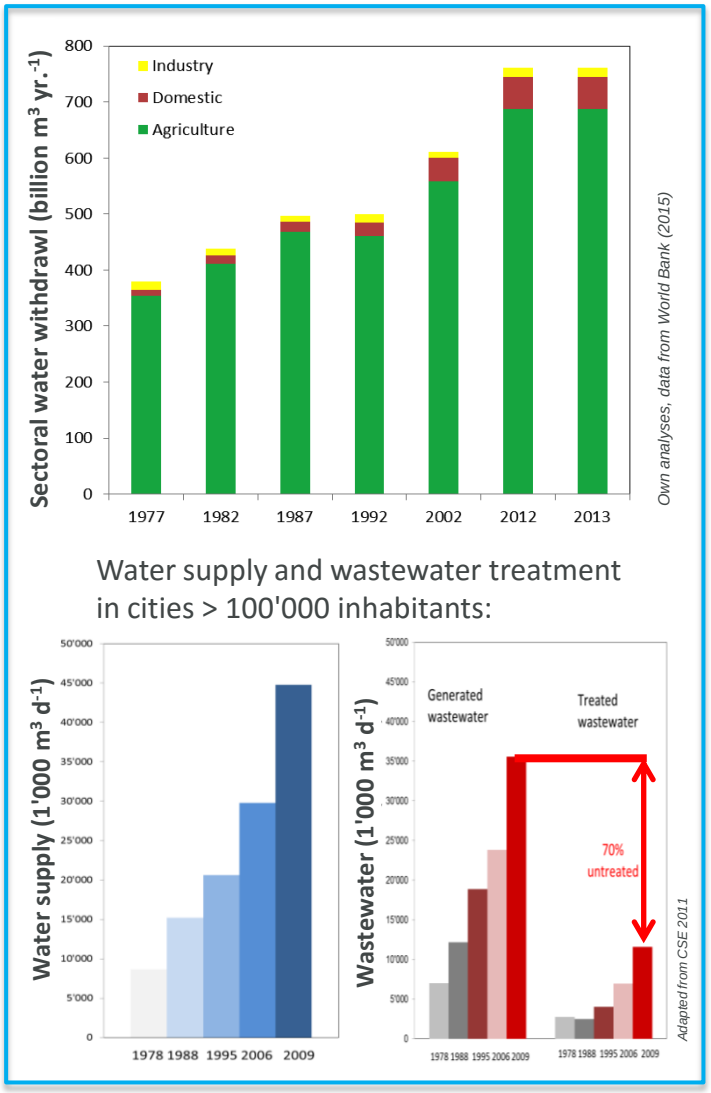
# Background

# DEVELOPMENTS INFLUENCING WATER RESOURCES IN INDIA

**Population growth**


**Industrialization**


**Urbanization**


**Depletion of water resources**

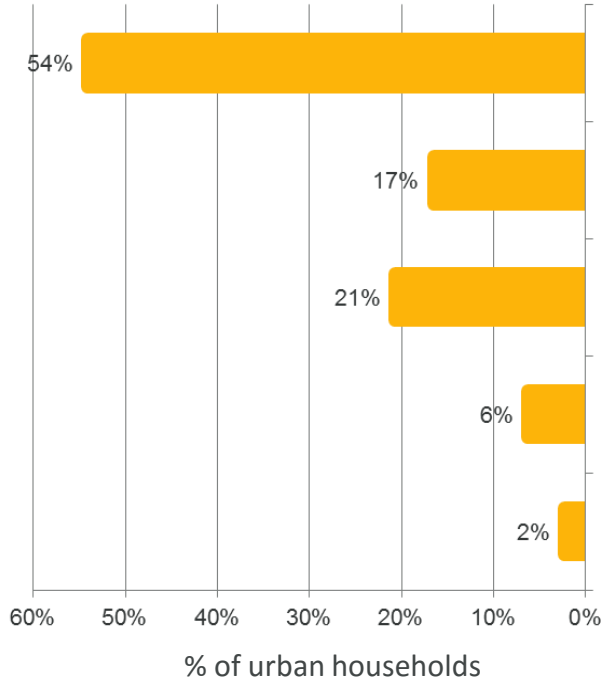

**Water pollution**


World Bank (2015). World development indicators. http://www.worldbank.org

# DISPARITIES IN DRINKING WATER SITUATION
## URBAN *VS.* RURAL



India URBAN



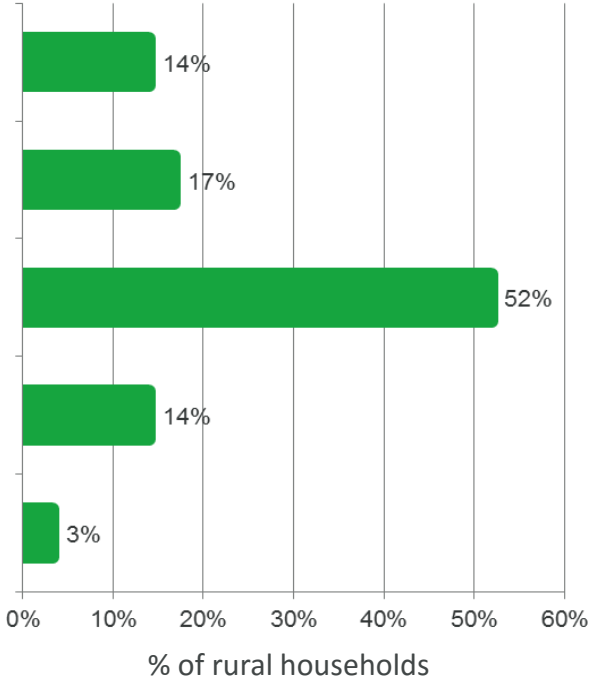

Household connections

Standposts

Tubewell, handpumps

Wells, protected springs

Unprotected source, shallow handpums, canals




India RURAL

Data used: Government of India (2011)

# IMPROVING DRINKING WATER SUPPLY

## National Rural Drinking Water Programme (NRDWP)




A

B

C

D

E

**Unprotected source, shallow handpumps, canals**

**Wells, protected springs**

**Tubewells, handpumps**

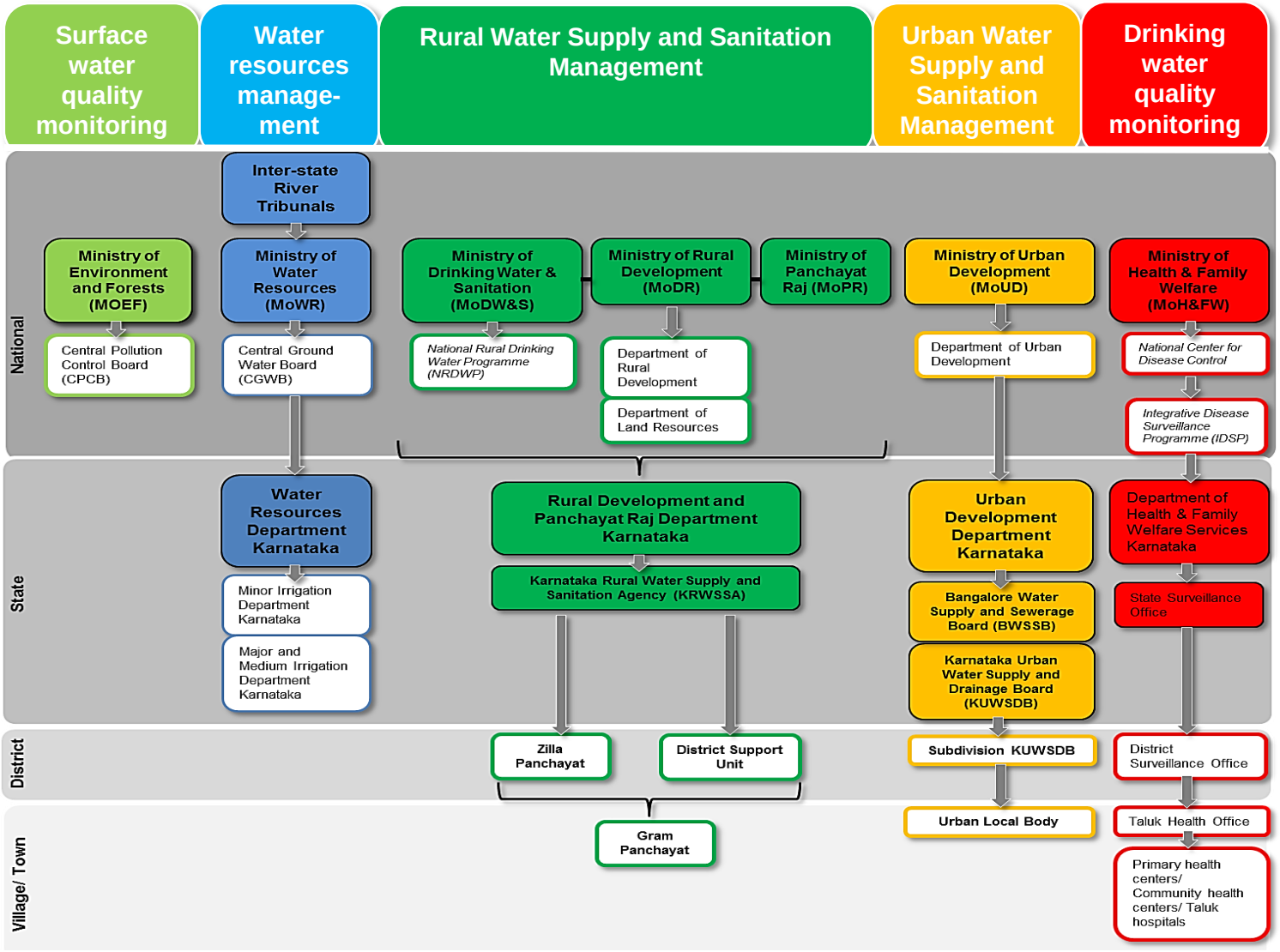
**Standposts**

**Household connections, individual & multiple**

| NRDWP targets | 2017 | 2022 |
|---|---|---|
| **Rural** households with access to **piped** water from **treated** source | **≥ 50%** | **≥ 90%** |
| Minimum water **supply** (per person and day) | **≥ 55 L** | **≥ 70 L** |

# MANY COOKS INVOLVED

## Overlapping responsibilities, lacking coordination




Institutional analysis for Karnataka State, © L Breitenmoser

# EFFECTIVITY AND COST-EFFICIENCY
## From sectoral to system view

**Interdisciplinary and multi-sectoral coordination** for effective and cost-efficient drinking water solutions

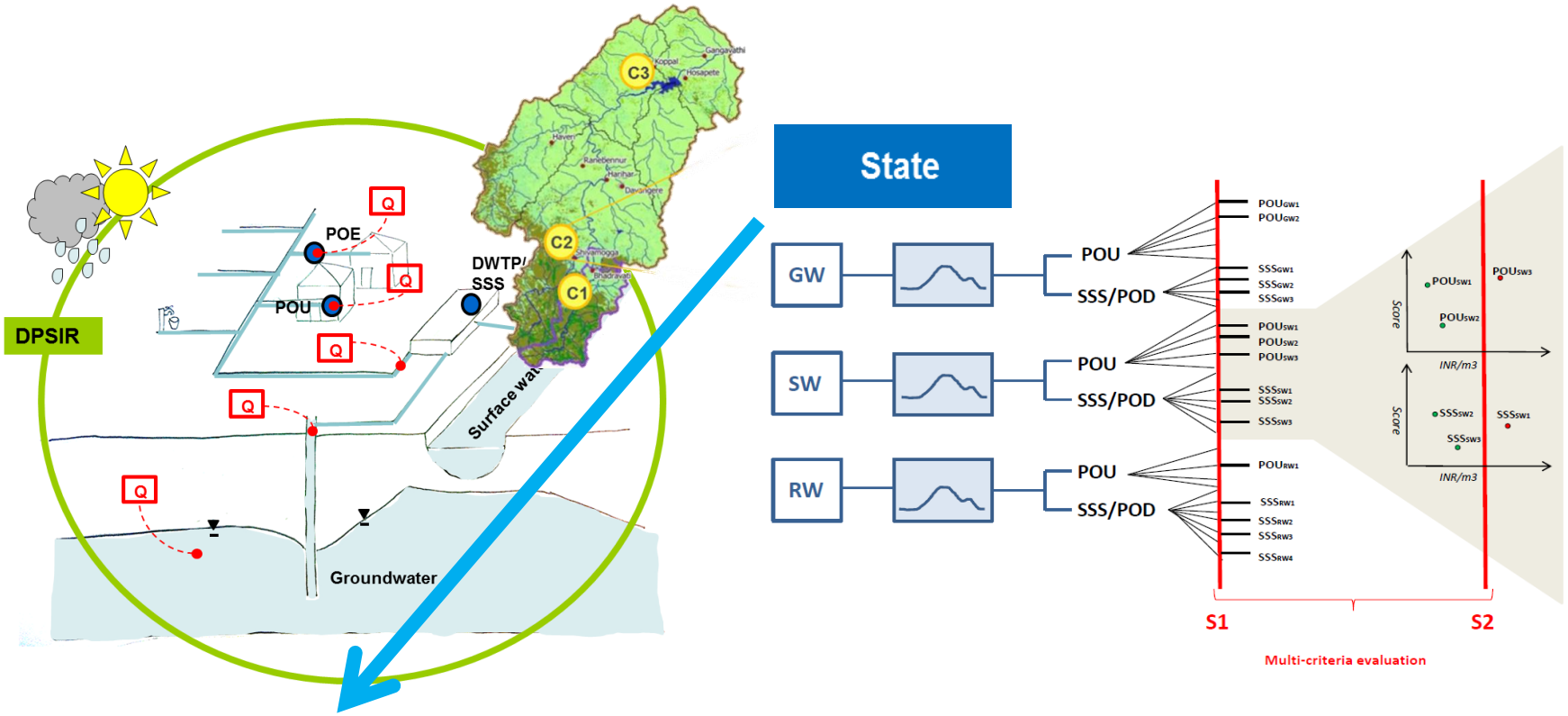
→ Selection of **effective** solutions requires knowledge on water quality state under current and future conditions, e.g. until 2022 (NRDWP), 2030 (SDGs) and longer

→ **Cost-efficient** solutions for society (community, riverbasin, nation) demand for multi-sectoral coordination at relevant scales

# Methodology

# RIVERBASIN, COMMUNITY, TECHNOLOGY

## DPSIR, QSWAT AND WetSuit




**Concept:**

**Drivers-Pressures-State-Impacts-Response (DPSIR)**

**Riverbasin model:**

**QSWAT**

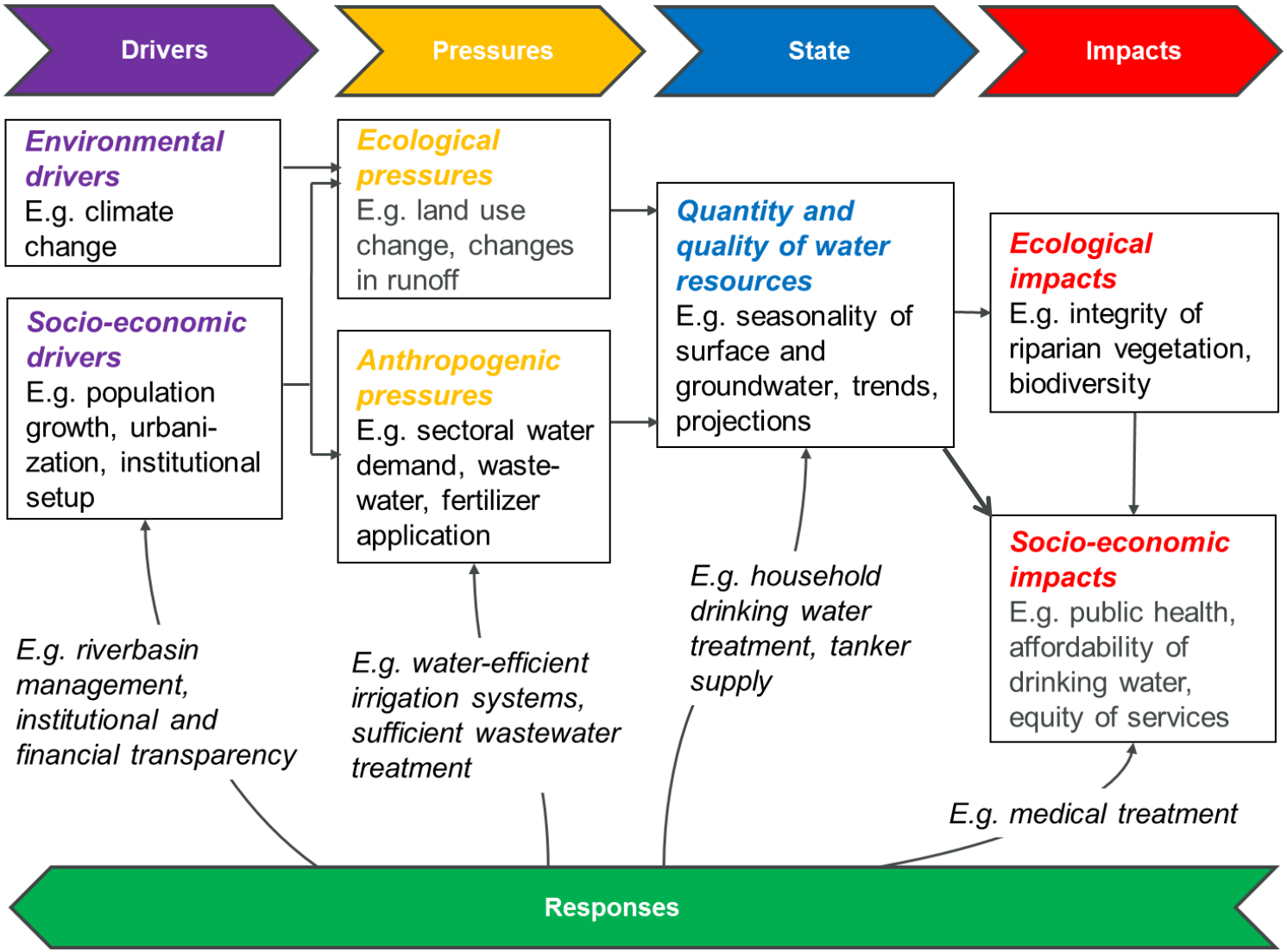
**Technology selection:**

**WetSuit**

→Presentation by Mr. Seyed Sadr

# WATER SITUATION IN COMMUNITIES

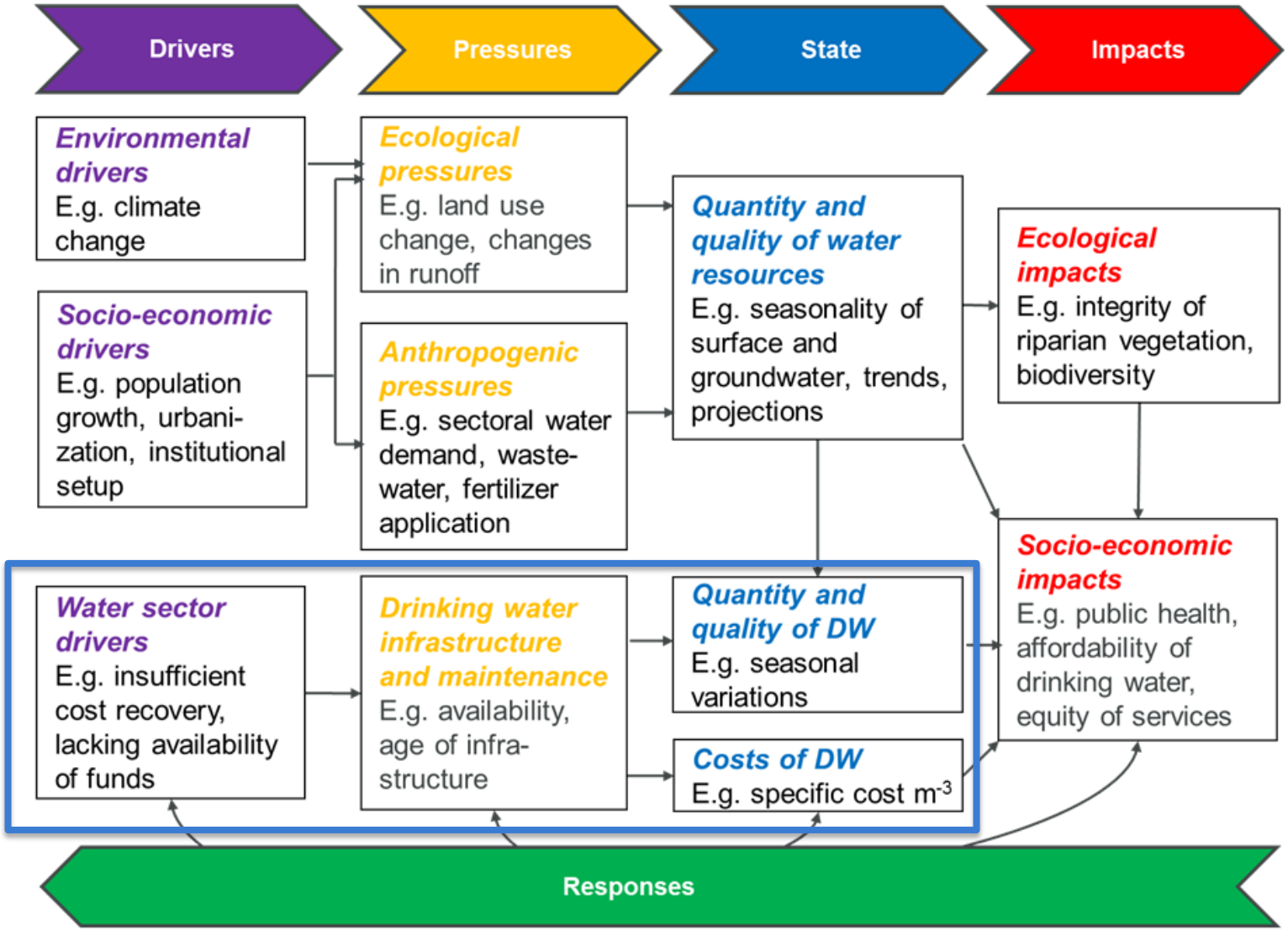
## Riverbasin cause-effects chains with DPSIR




Original DPSIR framework: EEA 1999

# WATER SITUATION IN COMMUNITIES

## Integration of drinking water infrastructure

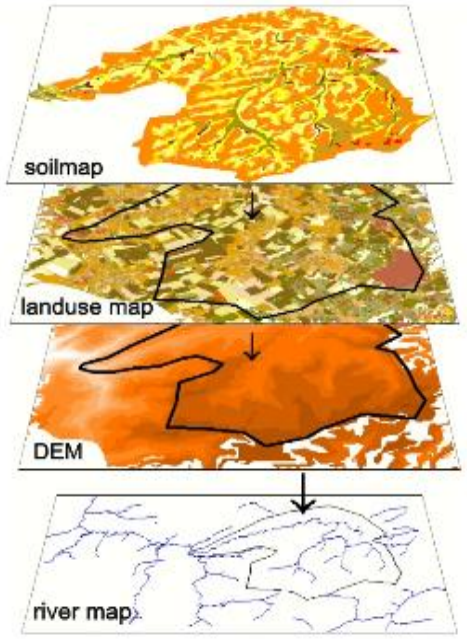



On the integration of infrastructure: Kossida et al. 2009

# DPSIR AND WATER MODELS

## Open source toolset applied

### SWAT: Soil and Water Assessment Tool




- **Physically based, spatially distributed**
- **Water quantity and quality** (nutrients, sediments, pesticides, bacteria etc.)
- Yearly, monthly, **daily modelling**
- Integration of **point- and non-point pollution sources** as well as sectoral water use
- Simulation of **changes** (climate, land use etc.)

http://swat.tamu.edu

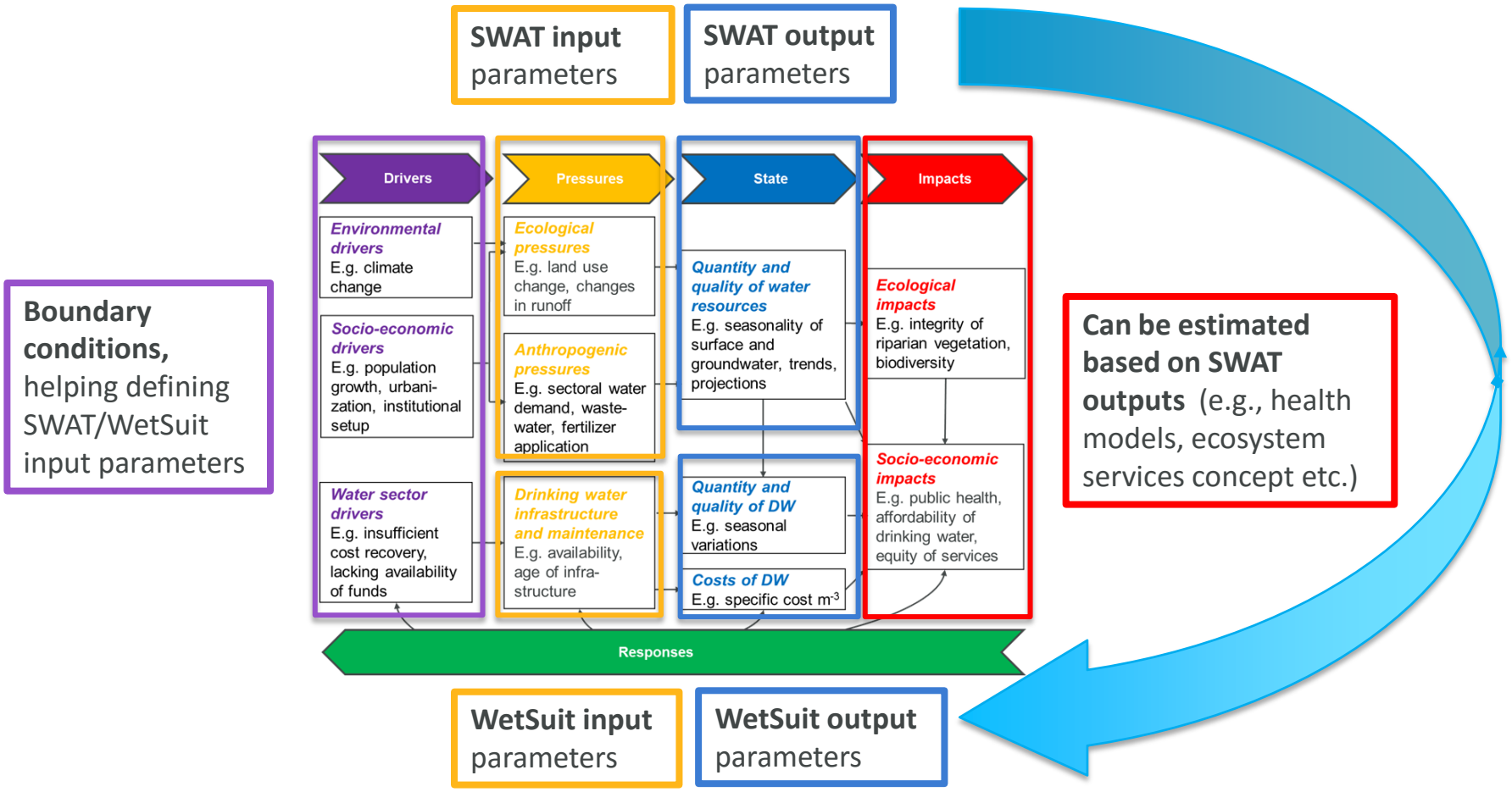
### QSWAT: Plug-in to QGIS

Newly released **QSWAT**: Integration SWAT with open source QGIS

http://swat.tamu.edu/software/qswat

# DPSIR AND WATER MODELS

## Integration of infrastructure

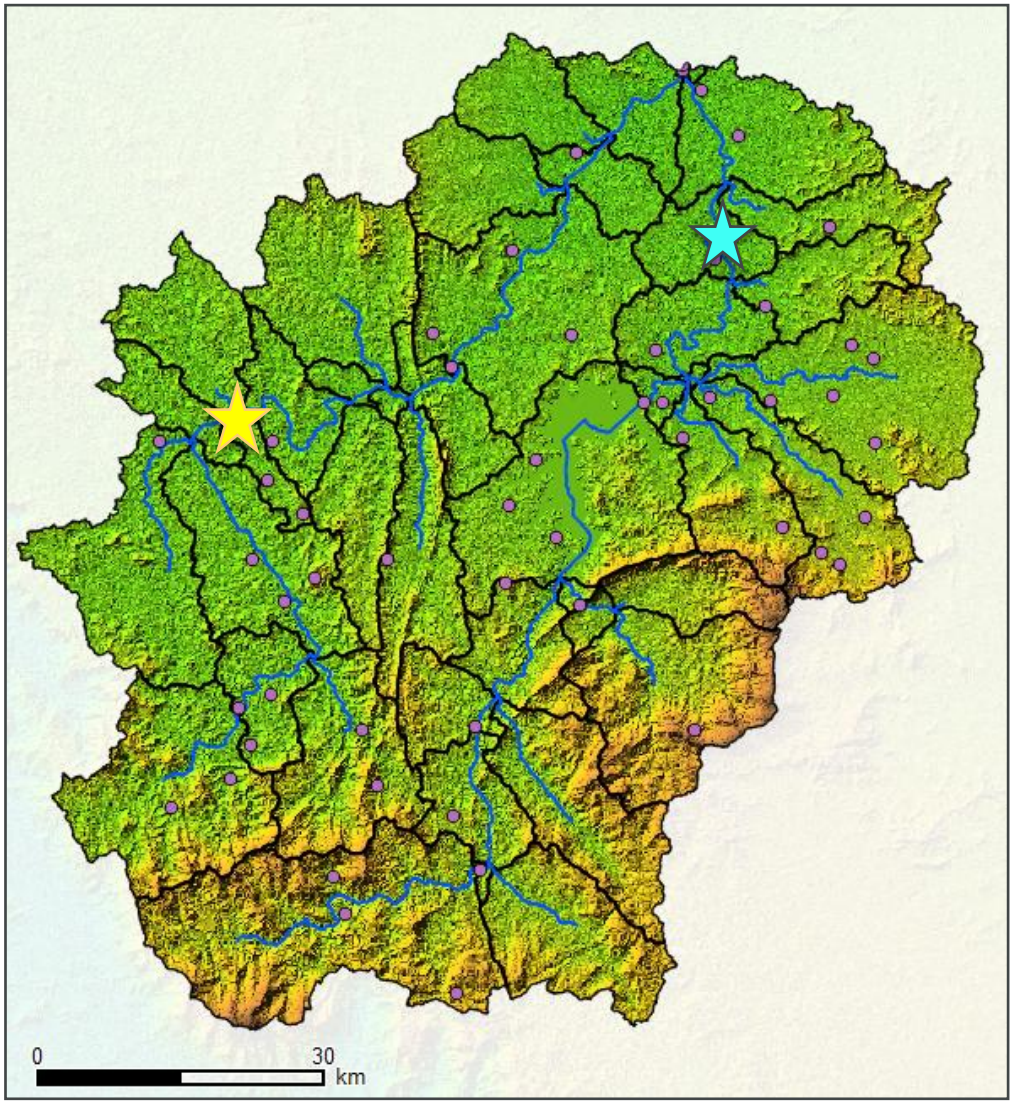



WetSuit is a drinking water technology selection tool developed in the **Water4India Project**

On the integration of infrastructure: Kossida et al. 2009

# CASE STUDY SITES

## Upper Tungabhadra Riverbasin


**Thirthahalli Town** (ca. 14'000 inhabitants) in **Tunga Riverbasin**

**Bhadravati CMC** (ca. 150'000 inhabitants) in **Bhadra Riverbasin**

Subbasins

Streams

# Results & Discussion

# MODEL SETUP AND VERIFICATION

## Basic data available at coarse resolutions (excerpt)

| Data type | Scale/resolution | Description | Data source |
|---|---|---|---|
| Digital elevation model (DEM) | 1' (ca. 30 m) | Topography | Aster: https://asterweb.jpl.nasa.gov/gdem.asp |
| Land cover | 5' (ca. 150 m) | Major land cover classes | Modis: http://glcf.umd.edu/data/lc |
| Soil | 1:5'000'000 | Major soil classes | FAO world soil map: |
| Weather | Ca. 38 km | Meteorological reanalysis data | CFSR: http://globalweather.tamu.edu/ |
| Population statistics | NA | Government of India, www.censusindia.gov.in | Government of India (1991, 2001 and 2011) |
| District statistics | NA | Fertilizer application, main crops | Government of India, Shimoga District administration: District statistics booklet: http://www.shimoga.nic.in/stats.htm |

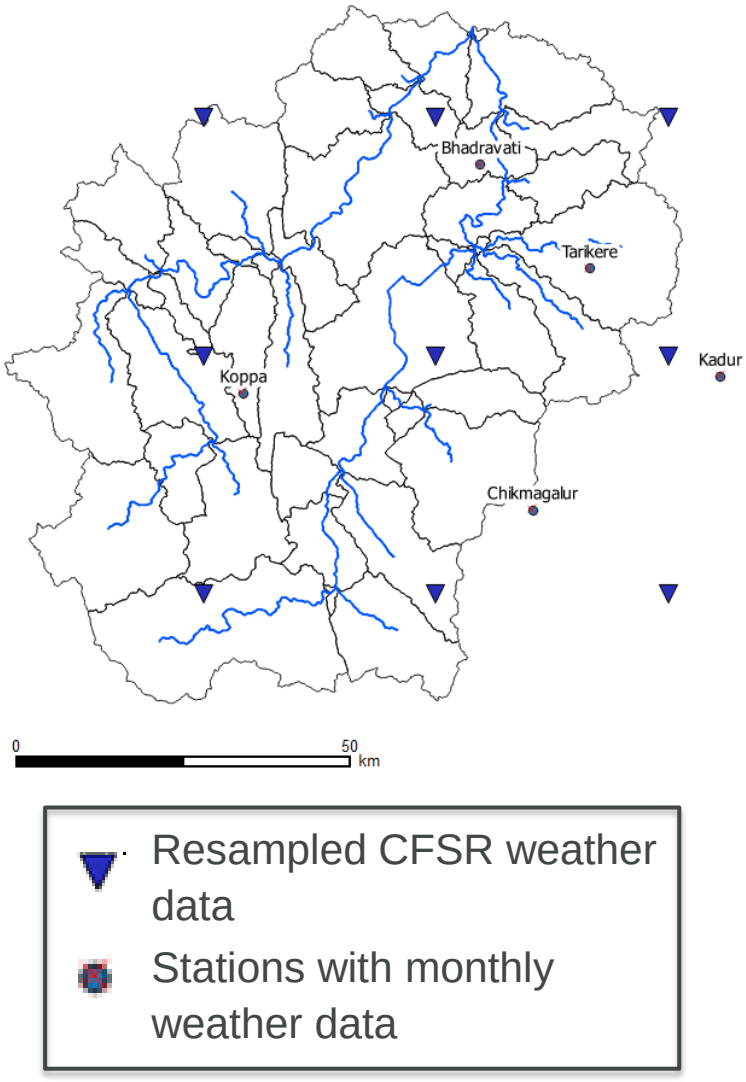
# MODEL SETUP AND VERIFICATION

## Basic data available at coarse resolutions (excerpt)

| Data type | Scale/resolution | Description | Data source |
|---|---|---|---|
| Digital elevation model (DEM) | 1' (ca. 30 m) | Topography | Aster: https://asterweb.jpl.nasa.gov/gdem.asp |
| Land cover | 5' (ca. 150 m) | Major land cover classes | Modis: http://glcf.umd.edu/data/lc |
| Soil | 1:5'000'000 | Major soil classes | FAO world soil map: |
| Weather | Ca. 38 km | Meteorological reanalysis data | CFSR: http://globalweather.tamu.edu/ |
| Population statistics | NA | Government of India, www.censusindia.gov.in | Government of India (1991, 2001 and 2011) |
| District statistics | NA | Fertilizer application, main crops | Government of India, Shimoga District administration: District statistics booklet: http://www.shimoga.nic.in/stats.htm |

# MODEL SETUP AND VERIFICATION

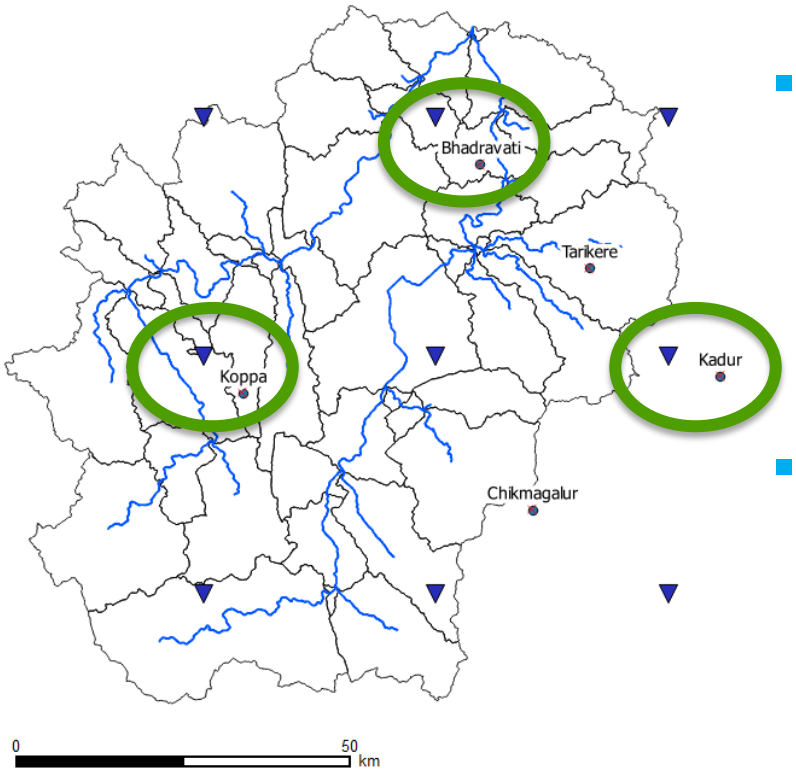
## Climate and weather data




- **High quality weather data** (temperature, precipitation, wind, solar radiation, relative humidity) at high resolution are **scarce in developing countries**
- **Global reanalysis weather data** are available globally and have yielded good results in water modelling (Fuka et al. 2014, Dile and Srinivasan 2014)
- Here: **Climate Forecast System Reanalysis (CFSR)** available at: http://globalweather.tamu.edu

# MODEL SETUP AND VERIFICATION

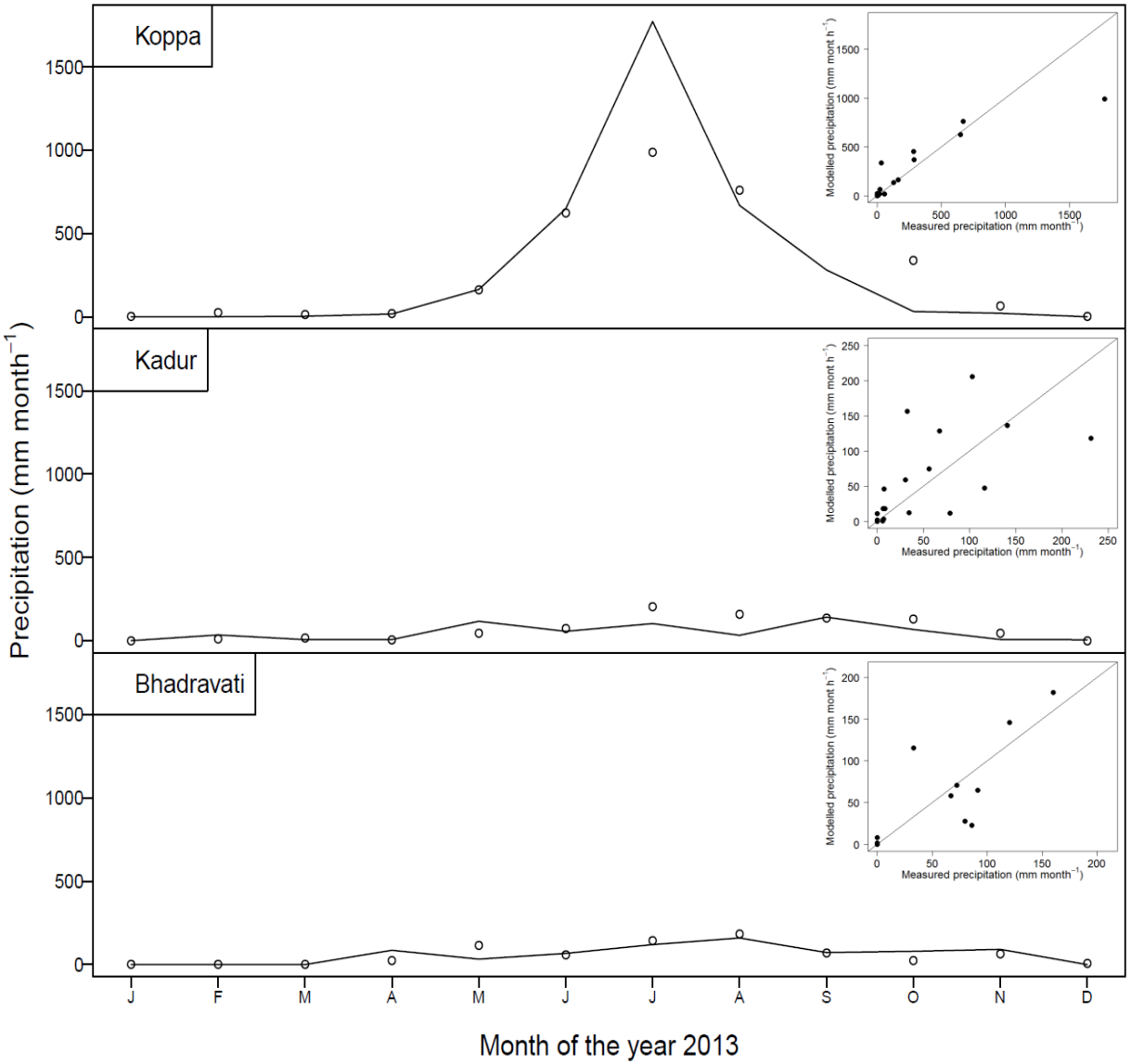
## Climate and weather data




- **High quality weather data** (temperature, precipitation, wind, solar radiation, relative humidity) at high resolution are **scarce in developing countries**
- **Global reanalysis weather data** are available globally and have yielded good results in water modelling (Fuka et al. 2014, Dile and Srinivasan 2014)
- Here: **Climate Forecast System Reanalysis (CFSR)** available at: http://globalweather.tamu.edu

# MODEL SETUP AND VERIFICATION

## CSFR weather *vs.* weather stations




**Fair to good agreement** with monthly statistics from weather stations

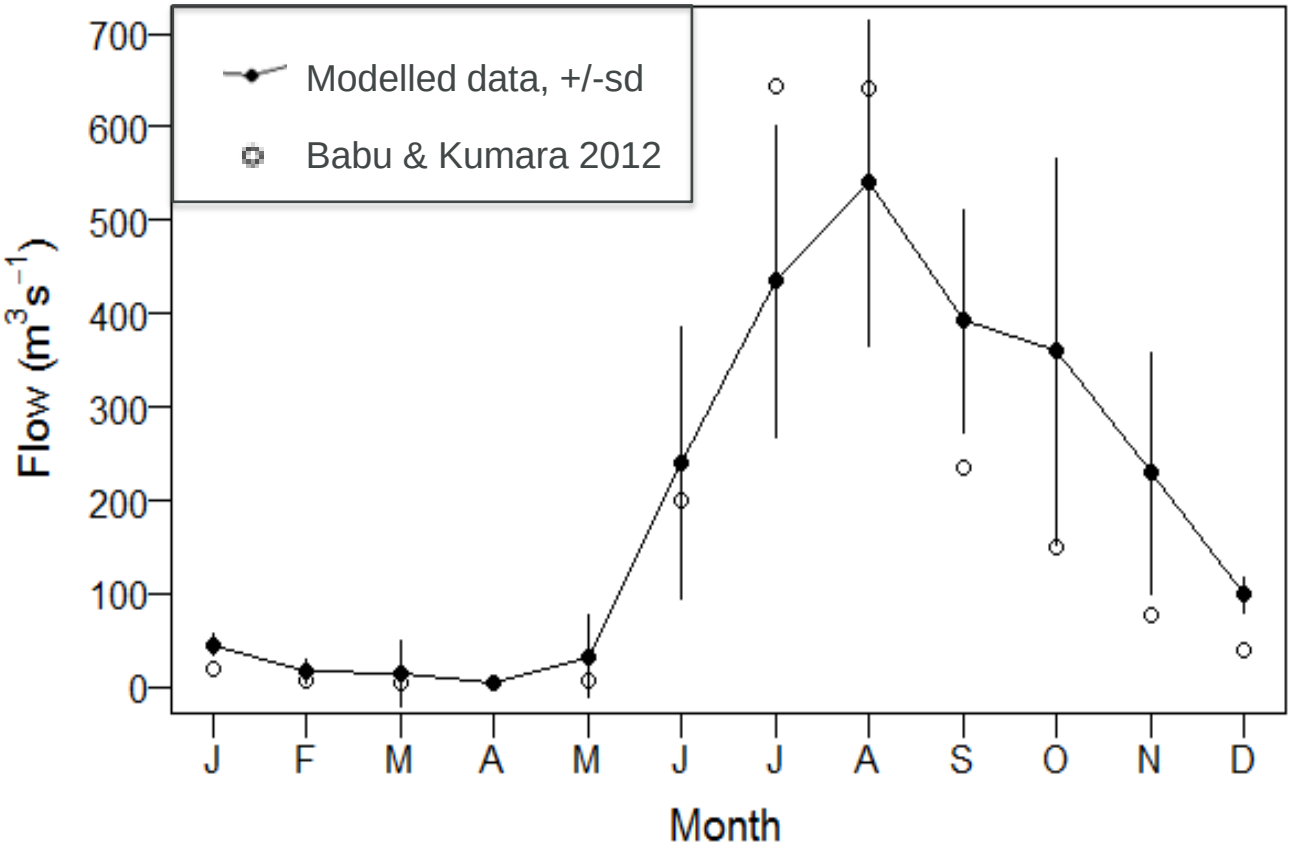
*Note: CSFR locations do not exactly match with weather stations (up to 15 km apart)*

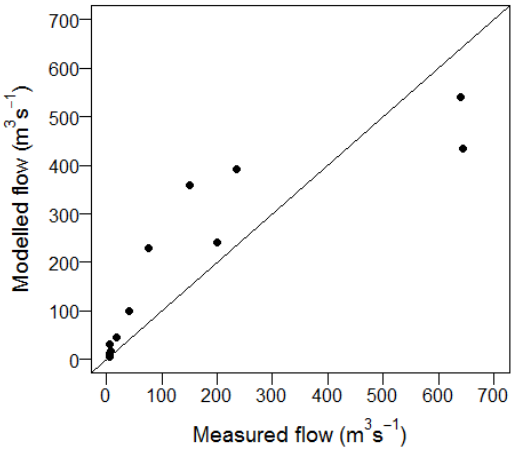
CSFR data

Weather station data

# MODEL SETUP AND VERIFICATION

## Streamflow model *vs.* measured



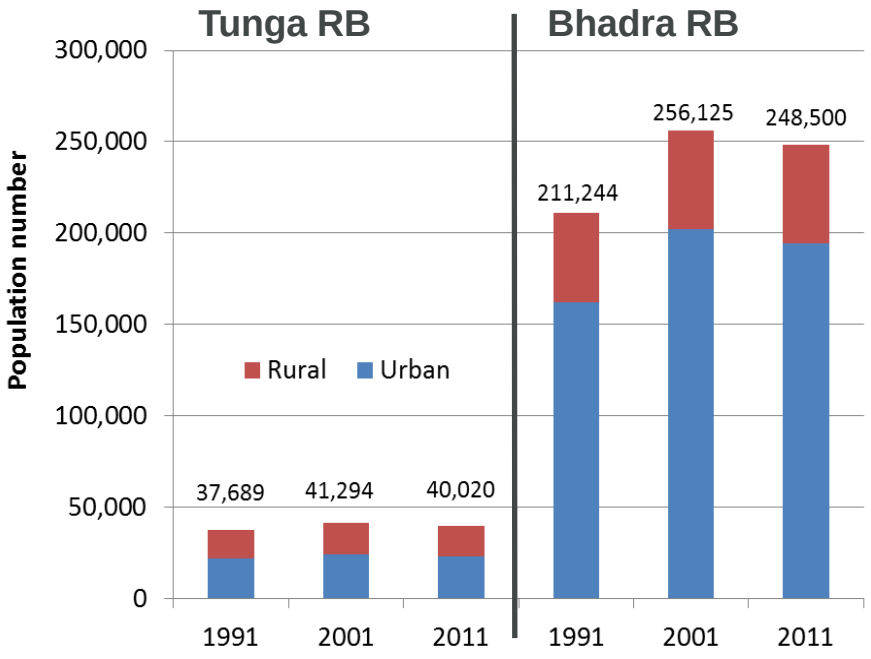

Flow data are 30 year means (1980 – 2010)

- **Insufficient data availability** for calibration
- Despite data lacks **fair model output**: $R^2 = 0.74$

# DPSIR SELECTED EXAMPLES

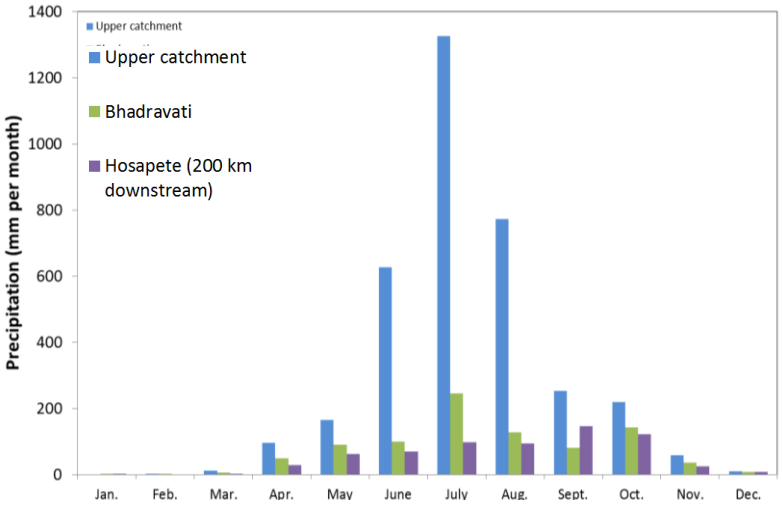
## Drivers: Population, agriculture and climate

### Population




**Agriculture** is the main source of income upstream of case study communities

### Climate




**Climate change predictions (Shimoga, BCCI-K 2011)**

JF: **-13%**

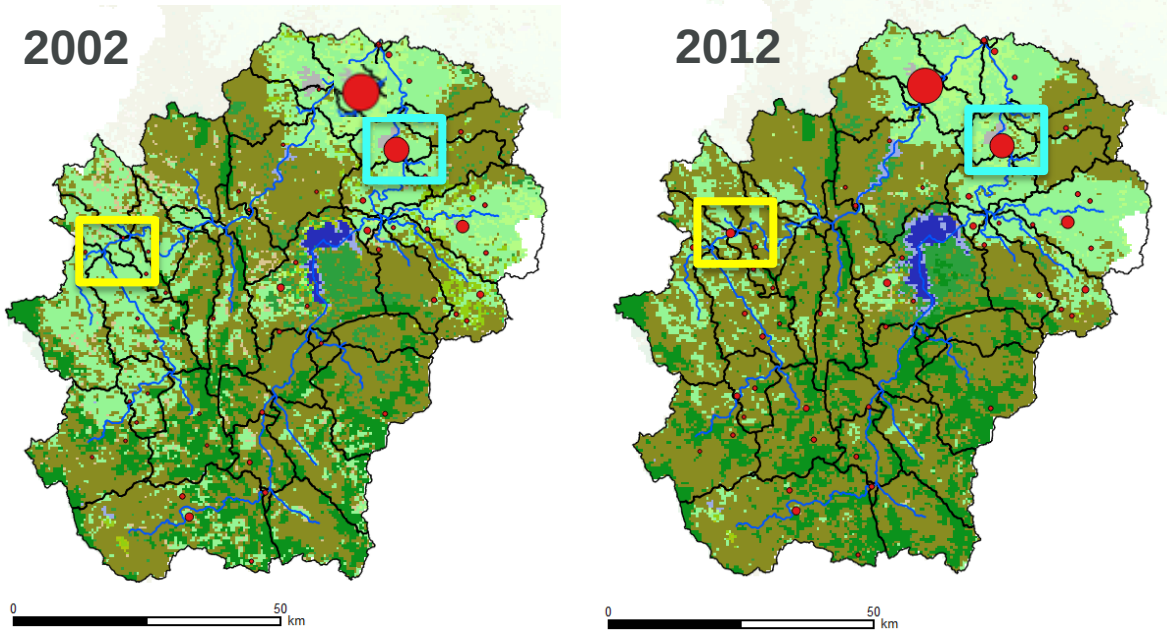
MAM: **+11%**

JJAS: **+4%**

OND: **+8%**

# DPSIR SELECTED EXAMPLES

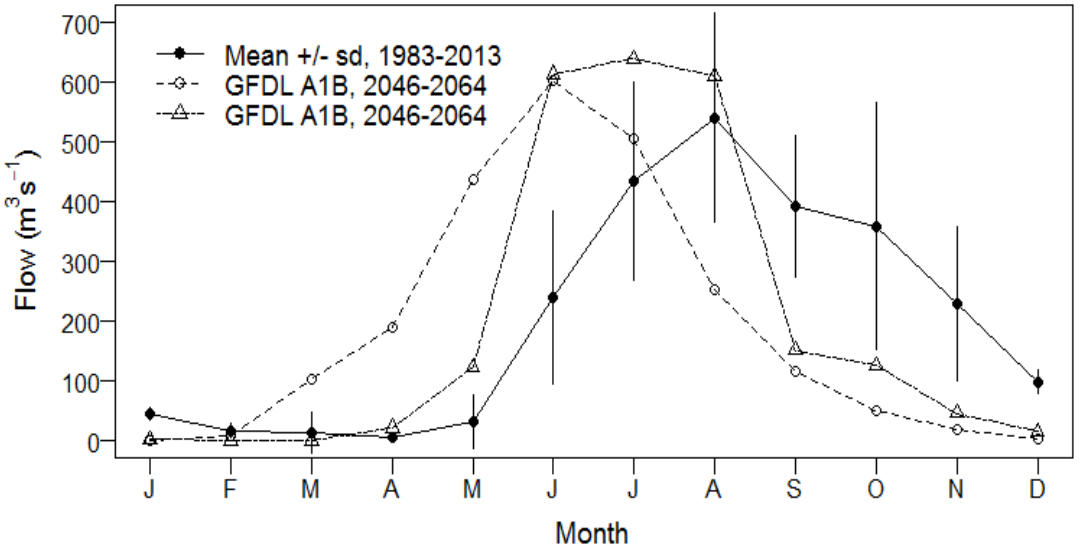
## Pressures: Land use/cover change




| | 2002 | 2012 | Change |
|---|---|---|---|
| **Woody savannas** | 2912 | 3340 | +15% |
| **Croplands** | 1811 | 1324 | -27% |
| **Forest** | 1076 | 1196 | +11% |
| **Built-up** | 23 | 25 | +8% |
| **Other** | 188 | 125 | |

# DPSIR SELECTED EXAMPLES

## State: Implications for drinking water (I)



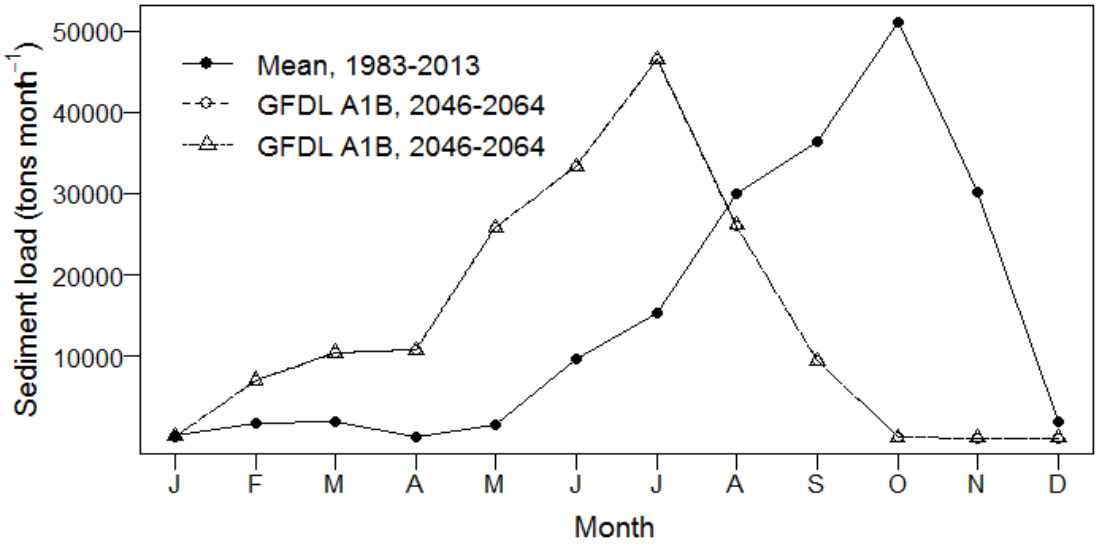

Modelled **river flow** under **current and projected future** climatic conditions

→ **Information on water availability, also groundwater recharge, precipitation etc.**

→ **Specific information for each subbasin** (in this study 48 subbasins in Tunga and Bhadra Riverbasins)

# DPSIR SELECTED EXAMPLES

## State: Implications for drinking water (II)




Modelled **sediment load** under **current and projected future** climatic conditions

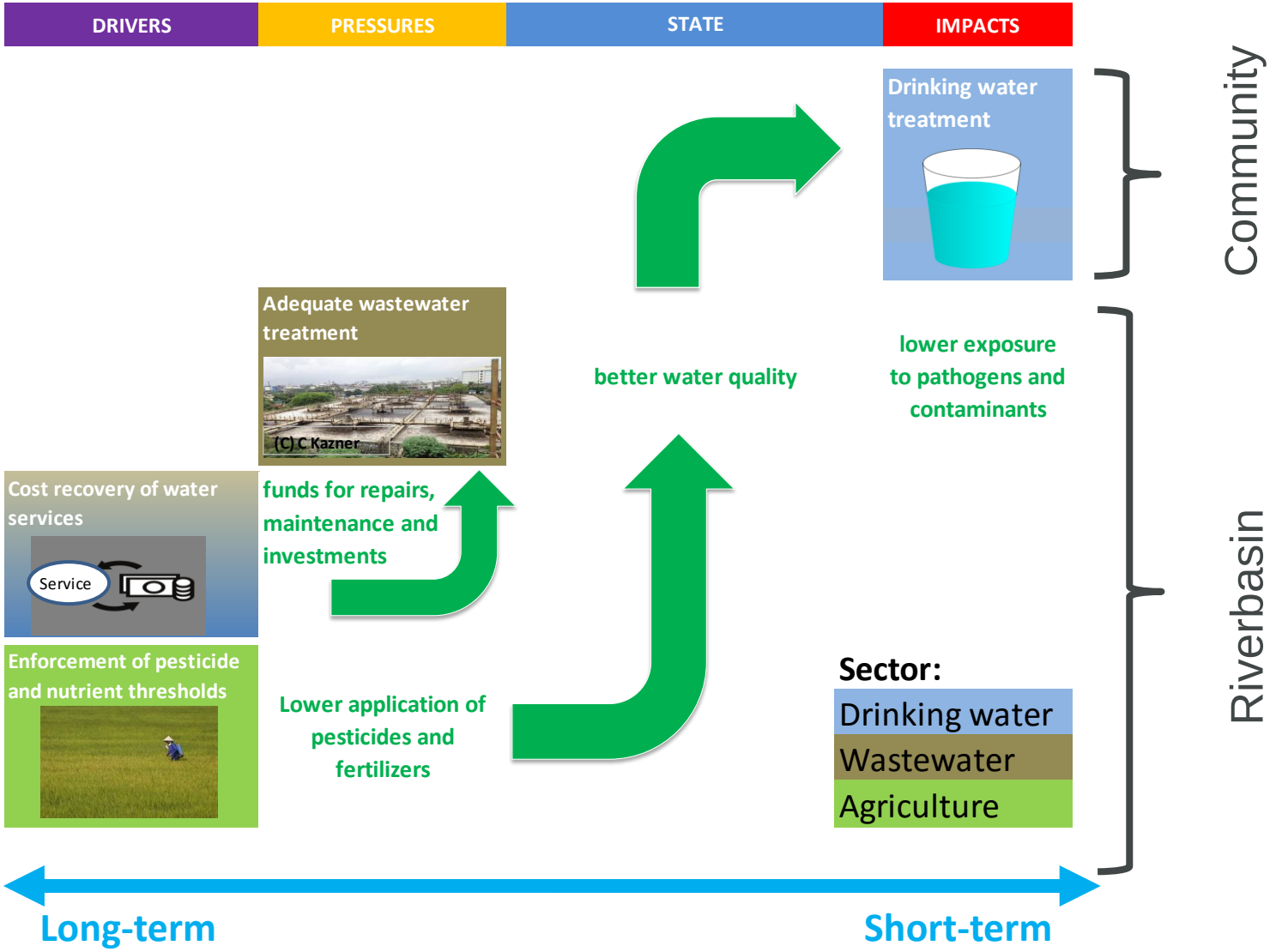
→ **Input for drinking water technology selection** (see presentation on WetSuit tool by Mr. Seyed Sadr)

→ **Many other parameters**, e.g. E. coli, nutrients

→ **Measured data** would allow for calibration!

# TOWARD SAFE AND SUFFICIENT DRINKING WATER

## End-of-pipe is not enough!



# Conclusions & Outlook

# CONCLUSIONS AND OUTLOOK

**DPSIR to identify challenges and formulate key messages** for stakeholders, highlighting inter-sectoral linkages

**→ Viable communication and planning tool for water management**

Remote sensing data, maps, sectoral statistics etc. offer **input to hydrological models** such as QSWAT for decision and policy making

**→ Models can be established and extended by measured data, to improve reliability of outputs**

**Inter-sectoral efforts required**

**→ Government bodies have detailed data which can be utilized to produce high-resolution calibrated and validated models for decision making**

# References

# REFERENCES


Babu K, Harish Kumara B (2012). In-stream water flows : A perspective from downstream environmental requirements in Tungabhadra River Basin. Working paper 279. 31

Dile YT, Srinivasan R (2014). Evaluation of CFSR climate data for hydrologic prediction in data-scarce watersheds: An application in the blue nile river basin. J Am Water Resour Assoc 50:1226–1241

EEA (1999) Environmental indicators: Typology and overview. European Environment Agency, Copenhagen

Fuka DR, Walter MT, Macalister C, Degaetano AT, Steenhuis TS, Easton ZM (2014). Using the Climate Forecast System Reanalysis as weather input data for watershed models. Hydrol Process 28:5613–5623

Government of India (2011). Hoselisting and household census. Table HH-14: percentage of households to total households by amenities and assets. Office of the Registrar General, Ministry of Home Affairs, Government of India, New Delhi

Kossida M, Koutiva I, Makropoulos C, Monokrousou K, Mimikou M, Fons-Esteve J, Iglesias A (2009). Water Scarcity and Drought: towards a European Water Scarcity and Drought Network (WSDN ). European Environment Agency, Copenhagen

# THANK YOU FOR YOUR ATTENTION

**Acknowledgements**

This study is part of the EU-FP7 **WATER4INDIA** project funded by the European Commission (GA No. 308496).


We are thankful for the support from stakeholders in Thirthahalli and Bhadravati, Karnataka State

**Contact:** Thomas Gross, M.Sc.: thomas.gross@fhnw.ch