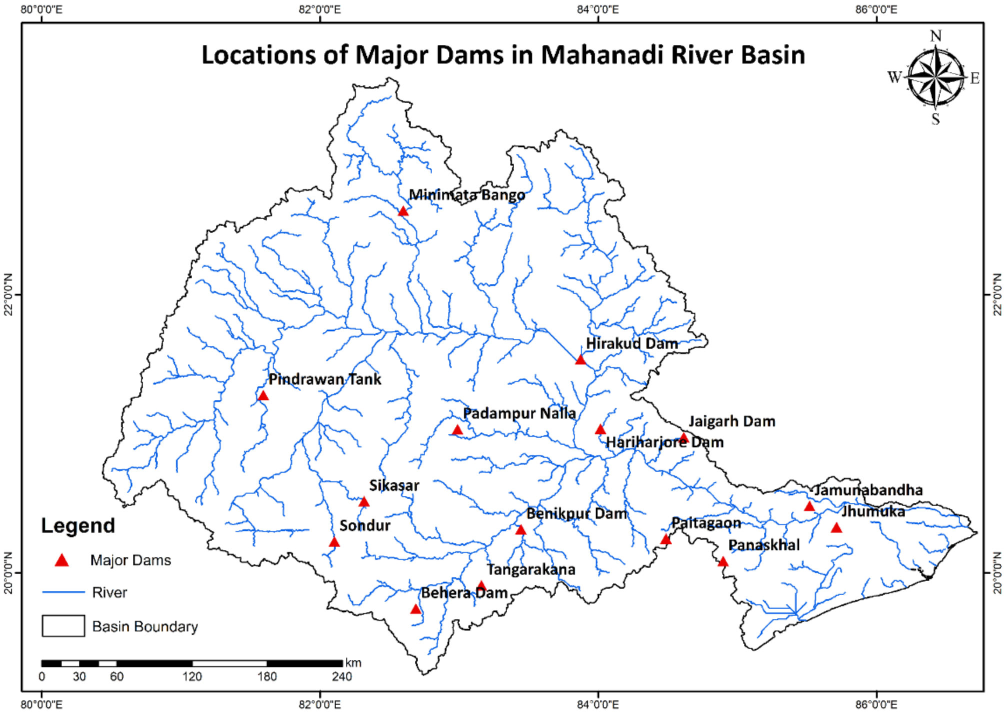
RIVER BASIN WATER BALANCE/ALLOCATION MODELLING USING WEAP: TWO EXAMPLES

M. Dinesh Kumar, Ph. D

25/01/2024

THE MAHANADI RIVER BASIN: CHHATTISGARH PART



It is one of the 20 major river basins of India, with a drainage area of **1,39,681 sq. km**

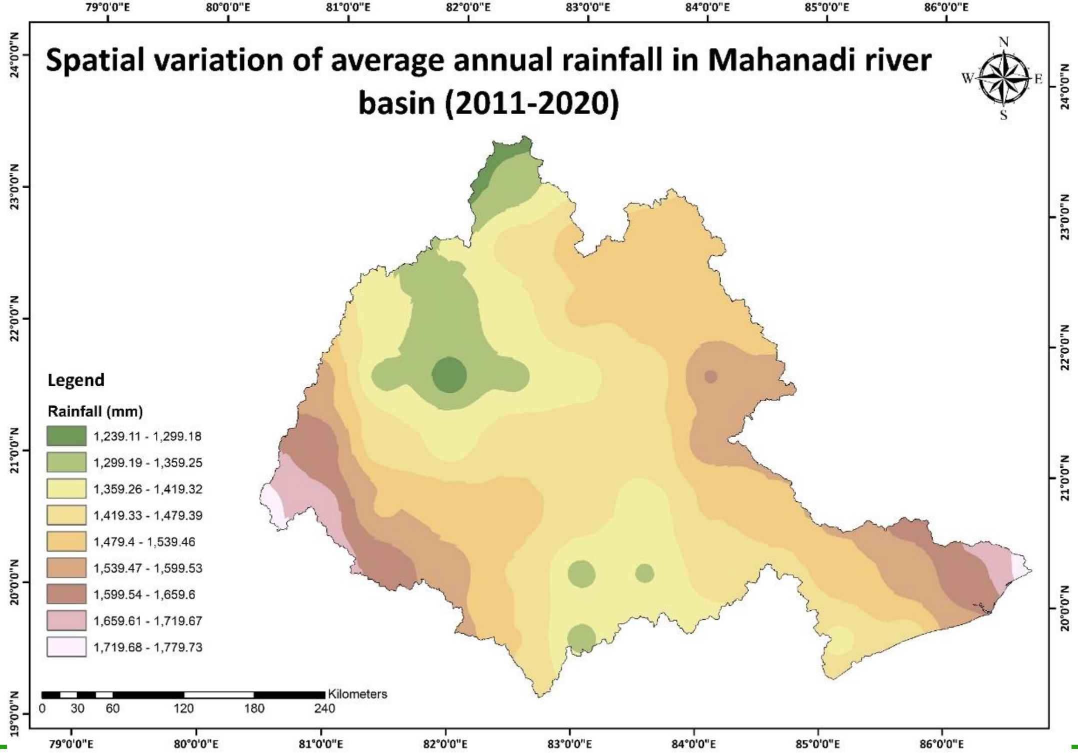
It is an inter-state river basin, with most of its drainage area in Chhattisgarh and Odisha

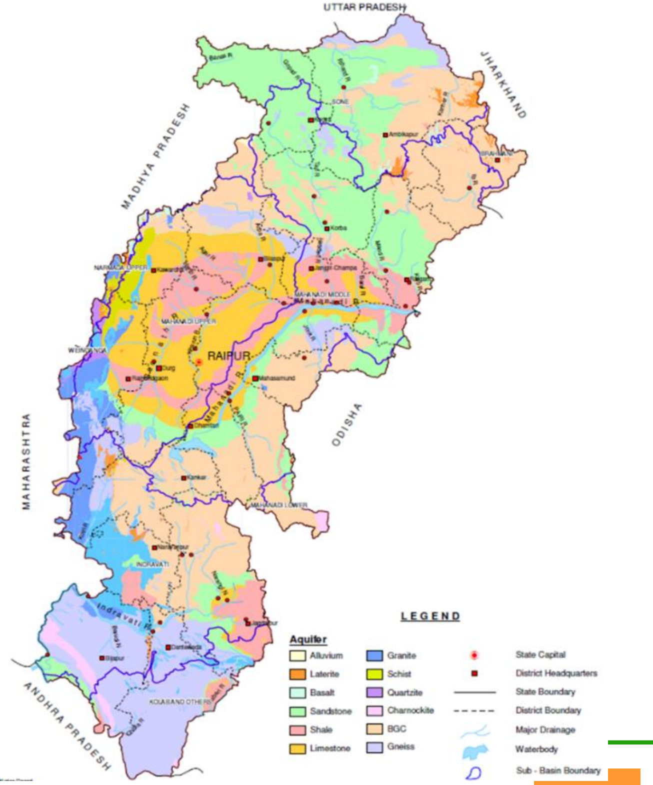
The basin has a total population of around 38.66 million people

A very large proportion of the people are rural and dependent on agriculture, forests and fishing

This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 821051.
This project has been co-funded by Department of Biotechnology (DBT), Government of India.

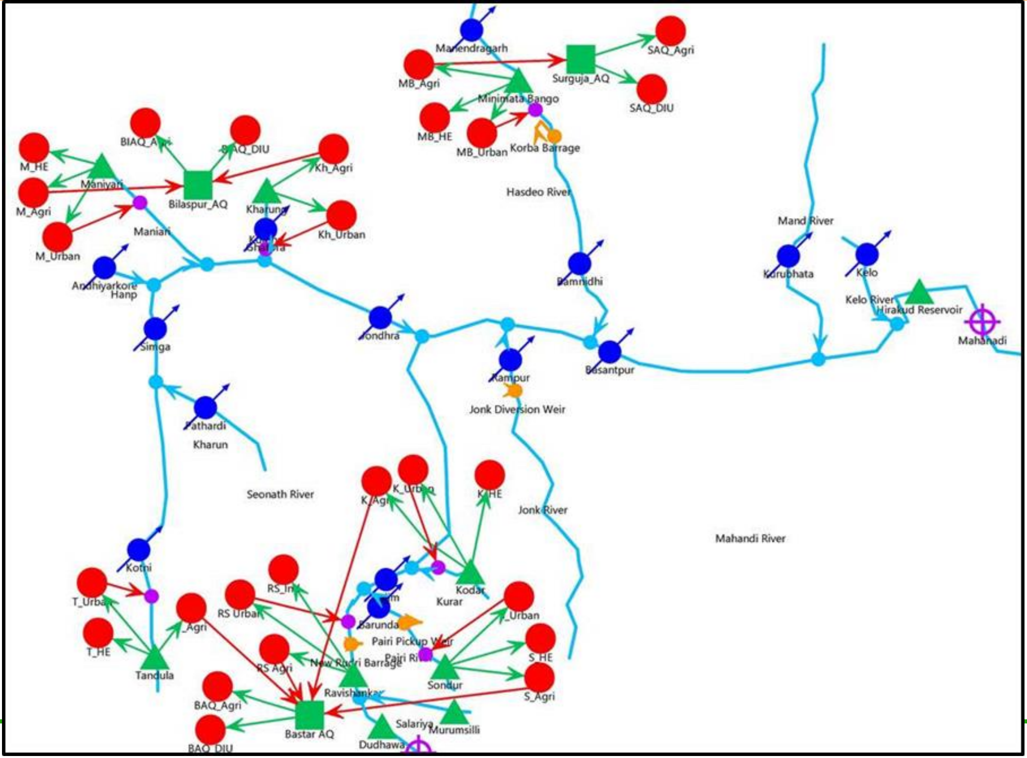
VARYING RAINFALL & COMPLEX AND HETEROGENEOUS AQUIFER SYSTEM





This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 821051.
This project has been co-funded by Department of Biotechnology (DBT), Government of India.

WEAP CONFIGURATION FOR MAHANADI RIVER BASIN: CHHATTISGARH PART



This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 821051.
This project has been co-funded by Department of Biotechnology (DBT), Government of India.

PAVITRA GANGA

SOME OF THE INPUTS USED IN THE WEAP MODEL

- Input data
  - Storage elevation curves
  - Reservoir inflows
  - Stream flows at gauging sites
  - Cropping and irrigation
  - Annual irrigation (CROPWAT) and domestic water use rates
- Outputs
  - Stream-flows (all rivers) for the reference years (2011-2050) for base case scenario
  - Total inflows into Hirakud Reservoir (terminal site of the Chhattisgarh part of Mahanadi river basin) for the reference years (2011-2050) for base case scenario

This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 821051.
This project has been co-funded by Department of Biotechnology (DBT), Government of India.

WATER ACCOUNTS OF CHHATTISGARH PART OF MAHANADI BASIN

- Water accounts were prepared for 2011-12.
- Basin water account were constructed using a continuity equation:

$$INFLOW_{TOTAL} = CU_{IRRIGATION} + CU_{RURAL-DOMESTIC} + CU_{URBAN} + CU_{LIVE\ STOCK} + CU_{INDUSTRY} + EVAP_{RESERVOIR} + OUTFLOW_{STREAM} + GWS_{CHANGE} + SC_{RESERVOIR}$$

- Thus, total annual inflows were estimated using the consumptive uses of water (both beneficial and non-beneficial), and the total storage changes.
- Industries were found to be major claimant for the water from the basin.
- Water accounts show that the upper part of Mahanadi basin (in Chhattisgarh) is still 'open'.

This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 821051.
This project has been co-funded by Department of Biotechnology (DBT), Government of India.

SCENARIOS OF WATER BALANCE FROM THE WEAP MODEL

No.	Scenario	Description
1	Base Case	Business-as-usual scenario where human population, livestock, irrigated area and industries continue to grow as per the past trend
2	High Growth	Uses drivers that affect higher growth in demand for water for various consumptive uses in the basin
3	End Use Water Conservation in Agriculture	Uses certain drivers to affect reduction in demand for water through improvements in efficiency of use of water
4	Projected Future Climate Change: Historical Trends	Captures the impact of expected future changes in magnitude of average annual rainfall on runoff and hence water availability in the basin
5	Projected Future Climate Change: IITM Findings	Use the findings of the climate model (A2B2) developed by IITM, Pune which estimate 5-20 % rainfall increase in Mahanadi river basin by 2050
6	Drought Scenario	Captures the situation during the drought years, determined on the basis of significant reduction in annual stream-flows from the mean values in the basin

This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 821051.
This project has been co-funded by Department of Biotechnology (DBT), Government of India.

MODELLING RESULTS UNDER CLIMATE CHANGE AND OTHER SCENARIOS

- Even under the base case scenario, there would be a some gap between water demand and water supplies from the existing systems by the year 2050.
- Even when the supply is increased under climate change scenarios, water deficit remains.
- However, there is a large amount of outflow from Chhattisgarh part of the basin under all scenarios.
- This indicates there is a need to augment supplies through building more water storage infrastructure in Chhattisgarh.
- However, building any water diversion infrastructure can compromise the water needs of the lower riparian state of Odisha, especially during drought years.

This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 821051.
This project has been co-funded by Department of Biotechnology (DBT), Government of India.

SEASONABILITY DIMENSION OF WATER BALANCE

- The water balance scenarios were also run for four different seasons (as identified by the IMD), viz., Monsoon (June to September); Post Monsoon (October to December); January to February (winter); and March to May (summer).
- Maximum deficit during any year occurs during the early months of monsoon, followed by summer.
- The maximum seasonal deficit (in 2050) was under the high growth scenario: 3,794.4 MCM during the monsoon season and 1061.3 MCM during the summer
- The lowest seasonal deficit was for the Climate Change (IITM) scenario. It was 1684 MCM during monsoon season and no deficit during summer season

This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 821051.
This project has been co-funded by Department of Biotechnology (DBT), Government of India.

FINDINGS AND CONCLUSIONS FROM THE WEAP STUDY

- During normal and wet years, good amount of water is discharged into the ocean, but droughts of high intensity occur during low rainfall years.
- There is greater probability of occurrence of a year being a drought year than being a wet year, hence presenting water management challenges.
- Water accounting for 2011-12 shows that upper part of Mahanadi basin (in Chhattisgarh) is still 'open'.
- Sufficient water flows into Hirakud during normal years, water deficit to be 1801 MCM in 2030 and 2812 MCM in 2050 under base case scenario.
- Under all water balance scenarios, the maximum deficit in any year will be felt during the early months of monsoon, followed by summer.

This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 821051.
This project has been co-funded by Department of Biotechnology (DBT), Government of India.

PAVITRA GANGA

FINDINGS AND CONCLUSIONS FROM THE WEAP STUDY

- Water deficit reduction will be 439 MCM in 2050 under a scenario of rainfall following the past trends, and 1,128 MCM under A2B2 scenario.
- Increased water appropriation during droughts can escalate conflict
- Scope for water demand management in agriculture through water use efficiency improvements in crop production is very limited.
- Most appropriate technical intervention with regard to droughts is to build water storage infrastructure for **multi annual storage of water.**
- To affect irrigation water demand reduction during droughts, volumetric rationing of water supplies in command areas should be introduced.
- There is scope of reducing water use (by around 525 MCM/annum) in the industrial sector by improving water use efficiency.

This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 821051.
This project has been co-funded by Department of Biotechnology (DBT), Government of India.

SHORT TERM AND LONG TERM TECHNICAL STRATEGIES

Short term

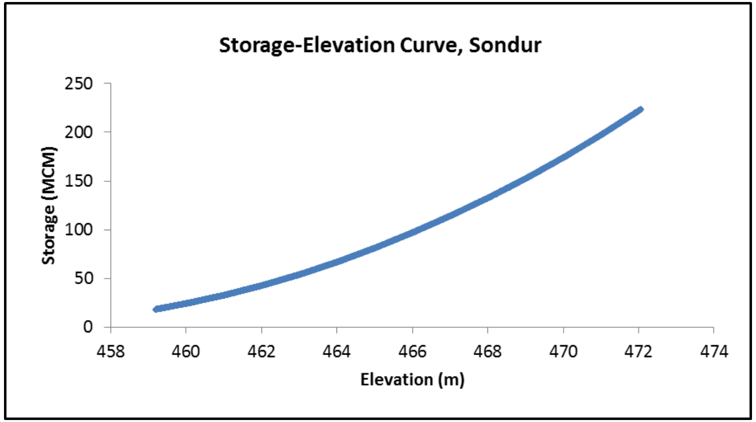
- ❑Tanks/lakes catchment needs to be protected to maintain the runoff yield.
- ❑Regeneration of indigenous trees species in the degraded forest areas
- ❑Drilling of irrigation wells in the catchments needs to be regulated.
- ❑For end use conservation, water saving technologies in irrigation and water efficiency in industry needs to be promoted
- ❑From climate resilience perspective, mulching can be very effective as it prevent soil evaporation and therefore moisture loss.

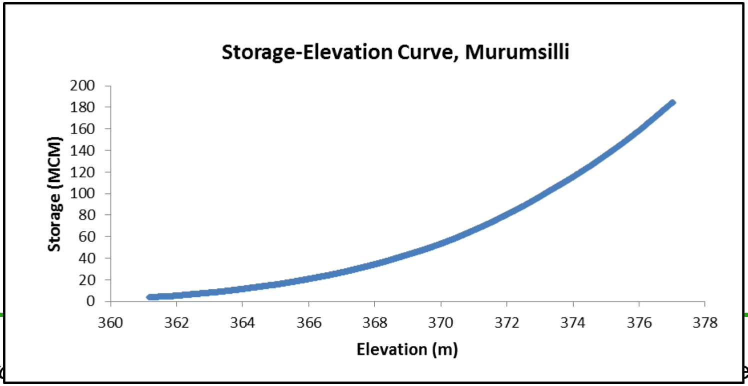
Long term: For Droughts

- ❑Most appropriate technical intervention for improving community climate resilience to droughts is to build water storage for multi annual storage of water. They will store water during wet year as buffer for use during drought years.
- ❑The volumetric storage capacity of such reservoir systems should be large (about 12000 MCM) to augment inflows (after meeting all demands) into Hirakud reservoir.
- ❑Volumetric rationing of water supplies in command areas can be resorted to affect reduction in irrigation water demand.

This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 821051.
This project has been co-funded by Department of Biotechnology (DBT), Government of India.

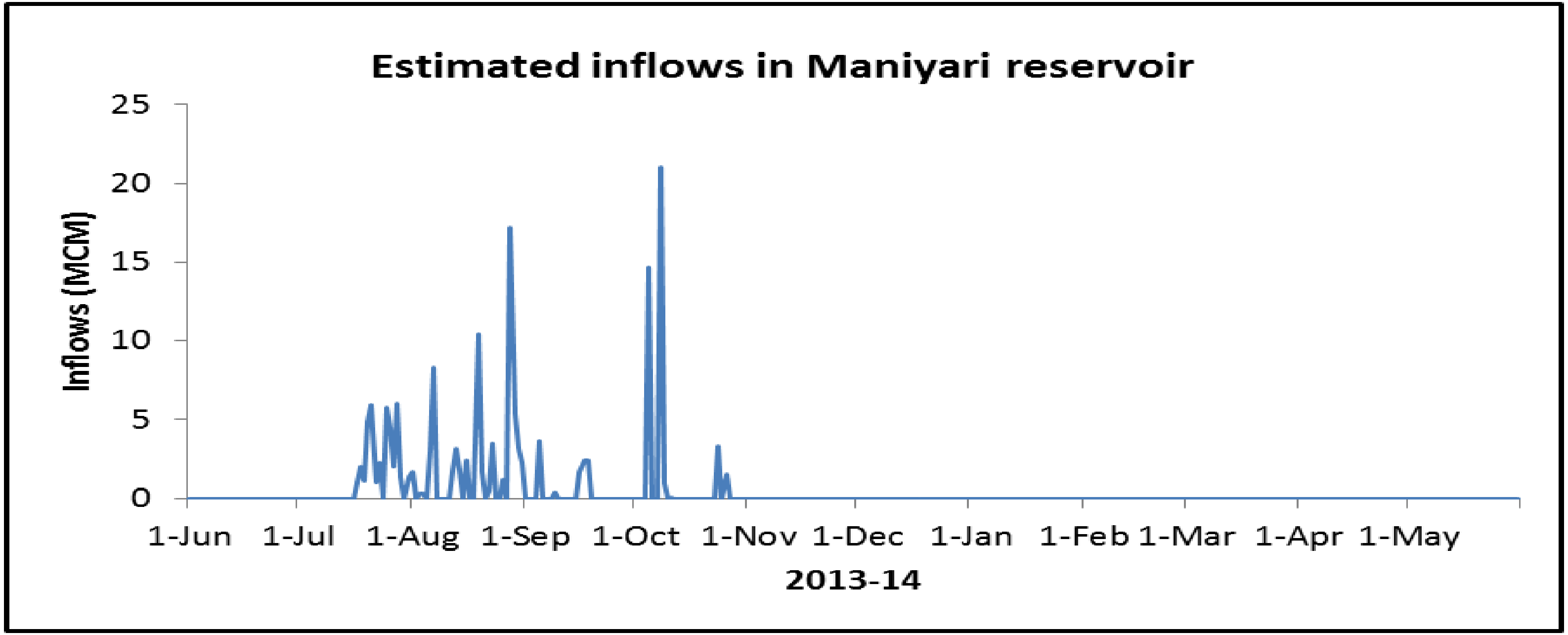
STORAGE-ELEVATION CURVES





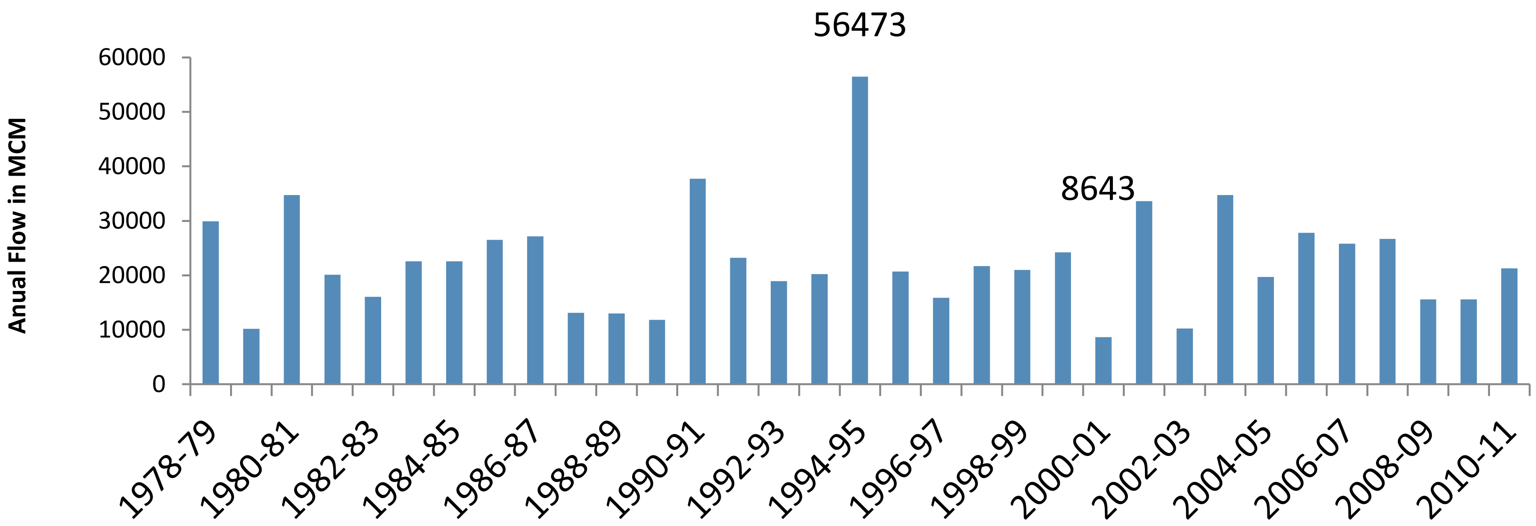
This project has received funding from the *Eur* ... r grant agreement No 821051.
This project has been co-funded by Department of Biotechnology (DBT), Government of India.

ESTIMATED INFLOW IN MANIYARI RESERVOIR



This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 821051.
This project has been co-funded by Department of Biotechnology (DBT), Government of India.

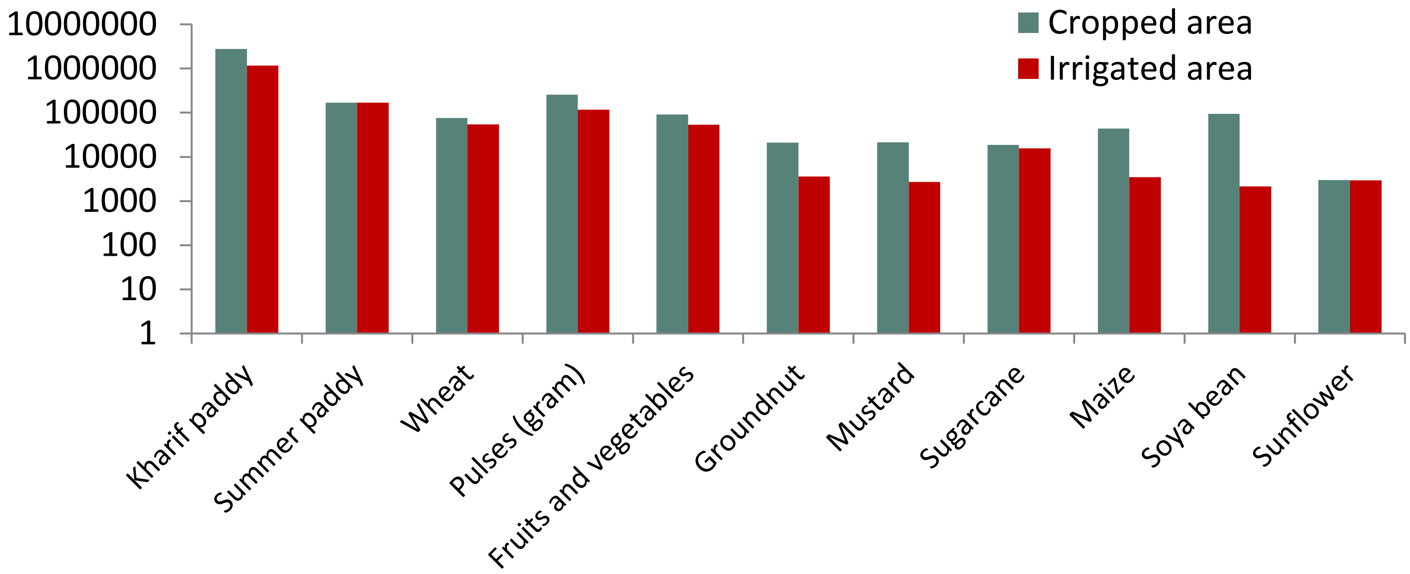
ESTIMATED STREAM FLOWS IN MAHANADI U/S OF HIRAKUD RESERVOIR IN CHHATTISGARH



This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 821051.
This project has been co-funded by Department of Biotechnology (DBT), Government of India.

PAVITRA GANGA

CROPPING AND IRRIGATION PATTERN IN CHHATTISGARH, MAHANADI BASIN



This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 821051.
This project has been co-funded by Department of Biotechnology (DBT), Government of India.

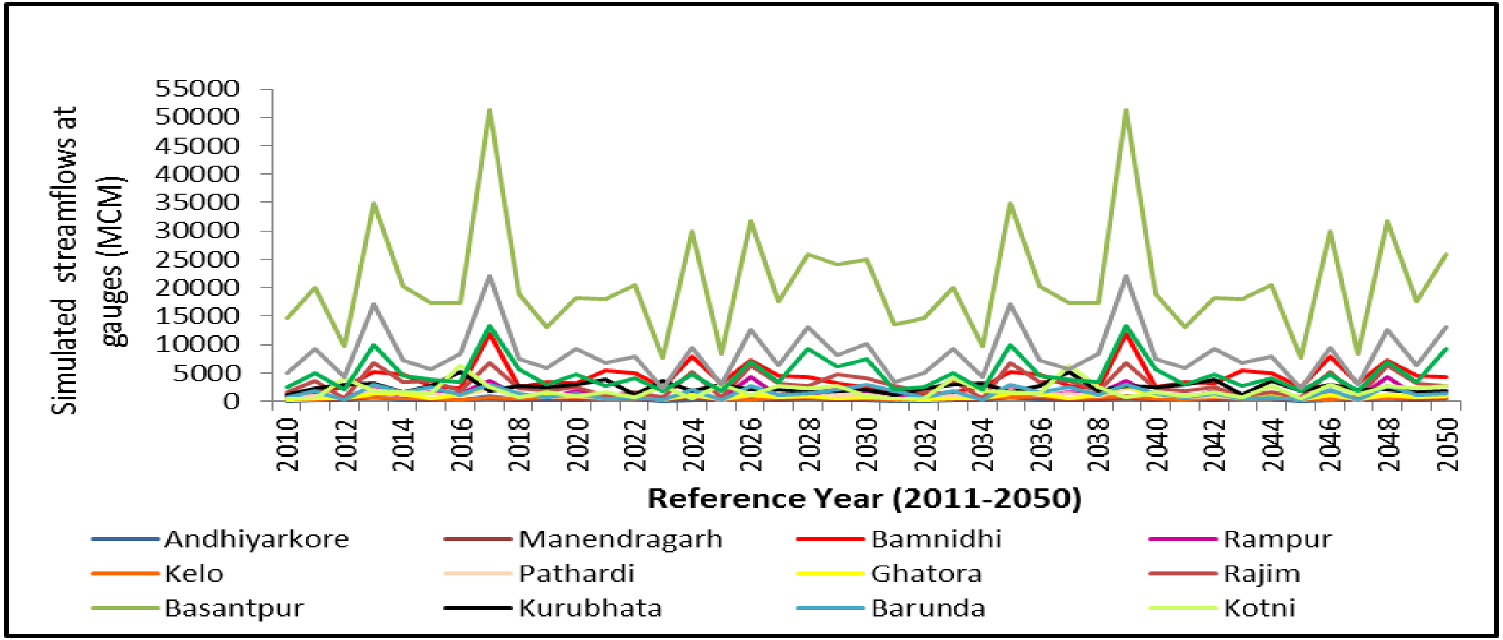
PAVITRA GANGA

IRRIGATION WATER DEMAND ESTIMATES

Name of the Crops	Season	Irrigation Consumptive Use rates by different crops at the demand sites ('000 m^3 per ha)											
		Ravishankar Sagar Dam (Mahanadi)	New Rudri Barrage (Mahanadi)	Sondur Dam (Pairi River)	Kodar Dam (Kurar river)	Tandula Dam (Seonath river)	Maniyari Dam (Maniari river)	Kharung Dam (Kurang River)	Minimata Bango Dam (Hasdeo River)	Jonk Diversion Weir (Jonk River)	Bilaspur Aquifer	Baster Aquifer	Surguja Aquifer
Paddy	Kharif	5.11	5.11	3.60	4.19	5.11	3.60	4.19	4.19	5.11	5.11	2.09	3.27
Paddy	Summer	9.94	9.94	9.33	9.07	9.94	9.33	9.07	9.07	9.94	9.94	8.72	8.21
Maize		0.43	0.43	0.24	0.46	0.43	0.24	0.46	0.46	0.43	0.43	0.06	0.49
Wheat		2.80	2.80	2.74	2.26	2.80	2.74	2.26	2.26	2.80	2.80	2.67	1.71
Gram		2.56	2.56	2.45	2.06	2.56	2.45	2.06	2.06	2.56	2.56	2.35	1.57
Pigeon Pea		0.05	0.05	0.02	0.08	0.05	0.02	0.08	0.08	0.05	0.05		0.12
Other Pulses	Rabi	2.56	2.56	2.45	2.06	2.56	2.45	2.06	2.06	2.56	2.56	2.35	1.57
Sugarcane		10.76	10.76	9.21	9.65	10.76	9.21	9.65	9.65	10.76	10.76	7.67	8.54
Fruits & Vegetables		5.14	5.14	4.34	4.71	5.14	4.34	4.71	4.71	5.14	5.14	3.53	4.29
Groundnut		0.73	0.73	0.49	0.75	0.73	0.49	0.75	0.75	0.73	0.73	0.26	0.76
Mustard		3.27	3.27	3.18	2.68	3.27	3.18	2.68	2.68	3.27	3.27	3.09	2.08
Soya bean													
Sunflower		5.15	5.15	4.12	4.74	5.15	4.12	4.74	4.74	5.15	5.15	3.09	4.34

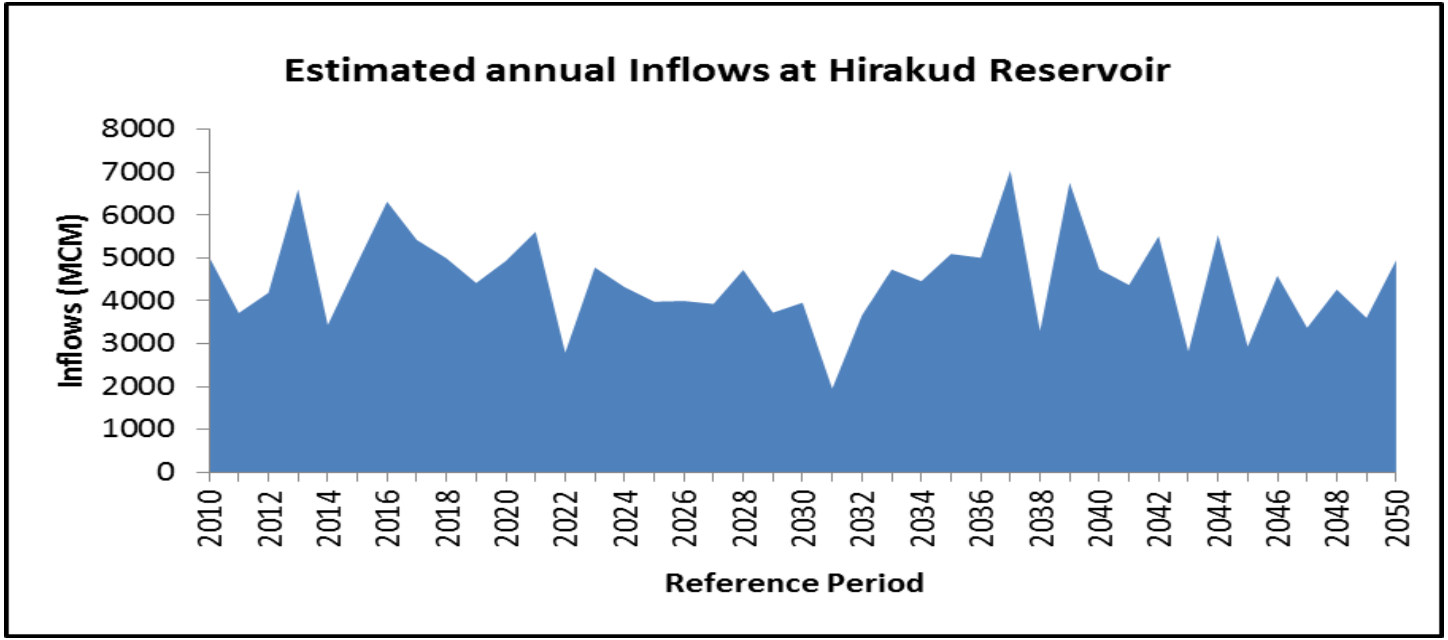
This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 821051.
This project has been co-funded by Department of Biotechnology (DBT), Government of India.

ANNUAL VARIATION IN STREAMFLOWS



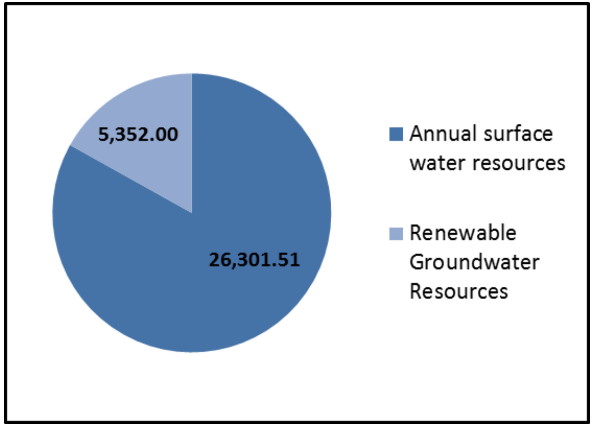
This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 821051.
This project has been co-funded by Department of Biotechnology (DBT), Government of India.

ANNUAL INFLOWS INTO HIRAKUD RESERVOIR

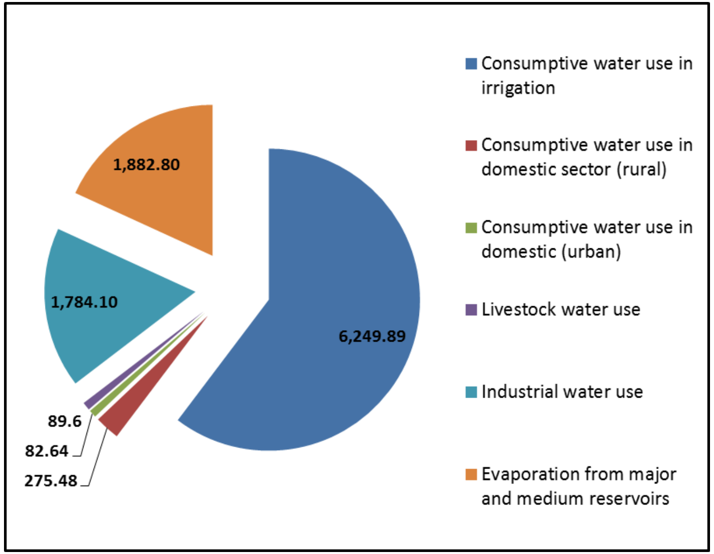


This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 821051.
This project has been co-funded by Department of Biotechnology (DBT), Government of India.

WATER ACCOUNTS FOR CH. PART OF MAHANADI BASIN (2011-12)



Estimated inflows: 31654 MCM

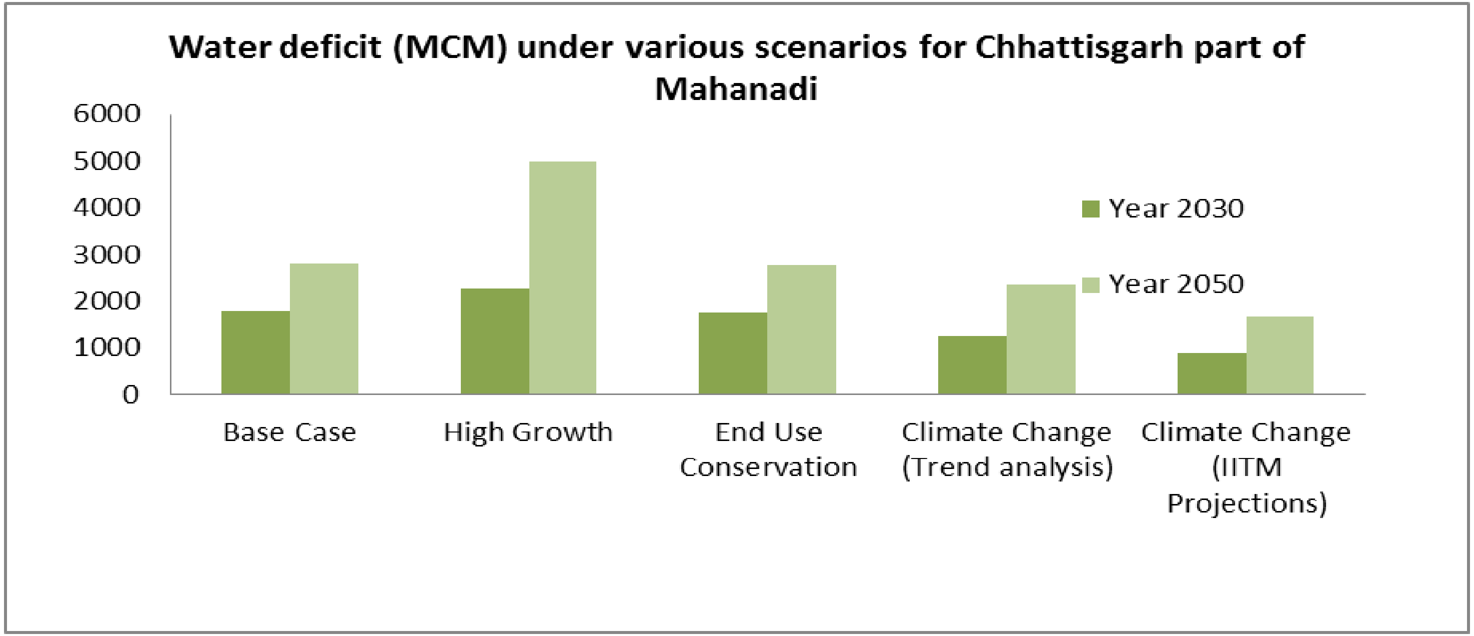


Estimated consumptive use: 10365 MCM

Surface water discharge at the last drainage point in Chhattisgarh part of the Mahanadi basin: 21289 MCM

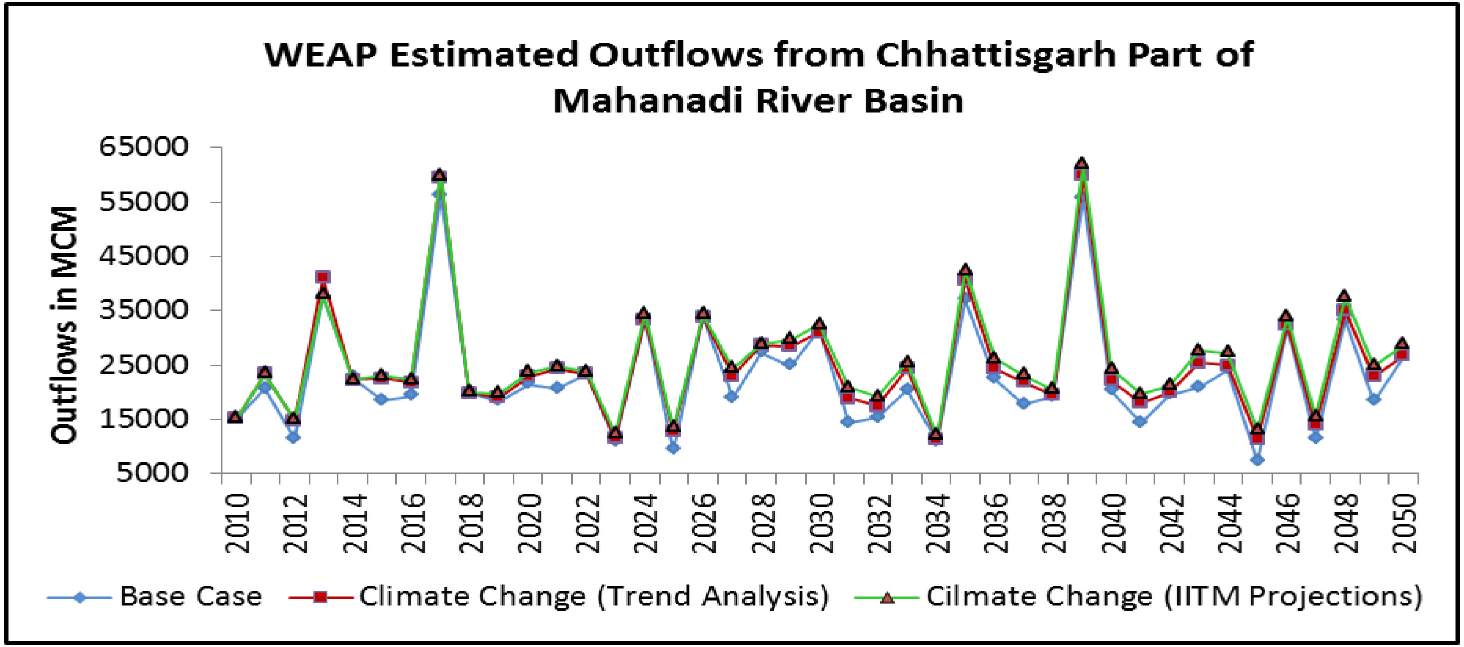
This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 821051.
This project has been co-funded by Department of Biotechnology (DBT), Government of India.

WATER DEFICIT UNDER DIFFERENT SCENARIOS



This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 821051.
This project has been co-funded by Department of Biotechnology (DBT), Government of India.

OUTFLOWS AT TERMINAL POINT OF MAHANADI BASIN IN CHHATTISGARH



This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 821051.
This project has been co-funded by Department of Biotechnology (DBT), Government of India.