Water Resources Management in Chhattisgarh part of Mahanadi River Basin under Climate Change

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Scope of the Presentation

- Discuss the hydrology, water resources and water resource system characteristics of Mahanadi, with particular reference to Chhattisgarh part
- Present the results of a basin-wide water balance modelling study with regard to future scenarios of water balance under climate change and socio-economic processes.
- Discuss the current practice of water resource planning and management by the state of Chhattisgarh
- Assess the technical, institutional and financial capacity of stakeholders in water resources management
- Discuss water governance in the state of Chhattisgarh
- Offer some recommendations for climate smart and sustainable water resources management

Results

- Rainfall mean and variability (CV) based on long-term data on point rainfall for several stations.
- Rainfall-runoff models for two catchments each of the two sub-basins of Mahanadi in Chhattisgarh.
- Long-term and seasonal trends in GW levels and average water level fluctuations for 350+ obs. wells; refined estimates of utilizable GW recharge based on estimates of groundwater discharge.
- Relationship between water level fluctuation (in wells) during monsoon & pre monsoon depth to WLs.
- PET and effective rainfall for various crops in Mahanadi part of the basin using FAO CROPWAT.

Results

- Chattisgarh part of the basin has sufficient quantity of water to meet its needs
- But the amount of surface water currently utilized is much less than what is available
- Issues of water allocation for priority sectors of use
  - Surface water allocation from public reservoirs & other schemes is by the WRD; water release for irrigation is mostly a political decision
  - Groundwater is mostly in the private domain: allocation follows only the individual priority
  - Water from public reservoirs follow state water policy guidelines
  - There is conflict between industry, farmers/fishermen

Results

- Present practices on water resources management (WRM) by the government, with reference to:
  - Data collection & analysis
  - **Method of resource evaluation**: uses GEC 1997 method for groundwater estimation, which is based on WLF approach; no water balance studies; ad hoc estimation of base flows; water balance estimates do not tally with water level trends
  - Current strategies for WRM, and the practice of considering climate change issues and adaptation strategies in WRM

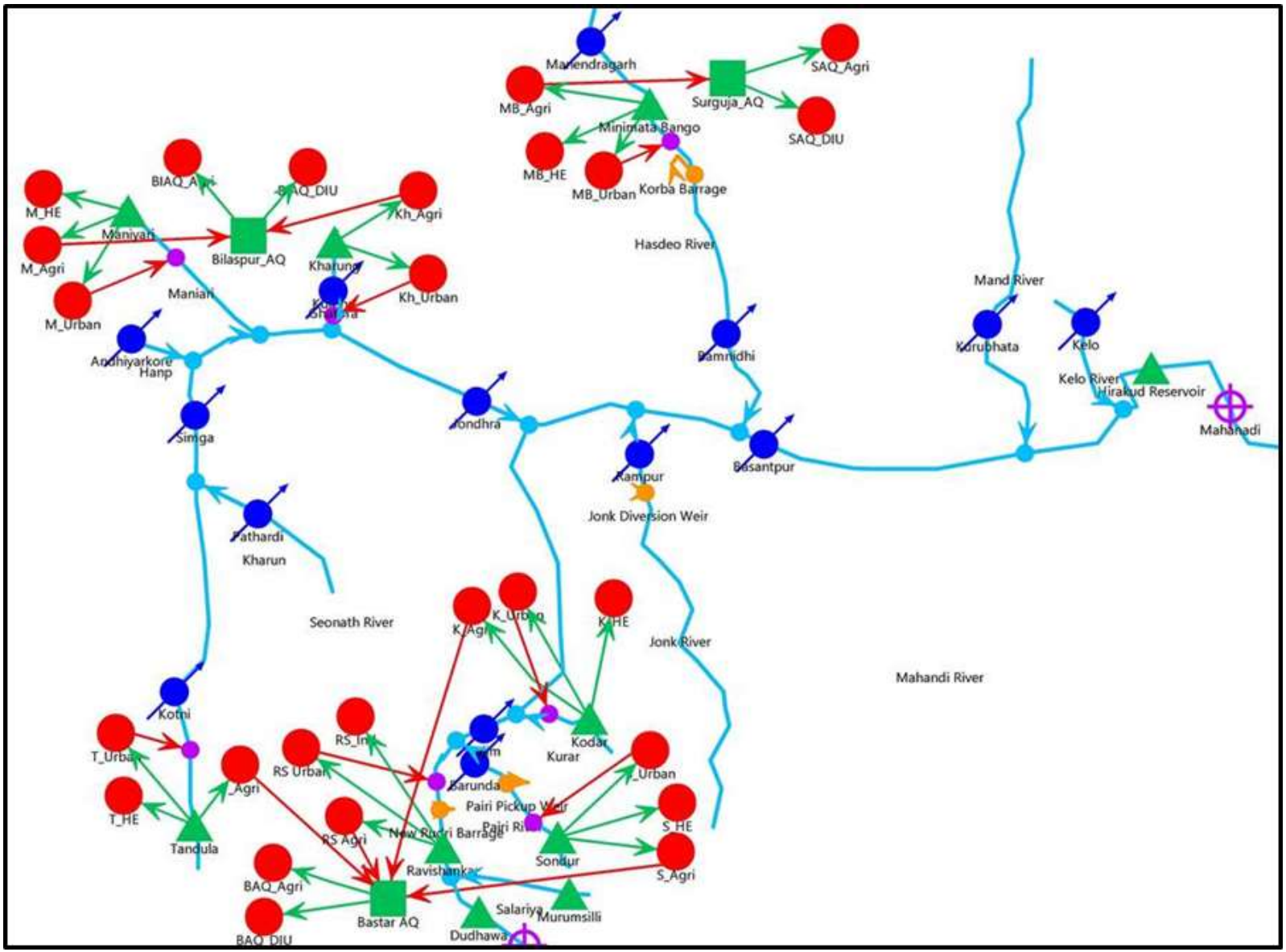
Results

- **Technical and institutional capabilities of government agencies in WRM**
  - Single agency performing multiple functions (poor focus on resource management; tendency to over appropriate, etc)
  - Sectoral approach
  - Good ability to execute engineering projects; but lack of ability to understand the impacts
- **Knowledge gaps and challenges in water resources management**
  - Present practice of water resource assessment does not take into account groundwater-surface water interactions.
  - Challenges in accurate estimation of utilizable groundwater resources in hard rock aquifers.
  - No serious consideration of forest-hydrology interactions: afforestation a major activity in state climate action plan

Results

- **Governance issues**
  - **Multiple governance structures**: state WRD, PHED, state Industrial Department, and Village Panchayats can all frame rules relating to planning, development, allocation and management of water resources
  - **Choosing the wrong governance unit**: river basin scale vs the local administrative units; “scale effects” leading to over-assessment and over-appropriation
  - No rules for allocation of water across sectors, based on sound criteria
  - Absence of an apex agency for water governance, setting rules for resources development & allocation; No pricing regulations; allocations are NOT based on serious considerations of the socio-economic realities

WEAP configuration for Ch. part of Mahanadi basin



Some of the Input data used and outputs generated by WEAP

- 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

Water accounts for the Ch. Part of Mahanadi basin

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

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

- 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'.

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

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 further water diversion infrastructure can compromise the water needs of the lower riparian state of Odisha, especially during drought years.

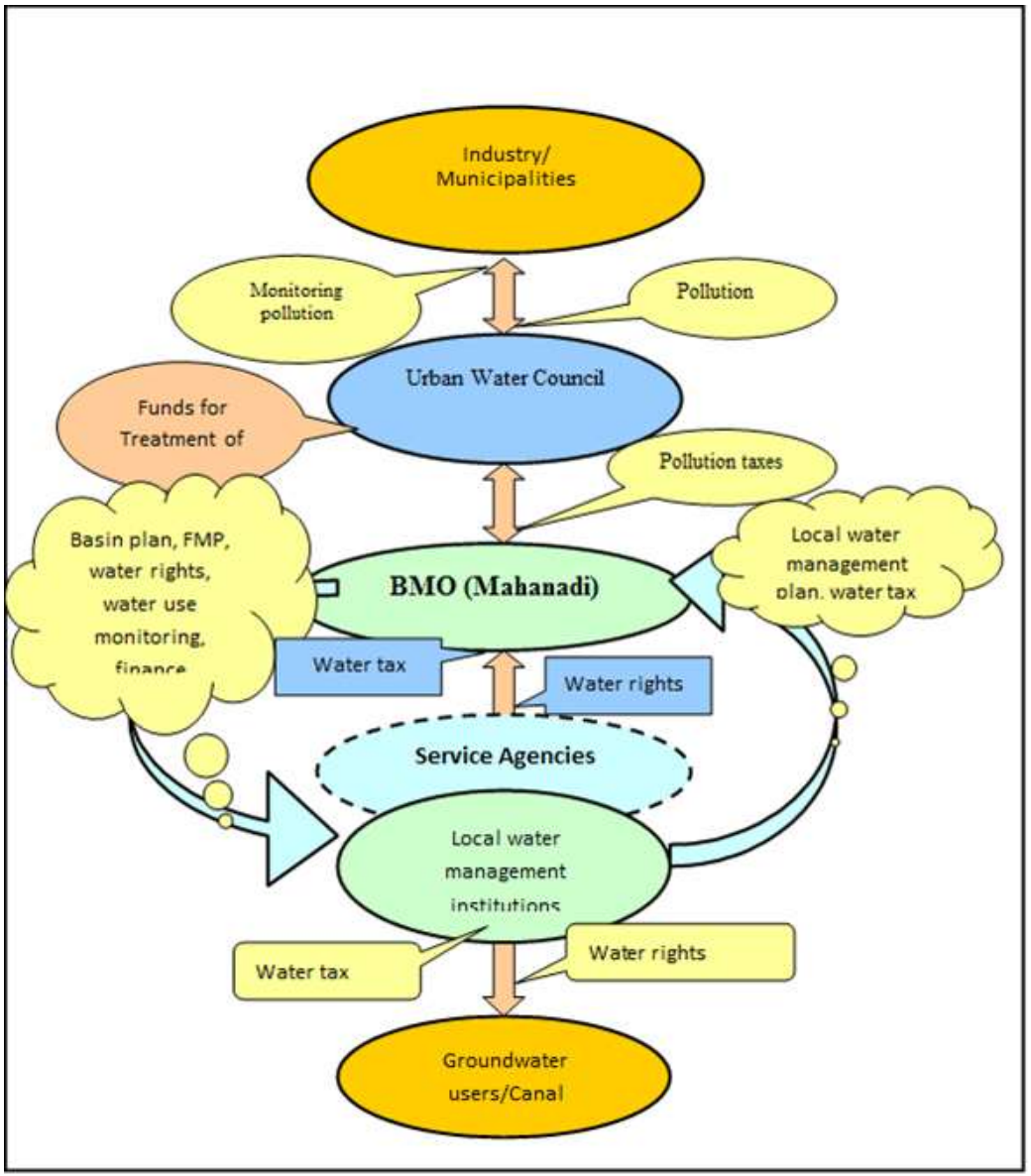
Seasonality dimension of water balance

- 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.

Improving Climate Resilience in Ch. part of Mahanadi Basin: Suggested Strategies and Reforms

- Technical Strategies
  - Short term
  - Long term mainly to make community climate resilience against droughts
- Institutional Reforms
- Governance Reforms and Institutional restructuring
  - Creation of Water Resources Regulatory Authority
  - Design principles for the restructuring of existing or creating of new water institutions to improve basin-wide water resources management.
  - Creation of River Basin Organisation as a coordinating institution at the basin level to monitor the performance of line agencies

Overall institutional arrangement for water management in Mahanadi river basin



Findings, conclusions and recommendations

- Mahanadi basin has high inter-annual rainfall variability, with runoff changing with rainfall in a linear fashion.
- 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.
- Aquifers display high degree of heterogeneity and monsoon recharge is influenced by pre monsoon depth to WL and magnitude of rainfall.
- The concept of WUE being used by the state for climate adaptation programme is not sound enough

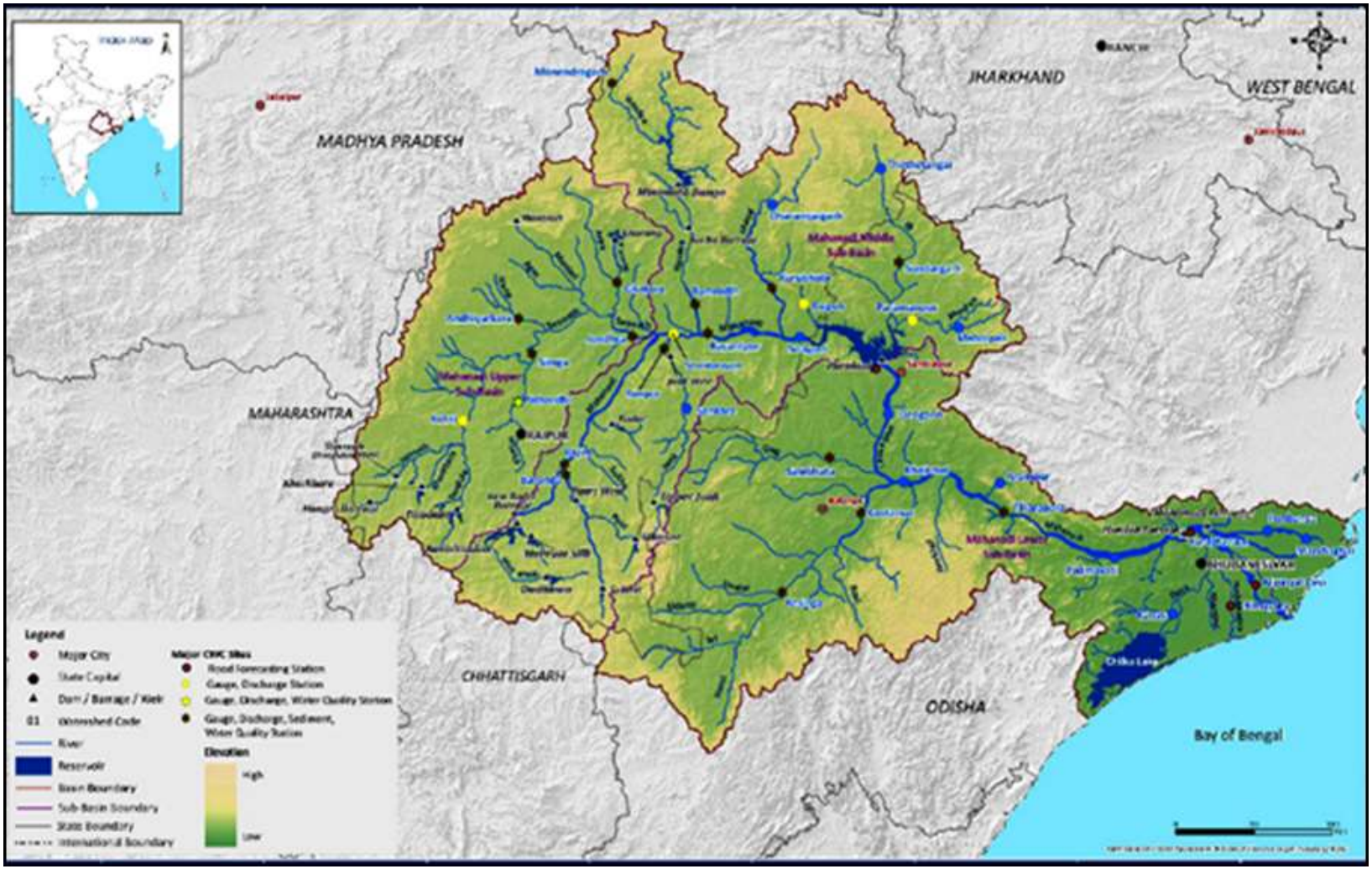
Findings, conclusions and recommendations

- There are some inadequacies in water sector agencies (related to institutional design), and the policies governing the use of water
- 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.
- 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 conflicts.

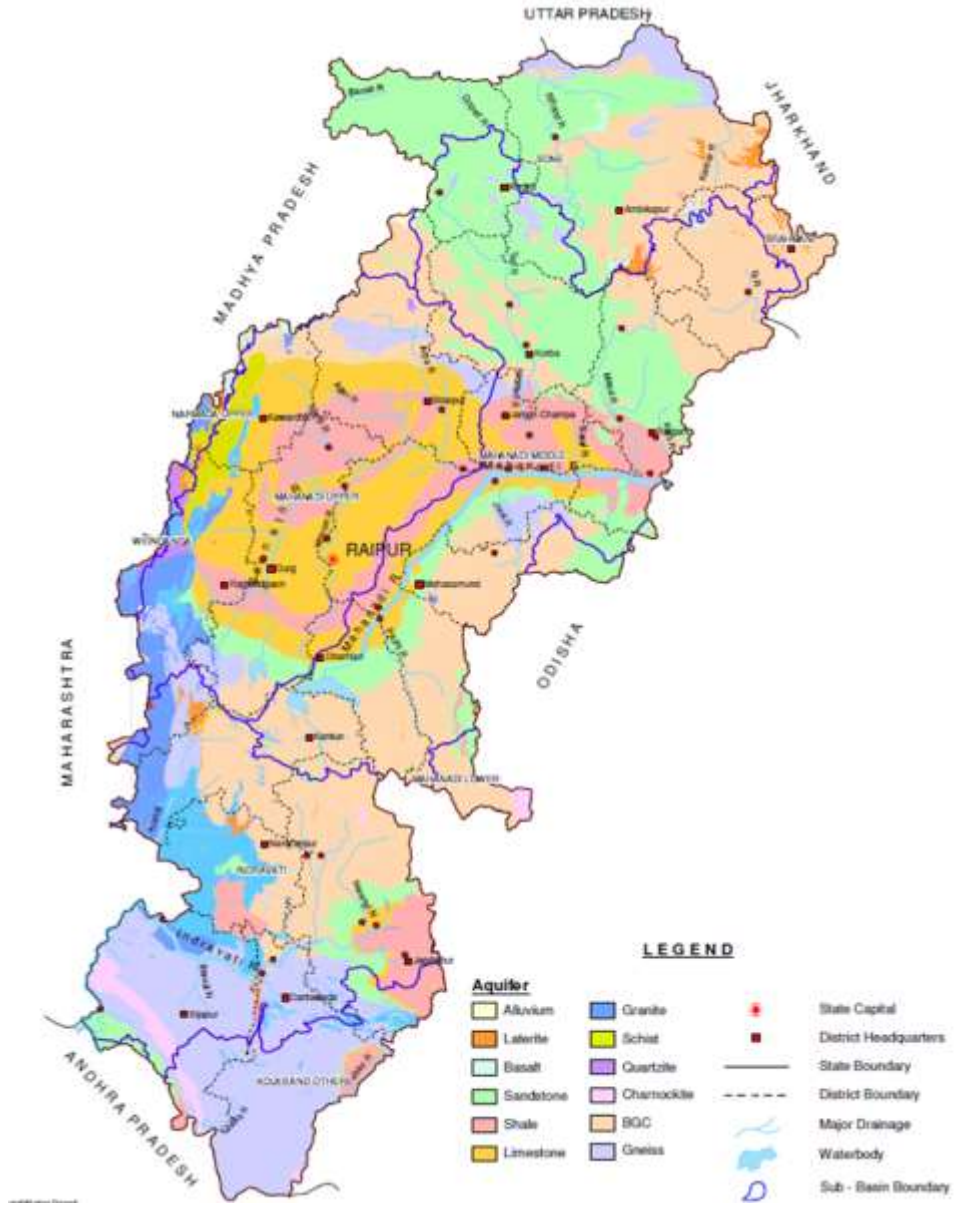
Findings, conclusions and recommendations

- 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.
- Long term, institutional change needs include marginal cost pricing of water, introduction of water rights/water entitlements & energy pricing.
- Governance reforms should include creation of State WRRA and RBO.
- RBO will be coordinating institution which would monitor the performance of all the line agencies

Drainage -basins of Mahanadi River



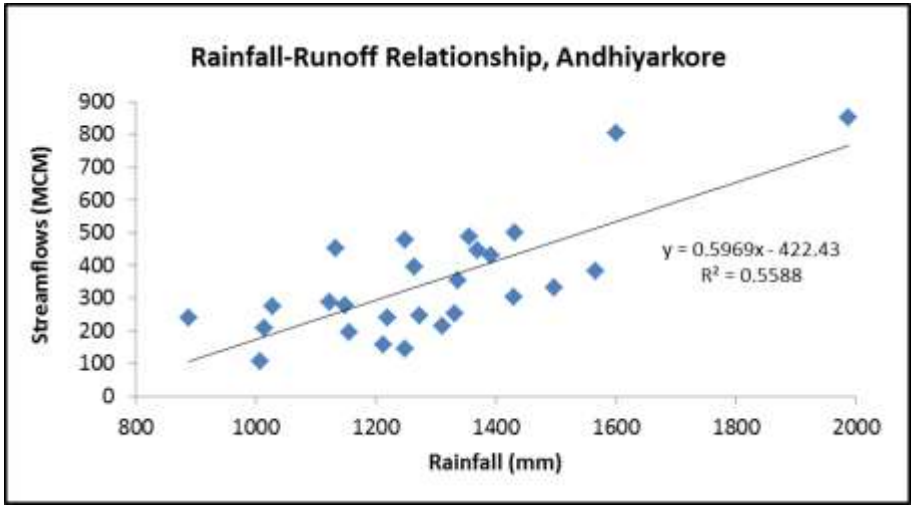
Complex and heterogeneous aquifer system in Chhattisgarh

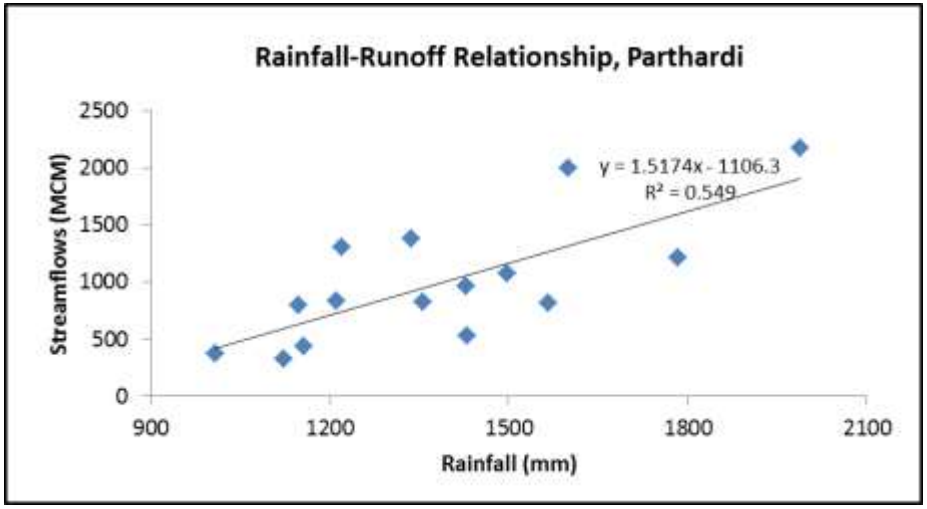


Spatial and temporal variation in rainfall

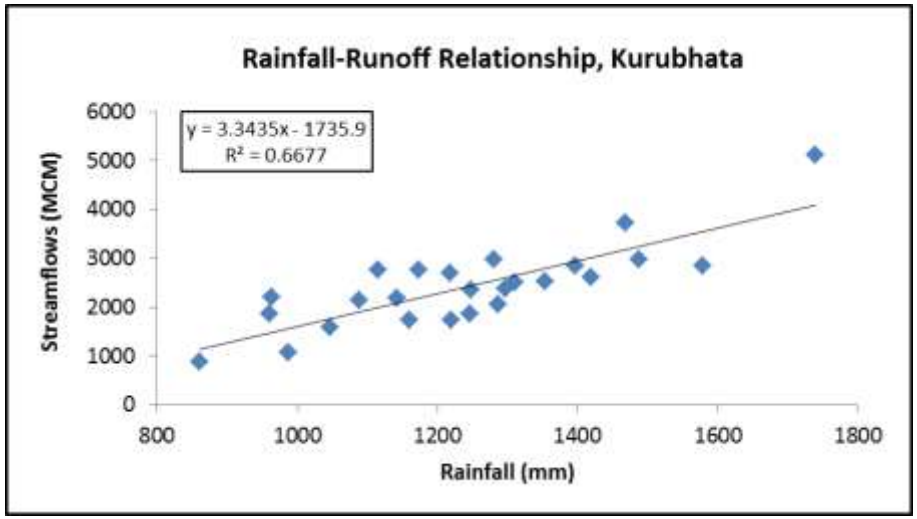
	Particulars	Gauging locations-Upper sub-basin		Gauging locations-Middle sub-basin	
		Andhiyarkore	Pathardi	Kurubhata	Manendragarh
1	Catchment Area (sq. km)	2210	2511	4625	1100
2	Average annual rainfall (mm)	1300	1300	1250	1250
3	CV in spatial average of rainfall	**17%** (888-1969)		**16%** (838 to	
4	Average annual stream flows (MCM)	331	1023	2352	337
5	Highest annual flows (MCM)	851	2170	5114	620
6	Lowest annual flows (MCM)	35	323	878	198
7	CV in annual stream-flow (%)	56	47	36	40

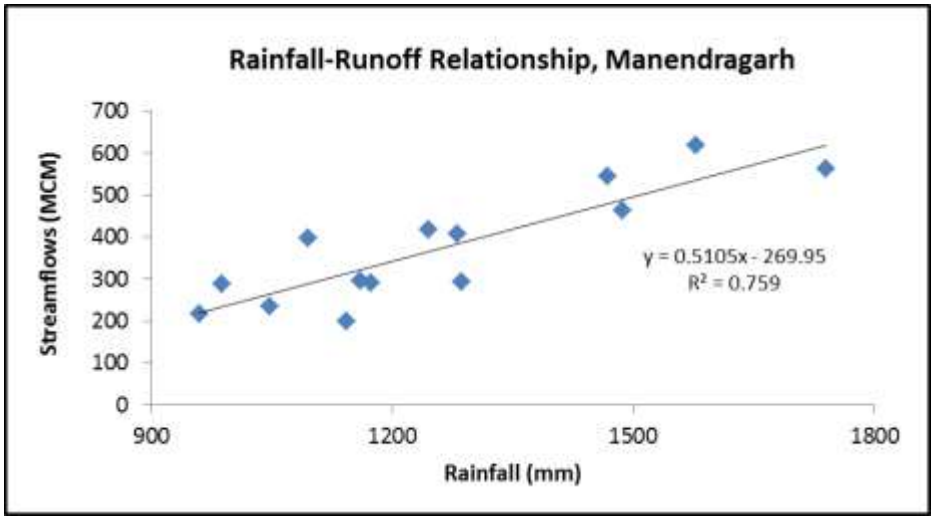
Rainfall-Runoff relationship





Upper Mahanadi Sub-basin





Middle Mahanadi Sub-basin

Trend in groundwater level fluctuations during Monsoon

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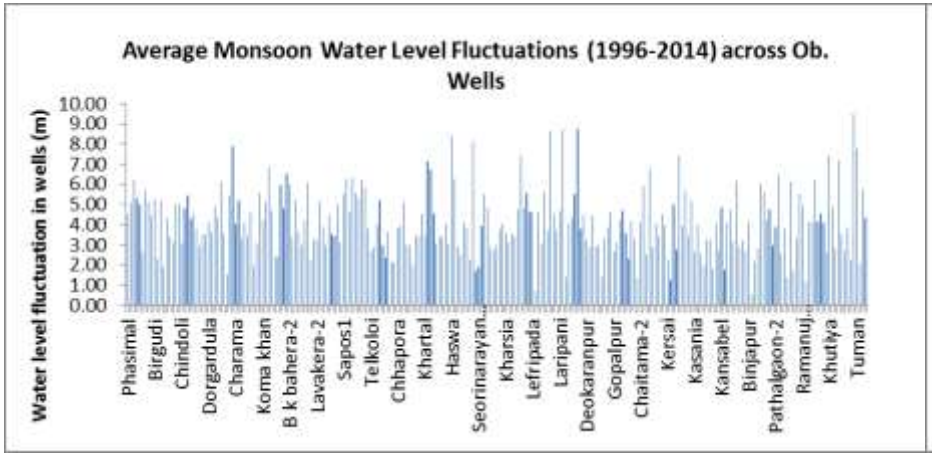
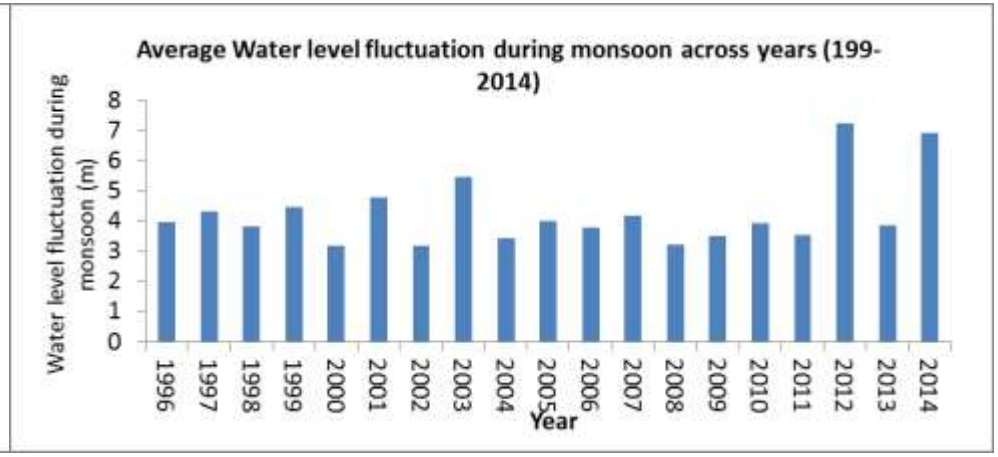
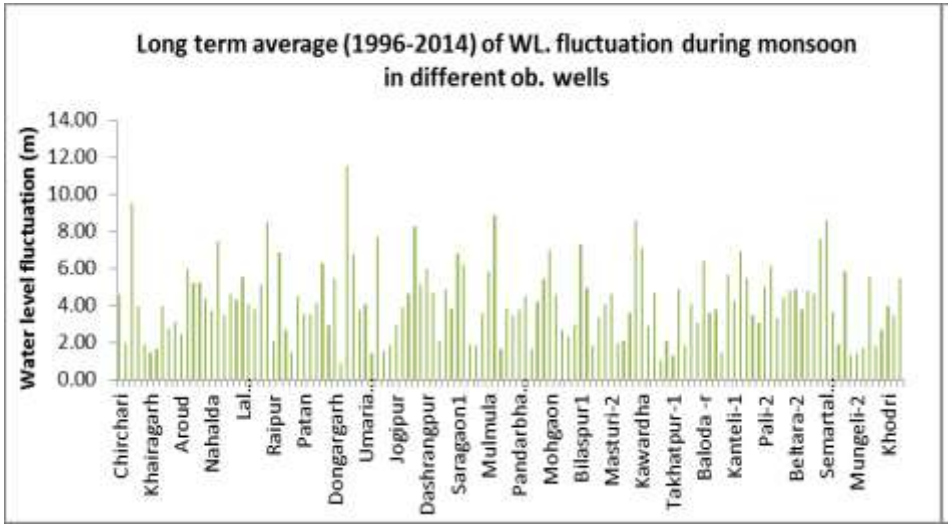
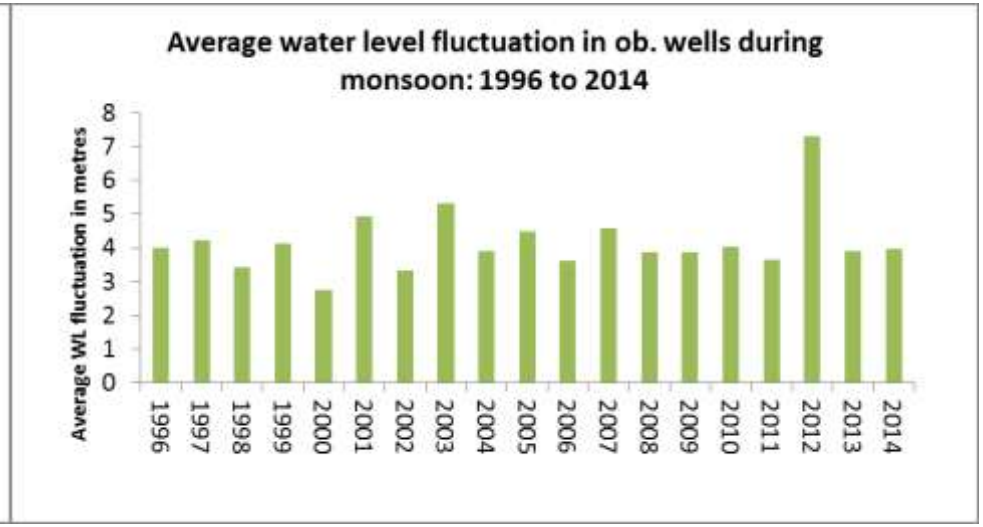




Middle Mahanadi Sub-basin

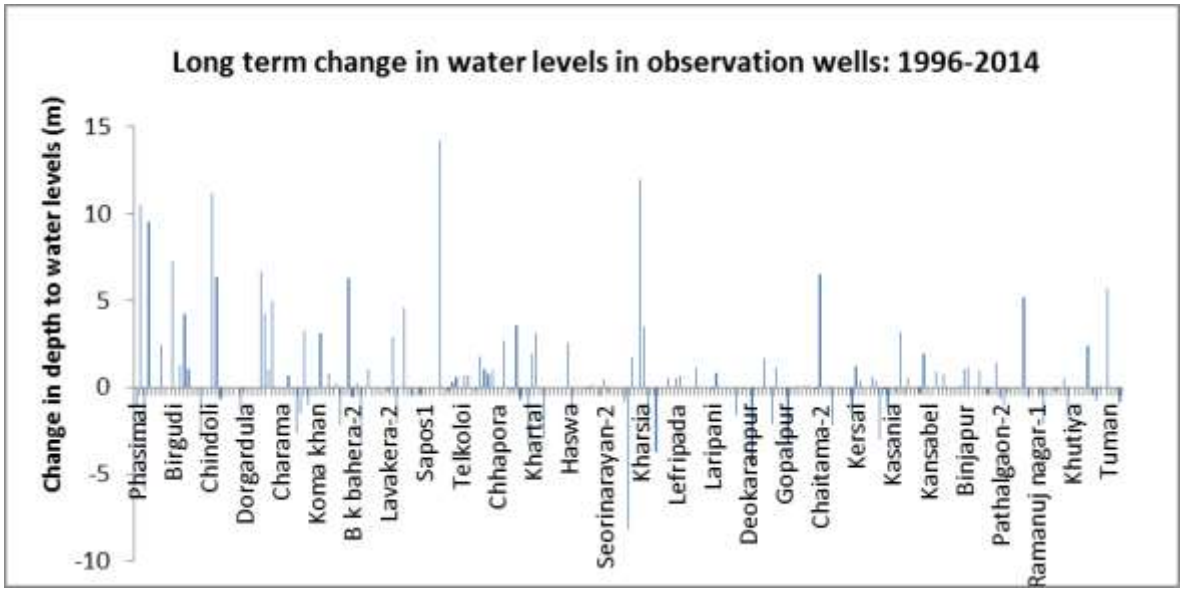




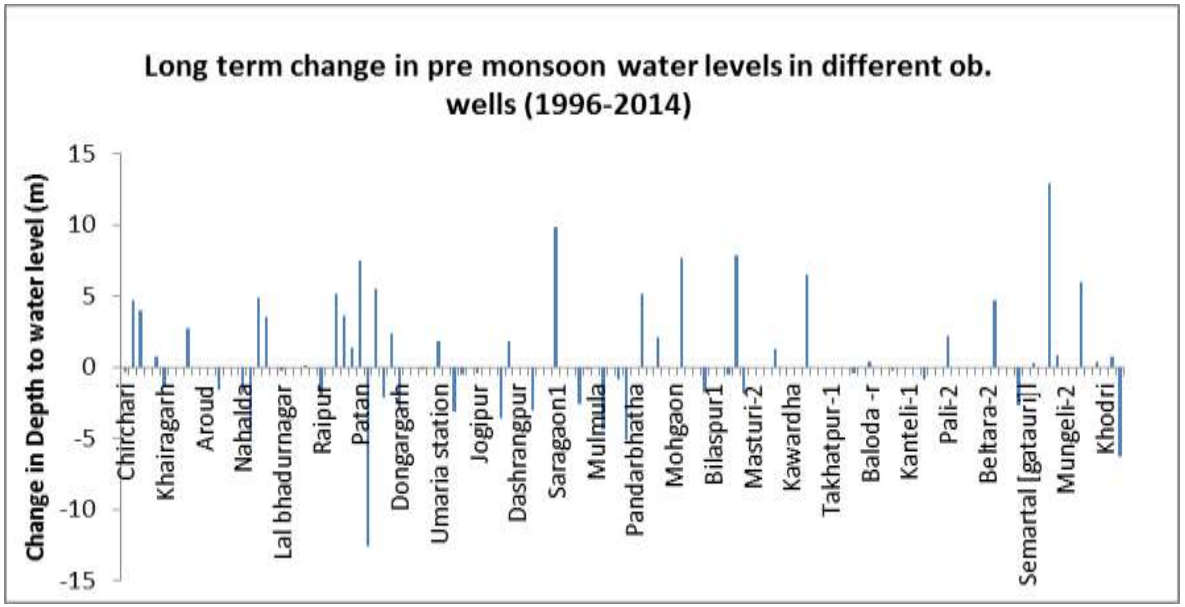
Upper Mahanadi Sub-basin

Long term change in pre monsoon water levels

Middle Mahanadi Sub-basin

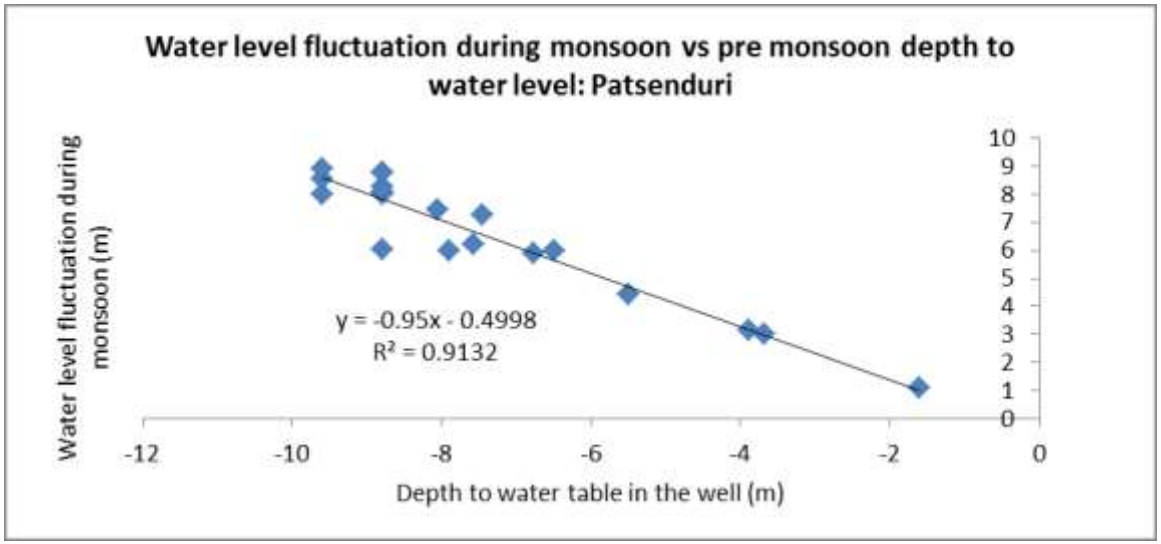


Upper Mahanadi Sub-basin

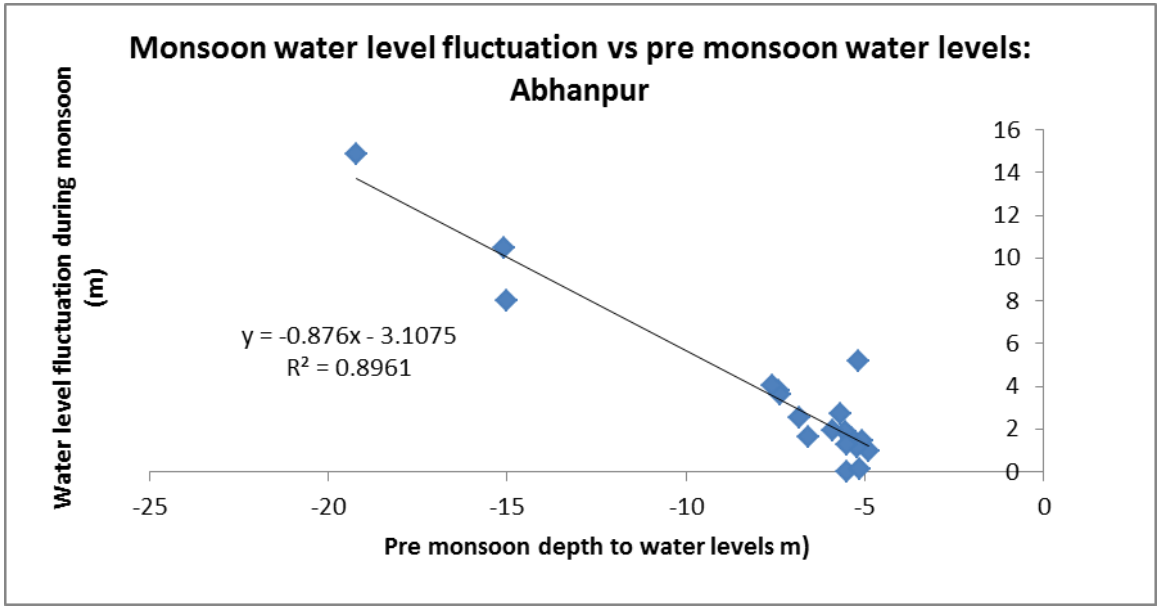


Monsoon water level fluctuation vs pre monsoon water levels

Middle Mahanadi Sub-basin



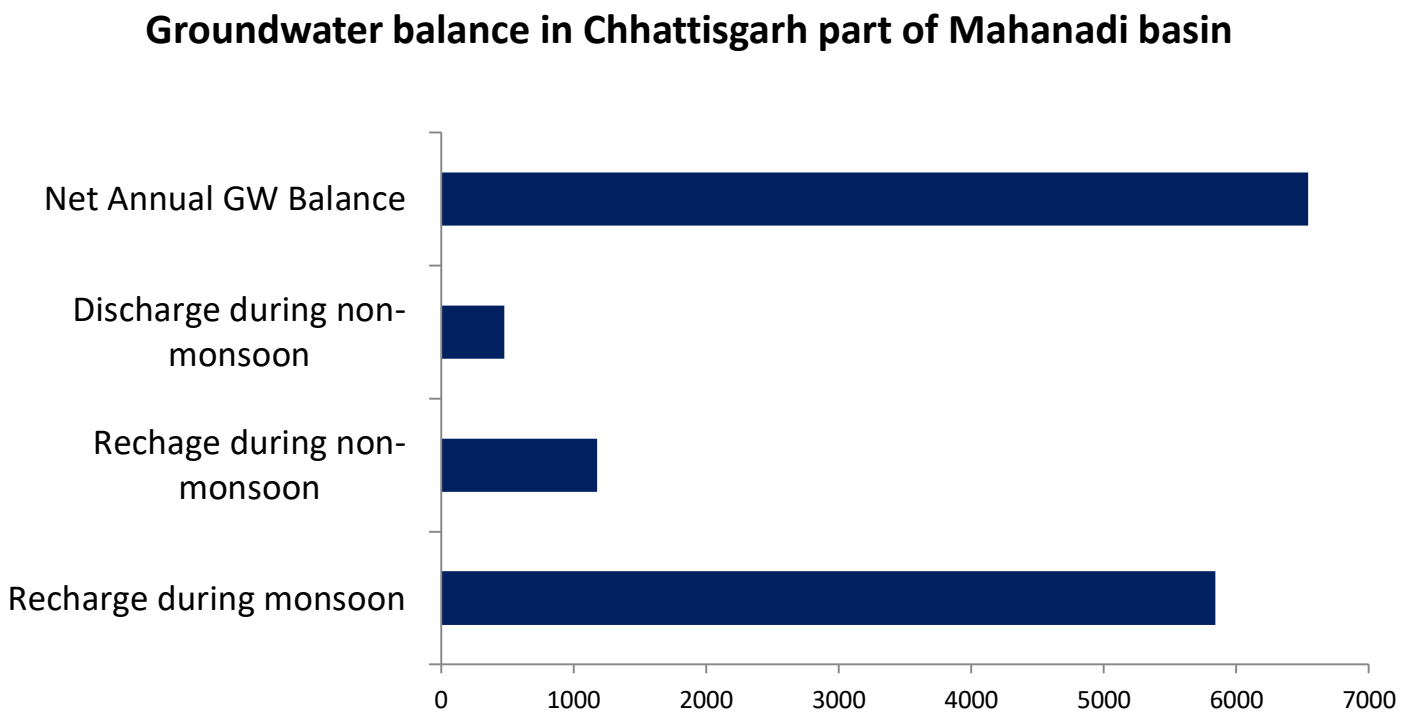
Upper Mahanadi Sub-basin



Gauging stations maintained by Chhattisgarh state in Mahanadi river basin

River Basin	Type	Number	Maintained by
1] Hydrological observation sites			
Part of Mahanadi basin in Chhattisgarh	Gauge & Discharge (GD)	33	State Water Data Centre (Hydrology Project), Chhattisgarh
	Gauge, Discharge & Water Quality (GDQ)	7	
	Rainfall stations (Standard)	27	
	Rainfall station (Automatic)	18	
	Weather Station	2	
2] Groundwater Observation wells			
Part of Mahanadi basin in Chhattisgarh	Including observations dug wells and piezometers	Around 900 (needs to be confirmed at the State level)	North Central Regional Office of CGWB
3] Meteorological stations			
Part of Mahanadi basin in Chhattisgarh	Rainfall stations outside HP	138	Water Resources Department and other departments, Chhattisgarh

Groundwater estimates need major improvements

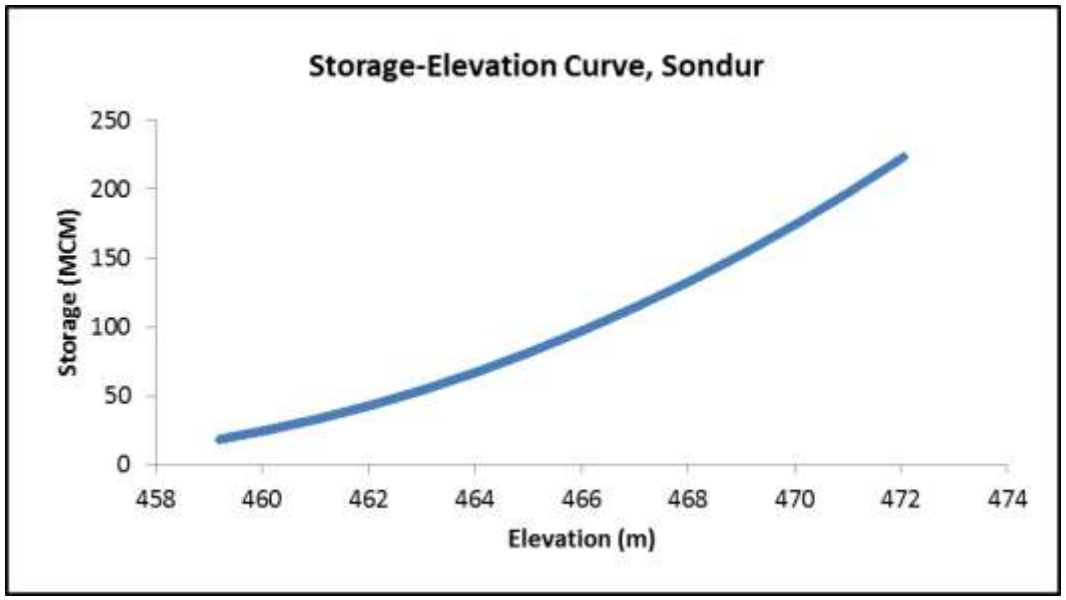


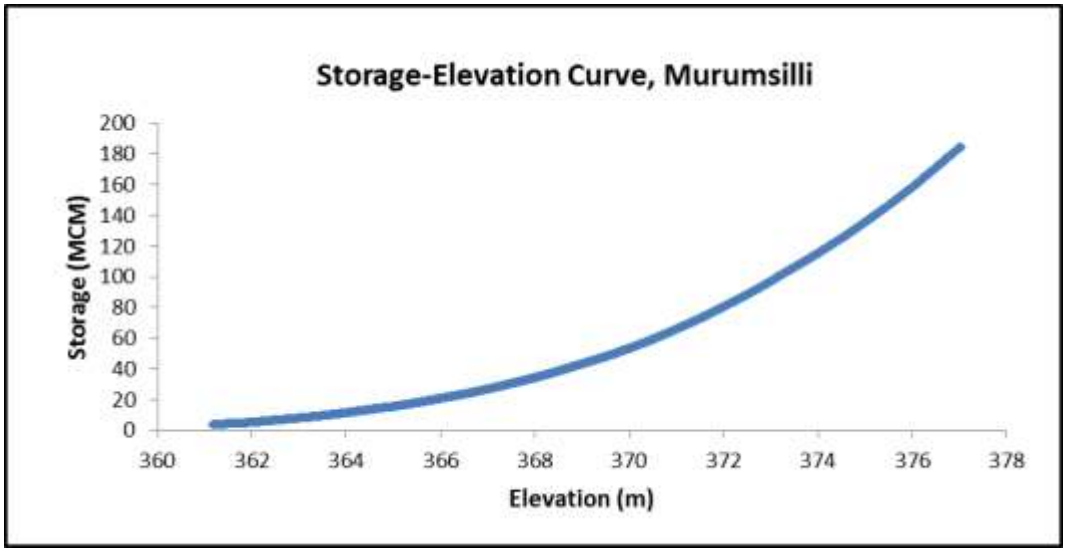
The average of total lean season flow in 20 years is 1633 MCM. But, the GW discharge considered by CGWB is only 480 MCM per annum. This means there is heavy over-estimation of total recharge.

Current practice of considering climate change issues in WRM

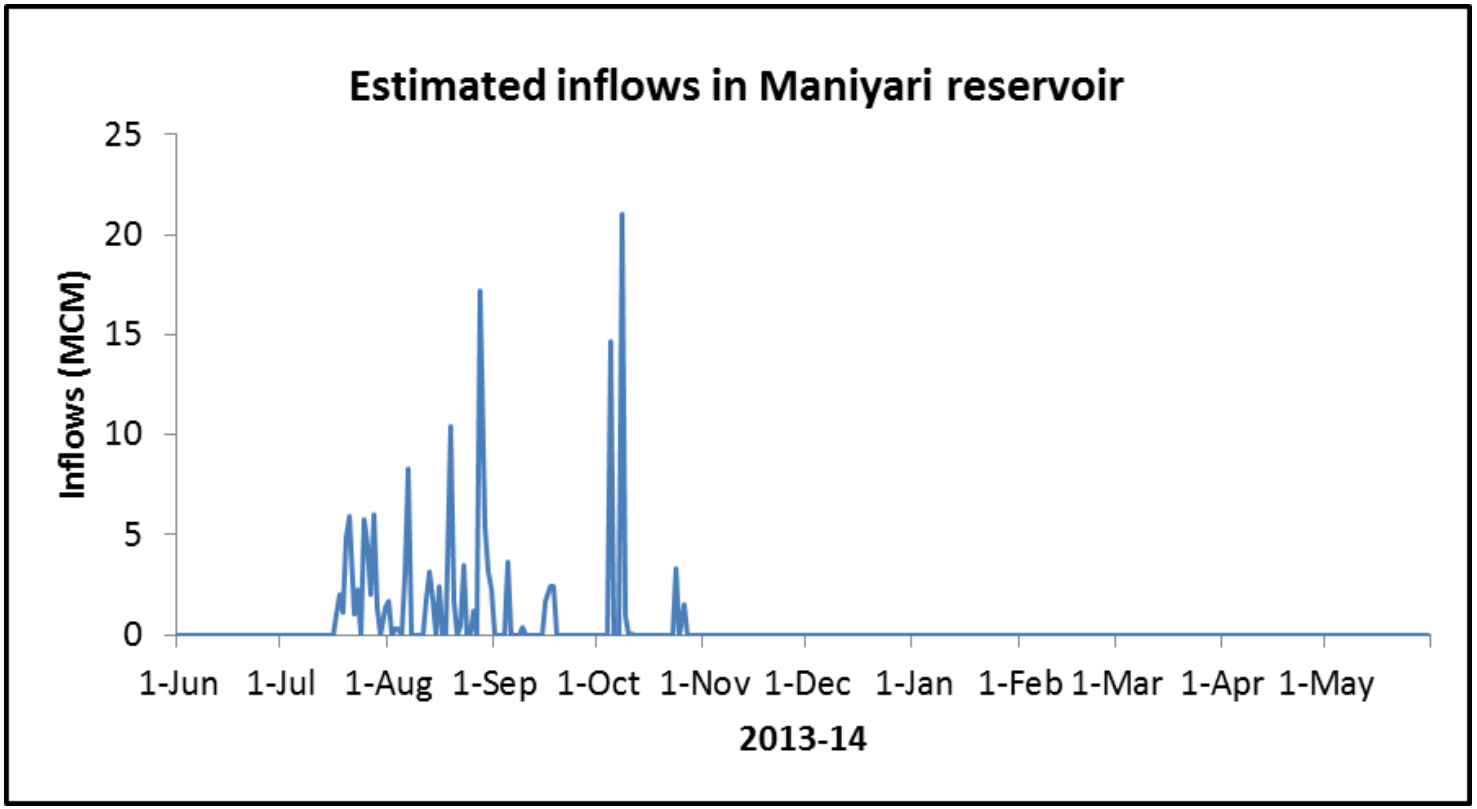
- As per the "Climate Change Action Plan for Water", the state plans to increase the irrigation potential to 64% of the net sown area
- It mention about integrated development of SW and GW for optimum irrigation development, but it doesn't say why it is relevant and **how the concept will be operationalized**
- The proposal to adapt to climate change (**like introduction of precision farming**) are not based on any real analysis of the hydrology and the socio-economic systems
- For instance, paddy, which dominates the cropping system of the state, is not amenable to any water saving irrigation devices
- The ongoing plans to augment the irrigation potential through building of M & M, and minor schemes will be crucial in enhancing **community resilience to increased risks associated with climate variability and change**.

Storage-elevation curves

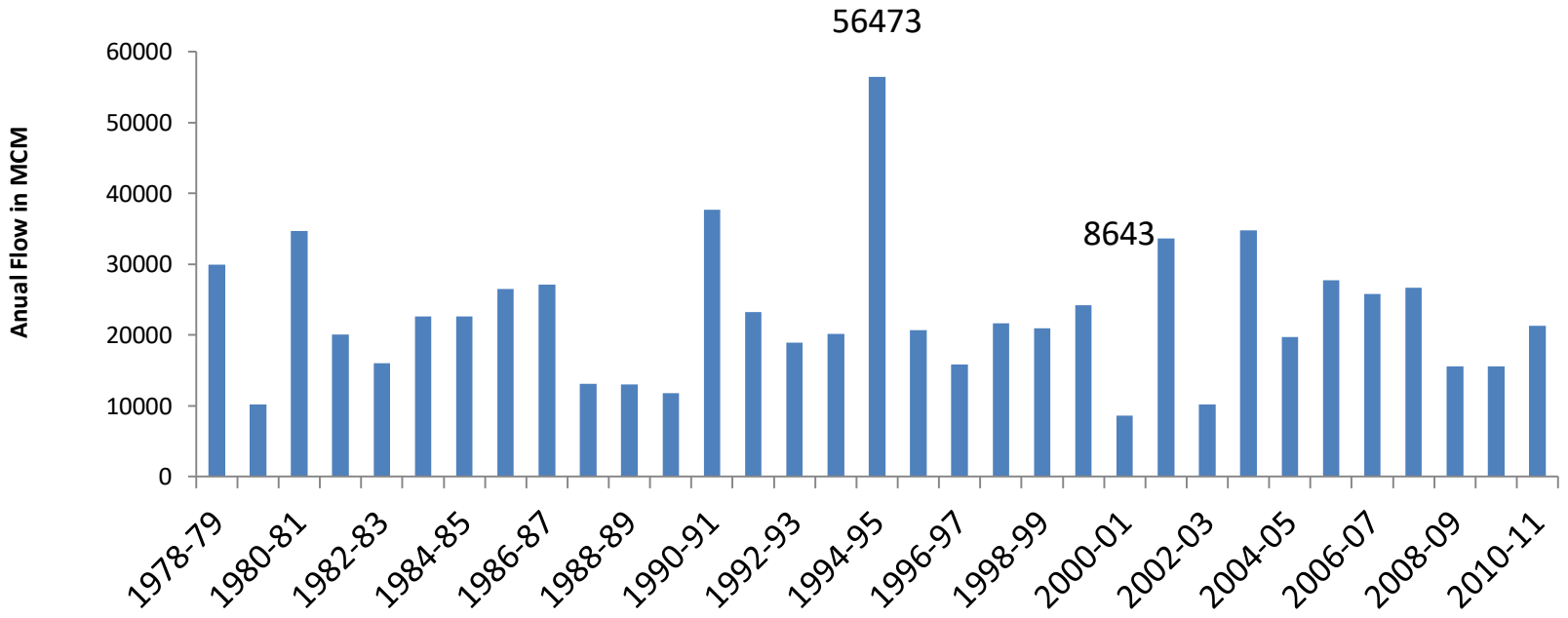




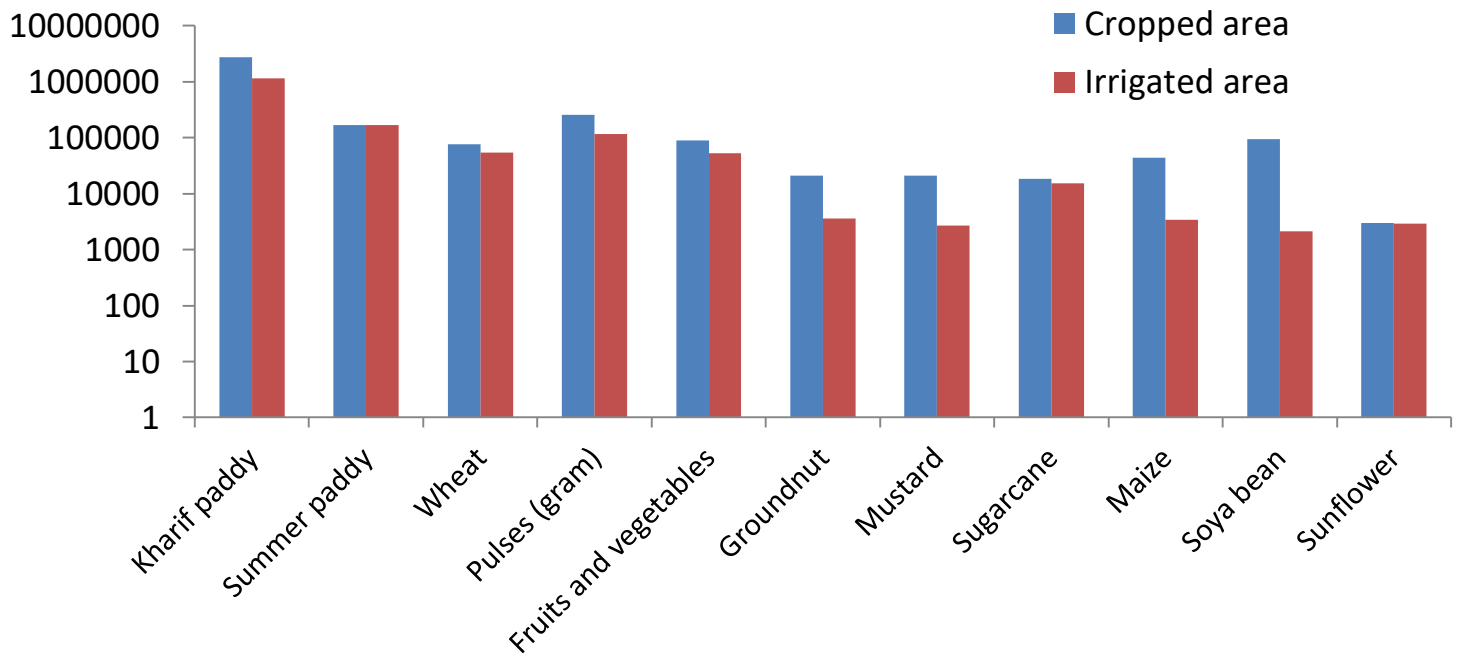
Estimated inflows in Maniyari reservoir



Estimated stream flows in Mahanadi u/s of Hirakud reservoir in Chhattisgarh



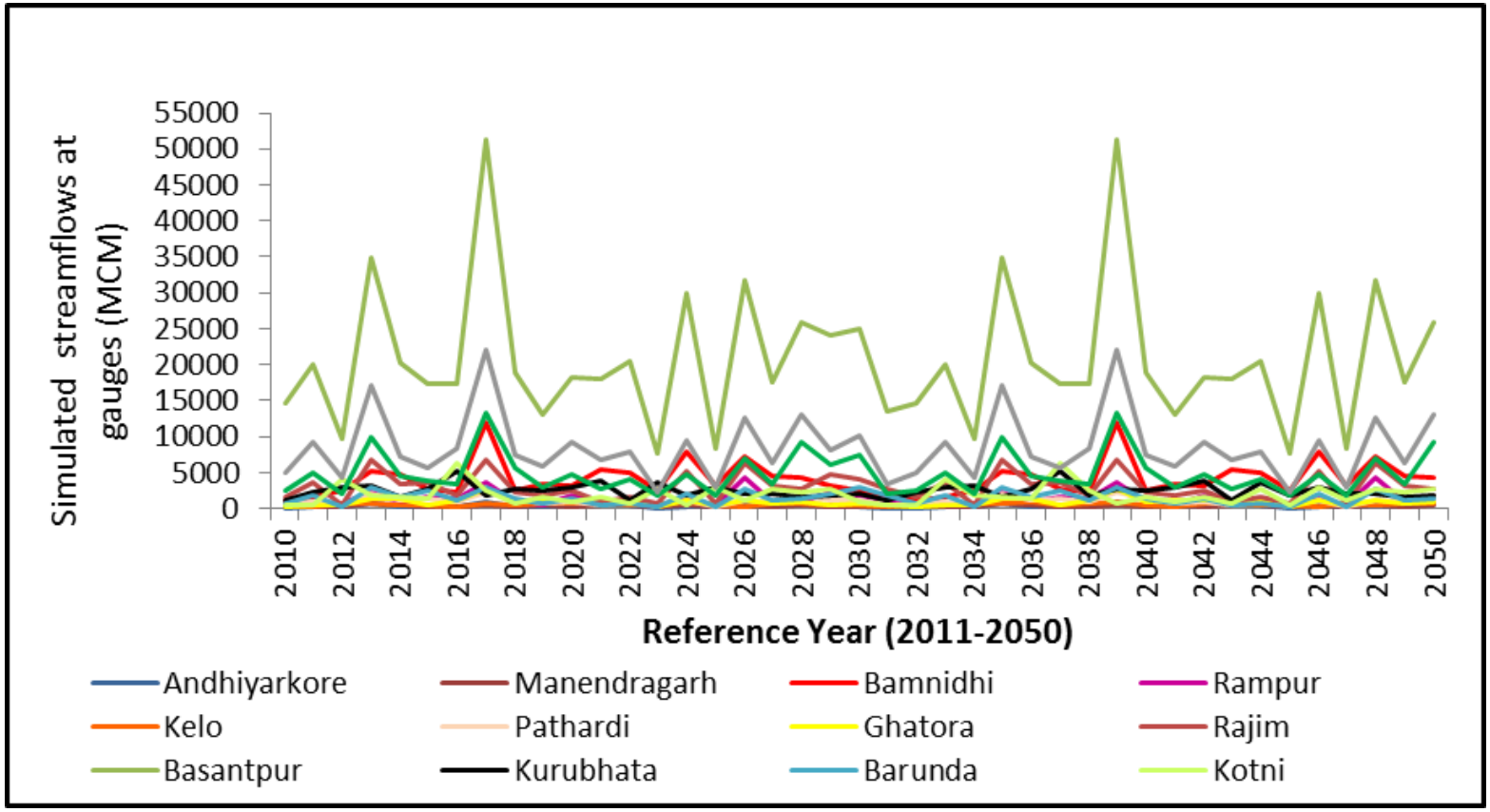
Cropping and irrigation pattern in Chhattisgarh, Mahanadi basin



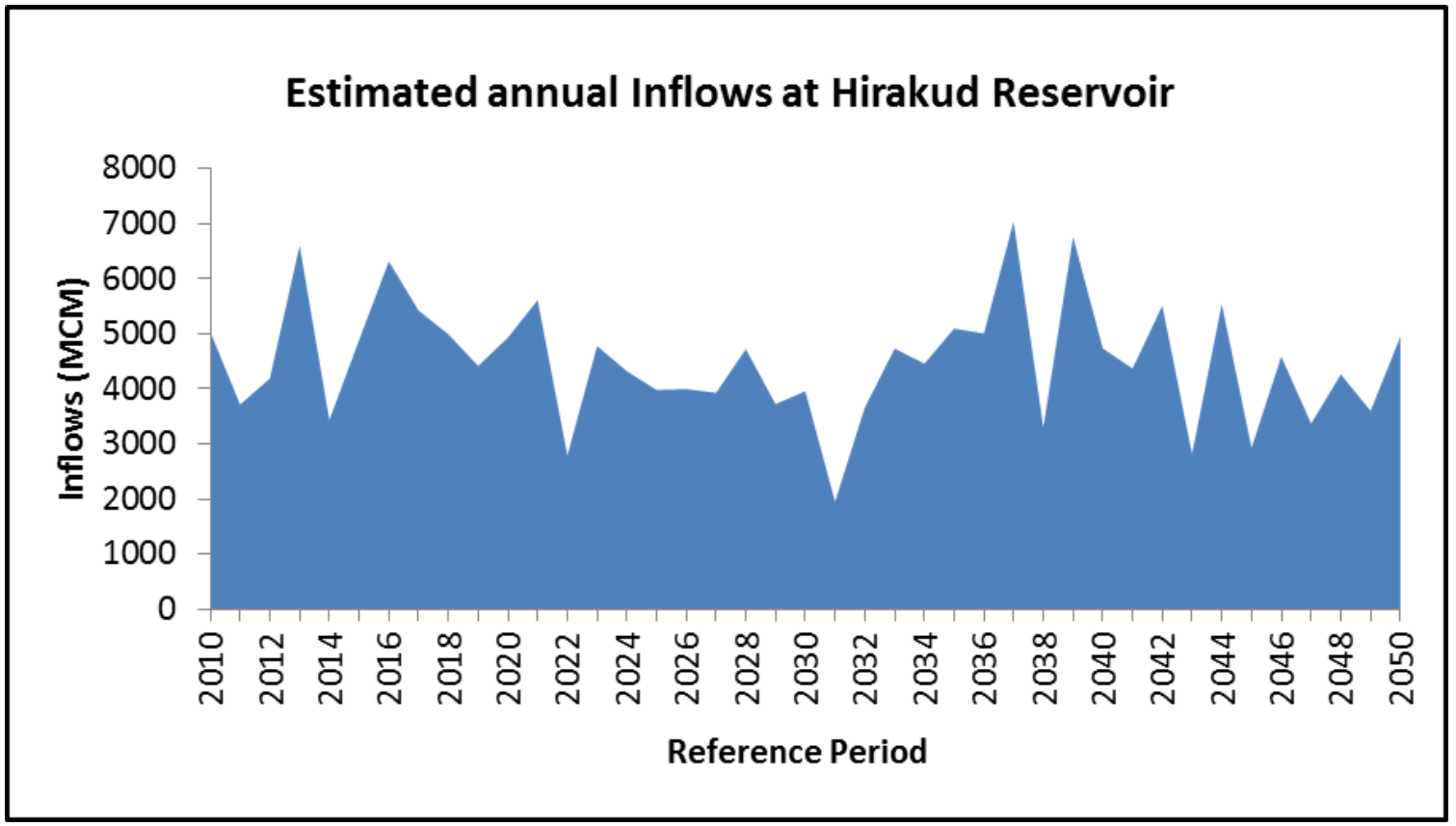
Irrigation water demand estimation (A X IWR)

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 (Manaiari 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

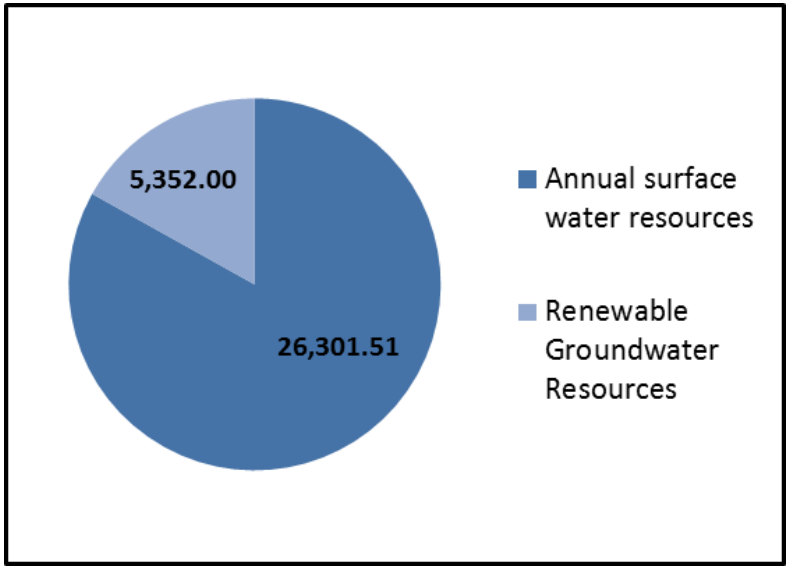
Annual variations in stream flows



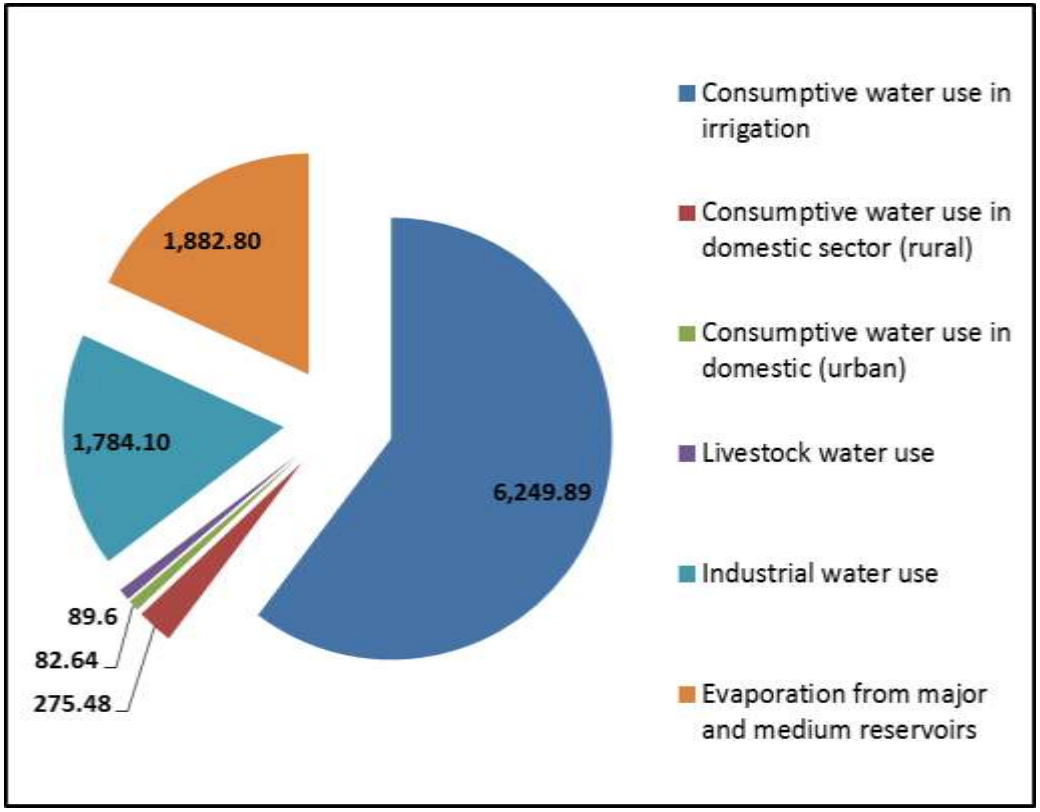
Annual inflows in Hirakud reservoir



Water accounts for Ch. Part of Mahanadi basin (2011-12)



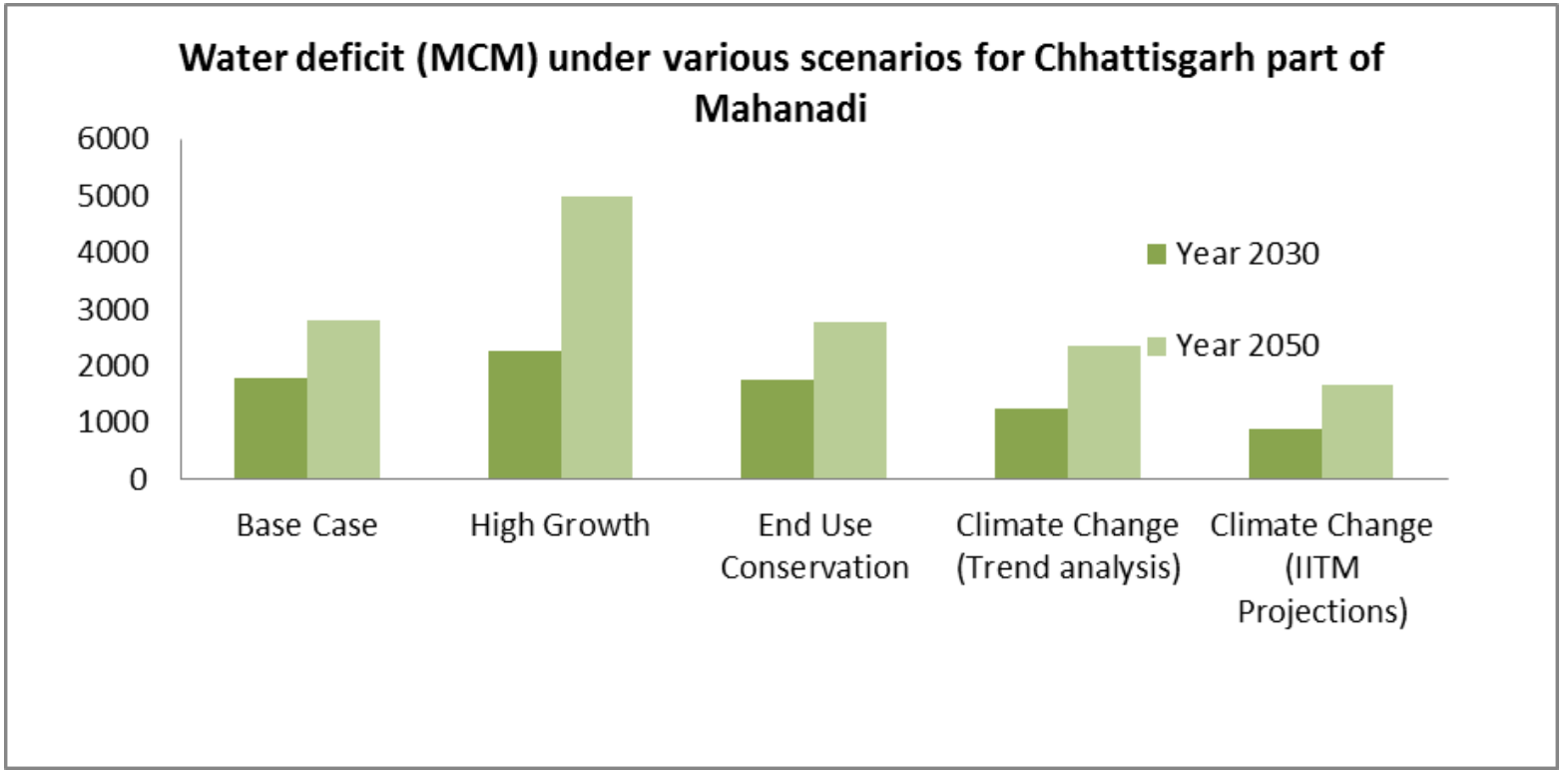
Estimated inflows: 31654 MCM



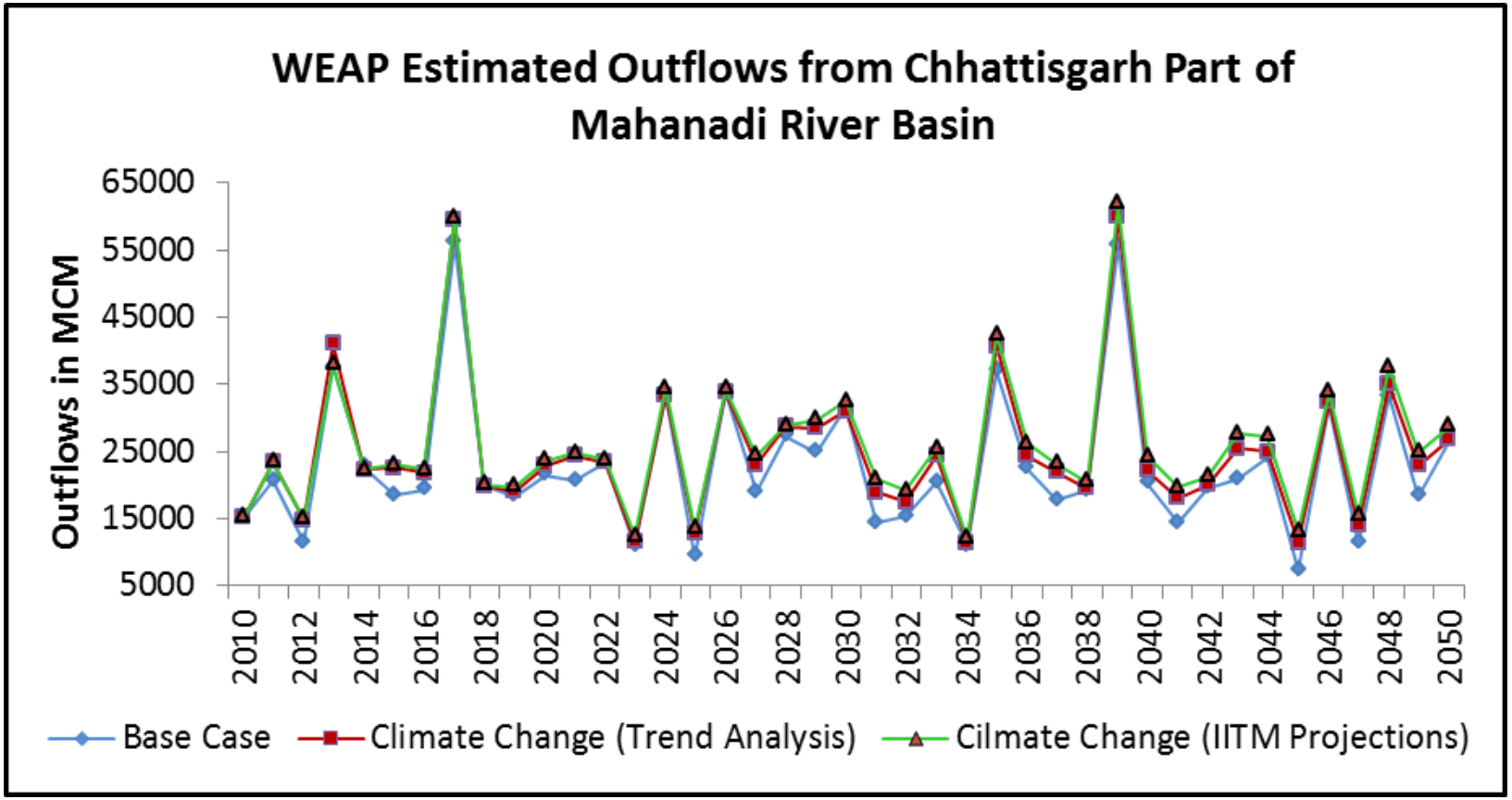
Estimated consumptive use: 10365 MCM

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

Water deficit under different scenarios



Outflows at terminal point of Mahanadi basin in Chhattisgarh



Year 2023, 2025, 2045 and 2047 are drought years

Short 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, WSTs in irrigation and WUE 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 resilience to droughts is to build water storage for multi annual storage.
- 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.

Institutional Reforms

- These reforms are required to create incentives for efficient use of water to affect water demand reduction and effectively manage inter-sectoral allocation of basin water.
- For canal water, the reform can focus on introduction of marginal cost pricing (MCP) of water and water rights.
- For groundwater, it will be introduction of MCP, water rights and pro rata pricing of electricity.
- For industries, water charges should be raised to reflect the opportunity cost of not having high quality water from surface sources.
- For irrigators in command areas, pricing should also be revised. However, this would require irrigation modernization.
- Water rights can be initiated first for water supplied from public systems, followed by reforms in the groundwater sector.

Water Resources Regulatory Authority, Mahanadi basin

- The authority can frame rules for water allocation across sectors using social, economic and environmental considerations. Also crucial for resolving future water conflicts.
- The authority should have powers to evolve rules regarding the pricing of water in different sectors.
- The ideal pricing norm should be based on cost of production of water, affordability for the user community, and the economic benefits that can be produced from its use.
- For allocating water for meeting ecological needs, the government should purchase water from the agency which bears the cost of ensuring such flows, and recover the same by charging from the benefitted community.

Design principles for restructuring existing or creation of new institutions

- Clear distinction between water development and water resources management functions
- Institutions responsible for water allocation/regulating water use have to be different from water service agencies;
- Institutions responsible for water quality monitoring and those for managing water quality cannot be the same; and,
- Institutions responsible for investment in water quantity management and WRM should also be enforcing norm and regulations on water use.

Suggested functions of River Basin Organisation, Mahanadi

- Developing basin management plan with strategies and integration with local management plans.
- Establishment of water rights system and water allocation amongst different sectors, levying water resource tax and pollution tax.
- Allocating funds for WRM activities: catchment management activities, wastewater treatment, water use and quality monitoring.
- Monitoring of flood control/regulation structures operations by the agencies concerned to ensure their accordance with the plan.
- Inspection system for WWT plants, flood control structures, monitoring and providing support for the flood fighting system.
- Monitoring the flood warning system, flood preparedness and maintenance system.