ECOSYSTEM
SERVICES SERIES

नमामि गंगे

FRAMEWORK FOR EVALUATING ECOSYSTEM SERVICES OF GANGA RIVER

FRAMEWORK FOR EVALUATING ECOSYSTEM SERVICES OF GANGA RIVER

FRAMEWORK FOR EVALUATING ECOSYSTEM SERVICES OF GANGA RIVER

The 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' (Figure 1) (CBD, 2008).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).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. Anthropogenic pressures, unplanned development activities, international and domestic conflict, politics etc. are degrading the quality of ecosystems across the globe and their ability to provide vital ecosystem services (Hancock, 2010).

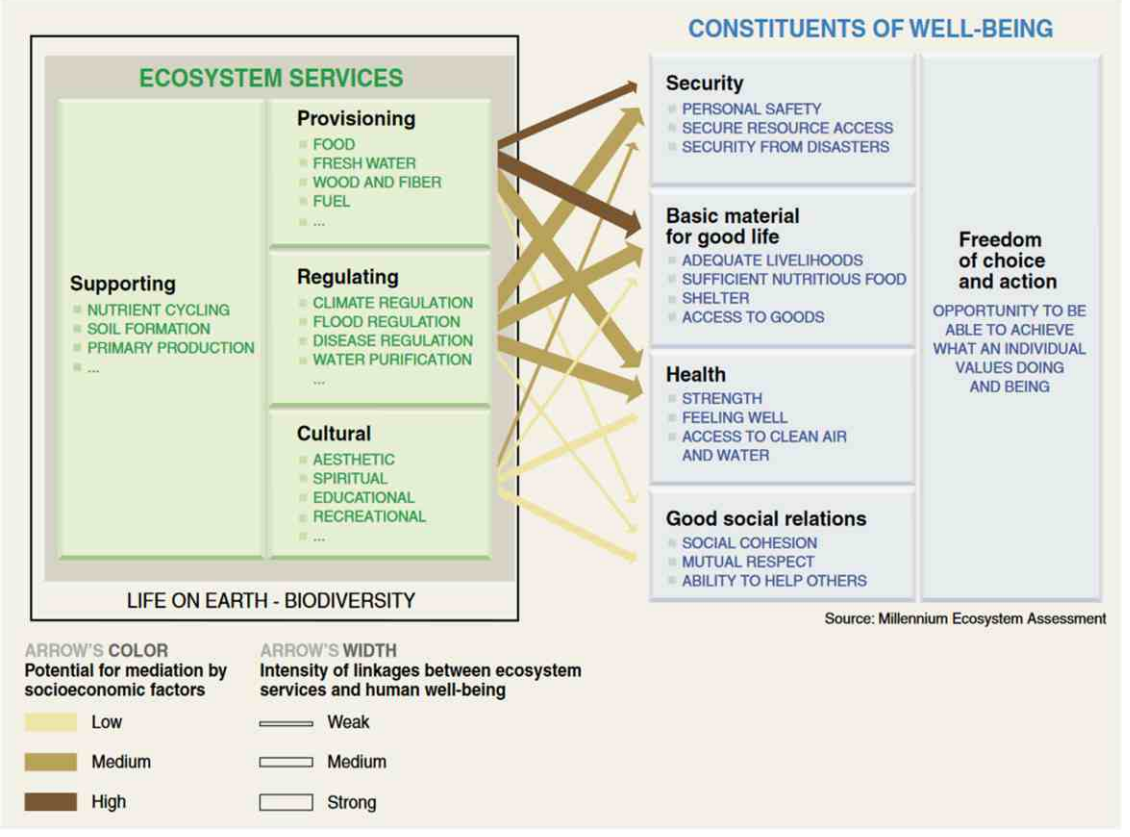
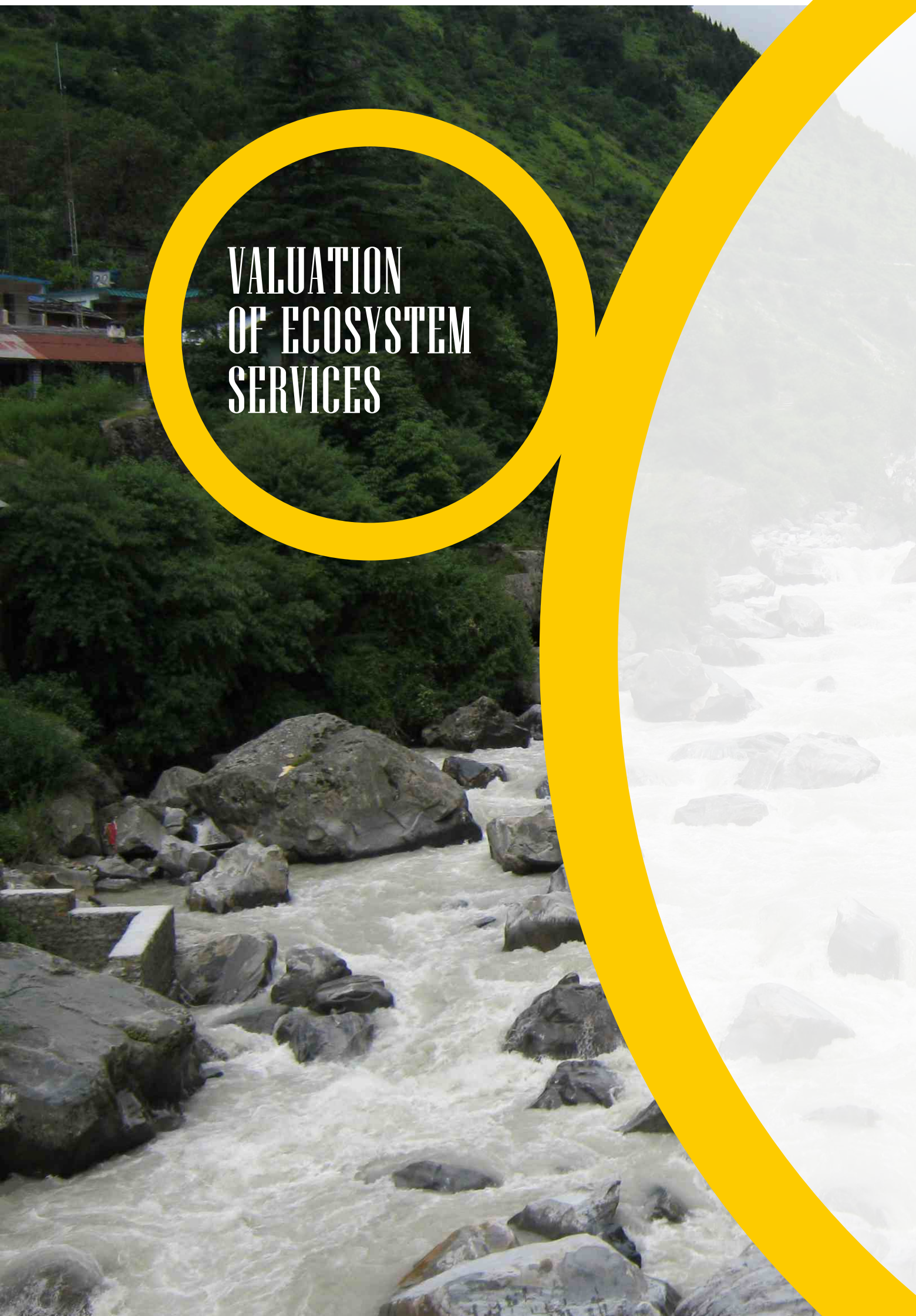


Figure 1: Linkages between Ecosystem Services and Human Wellbeing



VALUATION OF ECOSYSTEM SERVICES

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). Values generated can prove to be useful in raising awareness, environmental accounting, setting priorities, assess liability and designing implementation strategy (Pascua et al., 2017). The valuation process entails conducting a biophysical assessment as well as a social assessment (Figure 2).

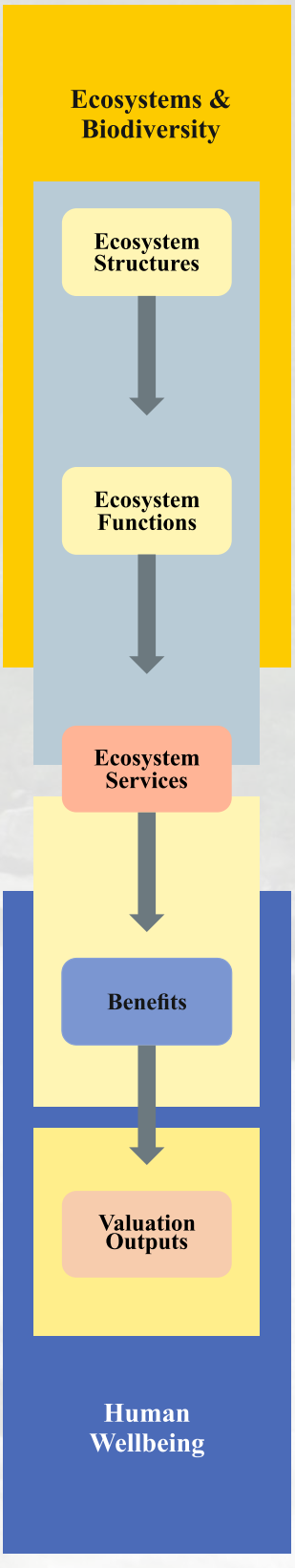
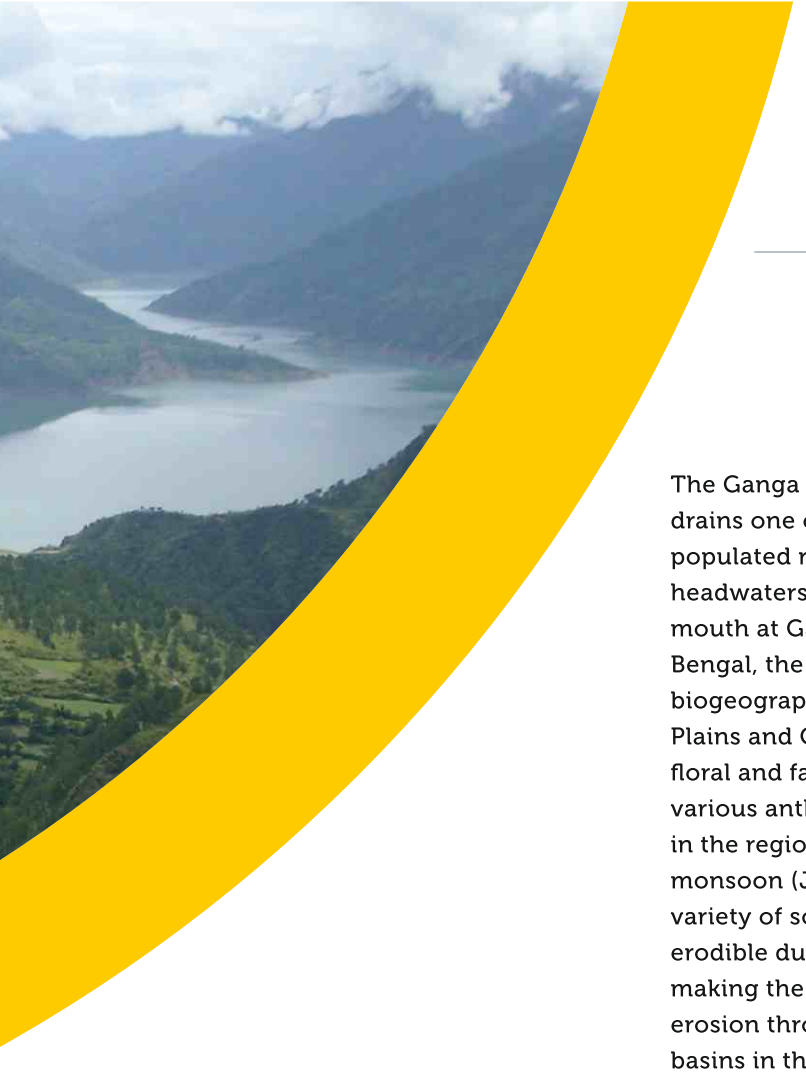


Figure 2:
The process of Ecosystem Service Valuation

(Adapted from Kelemen et al., 2015)

BIO-PHYSICAL ASSESSMENT

Once the objective of conducting the valuation exercise has been defined, the 'Biophysical Assessment' must be carried out wherein the biophysical systems and processes or the ecosystem structures and functions that provide ecosystem services for humans are mapped and assessed (Lavorel et al., 2017). This will result in a detailed description of the current state of the ecosystem and its capacity to provide ecosystem services, the synergies and trade-offs between ecosystem services from a biophysical perspective and the assessment of potential changes in the future via modelling (Kelemen et al., 2015)



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 (Figure 3). 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, Middle Ganga and Lower Ganga (Table 1) (WII-GACMC, 2018).

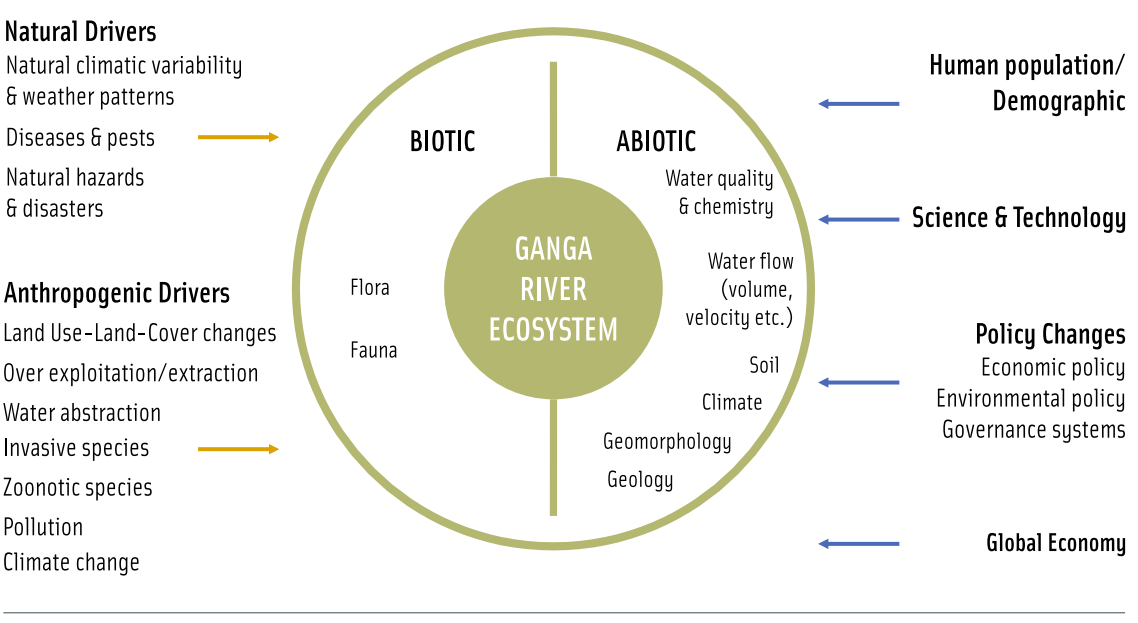


Figure 3: Constituents of the Ganga River Ecosystem

Table 1: 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 flood plain 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 Avg annual temp: <10°C-20°C	Annual rainfall: 60-160cm Avg annual temp: 5°C - 25°C in winter and 20°C - >40°C in summer	**Gangetic Plains** Annual rainfall: 60-160cm Avg annual temp: 5°C - 25°C in winter and 20°C - >40°C in summer **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.
Biogeographic zones	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)

	UPPER GANGA Gaumukh to Haridwar ~ 294 Km	MIDDLE GANGA Haridwar to Varanasi ~ 1082 Km	LOWER GANGA Varanasi to Ganga Sagar ~ 1134 Km
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 flapshelled 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]: 6,34,47,039 Population Density[1]: 878.30 per km^2 Major cities: Bijnor, Kanauj, Kanpur, Unnao, Allahabad, Mirzapur, Varanasi	Population[1]: 9,43,57,799 Population Density[1]: 1360.43 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 Ponding (ROR + RORP) hydroelectric projects Commissioned - 16 Under construction - 14 Proposed - 39 Inundation & diversion of Bhagirathi &Alaknanda Rivers	A substantial portion of the river water is diverted to support agricultural activities through a system of canals (Upper Ganga Canal, Eastern Ganga Canal, Madhya Ganga Canal, Lower Ganga Canal, Parallel Lower Ganga Canal) Construction Sand mining Biological resource extraction	Farraka barrage The 'Jal Marg Vikas Project' (JMVP) on the National Waterway (NW) 1 (from Allahabad to Haldia ~ 1620 km) Agricultural activities Construction Sand mining Bological 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).

SOCIAL ASSESSMENT

Building upon the biophysical assessment, the **'Social Assessment'** is carried out to identify the ecosystem service benefits to human beings of the concerned ecosystem, specific to time, scale and stakeholder (Kelemen et al., 2015). This exercise involves mapping and defining stakeholders, mapping and quantifying the demand of ecosystem services, and mapping and assessing this demand versus the supply (Ciftcioglu, 2017; Martínez-Sastre et al., 2017).

The evaluation of 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, there is a need to prioritize the ecosystem services for valuation based upon a pre-formed criterion. Given the distinctions in the three segments of the river, the ecosystem services provided by them will differ in extent. Following this logic, the ecosystem services identification for evaluation has been carried out stretch-wise. The ecosystem services have been selected based upon three factors,

1. Perception of various stakeholders, stretch-wise, regarding their contribution to human wellbeing and livelihood,

2. Extent and importance of services provided, and

3. Cost, time and man power requirement of conducting an evaluation.

The Ganga River hosts a vast population of diverse stakeholders with varying demands on the river and its resources (Table 2). Any meaningful attempt to rejuvenate the Ganga River will include the engagement of its stakeholders at all levels (Bower et al., 2017). Stakeholders, in the case of Ganga River, are entities who are directly or indirectly dependent upon the river and its resources, including its ecological services, and who have the power to influence any policy intervention pertaining to the management of the river. 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. The 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). The current attempt to clean and rejuvenate the river involves policy makers at all levels of the Government, from the Prime Ministers office to the Village Pradhan.

Based upon the manner in which they relate to ecosystems and its services, stakeholders can be categorized into four broad groups, namely, stakeholders who

1 directly benefit,

2 are negatively affected,

3 directly impact an ecosystem/ ecosystem service, and

4 indirectly influence an ecosystem/ ecosystem service.

STAKEHOLDER IDENTIFICATION AND ANALYSIS

Assessing the perception of all the stakeholders regarding the different benefits received from the Ganga River Ecosystem is a monumental task, hence, it is imperative that the stakeholders be prioritized and selected based upon their influence and dependency.

Table 2: Stakeholders of the Ganga River

- International funding agencies
- International Scientific Community
- International Conventions
- International organisations with ongoing projects along the Ganga
- National Ganga River Basin Authority (NGRBA)
- National Mission for Clean Ganga (NMCG)
- Central Government Ministries, Departments & Agencies
- State Project Management Group, NGRBA
- Uttarakhand, Uttar Pradesh, Bihar, Jharkhand and West Bengal State Government Departments, Directorates & Agencies
- Nuclear Power Cooperation of India Ltd. (NPCIL)
- Narora Atomic Power Station (NAPS)
- Political actors (legislators, ministers etc.)
- Village institutions
- Local communities
- Farmers
- Riverine fishing community & societies
- Sand miners
- Industrial Sector
- Real Estate Sector
- Tourism Sector
- Water Development Sector
- Agribusiness sector
- Religious institutions
- Non-Governmental Organisations
- Media
- Researchers
- Protected areas
- Common interested mass

The extent and importance of ecosystem services provided by Ganga River can be assessed by conducting an extensive literature review, surveying the river and conducting meetings with representatives of various stakeholder groups (Table 3).

Table 3: Ecosystem Services provided by the 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

SELECTION OF VALUATION METHODS

Over the past two decades, diverse valuation methods have been developed for different ecosystem services, however the field of river ecosystem service assessment is relatively less explored (Qureshi et al., 2012; Dobriyal et al., 2012; Gopal, 2016).

One of the most widely used frameworks for valuing ecosystem services is the Total Economic Value (TEV). It looks at the utilitarian value of ecosystems and disaggregates into two categories, namely, use values and non-use values (Figure 4) (Abson et al., 2011). The use value of ecosystem services is associated with the direct or indirect consumption, of the benefits derived, as a commodity or an input in producing marketed commodities etc. Option value is the value placed on the option of utilizing a resource in future. Non-use value (or passive use value) is derived from the knowledge that the resource exists (Fisher et al., 2009; De Groot et al., 2010).

The valuation methods for ecosystem service assessment can be determined by exploring the type of values we are trying to elicit for each ecosystem service, with the help of the TEV framework (Table 4) (Pascual et al., 2010).

Table 4: 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)

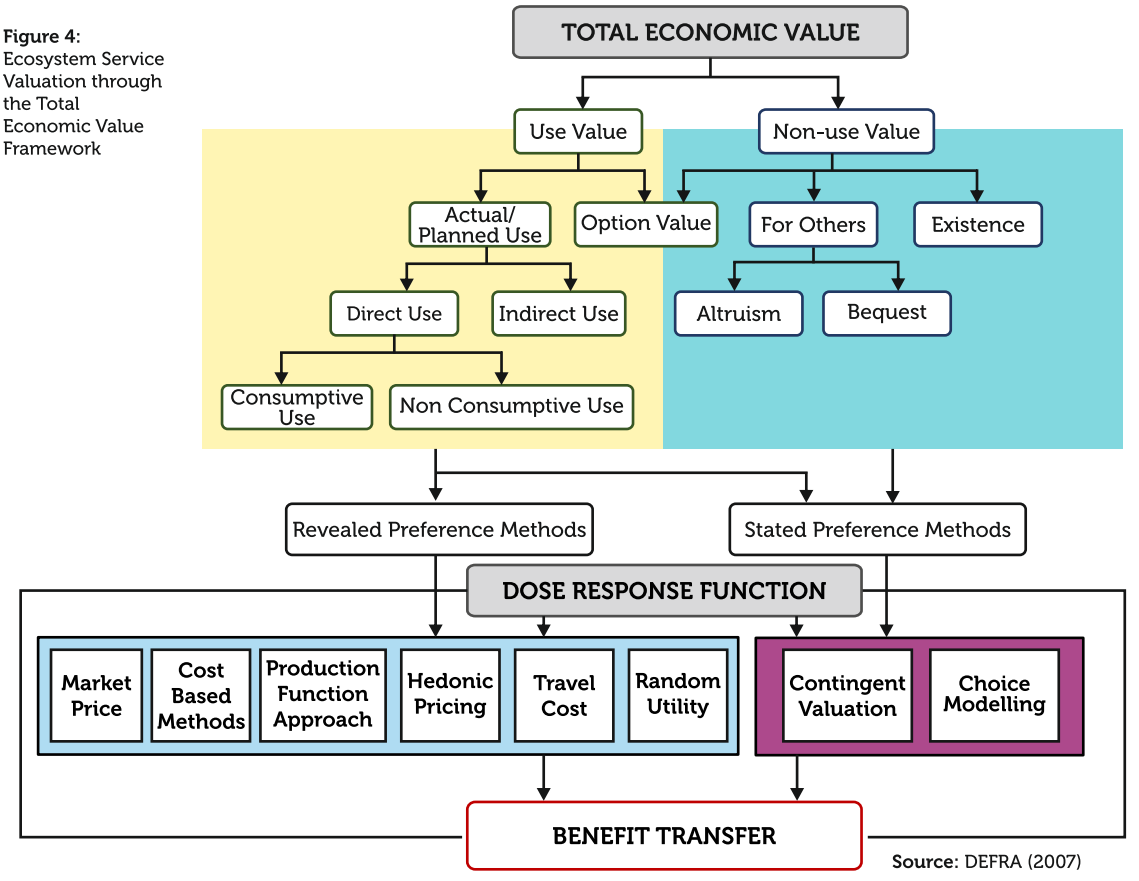


Figure 4: Ecosystem Service Valuation through the Total Economic Value Framework

Source: DEFRA (2007)

The methodology for evaluating the selected ecosystem services has been developed based on the objective of the evaluation i.e. 'economic appraisal of the ecosystem services provided by the Ganga River', the resources (time, cost and man power) required to execute the methods and the accuracy of results (Table 5).

Table 5: Methodology for assessing the value of selected Ganga River Ecosystem Services

Ecosystem Service	Study Area	Value Type		
			Method	Description
Water for Drinking & Domestic use	Middle Ganga, Lower Ganga	Direct	Market Price	Monetary value of the river water (including groundwater) used for drinking and domestic use by the general populace will be assessed by using the water tariffs charged by the city/state administration as a proxy.
Water for Agriculture	Middle Ganga, Lower Ganga	Direct	Market Price, Production Function	Assessing the relationship between cropping pattern (including yield) and availability of river water (including groundwater) for irrigation. Area along the river and the canal abstracting water from the river will be studied.
Water for Industry	Middle Ganga, Lower Ganga	Direct	Market Price, Production Function	Assessing usage of water in the production process of select water intensive industries along the river. Analysing changes in the production process of their respective commodities that will result due to changes in the availability of water.
Power Generation (Hydro)	Upper Ganga	Direct	Market Price	Tariffs for electricity will be used as a proxy for the value of hydropower generated by various dams. The policy regarding the supply of electricity to other states will studied as well in order to understand the significance of the production of electricity for the state as an entity.
Power Generation (Nuclear & Thermal)	Middle Ganga, Lower Ganga	Direct	Market Price, Production Function	Assess the usage of water in the production of nuclear and thermal energy. Analyse the changes in the production of electricity due to changes in the availability of water.
Transportion	Lower Ganga	Direct	Avoided Cost	Assessing the efficiency (time and cost) achieved in transporting goods via water in comparison to other means of transport (road, rail and air).

Valuation Methodology		
Data Source	Data Constraints	Reference
Data on annual river discharge will be collected from the Central Water Commission. Data on water tariffs will be collected from the appropriate city or state department. Questionnaire survey of local communities to assess the extraction of water for drinking and household uses.	Procedural delays in gathering data from Government departments/ agencies. Extreme weather conditions may influence primary data collection.	Toolkit for Ecosystem Service Site-Based Assessment (http://tessa.tools/) Young, 2010
Data on water abstractions pertaining to irrigation will be gathered from State Irrigation Departments and Central Water Commission. Data on cropping pattern will be gathered from State Agricultural Departments. Questionnaire survey (structured) of the local farmers to assess the extraction of water for irrigating fields.	Procedural delays in gathering data from Government departments/ agencies. Lack of information of usage of water (surface or ground) for various purposes. Extreme weather conditions may influence primary data collection.	Kelemen et al., 2015 Young, 2010
Data on industrial water use from select water intensive industries will be collected by interviewing industry representatives.	Data collection is contingent upon the cooperation of industry representatives.	Kelemen et al., 2015 Young, 2010
Data on power generated will be collected from the Central Government, State Government and Private sector developers of hydropower.	Procedural delays in gathering data from Government departments/ agencies.	Wang et al., 2010
Data on power generated and the abstraction and usage of water as a coolant will be collected from NPCIL and NAPS for nuclear power, and the relevant Central Government, State Government and Private sector developers for thermal power.	Procedural delays in gathering data from Government departments/ agencies.	Kelemen et al., 2015 Young, 2010
Data on goods transported via water will be gathered from Kolkata Port Trust, Inland Waterways Authority of India and Farakka Barrage Project. Data on costs incurred and time taken to transport by other means of transport will be gathered by interviewing representatives from the associated Government departments and transport companies.	Procedural delays in gathering data from Government departments/ agencies. The desired information might not available. Data collection from the private sector is contingent upon their cooperation.	Kelemen et al., 2015

Ecosystem Service	Study Area	Value Type	Method	Description
Fish	Middle Ganga, Lower Ganga	Direct	Market Price, Replacement Cost	Value of fish will be based upon both the diversity and the catch. Focus will be placed upon commercially viable or important species. Monetary value will be estimated by assessing the cost of replacing the fish production in the river with pisciculture.
Riverine Vegetation	Middle Ganga, Lower Ganga	Direct	Market Price	Assessing the usage of riverine vegetation for various purposes such as thatching, basket and mat weaving etc. The significance of livelihood generated will be evaluated.
Riverbed Material	Upper Ganga, Middle Ganga, Lower Ganga	Direct	Market Price, Production Function	Riverbed material mined from the river is primarily used for construction. Its value will be estimated by using the market price as a proxy and by studying the changes in the construction sector vis-a-vis the availability of sand etc.
Soil Fertility & Soil Formation	Middle Ganga, Lower Ganga	Indirect	Production Function, Avoided Cost	By focusing on the relationship between agricultural productivity and soil fertility, the value will be inferred by evaluating the changes in agricultural production with respect to changes in the fertility of soil. Comparison will be made between areas close to the river and areas farther away. Difference in the usage of fertilizer will also be estimated between the two areas.
Water purification & waste management	Upper Ganga, Middle Ganga, Lower Ganga	Indirect	Avoided Cost	Value will be assessed by estimating the treatment, monitoring and administrative costs of setting up a water treatment plant.
Cultural Services	Upper Ganga, Middle Ganga, Lower Ganga	Direct & Indirect	InVEST, Qualitative Assessment via Participatory and Deliberative Methods	InVEST is a GIS based software package with spatially explicit models that use maps as sources of information and produces maps as outputs. The InVEST recreation model quantifies the recreational value of an ecosystem by predicting the "spread of person-days of recreation", based on factors that influence people's decisions to visit any site. A qualitative assessment of the cultural and religious significance of the Ganga River. Value of water-based recreation and sports will be assessed as well.

Valuation Methodology		
Data Source	Data Constraints	Reference
Data will be collected from State Fisheries Department, Fishing cooperatives, landing sites. Semi structured and structured questionnaire-based interviews with local fishermen.	Procedural delays in gathering data from Government departments/ agencies. Extreme weather conditions may influence primary data collection.	Grizzetti et al., 2016
Semi structured and structured questionnaire-based interviews with local communities and market survey.	Extreme weather conditions may influence primary data collection.	Iponga et al., 2018
Data will be collected from the state geology and mining departments regarding allotments of licenses for riverbed mining. Market survey and a survey of the construction sector to assess the value of product.	Procedural delays in gathering data from Government departments/ agencies. Data collection from the private sector is contingent upon their cooperation.	Grizzetti et al., 2016 Kelemen et al., 2015
Data on cropping pattern and agricultural production will be gathered from the State Agricultural Departments. Questionnaire survey (structured) of local farmers regarding agriculture production and fertilizer usage.	Procedural delays in gathering data from Government departments/ agencies. Lack of information. Extreme weather conditions may influence primary data collection.	Grizzetti et al., 2016 Brady et al., 2015 Badola et al., 2010
Information on pollutants and their dilution will be collected from secondary sources and river survey. Data on cost of setting up a water treatment plant will be gathered by visiting similar plants and the relevant Government Departments, in charge of setting up sewage treatment plants.	Procedural delays in gathering data from Government departments/ agencies. Lack of information.	https://www.oecd.org/env/outreach/AM%20Water%20Value.pdf
InVEST uses geotagged photographs posted to the website Flickr as a proxy for visitation in order to parameterize the model. Information will be collected from the State Tourism Departments regarding visits by tourists.	InVEST uses data from Flickr (from 2005 to 2014). This data is primarily indicative of the recreational value of tourist savvy sites along the Ganga. Individual biases in information gathered via participatory and deliberative methods.	The Natural Capital Project. (https://naturalcapitalproject.stanford.edu/invest/) Wood et al., 2013.

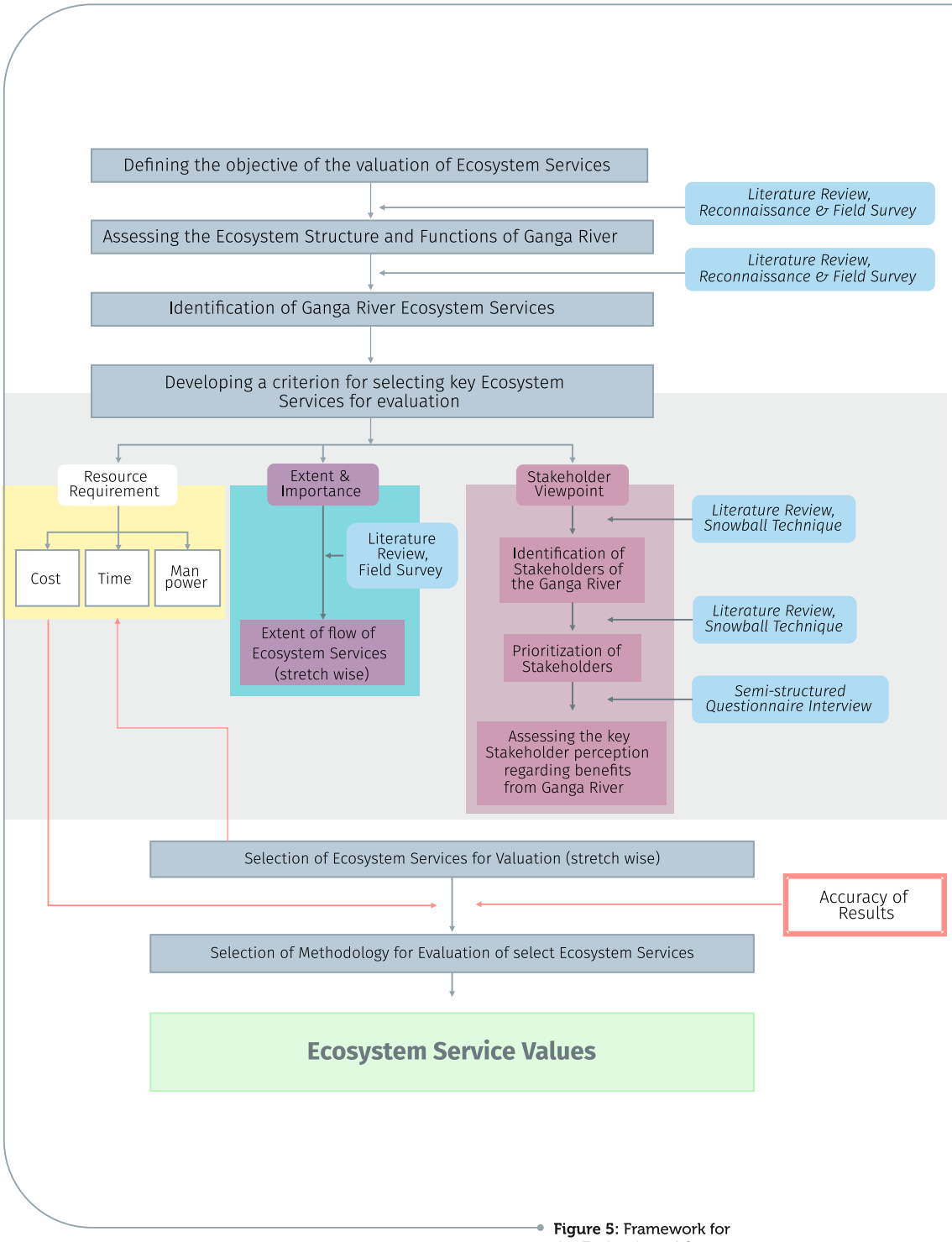


Figure 5: Framework for the Evaluation of Ganga River Ecosystem Services

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.

Badola, R., Hussain, S. A., Mishra, B. K., Konthoujam, B., Thapliyal, S., & Dhakate, P. M. (2010). An assessment of ecosystem services of Corbett Tiger Reserve, India. The Environmentalist, 30(4), 320-329.

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.

Brady, M. V., Hedlund, K., Cong, R. G., Hemerik, L., Hotes, S., Machado, S., ... & Thomsen, I. K. (2015). Valuing supporting soil ecosystem services in agriculture: a natural capital approach. Agronomy Journal, 107(5), 1809-1821.

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

Ciftcioglu, G. C. (2017). Assessment of the relationship between ecosystem services and human wellbeing in the social-ecological landscapes of Lefke Region in North Cyprus. Landscape ecology, 32(4), 897-913.

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.

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

Dobriyal, P., Qureshi, A., Badola, R., & Hussain, S. A. (2012). A review of the methods available for estimating soil moisture and its implications for water resource management. Journal of Hydrology, 458, 110-117.

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

Gopal, B. (2016). A conceptual framework for environmental flows assessment based on ecosystem services and their economic valuation. Ecosystem Services, 21, 53-58.

Grizzetti, B., Lanzanova, D., Liquete, C., Reynaud, A., & Cardoso, A. C. (2016). Assessing water ecosystem services for water resource management. Environmental Science & Policy, 61, 194-203.

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

Hancock, J. (2010). The case for an ecosystem service approach to decision-making: an overview. The International Journal of Student Research, 3(2), 188–196.

Iponga, D. M., Mikolo-Yobo, C., Lescuyer, G., Assoumou, F. M., Levang, P., Tieguhong, J. C., & Ngoye, A. (2018). The contribution of NTFP-gathering to rural people's livelihoods around two timber concessions in Gabon. Agroforestry Systems, 92(1), 157-168.

Kelemen, E., Barton, D., Jacobs, S., Martín-López, B., Saarikoski, H., Termansen, M., Bela, G., Braat, L., Demeyer, R., García-Llorente, M., Gómez-Baggethun, E., Hauck, J., Keune, H., Luque, S., Palomo, I., Pataki, G., Potschin, M., Schleyer, C., Tenerilli, P., Turkelboom, F. (2015). Preliminary guidelines for integrated assessment and valuation of ecosystem services in specific policy contexts EU FP7 OpenNESS Project Deliverable 4.3., European Commission FP7

Lavorel, S., Bayer, A., Bondeau, A., Lautenbach, S., Ruiz-Frau, A., Schulp, N., ... & Arneth, A. (2017). Pathways to bridge the biophysical realism gap in ecosystem services mapping approaches. Ecological Indicators, 74, 241-260.

Martínez-Sastre, R., Ravera, F., González, J. A., Santiago, C. L., Bidegain, I., & Munda, G. (2017). Mediterranean landscapes under change: Combining social multicriteria evaluation and the ecosystem services framework for land use planning. Land Use Policy, 67, 472-486.

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

OECD. https://www.oecd.org/env/outreach/AM%20Water%20Value.pdf Accessed on 14th August, 2018.

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.

Pascual, U., Muradian, R., Brander, L. Gómez-Baggethun, E., Martín-López, B., Verma, M., Armsworth, P., Christie, M., Cornelissen, H., Eppink, F., Farley, J., Loomis, J., Pearson, L., Polasky, S., (2010). TEEB: the Ecological and Economic Foundations - Chapter 5 – The economics of valuing ecosystem services and biodiversity.TEEB Publication.

The Natural Capital Project. (https://naturalcapitalproject.stanford.edu/invest/) Accessed on 9th August, 2018.

Tietenberg, T. H., & Lewis, L. (2016). Environmental and natural resource economics. Routledge.

Toolkit for Ecosystem Service Site-Based Assessment (http://tessa.tools/) Accessed on 14th August, 2018.

Wang, G., Fang, Q., Zhang, L., Chen, W., Chen, Z., & Hong, H. (2010). Valuing the effects of hydropower development on watershed ecosystem services: Case studies in the Jiulong River Watershed, Fujian Province, China. Estuarine, Coastal and Shelf Science, 86(3), 363-368.

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.

Wood, S. A., Guerry, A. D., Silver, J. M., & Lacayo, M. (2013). Using social media to quantify nature-based tourism and recreation. Scientific reports, 3, 2976.

Young, R. A. (2010). Determining the economic value of water: concepts and methods. Routledge.

Photo credits
Front cover & front inside photo: Goura Chandra Das,
Back cover & back inside photo: Vinay K. Bhargava,
Goura Chandra Das,
Vinay K. Bhargava,
Pariva Dobriyal,
Amanat K. Gill
Megha Shruti

Citation
WII-GACMC (2018). Framework for evaluating ecosystem services of Ganga River. Ganga Aqualife Conservation Monitoring Centre, Wildlife Institute of India, Dehra Dun. Uttarakhand, India Pp. 20

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

GANGA AQUALIFE
CONSERVATION
MONITORING CENTRE

Post Box #18, Chandrabani
Dehradun - 248001
Uttarakhand, India
t.: +91 135 2640114-15, 2646100
f.: +91 135 2640117

wii.gov.in/nmcg/national-mission-for-clean-ganga

XPRESSIONS: 9219552563 | DOC. NO. XPS2008181483