नमामि गंगे

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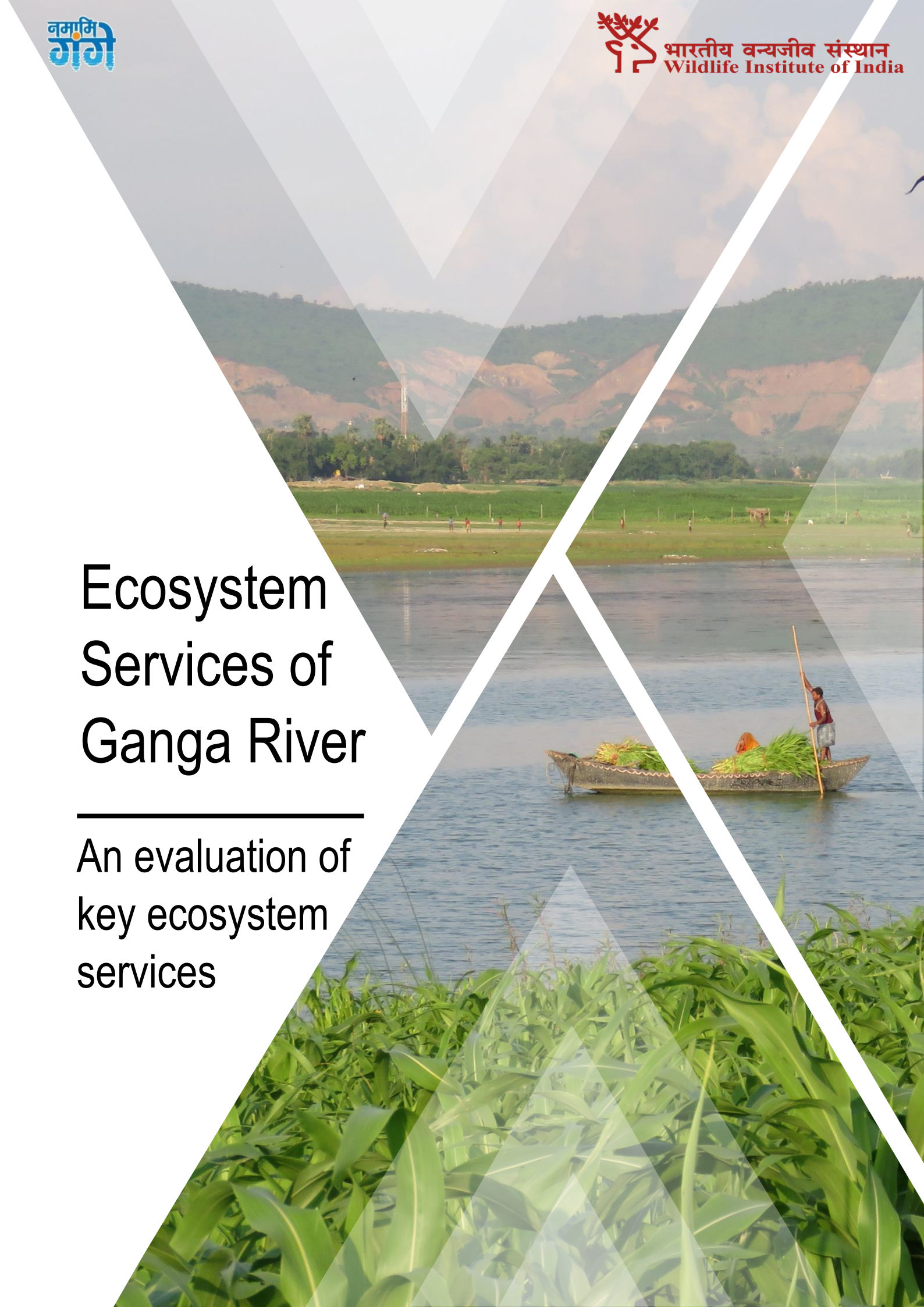
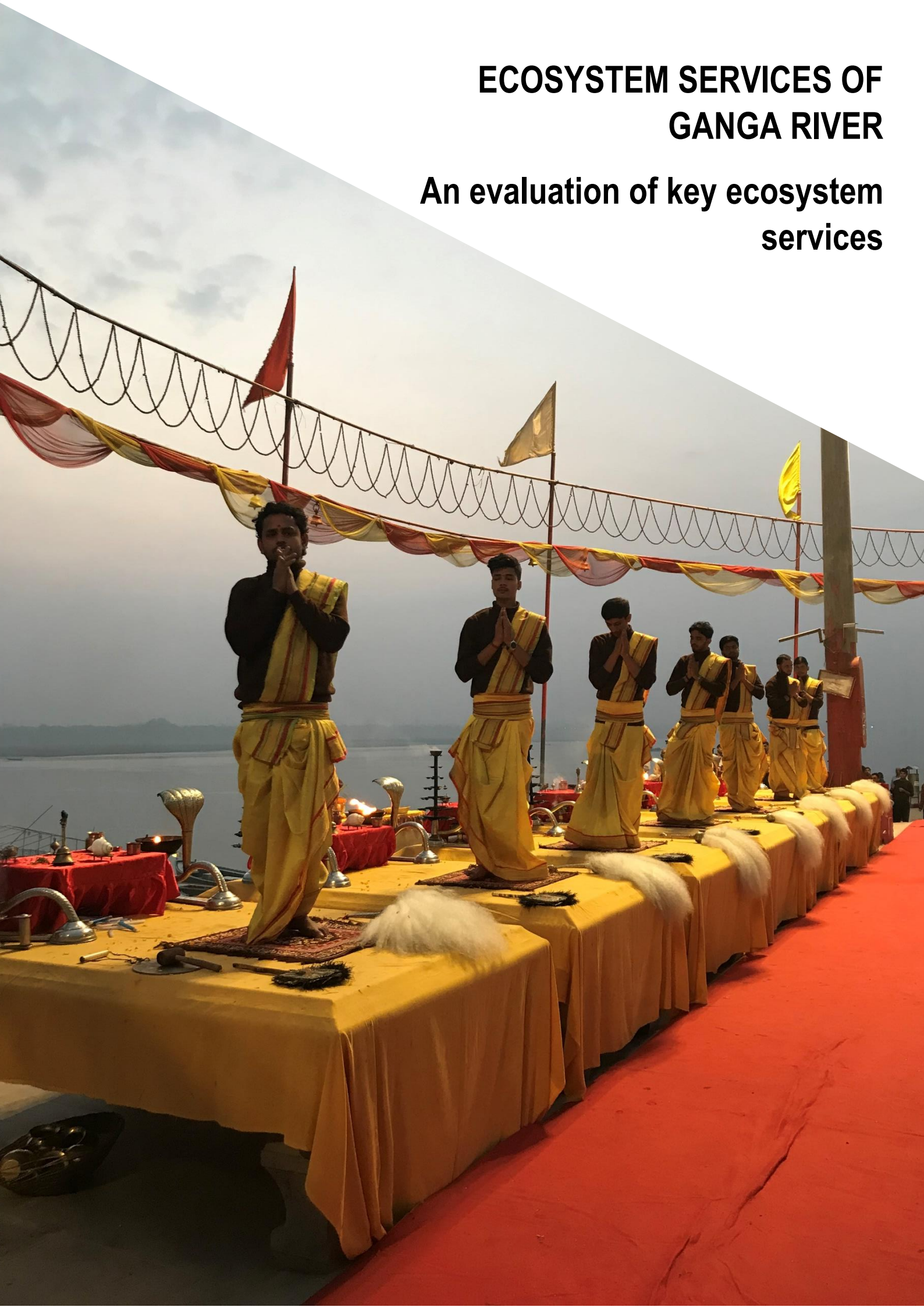


Ecosystem Services of Ganga River

An evaluation of key ecosystem services

ECOSYSTEM SERVICES OF GANGA RIVER

An evaluation of key ecosystem services



BIODIVERSITY CONSERVATION AND GANGA REJUVENATION

Ecosystem Services of Ganga River: an evaluation of key ecosystem services

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Executive Summary

Human wellbeing is contingent on the enumerable direct and indirect benefits provided by ecosystem functions and processes, collectively termed as 'Ecosystem Services' (CBD, 2008), which can be categorized into provisioning, regulating, supporting and cultural; for the present study regulating and supporting services have combined. The Ganga River hosts a vast population of diverse stakeholders with varying demands on the river and its resources. According to CPCB (2013), 7x107 cusec of Ganga's surface water (33x107 cusec), and 7x107 cusec of Ganga's annual groundwater potential (11x107 cusec) is being utilized.

To evaluate the ecosystem services of the Ganga River mainstem, a framework that accounted for both the resource constraints as well as the relevance of the ecosystem services provided was developed. The Ganga River mainstem was divided into three stretches i.e., Upper Ganga (Gaumukh to Haridwar), Middle Ganga (Haridwar to Varanasi) and Lower Ganga (Varanasi to Ganga Sagar) due to the variations in geology, geomorphology, soil type, climate, flora and fauna, and social and economic issues between the three stretches, which will influence the type and extent of services provided. The identification of ecosystem services was done stretch-wise and the services for valuation were selected based on stakeholder perception, their extent and perceived importance and resource requirement. The most resource efficient standardised method for conducting an economic appraisal was used.

A total of 30 stakeholder groups were identified with respect to the ecosystem services provided by the Ganga. A total of 503 respondents were surveyed along the Ganga River — 175 in Upper Ganga, 131 in Middle Ganga and 197 in Lower Ganga, using the opportunistic sampling technique. Water for drinking was the most cited ecosystem service in Upper Ganga, while in both Middle and Lower Ganga, water for irrigation was the most cited service, which is not surprising considering the intensive agriculture practices along the two stretches. 10.90%, 23.62% and 26.19% of the respondents in the Upper, Middle and Lower Ganga, respectively, mentioned that the Ganga River maintains population and habitat for diverse floral and faunal species.

After assessing the Ganga River ecosystem and its functions, 22 key ecosystem services were identified — 11 provisioning services, seven regulating and supporting services, and four cultural services. The extent and importance of provisioning services was primarily high only for the middle and lower stretch; except for power generation, which was high for the upper stretch due to the potential hydroelectric power generation. For cultural services, the extent and importance is high for all the three stretches.

Select ecosystem services, namely, water for drinking and domestic use and power generation, benefits to agriculture (water for irrigation and soil fertility), riverbed material, provision of fish, water for transportation, recreational and religious/spiritual services, were selected for valuation. In 10 urban centres along Ganga, namely, Srinagar, Uttarkashi, Haridwar, Meerut, Kanpur, Mirzapur, Varanasi, Patna Urban Area, Bhagalpur and Kolkata, 1574.29 MLD surface water and 1008.675 MLD ground water is being withdrawn daily, valued at ₹51.79 million and ₹33.19 million, assuming constant utility per unit of consumption. The cultivators in the Bihar Ganga districts earned, on an average, an estimated ₹107,614.34 million (±14,766.95 million), ₹82,736.06 million (±19,120.29 million) and ₹29,241.54 million (±5,018.29 million) from the cultivation of paddy, wheat and sugarcane, respectively (at MSP), between 2012-13 and 2017-18 (t=6 years). It was reported by the farmers in Bhagalpur, Bihar that the occasional floods helped reduce the cost of cultivation due to the nutrients replenished by flood waters. The nine commissioned hydropower plants in the Ganga and Alaknanda mainstem in Uttarakhand and the one nuclear power plant at Narora, prevented the emission of an estimated 9.93 million tCO2 and 3.22 (± 0.18) million tCO2, respectively, annually, considering coal burning thermal power plants as the

alternative. While inland waterways have the lowest comparative inter-modal cost of transporting freight at ₹1.06/TKm as opposed to ₹1.428/TKm for railways and ₹2.625/TKm for roadways, however, when considering the comparative intermodal cost advantage of transporting freight on National Waterway 1 from Haldia to Allahabad, inland waterways have a comparative advantage only over roads at ₹605.93/tonne, with a disadvantage of (-) ₹352.03/tonne versus railways. Lease holders in Uttar Pradesh Ganga districts earned revenue of ₹547,263,143.80/- by dispatching 1,716,849 m3 of sand from an area of 658.21 acre. Fish vendors and traders in Varanasi (n= 53) and Narora (n = 30), respectively, reported an estimated average annual income of ₹168,226.42 (±316,996.52) and ₹355,200 (±280,623.02), respectively. In Varanasi, 44.71% of local businessmen (n=110) reported an average income between ₹35,000/- and ₹134,999/- during tourist season. Vendors (n=136) at Ardh Kumbh Mela 2019 in Prayagraj reported a 210.07% (± 238) increase in daily income during Kumbh.

Any meaningful attempt to rejuvenate the Ganga River will include the engagement of its myriad stakeholders at all levels (Bower et al., 2017). Valuation of the ecosystem services provided by the Ganga River can aid in raising awareness, environmental accounting, setting priorities, assessing liability and designing an implementation strategy (Pascua et al., 2017) for the Ganga River that is just and ensures the sustained provision of these ecosystem services. The framework and evaluation can help identify the benefits and beneficiaries to develop a Payment for Ecosystem Services (PES) model that engages the custodians of the Ganga River in its conservation. The Ganga River ecosystem services interrelate in a 'complex dynamic' manner, with trade-offs and synergies between the services; consequently, river management strategies to ensure sustainable provision of ecosystem services must incorporate an analysis of the impact of any intervention to enhance the supply of one service on the provision of others.

Ecosystem Services of Ganga River
An evaluation of key ecosystem services

1. Introduction

Convention on Biological Diversity (CBD) defines an 'ecosystem' as "a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit". Ecosystem functions and processes provide enumerable direct and indirect benefits that contribute to human wellbeing, collectively termed as 'Ecosystem Services' (CBD, 2008). These "benefits from nature" contribute to the quality of human life and support local and global economies. Any change in the state of ecosystems and the consequent impact on the provision of ecosystem services will impact human wellbeing. The Millennium Ecosystem Assessment (MEA, 2005) categorizes these ecosystem services into four groups, (a) provisioning — products derived from ecosystem, (b) regulating — benefits derived from the regulation of ecosystem processes, (c) supporting — ecosystem services that are necessary for the maintenance of all other ecosystem services, and (d) cultural — non-material benefits obtained from ecosystems (www.teebweb.org) (Table 1). However, in this study, with the main focus on benefits and beneficiaries, we have merged the supporting and regulating services categories.

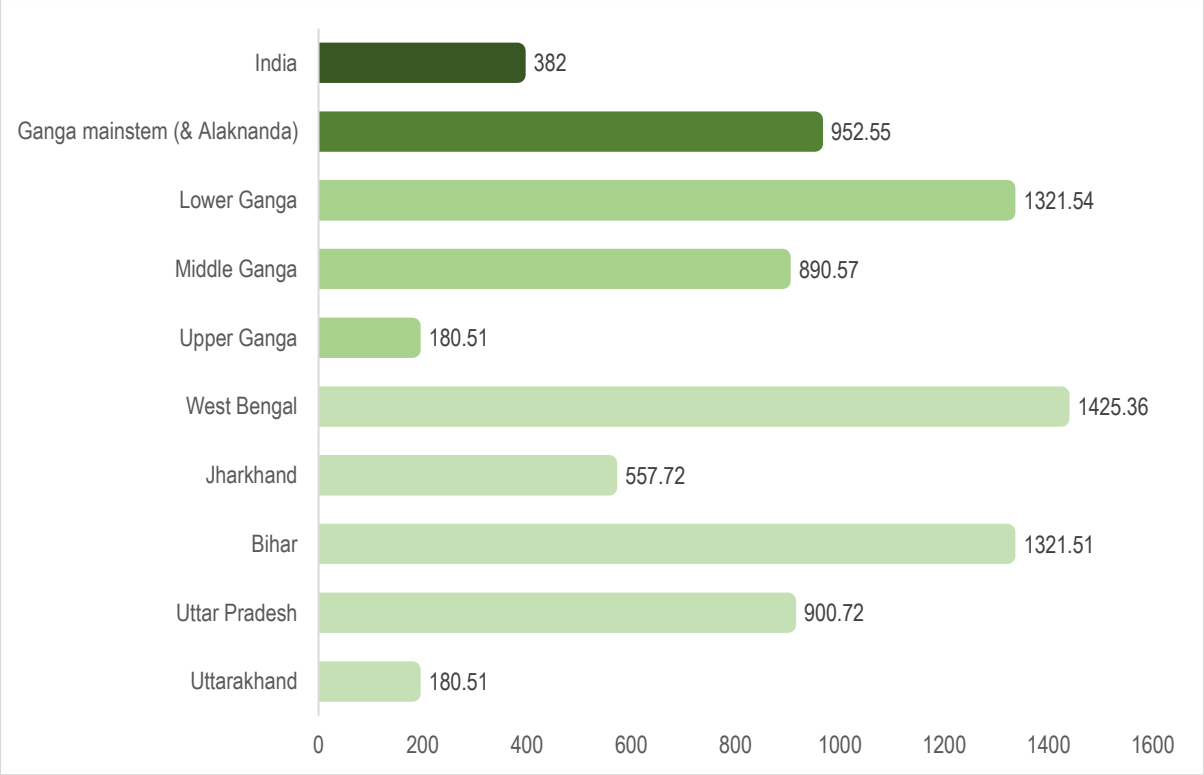
Table 1: Ecosystem Services provided by river ecosystems.

Ecosystem Service Category	Ecosystem Services		
	River Mainstem	Floodplain/ Wetland	Riparian Area
Provisioning	Consumptive use: drinking, domestic, agriculture & industry Non-consumptive use: power generation & navigation/transport Aquatic organisms (fish etc.) Raw (biotic) material Riverbed material (sand, stones etc.)	Consumptive use: drinking, domestic, agriculture & industry Non-consumptive use: power generation & navigation/transport Aquatic organisms (fish etc.) Raw (biotic) material Riverbed material (sand, stones etc.)	Food Raw (biotic) material Raw (abiotic) material (NTFPs etc.) Pest control
Regulating and maintenance (or supporting)	Maintaining Populations & Habitats Water cycling Water purification Nutrient cycling	Maintaining Populations & habitats Water cycling Water purification Nutrient cycling	Climate regulation Carbon storage & sequestration Erosion prevention Flood protection Soil formation Waste treatment Bank stabilization Maintaining Populations & Habitats Pollination Water supply & regulation Water purification Nutrient cycling

Cultural	Recreation Tourism Religious & Spiritual Education	Recreation Tourism Religious & Spiritual Education	Recreation Tourism Religious & Spiritual Education

The Ganga River, along with the Brahmaputra River, drains one of the largest, most diverse and densely populated river basins in the world. From its headwaters at Gaumukh, in the Himalaya, to its mouth at Ganga Sagar, where it flows into the Bay of Bengal, the Ganga River traverses three distinct biogeographic zones, namely, the Himalaya, Gangetic Plains and Coasts, harbouring a unique assemblage of floral and faunal diversity, and is influenced by various anthropogenic factors. The climate in the region is positively influenced by the southwest monsoon (June to October). Characterized by a wide variety of soils, the Ganga River basin is highly erodible due to a high proportion of erodible soils, making the floodplains and banks vulnerable to erosion through run off. One of the most fertile river basins in the world, the floodplains and the natural vegetation in the region has been extensively replaced by croplands. Reflecting the variations in geology, geomorphology, soil type, climate, flora and fauna, and social and economic issues, the main stem of the Ganga River can be divided into three stretches i.e. Upper Ganga (Gaumukh to Haridwar), Middle Ganga (Haridwar to Varanasi) and Lower Ganga (Varanasi to Ganga Sagar) (Table 2) (WII-GACMC, 2018).

The Ganga River provides life sustaining 'ecosystem services' to people residing along its banks. With an estimated population density of 952.55 per square kilometre (census 2011), as against 382 per square kilometre for India, the Ganga River hosts a vast population of diverse stakeholders with varying demands on the river and its resources, be it cultural, religious, social and economic (Figure 1). According to CPCB (2013), $7x10^7$ cusec of Ganga's surface water ($33x10^7$ cusec), and $7x10^7$ cusec of Ganga's annual groundwater potential ($11x10^7$ cusec) is being utilized. The local communities along the river are dependent upon the river for their very survival, be it water for drinking and domestic use or the ability to make a living by fishing, agriculture etc. Ganga has great cultural and religious significance that transcends not only the boundary of its basin but the borders of the country as well (Asanarong et al., 2017).



Source: Census 2011

Figure 1: Population density along the Ganga River mainstem.

Table 2: Description of the three Ganga River stretches.

	UPPER GANGA *Gaumukh to Haridwar* *~ 294 Km*	MIDDLE GANGA *Haridwar to Varanasi* *~ 1082 Km*	LOWER GANGA *Varanasi to Ganga Sagar* *~ 1134 Km*
Geology & Geomorphology	Steep mountainous valleys of the Himalaya A partly confined floodplain Braided channels	Gangetic plain region Piedmont, craton margin & valley interfluve landscape A partly confined floodplain Braided & sinuous channels	Gangetic plain region Distributary-delta system south and east of Farakka Craton margin & valley interfluve landscape A partly confined and confined floodplain Sinuous, braided channels and anabranches
Soil Types	Montane & sub-montane soils	Mainly alluvial soil – *high erodibility*; red soil – *highly erodible*; red and yellow soils and mixed red-and-black soil – *moderately erodible*; deep black, medium black and shallow black soils and lateritic soils – *low erodibility*	Mainly alluvial soil – *high erodibility*; red soil – *highly erodible*; red and yellow soils and mixed red-and-black soil – *moderately erodible*; deep black, medium black and shallow black soils and lateritic soils – *low erodibility*
Climate	**Close to the snow line & receives snowfall** Annual rainfall: 100-250 cm No. of rainy days: 100-150	**Gangetic Plain** Annual rainfall: 60-160cm Avg annual temp: 5°C - 25°C in winter and 20°C - >40°C in summer	**Gangetic Plain** Annual rainfall: 60-160cm Avg annual temp: 5°C - 25°C in winter and 20°C - >40°C in summer

	Avg annual temp: <10°C-20°C		**Sundarban Delta** *High temperatures & humidity (>80%) throughout the year* Annual rainfall: 166.1 cm Daily min. temp in winter varies between 2°C and 4°C, and rises to a max. of ~43°C in March.
Biogeography	**The Himalayas** (West Himalaya – 2B)	**Gangetic Plains** (Upper Gangetic Plain – 7A)	**Gangetic Plains** (Lower Gangetic Plain – 7B) **Coasts** (East Coast – 8B)
Flora	**Alpine scrub** (*Juniperus* sp., *Rhododendron campanulatum*) **Sub-alpine forest** (*Betula utilis*, *Abies spectabilis*, *Abies pindrow*) **Himalayan Dry temperate forest** (*Pinus gerardiana*, *Cedrus deodara*) **Himalayan Moist temperate forest** (*Quercus floribunda*, *Quercus leucotrichophora*) **Sub-tropical pine forest** (*Pinus roxburghii*)	**Tropical Dry deciduous forest** (*Dalbergia sissoo*, *Acacia nilotica*, *Madhuca indica*) **Tropical Moist deciduous forest** (*Shorea robusta*, *Tectona grandis*, *Terminalia arjuna*) *(most of the original vegetation has been converted to cropland)*	**Gangetic Plain** (same as Middle Ganga) **Sundarban Delta** **Swamp-and-littoral-forest type vegetation** (*Heritiera fomes*, *Nypa fruticans*, *Rhizophora apiculata*)
Fauna	**Representative terrestrial fauna:** Snow leopard, Himalayan tahr, Musk deer, Himalayan black bear **Representative aquatic fauna:** Golden mahseer, Snow trout, Mahseer, Eurasian otter, Smooth-coated otter **Avifauna:** Himalayan monal	**Representative terrestrial fauna:** Chital, Sambar **Representative aquatic fauna:** Gangetic river dolphin, Smooth-coated otter, Gharial, Mugger **Avifauna:** Sarus crane, Indian Skimmer	**Gangetic Plain** (same as Middle Ganga) **Sundarban Delta** **Representative terrestrial fauna:** Royal Bengal tiger, Barking deer, Leopard cat, Fishing cat **Representative aquatic fauna:** Northern river terrapin, Estuarine crocodile, Indian flapshell turtle, Indian soft-shelled turtle **Avifauna:** Lesser adjutant stork
Demography	**Population[1]:** 58,57,294 **Population Density[1]:** 180.51 per km^2 **Major cities:** Srinagar, Rishikesh, Haridwar	**Population[1]:** 6,99,96,324 **Population Density[1]:** 890.57 per km^2 **Major cities:** Bijnor, Kanauj, Kanpur, Unnao, Prayagraj, Mirzapur, Varanasi	**Population[1]:** 10,71,71,237 **Population Density[1]:** 1,321.54 per km^2 **Major cities:** Ballia, Patna, Bhagalpur, Sahibganj, Farakka, Berhampur, Serampore, Howrah, Kolkata
Land use/ Development	Run of the River and Run of the River with Pondage hydroelectric projects (nine HEPs)	A substantial portion of the river water is diverted to support agricultural activities through a system of canals *(Upper Ganga Canal, Eastern Ganga Canal,*	Farraka barrage The 'Jal Marg Vikas Project' (JMVP) on the National Waterway (NW) 1 (from Prayagraj to Haldia ~1620 km)

	Inundation & diversion of Bhagirathi & Alaknanda Rivers	*Madhya Ganga Canal, Lower Ganga Canal, Parallel Lower Ganga Canal)* Construction Sand mining Biological resource extraction	Agricultural activities Construction Sand mining Biological resource extraction
Water Quality[2]	**pH:** 6.6 to 8.5 *(8.05-8.79)* **DO:** decreasing trend, from 9.2 to 8.0 mg/L *(9.3 ± 0.3 mg/L)* **BOD:** increasing trend, from 1.3 to 1.9 mg/L **Nitrate concentration:** 2.2 ± 0.2 mg/L	**pH:** 7.3 to 8.8 *(7.4-8.8)* **DO:** increasing trend, from 7.4 to 7.9 mg/L *(7.5 ± 0.2 mg/L)* **BOD:** decreasing trend, from 4.31 to 3.2 mg/L *(higher than the permissible limit – 3 mg/L)* **Nitrate concentration:** 1.6 ± 0.2 mg/L	**pH:** 7.3 to 8.8 *(7.4-8.5)* **DO:** increasing trend, from 7.2 to 7.5 mg/L *(6.2 ± 0.1 mg/L)* **BOD:** decreasing trend, from 2.4 to 2.8 mg/L **Nitrate concentration:** 4.3 ± 0.5 mg/L

[1]estimates based upon the population of the districts along the Ganga River using 2011 census data.

[2] pH, DO and BOD estimates are sourced from the assessment carried out by CPCB between 2003 and 2014; the pH and DO estimates in brackets and the Nitrate concentration estimates are based upon the study carried out by WII in 2017.

Source: WII-GACMC (2018).

The current resource use/river management scenario is not only inequitable and unjust; but the increasing anthropogenic pressures, and planned and unplanned development of and along the Ganga River is degrading the river ecosystem and its ability to provide vital ecosystem services. Generally, policy decisions undertaken do not account for ecosystem services due to lack of documentation of quantified values. The evaluation of the ecosystem services, in both functional and monetary terms, will play a significant role in the decision-making processes pertaining to the management of Ganga River and its resources.

2. Aim

To identify and evaluate the ecosystem services provided by the Ganga River mainstem.

3. Objectives of the study

(i) To identify the key ecosystem services provided by the Ganga River.
(ii) To develop a framework for assessing the ecosystem services of Ganga River.
(iii) To evaluate select ecosystem services provided by the Ganga River at select sites.
(iv) To develop a payment for ecosystem services model to integrate ecosystem service value of Ganga in policy making

4. Methodology

4.1 Identification of key ecosystem services

Evaluating all the ecosystem services of a river as long and diverse as the Ganga is a cumbersome task requiring vast resources — financial, human and time; hence, a framework was designed for their valuation that not only accounts for the resource constraints but also the relevance of the ecosystem services provided, considering the vast and diverse population that resides along the Ganga River. Given the distinctions in the three segments of the river, the ecosystem services provided by them will differ in extent; therefore, the identification of key ecosystem services provided by the Ganga River was carried out stretch-wise by conducting an extensive literature review, and reconnaissance and field survey. Ecosystem services were selected for valuation based upon three factors, (a) the perception of various

stakeholders regarding their contribution to human wellbeing and livelihood, (b) the extent and importance of services provided, and (c) the resource *viz.* cost, time and human capital, requirement of conducting an evaluation, gauged by conducting a literature review and discussion with experts (Figure 2, Annexure 5.1).

Stakeholder groups were identified and prioritised for survey, based upon their influence and dependency, via an extensive literature review and snowball technique. The opportunistic sampling technique was used to conduct a semi-structured questionnaire-based survey of the stakeholders. The extent and importance of ecosystem services provided by Ganga River was assessed by conducting an extensive literature review, surveying the river, and conducting meetings with representatives of various stakeholder groups and local communities.

4.2 Valuation of key ecosystem services

By exploring the type of values to be elicited for each selected ecosystem service, using the Total Economic Value (TEV) framework, the available literature was reviewed to identify the valuation techniques. The TEV framework is widely used framework for valuing ecosystem services that examines the utilitarian value of ecosystems disaggregates into two categories, namely, use values and non-use values (Table 3, Figure 3) (Abson et al., 2011). Use value is associated with the direct or indirect consumption of the benefits derived; non-use value is derived from the knowledge that the resource exists; while option value is the value placed on the option of utilizing a resource in future (Fisher et al., 2009; De Groot et al., 2010).

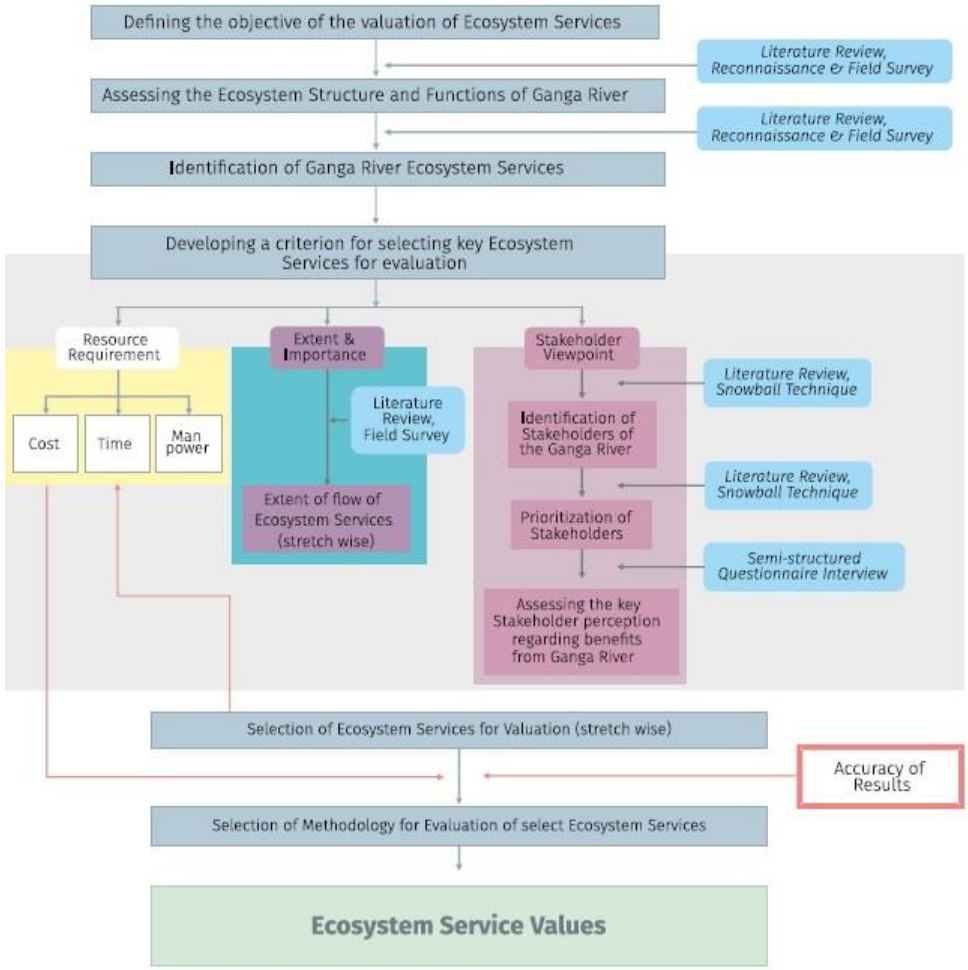
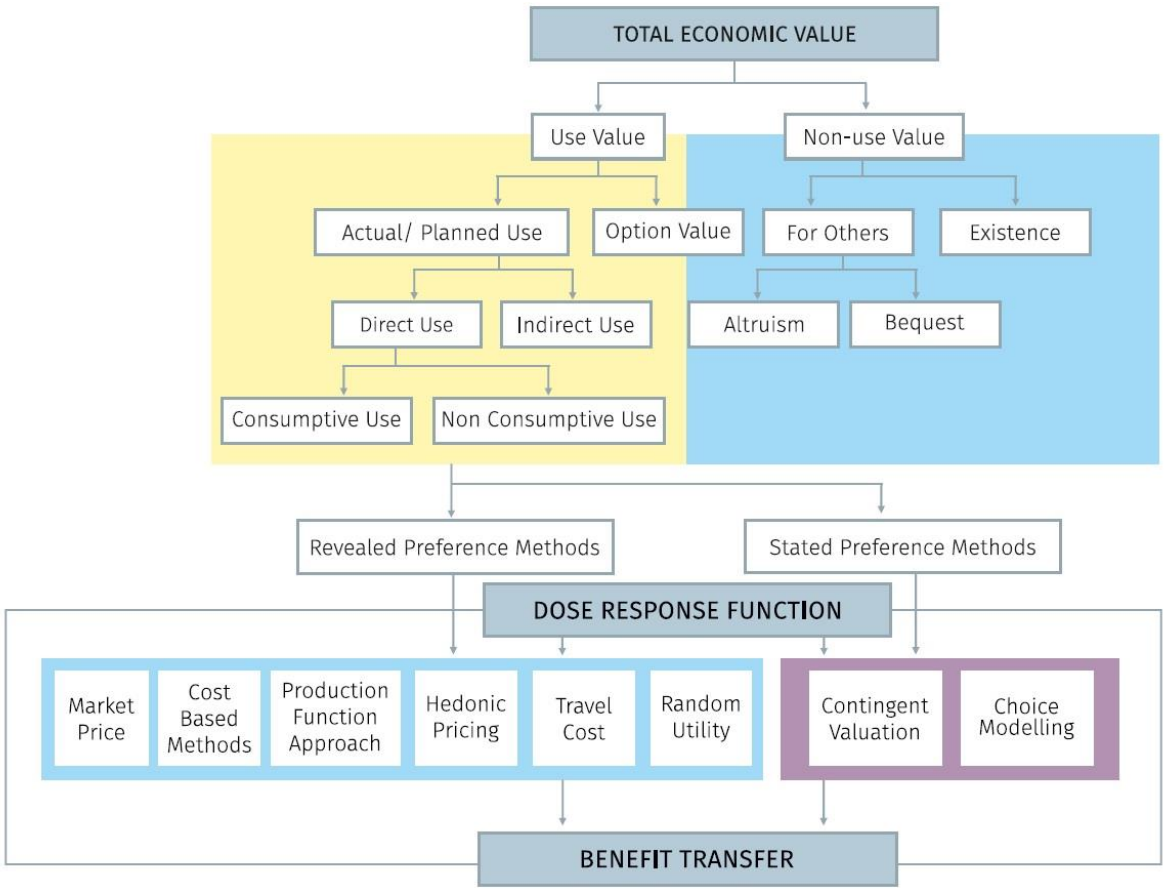


Figure 2: Framework for the evaluation of Ganga River ecosystem services.

Table 3: Classification of values arising from different ecosystem service categories.

Ecosystem Service Categories	Direct Use Value	Indirect Use Value	Option Value	Non-use Value
Provisioning Services	✓		✓	
Regulating Services		✓	✓	
Cultural Services	✓		✓	✓
Supporting Services	*Valued through other Ecosystem Services*			

Source: DEFRA (2007)



Source: DEFRA (2007).

Figure 3: Ecosystem service valuation through the Total Economic Value framework.

The resource requirements for executing the methods and the accuracy of results generated was examined and the most resource efficient standardised method for conducting an economic appraisal was used (Figure 1). Sites for valuation were selected by conducting a reconnaissance survey. Secondary data was collected from the concerned departments and their websites, peer reviewed journals and grey literature; this was supplemented by primary data collection at select sites.

5. Results

5.1 Stakeholder Perception Assessment

A total of 30 stakeholder groups were identified with respect to the ecosystem services provided by the Ganga (Table 4). For the survey, based on the resource use pattern along the Ganga River, interviews were conducted with representatives belonging to the following sectors: Agriculture, Horticulture, Animal Husbandry, Fisheries, Industry, Mining, Human Resource Development, Public Utilities, Conservation and Academia. The respondents primarily belonged to Government departments, directorates, line agencies, Non-Governmental Organizations (national and international), public administration, Industries, Research institutes, and Colleges and Universities.

Table 4: Stakeholders of the ecosystem services provided by the Ganga River

1. International funding agencies	14. Village institutions
2. International Scientific Community	15. Local communities
3. International Conventions	16. Farmers
4. International organisations with ongoing projects along the Ganga	17. Riverine fishing community & societies
	18. Sand miners
5. National Ganga River Basin Authority (NGRBA)	19. Wetland users
6. National Mission for Clean Ganga	20. Industrial Sector
7. Central Government Ministries, Departments & Agencies	21. Real Estate Sector
	22. Tourism Sector
8. State Project Management Group, NGRBA	23. Water Development Sector
9. Uttarakhand, Uttar Pradesh, Bihar, Jharkhand and West Bengal State Government Departments, & Directorates	24. Agribusiness sector
	25. Religious institutions
	26. Non-Governmental Organisations
10. Line Agencies	27. Media
11. Nuclear Power Cooperation of India Ltd. (NPCIL)	28. Researchers
12. Narora Atomic Power Station (NAPS)	29. Protected areas
13. Political actors (legislators, ministers etc.)	30. Common interested mass

A total of 503 respondents were surveyed along the Ganga River — 175 in Upper Ganga, 131 in Middle Ganga and 197 in Lower Ganga. In the Upper Ganga Stretch, water for drinking was the most cited ecosystem service (60.90% of the respondents), followed by water for irrigation (56.41%) and religious/spiritual services (44.87%). In the Middle Ganga Stretch, water for irrigation was the most cited ecosystem service (55.91% of the respondents), followed by religious/spiritual services (39.37%), and water cycle and water for drinking (28.35%). In the Lower Ganga Stretch, water for irrigation was the most cited ecosystem service (65.48% of the respondents), followed by provision of fish (50.60%), and water for drinking and religious/spiritual services (48.21%). 10.90%, 23.62% and 26.19% of the respondents in the Upper, Middle and Lower Ganga, respectively, mentioned that the Ganga River maintains population and habitat for diverse floral and faunal species (Figure 4a).

The respondents were also asked to rank the ecosystem services along a scale of '1 to 4', based on their perceived level of importance, with 'Rank 1' indicating 'very important'. In the upper stretch, water for drinking was assigned rank 1 by 68.39% of the respondents, closely followed by water for irrigation (62.07%) and water purification and waste management (60.34%); maintaining population and habitat was assigned Rank 1 by 35.63% of the respondents and 40.23% of the respondents did not give it any rank. In the middle stretch, 71.65% of the respondents assigned religious services Rank 1, followed by water for irrigation (70.08%) and provision of fish (66.93%); maintaining population and habitat was assigned Rank 1 by 44.09% of the respondents. In the lower stretch, water for drinking was given Rank 1 by 60.74% of the respondents, followed by water for irrigation (55.71%) and maintaining population and habitat (49.08%) (Figure 4b).

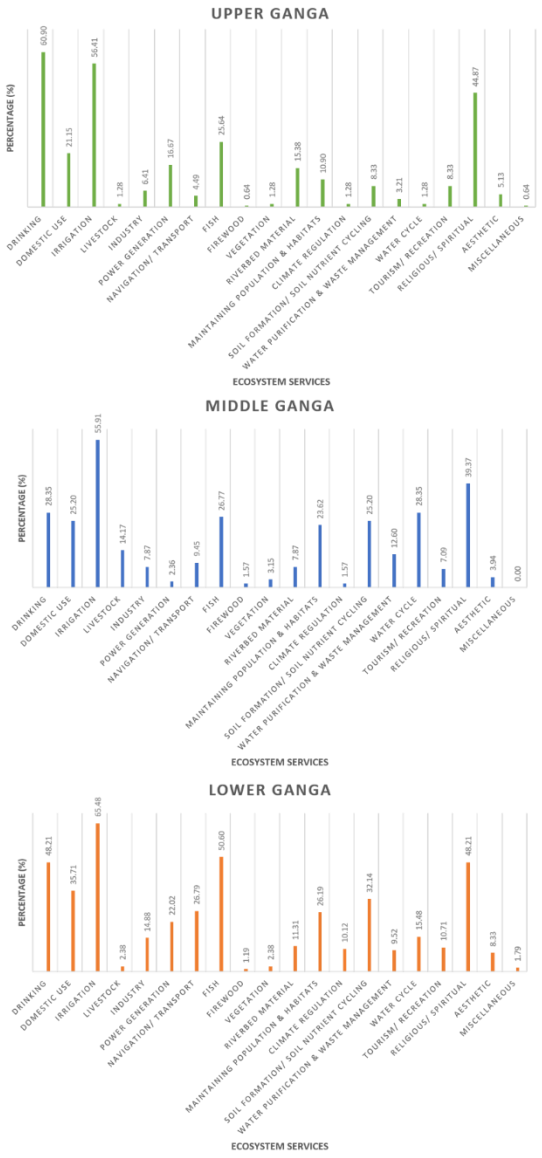


Figure 4a: Ecosystem services cited by stakeholders from Upper, Middle and Lower Ganga stretches.

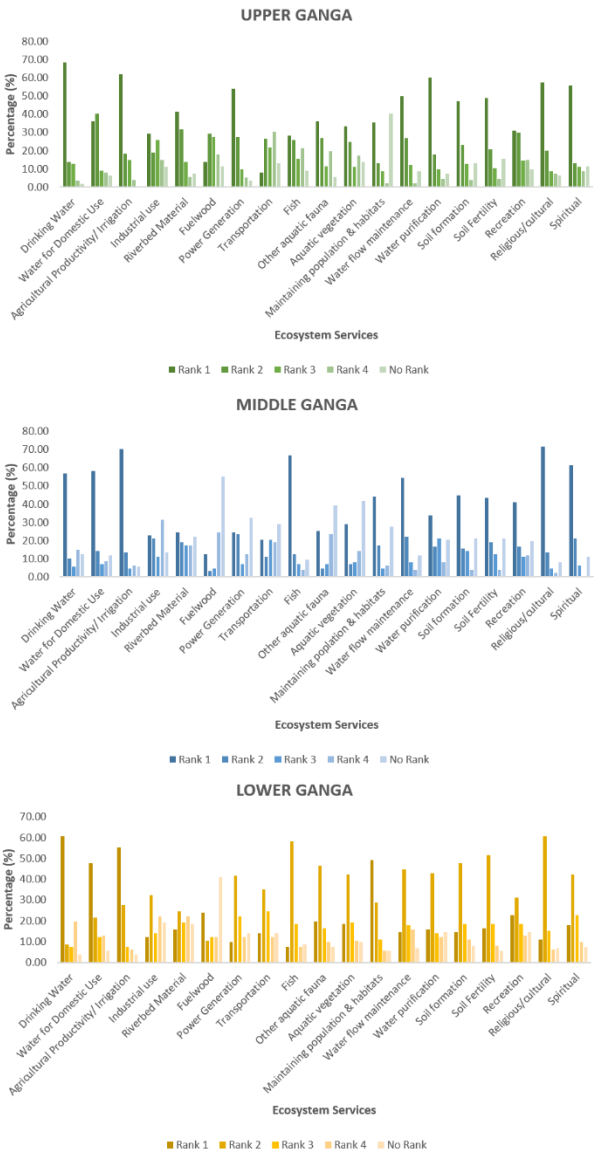


Figure 4b: Extent of the ecosystem services provided by the Ganga River as perceived by stakeholders from Upper, Middle and Lower Ganga stretches.

5.2 Ecosystem Service Extent Assessment

After assessing the Ganga River ecosystem and its functions, 22 key ecosystem services were identified — 11 provisioning services, seven regulating and supporting services, and four cultural services (Table 5). The extent and importance of provisioning services was primarily high only for the middle and lower stretch; except for power generation, which was high for the upper stretch due to the potential hydroelectric power generation. For cultural services, the extent and importance is high for all the three stretches.

Table 5: Ecosystem services provided by Ganga River and their extent.

Ecosystem Services	Upper Ganga	Middle Ganga	Lower Ganga
Provisioning Services			
Consumptive use of water			
Drinking	•	●	●
Domestic use	●	●	●
Agriculture (irrigation)	•	●	●
Livestock (drinking, bathing etc.)	•	●	●
Industry	•	●	●
Non-consumptive use of water			
Power generation (hydro, nuclear and thermal)	●	•	•
Transportation	○	●	●
Resource Material			
Fish and other aquatic fauna for food	●	●	●
Fuelwood	•	•	●
Riverine vegetation for multiple uses	•	•	•
Riverbed material	●	●	●
Regulating & Supporting Services			
Maintaining population & habitat	●	●	●
Regulation of micro climate	●	●	●
Soil fertility	•	●	●
Soil formation (sediment deposition)	○	●	●
Water purification and waste management	●	•	•
Water cycle	•	•	•
Storm protection (through mangroves)	○	○	●
Cultural Services			
Tourism	●	●	●
Religious/Spiritual	●	●	●
Aesthetic	●	●	●
Heritage sites	●	●	●

Ecosystem Services: ○ → none; • → little/sometimes; ● → medium; ● → large

5.3 Ecosystem Service Evaluation

Of the 22 key ecosystem services identified, water for drinking and domestic use and power generation, benefits to agriculture (water for irrigation and soil fertility), riverbed material, provision of fish, water for transportation, recreational and religious/spiritual services, were selected for valuation (Table 6).

Table 6: Methodology adopted for evaluating the key ecosystem services at select sites.

Ecosystem Service	Study Site	Methodology
Water for drinking and domestic use	Upper Ganga *(Srinagar, Uttarkashi, Haridwar)* Middle Ganga *(Meerut, Kanpur, Mirzapur, Varanasi)* Lower Ganga *(Patna Urban Area, Bhagalpur, Kolkata Municipal Corporation)*	Benefit Transfer* *Data: Secondary data from Government departments/reports; peer reviewed literature*
Benefits to agriculture (water for irrigation and soil fertility)	Lower Ganga *(Bihar)*	Market Price *Data: Secondary data from Government departments/reports*
Water for power generation *(Hydro, Nuclear & Thermal)*	Ganga River mainstem & Alaknanda	Benefit Transfer* *Data: Secondary data from Government departments/reports; peer reviewed literature*
Water for transportation	Middle & Lower Ganga *(National Waterway 1 — Prayagraj to Haldia)*	Avoided Cost *Data: Secondary data from Government departments/reports*
Riverbed material	Middle Ganga *(Uttar Pradesh)*	Market Price *Data: Secondary data from Government departments*
Provision of fish	Middle Ganga *(Varanasi, Narora)*	Market Survey *Data: semi-structured questionnaire-based interview survey*
Recreational/ religious/ spiritual services	Middle Ganga *(Varanasi, Prayagraj)*	Market Survey *Data: semi-structured questionnaire-based interview survey*

**The methodology adopted was changed from 'Market Price' to 'Benefit Transfer' since the pricing policy did not adequately measure the value of the ecosystem service/good*

Note: Data sources have been listed in Appendix 1.

5.3.1 Water for drinking and domestic use

The Ganga River is an important source of water for drinking, bathing, washing clothes and other domestic chores. There are 54 'Class-I' cities and 30 'Class-II' towns situated along the river, within 10 km from its banks (Table 7).

Table 7: Class-I cities and Class-II towns situated along the Ganga River.

State	Number of Districts	Class - Cities	Class-II Towns
Uttarakhand	7	Haridwar **(1)**	Rishikesh **(1)**
Uttar Pradesh	27	Kanpur, Varanasi, Prayagraj, Farrukhabad – cum – Fatehgarh, Mirzapur – cum – Vindhyachal, Ghazipur, Mughalsarai, Ballia **(8)**	Bijnor, Kannauj, Gangaghat, Sahaswan, Gajraula **(5)**
Bihar	12	Patna, Bhagalpur, Begusarai, Munger, Chhapra, Dinapur Nizamat, Hajipur, Jamalpur, Buxar **(9)**	Phulwari Sharif, Barauni, Bihat, Barh, Mokameh, Teghra, Sultanganj, Fatwah **(8)**
Jharkhand	1	*—None—*	Sahibganj **(1)**
West Bengal	10	Kolkata, Howrah, Maheshtala, South Dum Dum, Rajarhat Gopalpur, Bhatpara, Panihati, Kamarhati, North Dum Dum, Baranagar, Uluberia, Naihati, Bidhannagar, Haldia, Madhyamgram, Berhampore, Serampore, Hugli-Chinsurah, Chandannagar, Uttarpara Kotrung, Barrackpore, Santipur, North Barrackpore, Kanchrapara, Nabadwip, Halisahar, Rishra, Baidyabati, Titagarh, Dum Dum, Bally, Champdani, Khardaha, Bansberia, Bhadreswar, Kalyani **(36)**	Dhuliyan, Chakdaha, Dankuni, Jangipur, Garulia, Katwa, New Barrackpore, Budge Budge, Konnagar, Ranaghat, Tamluk, Gayeshpur, Kalna, Phulia, Jiaganj-Azimganj **(15)**
Ganga Mainstem (& Alaknanda)	**57**	**54**	**30**

The water supply system of 10 urban centres along the Ganga River, namely, Srinagar, Uttarkashi, Haridwar, Meerut, Kanpur, Mirzapur, Varanasi, Patna Urban Area, Bhagalpur and Kolkata Municipal Corporation (area serviced by Palta WTP and Garden Reach WTP), including Joka in Southwest Kolkata (area serviced by Raipur WTP), Anandapur and Patuli areas in Eastern Kolkata (area serviced by Jai Hind WTP), was examined. It was noted 1574.29 MLD surface water and 1008.675 MLD ground water is being withdrawn daily to meet the demands of the population (Figure 5). A study by Venkatachalam (2014), estimated the willingness to pay of urban poor for improved water supply in Chennai, Tamil Nadu at ₹ 370.12 per month; based on this estimate, the water extracted is valued at ₹51.79 million and ₹33.19 million, assuming constant utility per unit of consumption.

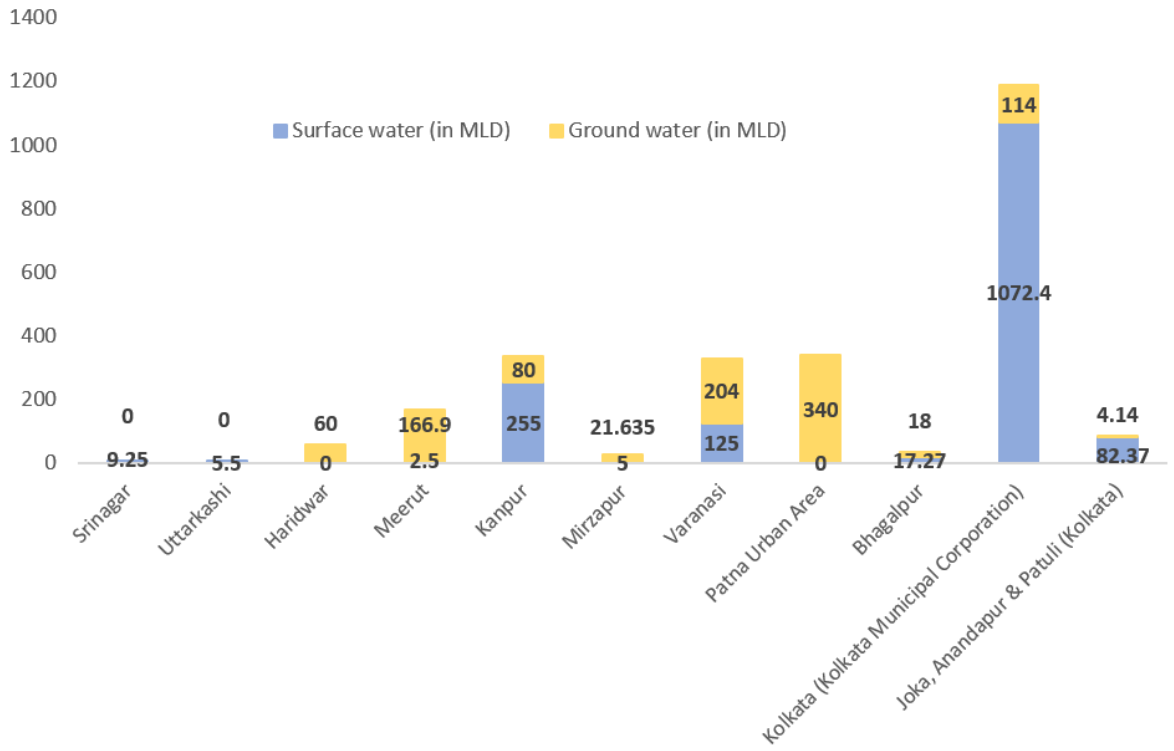


Figure 5: Surface and ground water supply of ten urban centres along Ganga River.

5.3.2 Benefits to Agriculture (water for irrigation & soil fertility)

Ganga and its tributaries drain a large flat and fertile plain in North India, irrigating millions of acres of agricultural fields along the river banks with 64.14% of area under agriculture (Table 8). There are five major canal systems in the middle reaches of the Ganga with a total head discharge of 40,636 cusec and a Cultivable Command Area 2,708,123 ha (Table 9). Eutric Cambisols, among the most productive soils on earth (FAO), covers 34.03% of the area in the five Ganga states (Figure 6). The Ganga states have a total cropped area of 45,955,000 ha (averaged over 2012-13, 2013-14, 2014-15), which comprises of 82.5% of the total geographical area of these states. There are an estimated 34,799,700 agricultural households (June 2012-July 2013) in the five Ganga states, which is 60.28 % of the estimated 57,731,200 rural households (Figure 7). In Bihar, agricultural/cultivable/culturable/arable land accounts for 69.88% of the geographical area with a cropping intensity of 144.6. The districts along the Ganga River in Bihar support 2,059,792 cultivators, which account for 16.03% of the cultivators in the Ganga districts, who earned on an average, between 2012-13 and 2017-18 (t=6 years), an estimated ₹107,614.34 million (±14,766.95 million), ₹82,736.06 million (±19,120.29 million) and ₹29,241.54 million (±5,018.29 million) from the cultivation of paddy, wheat and sugarcane, respectively (at MSP) (Table 11, Table 12). The percentage share of agriculture (crop and livestock) in total Gross State Value Added (GSVA) at current prices (2011-12 series) of Bihar for the year 2017-18 is 18.85%, which is higher than the percentage share of agriculture (crop and livestock) in GSVA of India at 14.90% (Table 13). It was reported by the farmers in Bhagalpur, Bihar that the occasional floods helped reduce the cost of cultivation due to the nutrients replenished by flood waters.

Table 8: Area under different Land Use Land Cover categories in the Ganga River basin.

SN	Land Use Land Cover category	(%)
1.	Built up	4.46
2.	Agriculture	64.14
3.	Forest	19.6
4.	Wasteland	7.68
5.	Water	3.75
6.	Snow	0.37

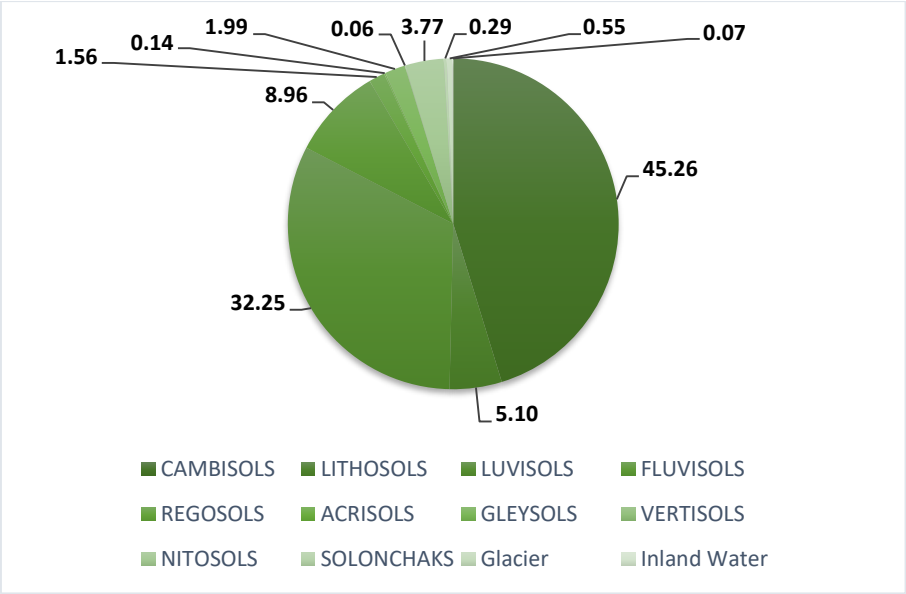
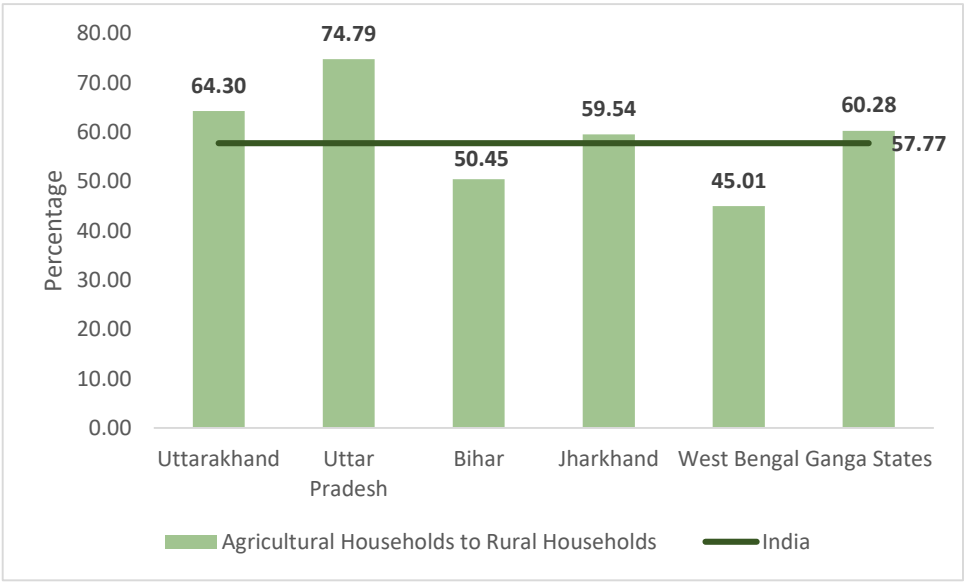


Figure 6: Percentage area under different soil categories in the five Ganga states.



Source: Department of Agriculture, Cooperation & Farmers Welfare (2019). Agricultural Statistics at a Glance 2018. Government of India.

Figure 7: Percentage of estimated number of agricultural households to rural households in the Ganga River states, June 2012-July 2013.

Table 9: Description of the major canal systems in Middle Ganga.

Canal System	Headwork	Length of Main Canal (km)	Length of distribution system (km)	Cultivable Command Area (ha)	Head discharge (cusec)	Major branches	Districts	Proposed cultivation (ha)	
Upper Ganga Canal *(1854)*	Bhimgoda Barrage, Haridwar	291.964	6290.275	907,690	10,500	Devband Branch Anupshahar Branch Matth Branch Hathras Branch	Haridwar, Saharanpur, Muzaffarnagar, Meerut, Ghaziabad, Hapur, Bulandshahr, Gautam Buddh Nagar, Aligarh, Hathras, Mathura, Etah, Firozabad	Kharif	429,612
								Rabi	404,353
Eastern Ganga Canal *(1992)*	Bhimgoda Barrage, Haridwar	48.55	1367.52	233,000	4,850	Chank Branch Najibabad Branch Nagina Branch Nahtor Branch Alawalpur Branch	Bijnor and Moradabad (between Kho River and Ramganga Feeder Canal of Ganga River)	Grains	105,000
Middle Ganga Canal *(1994)*	Chaudhary Charan Singh Madhya Ganga Barrage, Bijnor	116.45	1297.43	178,000	8,280	Lakhavati Canal Mott Branch feeder	114,000 hectares of CCA of the Upper Ganga Canal System; 64,000 via a new canal system Ghaziabad, Bulandshahr and Aligarh districts)	Kharif	178,000
Middle Ganga Canal (Phase-II)		66.20	1653	225,433	4,306	Bhazai Branch Chandausi Branch	Amroha, Moradabad and Sambhal	Grain	78,802
								Other Kharif	67,630
Lower Ganga Canal *(1878)*	Narora Barrage, Bulandshahr	98.8	8278	1,164,000	8,500	Farrukhabad Branch Bwear Branch Kanpur Branch Etawah Branch Bhognipur Branch	Etah, Kasganj, Mainpuri, Firozabad, Farrukhabad, Kannauj, Etawah, Auraiya, Kanpur Dehat, Kanpur Nagar, Fatehpur and Kaushambhi.	Kharif	41.5 %
Parallel Lower Ganga Canal *(1982)*		89			4,200			Rabi	36 %

Source: Irrigation and Water Resources Department, Government of Uttar Pradesh

Table 10: Average agricultural land by type of use (in '000 ha) in Ganga River states (2012-13 to 2014-15).

State	Geographical Area	Reporting area for land utilisation statistics	Forest	Land not available for cultivation	Other uncultivated land excluding Fallow Land	*Permanent pastures & other grazing lands*	*Land under Misc. tree crops & groves not incl. in net area sown*	*Culturable waste land*	Fallow Land	*Fallow lands other than current fallows*	*Current fallows*	Net area sown	Total cropped area	Agri. Land/ Cultivable Land/ Culturable land/ Arable land	Cropping Intensity
Uttarakhand	5348	5886	3695	450	897	192	389	316	141	86	55	702	1107	1549	157.6
Uttar Pradesh	24093	24170	1658	3457	805	65	327	413	1681	528	1153	16569	25955	18990	156.6
Bihar	9416	9360	622	2143	308	15	247	45	977	120	856	5311	7677	6580	144.6
Jharkhand	7972	7970	2239	1276	565	114	99	352	2498	1074	1424	1392	1628	4341	117.0
West Bengal	8875	8684	1174	1844	71	2	49	20	369	13	356	5226	9589	5663	183.5
Ganga States	***55704***	***56070***	***9388***	***9170***	***2647***	***389***	***1111***	***1145***	***5666***	***1822***	***3843***	***29200***	***45955***	***37122***	***157.4***
India	**328726**	**307702**	**71732**	**43773**	**25915**	**10257**	**3158**	**12500**	**25785**	**10941**	**14844**	**140498**	**197852**	**181940**	**140.8**

Source: Department of Agriculture, Cooperation & Farmers Welfare (2019). Agricultural Statistics at a Glance 2018, Government of India.

Table 11: Workers under different categories in the districts along the Ganga River.

State	Total workers (main + marginal)	Cultivators		Agricultural labourers		Household industry workers		Other workers	
		No.	%	No.	%	No.	%	No.	%
Uttarakhand	2359249	831326	35.24	177319	7.52	71906	3.05	1278698	54.20
Uttar Pradesh	25558289	7214226	28.23	7205104	28.19	1611957	6.31	9525903	37.27
Bihar	10935991	2059792	18.83	5253134	48.04	476691	4.36	3146374	28.77
Jharkhand	490202	109975	22.43	206902	42.21	43179	8.81	130146	26.55
West Bengal	23096505	2632083	11.40	5802704	25.12	1949984	8.44	11711734	50.71
Ganga Mainstem	**62440236**	**12847402**	**20.58**	**18645163**	**29.86**	**4153717**	**6.65**	**25792855**	**41.31**

Source: Department of Agriculture, Cooperation & Farmers Welfare (2019). Agricultural Statistics at a Glance 2018, Government of India.

Table 12: Average revenue earned by cultivators in Bihar Ganga districts, between 2012-13 and 2017-18.

SN	Crop	Revenue (₹ million)	
		Mean	Standard deviation
1	Total Rice	107614.34	14766.95
2	Wheat	82736.06	19120.29
3	Jowar	28.05	7.92
4	Bajra	54.11	11.33
5	Maize	38869.32	8138.06
6	Gram	2376.06	426.41
7	Tur	1596.04	198.13
8	Lentil	5374.88	728.24
9	Groundnut	29.46	8.26
10	Rapeseed & Mustard	3554.03	473.91
11	Sunflower	546.38	191.03
12	Sugarcane	29241.54	5018.29
13	Jute and Mesta	7688.99	827.85

Table 13: Share of Agriculture & Allied Sector in Gross State Value Added at current prices (2011-12 series) (₹ in Lakh).

State	Total GSVA		GSVA from Agriculture & Allied		% Share of Agriculture & Allied in Total GSVA		GSVA from Agriculture (Crop and Livestock)		% Share of Agriculture (Crop and Livestock) in Total GSVA	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Uttarakhand	17558135	19410404	1709505	1826884	9.74	9.41	1371893	1465519	7.81	7.55
Uttar Pradesh	115753009	126802899	29664900	32591371	25.63	25.70	27783730	30576635	24.00	24.11
Bihar	41450241	46753524	9839545	10391254	23.74	22.23	8484592	8814265	20.47	18.85
Jharkhand	20862770	22833819	3863940	4325710	18.52	18.94	2939721	3238235	14.09	14.18
West Bengal	82656625	95899924	19452043	22460294	23.53	23.42	15802682	18348653	19.12	19.13
Ganga States	278280780	311700570	64529933	71595513	23.19	22.97	56382618	62443307	20.26	20.03
India (₹ crore)	**13935917**	**15482715**	**2496358**	**2670147**	**17.9**	**17.2**	**2149097**	**2305225**	**15.7**	**14.9**

Source: Department of Agriculture, Cooperation & Farmers Welfare (2019). Agricultural Statistics at a Glance 2018, Government of India.

5.3.3 Power Generation (hydro, nuclear, thermal)

In the upper stretch, Ganga River flows on a steep and narrow bed, made of mostly rocks and boulders, and is considered to have tremendous potential for harnessing hydropower. There are currently nine commissioned hydro power plants (HEP) (> 1MW) in the Ganga and Alaknanda mainstem in Uttarakhand, with an estimated potential of 2,777.30 MW and annual generation of 10,441.54 million units (Figure 8). Additionally, there are nuclear and thermal power plants that draw water from the river for the cooling systems, in the middle and lower stretch. The Narora Atomic Power Station (NAPS) with an estimated potential of 440 MW, generated on an average 3,402.50 (± 194.80) million units, annually between 2015-16 and 2018-19. There are currently 17 commissioned thermal power stations, 14 coal and three gas powered, with an estimated potential of 14,091.40 MW (Figure 8). Based on the study by Gagnon et al. (2002) and considering coal burning thermal power plants as the alternative, the nine HEPs and NAPS prevented the emission of an estimated 9.93 million tCO^2 and 3.22 (± 0.18) million tCO^2, respectively, annually (Figure 9, Table 14).

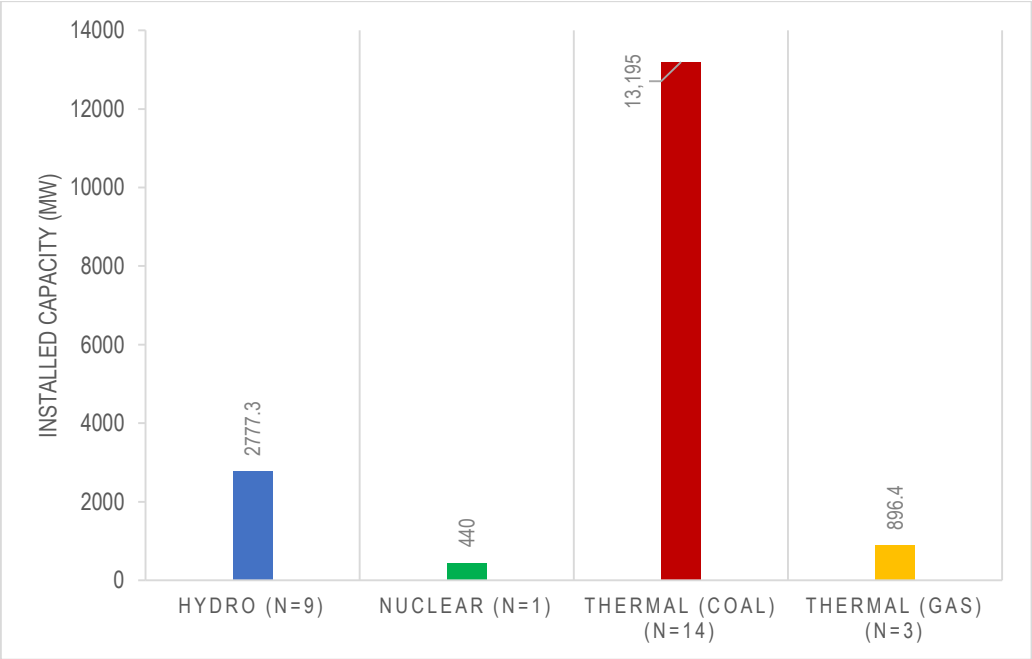


Figure 8: Installed capacity along the Ganga River mainstem and Alaknanda.

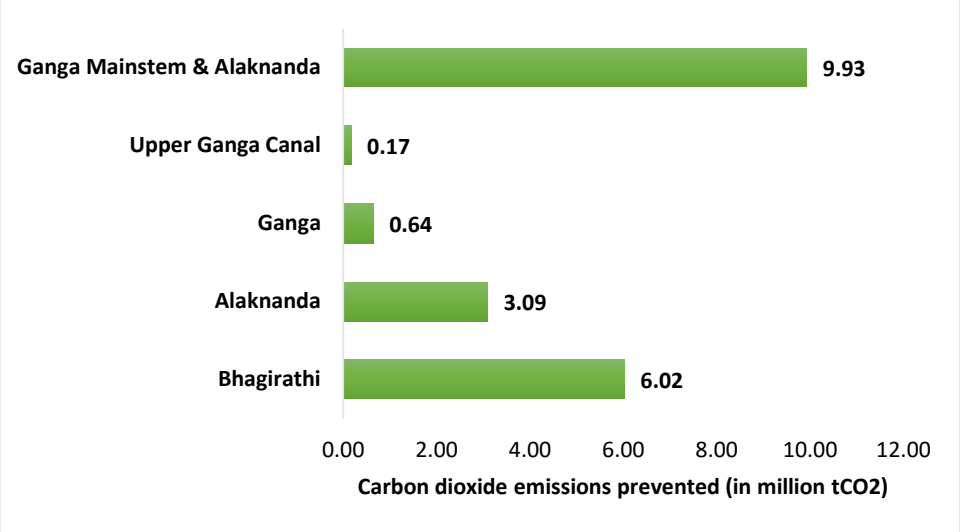


Figure 9: Emission of Carbon dioxide (in million tCO^2) prevented by the commissioned hydropower plants along Ganga mainstem and Alaknanda.

Table 14: Carbon dioxide (in million tCO^2) emissions prevented by commissioned hydropower power plants in Upper Ganga and nuclear power plant in Lower Ganga.

SN	Power Plant	River	Type	Installed Capacity (MW)	Annual Generation (MU)	Carbon dioxide saved	
						million tCO^2	USD million
Hydropower Plants							
1.	Tehri Stage I (2006)	Bhagirathi	Storage	1000	3497	3.30	284.20
2.	Koteshwar (2011)	Bhagirathi	Storage	400	1209	1.14	98.26
3.	Maneri Bhali – I (Tiloth) (1984)	Bhagirathi	Run-of-River	90	78.84	0.08	6.50
4.	Maneri Bhali – II (2008)	Bhagirathi	Run-of-River	304	1566.1	1.50	129.03
5.	Vishnuprayag (2006)	Alaknanda	Run-of-River	480	2060.5	1.97	169.76
6.	Srinagar (2015)	Alaknanda	Storage	330	1182.28	1.12	96.08
7.	Chilla (1980)	Ganga	Run-of-River	144	671.29	0.64	55.31
8.	Pathari (1955)	Upper Ganga Canal	Dam on canal	20	122.93	0.12	10.13
9.	Mohamadpur (1950)	Upper Ganga Canal	Dam on canal	9.3	53.6	0.05	4.42
TOTAL				**2777.3**	**10,441.54**	**9.93**	**853.67**

Nuclear Power Plant							
10.	Narora Atomic Power Station	Ganga		440	3402.50 (± 194.80)	3.22 (± 0.18)	276.52
TOTAL				**440**	**3402.50 (± 194.80)**	**3.22 (± 0.18)**	**276.52**

5.3.4 Inland Water Transportation

There are currently six operational and seven feasible national waterways in the Ganga river system with an approximate length of 3,222 km and 3,318 km, respectively, and covering the states of Uttar Pradesh, Bihar, Jharkhand, West Bengal, Haryana, Delhi (Table 15). Inland waterways have the lowest comparative inter-modal cost of transporting freight at ₹1.06/TKm as opposed to ₹1.428/TKm for railways and ₹2.625/TKm for roadways (Table 16). However, the comparative intermodal cost advantage of transporting freight on National Waterway 1, from Haldia to Prayagraj, is ₹605.93/tonne versus roads and (-) ₹352.03/tonne versus railways (Table 17). The National Waterway 1, extends from Prayagraj in Uttar Pradesh to Haldia in West Bengal, connecting major cities in the states of Uttar Pradesh, Bihar, Jharkhand and West Bengal with an estimated divertible traffic of 54.22 MMT by year 2021-22 (Table 18, Table 19).

Box 1: National Waterway 1

"From road bridge at Allahabad across the river Ganga, about 2 kms. up-stream of the confluence of the rivers Ganga and Yamuna at Triveni to the inland waterway limit on the tidal waters of the river Hooghly from a line drawn between no. 1 Refuge house at the entrance to Baratola river commonly called channel creek, to a position 2.5 kms. due south of Saugor lighthouse, and then connected to the right or south bank at the entrance to the Hijili or Russulpore river, through river Ganga, lock canal and feeder canal at Farakka, river Bhagirathi and river Hooghly"

— The National Waterway (Allahabad-Haldia Stretch of the Ganga-Bhagirathi-Hooghly River) Act, 1982

Table 15: Operational and feasible National Waterways in the Ganga River System.

Region	National Waterway	Operational	Feasible	Total
Ganga	**Number**	6	7	25
	Approximate Length (km)	3,222	3,318	6,335.5
	States Covered	*Uttar Pradesh, Bihar, Jharkhand, West Bengal*	*Uttar Pradesh, Bihar, Jharkhand, West Bengal*	*Uttar Pradesh, Bihar, Jharkhand, West Bengal, Haryana, Delhi*
India	**Number**	18	35	111
	Approximate Length (km)	8,735	10,654	20,275.5
	States Covered	*Uttar Pradesh, Bihar, Jharkhand, West Bengal, Assam, Kerala, Tamil Nadu,*	*Uttar Pradesh, Bihar, Jharkhand, West Bengal, Assam, Kerala, Tamil Nadu, Andhra*	*Uttar Pradesh, Bihar, Jharkhand, West Bengal, Assam, Kerala, Tamil Nadu, Andhra Pradesh, Telangana, Odisha,*

		Andhra Pradesh, Telangana, Odisha, Gujarat, Maharashtra, Goa	*Pradesh, Telangana, Odisha, Gujarat, Maharashtra, Goa, Karnataka*	*Gujarat, Maharashtra, Goa, Karnataka, Himachal Pradesh, Punjab, Haryana, Jammu & Kashmir, Rajasthan, Delhi, Nagaland, Mizoram, Meghalaya,*

Table 16: Comparative inter-modal cost (₹/TKm) of transporting freight.

Mode	Freight (₹/TKm)	GST (%)	Total (₹/TKm)
Railways	1.36	5	1.428
Roadways	2.50	5	2.625
Inland Water Transport	1.06	Nil	1.06

Source: IST Press Information Bureau, Government of India, Ministry of Shipping (20-March-2017 17:53); RITES 2014

Table 17: Comparative intermodal cost (₹/Tonne) of transporting freight from Haldia to Prayagraj, along National Waterway 1.

Mode	Total distance (km)	Total Cost (₹/Tonne) (before GST)	Total Cost (₹/Tonne) (after GST)
Railways	956	1300.16	1365.168
Roadways (NH 19)	885	2212.50	2323.125
Inland Water Transport	1620	1717.20	1717.20

Source: Based on the estimates by RITES 2014

Table 18: Major cities along National Waterway 1.

State	Cities
Uttar Pradesh	Prayagraj, Varanasi, Ghazipur, Ballia
Bihar	Buxar, Patna, Munger, Bhagalpur
Jharkhand	Sahibganj, Rajmahal
West Bengal	Farakka, Behrampur, Katwa, Tribeni, Kolkata, Howrah, Haldia

Table 19: Estimated divertible traffic (in MMT) by year 2021-22.

		From Rail	From Road	Total
Within National Waterway-1		25.90	17.44	**43.34**
Between National Waterways	*NW-1 & NW-2*	*1.00*	*1.13*	*2.13*
	NW-1 & NW-5	*5.02*	*2.77*	*7.79*
	NW-1 & NW-6	*0.02*	*0.94*	*0.96*
	Total	6.04	4.84	10.88
TOTAL		**31.94**	**22.28**	**54.22**

Base year → 2011-12 & commencement year → 2022-23
Source: RITES 2014

5.3.5 Provision of Riverbed Material

Sand is available in all the rivers in Uttar Pradesh (Table 20). In the Uttar Pradesh Ganga districts, 1,716,849 m^3 quantity of sand was documented to have been dispatched from an area of 658.21 acre by lease holders, on which they earned a revenue of ₹547,263,143.80/- (as on 27th January, 2020) (Table 21, Figure 10). The fertile alluvial Indo-Gangetic plains produce over 65% of the bricks manufactured in India (Centre for Science and Environment). The alluvial soil in the Indo-Gangetic plain is suitable for

manufacturing different types of bricks; there are 2389 brick kilns operating in the state of Bihar (Department of Geology and Mining, Government of Bihar).

Table 20: Rivers and the corresponding districts in Uttar Pradesh where sand is available.

SN	River	Districts
1	Ganga	Aligarh, Ballia, Budaun, Bulandshahr, Farukkhabad, Ghazipur, Hardoi, Kanpur Nagar, Mirzapur, Muzaffarnagar, Pratapgarh, Prayagraj, Raebareli, Sant Ravidas Nagar, Unnao, Varanasi
2	Yamuna	Agra, Etawah, Firozabad, Ghaziabad, Hamirpur, Kanpur Dehat, Mathura, Mainpuri, Meerut, Muzaffarnagar, Prayagraj
3	Ghaghara	Ambedkar Nagar, Ayodhya, Azamgarh, Barabanki, Basti, Bahraich, Deoria, Gonda, Gorakhpur, Mau
4	Gomti	Barabanki, Hardoi, Jaunpur, Lucknow, Sitapur, Sultanpur
5	Sai	Jaunpur, Pratapgarh, Raebareli, Unnao
6	Garra	Hardoi, Pilibhit, Shahjahanpur
7	Ramganga	Bareilly, Moradabad, Rampur
8	Rapti	Maharajganj, Sidharth Nagar
9	Chambal	Agra, Etawah
10	Kali	Farrukhabad
11	Betwa	Hamirpur
12	Karamnasa	Varanasi
13	Dandi	Gorakhpur
14	Kuano	Basti
15	Jamin	Azamgarh
16	Sarayu	Sitapur
17	Dehua	Pilibhit
18	Chhoti Gandak	Deoria

Table 21: Revenue earned from sand mining (leased) in Uttar Pradesh Ganga districts.

SN	Districts	Mineral	Area (acre)	Dispatched Quantity (m^3)	Selling price per m^3 (₹)	Revenue (₹)
1A	Aligarh *(Ganga)*	*Ordinary Sand 1*	—	—	—	—
1B		*Ordinary Sand 2*	*69.18*	*83500*	*611.50*	*51060000*
1		Ordinary Sand	69.18	83500	611.50	51060000
2A	Ballia *(Ganga, Ghaghara)*	*Ordinary Sand 1*	*28.45*	*0*	*560*	*0*
2B		*Ordinary Sand 2*	—	—	—	—
2		Ordinary Sand	28.45	0	560	0
3A	Badaun *(Ganga)*	*Ordinary Sand 1*	—	—	—	—
3B		*Ordinary Sand 2*	*55.11*	*97395*	*492.40*	*47957420*
3		Ordinary Sand	55.11	97395	492.40	47957420
4A	Bulandshahr *(Ganga)*	*Ordinary Sand 1*	*27.46*	*69066*	*560*	*38676960*
4B		*Ordinary Sand 2*	—	—	—	—
4		Ordinary Sand	27.46	69066	560	38676960
5A	Chandauli *(Ganga)*	*Ordinary Sand 1*	*85*	*0*	*250*	*0*
5B		*Ordinary Sand 2*	—	—	—	—
5		Ordinary Sand	85	0	250	0
6A	Farrukhabad *(Ganga)*	*Ordinary Sand 1*	—	—	—	—
6B		*Ordinary Sand 2*	*35.97*	*80419*	*323.56*	*26020745*
6		Ordinary Sand	35.97	80419	323.56	26020745

7A	Fatehpur *(Ganga)*	*Ordinary Sand 1*	—	—	—	—
7B		*Ordinary Sand 2*	*29.65*	*0*	*474*	*0*
7		Ordinary Sand	29.65	0	474	0
8A	Ghazipur *(Ganga)*	*Ordinary Sand 1*	*64.06*	*111627*	*484.28*	*54058698.19*
8B		*Ordinary Sand 2*	—	—	—	—
8		Ordinary Sand	64.06	111627	484.28	54058698.19
9A	Hardoi *(Ganga, Garra)*	*Ordinary Sand 1*	—	—	—	—
9B		*Ordinary Sand 2*	*25.64*	*0*	*530*	*0*
9		Ordinary Sand	25.64	0	530	0
10A	Kannauj *(Ganga, Kali)*	*Ordinary Sand 1*	—	—	—	—
10B		*Ordinary Sand 2*	*66.23*	*71972*	*352.65*	*25381200*
10		Ordinary Sand	66.23	71972	352.65	25381200
11A	Kanpur Nagar *(Ganga)*	*Ordinary Sand 1*	*25.94*	*0*	*360*	*0*
11B		*Ordinary Sand 2*	—	—	—	—
11		Ordinary Sand	25.94	0	360	0
12A	Kanshiram Nagar *(Ganga)*	*Ordinary Sand 1*	*29.65*	*0*	*380*	*0*
12B		*Ordinary Sand 2*	—	—	—	—
12		Ordinary Sand	29.65	0	380	0
13A	Mirzapur *(Ganga)*	*Ordinary Sand 1*	*308.09*	*184352*	*23.48*	*4328860.64*
13B		*Ordinary Sand 2*	—	—	—	—
13		Ordinary Sand	308.09	184352	23.48	4328860.64
14A	Prayagraj *(Ganga, Yamuna, Tamsa, Belan)*	*Ordinary Sand 1*	*322.42*	*903238*	*296.16*	*267500140*
14B		*Ordinary Sand 2*	*118.56*	*115271*	*280*	*32275880*
14		Ordinary Sand	440.98	1018509	294.33	299776020
15A	Raebareli *(Ganga)*	*Ordinary Sand 1*	—	—	—	—
15B		*Ordinary Sand 2*	*75.91*	*0*	*0*	*0*
15		Ordinary Sand	75.91	0	0	0
16A	Shahjahanpur *(Garra)*	*Ordinary Sand 1*	—	—	—	—
16B		*Ordinary Sand 2*	*17.99*	*0*	*933*	*0*
16		Ordinary Sand	17.99	0	933	0
17A	Sant Ravidas Nagar *(Ganga)*	*Ordinary Sand 1*	*25*	*0*	*578*	*0*
17B		*Ordinary Sand 2*	—	—	—	—
17		Ordinary Sand	25	0	578	0
18A	Unnao *(Ganga)*	*Ordinary Sand 1*	*18.06*	*9*	*360*	*3240*
18B		*Ordinary Sand 2*	—	—	—	—
18		Ordinary Sand	18.06	9	360	3240
Total		*Ordinary Sand 1*	*934.13*	*1268292*	*287.45*	*364567898.80*
		Ordinary Sand 2	*543.64*	*448557*	*407.30*	*182695245*
		Ordinary Sand	1477.77	1716849	318.76	547263143.80

Note: Category 1 sand is the coarse and clean sands without flaky minerals and is preferred due to higher strength and lower construction costs.

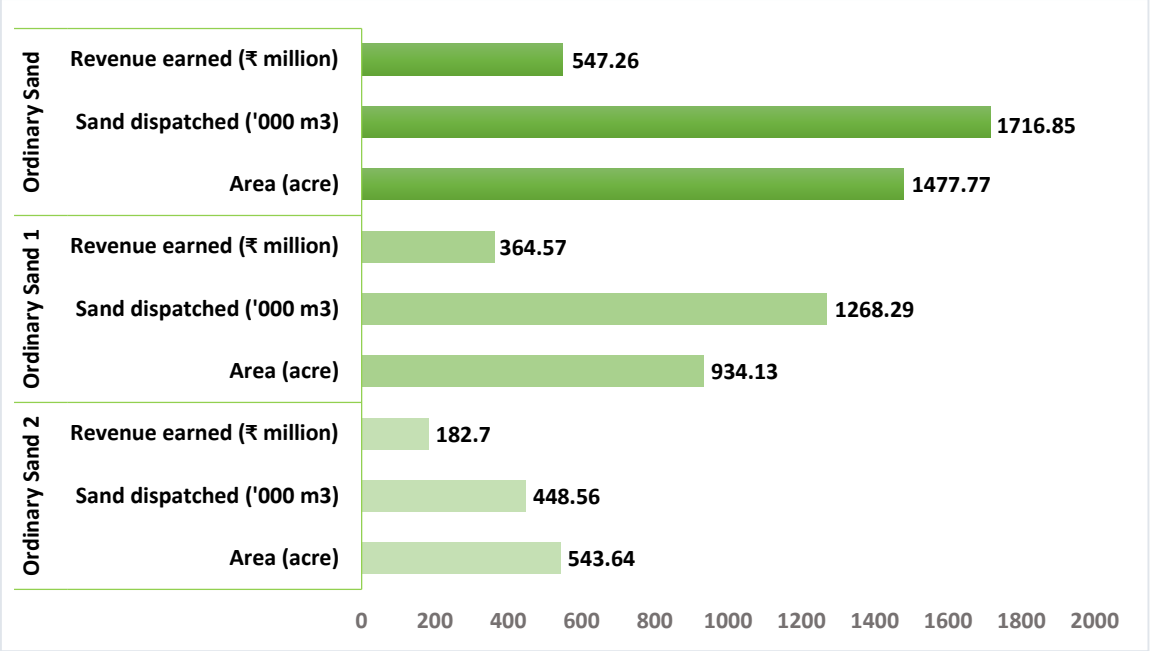


Figure 10: Details of the sand dispatched and revenue earned in the Uttar Pradesh Ganga districts.

5.3.6 Provision of Fish

The Ganga River supports 235 fish species — 58 species in Upper Ganga, 135 species in Middle Ganga and 180 species in Lower Ganga, belonging to 58 families, including the commercially important Indian Major Carps (WII-GACMC, 2018) (Figure 11). The mean catch per unit effort (CPUE) (kg fish per hour) of the Ganga River mainstem is 8.62 (±10.54), based on which the fish catch per day is 206.97 kg with an economic value ranging between ₹20,696.52 and ₹41,393.03 (Table 22). Fish vendors and traders surveyed in Varanasi (n=53) and Narora (n=30), respectively, reported an estimated average annual income of ₹168,226.42 (±316,996.52) and ₹355,200 (±280,623.02), respectively (Table 23).

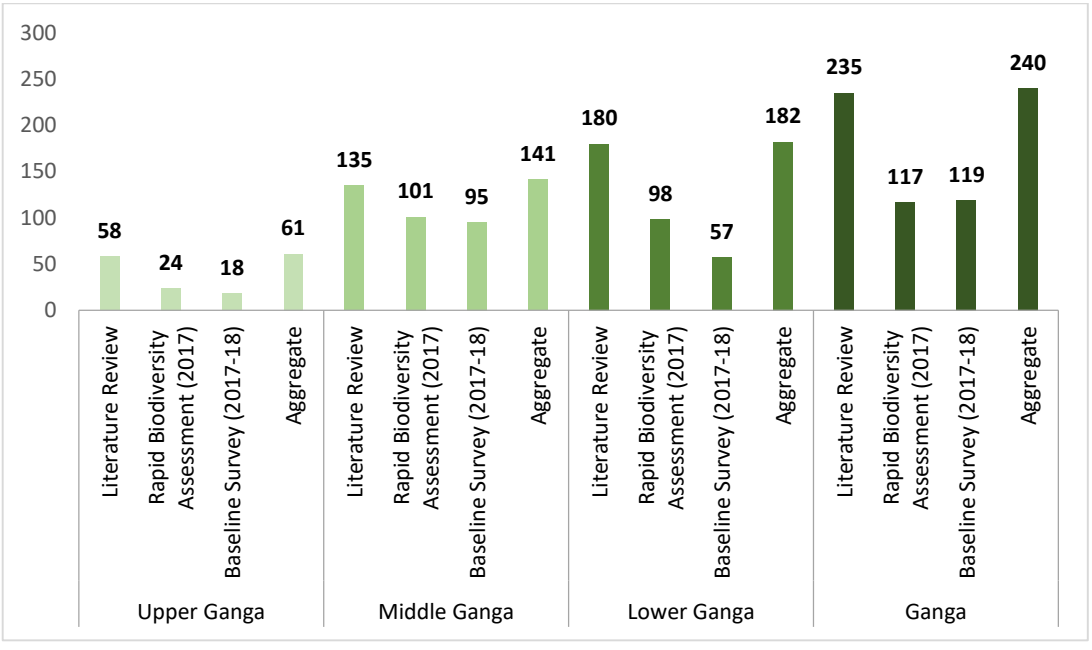


Figure 11: Fish species richness in Upper Ganga, Middle Ganga and Lower Ganga.

Table 22: Economic value of the fish in the Ganga River mainstem.

River Stretch	Species Richness	Mean Catch per Unit Effort (kg fish per hour)	Fish catch per day (kg)	Value (@₹100 per kg)	Value (@₹150 per kg)	Value (@₹200 per kg)
Upper Ganga	18	2.60 (±4.77)	62.34	6234	9351	12468
Middle Ganga	95	16.68 (±13.38)	400.30	40,030	60,045	80,060
Lower Ganga	57	3.79 (±3.07)	90.86	9,086.4	13,629.6	18,172.8
Ganga mainstem	119	8.62 (±10.54)	206.97	20,696.52	31,044.77	41,393.03

Table 23: Results of the survey conducted in select sites in Uttar Pradesh.

Site	Type	Average selling price (per kg)	Average catch/day (kg)	Fish sold/ day (kg)	Stated monthly income (₹)	Stated annual income (₹)
Varanasi (n=53)	vendors	108.40 (±61.18)	21.83 (±27.28)	17 (±19.48)	16,969.43 (±16,520.47)	168,226.42 (±316,996.52)
East Uttar Pradesh (n=53)		108.40 (±61.18)	21.83 (±27.28)	17 (±19.48)	16,969.43 (±16,520.47)	168,226.42 (±316,996.52)
Narora (n=30)	wholesalers	158.42 (±81.65)	44 (±29.48)	51.67 (±33.98)	27,900 (±20,726.07)	355,200 (±280,623.02)
Sambhal (n=20)	wholesalers	124 (±8.94)	40.75 (±36.42)	49 (±41.01)	9,000 (±2,545.58)	108,000 (±30,547.01)
Amroha (n=10)	wholesalers	180	10 – 20	20	5,400	64,800
West Uttar Pradesh (n=60)		152.40 (±72.40)	38.08 (±27.26)	45.50 (±30.92)	17,850 (±17,206.25)	224,400 (±229,053.57)

5.3.7 Tourism

The Ganga River has deep cultural significance, drawing people to its banks from all walks of life across the globe, supporting the economy of various cultural centres situated along the river. Uttar Pradesh, including the city of Varanasi) has witnessed an increasing trend in tourist footfall between 2013 and 2018 (Figure 12, Figure 13). Prayagraj in Uttar Pradesh, a major cultural and religious centre in India situated at the confluence of Ganga, Yamuna and the mythical Saraswati, shows a downward linear trend in tourist footfall between 2013 and 2018, due to the Kumbh Mela hosted in 2013 (Figure 14).

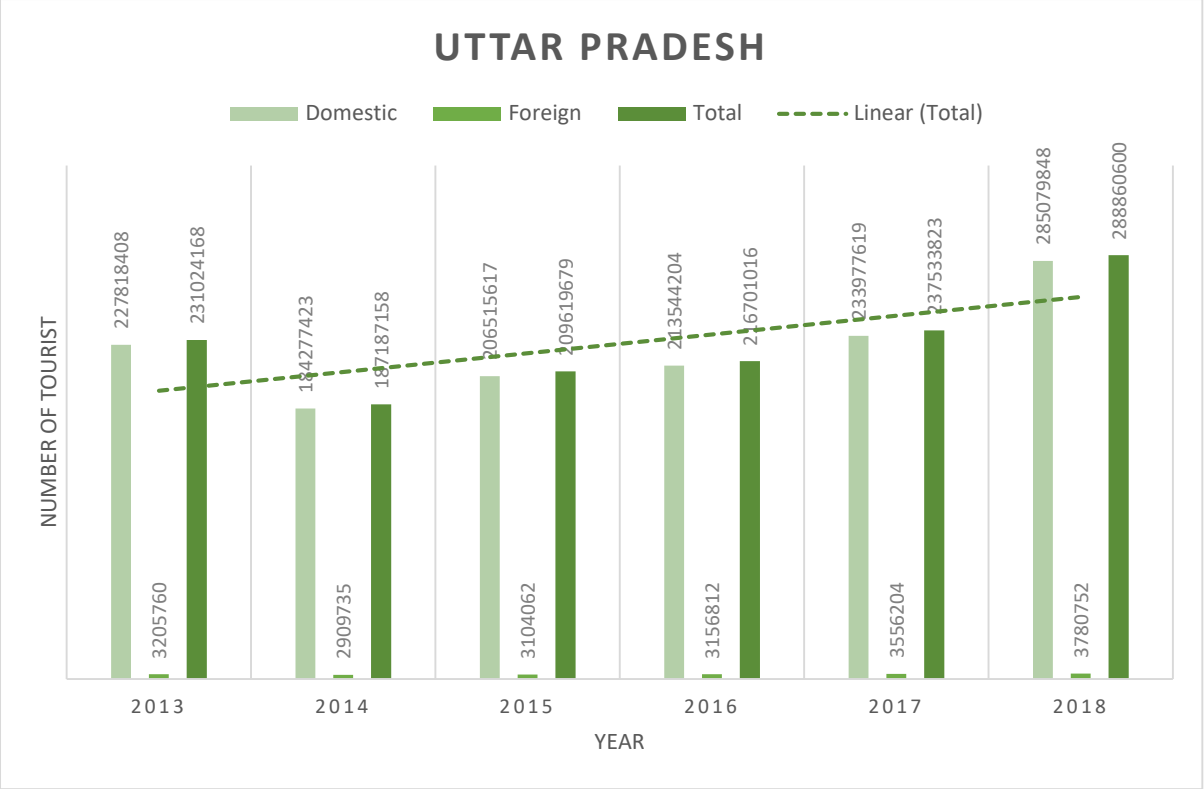


Figure 12: Tourist footfall for the state of Uttar Pradesh, between 2013 – 2018.

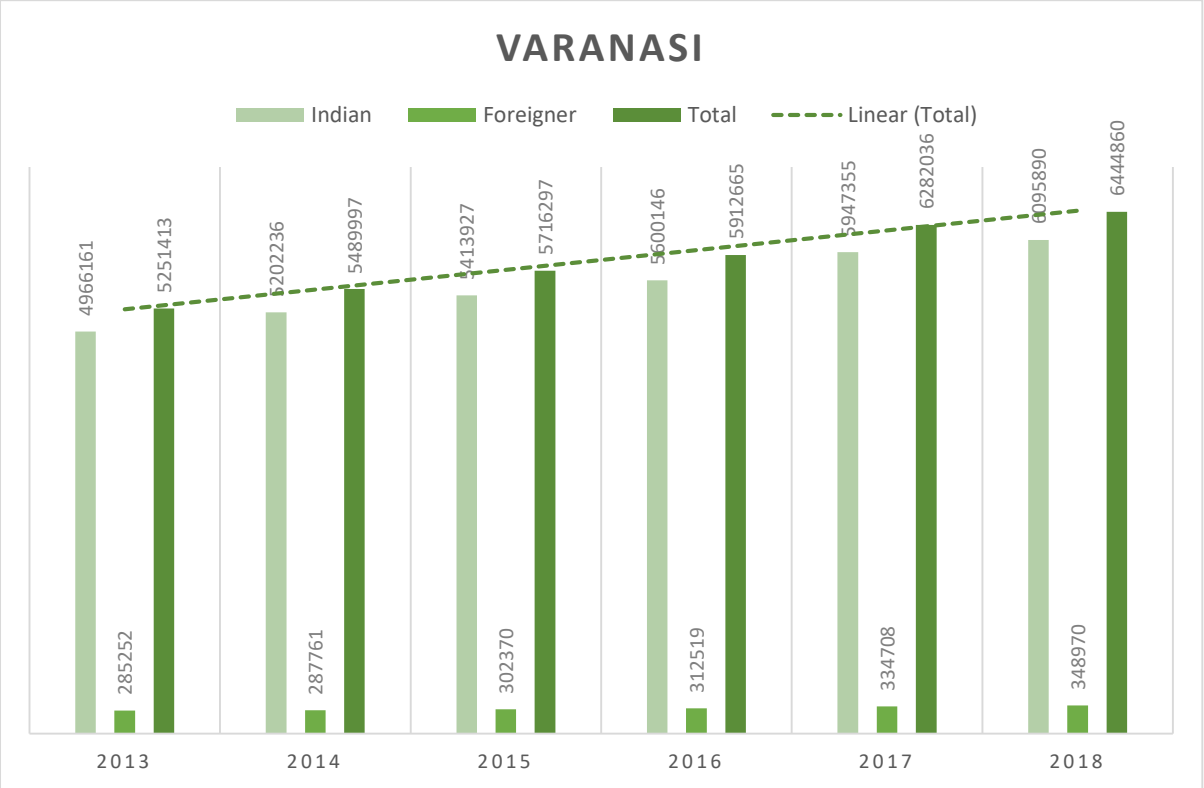


Figure 13: Tourist footfall for the cultural centre of Varanasi, Uttar Pradesh, between 2013 – 2018.

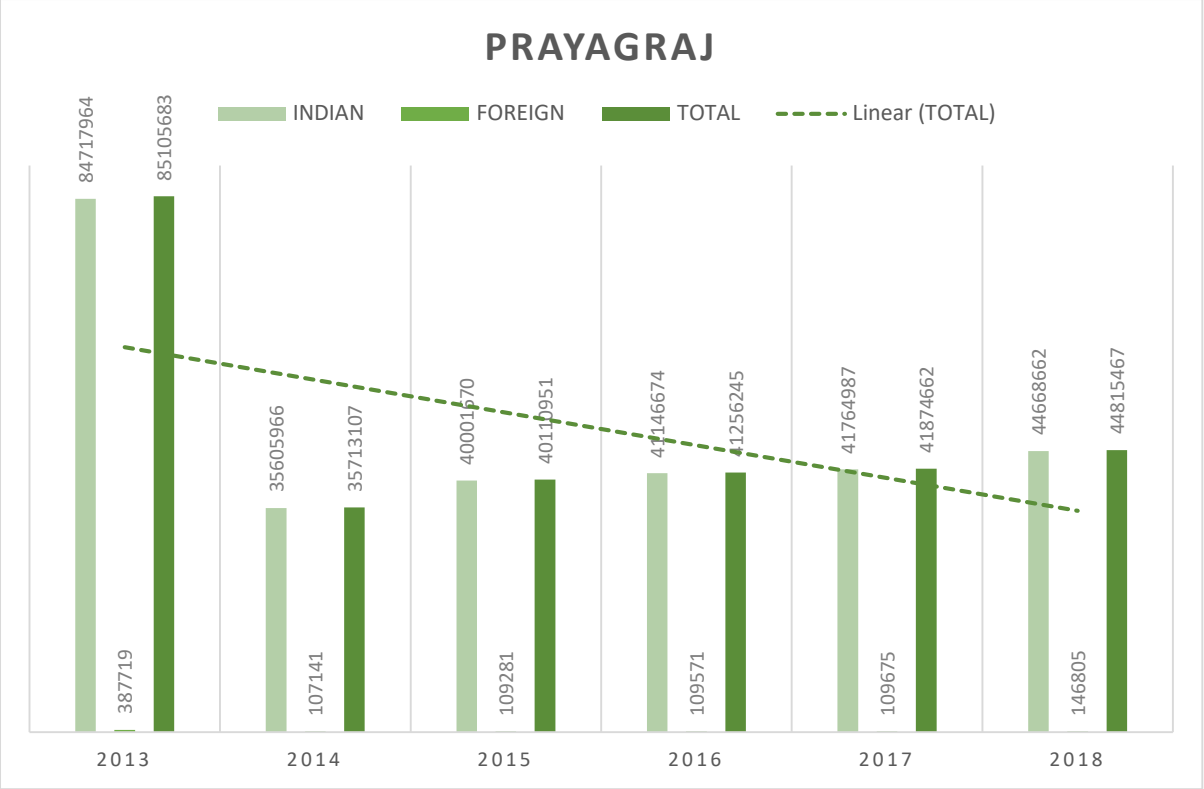


Figure 14: Tourist footfall for the cultural centre of Prayagraj, Uttar Pradesh, between 2013 – 2018.

Local businessmen (n = 110) were surveyed in Varanasi in order to assess the importance of tourism for their livelihood. 44.71% of the vendors that responded (n = 85) earned between ₹35,000 and ₹134,999 during the tourist season (Table 24, Figure 15). Vendors (n = 136) at the Kumbh Mela 2019 in Prayagraj reported a 210.07% (± 238) increase in daily income during Kumbh, with an average daily income of ₹6,231.56 (±26,852.17) during Kumbh as opposed to ₹2,251.787 (±7,717.24) during business-as-usual scenario i.e., without Kumbh (Table 25).

Table 24: Description of the respondents surveyed in Varanasi, Uttar Pradesh.

Number of respondents	110
Average age (n=71)	33.99 (±8.13) years
Type of business	Restaurants/food stalls etc. – 30.91% Hotels, Guesthouses etc. – 23.64% General & Departmental stores – 14.55% Local travel – 12.73% Boatmen – 10.91% Handicrafts, garment – 7.27%
Tourist season	September to April
Different types of tourists catered to	Domestic – 94.50% International – 31.19% Religious – 72.48% Local – 11.01%

	Recreational – 8.26% School trip – 5.50% Corporate tour – 4.59%
Success of business contingent upon tourists (n=101)	Completely – 15.84% Partially – 83.17% Not at all – 0.99%

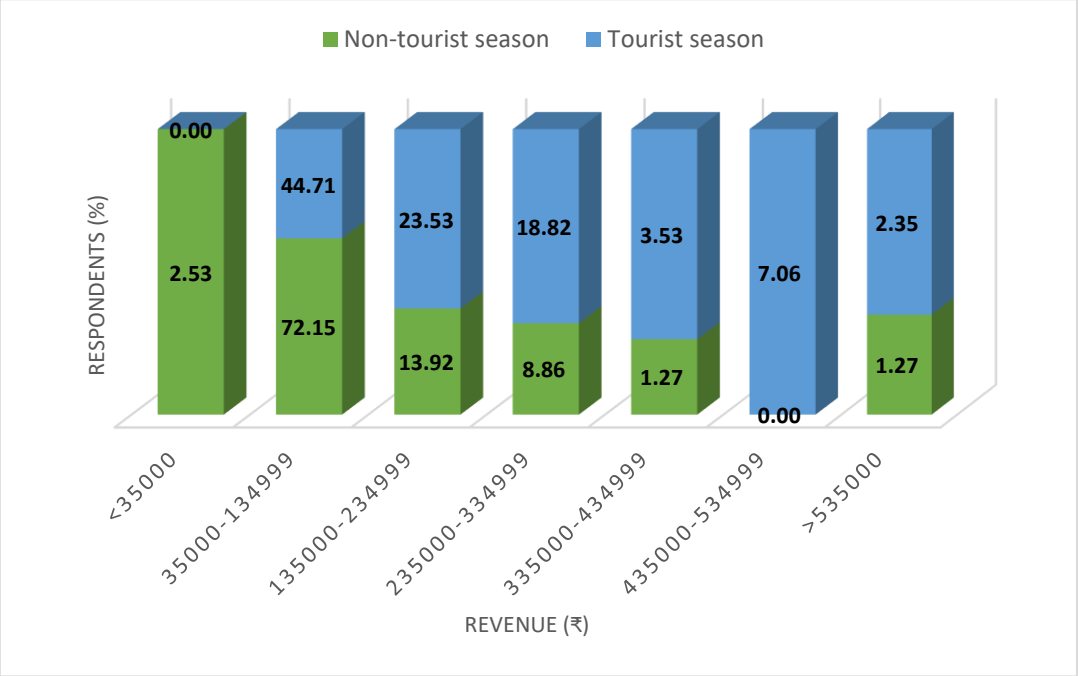


Figure 15: Revenue earned by local businessmen in Varanasi during the tourist season versus the non-tourist season.

Table 25: Description of the respondents surveyed in Kumbh Mela 2019, Prayagraj, Uttar Pradesh.

Number of respondents	160
Average age	33.07 (±10.62) years
Gender	Male – 77.5% Female – 22.5%
Education	Illiterate – 33.75% Till Class 5 – 15% Secondary – 21.875% Higher Secondary – 11.25% Under Graduate – 14.375% Graduate – 3.75%
Place of residence	Within Prayagraj – 31.25% Outside Prayagraj – 68.75%
Average household size	6.69 (±3.04) persons
Average household income	₹ 6010 (±24,757.39)
Type of business venture	Ritualistic Good-Ornamentals (RGO) – 10.625% Food/Snacks-Tea Stall – 5% Beverages-Tea Stall – 4.375%

	RGO with others – 1.875% Other Combinations – 6.25% Cloth Based – 11.25% Food/Snacks/Sweets Stall – 8.75% Tea Stall – 8.75% Ritualistic Goods – 7.5% Footwear – 6.875% Crockery – 6.25% Ornamentals – 4.375% Transportation – 3.125% Beverages/Juice Stall – 2.5% Hotel – 2.5% Others – 10%
Primary income source	Same type of venture as in Kumbh – 39.38% Daily wage Labourers – 17.50% Agriculture – 13.75% Private Sector – 7.50% Shopkeepers – 5.63% Students and Unemployed – 5% Transportation – 3.75% Others – 7.50%
Average primary daily income without Kumbh (n=144)*	₹ 2,126.69 (±7,516.11)
Average daily income during Kumbh Mela (n=160)	₹ 5506.04 (±24,795.98)
Average increase in daily income during Kumbh (n=136)^	210.07% (± 238) Kumbh daily income – ₹6,231.56 (±26,852.17) Non-Kumbh daily income – ₹2,251.787 (±7,717.24)
Frequency of visitation to fairs in Prayagraj (visits in the past)	0 – 2.5% 1 to 5 times – 85% 6 to 10 times – 3.125% 11 to 15 times – 1.25% Every year – 8.125%
Likeliness of return to Magh Mela 2020 in Prayagraj	0 to 20% – 4.375% 21 to 40% – 15.625% 41 to 60% – 23.75% 61 to 80% – 40.625% 81 to 100% – 15.625%

*excluding the respondents who earn a subsistence wage (n=16);
^excluding the respondents who do not have a primary/alternate source of livelihood or earn a subsistence wage

5.4 A payment for ecosystem services model to integrate ecosystem service value of Ganga in policy making

Payment for Ecosystem Services (PES) is *"a voluntary transaction where a well-defined ecosystem service (or a land use likely to secure that service) is 'bought' by a (minimum of one) ecosystem service buyer from a (minimum of one) ecosystem service provider; if and only if the service provider secures ecosystem service provision (conditionality)"* (Fripp 2014, Smith et al. 2013, Wunder 2005) (Figure 16). A 'PES scheme can develop in one of two ways: either at least one set of stakeholders recognizes a

noticeable depletion in resources, leading to true demand, or a particular aim is identified, usually in relation to protection or management of national resources and a PES system is introduced to create a market for the service' (Savy and Turpie 2004).

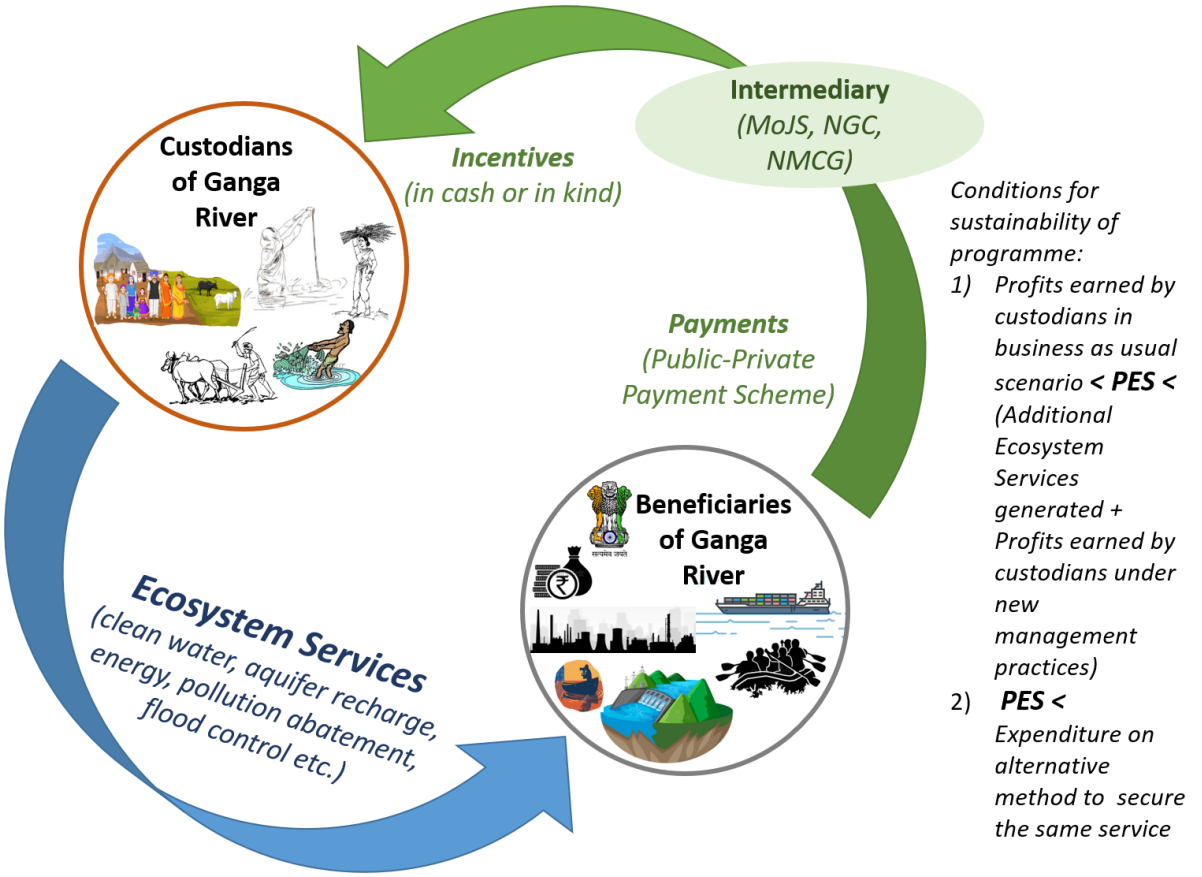


Figure 16: The underlying principle beneath a payment for ecosystem services programme.

Given the geographical extent of the Ganga River basin and poor economic status of its primary custodians and beneficiaries, an eco-compensation scheme designed to induce behaviour change in the local communities, particularly riverside communities, to enhance the productivity of the river ecosystem and ensure the sustainable supply of its services (Figure 17). The local communities, especially the farming and fishing community, must be incentivised, in cash or kind, to adopt best practices by the Government, centre or state, through various schemes that target an element of sustainable farming or fishing. With aquatic biodiversity conservation as the goal, interventions must be prioritised and initiated in the conservation priority zones identified in mainstem Ganga.

A detailed study of the river basin must be undertaken to identify and map the direct and indirect drivers of change, specifically the anthropogenic influences, and flow of ecosystem services locally, regionally and globally. Stakeholders at all levels of influence and impact must be identified, the beneficiaries verified and the benefits valued. Site specific interventions for biodiversity and river conservation, and the corresponding incentives for the interventions must be designed and implemented. In order to ensure the sustainability, efficacy and efficiency of the PES programme, a system of responsibility and accountability must be established, including a monitoring protocol with a clear evaluation criterion.

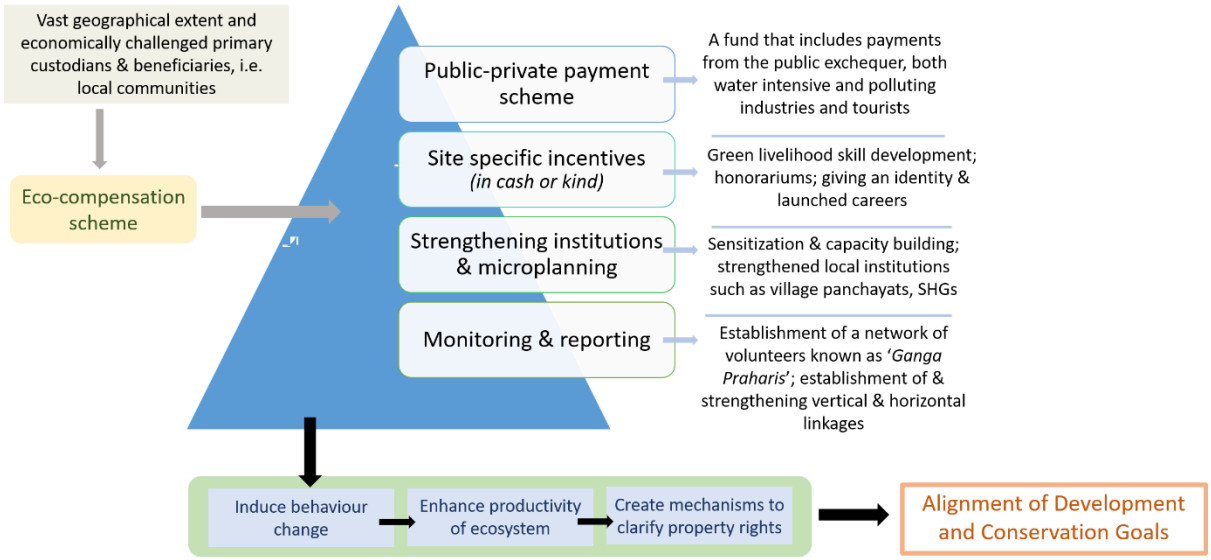


Figure 17: A payment for ecosystem services model for the Ganga River.

There are three types of PES financing schemes, namely, public payment scheme, private payment scheme or self-organised private deals, and public-private payment schemes (Figure 18). In the case of a mixed economy like India, with elements of both capitalism and socialism, and given the geographical scale of the Ganga River and the diversity of its stakeholders in the primary, secondary and tertiary sectors of the economy, a public-private payment is most apt than a purely private or purely public payment scheme.

Public Payment Schemes	Private Payment Schemes/Self-organized Private Deals	Public–Private Payment Schemes
Government pays resource managers to enhance ecosystem services on behalf of the public	Beneficiaries of ecosystem services contract directly with service providers	Both government and private players pay resource managers

Figure 18: Financing schemes for a payment for ecosystem services programme.

To finance the PES programme, budgetary allocations must be made in both the central and state budgets to a fund created specifically for the programme. Given the deep cultural and religious significance of the River, there is a thriving religious-based tourism along the River, especially in cultural and spiritual centres like Varanasi, Haridwar, Prayagraj, Rishikesh etc., which witness heavy tourist footfall, particularly during festival season. Tourists and hospitality sector actors like hotels, tourist operators etc. must be asked to contribute a token amount into the fund. Actors in the hydro, nuclear and thermal power sector, both generation and transmission, must also contribute to the fund. Urban centres and industries along the river drawing water directly from the River must contribute a token amount into a river conservation fund.

Additionally, Industries along the river that directly or indirectly benefit from River, such as agro-based industries, must encouraged to into partnership with local communities to facilitate the sustainable

management of source of raw material; for example, sugar mills can be encouraged to enter into partnership with sugarcane farmers for the adoption of sustainable cultivation practices.

Investments must be made into physical, human and social capital that support the generation of financial capital to encourage investment into and enhance the natural capital. Need to develop a PES programme funded via a public-private payment scheme wherein both the Government and private sector entities pay for the provision of the ecosystem service, that can replicated or adapted based on the requirements, at each level of governance, national, state, district and village levels, in order to generate a diversified, robust, efficient and sustainable combination of initiatives and programmes that attempt to create a market or correct for the market failures for the myriad ecosystem services. In order to improve the efficacy and efficiency of the PES programmes, continuous monitoring and evaluation of the management practices and the generation and delivery of the ecosystem services is must, in order to ensure additionality (increase in ecosystem services generation), and minimize wastage of resources. A scientific baseline must be prepared that not only details the current generation and delivery of resources, but also contains information on degradation and improvement under the current management regime.

6. Conclusion

Valuation of ecosystem services can aid in recognising, demonstrating and capturing ecosystem service values in policy, planning and management pertaining to natural resources (Haines-Young and Potschin, 2010). Ganga River ecosystem provides multiple direct and indirect benefits that affect the human wellbeing of the numerous stakeholders that are dependent upon it. Valuation of these ecosystem services can be an indicator of the values of some of the ecosystem services provided by this river, and can aid an informed decision-making process. Values generated can be useful in raising awareness, environmental accounting, setting priorities, assessing liability and designing an implementation strategy (Pascua et al., 2017) for the Ganga River that is just and ensures the sustained provision of these ecosystem services.

Ganga River caters to a large population of numerous stakeholders, who exercise competing demands on the river and its limited resources. Any meaningful attempt to rejuvenate the Ganga River will include the engagement of its stakeholders at all levels (Bower et al., 2017). One popular market-based mechanism to facilitate this is “Payment for Ecosystem Services” (PES); defined as *“financial incentives given directly to landholders to compensate them for implementing good (or comparatively “better”) land management, including conservation activities, to “voluntarily (voluntarily in this case does not imply “freely” or “without a return”)” provide (or continue providing) certain required (by private or public entities) services instead of monetizing their “natural capital” otherwise”* (Capodaglio and Callegari, 2018). PES schemes have the ability to induce behaviour change by making river conservation more attractive from an economic perspective than “business as usual”. The framework and evaluation can help identify the benefits and beneficiaries to develop a PES model that engages the custodians of the Ganga River in its conservation.

Additionally, the multitudinous services that the Ganga River provides interrelate in a ‘complex dynamic’ manner, resulting in synergies and trade-offs between the different ecosystem services. Development initiatives focusing on the production of a particular ecosystem like hydro power generation, can increase the production of some ecosystem services like power generation, recreation, at the cost of others such as biodiversity, fish etc.; benefiting some at the cost of others. River management strategies to ensure sustainable provision of ecosystem services must incorporate an analysis of the impact of any intervention to enhance the supply of one service on the provision of others.

Select references:

Asanarong, T., Jeon, S., Yuanlin, R., & Yeo, C. (2017). Creating a knowledge management culture for Ganga River: an essential tool for success. In O. Poocharoen & R.J. Wasson (Editors), Ganga Rejuvenation: Governance Challenges and Policy Options, 337-480pp.

Abson, D. J., & Termansen, M. (2011). Valuing ecosystem services in terms of ecological risks and returns. Conservation Biology, 25(2), 250-258.

Bower, S. D., Danylchuk, A. J., Raghavan, R., Danylchuk, S. C., Pinder, A. C., Alter, A. M., & Cooke, S. J. (2017). Involving recreational fisheries stakeholders in development of research and conservation priorities for mahseer (Tor spp.) of India through collaborative workshops. Fisheries research, 186, 665-671.

Capodaglio, A. G., & Callegari, A. (2018). Can Payment for Ecosystem Services Schemes Be an Alternative Solution to Achieve Sustainable Environmental Development? A Critical Comparison of Implementation between Europe and China. Resources, 7(3), 40.

CBD (2008). Convention on Biological Diversity, www.cbd.int/convention/articles/default.shtml.

DEFRA (Department for Environment, Food and Rural Affairs) (2007). An introductory guide to valuing ecosystem services. www.defra.gov.uk.

De Groot, R. S., Alkemade, R., Braat, L., Hein, L., & Willemen, L. (2010). Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. Ecological complexity, 7(3), 260-272.

Gagnon, L., Belanger, C., & Uchiyama, Y. (2002). Life-cycle assessment of electricity generation options: The status of research in year 2001. Energy policy, 30(14), 1267-1278.

Fisher, B., Turner, R. K., & Morling, P. (2009). Defining and classifying ecosystem services for decision making. Ecological economics, 68(3), 643-653.

Fripp, E. 2014. Payments for Ecosystem Services (PES): A practical guide to assessing the feasibility of PES projects. Bogor, Indonesia: CIFOR.

Haines-Young, R., & Potschin, M. (2010). The links between biodiversity, ecosystem services and human well-being. Ecosystem Ecology: a new synthesis, 1, 110-139.

MEA (Millennium Ecosystem Assessment) (2005). Ecosystems and Human Well-being: Synthesis. Island, Washington, DC.

Pascua, P. A., McMillen, H., Ticktin, T., Vaughan, M., & Winter, K. B. (2017). Beyond services: a process and framework to incorporate cultural, genealogical, place-based, and indigenous relationships in ecosystem service assessments. Ecosystem Services, 26, 465-475.

RITES (2014). Integrated National Waterways Transportation Grid Study (Stage 1 of Phase II), Final Report. Published by Inland Waterways Authority of India, New Delhi.

Savy, C. E. and Turpie, J. K. (2004). Payments for Ecosystem Services: A Review of Existing Programmes and Payment Systems – Appendix. Rhodes Gift, South Africa: Anchor Environmental Consultants CC.

Smith, S., Rowcroft, P., Everard, M., Couldrick, L., Reed, M., Rogers, H., Quick, T., Eves, C. and White, C. (2013). Payments for Ecosystem Services: A Best Practice Guide. Defra, London.

Venkatachalam, L. (2015). Informal water markets and willingness to pay for water: a case study of the urban poor in Chennai City, India. International Journal of Water Resources Development, 31(1), 134-145.

WII-GACMC (2018). Macro Fauna of the Ganga River: Status and Conservation of Select species. Ganga Aqualife Conservation Monitoring Centre, Wildlife Institute of India, Dehra Dun.

WII-NMCG (2019). Biodiversity profile of the Ganga River: Planning aquatic species restoration of Ganga River. Wildlife Institute of India, Dehradun, Uttarakhand, India. Pp 223.

Wunder, S. (2005). Payments for environmental services: Some nuts and bolts. Center for International Forestry Research Occasional Paper No. 42.

Appendix 1

List of data sources

Ecosystem Services	Parameter	Source
Water for drinking and domestic use	Surface and ground water supply	(1) Jal Sansthan, Government of Uttarakhand (2015). Initial Environmental Examination report of sub project: Rehabilitation of Water Supply System of Srinagar under Uttarakhand Emergency Assistance Project. (2) Jal Sansthan, Government of Uttarakhand (2015). Initial Environmental Examination report of sub project: Rehabilitation of Water Supply System of Uttarkashi under Uttarakhand Emergency Assistance Project. (3) Urban Development Department, Government of Uttarakhand (2007). Haridwar City Development Plan under Jawaharlal Nehru National Urban Renewal Mission (JNNURM). (4) BCEOM India Private Limited – CRAPHTS Consultants (I) Pvt. Ltd. (2006). Meerut City Development Plan under Jawaharlal Nehru National Urban Renewal Mission (JNNURM). (5) JPS Associates (P) Ltd. (2006). Kanpur City Development Plan under Jawaharlal Nehru National Urban Renewal Mission (JNNURM). (6) Jal Nigam, Government of Uttar Pradesh (2013). Detailed project report of Mirzapur Nagar Palika Parishad Water Supply Reorganisation Scheme under Atal Mission for Rejuvenation and Urban Transformation (AMRUT) Programme. (7) CDM Smith India Private Limited (2015). Report on Developing Strategy for Reduction of Non-Revenue Water in Varanasi Nagar Nigam. (8) Bihar Urban Development Agency, Urban Development Department, Government of Bihar (2006). Patna City Development Plan under Jawaharlal Nehru National Urban Renewal Mission (JNNURM). (9) Urban Development and Housing Department, Government of Bihar (2017). Initial Environmental Examination report of Bihar Urban Development Investment Program — Bhagalpur Water Supply Phase 2 (BWSP2) Subproject. (10) Kolkata Municipal Corporation, Government of West Bengal (2012). Initial Environmental Examination report of Kolkata Environmental

		Improvement Investment Program (Tranche 1) – Water Supply Subproject. (11) Kolkata Municipal Corporation, Government of West Bengal (2018). Initial Environmental Examination report of Kolkata Environmental Improvement Investment Program (KEIIP) Tranche 2 – Water Supply in Joka and Adjoining Area, Kolkata and Water Loss Management at Anandapur and Patuli Area of East Kolkata.
Benefits to agriculture (water for irrigation and soil fertility)	Crop production in Bihar Ganga districts (2012-13 to 2017-18)	Department of Agriculture, Government of Bihar
	Minimum Support Prices (2012-13 to 2017-18)	Farmers Portal, Government of India (www.farmer.gov.in/mspstatements.aspx#)
Water for power generation *(hydro, nuclear and thermal)*	Hydropower plants along the Ganga River mainstem in Uttarakhand and Alaknanda	Uttarakhand Jal Vidyut Nigam Ltd.; NTPC Ltd.; NHPC Ltd.; THDC India Ltd.; Alternate Hydro Energy Centre, Indian Institute of Technology Roorkee; South Asia Network on Dams, Rivers and People
	Description of Narora Atomic Power Station, District Bulandshahr, Uttar Pradesh	www.npcil.nic.in
	Thermal power plants along Ganga River	Central Electricity Authority CDM - CO2 Baseline Database Version 14.0 (www.cea.nic.in)
Water for transportation	Status of National Waterways in India	The National Waterways Act, 2016 (www.egazette.nic.in)
Riverbed material	Revenue earned from sand mining leases sanctioned in Uttar Pradesh Ganga districts	Directorate of Geology and Mining, Government of Uttar Pradesh
Provision of fish	Mean Catch per Unit Effort (baseline survey 2017-18)	Chapter 5: Status of Fish Diversity in Ganga River, Biodiversity profile of the Ganga River, WII-NMCG (2019).
Recreational/ religious/ spiritual services	Tourist Footfall in Uttar Pradesh and the cultural centres of Varanasi and Prayagraj, Uttar Pradesh	Department of Tourism, Government of Uttar Pradesh

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