REGIONAL MODELLING OF WATER QUALITY AND QUANTITY USING WEAP SYSTEM

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PAVITRA GANGA

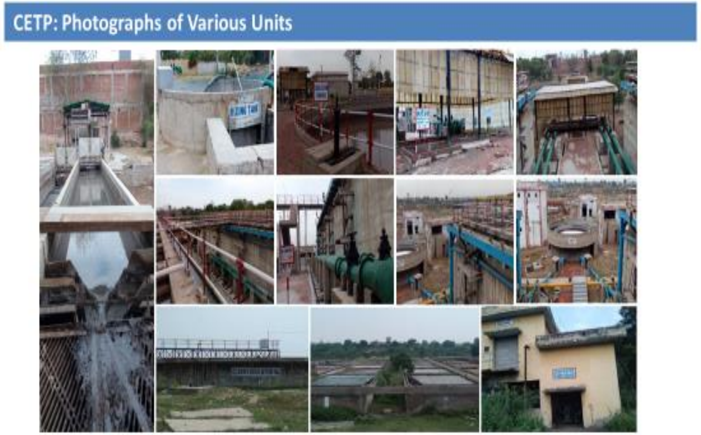
REGIONAL MODELLING OF WATER QUANTITY AND QUALITY CHANGES USING WEAP SYSTEM

- **One of the key objectives in Pavitra Ganga** is to analyze the changes in quality of water in the Ganges, especially at Kanpur and downstream of Barahpullah drain in Delhi due to a variety of climatic stresses, socioeconomic pressures and land use changes, and the impacts of the range of proposed water treatment technologies and changes water allocation decisions on the water quality and quantity.
- **Propositions**: water quality change will be affected by changes in flow regimes (seasonally and annually); and changes in quantum of pollution load (from urban & effluent effluents, and non-point pollution from agriculture). The changes in flow regime can be affected by land use changes, and climate variability and change, and changes in regional water allocation decisions

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 THE KANPUR POLLUTION PROBLEM

- The Ganges river gets polluted by the sewage generated from the city, and the effluent from hundreds of tanneries in and around the city
- The partially treated wastewater from the STPs and CETPs is diverted for irrigation (of paddy, wheat and maize) through canals
- Irrigation does degrade the land; but also results in further treatment of the partially treated wastewater
- The return flows from irrigated crops (especially paddy) contaminates the shallow groundwater, though the water is still used by the local people for a variety of uses except drinking



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FUTURE SCENARIOS CONSIDERED IN THE MODEL

- **Reference scenario**: It the 'business-as-usual scenario', the human population continues to grow as per the past trend, i.e., at 1.3% per annum. The three WWTPs having a capacity of 5 MLD, 36 MLD, and 130 MLD are operating at a TDS removal efficiency of 10.6%, 24.1%, and 30% respectively. BOD reduction efficiency of the three plants is 35.1%, 54.9%, and 82.9%, respectively. The Faecal Coliform (FC) removal efficiency of the three plants is 77.3%, 98.7%, and 99.4% respectively.

- **High Population Growth Scenario**: This scenario uses drivers that affect higher growth in water demand for consumptive use (domestic sector) in the KMA. It is assumed that the human population will grow at a higher rate than under the 'reference scenario'--at 1.8% per annum.

- **High Population Growth and WWT Efficiency Improvement**: In this scenario, the capacity of the treatment plants was assumed to remain the same. But the model considered improved TDS removal efficiency of the 5 MLD, 36 MLD, and 130 MLD plants to be 60%, 50%, and 60%, respectively. It further assumed that the BOD removal efficiency of the 5 MLD, 36 MLD, and 130 MLD plants will be 60%, 60%, and 90% respectively

- The Time period is **2009-2040**

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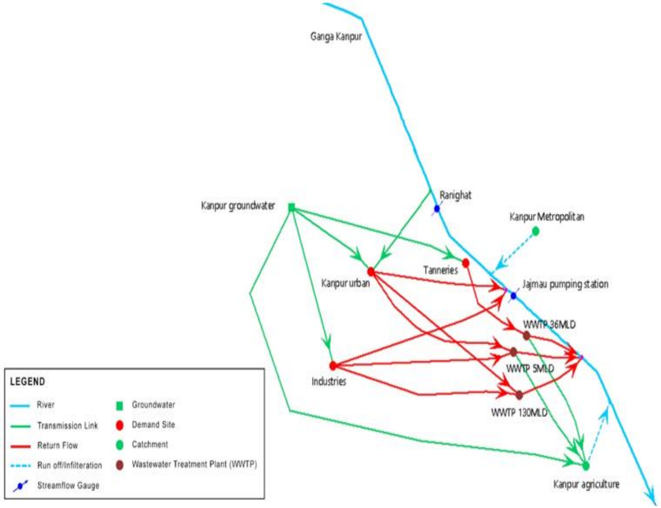
WEAP CONFIGURATION FOR KANPUR WATER SUPPLY, WASTEWATER TREATMENT AND REUSE SYSTEM

- ❖Catchment inflows from both upper basin area and Kanpur area--from rainfall and catchment land use & soil cover using SCS CN method
- ❖Water withdrawal from the river and groundwater for water supply to KMA
- ❖Wastewater treatment system characteristics
- ❖Water + treated wastewater diversion and use for agriculture
- ❖Groundwater withdrawal for industry, including tanneries
- ❖Return flows from KMA and agriculture to the river



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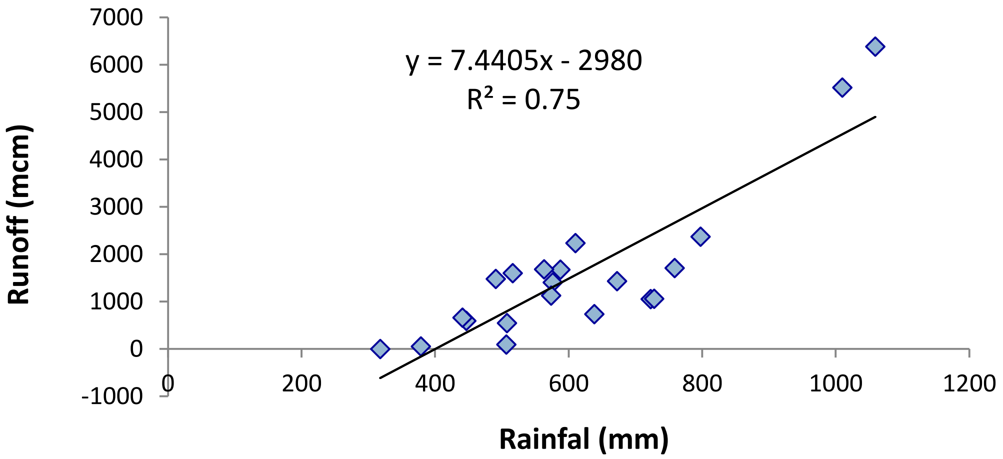
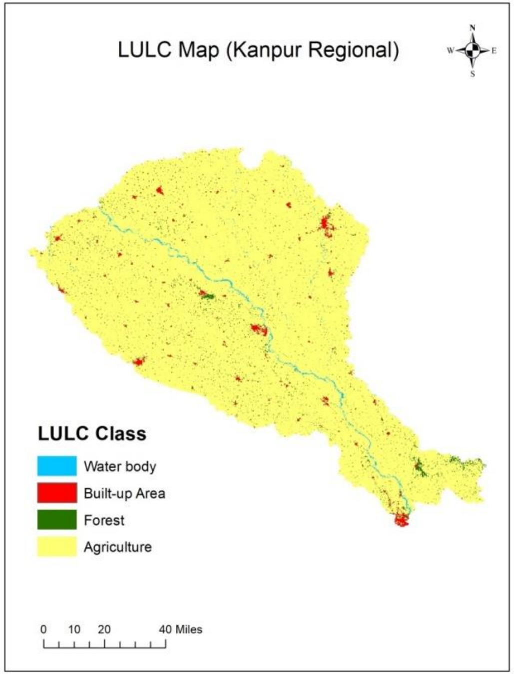
ESTABLISHING RAINFALL-RUNOFF RELATIONSHIPS AND ESTIMATING UPPER CATCHMENT FLOWS





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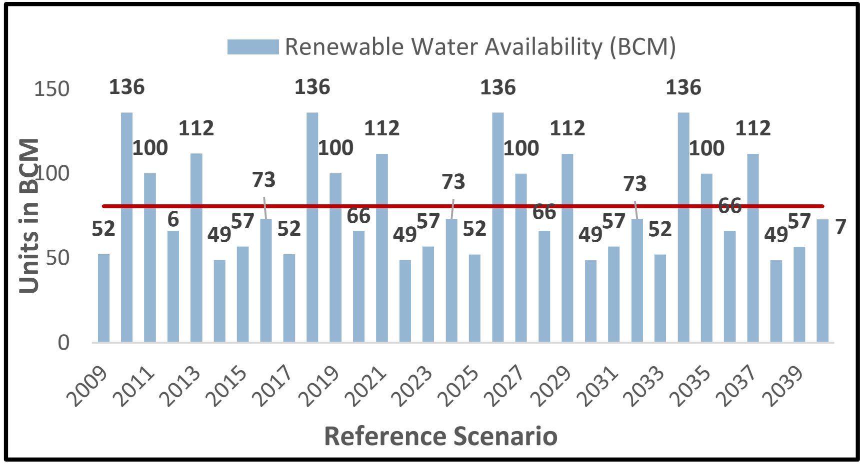
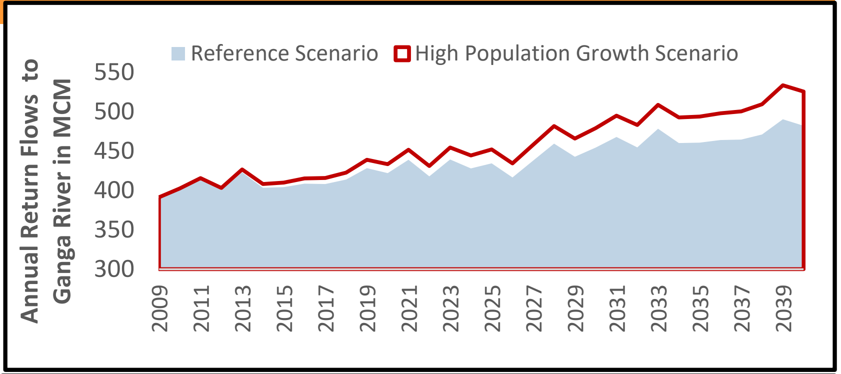
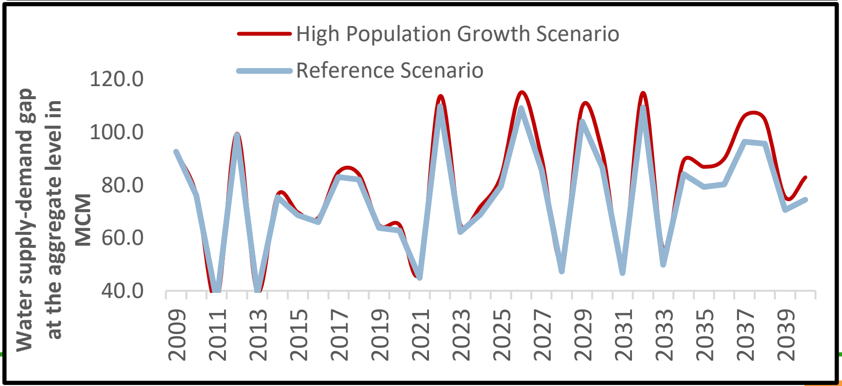
ANNUAL WATER FLOWS, AND FUTURE DEMAND-SUPPLY SCENARIOS: 2009-2040







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INFERENCES FROM MODELLING OF WATER AVAILABILITY AND SUPPLY

- Projected future scenarios (2009-2040) of flows in the Ganga based on hydrological simulations show that the flows will vary drastically between years– with a lowest of 49 BCM to a highest of 136 BCM
- Under the projected future (reference) scenario, with no improvement in water supply infrastructure, the demand-supply gap for KMA will keep fluctuating between years (from 36.4 to 109.4 MCM), with no long-term change.
- The demand-supply gap will be slightly higher under the 'high population growth scenario--from 36.6 to 114.9 MCM--, with the biggest change in water balance (of 9.20 MCM) estimated for 2038.
- Projected future scenario shows higher return flows to Ganga in 2039 as compared to the base year; and will be higher under high growth scenario

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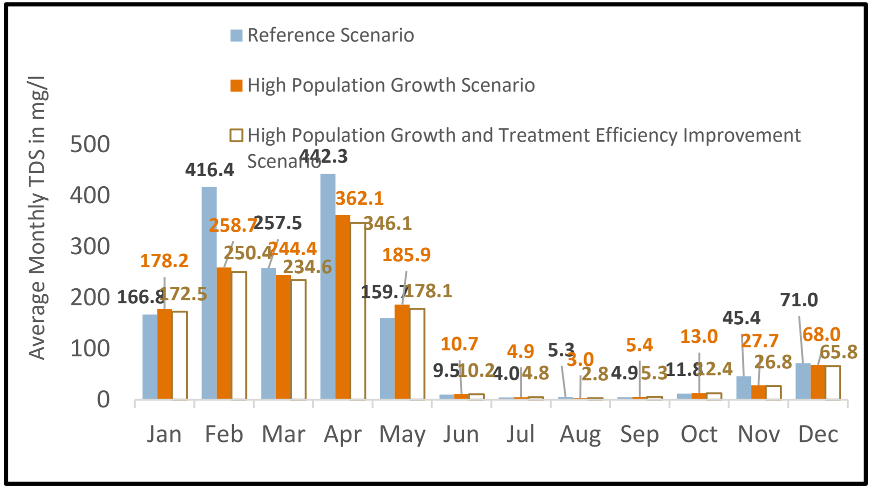
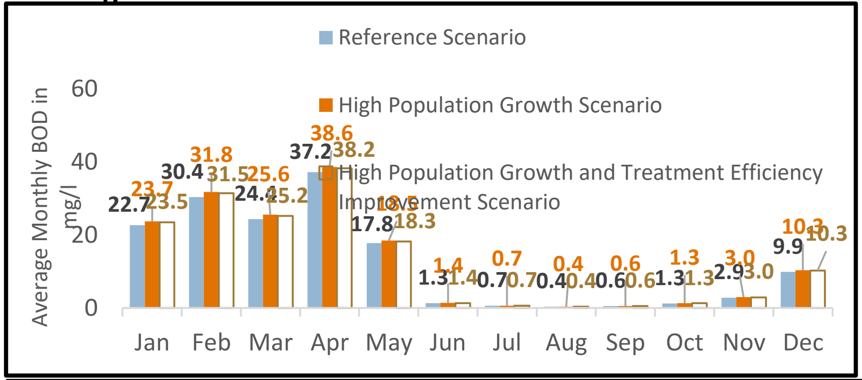
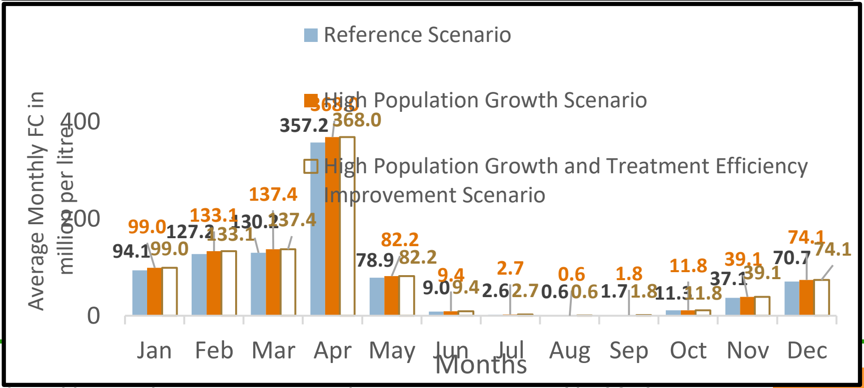
FUTURE CHANGES IN WATER QUALITY D/S OF WWT PLANTS

Average reduction in TDS in different months: 2009-40



Average reduction in BOD in different months: 2009-40





Average reduction in FC in different months: 2009-40

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INFERENCES FROM MODELLING OF WATER QUALITY CHANGES

- Projected future scenarios of water quality in the Ganga river shows sharp variation in average monthly values of TDS, BOD and fecal coliform of water between months, with the highest concentration during the lean season--February to April--, and the lowest in June to October months
- Under the ***high growth scenario***, the average monthly values of TDS, BOD and FC concentration of the water are all expected to increase for all months, except for TDS during certain months
- However, under the ***treatment efficiency improvement*** scenario, the average monthly values of TDS, BOD and FC are all expected to reduce; but the reduction will be marginal

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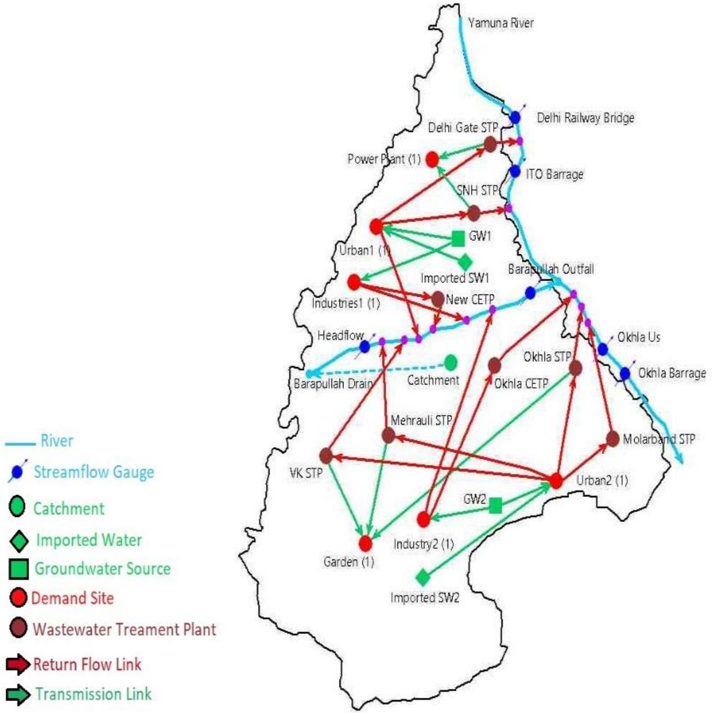
WEAP SET UP FOR BARAHPULLAH DRAIN, AND U/S YAMUNA CATCHMENT

- The model was used to analyze the water availability, demand and supply, river water quality, and wastewater quality in the Barahpullah catchment, for the present and also for the future years under different scenarios.
- The scenarios are created on the basis of the likely changes in the demand for water due to assumed socio-economic and environmental drivers and in supplies from year to year as a result of climate variability.
- The model was set up for the period 2009-40 on a monthly time step. The year 2009 was taken as the base year. Four scenarios, namely ‘reference’, ‘high population growth’, ‘CETP improvement’, and ‘high economic growth’ are developed.



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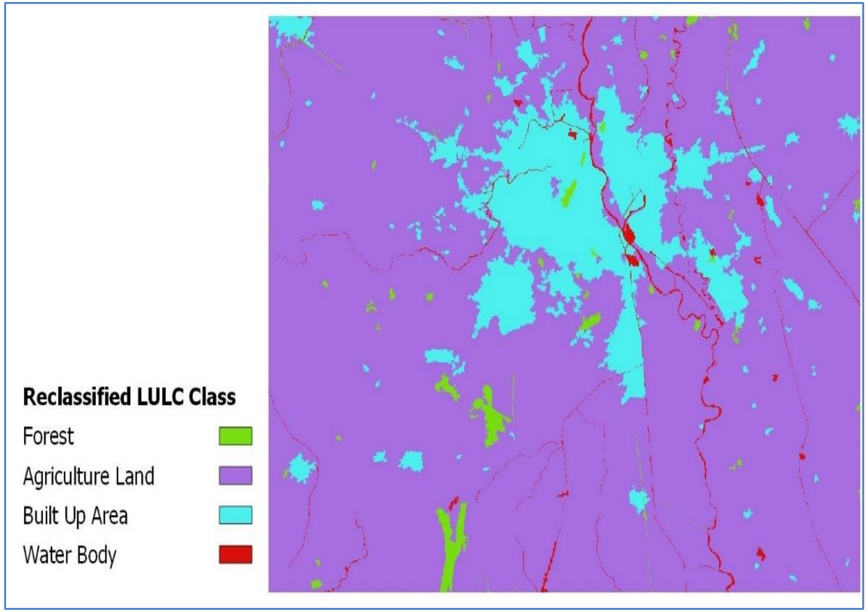
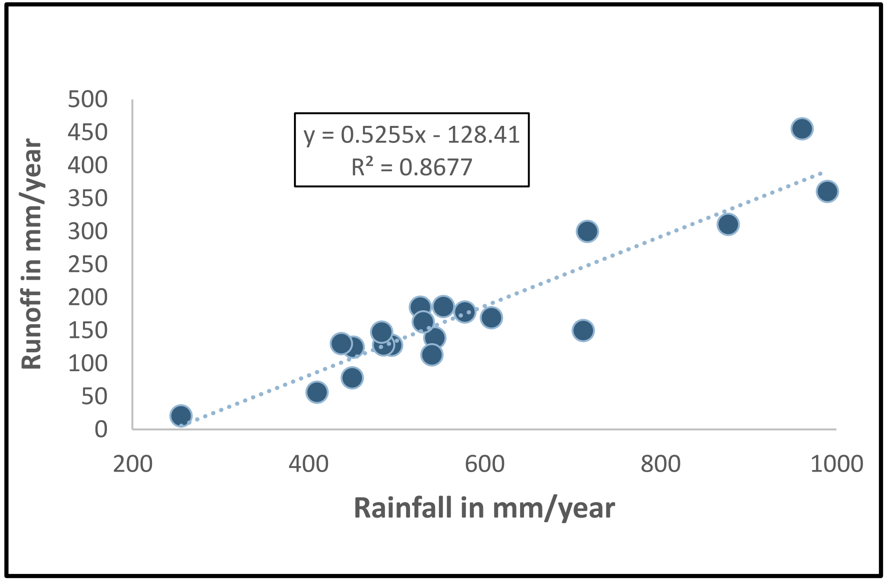
RAINFALL-RUNOFF MODELLING OF THE CATCHMENT





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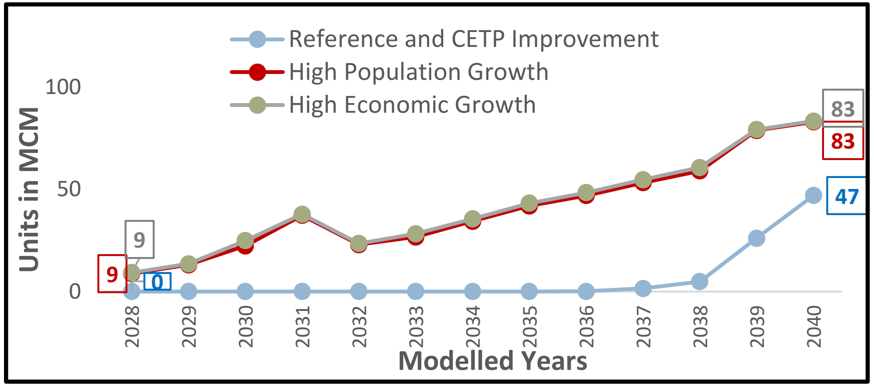
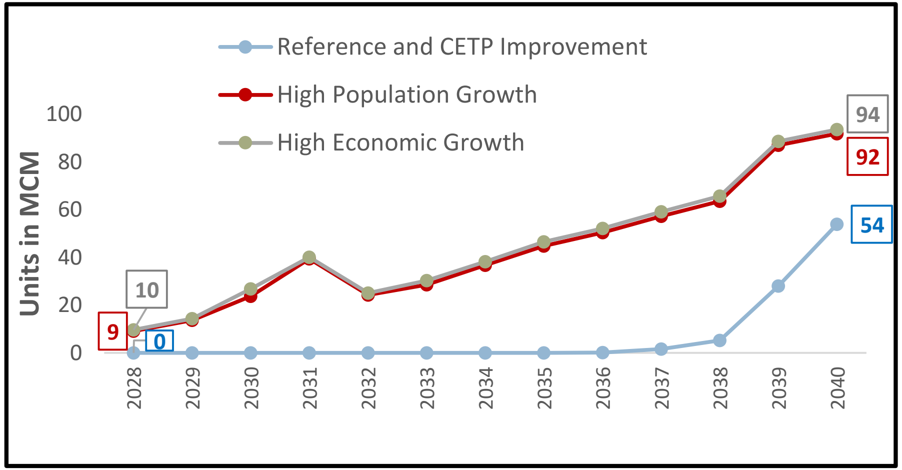
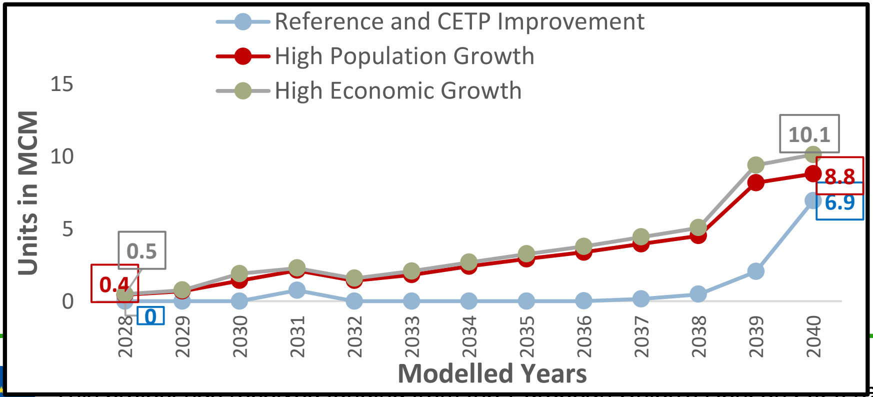
UNMET WATER DEMANDS IN DIFFERENT SCENARIOS



urban sector

Unmet water demand at the aggregate level





Industrial sector

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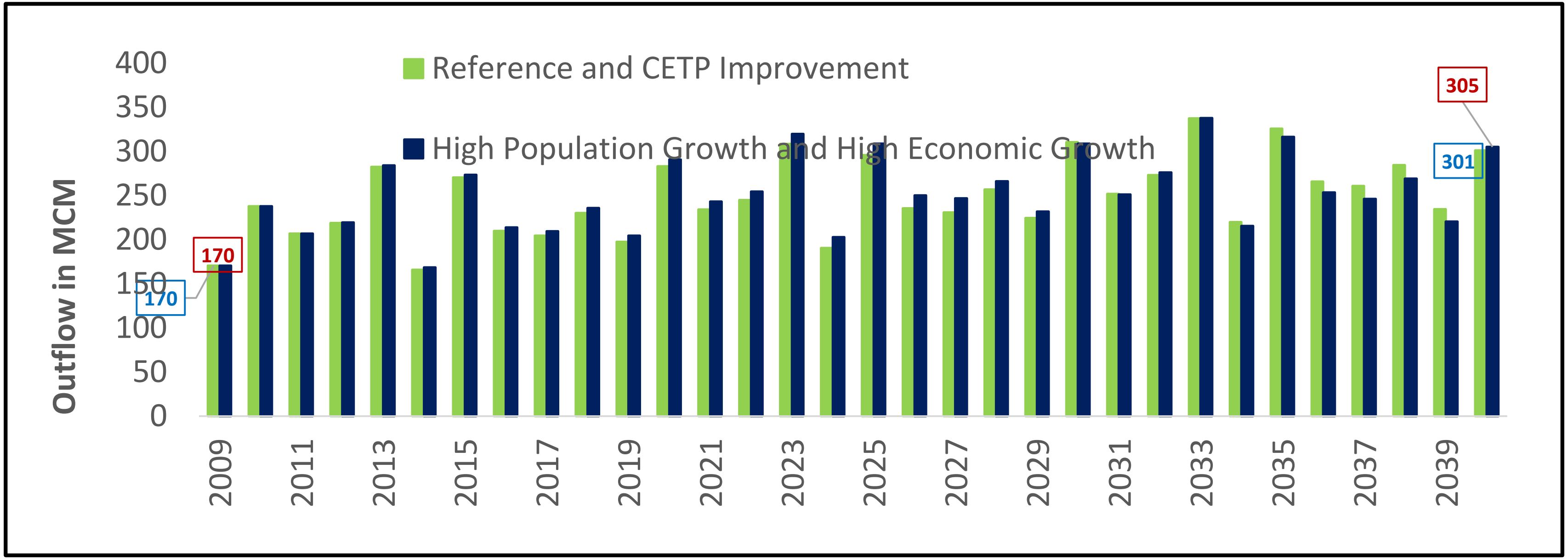
CONTRIBUTION OF BARAHPULLAH CATCHMENT TO FLOWS IN THE YAMUNA



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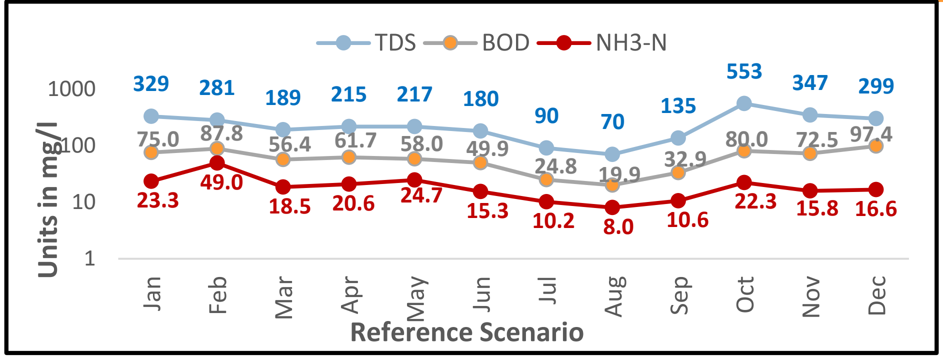
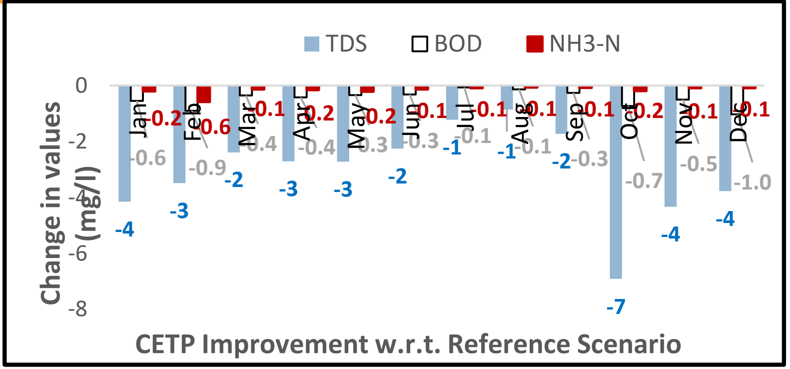
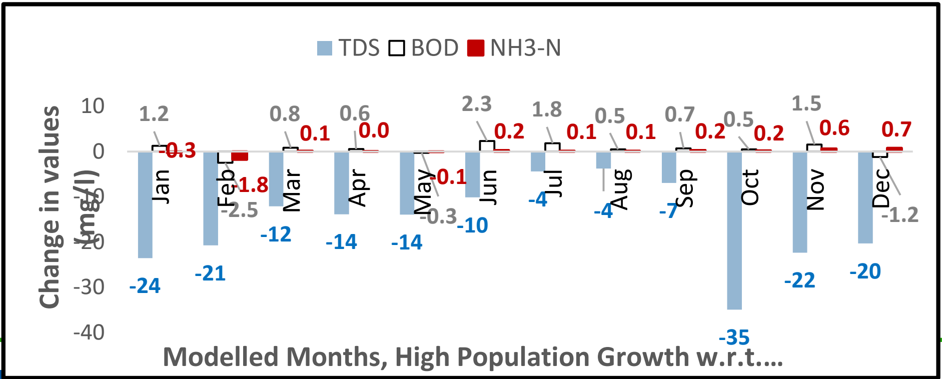
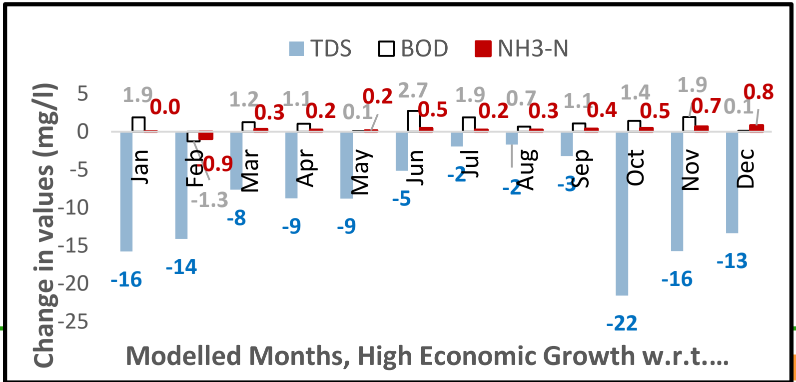
ESTIMATED FUTURE CHANGES IN QUALITY OF WATER OF BARAHPULLAH DRAIN AT THE OUTFLOW UNDER DIFFERENT SCENARIOS









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INFERENCES ON WATER FLOWS, SUPPLIES AND QUALITY CHANGES FROM MODELLING OF BARAHPULLA CATCHMENT

- The projections for future scenario of water balance (reference + CEPT improvement) shows a significant increase in the unmet water demands in the urban and industrial sectors, and at the aggregate level by the year 2040 (54 MCM). The unmet water demands are largest in the urban sector (47 MCM)
- The projected future unmet water demands were estimated to be much higher under high population growth and high economic growth scenarios (94 and 96 MCM, respectively), with the increment due to economic growth remaining insignificant
- Water quality modelling for future shows remarkable variation between months (with the highest values of TDS, BOD and NH_3 during Oct. to Jan.; water quality is likely to deteriorate under high population growth and high economic growth scenarios (except for TDS); but likely to reduce under CEPT improvement scenario

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FURTHER IMPROVEMENTS IN WEAP MODELLING

- Irrigated agriculture is a major source of pollution (nitrate) of shallow groundwater, especially that with partially treated wastewater.
- The impact of fertilizer residues and the other pollutants in the partially treated WW on the shallow aquifers needs to be assessed.
- The WEAP set up for Kanpur can be updated to incorporate this aspect of pollution
- In Barahpullah, because of sandy loam soils and deep water table conditions, groundwater pollution is unlikely.

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SUBSEQUENT IMPROVEMENTS IN THE WEAP MODELLING

- Climate trends in the two regions were incorporated in the two models
- The past trends in the rainfall of the two regions were extrapolated for predicting the future trends in water availability and water quality (special concern in Kanpur)
- The results of the rainfall trends were simulated in the rainfall-runoff models to estimate the changes in the annual runoff values for each year

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IMPROVEMENTS IN BARAHPULLAH WEAP MODEL

- Climate trends were incorporated into the Barahpullah WEAP model by estimating the annual rainfall for 2021 -2040 based on the rainfall trend of 2001-2020
- Then annual runoff for the respective years is estimated based on the rainfall-runoff relationship developed for Barahpullah.
- The annual runoff values estimated from the rainfall- runoff relationship is distributed among the 12 months of the year based on the proportion of rainfall received during the corresponding months.
- Then the flow contributed by Barahpullah catchment to Yamuna river is estimated.

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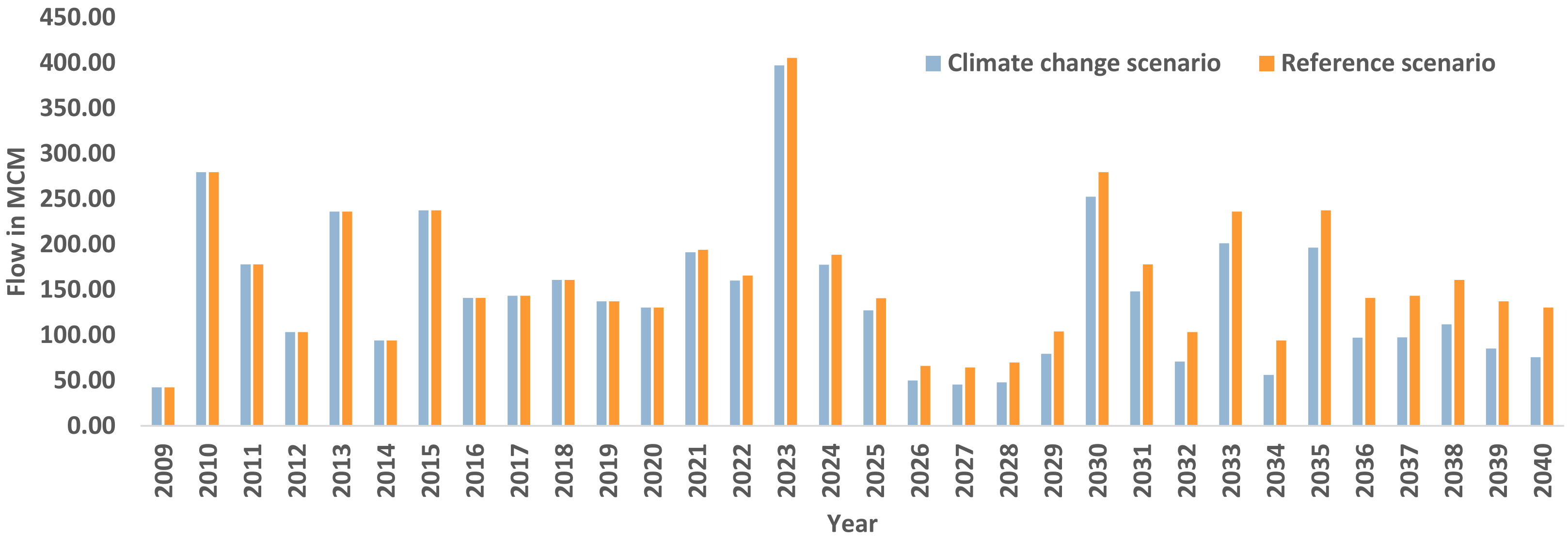
CONTRIBUTION OF BARAHPULLAH CATCHMENT TO FLOWS IN THE YAMUNA



The declining rainfall trends resulted in reduction of stream flow contribution from Barahpullah to Yamuna up to 42% by 2040

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IMPROVEMENTS IN THE KANPUR WEAP MODEL

- The groundwater stock for the modelled area was estimated from the estimates of static groundwater resource of Uttar Pradesh state and is given as input.
- It was assumed that 80% of drainage generated from the agriculture catchment will be the return flow to groundwater and the rest 20% will be surface runoff.
- The nitrate application rate in the Paddy fields is taken as 170 kg/ha (Børgesen *et al*., 2021) and the nitrate leaching rate is assumed as 75 kg/ha (Vinod *et al*., 2015) for paddy.

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IMPROVEMENTS IN THE WEAP MODELLING AT KANPUR

- The total water input to crops in excess of evapotranspiration is treated as the return flow, given the shallow aquifer conditions
- The decrease in nitrate intensity is estimated as 56% from the values of application and leaching rates obtained from literature.
- The WEAP model was run for the time period, 2010-40, with the above assumptions and the results were obtained for the new scenario.
- The return flow from the agricultural catchment and the annual nitrate load to groundwater were obtained for every year.

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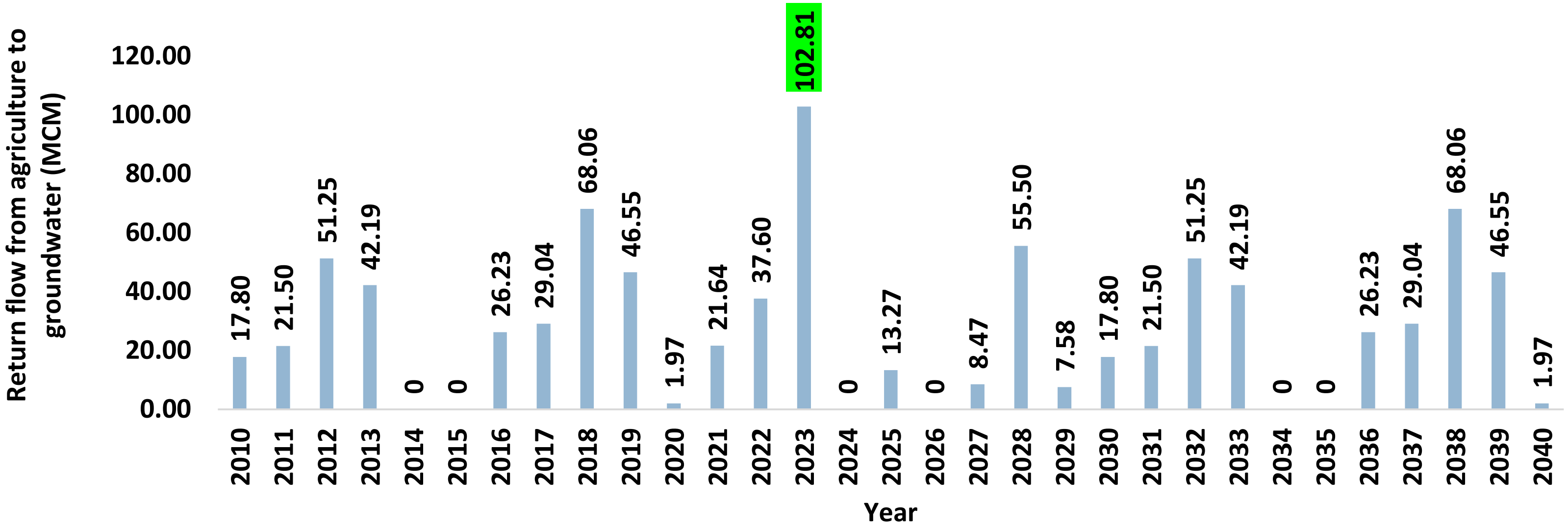
RETURN FLOW TO GROUNDWATER FROM AGRICULTURE AREA IN KANPUR



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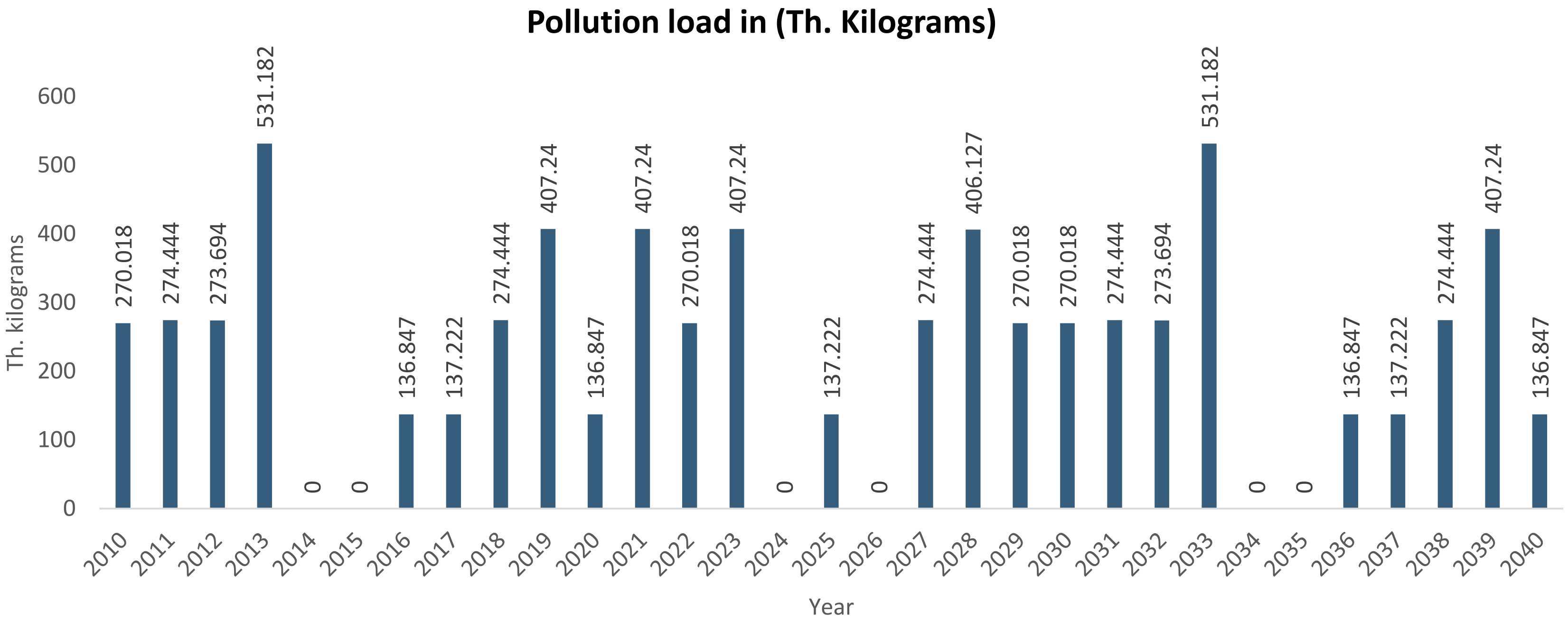
NITRATE POLLUTION LOAD ON GROUNDWATER



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INFERENCES

- The impact of **climate variability on the water supply-demand** situation and **water quality** is likely to quite large, and larger than the impact of many of the socioeconomic changes (increased water demand, increased waste generation, etc.) in both the regions
- The potential impact of the probable future change in rainfall on runoff from Barahpullah catchment to Yamuna river is much less than the impact of rainfall variability
- Non-point pollution of groundwater from agriculture in Kanpur is significant and needs to receive more attention in future. The analysis is quite indicative of the role of **water quantity management** and water allocation in managing river water quality--on an annual basis
- In **Kanpur**, availability of sufficient quantity of water to meet the demand is not a concern; it is a matter of building adequate infrastructure for augmenting the supply. However, in Delhi, water demand reduction in the municipal & industrial sectors has to receive great attention

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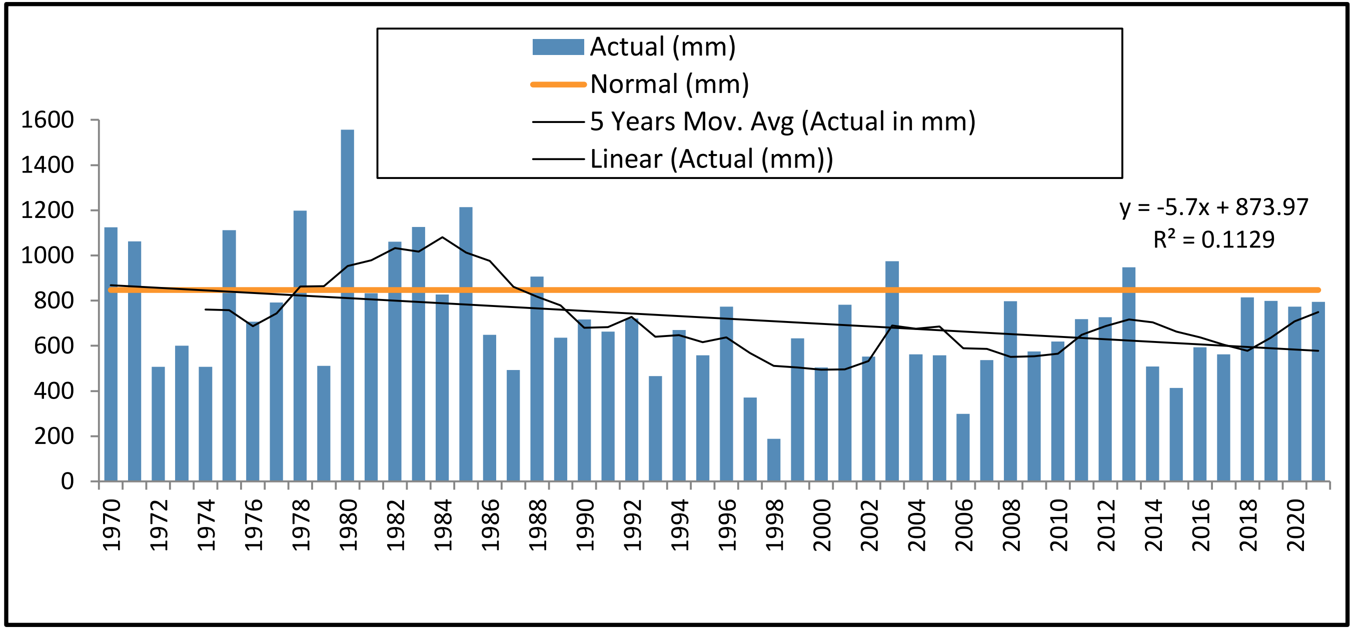
SUBSEQUENT IMPROVEMENTS IN THE WEAP MODELLING



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