Chapter 8
Impact of Efforts on Ganga Restoration and Conservation

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Abstract It is a well-known and recognized fact that water impacts everyone. During recent years, India’s water usage has increased and diversified, creating both increased water shortages and water quality degradation in rivers and aquifers, thereby threatening broader environmental sustainability. River healthcare gaps blight the quality of life of the average Indian who have been relegated to the periphery. Whereas governments are expected to restore and maintain the wholesomeness of the rivers ensuring environmental flows and preventing the pollution ingress into the water bodies, it is also noteworthy that the protection of water and environmental infrastructure is a social responsibility of every citizen—both individually and collectively. In this background, the paper examines the Ganga conservation and rejuvenation strategies and its impact on environment and drinking water. While government is committed for conserving and rejuvenating National River Ganga, and also addressing interrelated issues like sustainable agriculture, basin protection against floodplains disasters, river hazard management, urban river management, wastewater management and revival of water bodies for providing environmentally safe sanitation and through a well-designated scheme of afforestation in riparian zones to purify base flows and run-off draining into the river, they are also working on to enhance the ecosystem services of our rivers and water bodies that remain healthy for downstream users. In this regard, institutional network of integrated water resource management plan, policy and regulatory governance provides synergy and helps other key stakeholders, experts, investors and well-wishers. On micro-level, key points of river restoration include aspects of flows (aviralta, nirmalta) and functions of river as geologic entity and ecological entity. One may track river science, engineering and operations including afforestation and biodiversity to suggest ways of improving the overall efficacy of aquatic ecology, ecological restoration (lateral, longitudinal and vertical connectivity) and geological safeguarding (sediment transport, assessing quantity, quality and nutrient value). Critical success of recovering wastewater and restoration of drains are components of urban river management.
Decentralized infrastructure can greatly enhance the speed of water treatment leading to one city-one operator through reuse of treated sewage/trade effluents. In order to have a successful water economics, it essentially requires creating enabling environment for sustained infrastructure management through water valuation, pricing and effective implementation of the urban river management strategies, and well-functioning water markets. Ganga basin plan prepared including environmental flows allocations suggest three-pronged strategy for its implementation.

**Keywords** Environmental sustainability · Ecological integrity · Restoration and conservation · Afforestation · Sustainable agricultural · Urban River

**Introduction**

The National River Ganga has been engineered and shaped to serve humanity by controlling flows, digging riverbeds, encroaching floodplains and disturbing even stream-aquifer equilibrium in the basin. Hydropower is the main focus of development in the upstream mountainous regions, whereas in plains, the main river stem is regulated with dams and barrages to divert water in associated irrigation canal systems. These alterations are largely for food security, flood protection, domestic and industrial supplies and power generation. All these head control structural developments, and abstractions affect the river’s flow regime, which, in turn, impacts downstream water availability, water quality and riverine ecosystems. While the services a river renders are well recognized, it is equally critical that such interventions onto the river systems either substantially reduce its flows or bring in huge diurnal, daily or seasonal variability in flows, which is contrary to the natural regime of flows, as a result the river struggles to maintain its might and glory. In order to maintain the capacity of a population to safeguard water-related disasters (floods and droughts), and for preserving ecosystems in a climate change regime, it is important to find your own way to flows.

The Ganga is a trans-boundary and international river having total length of whopping 2525 km and a basin area of 1,087,300 km². It runs through China (3%), Nepal (14%), Bangladesh (4%) and India (79%). There are concerns about water sharing conflicts between countries, visible at Farakka Barrage and interstate issues regarding River Interlinking Projects of Government of India under study.

The Ganga Basin area in India is 861,404 km², spread in 11 states which include five main stem land states—Uttarakhand, Uttar Pradesh, Bihar, Jharkhand and West Bengal. The Ganga Basin covers 26% of India’s geographical area and 57% of fertile agricultural landmass and acts as a major source of lifeline around it. It caters of 43% of India’s population livelihood and contributes 28.1% of India’s water resources. Around 143 different freshwater fish species live and depend on its water. The river is considered as mother due to the multiple functions it plays in the lives of the people, pertaining to ecological, socio-cultural and livelihoods, which synonymies it as the most holy and worthy of being worshipped.
The longest middle stretch of 1136 km of River Ganga and 28.8% of its basin falls in the state of Uttar Pradesh which unfortunately is extremely polluted in terms of biochemical oxygen demand (BOD) and Faecal Coli form. Most ironically, this is true in case of several other rivers as well. Not only River Ganga but its tributaries are struggling to survive due to various kinds of pollution, and therefore, it is a major cause of concern. Due to the notion of holiness and purity attached with the River Ganga for Hindus (at Gangotri, the river has maximum level of dissolved oxygen than any other river system in the world), its good quality water is essentially desired along with its channel depths to fulfil religious and cultural activities of holi dip (astha ki dubki) and aachman (a drop of holi water in the mouth).

Governments regularly host the world fame Kumbh Mela (fair) at Prayagraj where about 30 million pilgrims take bath in a single day in Triveni Sangam, which is a largest religious congregation in the world. Propelled with tradition or the urge to seek salvation, pilgrims, saints and cultural tourists take dip in the holy confluence of the Rivers Ganga and Yamuna during Mahakumbh (organized after every 12 years during January–March for 45 days at Prayagraj) to wash away sins of lifetime that help attain salvation from rebirth and sufferings. Other visitors are drawn by desire to experience the power of congregation, for ritual bath, offer prayers and move out during auspicious period on ghats (river bank) extended over 2 km on both banks; one has to jostle for space. Kalpvasi (religious tourists who reside for a month in a make-shift tent city on the river’s bank) reside there for a month enjoying bliss of religious discourses (satsang) and two-square meal (prasad) served by Akharas (saint’s Ashram established in a big tent by various sects) to all devotees irrespective of caste, creed and religion. More water is allowed by state to flow in river during Maghi-Kumbh (a Hindu calendar month falling in January—a pot filled with elixir) mela (fair), even at the cost of irrigation water.

Even though human beings are interacting with rivers for fulfilling their basic needs since millennia, river’s role in shaping earth’s surface is recognized only during twentieth century when various researches started on it. Ecological studies on Ganga conducted at Varanasi in 1950s, River Yamuna at Delhi (Palla to Okhla) in late 1950s and many other such researches held post-1974 reported poor health of the rivers. Therefore, modelling the hydrology of the Ganga Basin is critical for estimation, planning and management of present and future water resources sustainability. In this background, on the basis of the study conducted in the state of Uttar Pradesh (SWARA 2020), the paper attempts to critically analyse and comprehend the desirability of maintaining environmental flows in the River Ganga along with its process, if it has to be done. Environmental flows mimic the natural pattern of river’s flow variation. To recognize the physical limit beyond which a natural water body suffers irreversible damage to its ecosystem functions, environmental flows are, therefore, one of the central elements in water resources planning and management for sustainable development to meet future water needs. To achieve the objective of restoration and conservation of the river Ganga, assessment of environmental flows and its maintenance throughout the year is one of the most important aspects towards river health.
River Health

The term health is used for the first time by Leopold and Wolman (1957) for addressing land issues. Ecosystem health since 1980s and river health debate from 1995 onwards gained attention of freshwater biology. The word stream health is used as an analogy, a metaphor that provides inspiration and insight into the understanding of river health. An analogy between human health and ecosystem health oversimplifies the complex issue (Boulton et al. 1998) of human existence and survival on earth. The term river health is useful since it is readily interpreted by the general public and evokes societal concern about human impacts on rivers. Health implies a flourishing condition, well-being, vitality or prosperity. A healthy organism is resilient, able to recover from many stresses (Karr and Chu 1998). No single indicator reveals river health unequivocally (Boulton et al. 1998).

A healthy stream is an ecosystem that is sustainable and resilient, maintaining its ecological structure and function over time while continuing to meet societal needs and expectations. Often, integrity is used synonymously to symbolize river health assessment. Integrity implies an unimpaired condition or the quality or state of being complete or undivided; it implies correspondence with some original condition. Biological integrity refers to the capacity to support and maintain a balanced, integrated, adaptive biological system having the full range of elements (genes, species and assemblages) and processes expected in the natural habitat of a region. Ecological integrity is the sum of physical, chemical and biological integrity (Karr and Chu 1998). For ecological integrity, the base flows in the rivers are critical, especially during pre-monsoon season.

A study suggests that ‘since 1970s the groundwater over abstractions for irrigation and other uses within Ganga Basin has led to decline of base flows (through aquifers) by 59%’ (Nature 2018). Many smaller tributaries of River Ganga have dried up due to groundwater over abstractions. The net flows reduction in Ganga River water could jeopardize domestic water supply, crop water requirements, river transport, ecology, etc., of densely populated northern Indian plains. In other words, the consumption of River Ganga water and its impact in terms of waste discharge both lead to deteriorating health of the river. Therefore, it needs immediate attention. While the water pollution is an issue that needs to be dealt at source, the reduced flows in the river should be addressed by maintaining environmental flows (E-Flows) in the River Ganga.

The Government of India, by becoming aware and sensitized about the significance of uninterrupted water flows, is promoting various programmes and activities for Ganga rejuvenation based on the principle of ‘Aviral Dhara’ (continuous free flow) and ‘Nirmal Dhara’ (pollution free stream) (GRBMP-2015). Moreover, apart from that, several other studies are also commissioned either by the government or by other agencies and institutions through which assessment of environmental flows for River Ganga has been done (Central Water Commission 2015; WWF-India 2012, 2013, 2019, cGanga and NMCG 2018, etc.) in order to provide some number (minimum or maximum) requirement of flows. In this background, the paper attempts to answer
the second-generation question that ‘if the E-Flows are to be maintained in the river Ganga, then how this can be done, especially in the light of existing committed water allocations for the rejuvenation of Ganga river in Uttar Pradesh’. The paper ends with suggesting various ways and means through which E-Flows’ implementation in the River Ganga can be achieved at an investment cost of $10,000 million towards integrated water resources management in the study area of the Ganga Basin.

**Study Area for Strategic Initiatives Under Ganga River Basin Management Plan in Uttar Pradesh**

Main stem Ganga Basin area falling in Uttar Pradesh is selected for the water management, wherein 80% of its waters are diverted for irrigation in Ganga-Yamuna doab. Ganga River’s largest stretch from Bijnor to Ballia passes through Uttar Pradesh, covering an area of 67,723 km² (i.e. 7.88% of the total Ganga Basin and 28.1% of the state). Location map of Ganga Basin (main stem) and its sub-basin in Uttar Pradesh is shown in Fig. 8.1. The basin covers (fully or partially) 27 districts of Uttar Pradesh.

Brief profile of Ganga Basin as compared with other basins of Uttar Pradesh is given in Table 8.1. Apparently, Ganga Basin and Yamuna Basin each cover over 28% area of the state. Ganga basin is characterized by highest population of 64.63 million (Census 2011) having population density of 954 persons/km². Land under cultivation is 67.63% and population involved in agriculture activity remains 57.85%. Net sown area irrigated is 94.20%. The area irrigated by source is canal 24.19%, groundwater 71.87% and by other sources 3.95%. Cropping intensity stands 161.76% (2015). The literacy rate of the area marks 69.00%, whereas the marginal landholding is 81.80%.

![Fig. 8.1 Location map of Ganga Basin (main stem in Uttar Pradesh) and its sub-basins. Source: Ganga Basin Plan 2020 prepared by M/S TAHAL Consulting Engineers Limited, Israel (90 m SRTM data) with which author is associated](image)
## Table 8.1  Brief profile of Ganga Basin as compared with other Basins of the state of Uttar Pradesh

| Basin   | Area (km²) | Land under cultivation (%) | Cropping intensity (%) | Net sown area irrigated (%) | Gross sown area irrigated (%) | Net area irrigated by (%) | Landholdings (%) |
|---------|------------|-----------------------------|------------------------|------------------------------|-------------------------------|--------------------------|-----------------|
|         |            |                             |                        |                              |                               | Canals | GW | Other | Marginal (<1 ha) | Small (1–2 ha) | Semi-medium (2–4 ha) | Medium (4–10 ha) | Large (>10 ha) |
| Gomti   | 31,434 (13.0%) | 64.35                       | 163.12                 | 90.59                        | 88.66                         | 21.80 | 78.17 | 0.03 | 84.58            | 10.59           | 3.96               | 0.85            | 0.03            |
| Gandak  | 974 (0.4%)  | 71.60                       | 137.13                 | 76.60                        | 75.10                         | 23.76 | 73.51 | 2.73 | 90.11            | 6.97            | 2.39               | 0.51            | 0.02            |
| Rapti   | 14,658 (6.1%) | 71.10                       | 155.71                 | 75.71                        | 63.47                         | 7.09  | 88.94 | 3.98 | 84.58            | 10.98           | 3.69               | 0.72            | 0.03            |
| **Ramganga** | **20,417 (8.5%)** | **78.79**                  | **161.61**             | **97.08**                    | **93.85**                     | **4.00** | **95.53** | **0.47** | **75.63**       | **15.56**       | **7.00**            | **1.74**        | **0.07**        |
| Ghaghra | 31,503 (13.1%) | 70.03                       | 156.55                 | 85.92                        | 78.53                         | 5.75  | 93.61 | 0.64 | 84.63            | 10.40           | 4.01               | 0.93            | 0.04            |
| Sone    | 5093 (2.1%)  | 19.16                       | 115.79                 | 17.74                        | 17.99                         | 17.63 | 32.31 | 50.07 | 67.58            | 17.26           | 9.61               | 4.69            | 0.87            |
| Yamuna  | 69,327 (28.7%) | 71.24                       | 151.33                 | 82.39                        | 69.63                         | 22.55 | 73.75 | 3.70 | 67.85            | 18.26           | 9.76               | 3.85            | 0.28            |
| Ganga   | 67,773 (28.1%) | 67.63                       | 161.76                 | 94.20                        | 85.15                         | 24.19 | 71.87 | 3.95 | 81.80            | 11.92           | 4.91               | 1.29            | 0.08            |

*Source*  Agriculture department data, 2014–15

Agriculture census, 2010–11

(continued)
| Basin | Area (km²) | Population involved in agriculture activities (%) | Population >1 lakh | Statistical Census Population >1 lakh | Population >1 | BPL households |
|-------|-----------|-----------------------------------------------|------------------|-------------------------------------|----------------|----------------|
| Gomti  | 31,434(13.0%) | 62.50 | 27,722 | 81.50 | 18.50 | 882 |
| Gandak | 974(0.4%) | 97.70 | 0.99 | 97.70 | 2.30 | 1013 |
| Rapti  | 14,658(6.1%) | 72.31 | 13,921 | 88.70 | 11.30 | 948 |
| Ramganga | 20,417(8.5%) | 72.98 | 25,862 | 91.94 | 8.06 | 821 |
| Ghaghra | 31,503(13.1%) | 72.98 | 25,862 | 91.94 | 8.06 | 821 |
| Sone   | 5093(2.1%) | 67.00 | 1.25 | 78.30 | 21.70 | 245 |
| Yamuna | 69,327(28.7%) | 68.70 | 47.17 | 68.67 | 31.33 | 680 |
| Ganga  | 67,773(28.1%) | 75.59 | 24.41 | 75.59 | 24.41 | 954 |

Source: Census of India, 2011
Ganga Basin is bestowed with large perennial rivers, and underlay is large groundwater resource too. Rainfall, subsurface flows and snowmelt from glaciers are the main sources of water in River Ganga. Ganges inflow at confluence of Bhagirathi and Alaknanda is 23.90 BCM. At Narora, it becomes 31.40 BCM. In route, the flow augmentation by major tributaries like Ramganga 15.62 BCM and Yamuna 93.02 BCM contributes flows at Allahabad to 152 BCM. In between, withdrawal of water for irrigation is committed in the order of 1606 cubic metre per second.

The first irrigation canal system in Uttar Pradesh dates back to Mughal dynasty in between 1719 and 1748 when Eastern Yamuna Canal was constructed. It was remodelled by British during pre-independence year 1830 for capacity 85 m$^3$/s. The calamitous events of the year 1837–38 and the extent of human misery then caused by the utter failure of the crops in the central provinces, leading to famine in its most aggravated shape. Upper Ganga Canal System (UGC) commissioned in 1854 Bhimgoda Head works, Haridwar, across the great Ganga River, initiated by P. T. Cautley (1839–45). Post-Tehri Dam, the capacity of PUGC has been increased to 13,500 cusec (382.43 m$^3$/s). In the backdrop of 1866 severe famine, Narora weir commissioned in 1878 that was modernized as Narora Barrage in 1961–68. The combined capacity of LGC/PLGC shall be 17,400 cusec (492.92 m$^3$/s) post-Tehri Dam.

**Ganga Canal Capacities on Increase**

The various irrigation canal systems have undergone modernization over time and their capacities are on increase. Post-Tehri Dam, the capacity of Kharif channels such as Eastern Ganga Canal (EGC) and Madhya Ganga Canal (MGC) has been increased along with PUGC, LGC and PLGC.

- **UGC** = 6500 (1854), 6750 (1938), 10500 (1951), PUGC = 13500 (1982)
- **LGC** = 6000 (1878), 8500 (1974), PLGC = 4200(1982), 6900 (2015), 8900 UPWSP-II.
- **EGC** = 4850 (1980-92), 5850 (2009) post-Tehri Dam
- **MGC-I** = 8280 (1998-2001), MGC-II = 4200 (still under construction).

Running days for UGC and LGC in Kharif is 183 and Rabi 182. Running days for EGC and MGC in Kharif is 154 only. For crop pattern, 46.5% in Kharif (wet crops) and 36% in Rabi (dry crops) the above canal systems are adequate. However, overuse of irrigation water has been less productive compared with other states of India.

Major and medium pump canals of seven numbers having combined capacity of 7410 cusec (209.92 m$^3$/s) are established on the banks of River Ganga in tail end of gravity canals to meet the irrigation demand in the district of Raebareli, Unnao, Mirzapur, Chaudauli, Ravidas Nagar and Ghazipur. There are four minor lift
pump canals situated in districts Kanpur, Fatehpur and Pratapgarh having combined capacity of 55.5 cusec (1.57 m³/s).

**River Behaviour: Loosing and Gaining Stretches of Ganga River in Uttar Pradesh**

To understand river behaviour about losing (where river water disappears in recharging groundwater) and gaining stretches (where groundwater augments river’s flow), long-term annual water flow volume of Ganga River for 55 years (based on Central Water Commission data from 1861 to 2015) indicating average and 75% dependability at various locations in Uttar Pradesh is summarized in Table 8.2 and shown in Fig. 8.2.

Ganga Basin flow volume at 75% dependability comes to 10,797 MCM against average annual flow volume of 13,108 MCM.

Perusal of Fig. 8.2 suggests that there are three catchment zones at Fatehgarh, Shahzadpur and Varanasi in which Ganga River’s annual flow volume diminishes (loosing stream) due to excessive pumping of groundwater resulting into reduced base flow and lowering of the groundwater table, lower than river top or bottom surface water. The details are as follows:

1. Kachhla bridge (Badaun)-Fatehgarh Zone: dip in annual flow volume from upstream Kachhla bridge 1419 MCM–1260 MCM (i.e. difference is 159 Million Cubic Metre) is noted.
2. Bhitaura-Shahzadpur (Kaushambi) Zone: there is dip in flow volume from 2017 MCM upstream Bhitaura to 1536 MCM at Shahzadpur (i.e. difference is 481 MCM). The missing water again re-appears at Prayagraj as catchment contribution often known as invisible Sarasvati River’s confluence into Ganga, which is popularly known as Triveni Sangam.
3. Mirzapur-Varanasi Zone: dip in flow volume from upstream Mirzapur of 6379 MCM–6136 MCM is noticed (i.e. difference is 243 MCM).

So, long distance release of water (from Tehri Dam, Bhimgoda and Narora Barrage downstream) is less effective towards E-flows’ maintenance in the Ganga River as being presently practised during Kumbh mela. This is at the cost of loss of water for irrigation. Better way will be decentralized local water resource management and merely 400 cusec (11.33 m³/s) release of Sharda-Sahayak canal water from Bhadri escape, 40 km upstream Sangam nose at Prayagraj, would be more effective.
Table 8.2 Catchment area, 75% dependable flow and average annual flow volume at various locations in Ganga Basin (Uttar Pradesh)

| Gauge-discharge site                  | Catchment area (km²) | 75% dependable flow volume (MCM) | Average flow volume (MCM) | Details of water diversion/abstraction structure in the zone |
|----------------------------------------|----------------------|---------------------------------|---------------------------|------------------------------------------------------------|
| Garhmukteshwar (Moradabad)            | 29,709               | 1068                            | 13,389                    | From Narora Barrage existing lower Ganga Canal system draws 226.6 cubic metre per second (m³/s) water for irrigation |
| Kachhla bridge (Badaun)                | 34,446               | 1097                            | 1419                      |                                                            |
| Fatehgarh                              | 40,096               | 893                             | 1260                      |                                                            |
| Ankit Ghat (Kanpur Rural)              | 82,209               | 1198                            | 1855                      |                                                            |
| Kanpur                                 | 87,650               | 1269                            | 1974                      | 5.7 m³/s water is diverted from Lav Kush Barrage at Kanpur for drinking |
| Bhitaura (Fatehpur)                    | 90,444               | 1237                            | 2017                      | Dalmau pump canal A & B combined draws 32.3 m³/s water at Raebareli and Unnao |
| Shahzadpur (Kaushambi)                 | 93,604               | 1127                            | 1536                      |                                                            |
| Prayagraj                              | 463,971              | 4047                            | 5931                      | Yamuna joins Ganga |
| Mirzapur                               | 485,277              | 4877                            | 6379                      | Narayanpur lift canal draws 40.8 m³/s water for irrigation |
| Varanasi                               | 489,087              | 4427                            | 6136                      | Gyanpur pump canal water draws 38.2 m³/s water for irrigation |
| Ganga Basin                            | 67,923.73            | 10,797                          | 13,108                    |                                                            |

Source Estimated by author

Ganga Basin Water Plan: Managing Demand and Supply of Water

Agriculture consumed 96% of water among all uses in the base study year of 2015. So, based on the analysis of past trends and the need for crop intensification and diversification, considering the available resources and options, the following Agriculture Growth Scenarios (Agr.Sc) have been considered.

- Agr.Sc-1: Projected Crop Areas as per the prevailing Trend (BAU) limited to Cultivable Area.
Fig. 8.2  Average annual and 75% dependable flow volume (million cubic metre) in Ganga River. 
Source Constructed by author based on Central Water Commission data (1861–2015)

- Agr.Sc-2: Projected Crop Areas as per the prevailing Trend limited to Cultivable Area along with crop diversification, implementation of conjunctive use management, equitable distribution of water and micro-irrigation in 10% of cropped area.

Future water balance scenario is calculated in Ganga Basin by considering agricultural scenario-1 and scenario-2 with additionally required infrastructure for groundwater use in conjunction with surface water and restriction on groundwater extraction within annual replenishment, maintaining minimum environmental flows with crop intensification/diversification—replacing paddy with SRI in 20%, 30% and 40% of canal command area in years 2025, 2035 and 2045, respectively, and introducing micro-irrigation in 10% of cropped area. The agricultural data used in water balance model are given in Table 8.3.

For anticipated crop yield in year 2025, the maximum yield achieved in last 10 years has been considered for all the crops. Further, for years 2035 and 2045, 20% increase per decade, i.e. 2% increase per year (over 2025 values) in yield of wheat and rice, has been considered, while, for others crops, 10% increase per decade, i.e. 1% increase per year (over 2025 values), has been considered. For rice (SRI), the yield has been considered as 1.5 times that of traditional rice cultivation. Still, these anticipated crop yields are very much on conservative side as some of the states of India have achieved these crop yields in present scenario and the potential yield for the main crops of rice and wheat of Indo-Gangetic Plains of India is much higher. Increased cropping intensity is based on the assumption that with implementation of conjunctive use and various land resource development and management programmes, more water resource will be available and soil health will improve, resulting into more seasonal fallow into crop area, giving ultimate cropping intensity of 189%.
Table 8.3  Proposed crop areas, crop yield and cropping intensity in Agr.Sc-2

| Crop          | Area 2025  | Crop yield (Qtl./ha) | Area 2035  | Crop yield (Qtl./ha) | Area 2045  | Crop yield (Qtl./ha) |
|---------------|------------|----------------------|------------|----------------------|------------|----------------------|
| Rice Kharif   | 1,432,651  | 32.76                | 1,297,453  | 39.31                | 1,133,530  | 47.17                |
| Wheat         | 3,162,176  | 45.97                | 3,317,788  | 50.57                | 3,400,341  | 55.62                |
| Barley        | 15,185     | 38.39                | 7688       | 42.23                | 6067       | 46.45                |
| Jowar         | 29,283     | 23.53                | 24,230     | 25.88                | 22,255     | 28.47                |
| Bajra         | 467,713    | 46.35                | 517,945    | 50.99                | 558,041    | 56.08                |
| Maize Kharif  | 220,005    | 33.82                | 185,387    | 37.2                 | 163,594    | 40.92                |
| Gram          | 48,417     | 19                   | 33,046     | 20.9                 | 25,114     | 22.99                |
| Pea           | 20,236     | 22.46                | 13,574     | 24.71                | 9386       | 27.18                |
| Arhar         | 64,325     | 28.02                | 50,116     | 30.82                | 40,286     | 33.9                 |
| Sugarcane     | 422,021    | 784.92               | 411,318    | 863.41               | 402,126    | 949.75               |
| Potato        | 230,416    | 394.18               | 241,460    | 433.6                | 251,799    | 476.96               |
| Other Kharif crops | 360,688 | 12.04               | 379,270   | 13.24               | 397,436 | 14.57               |
| Other Rabi crops | 311,238 | 20.53               | 317,640   | 22.58               | 334,089   | 24.84               |
| Rice (SRI)    | 358,132    | 49.14                | 556,055    | 58.97                | 755,733    | 70.76                |
| Jayad         | 242,045    | 18.96                | 306,942    | 20.86                | 354,372    | 22.94                |
| Total         | 7,384,529  |                      | 7,659,913  |                      | 7,854,169  |                      |
| Cultivable area | 5,091,612 |                   | 5,091,612 |                    | 5,091,612 |                    |

*Cropping intensity percentage with respect to 2015*

|    | Kharif | Rabi  | Jayad | Total |
|----|--------|-------|-------|-------|
| 2015 | 73     | 95    | 15    | 180   |
| 2024-25 | 75   | 97    | 17    | 189   |
| 2034-35 |       |       |       |       |
| 2044-45 |       |       |       |       |

*Source* Ganga Basin Plan 2020, prepared by M/S TAHAL Consulting Engineers Ltd. Israel/India

**Outcome of Water Balance Modelling**

The outcome of U.P. Ganga Basin Plan (2020) has been discussed for base year 2015 and future water balance scenarios for 2024–25, 2034–35 and 2044–45, with crop intensification and diversification as per prevailing trend (Business as Usual). The present and future sectoral water demand, supplies and shortages have been shown in Table 8.4.

For main-stem Ganga Basin falling in Uttar Pradesh, the water balance model results shown in Table 8.4 depicts that the future water demand in 2044–45 for projected population of 210 million as compared to 68.60 million in base year 2015 (i.e. three times increase) will grow in urban domestic from 978 MCM to
Table 8.4 Summary of annual water balance for Ganga Basin, Uttar Pradesh

| Scenario | Business as usual |
|----------|-------------------|
| Demand in MCM | 2014–15 | 2024–25 | 2034–35 | 2044–45 |
| Population | 68,634,723 | 80,193,999 | 18,863,480 | 20,990,224 |
| Urban domestic demand | 978.1 | 1322.6 | 1480.8 | 1588.3 |
| Urban groundwater supply | 714.3 | 1058.6 | 1238.9 | 1332.2 |
| Urban surface water supply | 263.8 | 264.0 | 241.9 | 256.1 |
| Wastewater production/treated | 547.7/29.7 | 772.4/52.1 | 905.5/88.0 | 1,016.5/98.9 |
| Rural domestic demand | 840.5 | 1314.4 | 1924.0 | 2157.4 |
| Livestock demand | 422.2 | 484.7 | 550.8 | 616.9 |
| Industry demand | 70.6 | 132.0 | 193.5 | 254.9 |
| Power plants demand | 318.8 | 395.3 | 473.9 | 473.9 |
| Unmet power plants demand | 0.00 | 18.3 | 41.3 | 41.3 |
| Unmet total demand | 1652.06 | 2326.4 | 3142.2 | 3503.1 |
| Total rural demand | 1352.5 | 1949.0 | 2685.8 | 3044.1 |
| Total rural groundwater supply | 299.56 | 359.1 | 411.1 | 417.7 |
| Irrigation demand in canal command area (CCA) | 15,406.9 | 17,333.1 | 18,171.1 | 18,593.7 |
| Surface water supply in CCA | 9160.9 | 10,121.2 | 10,087.7 | 10,190.1 |
| Groundwater supply in CCA | 5114.8 | 5918.7 | 6577.4 | 6794.5 |
| Irrigation shortage in CCA (%) | 7.34 | 7.46 | 8.28 | 8.65 |
| Irrigation demand outside CCA | 13,855.6 | 13,545.1 | 14,110.9 | 14,506.8 |
| Groundwater supply outside CCA | 5462.7 | 5218.2 | 5266.7 | 5292.0 |
| Irrigation shortage outside CCA (%) | 54.4 | 55.2 | 56.6 | 57.6 |
| Total irrigation demand | 29,262.5 | 30,878.20 | 32,282.00 | 33,100.5 |
| GW recharge from normal rain | 9824.2 | 9824.2 | 9824.2 | 9824.2 |
| GW recharge from other sources | 9392.5 | 9935.3 | 10,321.8 | 10,528.1 |
| Total GW availability | 19,216.7 | 19,759.4 | 20,146.0 | 20,352.2 |
| Groundwater pumping | 12,663.0 | 14,167.2 | 15,794.6 | 16,490.5 |
| Stage of groundwater extraction (%) | 65.90 | 71.70 | 78.40 | 81.02 |
| Total demand | 31,892.6 | 34,527.2 | 36,905.0 | 38,191.9 |
| Total groundwater supply | 12,644.3 | 14,144.5 | 15,768.8 | 16,462.7 |
| Total surface water supply | 9724.3 | 10,744.3 | 10,744.8 | 10,863.9 |
| Total unmet demand | 8671.4 | 8,784.3 | 9,541.5 | 10,014.5 |
| Total shortage in % | 27.19 | 25.44 | 25.85 | 26.22 |

Source: Draft Ganga Basin Plan, 2020QS, prepared by TAHAL Consulting Engineers Ltd., Israel for State Water Resources Agency, Uttar Pradesh with which the author is associated
1588 MCM (i.e. 1.62 times increase), rural domestic from 841 MCM to 2157 MCM (i.e. 2.57 times increase), livestock from 422 MCM to 617 MCM (i.e. 1.46 times increase), industrial from 71 MCM to 255 MCM (i.e. 3.61 times increase) and power plants from 319 MCM to 474 MCM (i.e. 1.49 times increase). Thus, total non-agricultural water demand shall increase from 1652 MCM to 3503 MCM (i.e. 2.12 times increase). For cropping pattern under business in usual scenario (i.e. cropping trend analysed for increase/decrease shall remain same in future also), the irrigation demand will increase from 29,263 MCM to 33,101 MCM (i.e. 1.13 times increase). Therefore, total water demand in U.P. Ganga Basin shall increase from 31,893 MCM to 38,192 MCM (i.e. 1.13 times increase), whereas the stage of groundwater extraction shall increase from present 65.91 to 81.02%. Thus, total unmet demand shall increase from 8671 MCM to 10,015 MCM (i.e. 1.15 times increase). The gap in demand and supply could decrease from 27.18 to 26.22%.

Ganga Basin Investment Summary

Water Conservation: Additional water 850.89 MCM will be available with an expenditure of 8072.32 Cr. Rs. on Watershed development, wetland development and rooftop harvesting activities.

Wastewater Generated and Treated

Generated wastewater production of 514.54 MLD (547.7 MCM) for base year 2015 and 861.41 MLD (1016.5 MCM) for the year 2045 with an additional expenditure of 710.76 Cr. Rs. for construction of remaining STPs will provide about 1000 MCM additional water to be considered for irrigation purposes.

This generated volume of water (conservation and treatment) amounting to 1850 MCM yearly will reduce the shortages from 26.22 to 21.38%, with area-specific additional expenditure.

For analysis, water conservation, groundwater recharge, rooftop rainwater harvesting, wetlands development, sodic land reclamation, watershed development, command area development, removing water system distribution deficiencies and drainage system deficiencies along with strengthening water user associations has been considered.

The inference drawn underlines that there is no surplus water in the basin for which any additional plan is required to be formulated. Existing resources are already overstressed and mismanagement is exaggerating problems day by day. It requires proper management with some policy constraint to keep the resources sustainable.

For overstressed urban areas, there is an urgent need to make a compulsory provision of harvesting for private/government buildings and offices along with common utility spaces. Use of recycled water in multi-storeyed colonies and offices may also be considered.
Table 8.5  Summary of development costs in Ganga Basin (Uttar Pradesh), 2017 prices

| S. No. | Components                                                      | Cost, in INR crores |
|-------|----------------------------------------------------------------|--------------------|
| 1     | Formation and strengthening of WUAs                             | 814.24             |
| 2     | Removing canal system deficiencies                             | 3471.86            |
| 3     | Removing drainage system deficiencies                          | 2603.90            |
| 4     | Shallow tubewell installations                                 | 353.59             |
| 5     | Watershed development                                          | 2136.21            |
| 6     | Sodic land reclamation                                         | 935.00             |
| 7     | Wetland development                                            | 2247.62            |
| 8     | Wastewater treatment                                           | 710.26             |
| 9     | Rooftop rainwater harvesting                                   | 1552.28            |
| 10    | Micro-irrigation                                               | 22,917.40          |
| 11    | Command area development and water management works            | 22917.40           |
| 12    | Preparatory activities @ 5%                                    | 3000.00            |
|       | **Total basin development cost**                               | **63,659.76, Say, $10,000** |

*Source:* Estimated by the author and is included in draft Ganga Basin Plan 2020, prepared by TAHAL Consulting Engineers Ltd. Israel for State Water Resources Agency, Uttar Pradesh

Total cost to be invested for the development of different infrastructures and institutions for Ganga Basin in Uttar Pradesh is summarized in Table 8.5.

Pollution in River Ganga

Pollution in River Ganga with respect to only Faecal Coliform is in stretch between Bijnor and Narora downstream, whereas critically polluted stretch in terms of Biological Oxygen Demand (BOD) and Faecal Coliform is between Kannauj, Kanpur, Allahabad and Varanasi to Ballia. Pollution load (BOD) from tributaries by Ramganga and Kali is most critical. Non-point source pollution includes agricultural run-off, open defecation, pious refuse, partially cremated bodies, associated materials, etc. Industrial pollution in enhancing its toxicity by 669 MLD (according to Central Pollution Control Board) through 1109 Grossly Polluting Industries (GPIs) such as tanneries, pulp and paper, sugar mills, textiles and dyeing and distilleries, etc. Sewage is additional source of pollution which is discharging 2953 million litres per day (MLD) in Ganga from 155 drains generated by 97 towns on the main stem in Uttarakhand, Uttar Pradesh, Bihar, Jharkhand and West Bengal.
Namami Gange and Other Restoration Programmes at National Level

Among several Ganga River’s restoration and conservation plans, Ganga Action Plans (GAP)-1 of 1985 and GAP-II of 1993, JNNURM started in 2005 and Atal Mission for Rejuvenation and Urban Transformation (AMRUT) began in 2015 had definite impact towards this end. A separate ministry was established for Ganga Rejuvenation in July 2014; thereafter, Ganga River Basin Management Plan (GRBMP) developed in January 2015 by consortium of IITs. A budget outlay of Rs. 20,000 crores approved by government in May 2015 for Namami Gange Project. National Mission for Clean Ganga, an implementing arm, is declared as an authority under Environment Protection Act, 1986, in October 2016. Establishment of State and District Ganga Committees in June 2017 and notification of the minimum environmental flow for River Ganga at different stretches in October 2018 can be called as a visionary step in this regard undertaken to achieve the mission.

Namami Gange Programmes aim at speedily rejuvenating and conserving National River Ganga. The seven thrust areas are: (i) Aviral Dhara; (ii) Nirmal Dhara; (iii) riverfront development; (iv) capacity building; (v) research and monitoring; (vi) protection of aquatic flora and fauna; and (vii) awareness creation.

Twenty-one action points were considered in Namami Gange Programme and most important are: determination and maintenance of environmental flow, upgrading existing STPs, creating additional STPs, industrial pollution abatement, managing agricultural runoff, development of modern Dhobi ghats, creating model cremation ghats, development of Ganga Grams (villages situated on river banks), Ganga task force, Ganga Institute of River Science at Varanasi, establishment of cGanga at IIT Kanpur, afforestation drive of medical plants and native tree species, conserving diversity of Gangetic aquatic life, etc.

The details of the projects sanctioned by Namami Gange Plan for the conservation and restoration of the River Ganga till November 2018 is given in Table 8.6.

These initiatives are moving towards an evidence-based policymaking, accelerating technology transfer, providing a platform for water entrepreneurship, developing market-based mechanism for water trade and making India a global hub for water innovation, global water stewardship, innovative financing models and engaging communities.

Detailed status of existing sewage infrastructure and interventions started in Uttar Pradesh is shown in Table 8.7.

Sewage generation in complete Ganga Basin is estimated 2953 MLD in year 2016 and projected 3603 MLD by the year 2035. Available treatment capacity through 84 STPs in 46 towns till 1 November 2017 is 1584 MLD. The status of existing sewage infrastructure is shown in Fig. 8.3. Perusal of Fig. 8.3 shows that defunct 31 STPs have capacity of 270 MLD. The operational but underutilized 14 STPs have capacity 581 MLD, whereas, recently commissioned and working fine along with 20 years Operation & Maintenance (O&M), 39 STPs have capacity of 733 MLD. Interventions are underway for 45 STPs, wherein 12 STPs (91 MLD) already upgraded and O&M
### Table 8.6  Projects sanctioned under Namami Gange (figures in crore)

| Projects sanctioned under Namami Gange | Sanctioned cost, November 18 | Expenses as on September 18 |
|---------------------------------------|-------------------------------|-----------------------------|
| **Pollution abatement projects**      |                               |                             |
| 1 Sewage Infrastructure (105 on Ganga, 26 on tributaries) | 131 19,742                   | 3708.54                     |
| 2 Modular STPs-decentralized treatment | 1 410                        | 0                           |
| 3 Bio-remediation                      | 11 201.23                    | 0                           |
| Sub-total                              | 143 20,353.23                 | 3708.54                     |
| 4 Rural sanitation (4465 villages along Ganga) | 1 1426.26                    | 1017.99                     |
| 5 Industrial pollution abatement       | 12 900.13                    | 0                           |
| Sub-total                              | 13 2326.39                    | 1017.99                     |
| Total                                  | 156 22,680.00                 | 4726.53                     |
| **River front, ghats and crematoria projects** |                           |                             |
| 6 River front development              | 1 243.27                     | 233.77                      |
| 7 Ghats and crematoria (Old)           | 24 921.78                    | 497.10                      |
| 8 Ghats and crematoria (New)           | 35 204.39                    | 0                           |
| 9 Ghats cleaning                       | 3 43.87                      | 8.43                        |
| 10 River surface cleaning              | 1 33.53                      | 2.37                        |
| Sub-total                              | 64 1242.45                   | 741.67                      |
| **Afforestation and biodiversity conservation** |                       |                             |
| 11 Afforestation                       | 16 236.56                    | 127.79                      |
| 12 Biodiversity conservation           | 6 33.42                      | 20.31                       |
| Sub-total                              | 22 270.00                    | 148.10                      |
| **Other projects**                     |                               |                             |
| 13 Institutional development           | 6 185.00                     | 37.67                       |
| 14 Project implementation support/research and study projects | 4 126.56 | 5.49 |
| 15 Composite ecological task force     | 2 167.63                     | 0.06                        |
| Sub-total                              | 12 479.26                    | 5.55                        |
| Grand total                            | 254 24,672.00                | 5660.06                     |

*Source* Namami Gange programme—at a Glance—2018, NMCG
Table 8.7 Status of STPs in U.P. as on 30 November 2018 (capacity in million litres per day (MLD))

| State                  | Projects Nos. | STP capacity | Completed | Work under progress | Tendering process |
|------------------------|---------------|--------------|-----------|---------------------|-------------------|
| Uttar Pradesh          | 40            | 1106.18      | 11        | 22                  | 7                 |
| **Total Ganga Basin**  | **131**       | **3869**     | **31**    | **64**              | **36**            |

*Source* Namami Gange programme—at a Glance—2018, NMCG

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Figure 8.3 Status of existing sewage infrastructure and initiatives in Ganga main stem. *Source* Namami Gange Programme—At a Glance-2018, NMCG

sanctioned, and 8 STPs (530 MLD) are integrated under One City One Operator. For another 23 STPs, tender for upgradation has been placed. STP Projects in four towns (Kanpur, Prayagraj, Mathura, and Farrukhabad) have already been awarded and in rest nine towns are under tendering process.

**Industrial Pollution Control**

Nine hundred and sixty-one gross polluting industries (GPI) on main stem of River Ganga and major tributaries have been inspected during the period of 12 April 2018 to July 2018 by twelve technical institutes. As on November 2018, polluting industries closed by itself figured out to be 278, whereas closure direction issued vide u/s 5 of Environment (Protection) Act to 10 and, show cause notice issued to 199 polluting industries for non-compliance of the norms.
Industrial Sector Development

By considering that certain industries are bound to emit water pollution due to the mechanisms involved in their production process, the state government formulated separate plan for them (SMCG). The details are as follows:

**Tannery:** Common effluents treatment plant (CETP) approved at Jajmau (Kanpur) at the cost of INR 554 crore with adoption of cleaner process and reduced water consumption.

**Paper and Pulp:** Zero black liquor discharge achieved. Estimated reduction in the freshwater consumption and effluent generation is about 45–50% as compared to 2012.

**Distillery:** Zero liquid discharge achieved in 32 molasses-based distilleries.

**Sugar:** Effluent generation reduced from 400 to 200 litres per ton of cane crushed.

**Textile:** Most of the units are in the process of upgradation of existing effluent treatment plant (ETPs)/installation of new ETPs/CETPs (common effluent treatment plants). Along the line, 6.25 MLD CEPT is sanctioned for Mathura.

**Water Quality Monitoring Stations (WQMS):** 44 real-time WQMS are made under operation to keep water quality in check.

Water Quality Status of River Ganga

Central Pollution Control Board (CPCB) has carried out an extensive survey of micro-invertebrates in the entire length of River Ganga. The study suggests that above two-thirds of the river length is moderately impacted. Significantly impacted reach lies at certain point locations, say near tannery hub of Kanpur. Near pristine situation is near source of mouth, and slightly impacted reach is in Alaknanda-Mandakini-Pinder system due to hydroelectric project under construction. Downstream Kachhla Ghat to Ghatia Ghat is due to Kali River which is highly polluted.

Impact of lockdown imposed to curb COVID-19 (since 24 March 2020 to 15 April 2020) has resulted in overall improvement in water quality of River Ganga, especially with regard to increased DO, and reduced nitrate concentration (CPCB, April 2020). This may primarily be attributed to the absence of industrial wastewater discharge (300 MLD, i.e. 9% of total wastewater being discharged into the river every day), agricultural runoff and increased freshwater flow. The reduction in BOD and COD concentration was relatively less due to continuous discharge of domestic water into the river. Reduced activities at ghats and entrainment of solid organic waste into the river may also have contributed to better water quality.
**Afforestation**: Forest Research Institute, Dehradun, has prepared afforestation plan of 134,106 ha at an estimated cost of INR 2294 crores. For 2016-19, Uttar Pradesh state details are given in Table 8.8.

#Uttar Pradesh has launched ‘Haritima Abhiyan’ to provide common platform for all to participate so that the campaign for Cleaning Ganga is promoted as a massive Jan Andolan (mass movement). The scheme has been made a huge budgetary allocation dividing into state and centre. A budgetary allocation of INR 71 crores for states and INR 164 crore for centre (totalling INR 235 cr.) is made for the activities like sponsorship of awareness programmes, plantation by institutions/industries/NGO/citizen groups on common lands and adoption of Ganga villages by corporate/institutions.

On similar line, some more interesting steps have been taken by government in an effort to clean Ganga River. Few of them are as follows:

**Ganga Task Force**: A battalion of 532 ex-servicemen is engaged in creating public awareness, tree plantation, participating in campaigns and patrolling Ganga River for biodiversity protection and monitoring river pollution.

**Ganga Vichar Manch**: It is actively involved in public outreach activities, tree plantation and ghat cleaning.

**Ganga Praharis**: Self-motivated individuals who will mobilize others in Ganga conservation efforts. The Ganga Praharis are being trained for ecological monitoring of biodiversity of Ganga River along with tree plantation techniques, awareness generation and community mobilization.

**Jalaj Scheme**: It advocates innovative steps for Ganga Praharis to combine livelihood improvement with aquatic life and Ganga conservation.

**Treatment of sick rivers**: Treatment of water depends upon the diagnosis of the biodiversity along with the attaining of desirable ‘standard’ and the adoption of treatment system. Therefore, realizing it, on priority basis, one river in a district totalling for eight rivers in Uttar Pradesh is selected for treatment purpose. Few of them are, for example, Gomti, Aril, Tamsa, Varuna, Manorama Rivers, etc.

**Preventive Measures**: To this end, catchment land use, waste treatment, flows, habitat alteration studies are under consideration.

**Curative Measures**: In this, maintenance of environmental flows, revival of meanders and habitat features, changes in land use practices, restoration of riparian/floodplain habitats, groundwater recharge, controlling exotic species, regulating gravel/sand extraction, etc., have been considered.

### Table 8.8  Afforestation targets in Uttar Pradesh

| State            | Area in ha | INR crore |
|------------------|------------|-----------|
| Uttar Pradesh#   | 4942       | 40.51     |
| Total Basin      | 26,810     | 199.98    |

*Source* Namami Gange programme—at a Glance—2018, NMCG
Environmental Flows at Critical Locations on River Ganga

E-Flows’ assessment was carried out at two locations on Ganga main stem which include (i) downstream Madhya Ganga Barrage and (ii) downstream Narora Barrage. Cross-section (CS) surveys at these two locations were carried out (Fig. 8.4), and E-Flows were recommended keeping in view water requirements of Indian Major Carps (IMP) by WWF-India and cGanga, IIT Kanpur, in May 2019.

The summary of Hydraulic Parameters is given in Table 8.9.

Perusal of Table 8.9 shows that Ganga River top width, average depth and average velocity are increasing from Madhya Ganga Barrage to Narora Barrage. E-Flows estimated and gap with present flows in Ganga River downstream Madhya Ganga Barrage at Balawali and downstream Narora Barrage is given in Tables 8.10 and 8.11, respectively.

The percentage of shortfall in terms of present water availability along with E-Flows’ recommendations for downstream Bhimgoda Barrage at downstream of Madhya Ganga Barrage at Balawali is illustrated in Fig. 8.5. Similar gap in recommended and observed flows is shown for downstream Narora Barrage site in Fig. 8.6.

According to Gazette of Government of India by NMCG Order of 9 October 2018 (MOWR, RD and GR 2018), the 20%, 25% and 30% of monthly flows are be maintained at locations downstream of structures at Devprayag to Haridwar in Uttarakhand during non-monsoon and monsoon respectively in upper stretch of River Ganga. In plains, downstream Bhimgoda Barrage 36–57 m³/s and downstream Bijnor, Narora and Kanpur Barrage 24–48 m³/s flows during non-monsoon and monsoon respectively have been issued.

![Fig. 8.4](image1.png)

*Fig. 8.4* Elevation profile from DGPS: CS-1 at Madhya Ganga Barrage and CS-2 Narora Barrage.

*Source* WWF-India Report 2019 for IWMI
Table 8.9  Summary of hydraulic parameters at Madhya Ganga and Narora Barrage

| Site details               | Cross-sectional Point | Top width (m) | Average depth (m) | Average velocity (m/s) |
|---------------------------|-----------------------|---------------|-------------------|------------------------|
| Madhya Ganga Barrage      | Upstream              | 257.89        | 1.38              | 0.38                   |
| Cross Section-1           | Main                  | Channel 1: 316.71 | Channel 1: 0.96  | Channel 2: 148.02      | Channel 2: 0.85         |
|                           | Downstream            | 248.32        | 1.38              |                        |
| Narora Barrage            | Upstream              | 407.37        | 1.55              | 0.54                   |
| Cross Section-2           | Main                  | 495.26        | 1.34              |                        |
|                           | Downstream            | 388.56        | 1.54              |                        |

Source: Cross-sectional survey of Ganga River at Bijnor and Narora, WWF-India, 2019

Since Lower Ganga irrigation canal off-taking from Narora Barrage receives water perennially from Tehri Dam/Bhimoda Barrage, and supplemented by Kalagarh Dam on Ramganga through Ramganga feeder Canal meeting Ganga at Brijghat (Moradabad), the actual challenge is ensuring E-Flows downstream Narora Barrage. Secondly, River Ganga is losing stream between Narora to Allahabad particularly during non-monsoon period; hence, the above shown minimum E-flows seem to be inadequate. WWF-India has assessed E-flows at Prayagraj as 225 m$^3$/s during Kumbh on normal days and 310 m$^3$/s on main bathing dates for the presence of millions of pilgrims (WWF-India 2013).

Alternatively, if we improve water-use efficiency (WUE) in canal command area, huge amount of water may be freed from agriculture and can fill up the deficiency. An exercise in this regard has been done with Upper Ganga Canal (UGC) system and Lower Ganga Canal (LGC) system, which are depicted in Table 8.12.

Augmentation of flows at downstream of Bhimgoda Barrage for maintenance of E-Flows can also be achieved by having additional releases from the upstream reservoir (Tehri Dam). However, the long-term solution lies in enhancing water-use efficiency, thereby reducing the irrigation demand, leading to reduced withdrawals at the head of the irrigation systems.

Change in Crop Pattern

The potential of crop diversification for E-Flows’ maintenance has been considered looking at marginal reduction in area under some of the water-intensive crops while suggesting less water-intensive crops, but with good economic gains.
Table 8.10  E-flows assessment downstream Balawali Barrage on River Ganga and gap with present flows (average and 90% dependable)

Balawali (all values are in cumec, i.e. m³/s)

|                | Avg present flow | 90% dependable flow | Minimum ecological requirement (recommended) | Gap towards Avg present flow | Gap towards 90% dependable flow | E-flows (recommended) | Monthly values in MCM | Gap towards Avg present flow | Gap towards 90% dependable flow |
|----------------|------------------|----------------------|----------------------------------------------|-----------------------------|--------------------------------|------------------------|-------------------------|-----------------------------|-----------------------------|
| Jan (1–10)     | 60.46            | 13.93                | 28.00                                        | 32.46                       | −14.07                         | 57.9                   | 120.5                   | 2.58                        | −43.95                      |
| Jan (11–20)    | 60.31            | 7.70                 | 28.00                                        | 32.31                       | −20.30                         | 32.0                   | 28.31                   | −24.30                      |                             |
| Jan (21–31)    | 51.19            | 11.96                | 28.00                                        | 23.19                       | −16.04                         | 49.7                   | 1.50                    | −37.73                      |                             |
| Feb (1–10)     | 47.76            | 7.99                 | 28.00                                        | 19.76                       | −20.01                         | 33.2                   | 110.0                   | 14.58                       | −25.19                      |
| Feb (11–20)    | 70.11            | 11.33                | 28.00                                        | 42.11                       | −16.67                         | 47.1                   | 23.05                   | −35.73                      |                             |
| Feb (21–28)    | 60.34            | 11.36                | 28.00                                        | 32.34                       | −16.64                         | 47.2                   | 13.15                   | −35.83                      |                             |
| Mar (1–10)     | 61.22            | 6.74                 | 28.00                                        | 33.22                       | −21.26                         | 28.0                   | 111.3                   | 33.22                       | −21.26                      |
| Mar (11–20)    | 52.22            | 12.96                | 28.00                                        | 24.22                       | −15.04                         | 53.8                   |                       | −1.61                       | −40.87                      |
| Mar (21–31)    | 60.03            | 11.33                | 28.00                                        | 32.03                       | −16.67                         | 47.1                   | 12.97                   | −35.73                      |                             |
| Apr (1–10)     | 48.80            | 11.33                | 28.00                                        | 20.80                       | −16.67                         | 47.1                   | 163.4                   | 1.74                        | −35.73                      |
| Apr (11–20)    | 70.12            | 17.05                | 28.00                                        | 42.12                       | −10.95                         | 70.8                   |                       | −0.73                       | −53.79                      |
| Apr (21–30)    | 101.64           | 17.18                | 28.00                                        | 73.64                       | −10.82                         | 71.4                   | 30.28                   | −54.19                      |                             |
| May (1–10)     | 133.91           | 26.47                | 28.00                                        | 105.91                      | −1.53                          | 110.0                  | 683.2                   | 23.93                       | −83.51                      |
| May (11–20)    | 215.37           | 42.44                | 28.00                                        | 187.37                      | 14.44                          | 176.3                  | 39.07                   | −133.87                     |                             |

(continued)
Table 8.10 (continued)

Balawali (all values are in cumec, i.e. m$^3$/s)

|                     | Avg present flow | 90% dependable flow | Minimum ecological requirement (recommended) | Gap towards Avg present flow | Gap towards 90% dependable flow | E-flows (recommended) | Monthly values in MCM | Gap towards Avg present flow | Gap towards 90% dependable flow |
|---------------------|------------------|---------------------|---------------------------------------------|----------------------------|--------------------------------|------------------------|-------------------------|-----------------------------|--------------------------------|
| May (21–30)         | 298.33           | 121.56              | 28.00                                       | 270.33                     | 93.56                          | 505.0                  | −206.71                 | −383.48                     |
| Jun (1–10)          | 363.12           | 126.06              | 53.00                                       | 310.12                     | 73.06                          | 523.7                  | −160.63                 | −397.69                     |
| Jun (11–20)         | 453.31           | 112.24              | 53.00                                       | 400.31                     | 59.24                          | 466.3                  | −13.01                  | −354.08                     |
| Jun (21–30)         | 725.21           | 365.37              | 53.00                                       | 672.21                     | 312.37                         | 733.8                  | −8.54                   | −368.39                     |
| Jul (1–10)          | 1072.40          | 489.74              | 146.93                                     | 925.47                     | 342.81                         | 927.2                  | 4033.2                  | 145.16                      | −437.49                       |
| Jul (11–20)         | 1489.48          | 736.87              | 146.93                                     | 1342.55                    | 589.94                         | 1451.2                 | 38.27                   | −714.34                     |
| Jul (21–31)         | 1937.87          | 1134.74             | 138.39                                     | 1799.48                    | 996.35                         | 2293.2                 | −355.35                 | −1158.48                    |
| Aug (1–10)          | 2362.55          | 1243.81             | 240.86                                     | 2121.70                    | 1002.95                        | 2561.3                 | 6312.8                  | −198.74                     | −1317.49                     |
| Aug (11–20)         | 2410.94          | 1188.78             | 240.86                                     | 2170.09                    | 947.92                         | 2436.9                 | −25.97                  | −1248.13                    |
| Aug (21–31)         | 2138.11          | 1136.15             | 223.78                                     | 1914.33                    | 912.37                         | 2313.9                 | −175.82                 | −1177.78                    |
| Sep (1–10)          | 1829.91          | 874.04              | 240.86                                     | 1589.06                    | 633.18                         | 1725.5                 | 2973.2                  | 104.43                      | −851.45                      |
| Sep (11–20)         | 1403.63          | 549.79              | 146.93                                     | 1256.70                    | 402.86                         | 1054.5                 | 349.09                  | −504.76                     |
| Sep (21–30)         | 930.85           | 365.51              | 146.93                                     | 783.93                     | 218.58                         | 663.8                  | 267.04                  | −298.31                     |
| Oct (1–10)          | 545.70           | 323.38              | 124.43                                     | 421.28                     | 198.95                         | 574.5                  | 1378.0                  | −28.78                      | −251.11                      |
| Oct (11–20)         | 457.55           | 156.31              | 28.00                                      | 429.55                     | 128.31                         | 649.4                  | −191.87                 | −493.11                     |
| Oct (21–31)         | 367.07           | 89.59               | 28.00                                      | 339.07                     | 61.59                          | 372.2                  | −5.13                   | −282.62                     |
Table 8.10 (continued)

Balawali (all values are in cumec, i.e. m³/s)

|         | Avg present flow | 90% dependable flow | Minimum ecological requirement (recommended) | Gap towards Avg present flow | Gap towards 90% dependable flow | E-flows (recommended) | Monthly values in MCM | Gap towards Avg present flow | Gap towards 90% dependable flow |
|---------|------------------|---------------------|----------------------------------------------|-----------------------------|---------------------------------|-----------------------|------------------------|--------------------------|-------------------------------|
| Nov (1–10) | 229.44           | 41.97               | 28.00                                        | 201.44                      | 13.97                           | 174.4                 | 266.1                  | 55.07                    | −132.40                       |
| Nov (11–20) | 113.55           | 15.23               | 28.00                                        | 85.55                       | −12.77                          | 63.3                  | 50.29                  | −48.03                   |                               |
| Nov (21–30) | 62.22            | 16.99               | 28.00                                        | 34.22                       | −11.01                          | 70.6                  | −8.37                  | −53.60                   |                               |
| Dec (1–10)  | 62.28            | 16.99               | 28.00                                        | 34.28                       | −11.01                          | 70.6                  | 148.5                  | −8.31                    | −53.60                       |
| Dec (11–20) | 76.43            | 11.40               | 28.00                                        | 48.43                       | −16.60                          | 47.4                  | 29.08                  | −35.96                   |                               |
| Dec (21–30) | 68.85            | 13.01               | 28.00                                        | 40.85                       | −14.99                          | 54.0                  | 14.82                  | −41.03                   |                               |
Table 8.11  E-flows’ assessment downstream Narora Barrage on River Ganga and gap with present flows (average and 90% dependable)

Narora (all values are in cumec i.e. m$^3$/s)

|                | Avg present flow | 90% dependable flow | Minimum ecological requirement (recommended) | Gap towards Avg present flow | Gap towards 90% dependable flow | E-flows (recommended) | Monthly values in MCM | Gap towards Avg present flow | Gap towards 90% dependable flow |
|----------------|------------------|---------------------|---------------------------------------------|-----------------------------|---------------------------------|-----------------------|------------------------|--------------------------|---------------------------------|
| Jan (1–10)     | 15.99            | 3.96                | 19.00                                       | −3.01                       | −15.04                          | 19.0                  | 49.2                   | −3.01                    | −15.04                          |
| Jan (11–20)    | 15.50            | 3.96                | 19.00                                       | −3.50                       | −15.04                          | 19.0                  | −3.50                  | −15.04                   |
| Jan (21–31)    | 9.04             | 3.96                | 19.00                                       | −9.96                       | −15.04                          | 19.0                  | −9.96                  | −15.04                   |
| Feb (1–10)     | 4.98             | 3.96                | 19.00                                       | −14.02                      | −15.04                          | 19.0                  | 49.2                   | −14.02                   | −15.04                          |
| Feb (11–20)    | 7.15             | 3.96                | 19.00                                       | −11.85                      | −15.04                          | 19.0                  | −11.85                 | −15.04                   |
| Feb (21–28)    | 11.18            | 3.96                | 19.00                                       | −7.82                       | −15.04                          | 19.0                  | −7.82                  | −15.04                   |
| Mar (1–10)     | 8.79             | 3.96                | 19.00                                       | −10.21                      | −15.04                          | 19.0                  | 73.1                   | −10.21                   | −15.04                          |
| Mar (11–20)    | 16.24            | 5.22                | 19.00                                       | −2.76                       | −13.78                          | 25.0                  | 20.31                  | −8.76                    | −19.78                          |
| Apr (1–10)     | 15.79            | 8.50                | 19.00                                       | −3.21                       | −10.50                          | 40.7                  | 105.5                  | −24.92                   | −32.22                          |
| Apr (11–20)    | 23.23            | 8.50                | 19.00                                       | 4.23                        | −10.50                          | 40.7                  | −17.49                 | −32.22                   |
| Apr (21–30)    | 35.64            | 8.50                | 19.00                                       | 16.64                       | −10.50                          | 40.7                  | −5.07                  | −32.22                   |
| May (1–10)     | 51.43            | 8.50                | 19.00                                       | 32.43                       | −10.50                          | 40.7                  | 105.5                  | 10.71                    | −32.22                          |
| May (11–20)    | 51.27            | 8.50                | 19.00                                       | 32.27                       | −10.50                          | 40.7                  | 10.55                  | −32.22                   |

(continued)
| Table 8.11 (continued) |  |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Narora (all values are in cumec i.e. m\(^3\)/s) | For minimum ecological requirement | For E-flows | Monthly values in MCM | Gap towards Avg present flow | Gap towards 90% dependable flow | E-flows (recommended) | Gap towards Avg present flow | Gap towards 90% dependable flow | E-flows (recommended) | Gap towards Avg present flow | Gap towards 90% dependable flow |
| Avg present flow | 90% dependable flow | Minimum ecological requirement (recommended) | Gap towards Avg present flow | Gap towards 90% dependable flow | | | | | | |
| May (21–30) | 63.91 | 8.50 | 19.00 | 44.91 | −10.50 | 40.7 | 23.20 | −32.22 |
| Jun (1–10) | 140.65 | 8.20 | 31.00 | 109.65 | −22.80 | 39.3 | 101.36 | −31.09 |
| Jun (11–20) | 376.84 | 14.80 | 31.00 | 345.84 | −16.20 | 70.9 | 305.93 | −56.12 |
| Jun (21–30) | 678.85 | 151.73 | 31.00 | 647.85 | 120.73 | 231.0 | 447.81 | −79.31 |
| Jul (1–10) | 1292.45 | 502.43 | 31.00 | 1261.45 | 471.43 | 765.1 | 527.37 | −262.65 |
| Jul (11–20) | 1820.62 | 652.63 | 150.00 | 1670.62 | 502.63 | 960.8 | 859.84 | −308.15 |
| Jul (21–31) | 2623.63 | 1479.05 | 247.36 | 2376.26 | 1231.69 | 2282.2 | 341.43 | −803.15 |
| Aug (1–10) | 3202.67 | 1244.07 | 388.00 | 2814.67 | 856.07 | 1899.6 | 1303.10 | −655.51 |
| Aug (11–20) | 3297.02 | 1305.67 | 388.00 | 2909.02 | 917.67 | 2007.2 | 1289.83 | −701.51 |
| Aug (21–31) | 2960.56 | 1510.91 | 355.55 | 2605.01 | 1155.36 | 2357.6 | 602.99 | −846.66 |
| Sep (1–10) | 2610.53 | 1294.76 | 269.00 | 2341.53 | 1025.76 | 1981.2 | 629.29 | −686.48 |
| Sep (11–20) | 2159.30 | 473.19 | 269.00 | 1890.30 | 204.19 | 622.8 | 1536.47 | −149.63 |
| Sep (21–30) | 1039.28 | 306.78 | 150.00 | 889.28 | 156.78 | 414.0 | 625.24 | −107.27 |
| Oct (1–10) | 490.64 | 68.71 | 139.20 | 351.44 | −70.49 | 37.7 | 452.93 | 31.01 |
| Oct (11–20) | 252.65 | 21.83 | 19.00 | 233.65 | 2.83 | 104.6 | 148.01 | −82.80 |
| Oct (21–31) | 213.68 | 8.50 | 19.00 | 194.68 | −10.50 | 40.7 | 172.96 | −32.22 | (continued)
| Month (Start–End) | Avg present flow | 90% dependable flow | Minimum ecological requirement (recommended) | Gap towards Avg present flow | Gap towards 90% dependable flow | E-flows (recommended) | Monthly values in MCM | Gap towards Avg present flow | Gap towards 90% dependable flow |
|------------------|------------------|---------------------|-----------------------------------------------|----------------------------|--------------------------------|-----------------------|-------------------------|----------------------------|-------------------------------|
| Nov (1–10)       | 119.24           | 8.50                | 19.00                                         | 100.24                     | −10.50                        | 40.7                  | 105.5                   | 78.53                     | −32.22                        |
| Nov (11–20)      | 56.99            | 8.50                | 19.00                                         | 37.99                      | −10.50                        | 40.7                  | 16.27                   | −32.22                     |                               |
| Nov (21–30)      | 14.76            | 8.50                | 19.00                                         | −4.24                      | −10.50                        | 40.7                  | −25.95                  | −32.22                     |                               |
| Dec (1–10)       | 12.64            | 8.50                | 19.00                                         | −6.36                      | −10.50                        | 40.7                  | 77.3                    | −28.07                     | −32.22                        |
| Dec (11–20)      | 10.79            | 6.23                | 19.00                                         | −8.21                      | −12.77                        | 29.9                  | −19.07                  | −23.63                     |                               |
| Dec (21–30)      | 7.07             | 3.96                | 19.00                                         | −11.93                     | −15.04                        | 19.0                  | −11.93                  | −15.04                     |                               |

Source: IIT Kanpur for WWF-India
Agriculture Income Gain

The annual value gain for the farmer is estimated in terms of the changes in farm income by calculating the difference in total value of crop production from the business-as-usual scenario to the other water management schemes proposed due to increased crop yields and with increase in cropping intensity to 189%.
Table 8.12 Different WUE scenarios for both UGC and LGC systems for the fulfilment of E-flows in Ganga

| Scenarios | Description                          | Whether E-flows would be achieved | Percentage of E-flows gap fulfilled (%) | Scenarios | Description                          | Whether E-flows would be achieved | Percentage of E-flows gap fulfilled (%) |
|-----------|--------------------------------------|----------------------------------|----------------------------------------|-----------|--------------------------------------|----------------------------------|---------------------------------------|
| BAU       |                                       | No                               | –                                      | BAU       |                                       | No                               | –                                     |
| A         | Water-use efficiency enhanced by 5%   | No                               | 35                                     | A         | Water-use efficiency enhanced by 1%   | No                               | 46                                    |
| B         | Water-use efficiency enhanced by 10%  | No                               | 70                                     | B         | Water-use efficiency enhanced by 3%   | Yes                              | 137                                   |
| C         | Water-use efficiency enhanced by 15%  | Yes                              | 104                                    | C         | Water-use efficiency enhanced by 5%   | Yes                              | 228                                   |
| D         | Water-use efficiency enhanced by 20%  | Yes                              | 139                                    | D         | Water-use efficiency enhanced by 20%  | Yes                              | 910                                   |

Source WWF-India Report, 2019

Institutional Efforts

Under Uttar Pradesh Water Structuring Project Phase-I (in Ghaghra-Gomti Basin) and ongoing Phase-II (in LGC command in Ganga Basin), there are various reforms underway to streamline the situation by setting up water users associations (WUAs) through passing and enforcing necessary legislations and executive orders. There is a growing debate within the formal circles that by extending necessary services to farmers, i.e. Soil-Health Card and pressure irrigation (drip and sprinkler), water-use efficiency can be enhanced. And it can effectively be implemented through the involvement of WUAs.

Policy Implications

Since irrigation is the biggest user of Ganga waters, therefore, a much more concerted effort is required to ‘free-up’ water from irrigation in order to maintain environmental flows in River Ganga. A regulated groundwater use in protected areas will go a long
way in supporting the cause of restoration and conservation of the River Ganga through base-flow augmentation, especially during dry season flows. The challenge of implementing environmental flows in Ganga Basin is: (a) enhancing flows in the rivers by demand and supply management in farming which can be achieved by implementing better water management practices in agriculture and irrigation activities; (b) Changed Operation Rule of barrages and dams in alignment with the E-Flows’ requirements; (c) recycle and reuse of wastewater generated and (d) groundwater use limited to 90% of annual replenishment. Apart from regulation of groundwater through policies, acts and supply interventions, institutional instrumentation should also be considered for rejuvenation of wetlands, ponds, etc., and water conservation and rainwater harvesting. It would provide myriad of ecosystem services and most importantly recharging the aquifers.

Good impact of lockdown to curb COVID-19 (imposed by India since 24 March 2020) on water quality of River Ganga as reported by CPCB suggests that Ganga is self-sufficient to cleanse herself if human intervention is limited to natural limits. Therefore, it provides institutional mechanism for coordination involving the states, local bodies and elements of civil society regarding rejuvenation and conservation of mother Ganga.

Conclusions and Recommendations

In a tropical country like India, the mismatch in demand and supply of water can be regulated with infrastructural improvement and efficient water use in Ganga Basin. Most importantly, it is noteworthy that demand-side management of water is equally important over supply-side solutions to maintain a balance. The research underlines that for main-stem Ganga Basin falling in the state of Uttar Pradesh, future water demand in 2044–45 for projected population of 210 million is expected to increase by three times as compared to 68.60 million population in base year 2015. The estimations highlight that the water demand in urban domestic areas will grow 1.60 times from existing 978 to 1588 MCM. Similarly, the water demand for rural domestic purposes will rise 2.57 times, from existing 841 MCM to 2157 MCM; for livestock, it will enhance 1.46 times, from 422 MCM to 617 MCM; and for industrial purposes increase recorded is 3.61 times, which is from 71 MCM to 255 MCM. Likewise, the demand of water for power plants will also accelerate 1.49 times, from existing 319 MCM to 474 MCM. Thus, in a nutshell, total non-agricultural water demand shall increase 2.12 times, from 1652 MCM to 3503 MCM. For cropping pattern under business as usual scenario (i.e. cropping trend analysed for increase/decrease shall remain same in future also), the irrigation demand will increase 1.13 times from 29,263 MCM to 33,101 MCM. Therefore, total water demand in U.P. Ganga Basin shall increase 1.13 times from 31,893 MCM to 38,192 MCM, whereas the stage of groundwater extraction shall increase from present 65.91 to 81.02%, which is quite a dismal figure. Thus, total unmet demand of water in the existing situation shall increase 1.15 times from 8671 MCM to 10,015 MCM, which is quite huge in nature.
and may create water problem. The gap in demand and supply could decrease from 27.18 to 26.22% only.

If we look at the water resource augmentation, reuse of generated wastewater in urban centres appears as the first most viable alternative. The wastewater production is estimated as 861.86 million litres per day (MLD) by the year 2045 in U.P. Ganga Basin. For treatment of wastewater of major towns having population of 20,000 or more, the existing treatment capacity is 443.50 MLD, while 183.95 MLD capacities are under construction. Sewage treatment plants for rest of wastewater treatment of 234.41 MLD in Ganga Basin are to be constructed by UP Jal Nigam department under Clean Ganga Mission or under any other scheme to meet out the water requirement. The approximate present cost of STPs for fulfilment of additional treatment requirement will be INR 710.26 crore. It will provide 314.89 MCM additional water to be considered for irrigation purposes. Further, 840.89 MCM additional water can be made available with an expenditure of 5906.11 crore through watershed development, wetland development and rooftop rainwater harvesting activities. Thus, additional generated volume of water amounting to 1155.78 MCM yearly will reduce the water shortage by 11.54%, with area-specific additional expenditure in Ganga Basin of Uttar Pradesh.

**Way Forward**

There are an opportunity and challenge for implementing environmental flows in Ganga River Basin. To address the issue, three-pronged approach is considered in Draft Ganga Basin Plan from 2025 to 2045. These are: (a) enhancing flows in the rivers by demand and supply management in farming which can be achieved by implementing better water management practices in agriculture and irrigation activities; (b) Changed Operation Rule of barrages and dams in alignment with the E-Flows’ requirements; and (c) recycle and reuse of wastewater generated and groundwater use limited to 90% of annual replenishment. Along the line, apart from regulation of groundwater through policies, acts and supply interventions, institutional instrumentation should also be considered for rejuvenation of wetlands, ponds, etc. It would provide myriad of ecosystem services and most importantly recharging the aquifers.

Since irrigation is the biggest user of Ganga waters, a much more concerted effort is required to ‘free-up’ water from irrigation in order to maintain E-Flows in River Ganga. At times, the phenomenon of surface water–groundwater interaction is natural one, but a regulated groundwater use in protected areas will go a long way in supporting the cause of restoration and conservation of River Ganga.
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