# Socio-hydrology model of inter-basin water transfers with stakeholder elicitation

Session 2- Water Assessments in River Basin: Perspectives

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# Motivation: Water resources are stressed in many parts of the world

Solutions being explored:

1. More storage (small or big reservoirs)
2. Rainwater harvesting
3. **Inter-basin transfer (IBT) of water**
4. Demand reductions

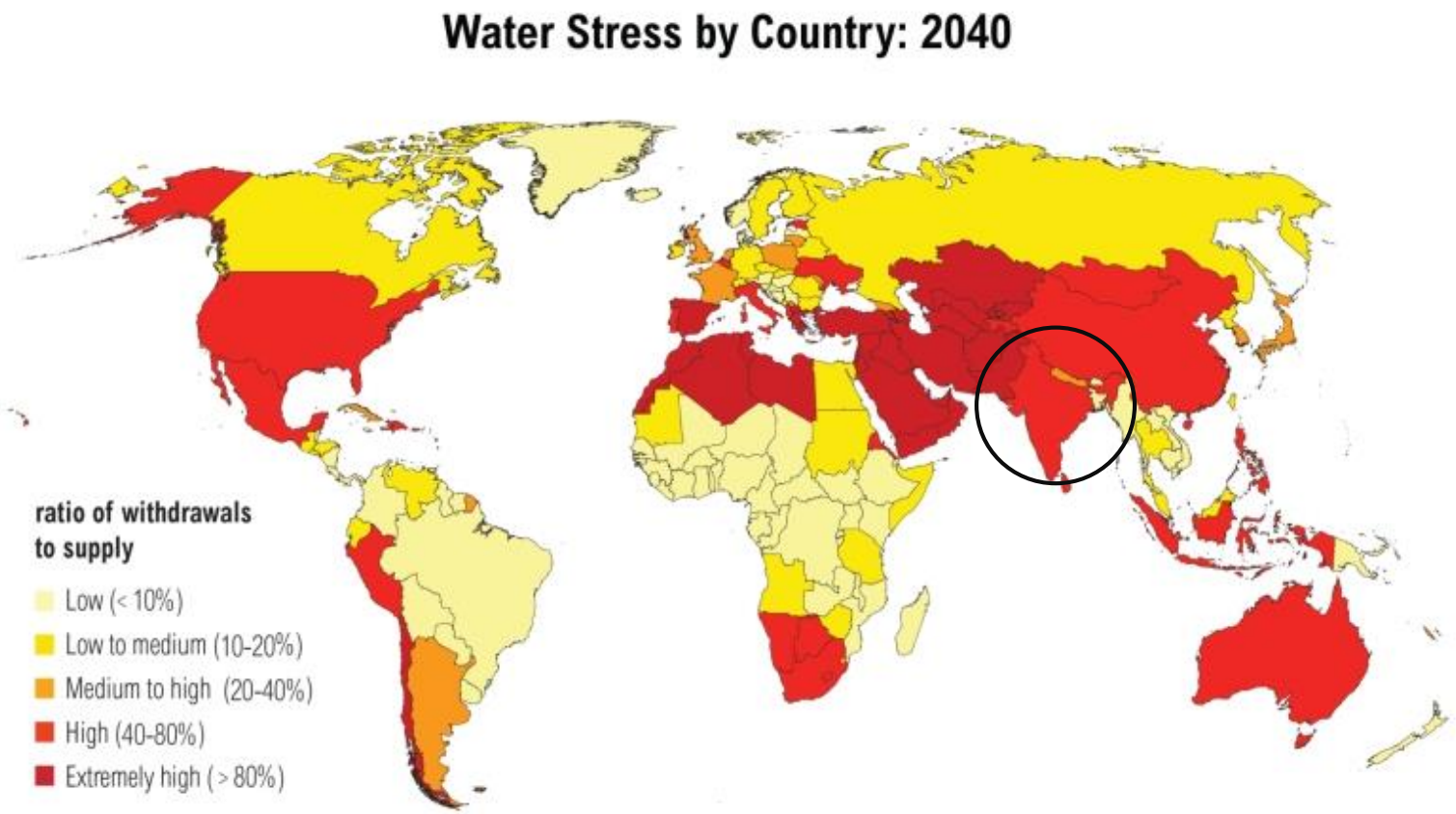
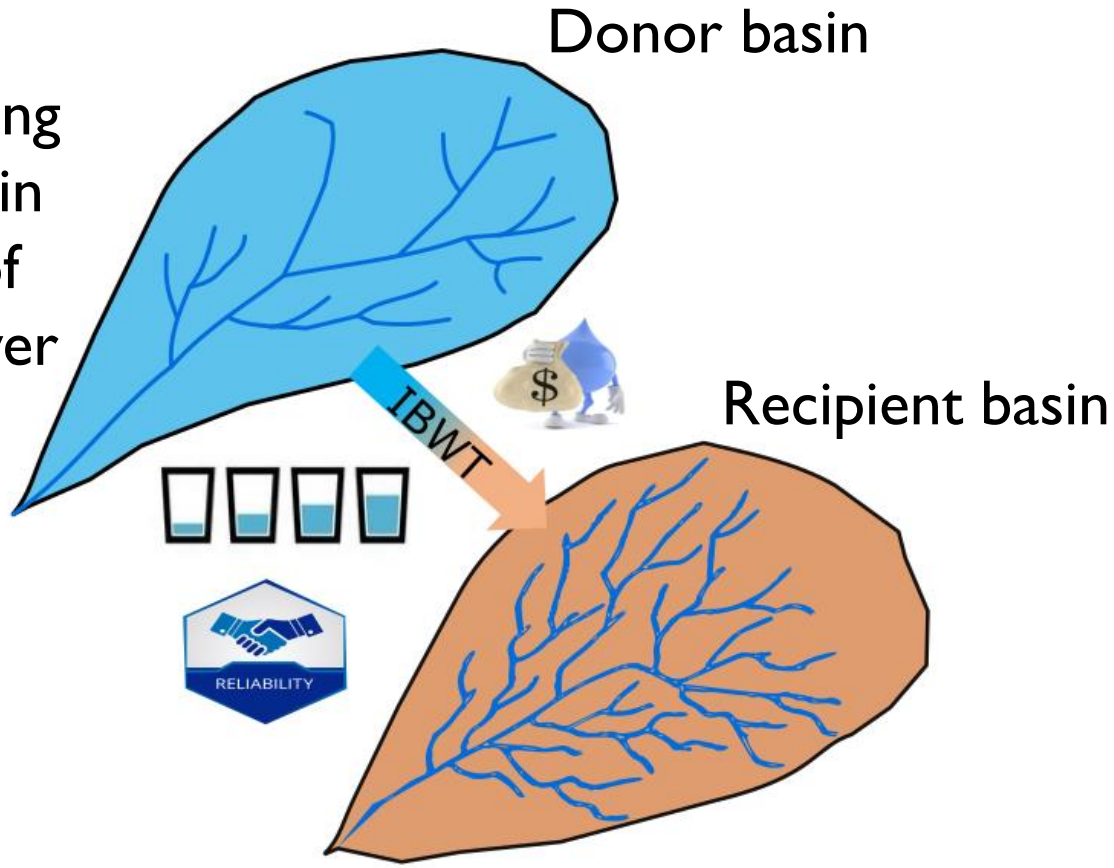



Image Source: World resources institute

# Global inter-basin water transfers: >25% by 2025

Conceptualizing the river link in the context of connected river basins




| Region | Water withdrawals through IBTs |
|---|---|
| South America | 2% |
| North America | 43% |
| Asia | 6% |
| Europe | 17% |
| Africa | 5% |
| Australia | 3% |
| **World total** | **14% (540 billion cubic meter)** |

Table: Contribution of IBTs to all water withdrawals of the world (adopted from Gupta and Van der Zaag, 2008)

Proposed schemes will transfer additional 940 billion cubic meter out of basins, will represent >25% of global water withdrawals by 2025



Gupta and van der Zaag, 2008, Interbasin water transfers and integrated water resources management: Where engineering, science and politics interlock, *Physics and Chemistry of the Earth*

# IBTs in India: National River Linking Program (NRLP)

- Proposed and on-going projects of inter-basin water transfers for India
- Additional irrigation potential: 35 Million hectare
- Additional hydro-power potential : 34,000 MW
- Estimated cost of nearly $90 billion
- Three Links proposed to transfer water from Godavari to Krishna Basins (Godavari is the largest river basin in Southern India)

# Challenges for interbasin water transfers

- Do we need IBT or not? Is water transfer justified?
- Why is water availability different in both the basins? Is it due to natural processes or socio-economic factors?
- What is the role of interaction between human and nature in decision making?
- What are the insights gained from stakeholder elicitation?

# Case study: Link from Godavari to Krishna basin

## No Water for Nagarjuna Sagar canal: Andhra government

Samdani MN | TNN | Jul 31, 2018, 23:10 IST

A- A+

GUNTUR: In what could be big setback to the farmers, the state government has expressed its inability to release water from Nagarjuna Sagar for cultivation of paddy. Citing the poor water reserves in the Sagar project, the state government asked the farmers to go for Irrigated Dry (ID) crops.

Incidentally, this is the fourth consecutive year for the state government not to release water for paddy cultivation under Nagarjuna Sagar right canal ayucut. About 10 lakh acres of paddy fields are slowly turning barren lands as majority of the farmers are not switching to the cultivation of ID crops for fear of losing the soil fertility and change of its nature.

## Hyderabad faces water shortage as Nagarjuna Sagar drops below dead storage level

The state is looking at Manjeera water from the Singur dam in Medak to meet the city's needs.

TNM Staff | Thursday, August 31, 2017 - 08:49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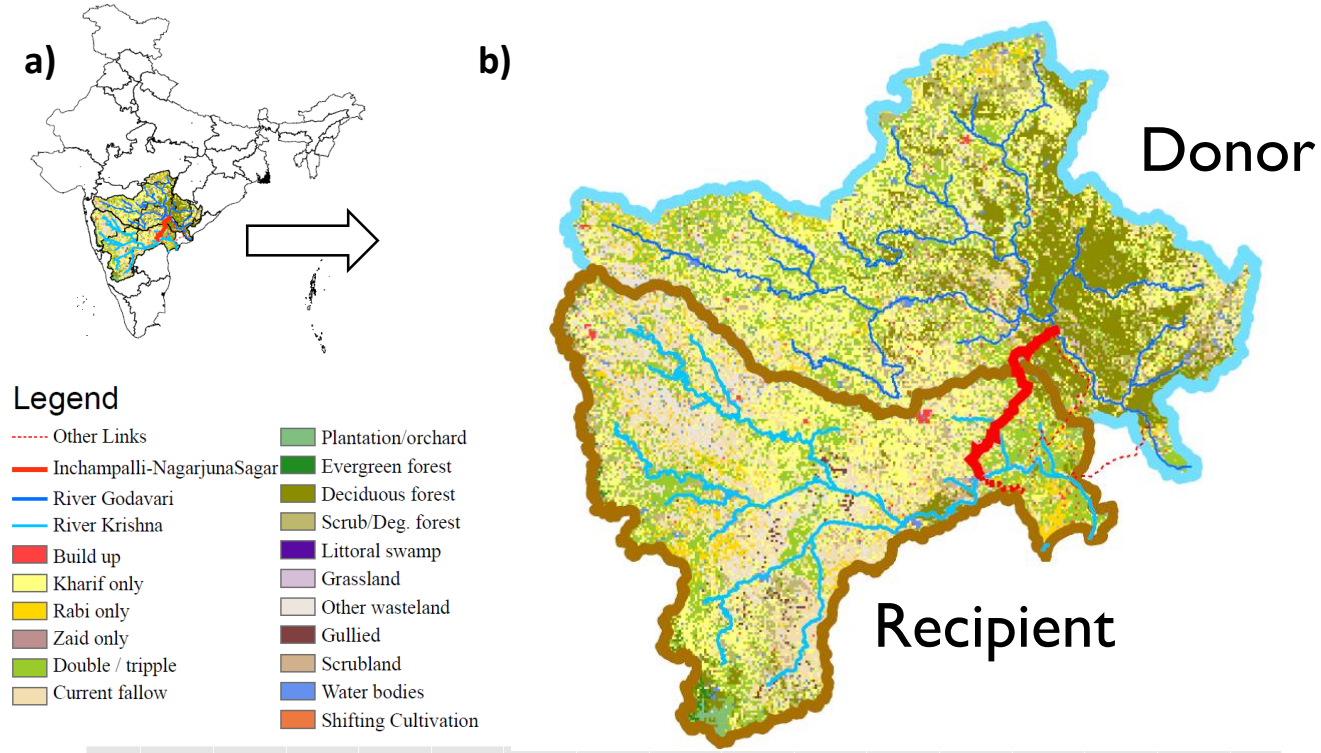
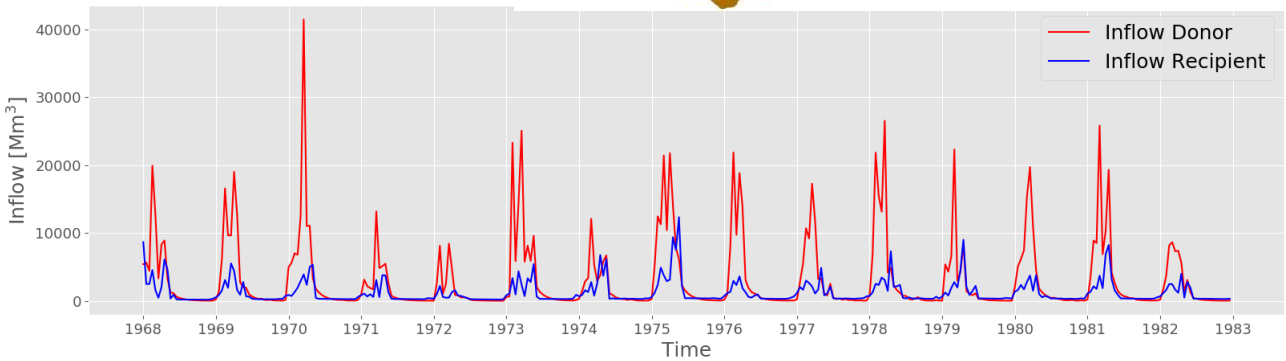


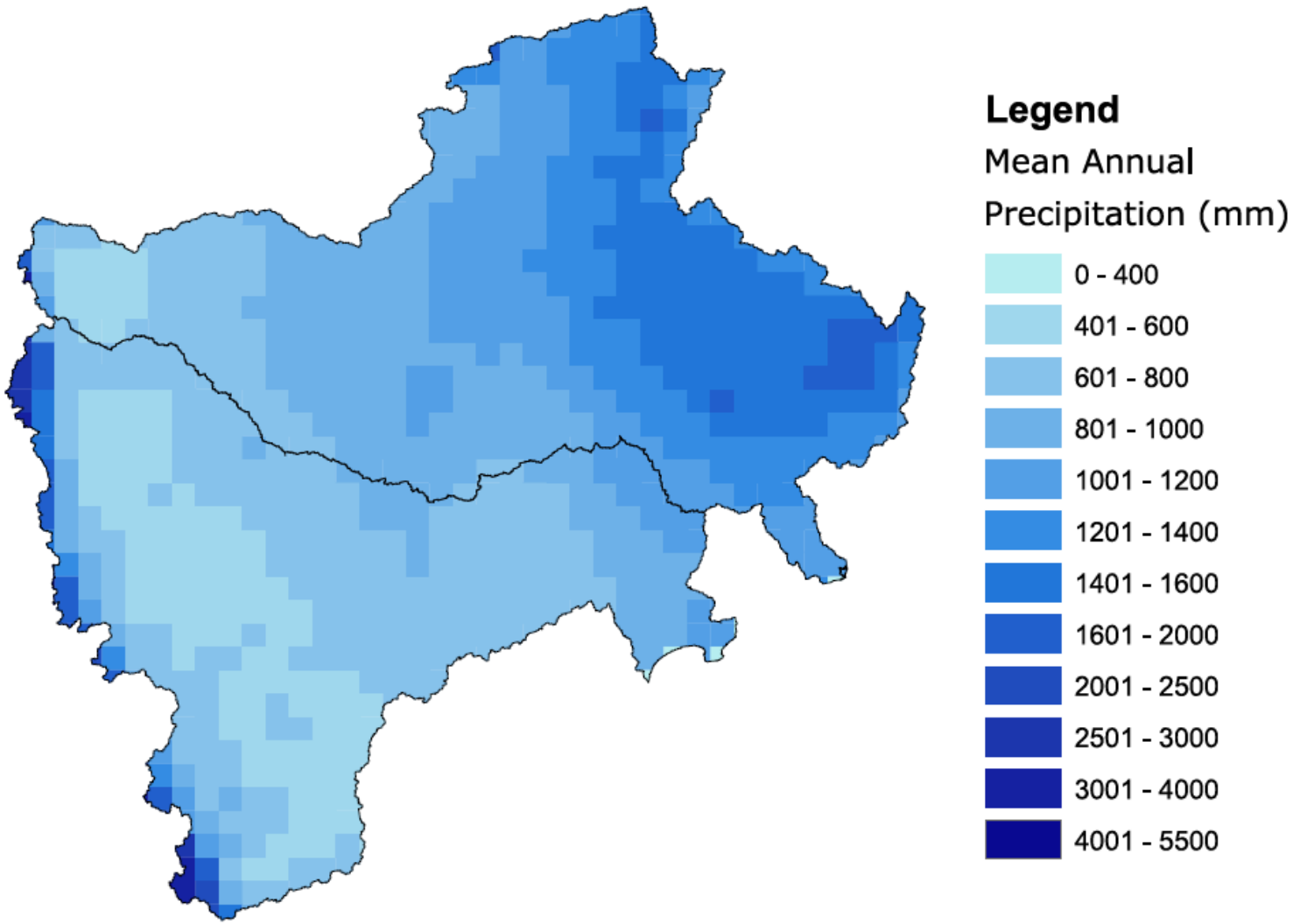




Proposed transfers are around 20% of mean annual inflows to the donor basin

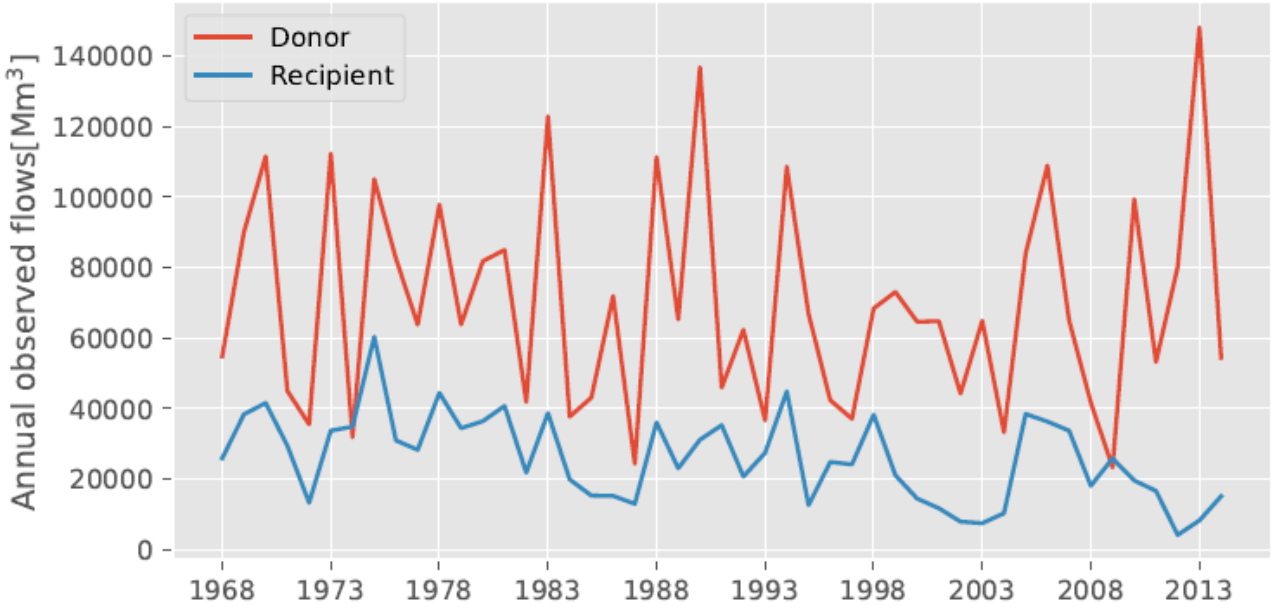
# Higher Precipitation in the Godavari basin

- Figure shows mean annual precipitation of Godavari and Krishna basins for the years 1901-2015 (IMD data)

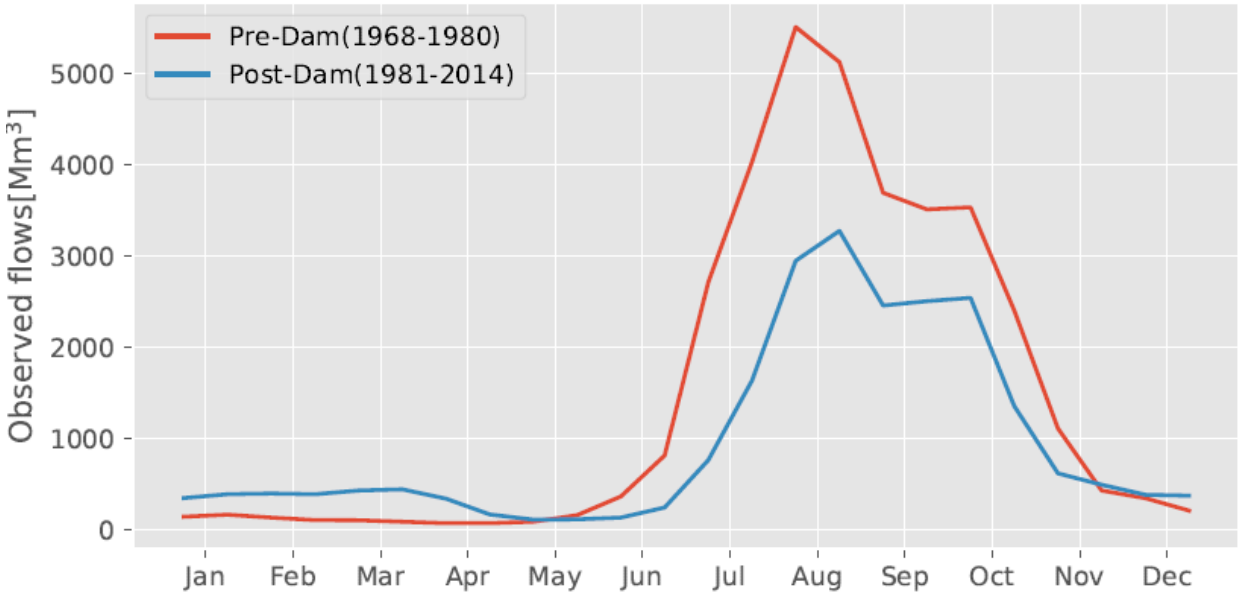
- Godavari basin has high precipitation compared to the Krishna basin, hence high volumes of inflows in the Godavari basin



# Higher Inflows in Donor and Human Impacts on Inflows




Annual observed flows of donor are very high compared to recipient (more than double). This shows that the donor basin has surplus water

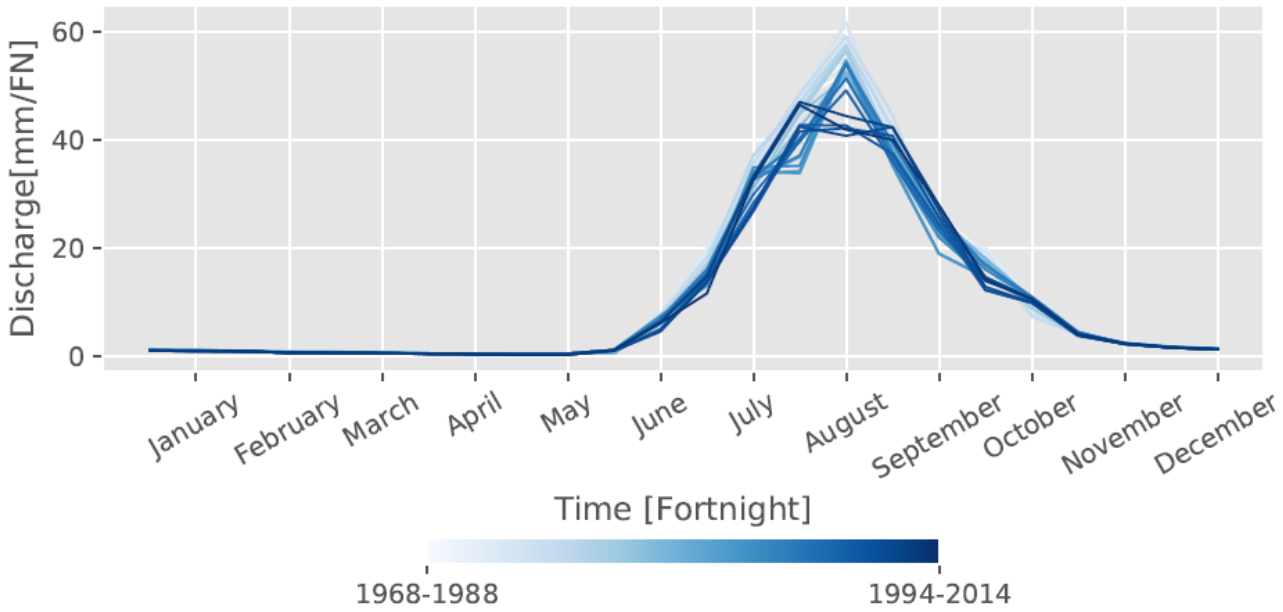



Mean monthly observed flows in the recipient basin for pre-dam and post-dam scenarios. In the year 1981, a dam was under operation in the upstream of Nagarjuna Sagar dam

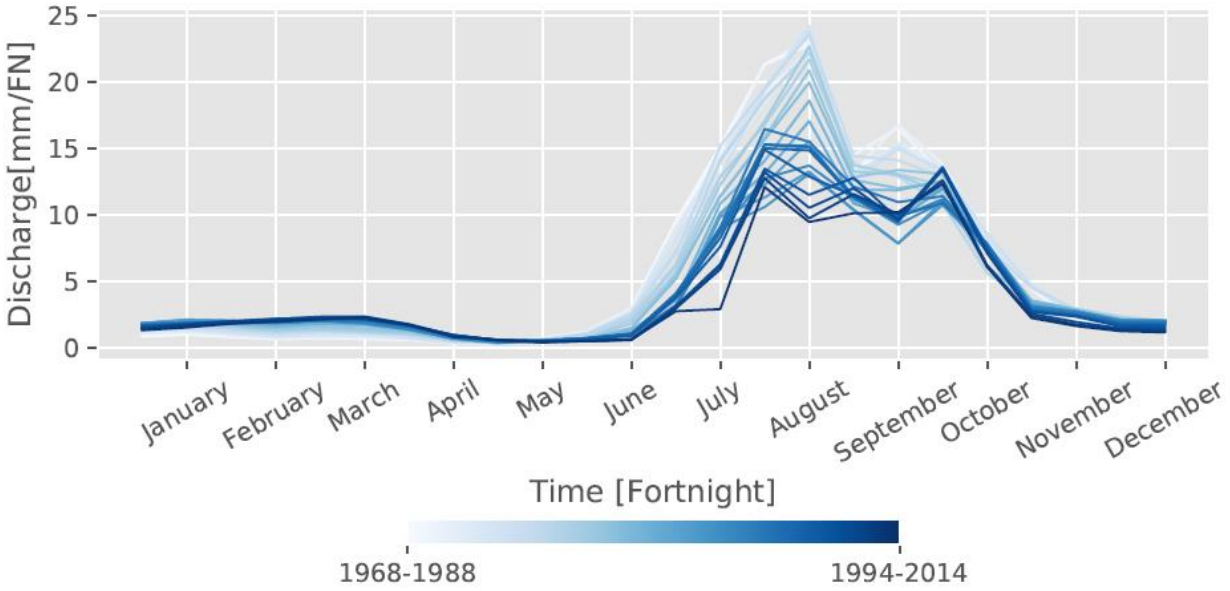
# Trend Analysis: Long term trends in Inflows

Trend analysis of the FN inflows over the time horizon 1968–2014

Godavari Basin

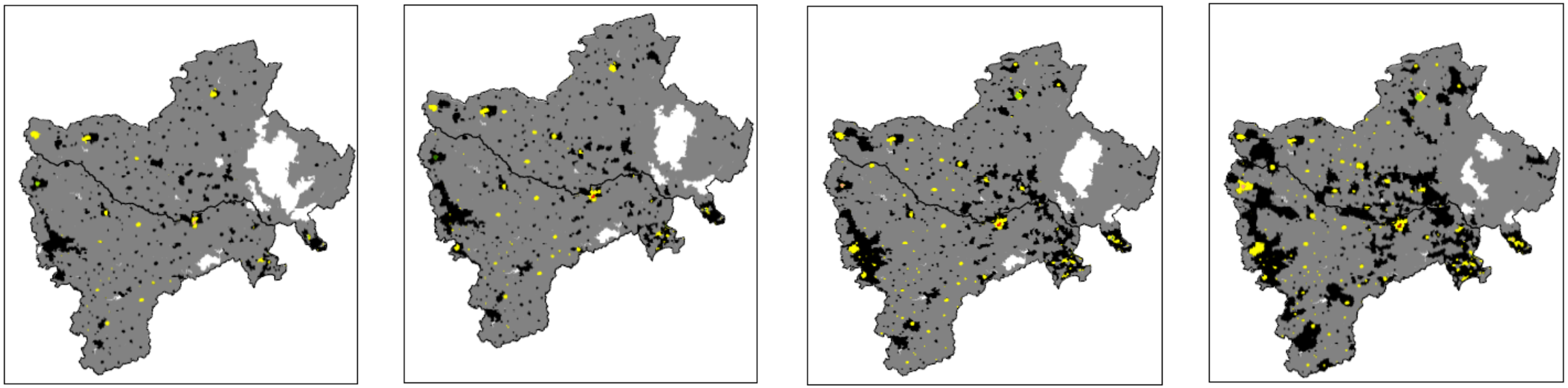



Krishna Basin




The inflows show a clear decreasing tendency during the monsoon leads to drought situations especially notable in the case of recipient basins

# Population Density



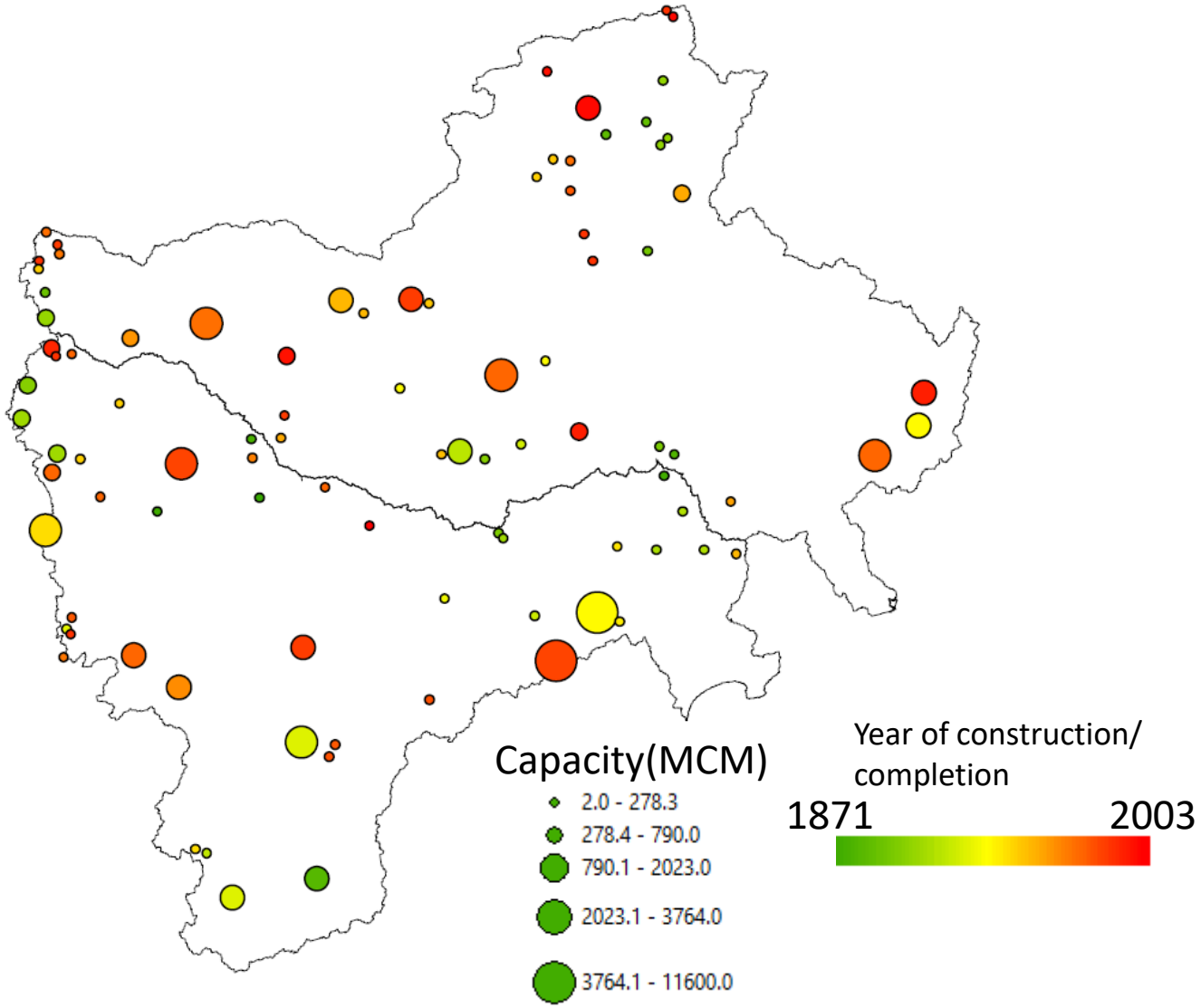
1970 1980 1990 2000

- The density is higher in recipient basin compared to the donor basin for all the years
- Population density is increasing with time in both the basins
- Water demands and abstraction increase due to increase in population density

Data from: Center for International Earth Science Information Network - CIESIN - Columbia University. 2017. Global Population Density Grid Time Series Estimates. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). https://doi.org/10.7927/H47M05W2.

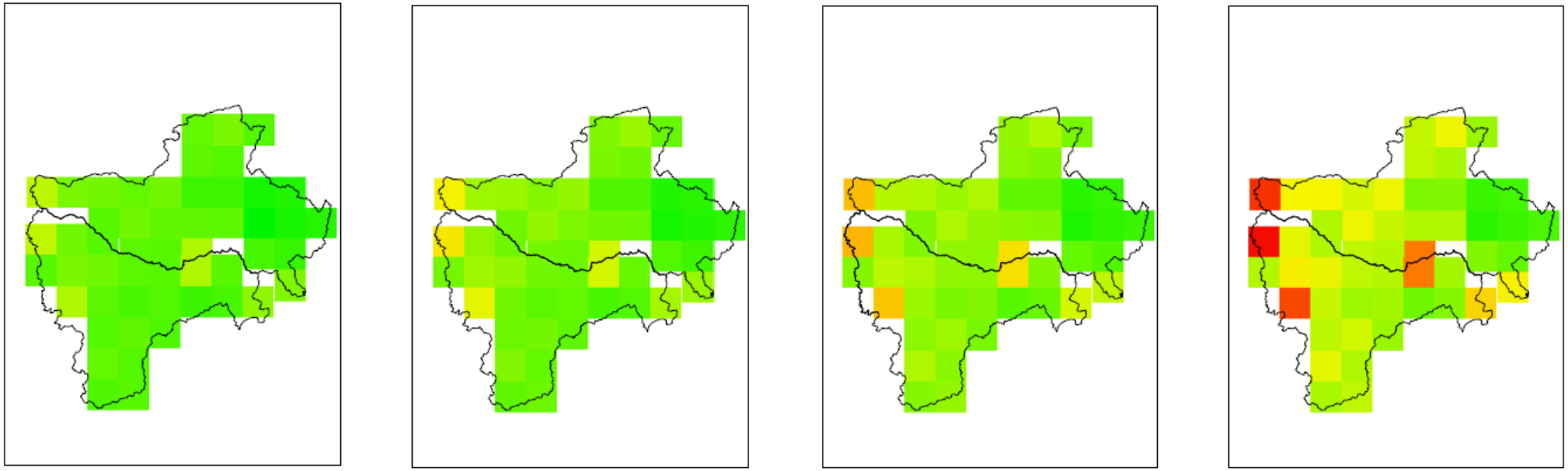
# Spatial and Temporal Variation in Construction of Dams

- Figure shows the construction of dams in donor and recipient basins with capacity, location and year of construction
- The recipient basin has large dams constructed earlier (w.r.t time) compared to the donor basins




Dam data source: Lehner, B., Liermann, C.R., Revenga, C., Vörösmarty, C., Fekete, B., Crouzet, P., Döll, P., Endejan, M., Frenken, K., Magome, J. and Nilsson, C., 2011. High-resolution mapping of the world's reservoirs and dams for sustainable river-flow management. *Frontiers in Ecology and the Environment*, *9*(9), pp.494-502.

# Gross domestic products (GDP)



1990 1995 2000 2005

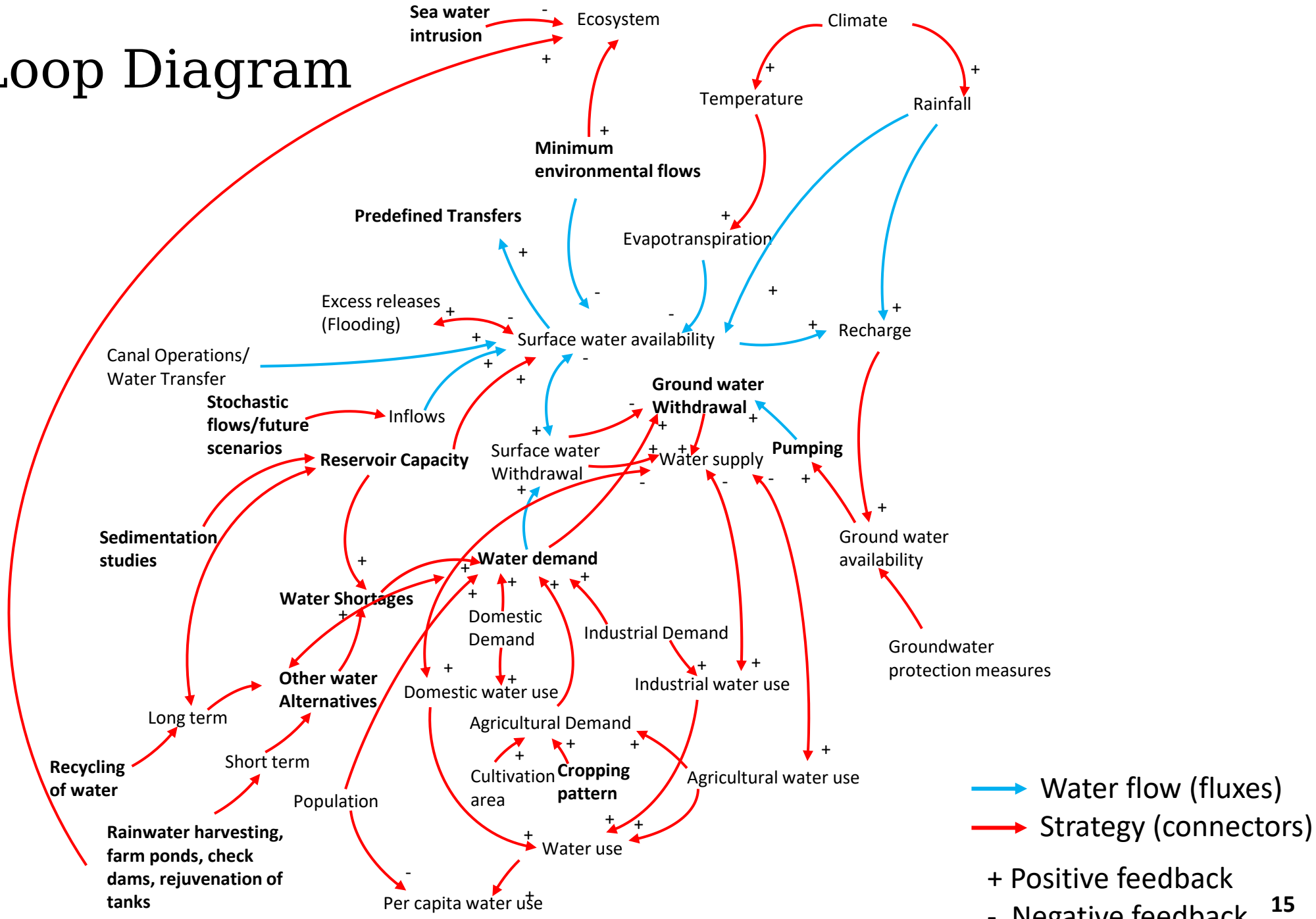
The overall GDP of recipient is found to be higher than the donor basin over the years. Also, GDP is increasing in both the basins with time.

Data Source: Nordhaus, W.D., and X. Chen. 2016. Global Gridded Geographically Based Economic Data (G-Econ), Version 4. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). http://doi.org/10.7927/H42V2D1C

# Interviews were held with the following stakeholders categorised into different groups

| Group 1 (Decision makers) | Group 2 (Water Users) | Group 3 (Environmental Groups) |
|---|---|---|
| NWDA | Aranya Agricultural Alternatives | EPTRI |
| Irrigation and CAD department | Farmer Training center | Hyderabad Greens |
| Nagarjuna Sagar dam division | Center for sustainable agriculture | Centre for Environmental concerns |
| Krishna River Management Board | Uppal  Industries Association | Prakriti Environment Society |
| Godavari River Management Board | Other farmers on phone | WASSAN: works with watershed management |
| Irigation-Nagarjuna Sagar Project | | |
| CWC | | |
| HMWSSB | | |

# Causal Loop Diagram




*Highlighted information is from the decision makers; CLD is for command area

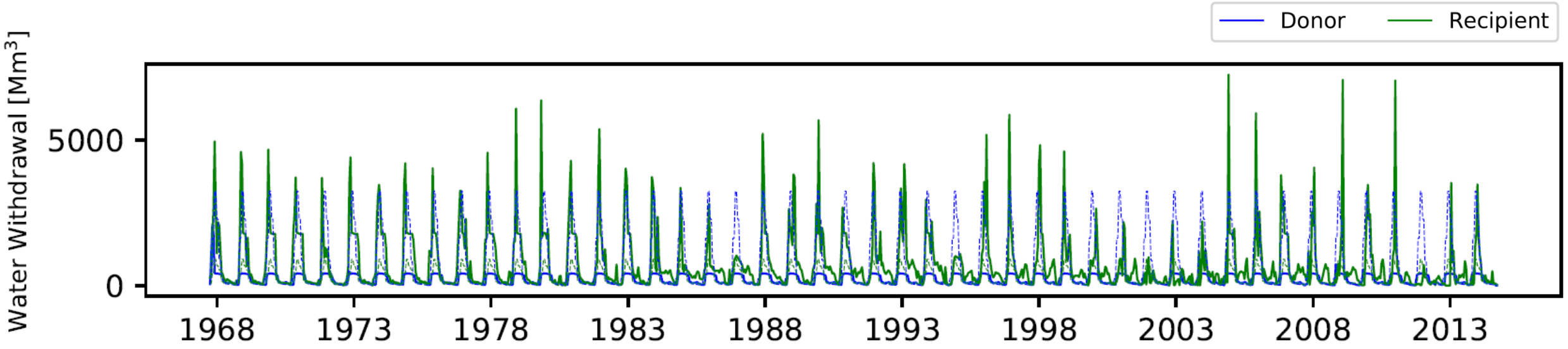
# Sub-models in the socio-hydrological model

- Lumped rainfall runoff model of upstream catchments : Climate (Temperature and Rainfall)
- Reservoir (infrastructure)
  - Decision maker response for water transfer (governance)
    - Performance metrics
  - Decision maker response for water releases to satisfy demands
- Command area sub-model (Mass balance model)
  - Aquifer : recharge and pumping
  - Demand
    - Related to population and cultivable area
- Consumer water use sub-model – accounts for human behaviour
  - other alternatives for water (infrastructure)
  - Demand Satisfaction

# Model Dynamics for the Base Case Scenario

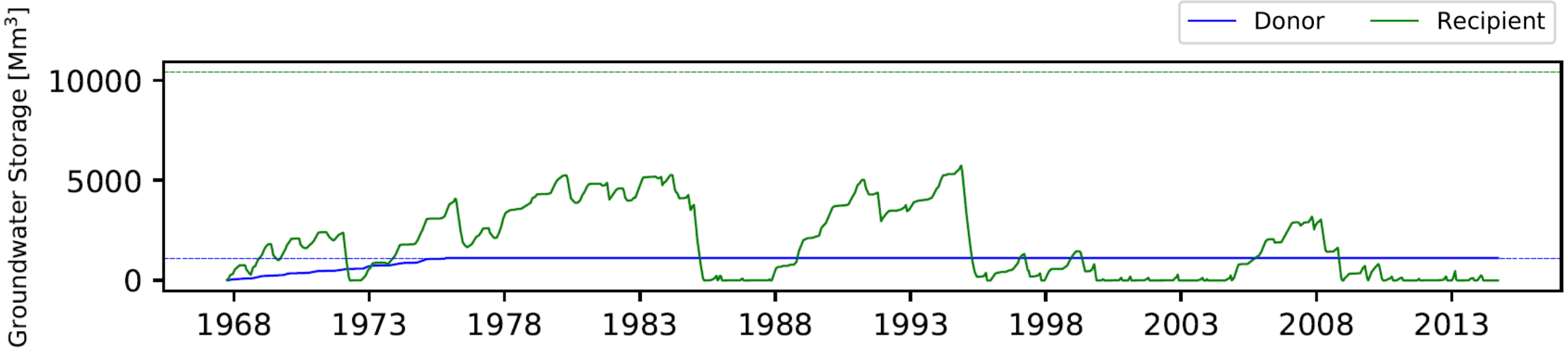
- Considering there is no transfer from donor to recipient basin
- The model is run from 1968 June to 2015 May (47 years)
- Demands are constant and assumed that they do not change with time

# Bluewater withdrawal limits



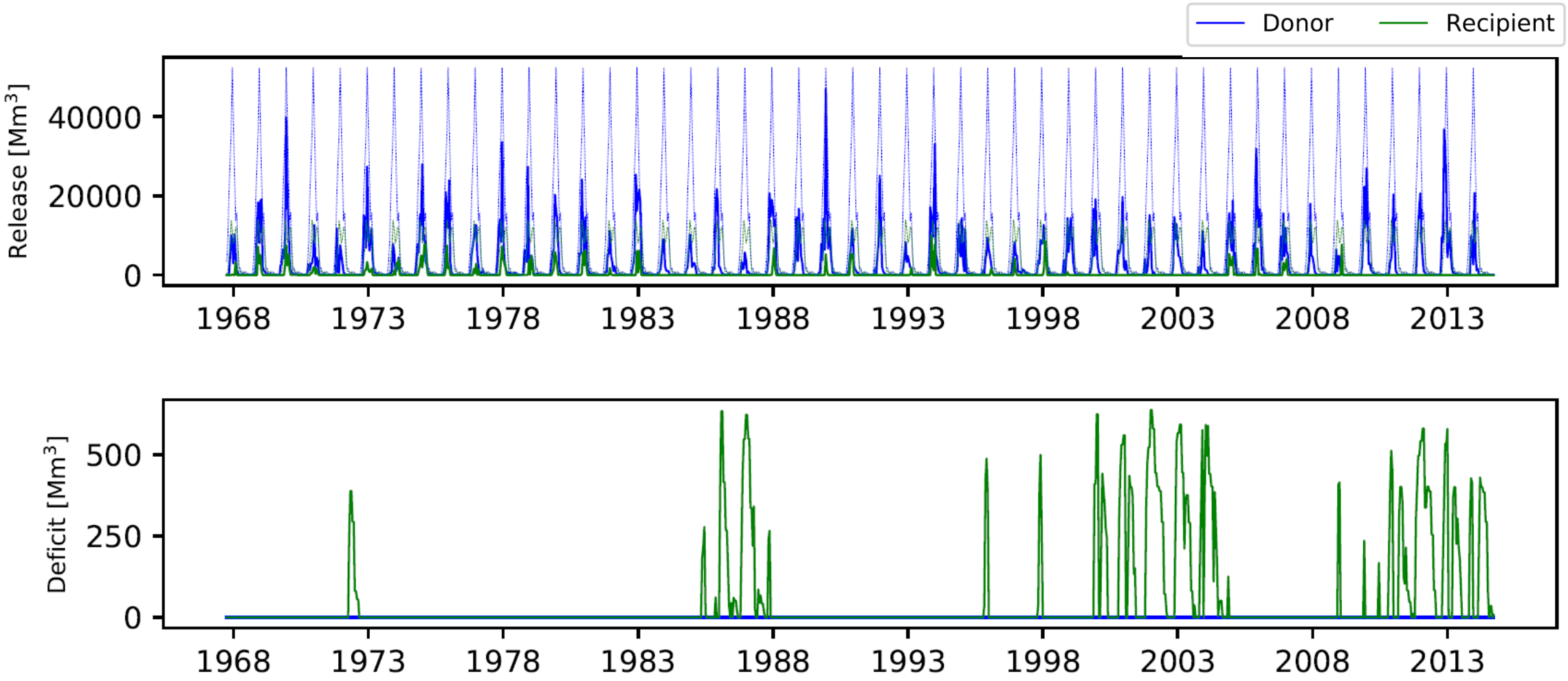

- The dotted lines are the withdrawal limits in both the basins
- In the donor basin, withdrawal is within limits whereas in recipient it is exceeds most of the time

# Groundwater Storage




- Groundwater storage is always full in the donor basin
- In recipient, it does not reach to  that level and is frequently used in the case of deficits

# Deficits and Downstream releases




- The dotted lines are the thresholds for flood releases
- No deficits in donor but high volumes of deficits in the recipient basin

# Conclusions

- Continuous deficits are observed in the recipient basin which justifies the transfer of water
- Socio-economic status of the recipient basin is one of the reason for these deficits. If donor basin follows similar trend as recipient basin, it may also face droughts in the future.
- Elicitation from stakeholders helps in defining the model structure and understanding human behaviour

# Further Study

- Define demands changing with time
- Find the optimal transfers of IBTs
- Predict the shortages in donor basin

# Thank You