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Draft Report

05 Economics of Biodiversity and Ecosystem Services of Rivers for Sustainable Management of Water Resources

THE ECONOMICS OF ECOSYSTEMS AND BIODIVERSITY-INDIA INITIATIVE

WETLANDS

Ministry of Environment, Forest and Climate Change
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- The Economics of Ecosystems and Biodiversity - India Initiative (TII)
- India Business and Biodiversity Initiative (IBBI)
- Conservation and Sustainable Management of Existing and Potential Coastal and Marine Protected Areas
- Himachal Pradesh Forest Ecosystem Services Project
- Access and Benefit Sharing Partnership Project

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Economics of Biodiversity and Ecosystem Services of Rivers for Sustainable Management of Water Resources

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THE ECONOMICS OF ECOSYSTEMS AND BIODIVERSITY-INDIA INITIATIVE

The Economics of Ecosystems and Biodiversity – India Initiative (TII) aims at making the values of biodiversity and linked ecosystem services explicit for consideration and mainstreaming into developmental planning. TII targets action at the policy making levels, the business decision level and awareness of citizens. TII has prioritized its focus on three ecosystems - forests, inland wetlands, and coastal and marine ecosystems - to ensure that tangible outcomes can be integrated into policy and planning for these ecosystems based on recommendations emerging from TII.

In addition to the existing knowledge, TII envisions establishing new policy-relevant evidences for ecosystems values and their relation to human well-being through field-based primary case studies in each of the three ecosystems. In response to an open call for proposals for conducting field-based case studies in the context of relevant policy or management challenges for conservation and the sustainable use of biodiversity and ecosystem services, over 200 proposals were received. A Scientific and Technical Advisory Group (STAG), comprising eminent ecologists and economists, appraised the proposals and recommended 14 case studies for commissioning under TII.

These studies in forests deal with issues such as hidden ecosystem services of forests, conflicts between humans and wildlife, and the economic consequences of species decline. In wetlands, the studies draw lessons on water resources management, community stewardship and equity, and the economics of hydrological regime changes. In coastal and marine ecosystems, the studies explore the opportunities and economic efficiency of interventions such as eco-labelling, seasonal fishing bans, mangrove regeneration, and the challenge of bycatch in marine fisheries.

The reports of these 12 case studies have been published in this TII series.

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KEY MESSAGES

River Ken, a tributary of the Yamuna, regulates groundwater recharge and provides riparian vegetation, fish and sand. Its biodiversity, two waterfalls and the Panna Tiger Reserve are tourist attractions. In light of proposed diversion of water from Ken, it is crucial to note that any change in flow may stifle ecosystem services.

FINDINGS

- Sand extracted from the lower reaches is used extensively in Uttar Pradesh. The annual value is around **₹25.75 billion** (**US$ 429m**).
- The value of fish varies from **`300,000** (**US$ 5,000**) to **₹1.7 million** (**US$ 28,333**) at different fishing sites during winter.
- Panna Tiger Reserve, Raneh falls and a Gharial sanctuary have a combined value of **₹76.9 million** (**US$ 1.3m**) per year.
- Invasion by the exotic common carp is already an indicator of reduced river flow.
- So far, the river has remained in near pristine state because of little urban or industrial development and a largely rainfed agriculture in its basin, but the downstream areas in Banda, Panna and Chhatarpur districts will be impacted by the proposed flow diversion.

RECOMMENDATIONS

- Assess impact of flow diversion on downstream areas in terms of groundwater recharge, sand, fish, riparian vegetation and water quality.
- The river has to be monitored over at least a 2-year period for flow, groundwater and human uses.
- A detailed policy should be formulated to regulate sand extraction based on its annual availability.
- Other smaller rivers should be studied to develop an appropriate methodology and framework for evaluation of river ecosystem services.
- The forests, wildlife and river are interdependent, so benefits from the forest should be accounted for in the ecosystem services of the river.

Photo: Brij Gopal

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EXECUTIVE SUMMARY

Economics of Biodiversity and Ecosystem Services of Rivers for Sustainable Management of Water Resources

Wetlands are now well known to provide many ecosystem services for human well being. According to Ramsar Convention, wetlands include a wide spectrum of aquatic ecosystems – both inland and marine – including rivers. Rivers differ from other wetlands in many characteristics; yet most wetlands lie within a river basin and are connected to the river through the hydrological cycle.

Studies and experiences worldwide show that the diversion and abstraction of water from rivers for various uses seriously impacts the riverine and associated wetland ecosystems, both upstream and downstream of the diversion structures. Such practices adversely affect wetland biodiversity and ecosystem goods and services, on which the local communities particularly depend. Reduction in flow alone causes some loss of biodiversity and ecosystem services which are not yet accounted in the cost-benefit analysis of the water resources development projects

Whereas several ecosystem services of a few wetlands in India have been assessed and their economic values have been estimated, the ecosystem services of rivers have not been assessed or discussed so far. The present short-term study (September 2014 to April 2015) is the first attempt of its kind to assess some of the ecosystem services of River Ken (in the Ganga river basin) in relation to its biodiversity. The study aims to understand the river's ecosystem services, develop a methodology and provide baseline data for evaluation of the changes in ecosystem services and their values. Such an assessment based on all or most of the ecosystem services can be used to compare the losses and gains against the net gains from the use of diverted water over different time scales. The study aims therefore to contribute to the policies related to biodiversity and water resources management besides overall environmental conservation.

River Ken – a major tributary of River Yamuna – forms a single thread channel with rocky or boulder bed, flows through deeply incised undulated terrain that results in steep rocky banks, with poorly developed riparian fringes, and passes through several gorges, making scenic falls. River Ken is currently in near-pristine state because of practically no urban or industrial development (except the Banda city in its lower reaches) and largely rainfed agriculture in its basin. The river hosts the Panna National Park – a tiger reserve, and a gharial sanctuary, along with two falls as tourist attraction. It supports fairly high fish and other aquatic biodiversity. Unfortunately, River Ken is the least investigated river, and preliminary information was only published during the past 4-5 years.

During this study, available published and unpublished studies were collected, a large part of the river basin was physically surveyed and river morphology, water quality, and biodiversity were

River Ken is in near-pristine state. It is subject to practically no urban or industrial development and largely rainfed agriculture in its basin. The river hosts the Panna National Park, two waterfalls as tourist attractions, and fairly high aquatic biodiversity. Unfortunately, research on River Ken is minimal, with preliminary information first published during the past 4-5 years

documented. Human use of the river was assessed and focused group discussions were organised with the local community and other stakeholders in more than 30 villages.

Two provisioning ecosystem services (sand and fisheries and a cultural-recreational service -– ecotourism related to PTR) have been assessed, and their economic values estimated using standard market prices and Travel Cost methods. Other ecosystem services (water supply for domestic use and irrigation, groundwater recharge and riparian agriculture) have been examined and described in qualitative and semi-quantitative terms. More emphasis is laid on the downstream areas in Banda, Panna and Chhatarpur districts, where it is believed the river is impacted more by the proposed flow diversion project. Normally, water supply for irrigation and drinking water would be the most important and valuable ecosystem service of the river, but in the case of River Ken, human populations depend mostly on groundwater. In Banda town as well, where drinking water is lifted directly from the river, its contribution is only about 30% of the total domestic water requirement. Our survey, however, indicates that the river does play a significant role in the groundwater recharge along its course, with large annual and seasonal changes in the groundwater table (3 to 8 m). Its value was not assessed in the absence of adequate time-series data that can be correlated with river flows. The river has been supporting agriculture through Bariyarpur canal system for above 100 years, but irrigated only 66,500 to 85,000 ha during 1994-99 (although designed to serve a command area of 2.3 lakh ha). An estimated 127 cusecs of water is abstracted by the lift irrigation schemes to irrigate about 5000 ha.

The sand extracted from River Ken is of the highest quality, which is why it is preferred and extensively used in many districts of UP. The value of the sand extracted in downstream areas alone is estimated at ₹2500 crores annually from the leased mines, and at least ₹75 crores annually by other individuals in the adjacent villages. Of particular interest are the livelihoods of hundreds of families, who extract small amounts of sand and transport it on ponies to the narrow bylanes of Banda city. River Ken supports a high diversity of fishes, of which 9 species are rare, endangered and vulnerable, and some are restricted to reaches upstream of Ganga weir only. Fish have been estimated to contribute about ₹2 lakhs to ₹17 lakhs during winter season alone in four different downstream stretches, from Banda to Chilla Ghat, but a total economic value from the river has not been attempted, because the study was made only during the low flow period.

An important observation, however, is the spread of exotic common carps in the lower reaches of the river, where flow has been reduced since the diversion at Bariyarpur. The river also contributes significantly to the sustenance of the Panna Tiger Reserve & National Park. The falls on the river are important recreational sites, and the river directly supports the gharial, mugger, mahaseer, and several endangered and vulnerable species of fish. Based on the average values computed for other tiger reserves in India, the Panna Tiger Reserve itself has an estimated value of ₹369 crores annually for its various ecosystem services. We estimate the ecotourism value of the PTR at 7.69 crores by the Travel Cost method. Other ecosystem services of major importance include waste assimilation potential, which will be appreciated only after wastewaters increase with the development in the area. There are also many river-dependent livelihoods, such as riparian agriculture, that could not be valued but are described qualitatively. In fact, the ecotourism potential of the River Ken (e.g., sites of geo-heritage importance) has not yet been explored.

The impacts of the century-old flow diversion on the downstream system are impossible to assess due to total lack of information on the river. May be it has been minimal so far because of the very low population density and limited direct dependence on the river, as well as lack of development in the region. Today, Banda remains one of the most backward districts in India. However, the invasion of the river by the exotic common carp (Cyprinus carpio) is definitely a positive indicator of the altered and lower flow regime.

It is concluded that the ecosystem services of River Ken obtained by humans are over- whelmed at present by the sand, whereas the water use for irrigation and domestic supplies is minimal, because of the characteristics of the basin terrain and low human population. It must be realised that the biodiversity-rich forest landscape of the Panna Tiger Reserve is also sustained by the river and the value of the PTR attributable to the River Ken includes visits for its gorges, falls, gharial, mugger, and boating. The low economic value of fisheries is not an indicator of the river's potential, but reflects the social and cultural factors besides the protection from fishing in a large part of the river. Further, the value of groundwater recharge from the river has not yet been assessed, and would expectedly be high because of dependence on it for most water needs.

A longer-term comprehensive study that draws upon time-series data on various biophysical and socio-economic parameters is required for improved assessment of ecosystem services and their valuation. It is cautioned that the proposed diversion of river flow is likely to cause significant economic losses downstream besides to the Tiger Reserve and the riverine biodiversity.

We recommend the following.

(a) Detailed studies should be undertaken to assess various ecosystem services and their value, which must be considered in the cost-benefit analyses of the water resources development projects in river basins.
(b) Groundwater recharge, sand, fish, riparian vegetation/agriculture and water quality regulation are major ecosystem services obtained in downstream areas that should be examined for the likely impacts of flow alterations.
(c) Sand contributes also to other ecosystem services (such as habitat support), which are adversely affected by its over-exploitation, and therefore a detailed policy should be formulated to regulate its extraction after considering its annual availability.
(d) The forests and the wildlife therein also depend upon the river as much as the river depends upon the forests. Forests regulate the flow and water quality, and indirectly the biodiversity of the rivers, and the rivers contribute to the sustenance of the forest. The benefits from the forest should therefore be accounted for in the ecosystem services of the rivers.
(e) Several studies on other smaller rivers should be undertaken to develop an appropriate methodology and framework for evaluation of rivers' ecosystem services.

1. Background

1.1. Ecosystem Services

Human evolution is a process dependent upon and embedded in Nature. However, during the past few centuries, humans made technological advancements that allowed them to exploit nature to their advantage and also to gain control over it. The resultant decline and degradation of natural resources raised concern about the impacts of human actions on their own well being in the future. Among many approaches to promote the conservation of nature was the conceptualisation of an utilitarian view of nature through the notion of 'nature's services' or 'environmental services' (SCEP 1970). The field was first formalised by Ehrlich and Ehrlich (1981), who introduced the term 'ecosystem services', then elaborated by Daily (1997), who defined ecosystem services as "the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life". The ecosystem services turned into an international buzzword after the Millennium Ecosystem Assessment (MEA 2005) defined them simply as "the direct and indirect benefits derived by humans from the functions of the ecosystems". The Millennium Ecosystem Assessment focused specially on direct and indirect linkages between ecosystem services and human well-being (including poverty alleviation). The numerous benefits derived by humans from different ecosystems have also been categorised variously over the past decade or so (DeGroot et al. 2002, Wallace 2007, 2008, Fisher and Turner 2008, Costanza 2008, Fisher et al. 2009, Haines-Young and Potschin 2011, 2013). Although their grouping of ecosystem services into Provisioning, Regulating, Cultural and Supporting services is followed most commonly, a simpler listing of ecosystem services is quite useful, because some benefits fall in more than one category. For example, the biomass production in an ecosystem is not only a provisioning service, as it can be used directly, but is also a regulating service, inasmuch as it contributes to carbon sequestration and, hence, mitigating climate change. Water is often considered to be a provisioning service of aquatic ecosystems, however they do not produce water, they simply make it available through storage and transport and provide a regulating service by regulating its distribution and quality. A recently developed classification of ecosystem services is presented in Table 1.

1.2. TEEB

Recognising that the biodiversity in ecosystems plays the most critical role in the functioning of ecosystems, and hence their ecosystem services, an international study lead by Dr Pavan Sukhdev, The Economics of Ecosystems and Biodiversity (TEEB), showed that "economic concepts and tools can help equip society with the means to incorporate the values of nature into decision making at all levels" (TEEB 2010). According to the TEEB Report, "applying economic thinking to the use of biodiversity and ecosystem services can help clarify two critical points: why prosperity and poverty reduction depend on maintaining the flow of benefits from ecosystems; and why successful environmental protection needs to be grounded in sound economics,

Table 1: The CICES classification of ecosystem services based on the broad MEA types (adopted from Weber 2011)

MEA type	Class	Generic examples
Provisioning	Nutrition	Plant and animal food stuffs, potable water
	Materials	Biotic and abiotic materials
	Energy	Renewable bio-fuels, renewable abiotic energy sources (hydropower, wind, tidal)
Regulating	Regulation of wastes	Bioremediation, dilution, sequestering
	Flow regulation	Flow of air, water or mass
	Regulation of the physical environment	Atmospheric, water quality, soil quality
	Regulation of the biotic environment	Life cycle maintenance and habitat protection, pest and disease control, gene pool protection
Cultural	Symbolic	Aesthetic, heritage, religious and spiritual
	Intellectual and experiential	Recreation and community activities, information and knowledge

Wetlands are generally among the most productive ecosystems. They support high biodiversity and are an invariably important link in the hydrological cycle, particularly at the local and regional scales. There exists an intimate relationship between wetlands and their surroundings, and they must be managed together

including explicit recognition, efficient allocation, and fair distribution of the costs and benefits of conservation and sustainable use of natural resources".

According to Sukhdev et al. (2014), the TEEB initiative seeks to draw attention to the invisibility of nature in economic choices, an invisibility that is "a key driver of the ongoing depletion of ecosystems and biodiversity". TEEB considers that valuation can play a major role in stemming the rising tide of degradation of ecosystems and the loss of biodiversity (Sukhdev et al. 2014).

1.3. Wetlands

Wetlands include a very wide range of ecosystems where water is the predominant component of the physical environment and thereby affects all ecosystem attributes and functions. The Ramsar Convention (Ramsar Convention Secretariat 2013) defines wetlands as "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres".

According to the Ramsar Convention, wetlands "may incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six metres at low tide lying within the wetlands".

The wide spectrum of wetland habitats thus covered by the Ramsar Convention's definition includes marine coastal lagoons, rocky shores and coral reefs; estuarine (including deltas, tidal marshes, and mangroves); lakes and their littoral areas; rivers and their floodplains; various other marshes, swamps, bogs and fens; as well as human-made or modified habitats such as aquaculture, farm ponds, paddy and similar agricultural lands, salt pans, reservoirs, gravel pits, sewage farms and canals.

Wetlands are generally among the most productive ecosystems and support often very high biodiversity (Gopal and Masing 1990, Gopal 2009). They are invariably an important and critical link in the hydrological cycle, especially at the local and regional scale. It is now well-recognised that there exists an intimate relationship between wetlands and the landscape of which they are an integral part at the river basin scale, and that neither of them can be managed independently (also see Russi et al. 2013). The value of wetlands to humans has been known for millennia, as most of them depend upon wetlands for their food (fish and rice in particular), and throughout their evolutionary history humans have utilised wetlands for various resources for their sustenance, besides water. In this context, Gopal (2015) has argued that the term wetlands should be restricted to shallow water habitats with predominant influence of macrophytes which contribute most to their ecosystem services and should be distinguished from deep open water systems such as lakes, reservoirs and rivers (see also the next section).

1.3.1. Rivers and their Ecosystem Services

Rivers have been the cradle of human civilisation. Humans learned agriculture and perfected it in the floodplains of rivers in Asia (Tigris-Euphrates, Yangtse and Indus). Fishing in rivers predated agriculture. Humans were also aware of the renewal of soil fertility in the floodplains by the annual floods and of the rivers' potential for assimilating the wastes.

Rivers form the main link in the hydrological cycle, carrying back the precipitation over land to the oceans. However, they have been greatly misunderstood, and treated as mere conduits and source of water. Only during the past couple of decades has an ecosystem perspective of the rivers developed (see Gopal 2013).

The Ramsar Convention has expanded its scope to include the rivers also as wetlands, which already cover a very wide range of disparate habitats. Ramsar Convention (2013) states that, "It is also worth emphasising that lakes and rivers are understood to be covered by the Ramsar definition of wetlands in

It needs to be pointed out that in India, the MOEF-CC adheres to the Ramsar Convention in considering rivers as wetlands. In our view, rivers must be distinguished from other wetlands because they constitute a single system from their sources to their mouths

their entirety, regardless of their depth". The only characteristic common to diverse kinds of wetlands is water as the dominant component of their physical environment that regulates all structural and functional attributes of different wetlands. It is also widely recognised that all kinds of wetlands are linked together within a river basin through the hydrological cycle even though they may not be physically connected.

It needs to be pointed out that in India, the Ministry of Environment and Forests (now MOEF-CC) adheres to the Ramsar Convention in considering rivers as wetlands. The stretch of river Ganga from Braj ghat to Narora in UP, and the Wular Lake (in Jammu & Kashmir) through the River Jhelum flows, are designated Ramsar sites. Major reservoirs on rivers such as Harike and Pong Dam are also Ramsar sites. However, the rivers and paddy fields were excluded from the wetlands covered by the regulatory provisions of Wetland Rules, 2010, for practical reasons.

In our view, the rivers must however be distinguished from other wetlands because they constitute a single system from their sources to their mouths (confluence with the larger water body, generally the sea) that comprises of a network of numerous small to large streams; rivers transfer materials, energy and biota, especially longitudinally and laterally, depending upon their flow regimes. Most often, they traverse large landscapes that vary along the river courses in their geology, geomorphology, climate and anthropogenic influences. Thus, the rivers differ greatly among themselves as well as along their course. They may or may not be associated with some wetlands along their course. The rivers in their mountainous or hilly stretches generally flow along a steep gradient and through relatively narrow, straight and V or U-shaped channels, without developing a distinct floodplain. Floodplains develop along low gradient rivers depending upon the geology of the terrain, flow regimes and sediment loads of the river.

Although, for millennia, the river flows have been diverted for agriculture, rivers have been increasingly exploited for their water during the past century or two, through the construction of large dams for storage and the diversion of their flows for irrigation, domestic and industrial supplies, and hydropower. Further habitat alterations have occurred by constructing embankments and through the discharge of domestic, industrial, and solid wastes. The impacts of such flow diversion and habitat alterations on the biodiversity and ecosystem functions of rivers and associated wetlands have been highlighted in many studies (Bunn & Arthington 2002, Giller et al. 2004, Dudgeon et al. 2005, Poff & Zimmermann 2010), and a considerable amount of published literature has appeared on the need and methodologies for maintaining environmental flows for sustaining the ecological integrity of rivers (Arthington 2012, Gopal 2013).

1.3.2. Ecosystem Services of Rivers

The ecosystem services of rivers and their valuation have started receiving some attention only recently. Most studies on the economic valuation of the ecosystem services of rivers have focused only on recreation, fisheries, and the functions of floodplain wetlands such as groundwater recharge, water quality improvement and habitat provision (Amigues et al. 2002, Hitzhusen 2007, Karanja et al. 2008, Morris and Camino 2011, see also bibliography by National Park Service 2001; http://blog.lib.umn.edu/polasky/ecosystem/). Loomis et al. (2000) used Contingent Valuation to assess the costs of restoration of a highly polluted river. Straton and Zander (2009) discussed the ecosystem services of rivers in Australia in a broader perspective, but valuations of ecosystem services of rivers on a basin scale are rare (see

DeGroot et al. 2008, Batker et al. 2010, 2014, Zander and Straton 2010, Kaval 2011, James et al. 2014). A few studies have used economic inputs into modeling for river basin management (Caix et al. 2003, Heinz et al. 2007). Studies on the ecosystem services of rivers have been initiated in Europe only very recently, under the Framework Programme-7 of the EU (Vermaat et al. 2014). Yet TEEB considers the rivers along with other wetlands, following the Ramsar Convention (Russi et al. 2013). Following this, Wetlands International has recently highlighted the importance of the valuation of the ecosystem services of rivers in the context of their restoration (Burgos and Honey-Rosés 2013).

In India, the ecosystem services of rivers as such have never been examined. The only relevant study is that of Markandya and Murty (2001), who estimated the cost of providing and maintaining the wastewater treatment systems in the Ganga basin and, therefore, indirectly emphasised the value of the waste assimilation service of river Ganga. Of course, there are estimates made in every water resource development project of the benefits of flow diversion accruing through irrigation, power generation, domestic water supplies and employment generation. Similar assessments were also made in the context of the programme of interlinking the rivers in India. The NCAER (2008) estimated the costs and benefits of each of the 29 proposed links in terms of their impact on enhanced agricultural production and various other sectors of economy (steel, cement, etc.). The impacts on the river ecosystem itself were not considered at all.

It may also be pointed out here that an assessment of the ecosystem services of rivers is somewhat complex because of several reasons. First, the rivers differ from terrestrial ecosystems in their biotic and abiotic components and in their temporal dynamics. Second, rivers vary in the hydrogeomorphic features from their source to the mouth and are influenced by tributaries (Rice et al. 2008) and their basin characteristics. Segments of a river entrenched in a deep, narrow, and steep valley, differ from those in the plains, where they may meander or form braided or anastamosing channels, and may have narrow or wide alluvial floodplains. The floodplains contribute most to the ecosystem services of the river as they may: (a) support and enhance the riverine biodiversity by providing numerous niches for the large diversity of plants, animals and microorganisms; (b) contribute to increased productivity by providing feeding and breeding habitats for fish and other aquatic/amphibious fauna (including birds), as well as provide nutritious forage for cattle and other grazers; (c) mitigate floods and promote groundwater recharge; (d) regulate and sustain high water quality; (e) protect river banks against erosion; (f) enhance soil fertility by retaining nutrients and fine sediments; (g) support recreation and enhance aesthetics of the riverscape/landscape; and (h) support many livelihoods based upon their natural resources. The interactions between flow, river ecosystem attributes, biodiversity and ecosystem services are shown in Figure 1.

The fact that the rivers differ in their ecosystem services according to their hydro- geomorphic features has been discussed by Thorp et al. (2010) (Table 2). It is important to note that the floodplains regularly interact with the river channels, and the downstream hydro-geomorphic patches depend upon the flows and sediments from upstream areas.

Further, ecosystem services also vary in their nature and magnitude at different spatial scales (Hein et al. 2006). For example, ecosystem services of small rivers, such as those of the Western Ghats in India, would differ greatly from those of large rivers like the Ganga and Brahmaputra. Anthropogenic interventions such as land use changes in their catchments and the discharge of wastes that affect water quality as well as flow characteristics directly also affect these ecosystem services

More recently, in the context of river restoration in Europe, Vermaat et al. (2013) recognised 22 types of rivers (including an entirely artificial river channel) based on channel and sediment characteristics (Table 3). These types include rivers with bedrock and colluvial

Figure 1: Flow of a river governs the interactions between morphology, water quality and floodplain wetlands, which affect the riverine biodiversity and consequently, a river's ecosystem services.

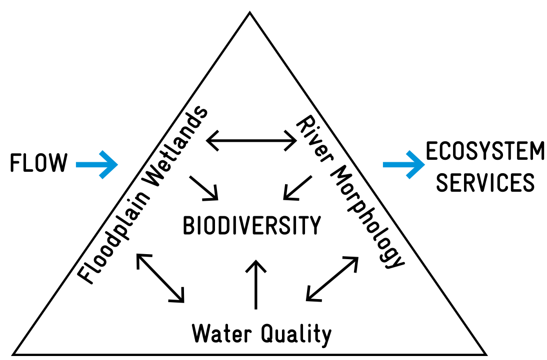

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Table 2: Relationship of ecosystem services of different kinds of rivers to their hydro-geomorphic attributes (adapted from Thorp et al. 2010).

Ecosystem services and benefits	Constricted + Straight	Meandering	Braided	Anastomosing +Anabranching	Leveed	Reservoir
Hydrogeomorphic attributes						
Sinuosity (shoreline length to downstream length ratio)	•	•●	⬤	⬤	•	●
Relative number of channels	•	•	⬤	⬤●	•	•
Functional habitats within channels	•	•●	●	⬤	•	•●
Permanence of channel/islands	●	●	•	⬤	●	⬤
Floodplain size and connectivity with main channel	•	●⬤	●	⬤	•	•
Natural ecosystem services						
Species richness and trophic diversity	•	●	•	⬤	•	●
Proportion of native biota	⬤	⬤	⬤	⬤	•	•
Primary and secondary productivity	•	●	●	⬤	•	●
Nutrient cycling and carbon sequestration	•	•●	•●	⬤	•	⬤
Water storage	•	•●	•	⬤	•	⬤
Sediment storage	•	●	●	⬤	•	⬤
Anthropocentric services						
Food and fiber production (excluding agricultural production)	•	●	•	⬤	•	●
Potential for water abstraction	●⬤	●	•	●	⬤	⬤
Recreation	•●	•●	•	⬤	•	⬤
Disturbance and natural hazard mitigation	•	●	•	⬤	⬤	⬤
Transportation/ navigation	⬤	●	•	●	⬤	⬤

The hydrogeomorphic attributes and ecosystem services are noted at three levels: • *Low;* ● *Medium and* ⬤ *High* channels; alluvial single thread channels with coarse bed material; gravel bed rivers, from sinuous via meandering and braided to anabranching; sand bed rivers (also with sinuous via meandering and braided to anabranching channels); and rivers with fine sediment cohesive alluvial sediments.

The provisioning, regulating and cultural services of these river types differ considerably (Vermaat et al. 2013; Table 4).

It is interesting to note that the ecosystem services of rivers listed in Tables 3 and 4 are apparently guided by those in wetlands such as marshes, swamps and floodplains. Whereas retention of sediments and nutrients is recognised, the more important fluvial function of transporting sediments, nutrients, organisms and organic matter is completely overlooked. The transport of sediments is accompanied by the conversion of rocks and boulders into sand and silt that are directly used by humans, and hence a provisioning service of the rivers. The transport of water and nutrients, along with the sediments, to downstream reaches regulates the fertility of floodplain soils, water quality and biodiversity.

1.4. Studies on Economic Valuation of Ecosystem Services in India

In India, studies in the economic valuation of different ecosystems started under the World Bank's Capacity Building programme at the Indira Gandhi Institute of Development Research, Mumbai (Parikh and

Table 3: Ecosystem services of river systems with examples of the benefits they provide

Ecosystem services	Examples of goods, activities and benefits provided
Provisioning	
Food	Production of fish, other aquatic and terrestrial species, fruit, and grains for recreation and subsistence hunting and gathering
Fresh water	Storage and retention of water for domestic, agricultural and other uses
Fibre and fuel	Production of logs, fuelwood, and fodder for building, cooking, etc.
Ornamental resources	Production of ornamental material
Biochemical	Production of biochemicals and medicines
Genetic materials	Production of genetic material
Regulating	
Climate regulation	Source of and sink for greenhouse gases; influence local and regional temperature, precipitation, and other climatic processes
Water regulation (hydrological flows)	Groundwater recharge/discharge
Water purification and waste treatment	Retention, recovery, and removal of nutrients and pollutants
Erosion regulation	Retention of soils and sediments
Natural hazard regulation	Flood control, storm protection
Biological control	Control of pests and diseases
Cultural	
Spiritual and inspirational	Source of inspiration for well-being and art; spiritual benefit; specific indigenous spiritual and cultural values
Recreational	Opportunities for recreational activities and tourism
Heritage	Cultural heritage and identity
Aesthetic	Appreciation of beauty or aesthetic value of the landscape
Educational	Opportunities for formal and informal education and training
Supporting	
Soil formation	Sediment retention and accumulation of organic matter
Habitat provision	Provision of habitat for wildlife feeding, shelter, and reproduction
Nutrient cycling	Storage, recycling, processing, and acquisition of nutrients

Table 4: Ecosystem services of different types of rivers (from Verma at et al. 2013)

River type (number)	Longitudinal slope	Service		
		Provisioning	Regulating	Cultural
single thread, confined in bedrock or colluvial deposits (90%) (1-3)	often steep (>5%)	hydropower, forestry products, drinking and irrigation water	carbon sequestration in forests; reduction of organic and inorganic pollutant load (in-stream 'self- purification')	trout and salmon* fly fishing, hunting, rafting, kayaking, hiking, scenic beauty of the landscape
single thread, on alluvial, coarse beds (boulders to gravel) (4-6)	fairly steep, (up to > 3%)	construction gravel, water for drinking and irrigation, forestry products, hydropower	carbon sequestration in forests; flood retention, notably when channel path >> talweg; self purification	trout and salmon* fishing, hunting, rafting, kayaking, hiking, scenic beauty of the landscape
single thread on alluvial gravel beds (sinuous, meandering) (7-10)	> 0.5%	construction sand and gravel; water for drinking and irrigation; agricultural dairy and fruit trees, crops on terraces, hydropower (reservoirs), commercial fisheries, poplar plantations	carbon sequestration in riparian woodland; flood retention in floodplain (water, sediment, nutrients); self-purification	trout and salmon* fishing, sunbathing, hiking, canoeing, swimming, scenic beauty of the landscape
multiple thread on alluvial gravel (braided, anastomosing) (11-13)	>0.5%	as above for single thread; probably more extractable gravel	as above for single thread	as above; good chance for wildlife and biodiversity in complex mosaic landscapes of islands, bars, channels and pools
single thread on alluvial sand (14, 15)	<0.5%	construction sand and gravel; water for drinking and irrigation; agricultural dairy and fruit trees, crops on terraces; hydropower (reservoirs), commercial fisheries, poplar plantations	as above for single thread gravel	angling, waterfowl hunting, sunbathing, canoeing, hiking and swimming, scenic beauty
multiple thread on alluvial sand (17, 18)	<0.2%	as above for single thread; probably more extractable sand	as above for single thread gravel	as single thread but better chance for biodiversity in complex landscapes
single thread on alluvial silts and clays (19, 20)	~0%	agriculture: dairy, meat; clay for construction, bricks and pottery; commercial fisheries; in artisanal communities reed and stems and branches are used for thatching, tools, baskets, seats and floor mats; poplar plantations	as above	angling, waterfowl hunting, sunbathing and swimming, yachting, sailing, scenic beauty
multiple thread on alluvial silts and clays (21)	~0%	as above	as above	as single thread but better chance for biodiversity in complex landscapes

Datye 2003). Wetlands – such as Keoladeo National Park (Murty and Menkhus1994, Chopra 1998), Bhoj wetland (Verma et al. 2001), Yamuna floodplain (Kumar P 2001, Kumar et al. 2001), Nainital lake (Singh and Gopal 2002), Harike (WISA 2001), Chilka (Kumar 2004, WISA 2009), Loktak (WISA 2012), Pong dam (Prasher et al.2006), Khecheopalri lake in Sikkim (Maharana et al. 2000), Varthur lake (Ramachandra et al. 2011) and several others (Islam 2009, Mukherjee and Kumar 2012, Pandit and Gupta 2005) – have been studied for biodiversity and/or hydrological functions. These studies have been reviewed by Kumar (2012) and Kumar & James (2012), and therefore not discussed here in detail. All these studies generally considered only one or two ecosystem services – mostly provisioning and cultural services, and only rarely the regulating services.

The river ecosystems have, however, escaped attention almost completely, despite their far greater services, that include sustaining wetlands. Jhunjhunwala (2010) used some examples from the USA to draw attention to the monetary value of downstream services lost due to flow storage and diversion for hydropower generation upstream. Only a preliminary study of ecosystem services of a river in India was made by Gopal and Rao (2012), who examined the impact of irrigational water use (storage and diversion) in Shivna river basin (a tributary of R. Godavari in Maharashtra) on other ecosystem services of the river. However, River Shivna being an entirely seasonal river in a semi-arid region, the only significant ecosystem services were those related to fisheries, groundwater recharge and some support to biodiversity. Economic valuation was however not attempted. In yet another study, a German student examined the ecosystem services of the highly polluted Oshiwara river in Mumbai, and described flood control and sewage transport as 'ecosystem services' (Haufe 2013). Freshwater supply, groundwater recharge, fish and recreation were identified as the ecosytem services before rapid urbanisation degraded the river into a sewer. Economic valuation was not attempted.

1.4.1. Policy and Management Context

Water resources managers are increasingly confronted with the fact that diversion and abstraction of water from the rivers for irrigation, domestic and industrial supplies and hydropower among other economic uses, seriously impacts the riverine and associated wetland ecosystems, both upstream and downstream of the diversion structures. As noted above, the rivers and wetlands (including floodplains) support a rich biodiversity and provide a range of ecosystem goods and services on which the local communities particularly depend. Reduction in flow alone can cause considerable loss of biodiversity and ecosystem services. The reduction in flows of River Ganga and other rivers has resulted in the invasion by the exotic common carps (Cyprinus carpio) and gradual decline of the native Indian Major carps. Similarly, the Farakka barrage has caused a rapid decline of the migratory hilsa fisheries in the Ganga river system. The reduced flows or their total absence for long periods have contributed to the degradation of water quality in all Indian rivers, and have resulted in declining groundwater tables, in conjunction with over-abstraction. In the absence of an understanding of ecosystem services of rivers and their value, water resources development projects do not account them in the cost-benefit analysis.

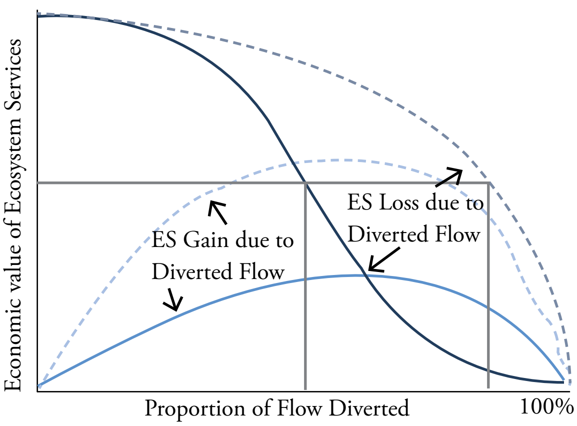
It is pertinent to emphasise here that the current environmental impact assessments (EIAs) of all water resource development projects (river valley projects) in India follow the template designed for terrestrial ecosystems, and therefore require the impacts to be assessed only within a 10 km radius of the project site. This means that only a part of the river and its catchment area affected upstream and downstream of the project site are examined, if at all, irrespective of the length of the rivers and whether their tributaries are affected upstream by the impoundment. The EIAs totally ignore the reality that the impacts of reduced flows and altered flow regimes downstream of the diversion structures cascade down the entire length of the river below, and even affect the existing downstream projects, if any.

Currently, the water resource development projects consider the benefits from irrigation, domestic water supplies, hydropower and associated industrial development, against the costs of the project, which also include compensation and rehabilitation of affected people and some environmental management activities. The actual losses of biodiversity and various ecosystem services of the river over the long term are always ignored. It is only during the past year or two that the environmental clearances have started requiring a provision for environmental flows in the river valley projects. An assessment of biodiversity and ecosystem services of the rivers together with their economic values before the project and the changes expected to result from water storage and diversion, will help provide an additional dimension to the cost-benefit analysis of the water resource development projects. One can then compare the costs due to the loss of ecosystem services against the net gain from the diverted water over different time scales, and for different scales of project intervention (e.g., amount of flow diversion). The assessment of biodiversity and ecosystem services will also contribute to the policies related to biodiversity, water resources management and poverty alleviation – besides overall environmental conservation – in local, national and international contexts. The economic valuation of ecosystem services will further guide appropriate decisions concerning Integrated Water Resources Management (IWRM) for striking a balance between the water use for economic development, social benefits and the goals of biodiversity conservation.

We hypothesise that the losses of biodiversity and ecosystem services of a river increase sharply with the increased diversion of water from the river, and that their loss in economic terms may not be compensated by the economic benefits gained from the diversion of water flows, because these benefits also decline beyond a certain threshold of water diversion (Figure 2).

In order to determine such thresholds it is necessary to assess all ecosystem services and river-dependent livelihoods and to estimate their economic value using appropriate methods of ecological economics. It must be borne in mind that no two rivers or river reaches are similar, and currently our understanding of the rivers and their ecosystem services is practically non-existent. Therefore, the testing of the hypothesis mentioned above will require extensive studies over a couple of years and time-series data on the changes in natural flow regimes, human uses and impacts on biodiversity and other biophysical attributes of the river for the past three to five decades.

Figure 2. Theoretical relationship between Ecosystem Services and Flows



2. Research Questions

2.1. For Water Resource Management

Formulation of an appropriate policy and guidelines for integrated management of water resources requires answers to a number of questions:

- What are the specific geological, geomorphological, hydrological, biophysical and functional characteristics of the river whose water resources are to be used?
- What are the ecosystem services provided by the river in question? How dependent are the human communities upon the river for various resources and livelihoods? What are the economic values of these ecosystem services?
- How much of the normal flow of the river is proposed to be diverted and/or stored?
  When, where and how? Are there any other similar projects – existing or planned – upstream or downstream? How and to what extent will the proposed project affect or be affected by those projects?
- How and which components of the biodiversity and ecosystem services of the river-
  wetland system - both upstream and downstream - will respond to different levels of diversion of river flows? What is the economic value of all these ecosystem services lost or reduced due to diversion of flows over the project's life span?
- What are the net social and economic benefits from the diverted flow and do they compensate the loss of benefits from biodiversity and ecosystem services in the river upstream and downstream?
- In the context of social and economic benefits, which sections of the society will benefit and which sections of the community will be impacted and how? The relationships between the two sections or groups in the society will be important to consider.
- How much of the water flow in a river can be abstracted, and how, without appreciably affecting the biodiversity and ecosystem services?
- What are other options available for meeting the water requirements of the areas to be benefitted by the project?

2.2. Why River Ken?

River Ken has been known globally among tourists for its magnificent gorge and the Raneh Falls, which lie close to the famous Khajuraho temples. However, in recent years it has attracted international attention because of the proposed Ken-Betwa Link – the first

River Ken offers an opportunity to examine, with relatively less effort and resources, the ecosystem services of a least impacted river ecosystem and understand the likely impacts of a water diversion project. Further, it has suitable characteristics for the development of an appropriate methodology that can be tested and validated in studies of similar rivers.

among many proposed projects for interlinking rivers in India. Interestingly, there had been no detailed scientific investigation of any aspect of the River Ken (except the Feasibility Studies by the NWDA) before the proposal for a link canal between Ken and Betwa – another tributary of R. Yamuna – to divert its water to the latter. The proposed K-B Link envisages a 78 m high dam near village Daudhan for diverting water through a 221 km long canal to River Betwa. It will also utilise the stored water for generating about 78 MW hydropower.

River Ken is distinguished by more features than its geological and geomorphological settings. These features will be described in detail later. It is a rain-fed yet perennial river. Such particularities are discussed in the section on River Ken. The river remains nearly pristine in its water quality because there is no significant domestic or industrial wastewater discharge throughout its course, except at Banda in the lower reach. Relatively low density of human population ensures that the river experiences very little disturbance and the water quality remains high throughout, even during the dry season. An approximately 50 km stretch of the river passes through the Panna National Park and Ken-Gharial Sanctuary, which further ensures high water quality and biodiversity. The main-stem of river has escaped flow diversion by any major project except the Bariyarpur Weir and the Gangau barrage, which were constructed more than 100 years ago. These facts make it somewhat unique among the rivers of the Ganga basin.

River Ken offers an opportunity to examine, with relatively less effort and resources, the ecosystem services of a least impacted river ecosystem and understand the likely impacts of a water diversion project. Further, it has suitable characteristics for the development of an appropriate methodology that can be tested and validated in studies of similar rivers. The baseline data collected during a comprehensive study of the river will be useful to the proposed flow diversion project in avoiding undesirable impacts and for future monitoring of the changes in the river ecosystem and its ecosystem services.

3. Study Objectives

An analysis of ecosystem services requires large amounts of data on biophysical and functional aspects of the river and associated wetlands over a time period of several years, as well as long-term time-series (three to five decades) data on both biophysical characteristics of the river ecosystem and the socio-economic and cultural aspects of the dependent communities. Some wetlands and river systems (like Ganga and Yamuna) have been investigated for over a century by hundreds of researchers with an enormous investment of financial resources, and yet, it is difficult to put the pieces of information together for a meaningful trend analysis.

The characteristics of River Ken – its fluvial morphology, nature of sediments, water quality, and biodiversity, various human uses of the river system, and changes over past few decades (if any) – are totally unknown. Data on population growth, resource use patterns and land use changes in the catchment and various developmental activities are inadequate, scattered, and difficult to correlate with the river system. The hydrological (river discharge) data are classified and, hence, not accessible. It was practically impossible to collect a reasonable amount of data related to even a few ecosystem services within a span of 6–7 months. The present study – the first attempt of its kind in India – is therefore necessarily very preliminary. We had originally planned to test our hypothesis and answer several of the research questions mentioned earlier, however all the information available in published literature and in various official or research reports was grossly inadequate for the study.

Therefore, we have restricted our study to the following specific objectives:

i. To understand the main characteristics River Ken;
ii. To undertake a rapid assessment of biodiversity of River Ken and associated wetlands;
iii. To assess major ecosystem services of River Ken and associated wetlands;
iv. To estimate economic value of main ecosystem

services using applicable methods.

We have not attempted an Impact Analysis of the proposed flow diversion, but our assessment of the changes in biodiversity and ecosystem services to be caused by water diversion is presented in a separate section.

4. Project Methodology

During the conceptual formulation of the project, the only information available on the River Ken was in the Feasibility Report of the proposed Ken-Betwa Link prepared by the National Water Development Agency, some general information on the Panna Tiger Reserve and Ken-Gharial sanctuary, and a couple of research papers on different aspects of Ken river basin. There was no information on the River Ken itself – its morphology, hydrology, water quality, biological resources (other than fish), human uses and impacts. Therefore, much effort had to be devoted to the collection of basic information on the river system, and then on understanding the ecosystem services specific to this river and qualitative and quantitative data that could be used for economic valuation of the major ecosystem services.

4.1. Data Collection

The data required for the study were obtained in three ways:

A. Collection of information from secondary sources

All accessible published or unpublished literature on all aspects of the river basin was gathered from diverse sources. Officers of the Government Departments of Forest, Agriculture, Fisheries, Water Resources and Environment, and researchers from concerned institutions and universities in the states of M.P. and U.P. were contacted to seek relevant information and data, but with very little success. None of the officers in the CWC, NWDA and state water resource departments responded to our communications. They were invited to the scoping workshop held in November 2014 but none responded. The scientists at NIH and IIT, Roorkee, who have studied River Ken, did not respond to any communication though their publications were procured through other means.

B. Extensive field surveys

During the study period, most of the river basin area downstream of the confluence of R. Sonar and R. Bearma (at village Jhingra), and up to the confluence of River Ken with R. Yamuna (at Chillla ghat, Banda), was physically visited. At least some stretch of all major and several minor tributaries were visited together with the main reservoirs constructed on them. Observations were made on river morphology, biodiversity, ground water, agricultural and other land use, fisheries, and other human uses of the river. Water samples were analysed for quality parameters such as pH, Electrical Conductivity (EC), dissolved oxygen concentration (DO), fluorides, and total hardness. Biodiversity in the river and in its riparian areas was recorded. For fisheries, experimental fishing was done and fish markets were surveyed. Details of all field visits and the activities undertaken during the project are listed in Table 5.

C. Focused group discussions

A wide range of stakeholder communities in different parts of the river basin, especially along the main river, and also tourists visiting Khajuraho and Panna National Park (including the Tiger Reserve), were approached to discuss river-related issues.

Group discussions with the local communities were made during field visits. People working or visiting the fields, along the river, in the markets, on the wells, near their houses, were engaged in discussion on their perceptions of the river, their dependence on the river's resources (water supply, agriculture, domestic use, sand, etc.), and various river-related issues (floods, droughts, human impacts, dams, etc.). About thirty villages were covered during the study. Of these, a few villages in Banda district, in the area around the proposed project, and around the Panna Tiger Reserve, were visited several times for more detailed interaction. In two villages, formal meetings were also held, to which a large number of stakeholders from the neighbouring villages were invited. Discussions were also held with contractors, transporters, and labour engaged in sand mining, and the fisherfolk engaged in fishing and marketing.

Field surveys and focused group discussions were undertaken during the post-rainy and winter season (October to March). Severe fog during December-January caused large disruptions and difficulties in access to the field sites and unwillingness among people to engage in discussions.

At the beginning of the project, a Scoping Workshop (stakeholder consultation) was organised in Khajuraho (11–12 November 2014), which was preceded by a meeting of the project team and a few invited experts on 10th November 2014. Another expert consultation was organised to discuss the results and bring together most of the team members during 20–24 March 2015.

Table 5: Activities undertaken during the study period August 2014 to April 2015

Month	Activities undertaken
August 2014	Contract signed on 27 August 2014 Applications for Research Fellows invited; Interviews held at Khajuraho; No candidate appeared; Field survey in Chhatarpur & Panna;
September 2014	Field survey in Chhatarpur ,Panna, Banda, Chitrakoot; Collection of secondary data, published literature; Correspondence with Government Departments and various institutions
October 2014	Visits made to Lucknow, Allahabad, and Bhopal to various Government Departments and institutions for discussions, permissions, and information; Field surveys and focused group discussions along River Ken Preparation of a drainage basin map of River Ken
November 2014	Field Surveys and focused group discussions; Expert Panel meeting (10 Nov. 2015); Stakeholder Consultation (11-12 November), \ Interaction with tourists/visitors Survey of tributaries
December 2014	Field surveys and focused group discussions; Sand mining suveys in Banda; Water supply and ground water survey Extensive interaction with stakeholders during Public Hearing on EIA of K-B link project at Silon and Hinauta
January 2015	Field surveys and focused group discussions; Interaction with tourists/visitors Surveys on fisheries, biodiversity, water quality along main river and tributaries
February 2015	Field surveys and focused group discussions; Experimental fishing; fish market survey; Community Stakeholder meeting in Banda (village); Sand mining surveys; riparian agriculture in Banda;
March 2015	Field surveys and focused group discussions along Rivers Sonar, Bearma and other tributaries; Visitors' survey (Ecotourism) Stakeholder Workshop and Consultation for data analysis (20-24 March);
April 2015	Field surveys and focused group discussions Data analysis, Report preparation
May-June 2015	Field surveys and contacts with different departments for additional data; Literature survey and Report revision

4.1.1. Ecosystem Services of River Ken

Based on our discussions and field observations, we found that the most important ecosystem services of River Ken, with a rocky and boulder bed and relatively poor development of a typical floodplain, are confined largely to the transport of water and sediments (sand) and provisioning for biodiversity-rich fisheries. The groundwater recharge function was highly variable – with large differences within a few meters. It appeared that most of the vegetation along the river had already been over-exploited, making a quantitative assessment nearly impossible. Riparian agriculture, dependent upon annual flooding, was found to be significant in many areas. Ecotourism centered around the Panna Tiger Reserve, Raneh Falls and Ken- Gharial sanctuary in the middle reaches of the river, was the most significant cultural ecosystem service, whereas fisheries and sand extraction were the dominant economic benefits, other than water supply, from the river. Therefore, we focused on the following ecosystem services along with their biophysical indicators:

4.1.2. Data Sources

We still had difficulty in obtaining secondary data for a few previous years (time-series) from any source. Some of the officially available data are at least a decade old and cannot be used effectively to assess the ecosystem services because of considerable variability in climate, plus recent changes in land use, population density and other developmental programmes.

4.2. Methodology for Economic Valuation of Ecosystem Services

River Ken, as mentioned earlier, is a unique wetland ecosystem, and benefits or ecosystem services provided by it extend beyond its boundaries and have national and global significance. This exercise should, in principle, be based on a full appreciation of the Total Economic Value (TEV) of Ken. While some measurements and valuation of direct use value, expressed in terms of environmental commodities and amenities of direct benefit to human population (sand, fish, water use in agriculture, and domestic use), have been undertaken, indirect use value remains difficult to quantify for a few services (e.g., existence and bequest) due to factors including market failure, information failure, externality, public good failure, intersectoral policy inconsistency, and time constraints. However, perceptions inferred during our interaction with domestic and foreign visitors indicate unambiguously that existence and option values of River Ken and its landscape are positive and significant and any attempt to divert its water and natural flow may result in irreversibility.

Existence and option values were empirically estimated using the Contingent Valuation Method (CVM). A range of economic techniques can be used to place monetary values on River Ken's goods, services and functions, subject to availability of data and information. For example, to attach value for conservation, we need public prices/market values expressed by the different sections of society. For direct benefit estimation on fish, sand, Civil Practice Laws and Rules (CPLR) use, and agricultural output, we have used participation methods like focused group discussions, interactive meetings, and direct market prices, rather than production function, replacement cost approach, or opportunity cost approach, as estimation requires cross-sectional data from different stakeholders. We have used Travel Cost Method (TCM) to understand recreational value and nature of demand for River Ken

Table 6: Data resources

River Flow - available with CWC	Could not be procured; some information extracted from publications and old reports
No. of tourists & revenue	From Panna Tiger Reserve Collected from Hotels in Khajuraho
Biodiversity and Fisheries	Publications and Field survey
Water supply (irrigation/ domestic use)	Publications; Field survey; Focused Group meets, Jal Nigam in Banda
Groundwater	Publications ; Field survey; Focused Group meets
Sand Extraction	Field Study; Focused Group meets
River Habitats	Field survey
Livelihoods	Sand, fish, ecotourism, agriculture

Table 7: Ways to measure ecosystem services

Ecosystem Services	Biophysical indicators	Socio-economic indicators
Provisioning services Fisheries Sand Water supply	Fish catch (composition, weight) Amount of sand extracted Amount of water used (domestic & agriculture/ other use)	Number of fisher folk Fishing effort & income No. of persons engaged in sand extraction/transport irrigated area;
Regulating services Groundwater recharge	Change in groundwater table	Number of borewells/ dugwells; Crop area using groundwater Energy use for water withdrawal
Cultural services Ecotourism	Natural /cultural sites of tourist interest	Number of visitors Number of persons employed Revenue to government Income of local people
Supporting services Lifecycle maintenance	Dependence of life cycle stages of organisms such as gharial and fish	

and associated sites. For estimation of TCM, online booking and entry fees, time of travel and time spent by individual visitor variables, have been included; the level of significance of these variables can also provide some indication of an individual visitor or category of visitors' willingness to pay (WTP).

Indirect functional benefits like flood control, groundwater recharge, and life support function, can be estimated only if time-series or panel data are available, using Damage Cost Avoided Analysis, Substitute Costs, Energy Analysis, and other techniques of indirect valuation.

5. River Ken and its Basin

River Ken, also known as Karnavati, is a north-flowing, right-bank tributary of River Yamuna, which is the largest tributary of River Ganga. River Ken is relatively small but qualifies to be a medium river on the basis of its total basin area (Figure 3). It rises near village Ahirgaon (2405' N, 80011' E), about 20 km north-west of Katni city (M.P.) and at about 550 m above mean sea level (MSL) in the eastern fringes of the Bhander Ranges of the Vindhyas. It flows northwards for about 427 km before discharging into River Yamuna near village Chilla (25048' N, 80032' E; 95 m above MSL), about 40 km north-north-east of Banda city (U.P.). It flows for 292 km in MP, 84 km in U.P. and along the remaining 51 km it forms the boundary between the two states. The total area of its basin (catchment) is 28,058 km2 though Murty et al. (2013) estimate it to be 28574 km2. Most of the river basin (24,576 km2 or 87.6% of the total) lies in M.P. and only the downstream area of 3,482 km2 (12.4%) lies in U.P.

From its source, River Ken flows north for a short distance, turns westwards in Panna district, before again turning north. It is first joined on its left bank by R. Patne, near Pawai, within Panna district. After flowing a few kilometres westwards, it is met by R. Sonar on its west (left) bank about 2 km upstream of a location called Pandavan, between villages Udla and Singora. R. Sonar rises in the Raisen district and flows for 227 km through Sagar and Damoh districts. Another large river, R. Bearma, rises from Vindhyan highlands in Sagar and Damoh districts and flows north, almost parallel to R. Sonar, before meeting the latter on its right bank at Village Jhingra. Both Rivers Sonar and Bearma are longer than River Ken at their confluence. The main tributaries of Sonar are R. Bewas and R. Kopra. After its confluence with R. Sonar, River Ken runs northwards through the Panna Tiger Reserve. At Pandavan, River Ken meets R. Midhasan on its right bank. Another left bank tributary, R. Shyamari, meets it downstream, near village Daudhan. Further downstream, River Ken is met by its left bank tributaries: R. Banne, R. Khudar, R. Kutni, R. Urmil, R. Kail and R. Chandrawal. The drainage of the Ken river basin is shown in Figure 4.

Currently there is one major irrigation system on the main stem of River Ken, built by the British Government in 1905 then expanded and upgraded after independence. This system involves the Bariyarpur Barrage, a few km upstream of Raneh Falls, constructed in 1905, and is supported by the 16-metre-high Gangau Barrage, 40 km upstream of Bariyarpur and about 2 km downstream of village Daudhan, which was built in 1911 and operational since 1915. Another 27-m-high dam, Ranguwan Dam, had been constructed in 1957 on River Banne, 8 km upstream of its confluence with River Ken, to augment the flow at Bariyarpur Barrage. The right bank Ken canal system of Bariyarpur Barrage has been in operation to irrigate areas in Banda district for over 100 years. A left bank canal from Bariyarpur Barrage, for irrigation in Chhatarpur district, was completed in 2013. Several small reservoirs have been constructed on various small tributaries of River Ken, mostly close to their headwaters. Benisagar reservoir on River Khudar, which passes through Khajuraho, was completed in 1960 and inaugurated by India's then Vice President, Dr Radhakrishnan. The latest

Figure 3: Part of the Ganga river basin showing the location of Ken river basin (red line).

WETLANDS

to be completed are the dams on River Kutni, River Urmil and River Chandrawal, while some are under construction on the tributaries of R. Sonar and R. Bearma.

5.1. Important Geomorphic Features of River Ken

River Ken is somewhat unique in many respects, despite the fact that it is among the least investigated rivers in the Ganga basin. This north-flowing river traverses the undulating Bundelkhand plateau. Throughout its course, except near its confluence with R. Yamuna, it has a rocky bed littered with large bounders, unlike the sandy bed of R. Yamuna. Whereas the overall gradient in the river is 2 m per km in the upper reaches and less than 1 m per km in the lower reaches, the river forms several deep gorges with magnificent small falls.

The River Ken and its tributaries have cut through their rocky beds and alluvial deposits to form ever-widening single-thread channels with high banks. Rock terraces are common in the basins of R. Sonar and R. Bearma (Rai 1980). The riverbanks along R. Sonar are 5–21 m high above the channel bed, 15–17 m high near Hatta, and 3–12 m high along R. Bearma. There are two 5–7 m high falls on R. Sonar 6 km south of Garhakota and 4 km west of Hatta. Some interesting and little-known features are the innumerable potholes in the large boulders and rocks scattered over the deep sinkhole-like area at Pandavan. Here the river suddenly disappears into a 15–20-metre-deep gorge. Another 7 km downstream, the river channel is blocked and forms a large fall and a wide and deep gorge at Gehrighat – far more scenic than Raneh Falls and the gorge there. Further downstream, within the Tiger Reserve, the river again forms a deep gorge at Sakora. Throughout its course, River Ken has a rocky bed with boulders and alluvial gravel, and high banks. Typical floodplains are formed only at a few places, where the gradient is low and sandy, so clayey alluvium has been deposited; e.g., at Sakra – upstream of Daudhan and opposite village Khariyani. A significant part of the river passes through the Panna National Park – now a 542.67 km2 Tiger Reserve. Further downstream of Bariyarpur Barrage, the river passes through a narrow, deep gorge and forms the well-known Raneh Falls over the multi-hued granitic rocks, before emerging into a wider valley inhabited by the gharial (Gavialis gangeticus). This area is now well known as the Ken Gharial sanctuary, with a land cover of 45.2 km2.

Figure 4: Ken River basin. Red dot marks the location of proposed Daudhandarn.

5.2. Climate

Climatically, the river basin lies in the subtropical belt with monsoonal rainfall restricted to July-September period. Summers are very hot and dry. The average maximum and minimum temperatures are 44.2°C and 6.7°C, respectively; the relative humidity varies between 9% and 95%. Whereas the long-term data on precipitation in the Ken river basin is available for several stations, the data on river discharge (flow) is not accessible. Recently, researchers at the NIH and IIT at Roorkee have analysed the long-term data in different contexts (Jain et al. 2013, Murty et al. 2014). These publications report that the annual rainfall in the Ken river basin varied from 800 to 1500 mm during the period 1960 to 2009. In general, Chhatarpur and Banda districts have lower annual rainfall, whereas Sagar receives higher rainfall. Murty et al. (2013) have analysed the variation in rainfall, groundwater infiltration and evapotranspiration in different sub-basins of the Ken river basin. These data are reproduced below in Figure 5. It is noteworthy that the two most northern sub-basins (lying in U.P.) and the one in the northwest of Gangau Weir, receive the lowest rainfall, and hence also the lowest runoff and groundwater

Climatically, the river basin lies in the subtropical belt with monsoonal rainfall restricted to July-September period. Summers are very hot and dry. Annual rainfall in the Ken river basin varied from 800 to 1500 mm during the period 1960 to 2009

recharge. Figure 6 also shows that during the past 50-year period (1960-2009), there were 15 years with rainfall in the basin falling short by more than 25% of the normal, whereas in 10 years, the rainfall exceeded the normal by more than 25%. Overall, the rainfall in the Ken river basin was less than the normal in thirty years, whereas it equaled or exceeded the normal in only twenty years.

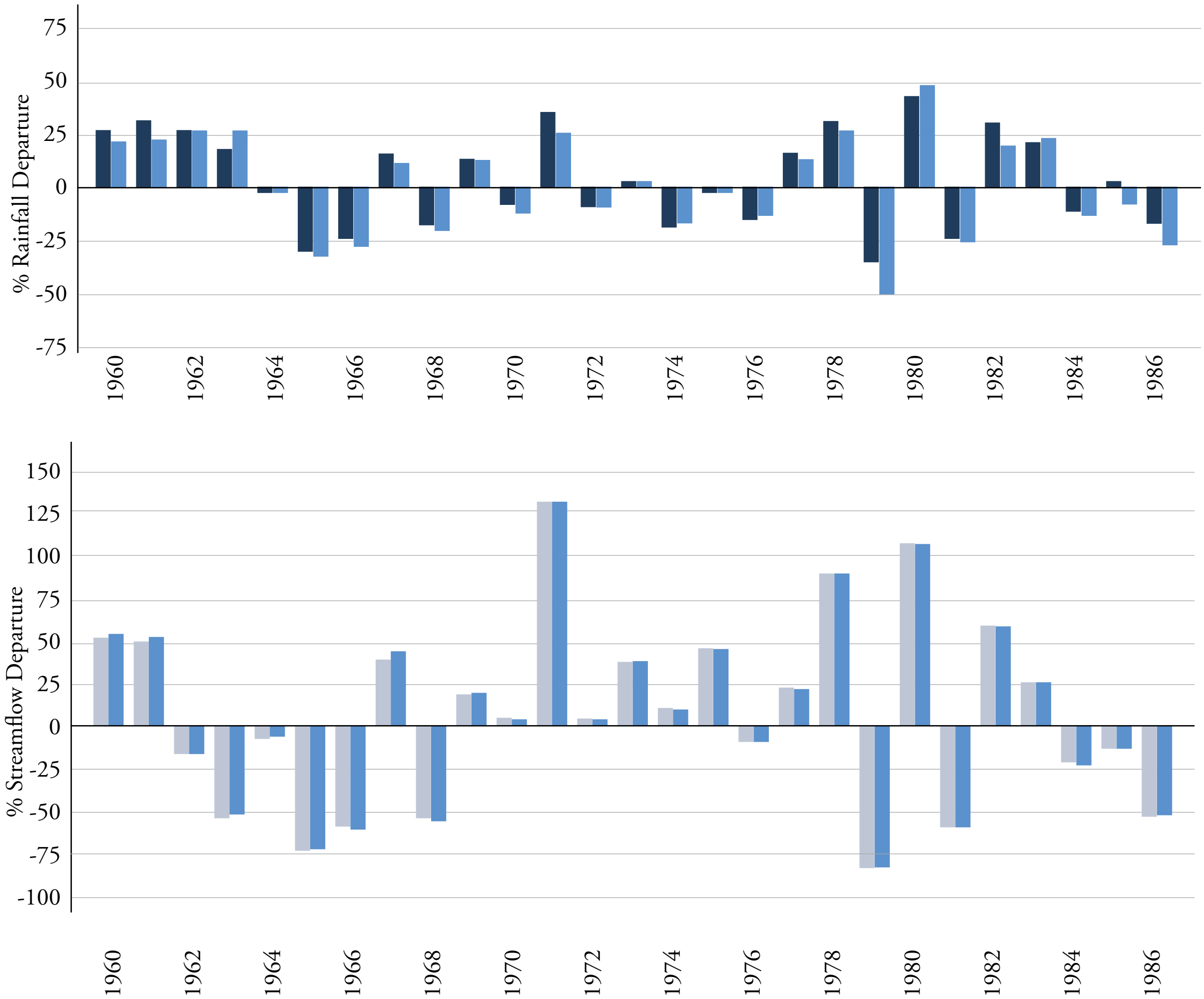
5.3. Stream Hydrology

The earliest study on Ken river hydrology is probably that of Thamas and Jaiswal (1997–98, 2002), which analysed rainfall-runoff relationships for rivers Bearma, Sonar and Bewas – the major tributaries of River Ken – and validated the model with observed data for the early 1990s. Based on the data for the past 50 years (1960–2009) for the Ken basin, Jain et al. (2014) found a strong correlation between the annual rainfall and total annual discharge at Banda (Figures 6 and 7). The average annual stream flow at Banda gauging site is reported to be about 9,667.23 million cubic meters (MCM), out of which approximately 95% of the flow occurs between July and October. Maximum 10-daily discharge falls to 10 MCM towards the end of April,

Figure 5: Different sub-basins of River Ken basin and the variation in their rainfall and water balance (from Murty et al. 2013)

Subasin	Area km2	Rainfall, mm	Runoff (mm)	GW (mm)	ET (mm)
1	2514.90	841.81	68.87	2.81	786.72
2	763.03	841.81	84.70	3.21	769.69
3	2275.88	1176.89	318.54	19.65	842.79
4	3533.57	965.85	165.86	25.91	782.85
5	2979.05	1125.57	336.71	79.94	702.38
6	4283.04	1178.98	263.92	31.23	887.10
7	2511.13	1250.23	343.84	14.32	890.11
8	5863.72	1237.18	309.92	57.14	869.72
9	1825.34	1239.76	260.42	29.86	950.68
10	2024.07	1209.12	316.26	68.61	802.45
Ken,	28 573.73	1132.43	261.73	37.87	834.21

Figure 6: Variation in rainfall and stream flow over the period 1960–2009 (from Jain et al. 2014)



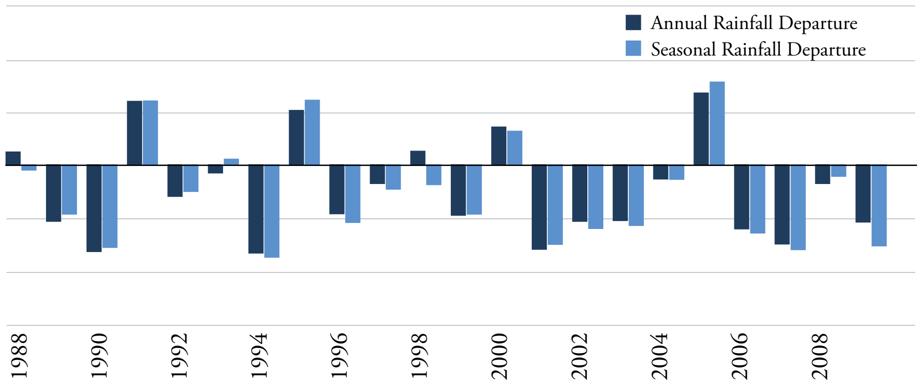
but reaches 8000 MCM or more during July-August. The 75% dependable flow (Q75) for the 10-daily period Jan-I (Jan 1-10) ranges from 2.87 to 7.31 MCM, with a maximum deviation of 11 MCM during the entire non-monsoon period. The Q75 for the 10-daily period Aug-I (August 1-10) ranged from 173 MCM to 1023 MCM, with a maximum deviation of approximately 850 MCM when analysed for different periods. It is interesting to note that according to Jain et al. (2014), data spanning 30 years or more should be used for realistic assessments and for characterising stream flow drought. We get some insight into the inter-annual variability in river discharge at Banda from the data analysed by Murty et al. (2013). These data for the periods 1986-1996 and 1997-2009 are reproduced in Figure 7.

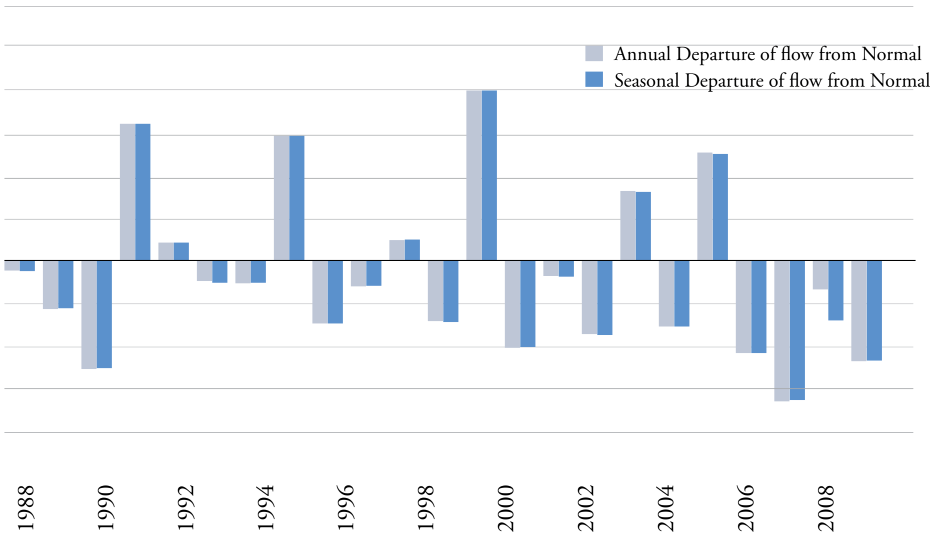
5.4. Vegetation of the River Basin

The general vegetation of the basin is a biodiversity-rich tropical dry deciduous forest. Garima and Singh (2009) analysed the plant diversity within the Panna National Park using remote sensing data. They observed highest species richness in northern mixed dry deciduous forest, followed by dry deciduous open scrub and southern tropical dry deciduous teak forest, with lowest species richness for the open thorny deciduous forest with grasses.

5.5. Development Pressures

The area of the river basin, like most of Bundelkhand, has not witnessed any major development – urban or industrial. About 80% of the human population is rural, largely dependent on mostly rainfed agriculture,





and a significant proportion of the population remains below the poverty line. The area has a rich history of tank construction by the rulers, and there are thousands of these tanks, most of which are now neglected and degraded. Despite land degradation, the river remains in nearly pristine state, with high water quality, as there are no industrial and domestic wastes entering the river. In fact, there is no major or medium town along the River Ken, except Banda city in its lower reach. A 4000 MW thermal power plant has just started construction in Chhatarpur district. The area in the lower part of the basin, which includes Chhatarpur, Panna, Mahoba, Banda, is of considerable historical and cultural importance. Besides Khajuraho – a World Heritage site known for its 10th and 11th century temples – the area is known for the diamond mines at Panna, and several important areas of nature tourism, such as Pandav Falls, Raneh Falls, Panna Tiger Reserve, and the Ken-Gharial sanctuary.

The proposed Ken-Betwa Link project will transfer Ken river water to Betwa river. The project involves the construction of a 78-metre-high dam at village Daudhan, about 2 km upstream of Gangau weir, and a 221 km long canal. It will generate 72 MW of hydropower and is projected to provide irrigation and drinking water to enroute areas in Chhatarpur and Tikamgarh districts in M.P. However, it will submerge over 125 km2 of forest, including a critically important section of tiger habitat, in the Panna Tiger Reserve. A feasibility study had been conducted long ago (NWDA 1996), a Detailed Project Report has been prepared (available online) and an Environment Impact

Figure 7: Monthly Ken river discharge at Banda over the period 1986 to 2009 (from Murty et al. 2013).

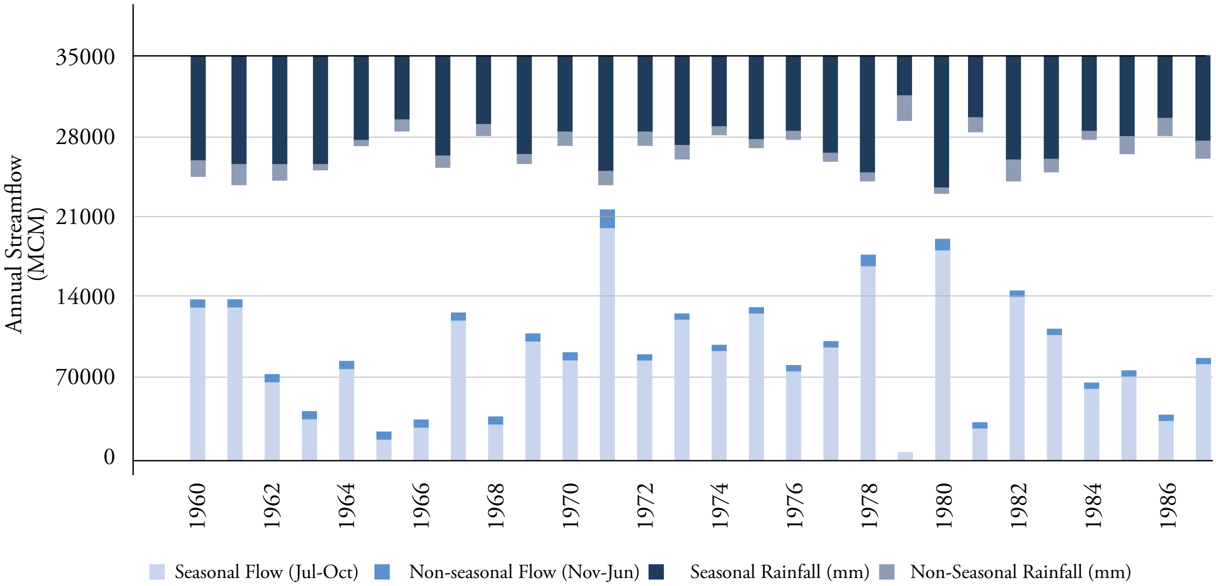
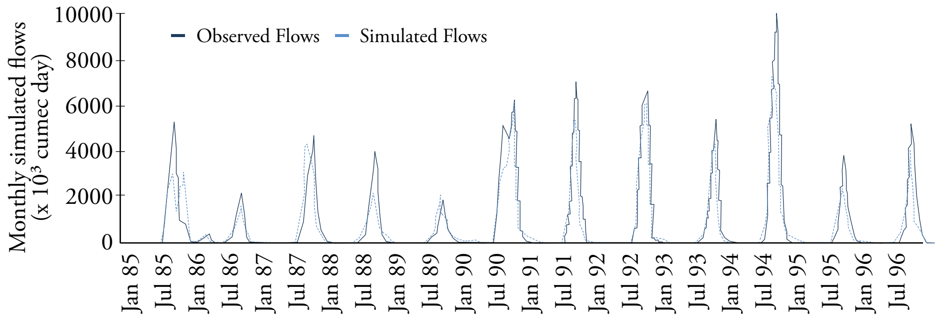
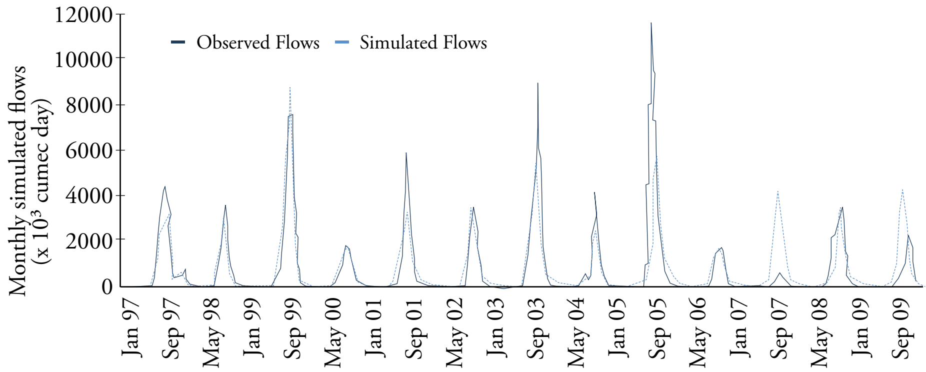
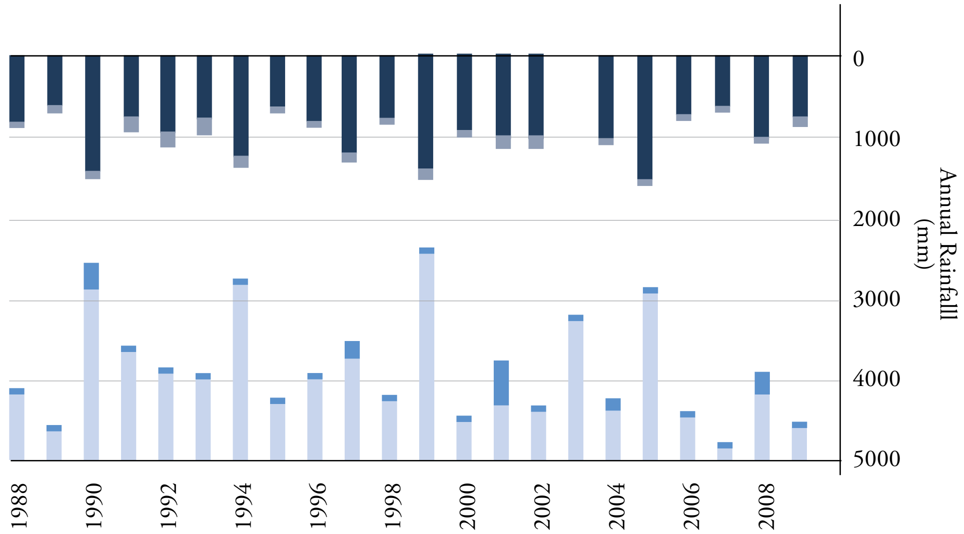


Figure 8: Monthly Ken River discharge at Banda over the period 1986 to 2009 (from Murthy et al 2013)







Assessment has been completed. After the mandatory Public Hearing conducted in December 2014, the project is awaiting final clearance.

The anticipated impacts of the flow diversion on the ecosystem services of the river both upstream and downstream of the project site will be discussed in a separate section at the end of this report.

6. Biodiversity of River Ken

The biodiversity of the Ken river basin in general has never been investigated in detail. Only general accounts of vegetation types and flora and fauna are available for the Panna National Park (e.g. Kumar and Suman 2009, Porwal and Singh 2009, EPCO 2011). Some publications describe the grasses (Saxena and Vyas 1978-79) and pteridophytes (Saxena and Tripathi 1988) of Banda district. The flora of Chhatarpur and Damoh districts was described in a report by Roy et al. (1992).

Aquatic biodiversity of the River Ken and its tributaries, as well as the numerous tanks and reservoirs, has received very little attention; what information there is only arose in the last few years. The aquatic plants in and around Banda were reported on by Saxena et al. (1981) and Satya Narain and Mishra (2008). The diatom flora has been investigated by Nautiyal and Verma (2009), whereas the benthic macroinvertebrates have been described in detail by Nautiyal and Mishra (2012) and Mishra and Nautiyal (2011, 2013, 2015). The phyto- and zooplankton, the benthic diatoms and macro-invertebrates, were also recorded during our field surveys. The organisms actually collected from the field are listed in Annex 1. It is noteworthy that the dominant groups of macro-invertebrates exhibit marked changes between the upstream and downstream sites reflecting a change in the habitats and water quality (Annex 1, Table 23; Nautiyal and Mishra 2012).

The macrophytic vegetation is confined to shallow stagnant pools or river margins. The riparian vegetation is very poor in species and extensive monospecific stands of a Cyperus species are common on the river margins. In lower reaches or where some sand or silty sediments accumulate in between the boulders, a few other emergent macrophytes do occur. Several species of grasses and sedges were recorded from the drawdown areas of reservoirs where these are grazed commonly. Several macrophytes occur also in the canals. The species of some interest include the free floating Salvinia molesta (an exotic invasive species), Pistia stratiotes and water hyacinth which were observed only in some pockets but have the potential to spread and colonise large areas. In shallow stagnant or slow-flowing waters a variety of submerged macrophytes occur. These are listed in Annex I. We did not find any aquatic plant along the river that may be used by humans, except that Vetiveria zizanioides was reported to occur in some pockets and is exploited for its roots. Grazing is rare along the river margins. In wetlands associated with the tributaries and in nearby water bodies, Trapa bispinosa is commonly cultivated. Nymphaea species and lotus (Nelumbo nucifera) are also common and widely used. Nymphaea flowers are sold for offering in temples.

The diversity of fishes has been examined in some detail, along with an attempt to relate the distribution pattern with various habitat factors (Johnson et al. 2012; Dubey et al. 2012; Joshi and Biswas 2010; Sarkar et al. 2014; Joshi et al. 2015). The number of fish species recorded by different studies varies greatly according to the fishing effort, sites selected for sampling, and the time of the year. Joshi et al. (2015) have recorded a total of 89 species. Of these, during our own studies, 48 species were recorded between Banda and Chilla during February 2015. These fishes include several endangered and vulnerable species (Sarkar et al. 2013). There are at least two exotic species, C. carpio var. communis and Oreochromis niloticus, which occur regularly in large numbers. Cypriniformes and Cyprinidae were the most species-rich order and family respectively. Anguilla bengalensis is a very rare species found in September and has very high market value (up to ₹1000/kg) for its medicinal importance. Chitala chitala is another rare species. Another species of great interest in mahaseer (Tor tor) - an endangered species that occurs in the river inside the Panna National Park. The published studies and our own field survey show large variation in the species richness along the river course. The downstream reaches near Banda and up to Chilla are quite rich in species. The species recorded in different studies are listed in the Annex.

Among the aquatic fauna of River Ken, special mention needs to be made of the Long-Snouted Crocodile (Gharial) and Marsh Crocodile (Mugger). It is interesting that in River Ken, the Marsh Crocodile (Crocodilus palustris) and Long-Snouted Crocodile (Gavialis gangeticus) co-exist, whereas the two species generally occur separately.

7. Ecosystem Services Examined and their Valuation

7.1. Sand Extraction

One of the major functions of rivers is to transport water. Huge amounts of water flowing down steep valleys carry with them large rocks and boulders, which get crushed into fine sand as they move downstream. Thus, the water carries sediments and nutrients to downstream floodplains, and finally to the oceans. Himalayan rivers are known to carry more sediments to the oceans than most other rivers in the world. On a regional and local scale, the alluvial sediments (gravel and sand) transported by the rivers constitute the most important construction material. Rivers transport and distribute them along their course, free of cost. Flow diversion structures (dams and barrages) prevent downstream transport of these sediments and make them inaccessible for use elsewhere, and in turn the trapped sediments reduce the life span and efficiency of these infrastructures. These alluvial sediments also determine the fertility and natural productivity of the floodplains, as well as that of the coastal waters. For example, the retention of sediments in Lake Nasser behind the Aswan Dam over the past fifty years has resulted in the collapse of Mediterranean fisheries around Nile river delta, subsidence of the delta and increase in salinity.

In the River Ken, sand is extracted on a large scale in the downstream reaches. Occasional sand removal was reported by the communities in the upstream areas, but we did not observe any commercial activity during our survey. In the downstream areas, there are two distinct modes of sand extraction.

First, there are sand mines in Panna, Chhatarpur and Banda districts, officially leased out by the government. Sand is mined mechanically by using JCB machines, which excavate often to a depth of 35-40 feet, i.e. 10-12 m, or even far more. The contractors tend to exploit a larger area than that leased to them. Operators reported (and we also recorded at some places) that 5 to 8 JCBs are used at each mine. Generally, the mined sand is stored in huge dumps on the site and then loaded into the trucks by another JCB that takes less than 15 minutes to load one truck of 700 ft^3, or about 19 m^3, capacity. The sand is then transported to distant parts of U.P.

Second, is sand extraction by private parties, usually in an unauthorised manner, and mostly for local or nearby markets. The sand is extracted manually and transported by tractor trolleys, which range in their capacity from 20 to 150 ft^3, and sometimes 250-300 ft^3, i.e. 2.5 m^3 to 4 m^3 or even 8 m^3. Many people in each village are engaged in this process. In some cases, the sand is also extracted from small tributaries and canals. Another mode of sand extraction, particularly at Banda, involves a large number of ponies. The area of the river near Bhuragarh is apparently reserved for this purpose. Each family owns 10-12 ponies and each of them carries 2.5 to 4 ft^3 of sand, manually extracted and loaded. These ponies are then taken to the city through narrow bylanes, where sand cannot be carried by other means of transport and is required in small amounts only.

7.1.1. Economic Value of Extracted Sand

Although we could visit four sand mines and talk to several people in a few villages to gather fairly reliable information on the economics of sand extraction, the business is largely conducted illegally and is controlled by mafia and powerful contractors who are unwilling to talk to any outsider and even prevent access to the site. (I personally faced threats from the people at Pailani, near Banda). Even the villagers do not want their sand-laden tractor trolleys to be photographed.

Noted below is the information used for estimating the value of sand extraction in downstream 100 km reach of River Ken.

7.1.2. Leased Mines

- Chhatarpur: 7–8 (Nehra, Chukehra, Harrahi, Banehra, Baghari, Kandehla, Mawai, Parai) - - Panna: 7–8 (Chandipati, 2 in Beera, Muhana, Sunaehra, Barkaula, Chandaura, Kharoni)
- U.P.: 6 (Bhureri, Kanwari, Achhrod, Duredi, Sonapati, Pailani)
- Leased mine area: 8–15 ha
- Lease value: ₹1.0 to 5.0 crores
- Total lease value of all mines (estimated by contractors): ₹60–70 crores every year
- Trucks loaded: 500–1000 per day depending upon the demand. We counted 112 trucks line up along the road at one place between Bhuragarh and Matondh. Twenty trucks moved out of the Achhrod mine in an hour on another day.
- JCBs: 5–8 per mine; 15 minutes per truck loading - Volume: 700 to 1250 ft^3, or 19–34 m^3, per truck
- Royalty received by the Contractor: ₹13000-18000 per truck (depending upon quality) - Sale price: ₹20,000 to ₹50,000 per truck (depending upon distance & volume).

  When truck movement is prohibited, sand is supplied from the dumps by tractor trolleys.

  Six persons take about 15 minutes to load one trolley, which is about 150 ft^3, and are paid ₹150 per trolley. Up to 15 trolleys are supplied each day from the dumps, and the trolley tractor saves at least ₹500 per trip. Local Sale price in Banda is ₹1200 to 1500 per trolley.

7.1.3. Estimated Net Economic Value

The contractors themselves reported a net sale of ₹50 lakhs per day per mine, for 250-300 days a year. Assuming an output of only 500 trucks per day, and a royalty of ₹14,000 per truck, the contractor will receive ₹70 lakhs per day. The actual turnover is certainly much higher after accounting for the cost of hiring the JCB machines (up to ₹1.75 lakh per month, including the operator's salary), the cost of diesel and maintenance, etc. The contractors shared in confidence that large sums are paid to the police and checkposts, and there are several other hidden costs.

It will be safe to estimate a conservative minimum net annual return of ₹125 crores per mine (250 days x ₹50 lakh per day), and a total economic return of ₹2500 crores per year from the 20 or so leased mines alone. This value does not include the economic value of the livelihoods of people engaged in the process of excavation and transport.

7.1.4. Private Extraction

Numerous families in every village are engaged in sand extraction, transport and sale using their tractor trolleys. There are more than 30 villages in and around the River Ken in Banda district alone. We had detailed discussion with the people in village Kharauni (district Panna) where 18 families were reported to be dependent on sand extraction alone and each had at least one tractor trolley. Each tractor makes 2 to 5 trips per day. In other villages in Banda, also, there were 10–12 families in this business. Other people extracted sand for personal use. Some of these people extract sand themselves, whereas others load and transport sand from the dumps near the mines.

Tractors: carry from 90 to 100, or even up to 150 ft^3, or 2.5–4.0 m^3, sand per trolley

Sale Price (reported in different places): ₹1400–1800

Based on our assessment that at least 50 tractor-trolley loads of sand are carried away every day by households in each of the 50-odd villages in the three districts around Ken alone, and with a minimum market price of ₹1200 per trolley, during only 8 months of the year, the Net Economic Value of the sand is estimated at ₹72 crores per year.

7.1.4.1. The ponies-based Economy of Sand

In Banda alone, about 100 families own 10–12 ponies each and are engaged in extraction and distribution of sand. Usually only two persons from each family make 3–5 trips per day, and carry 2.5–4 ft^3 sand on each pony. Each pony-load of sand is sold at ₹50 to 60. These ponywallahs themselves informed us that they earn at least ₹500–600 per day, even if only a single

In River Ken, fishing is prohibited in the areas of the Panna National Park and Ken- Gharial Sanctuary, and deep gorges make other sections of the river unsuitable for fishing. In the upstream reaches, outside the Panna Tiger Reserve, fishing is common, but fish seem to be harvested on a larger scale in the lower stretch, around Banda

trip is made. Two trips per day is quite common, but this all depends upon the demand in the city. Assuming only ₹1000 per family per day for 100 families and over 250 days in a year, the net contribution of sand from River Ken by this method is estimated at ₹2.5 crores every year. In view of the limited area where this sand is utilised, the livelihood support is of greater importance than the actual economic value. Also, it must be realised that this mode of sand extraction and transport saves the city dwellers from the inconvenience and cost that would result if larger dumps were to be made outside the residential or market areas and sand carried manually for construction.

7.1.5. Total Economic Value of the River Based on Sand

We did not survey the upper part of the Ken River, comprising R. Sonar, R. Bearma and their tributaries, where sand extraction is reported in relatively smaller amounts. There is no sand extraction activity in the fairly large stretches of the River Ken that pass through the Panna Tiger Reserve and Ken Gharial Sanctuary. Therefore, for a conservative estimate of the value of sand, only the lower reaches of the river may be taken into account. Accordingly, we estimate the minimum value of sand at ₹2575 crores per year.

7.2. Fisheries

Fish are the most prominent component of a river's biodiversity, and also reflect the nature and kind of other biota, as well as the overall water quality. Fish are a major provisioning service of the rivers as they are harvested and marketed along most of the river course. Fish are also linked to several other ecosystem services (e.g., water quality, recreation) and invariably support numerous livelihoods.

In River Ken, fishing is prohibited in the area of the Panna National Park and Ken- Gharial Sanctuary, although illegal fishing is commonly reported from Gangau Barrage and throughout its downstream reaches. Some sections of the river with deep gorges are unsuitable for fishing. It is interesting that many of the individuals who fish also grow vegetables and, in many cases, are engaged in sand extraction. There are no fish cooperatives and there are no official fishing leases. In Madhya Pradesh, river fisheries are treated as a common pool resource, free to the local community, according to a personal communication from the Assistant Director of the Fisheries at Chhatarpur. However, fishing rights are assigned by village panchayats to individuals. In some areas, such as near Toria, in Panna, and in villages of Banda, illegal fishing appears to be common, as the fishers did not want to talk about or show their fish catch. Yet we found 15-20 fishers and fishing boats active in both these areas.

In the upstream reaches, outside the Panna Tiger Reserve, fishing is common, as hundreds of fishers catch fish and sell their catch to shop owners in the local market. A larger fish market is at Hatta, where fish are brought from many distant areas. Conversation with two shopkeepers selling fish by the side of Midhasan stream (drain) between Amanganj and Pawai revealed that around 400 fishers catch 1 to 2 kg fish per day (per person) and sell it at the shop at ₹100–120 per kg. The fish are readily sold to the people at ₹140–150 per kg. Thus a fisher normally earns an average of ₹200, and even up to ₹500, per day, as the market price for some fish goes up to ₹200–300 per kg. During the rainy season, more than 1000 people engage in fishing, though the catch is somewhat small, nearer to 0.5 to 1 kg per person per day.

As far as we could observe during our surveys, fish are harvested on a larger scale in the lower stretch, around Banda. The number of fisher households, other fishers and fishing boats vary a great deal between villages. At Banda, several fishers said that they even come from outside the district. We conducted a detailed study of the fisheries' potential, fishing community, and fish market, and carried out experimental fishing near four villages during the first week of February 2015, to assess the economic value of Ken river fisheries at Banda.

The results are summarised in Tables 8 to 10 below.

Our study, conducted during a non-fishing season, and based largely on discussions with the fisher community, shows that fishing in Ken is not organised and not the sole profession of any section of the local community. In some cases, it is a major activity and in other cases it is an additional source of income. The fisheries are estimated to contribute a highly variable amount to the economy of the households in different villages, from ₹2 lakhs to 17 lakhs per year, depending upon the number of households and their effort. The economic value of River Ken fisheries also depends upon the fish species and the size of fish caught from the river, as they are priced differently. In the absence of data on the fishing households from a larger number of villages along different reaches of the River Ken, it is not possible to guess the TEV of fisheries. However, the study on fish biodiversity clearly shows that they contribute a highly significant amount, that their value varies along the course of the river in relation to habitat characteristics, species composition and price, and that the species composition and amount of fish caught are directly related to the seasonal and annual variations in flows and associated habitat changes.

7.3. Water Supply: Irrigation and Domestic Use

Water is considered to be the most important provisioning service of rivers and other wetlands. As mentioned earlier, river flows are extensively used for irrigation, domestic supplies and industrial use. It should be realised that the rivers do not produce water in a manner similar to that of producing fish or other biological resources, or creating sand out of rocks. Rivers receive runoff from different parts of their basin through a network of channels, and transport it to distant places, which make it available to humans over longer periods for various uses downstream. In the process, the rivers influence the hydrological cycle, including groundwater recharge, and therefore also provide a regulating service.

An assessment of this provisioning service of River Ken requires a brief look at the water resources and history of their management in the Bundelkhand Plateau region, which is largely occupied by the Ken and Betwa river basins. Prakash (2013) has compiled and synthesised the scattered information on natural resources of Bundelkhand and his work is a major source

Table 8: Landing scenario of fishes at Banda and Chilla sites from the Ken river

Species	Banda			Chilla		
	kg /day	kg per yr	%	kg per day	kg per yr	%
Tor tor	1.86	679	2.01	0.50	91	0.50
Catla catla	2.4	876	2.59	1.0	365	2.00
Labeo rohita	3.0	1095	3.24	1.65	602	3.30
Cirrhinus mrigala	7.37	2689	7.95	4.15	1515	8.30
Labeo calbasu	0.57	207	0.61	1.0	365	2.0
Cyprinus carpio	25.33	9247	27.34	8.3	3030	16.60
Oreochromis niloticus	7.9	2884	8.53	3.9	1424	7.80
Sperata seenghala	13.47	4915	14.53	2.15	785	4.30
Sperata aor	2.37	864	2.55	1.15	420	2.30
Clupisoma garua	1.77	645	1.91	1.30	475	2.60
Eutropiichthys vacha	1.0	365	1.08	2.4	876	4.8
Wallago attu	2.0	730	2.13	0.85	310	1.70
Rita rita	0.93	341	1.01	1.05	383	2.09
Labeo bata	2.47	900	2.67	1.55	566	3.10
Cirrhinus reba	1.83	669	1.98	0.55	201	1.10
Miscellaneous	18.4	6716	19.86	18.75	6844	37.50
Total landings	92.66	33821		50	18250	

Table 9: Price of fish (Rupees kg^{-1}) from the fish market at Banda and Chilla for River Ken

	Categories based on weight of fishes (in kg.)				
Fish Species	<0.5 kg	<1.0 kg	<2.0 kg	>3.0 kg	>4.0 kg
Major carps					
Catla catla	55	75	125	160	190
Labeo rohita	70	90	140	170	200
Cirrhinus mrigala	50	70	110	140	175
Labeo calbasu	55	80	130	165	
Tor tor	80	100	150	200	260
Exotic carps					
Cyprinus carpio	45	65	100	140	150
Oreochromis niloticus	40	60	80		
Important catfishes					
Sperata spp.	65	95	140	80	225
Wallago attu	35	45	55	60	
Rita rita	100	180	240		
Clupisoma garua	210	240			
Eutropiichthys vacha	180				
Other important species					
Labeo bata	75				
Cirrhinus mrigala	75				
Channa spp.	60	85	135	160	180
Notopterus notoperus	50	65	125	200	
Miscellaneous	45-100 Kg^{-1}				

of about a century's worth of historical information. Despite these rivers, the physiography and the climate of the region are such that people are mainly dependent on ground water and on rain harvesting in thousands of large tanks constructed by former rulers. River water had been sparingly used for domestic purposes or irrigation except by the people living along the river banks. It is interesting to note that in District Chhatarpur, the total cultivated area increased from only 205,000 ha in 1950 to 428,600 ha in 2011–12, and the irrigated area increased from <18% to 56.5% of the total cultivated area during the same period. However, even in 2011–12, less than 5.6% of the irrigated area was under canal irrigation (Prakash 2013). Similarly, in Panna district, only 4.37% of the total cultivable area was irrigated in 1981; though it increased to over 29% in 2010–11, the canal irrigation still accounted for less than 7% of the total irrigated area. The situation in districts Damoh and Sagar, which lie in the upper catchment of River Ken, has been similar until now. River Ken

Despite these rivers, the physiography and the climate of the region are such that people are mainly dependent on ground and rain water. River water has been sparingly used for domestic purposes or irrigation except by the people living along the river banks

Table 10: Computation of economic returns from fisheries of River Ken at Banda

Particulars	Villages			
	Bhuragarh	Chhotapurva	Budhapurva	Chilla *
Length of river (km)	2	3	2	12
Type of River bank	CS	CS	CL & WS	CL & WS
Distance from City (km)	5	15	12	39
Nearest market	Sabji Mandi, Banda city	Sabji Mandi, Banda city	Sabji Mandi, Banda city	Kanpur
Total population	1500	1500	1000	10000
Total number of Households	200	214	143	1429
Fisher households	100	60	50	200
Active fishers	40	10	10	50
Main occupation	Agric., Fishing & sand	Agric., Fishing & sand	Agric. & Fishing	Agric. & Fishing
No. of boats (approx)	40	15	10	50
Catch Per boat	2-5 kg	2-7 kg	2-5 kg	2-5 kg
Fishing days/month	20-25	20-25	20-25	20-25
Peak fishing period	April-June	April-June	April-June	Oct-Dec
No. of high priced fishes	10	5	5	12
No. of low priced fishes	30	20	20	35
Fish biodiversity (no. of species)	40	10	10	48
Type of net used	Gill net	Gill net	Gill net	Gill net
Lease amount ₹/year	20 % of fish catch	20 % of fish catch	20 % of fish catch	20 % of fish catch
Income from fish (per month)	5000- 7000 max 2000-3000 min	20000-25000 max 1000-3000 min	5000-10000 max 1000-2000 Min	10000-20000 max 1000-3000 Min
Average income/ Month	4250	12500	4500	8500
Total Income of fishing households	425,000	750,000	225,000	1700,000

was exploited for irrigation in Banda district for the first time in 1905–06 by the British, who constructed a weir at Bariyarpur and a canal system on the right bank. This was supplemented by constructing Gangau Weir upstream in 1916, and was later further augmented by building the Ranguwan reservoir. Thus, River Ken has supported irrigation in District Banda in U.P. for over a century, and yet only 50,600 ha receives canal irrigation (Pant, undated), less than 33% of the total irrigated area. The irrigation in Chhatarpur from River Ken started only a year ago, after the construction of the left bank canal from Bariyarpur Weir. The canal lies 6–8 m below the level of cultivable lands and the farmers have to use 2–5 HP diesel pumps to lift water from the canal to their fields. Other reservoirs constructed in recent years on the tributaries of River Ken also contribute a very small share of irrigation water. Similarly, drinking water supplies from the river are also very small compared to those from groundwater.

During the present study, we were able to assess only the extent of water used by people living along the river course and the river-dependent livelihoods. Throughout the study area, except in the protected areas, people use the river extensively for washing, bathing, cleaning but depend almost exclusively on bore wells, dug wells and hand pumps for their drinking water and other domestic use.

The groundwater situation is somewhat erratic, inasmuch as the water table varies from 5 m to 60 m, up to even 90 m within the same village, and within a distance of less than 100 m, as in some villages of Banda and Panna. Overall, the water table fluctuates seasonally with the river flow and falls rapidly during the years with low rainfall, such as 2014. Within and around Banda city, domestic water supply to municipal and rural areas is based on direct withdrawal from the river as well as the borewells. The total human population of Banda district was 1.8 million (2011 census). The current state of the water supply is described in Table 11.

Table 11: Domestic Water Supply in Banda

- Total Water demand in Banda city: 35.85 MLD Present supply: 30.05 MLD Source : River Ken at Bhuragarh (7.50 MLD) and at Bambeshwar (5.0 MLD)
- Water supplied: only 8.04 MLD; rest is wasted
- Remaining water supplied from 26 bore wells and 40 dug wells (open wells) Overhead tanks: 7; Total pipeline in the city: 196.8 km
- Tankers used: 28 (free supply; average cost ₹500 per tanker)
- Rural water supply:
- Demand 19.92 MLD Present supply 17.03 MLD); Source: 66 Bore wells, two dug wells (open wells)
- No investment in past 5 years
- Expenditure by Jal Sansthan: Salary (Jan-Dec. 2014) ₹90.644 lakh (Urban); ₹165.452 lakhs (Rural)
- Maintenance (by Contractors/Tenders): Urban - ₹38.289 lakhs; Rural ₹66.383 lakhs
- Electricity consumption on 10 to 25 HP pumps which operate 16 hr a day: (cost until March 2015): Urban supply ₹275.738 lakhs; Rural supply ₹416 lakhs
- Water Treatment costs (chloride bleaching only required) Urban: 4.013 lakhs; Rural 4.385 lakhs
- Receipts: Collection (through bills): Urban: 173.951 lakhs; Rural 32.570 lakhs
- Number of connections: Urban: 19797 Rural 9257
- Billing: Urban: ₹720.60 (once in 6 months); Rural ₹372 (once in 6 months)

Irrigation supplies around Banda also depend upon the River Ken, from which six lift canals are operated that pump water from the riverbed to heights of up to 40–50 m and carry it to 24 villages for irrigating an estimated 5000 ha. The relevant data and costs are given in Table 10.

- Total water lifted = 125.5 cusec
- Irrigation potential @ 40 ha per cusec = 5100 ha
- The canals are operated for 8 months a year (15 October to 15 June)
- 150 HP pumps operate for 15-16 hr every day.
- Average cost of electricity per canal : ₹5 lakhs (as reported to us) Total length of canals 40-45 km - into 25 villages
- Maintenance and electricity cost borne by the State.

Water is also lifted directly for irrigation by the individual farmers, from the River Ken, its tributaries, as well as from the canal system throughout the river basin (see plates). More than 100 electric pumps of 2 to 5 HP capacity were observed in a day along the 2 km stretch of the left bank canal from Bariyarpur Barrage alone.

In view of the limited use of river water for domestic supplies in Banda district and inadequate information on similar use in other towns, if any, we do not consider it appropriate to hypothesise the river's value for these provisioning services. The main River Ken at present provides irrigation water for only about 55,000 ha in Banda and Chhatarpur districts.

7.4. Panna Tiger Reserve

Tiger reserves are often perceived as large forest areas 'reserved' only for tigers and some other wildlife, while denying their benefits to humans. At best, people perceive them as areas of recreational value for watching wildlife in their natural habitats. However, these tiger reserves and other similar protected areas provide a wide range of indirect tangible and intangible benefits that are not readily recognised. The forest contributes to climate change mitigation through carbon sequestration, prevents soil erosion, regulates the volume and quality of water in the streams, protects fish nurseries in the streams and other water bodies, conserves genetic material for future generations, mitigates natural disasters, and drives tourism that supports livelihoods. Recently, a detailed study has been made on the diverse ecosystem services of six tiger reserves in India (Verma et

Table 12: Irrigation in and around Banda through Lift Canals withdrawing water directly from the River Ken

Pump Canal	Water withdrawn
Kanwara	15 cusec
Triveni	7.5
Daulatpur	20 cusec
Kazipur	15 cusec
Alona	40 cusec
Chhani pump canal (to Hamirpur)	30 cusec

The interdependence of the aquatic and terrestrial ecosystems is an often overlooked aspect of ecosystem services. While forests help to regulate riverine water quality and biodiversity, rivers provide water and forage for forest wildlife, making the River Ken an integral part of the Panna Tiger Reserve

al. 2015). The study used a multiplicity of frameworks including Total Economic Value; Millennium Ecosystem Assessment; Stock and Flow; and Tangible and Intangible Benefits, to communicate the diverse values of the tiger reserves.

The study examined a wide range of ecosystem services which included: agriculture; fishing; fuel wood; fodder and grazing; timber; non-timber forest produce; gene-pool protection; carbon sequestration; water provisioning; water purification; soil conservation and sediment regulation; nutrient cycling and retention; biological control; moderation of extreme events; pollination; nursery function; habitat and refugia; cultural heritage; recreation; spiritual tourism; research; education and nature interpretation; gas regulation; waste assimilation; and employment generation. The study also identified relevant ecosystem services for each of the tiger reserves, which differed considerably in services and their extent. The study estimated the economic benefits flowing from these reserves to range from ₹50,000 to 190,000 per hectare per year depending upon the characteristics of the ecosystems of the tiger reserves. Using the Millennium Ecosystem Assessment framework, the study further brought out extremely large differences in the value of different services. For example, the cultural services of Kanha Tiger Reserve were estimated at ₹383.7 million per year (1.4% of the total value of all ecosystem services), whereas they had no value in the case of Ranthambore Tiger Reserve.

While the application of the methodology used by Verma et al. (2015) to the Panna Tiger Reserve requires a large amount of time-series data on many parameters, a rough estimate can be made from the value of a relatively similar tiger reserve. Our understanding of the Panna Tiger Reserve and our discussions with PTR authorities, including the Director, Mr R. Sreenivasa Murty, show that it is somewhat intermediate in character between the Kanha and Ranthambore Tiger Reserves, whose ecosystem services have been valued at ₹0.80 lakhs and ₹0.56 lakhs per hectare. Panna Tiger Reserve covers a quite small area, about one-third of Ranthambore and one-fourth of Kanha Tiger Reserve. Assuming an average value of only ₹0.68 lakhs per ha, the total economic value of the Panna Tiger Reserve would be approximately ₹369 crores (₹3.69 billion) per year.

Another aspect of ecosystem services that is usually overlooked is the interdependence of the aquatic and terrestrial ecosystems. The contribution of the forests to the riverine ecosystem in regulating hydrology water quality and biodiversity is mentioned above. However, the forest also depends on the river and its network of tributaries and riparian areas for the water and forage for wildlife. In the case of Panna National Park & Tiger Reserve, the herbivores graze in riparian areas that are richer in nutritious plants than the forest floor, and all wildlife drinks water from the tributaries. In a dry landscape with no source of water, waterholes have to be provided for the wildlife. The river itself contributes to the diversity of wildlife by supporting gharials, muggers, and the bird populations. The recreational value of the PTR is enhanced by their presence and opportunities for boating. Thus, the River Ken is an integral part of the PTR and contributes to its recreational services in the form of ecotourism.

We therefore made an initial assessment of the value of ecotourism-related ecosystem services in Panna Tiger Reserve using the Travel Cost Method. The results are presented below.

7.5. Cultural-Recreational Services (Ecotourism)

All natural ecosystems provide a variety of cultural and recreational services, and rivers generally hold a place of greater importance, as they contribute immensely to the aesthetic beauty of the landscape. River Ken is no exception. The river, known as Karnavati, is associated in mythology with the Pandavas of the Mahabharat period, who are believed to have spent some of their time in exile near this river. At the village Pandavan on Amanganj- Kishengarh highway, associated with the Pandavas, the River Ken suddenly falls into a sinkhole and runs belowground. Shortly after emergence, it forms a fall and then flows through a wide gorge at Gehrihat. The riverbed at Pandavan is of great geological interest, though not yet investigated and not yet on the visitors' map. The riverbed has hundreds of potholes, created by high fluvial activity in the past. When he saw photographs of the potholes in April of 2015, Prof. V.S. Kale, from the University of Pune, stated, "I have never seen such classic potholes (100s) anywhere". The site certainly deserves to be a geoheritage.

There are excellent opportunities and facilities for boating the river through breathtaking scenic landscapes inside the Tiger Reserve and at the Ken Gharial Sanctuary, but these are neither well-publicised nor properly utilised. The waterfall and the gorge at Gehrighat are spectacular sites for visitors to enjoy nature's beauty. There are also Pandav Falls, in the Panna National Park, which offer a scenic view and are commonly visited by Indian and overseas tourists in significant numbers. The famous Kalinjar Fort, though somewhat neglected now, rests beside the river in Panna district. Mesolithic (Stone Age) paintings grace caves in the river's vicinity, at Barachha, in Panna. Thus, the River Ken and its environs have enormous historical, cultural and recreational value, though the potential has not yet been explored nor utilized, due to neglect of the area in general. It is worth pointing out that an area around the Panna National Park has been proposed for the creation of Panna Biosphere Reserve (EPCO 2012) and deserves urgent attention.

However, currently of the greatest importance are the Panna Tiger Reserve, the Gangau sanctuary, the Raneh Falls, and the Ken Gharial sanctuary, all of which are visited by large numbers of Indian and foreign tourists. The latter two sites owe their importance entirely to River Ken. Even the Panna Tiger Reserve, which attracts visitors primarily for its rich wildlife, presents a scenic view of the pristine river that flows through it, and offers opportunities for visitors to view the gharial, the mahaseer and other aquatic wildlife closely, and enjoy the pleasure of boating in a serene setting of tree-fringed river. It can be readily appreciated that the river and its numerous tributary channels running through the undulating forest provide the necessary sustenance to the wildlife in particular and the vegetation in general. Only about 30 km away stand the famed Khajuraho temples, which attract several lakhs of visitors from all parts of the world. In 2013, 276,434 Indians and 89,511 foreign tourists from more than 70 countries visited the World Heritage site. A significantly large number of these visitors go to the Tiger Reserve and Raneh Falls every year. We have collected a large amount of visitors' data from the office of the Panna Tiger Reserve, several hotels and resorts in Khajuraho, the temple booking office, and interviewed many tourists and service providers during the entire study period. We present here some of this data and our analysis of a part of the data for 2014 visitors to the Panna Tiger Reserve, in order to arrive at the current economic value of the Tiger Reserve, and hence River Ken, using the single recreational service-ecotourism alone.

7.5.1. Methodology

Use of the rivers and wetlands is largely dependent

Figure 9: Number. of Visitors to PTR (data from Madla Gate)

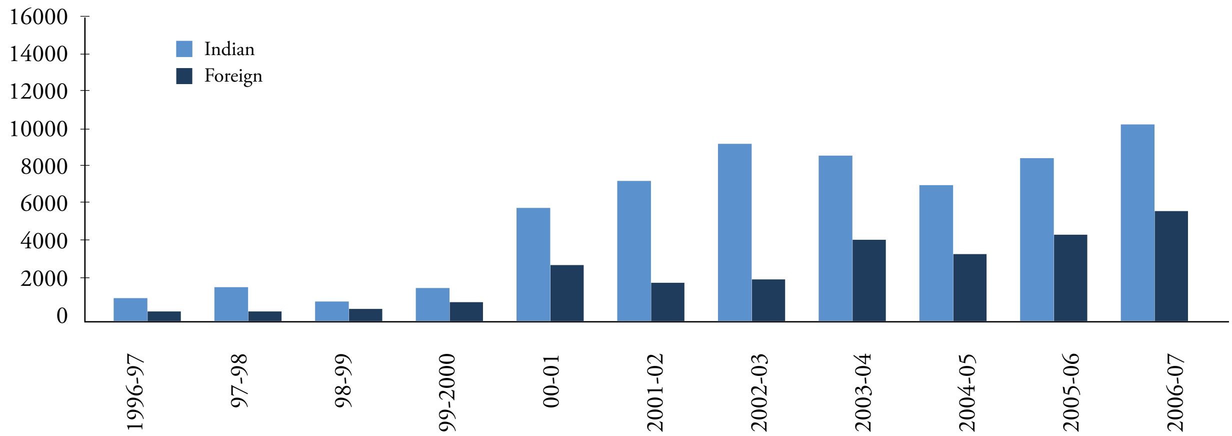
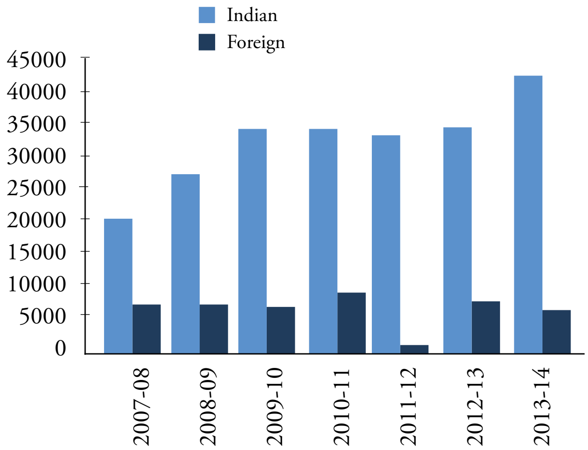


Figure 10: Number of visitors to Raneh Falls & Ken Gharial Sanctuary (courtesy :Director, PTR)



Courtesy: Director, PTR

on the property rights regime. For this reason, the property and management regimes and the institutional arrangements of River Ken were also examined. The questionnaires and schedules were prepared and finalised for investigations on valuation. Various valuation methodologies, like Travel Cost Method and Contingent Valuation Method, are generally used to estimate the economic use values of ecosystems services. In view of the quality of data in this study, Contingent Valuation Method was omitted in the analysis. We used only the popular Travel Cost Method (TCM) to estimate the economic value of recreational uses associated with the Ken River ecosystem. The relationships between number of visits and other variables were regressed using data on both Indian and foreign tourists, and consumer surplus for the study site was estimated. The variables used in the study are described in Figure 9. The number of visitors – both Indian and foreign – to Panna Tiger Reserve (PTR) was the dependent variable. The explanatory (independent) variable was divided into 2 categories, viz. quantitative variables and binary variable. The quantitative variables include online ticket booking, offline ticket booking, cost incurred in travelling, time taken to reach Panna Tiger Reserve (PTR), and time spent in PTR. The binary variable was incorporated based on visitors' perceptions towards tourism focused on the River Ken. In regression analysis, the dependent variable is frequently influenced not only by ratio scale (quantitative) variables, but also by nominal (qualitative) variables. Since Ken River is famous for its unique geological formation, a nominal variable regarding visiting Ken River ecotourism site was also added in the analysis. Also, Ken River has significant religious importance, too, that was also taken into consideration for analysis. The data were collected mainly from Mandla and Hinnota gate of Panna Tiger Reserve and Department of Tourism, Madhya Pradesh. Also, some data were collected from police reports and travel agencies concerned with tourism.

7.5.2. Analytical Technique

This study employs the Travel Cost Method (TCM) to estimate the tourism potential of Ken River. TCM provides a mean to estimate the monetary values of non-marketed commodities based on actual behaviour, by using the individual's expenses with

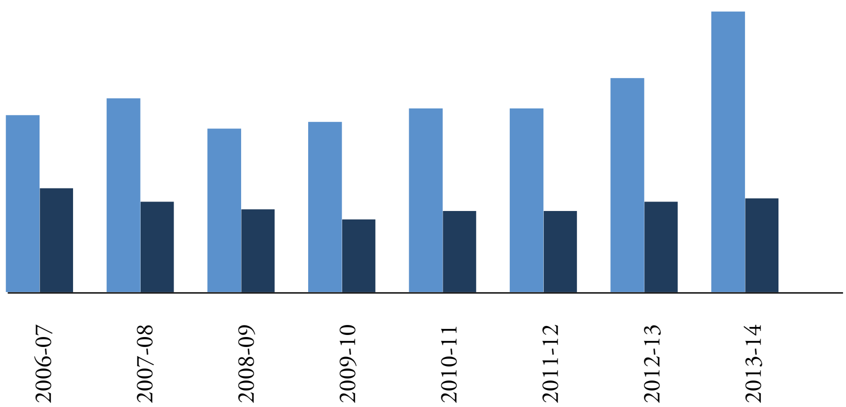
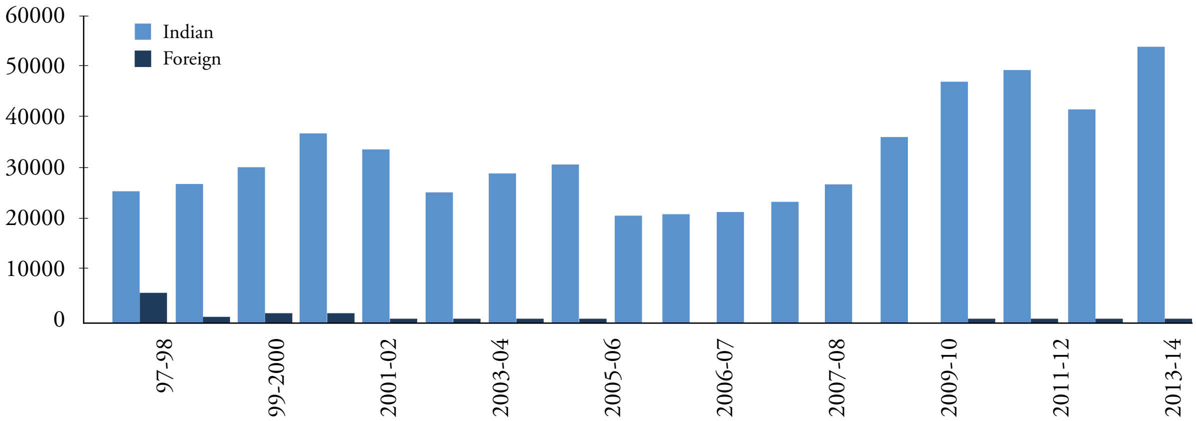


Figure 11: Number of visitors to Pandav Falls



Courtesy: Director, PTR

marketed commodities that are weakly complementary with the non-marketed ones – an indirect way to reveal individual preferences (Freeman, 2003). The method establishes a relationship between the costs incurred by travellers to a site and the trips taken. In the present analysis, the number of visitors to Panna Tiger Reserve was regressed with the cost incurred. This relationship is further exploited to derive Marshallian Consumer Surplus for access to the site, for a recreation experience, by simply integrating the area under the demand recreation curve, between two levels of cost: the actual price and the choke price, which refers to no demand at all (Fischer, 1999). The general theoretical basis derives from the basic economic notion of an individual utility function subject to budget and time constraints. The representative visitors are represented by the utility function (Pendleton & Mendelsohn 2000).

By applying the concept of utility function, the functional equation can be expressed as follows:

For Indian Visitors

VISITOR_IN = f (ONBK, OFBK, COST INC, TIME TRV, TIME SPT, PTR, KEN_{IN})

For Foreign Visitors

VISITOR_FN = f (ONBK, OFBK, COST INC, TIME TRV, TIME SPT, PTR, KEN_{FN})

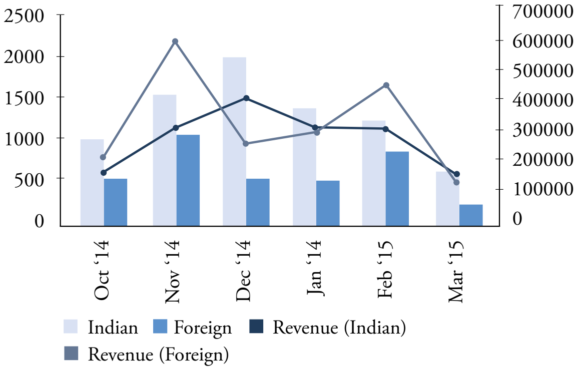
Dependent variable: No. of Foreign visitors

ANOVA models are used to assess the statistical significance of the relationship between quantitative and qualitative variables and can be accomplished

Table 13: We used more detailed data for the period 2014-15 noted below for our analysis.

Months	Indian Visitors	Foreign Visitors	No. of vehicle (Indian)	No. of vehicle (foreign)	Entry fees (Indian)	Entry fees (foreign)	Portal fees @ 50 per vehicle (Indian)	Portal fees @ 50 per vehicle (foreigner)	Total Revenue (Indian)	Total Revenue (foreign)
October	1071	583	183	170	182400	236400	9150	8500	191550	244900
November	1639	1136	306	338	327600	636000	15300	16900	342900	652900
December	2104	586	464	181	423600	283200	23200	9050	446800	292250
January	1470	562	314	177	328800	324000	15700	8850	344500	332850
February	1300	930	294	285	326400	484800	14700	14250	341100	499050
March	662	265	150	92	170400	146400	7500	4600	177900	151000
Total	8246	4062	1711	1243	1759200	2110800	85550	62150	1844750	2172950

Figure 12: Number of visitors and revenue collected at the PTR



within the framework of regression analysis. For present analysis, the following model was applied

+ Where, = Dependent variable

= Intercept

….. = Quantitative independent variable

& = Dummy or qualitative variable

= Error term

7.5.3. Results

7.5.3.1. Descriptive Statistics of the variables under study

The average number of Indian visitors visiting the site was 58 per day, while the number is around 28 in the case of foreign visitors. The active tourist period was from October to the end of March. The incidence of offline booking is more than online booking in the cases of both Indian and foreign tourists.

The cost incurred in travelling varies from ₹11142.54 to 16106.29 for Indian and foreign tourists. Here, for foreign tourists, the cost incurred is estimated based on their actual Start of Journey when visiting Panna Tiger Reserve.

Around 65% of Indian tourists visit Panna Tiger Reserve as their first priority site, compared to the 35% of Indians who visit PTR as an additional tourist spot covered with other sightseeing places of their interest. In the case of foreign tourists, 65 % visit Panna Tiger Reserve as their additional sightseeing place. When enquired about their reason for visit, 65% of Indian tourists visit Ken River due to its religious importance. Roughly 38% of foreign tourists' visits are due to the unique geological formations, while the other 62% of tourists visit the site as an additional tourist spot.

The model was fitted using the SAS software package in Enterprise guide 4.2 (2006–2008 by SAS Institute Inc., Cary, NC, USA). The results were given in Table 16 for foreign visitors. The model algorithm converged with a log, with a likelihood of 190.825. Only two variables – online booking (ONBK) and offline booking (OFBK) – were found significant. Since other variables like cost incurred, time spent, and time travelled were found insignificant, they were completely omitted from further analysis.

For the estimates of Indian visitors, all seven variables were included in the model, but the predicted model was ambiguous. Therefore, the quantitative variable and dummy variable were separately regressed. The results of the dummy variable were found insignificant for the model applied. (See Table 17). The linear regression of Indian visitors with 3 quantitative variables was fitted for analysis. Other variables were omitted due to its insignificance in the model applied.

Table 14: Description of variables under study

Variables name	Description
Dependent Variables	
VISITOR_IN	Total no. of Indian visitors per day
VISITOR_FN	Total no. of foreign visitors per day
Quantitative Variables	
ONBK	No. of visitors booked ticket online
OFBK	No. of visitors purchased ticket from counters (offline)
COST INC	Cost incurred in Travelling (In ₹)
TIME TRV	Time taken to reach PTR (in hours)
TIME SPT	Time spend on PTR (in hours)
Binary Variables	
PTR	Indian & foreigner visitor's perception towards visiting PTR as first priority site : 1 for positive response; 0 otherwise
KEN_{FN}	Foreigner visitor's perception of reason for visiting Ken river based tourist sites 1 for uniqueness ; otherwise 0 (as additional tourist spot)
KEN_{IN}	Indian visitor's perception oof reason for visiting Ken river based tourist sites: 1 for uniqueness & otherwise 0 (Religious importance)

WETLANDS

All the variables included – i.e. online booking, offline booking and cost incurred – were found significant at 0.01% and 0.8% respectively. Only Regression results of Indian visitors (See Table 18) were used in further estimation of consumer surplus of the visitors.

7.5.3.2. Estimation of Consumer Surplus

Peoples' willingness to pay to visit the site can be estimated based on the number of visits that they make at different travel costs. By finding the consumer surplus of the individual visitors, we can estimate the tourism potential of the tourism site.

Since the significant result was obtained only for Indian visitors, the following fitted regression line was obtained.

VISITOR_IN = 16.72376 + 0.72343* ONBK + 1.08397* OFBK + -0.002774509 *COST INC

= 16.72376 + 0.72343*47+ 1.08397*11 + (-0.002774509) *11142.54

= 32

Thus, the value of Yi (VISITOR_IN) was estimated to be 32 Indian visitors per day. For estimating consumer surplus, the cost incurred in travelling is increased by keeping all other variable constant and again a regression line is fitted till the value of Yi (VISITOR_IN) becomes zero. And the consumer surplus is obtained by the following formula:

Consumer's surplus = what is a consumer is willing to pay – what he actually pays

Marginal Utility – (Price * No. of visits to the site)

Based on the analysis, the following results were obtained. As depicted in Table 19, when the cost is increased to ₹1000 only 29 visitors agreed to visit the tiger reserve based on a fitted regression line. Likewise, as the cost increases, the number of visitors to the park decreases till we get zero visitors. The average consumer surplus was estimated to be ₹9344.51 per visitor per day. Based on the data of tourists visiting Panna Tiger Reserve in the year 2014–15, the tourism potential was estimated to be around 7.69 crore rupees.

Table 15: Descriptive Statistics of the variables

Parameters	Indian Visitors	Foreign Visitors
No. of visitors	58	28
Online Booking	11	8
Offline Booking	47	20
Cost Incurred in Travelling (In ₹)	11142.54	16106.29
Time Travelled (in hrs)	6.95	3.2
Time spent	9.8	10.1
PTR as first priority sightseeing (Yes =1)	93 (65%)	51 (35 %)
PTR as first priority sightseeing (No =0)	50 (35%)	92 (65%)
Reason for visit to Ken river (Yes =1)	78 (55%)	54 (38%)
Reason for visit to Ken river (Yes =0)	65 (65%)	89 (62 %)

Table 16: Variable estimates of number of Foreign visitors to Panna Tiger Reserve

Model: Analysis of Variance				No. of observations : 143		
Log. Likelihood of the model: 190.825						
Analysis Of Maximum Likelihood Parameter Estimates						
Parameter	Estimate	Standard	Error	Wald 95% Confidence Limits	Wald Chi-Square	Pr > ChiSq
Intercept	0.0968	0.0610	-0.2163	0.0228	2.52	0.1125
ONBK	1.0004	0.0014	0.9977	1.0031	532133	<.0001
OFBK	0.9996	0.0018	0.9962	1.0030	324177	<.0001
COST INC	-0.0003	0.0042	-0.0082	0.0081	0.00	0.9992
TIME TRV	0.0001	0.0000	-0.0000	0.0000	0.34	0.5591
TIME SPT	-0.0007	0.0034	-0.0073	0.0060	0.04	0.8426
PTR (1 vs 0)	0.0515	0.0391	-0.0251	0.1280	1.73	0.1878
KEN (1 vs 0)	0.0219	0.0377	-0.0520	0.0958	0.34	0.5615

Table 17: Dummy Variable estimates of No. of Indian visitors to Panna Tiger Reserve

Dependent variable: No. of Indian visitors						
Model: Analysis of Variance				No. of observations : 142		
Log. Likelihood of the model: -731.72						
Analysis Of Maximum Likelihood Parameter Estimates						
Parameter	Estimate	Standard Error	Wald 95% Confidence Limits	Wald Chi-Square		Pr > ChiSq
Intercept	56.5027	5.5112	45.7009	67.3045	105.11	<.0001
PTR (1 vs 0)	-0.0422	7.5259	-14.7927	14.7082	0.00	0.9955
KEN (1 vs 0)	2.7102	7.1812	-11.3646	16.7850	0.14	0.7059

Table 18: Linear regression result of No. of Indian visitors to Panna Tiger Reserve

Dependent variable: No. of Indian visitors				
Model: Linear Regression		F value = 169.59		
No. of observations : 142		R2 = 0.77		
Parameter Estimates				
Parameter	Estimate	Standard Error	t value	Pr > ChiSq
Intercept(ß)	16.72376	4.24990	3.94	0.0001
ONBK	0.72343	0.05843	12.38	<.0001
OFBK	1.08397	0.07728	14.03	<.0001
COST INC	-0.002774509	1.117439E-8	0.25	0.0843

7.5.4. Conclusion

The ecotourism potential of Panna Tiger Reserve has thus been estimated to be ₹7.69 crores per year, which indirectly represents the tourism importance of Ken River in monetary terms.

7.6. Other Ecosystem Services

It is not possible to estimate the value of many direct and indirect use and non-use ecosystem services in the absence of time-series data and inputs by a large cross section of stakeholders within a span of a few months. We have, however, identified some of these services and tried to obtain semi-quantitative or qualitative descriptive information on these services to demonstrate their significance. These services are briefly presented below.

7.6.1. Riparian Agriculture

In the context of water use for irrigation, the agriculture practiced in the floodplains and riparian areas of the river is of considerable significance, both in terms of its economic value and the livelihoods it sustains. Riparian and floodplain cultivation is generally based on the natural fertility and water-holding capacity of the soils, renewed every year by the monsoonal flows, also known as floods.

As mentioned earlier, River Ken flows through wide channels cut through rocky beds and high, nearly-vertical banks. The floodplains lie at 3 to 20 m elevation from the channel surface. However, in several areas along its course, there are large pockets of alluvial deposits near the riverbanks. Here the soils are usually loamy or even clayey and quite fertile. These riparian areas subjected to annual flooding are cultivated for growing a variety of vegetables by the poorer sections of the village community. This cultivation, locally called "begari", supports the livelihoods of many people, as they are allotted small plots by the village and earn substantially to support their families. We observed such begari cultivation along River Sonar, at Jhingra Village, and River Ken, at villages Kahla and Banda. At other places with somewhat table land, for example along R. Patne near Pawai, crops are cultivated using water pumped directly from the river. Extensive agriculture is practiced on the drawdown areas of Gangau Reservoir adjacent to the barrage, taking advantage of thick alluvial nutrient rich deposits and natural soil moisture to grow wheat. Farmers even use tractors to cultivate their fields. Further upstream, at Daudhan village, there are extensive agricultural fields along the river. It appears that these fields have developed on the alluvial deposits in the century since the construction of Gangau Barrage. The villagers at Daudhan informed us that the soils are very smooth and extremely fertile, and productivity is quite high without the use of fertilisers, pesticides or irrigation.

7.6.2. Water Quality Waste Assimilation Potential

One of the most important ecosystem services of the rivers is their waste assimilation capacity, which is directly related to their specific flow regimes and biophysical characteristics. River Ken, with a single thread channel and a rocky substratum mostly composed of boulders and gravel that intercept some sand in between, has so far retained a high water quality in the absence of any significant point source pollution. The high water quality of the river was observed in our analysis of a few parameters, which included: pH, dissolved oxygen, transparency, electric conductivity, total dissolved solids, and nutrient density. The water has a moderately high hardness because of relatively high calcium content from natural sources. The riverbed and surrounding soils have very high concentrations of calcium in the form of large calcareous granules, called "kankar", and enormous density of both gastropod and bivalve molluscan shells. The high quality of water of a potable nature is also reflected in the fact that Banda City's domestic water supply requires no treatment except chlorination. This high water quality of the main channel of River Ken is currently observed even during the lowest flow period in winters.

The economic value of the waste assimilation service of the rivers can be assessed in terms of the costs involved in setting up the infrastructure and the operation and maintenance of appropriate wastewater treatment systems and the increased costs of treating raw water for domestic supplies. Such economic analyses have been made for River Ganga by Markandya and Murty (2001), and a recent report of a Working Group of the Planning Commission shows that the cost of water treatment, which depends on the quality of the water to be treated, technology used, and the level of treatment desired, can rise at the current prices to a phenomenal ₹1 crore per million liters per day for infrastructure, and of ₹4 per kilolitre for operations and maintenance (O&M) (Narain 2011).

Table 19: Consumer surplus of Panna Tiger Reserve

Increase in Cost (In ₹)	No. of visitors	Consumer surplus
0	32	0.0
1000	29	322677.4
2000	26	291762.3
3000	23	260847.3
4000	21	229932.2
5000	18	199017.1
6000	15	168102.0
7000	12	137186.9
8000	10	106271.9
9000	7	75356.8
10000	4	44441.7
11000	1	13526.6
11100	1	10435.1
11300	0	0.0
	199	1859557.4
Total consumer surplus (in ₹)		1859557.4
Average (per visitors) (in ₹)		9344.51
Tourism potential as on 2014-15 (8230 visitors as on 11.03.2015 data)		76905317.3

8. Anticipated Impacts of Proposed K-B Link

A river's flow is invariably associated with a set of concomitant services, such as transporting and distributing sediments and nutrients, sustaining and renewing soil fertility for higher productivity, supporting and dispersing biodiversity, recharging the groundwater along its course and, above all, maintaining high water quality through assimilation of wastes. These services are closely interlinked with the volume, velocity, duration and timing of the flow at a point along its course. Storage and diversion of river flows provide certain benefits, such as agriculture, domestic supplies, industry or hydropower, but these benefits have a cost. Altered river flows beyond a certain threshold have an adverse impact upon the downstream ecosystem services of the river.

We note that the provisioning services of River Ken's water supply for irrigation and domestic use would be fully exploited by diverting the flow at Daudhan, but this will deprive the downstream people in Panna, Chhatarpur and Banda of the same services

In the case of River Ken, the first and so far only diversion of flow was made at Bariyarpur over a century ago for irrigation in Banda. There is no information readily available on the biodiversity or ecosystem services of the river at that time. However, it is well known that the reduced flows have facilitated the establishment of common carps – an exotic species introduced in India in the late 1950s. After the Gangau Weir got completely silted up, there was a proposal to construct another larger weir upstream to sustain the canal system. However, the proposal was replaced with the current proposal of developing a link canal to transfer some water from River Ken to R. Betwa. The K-B Link involves a 78-metre-high-dam at Daudhan Village, upstream of Gangau, which will also provide hydropower and irrigation along the link canal. According to feasibility studies (NWDA 2005), the entire project (including Phase II on R. Betwa) was estimated to cost ₹1988.74 crore (1994–95 price level) and provide net annual benefits of ₹449.79 crore from the irrigation alone. The Benefit-Cost Ratio for the project as a whole, including the power component, was projected to be 1.87. The revised financial estimate in the DPR (NWDA 2008) at 2007–08 price levels raised the project cost to ₹7614.63 crores and the net benefits from agriculture and hydropower to ₹1607.62 crores, but lowered the Benefit-Cost Ratio to 1.71. The project is yet to get started and will take 10 years to complete.

An Environmental Impact Assessment (EIA) was conducted by the Agricultural Finance Corporation Limited, and the report was made public in December 2014 for public hearing. It is neither our mandate nor our intention to analyse this EIA report here. Suffice it to point out that the EIA report considers impacts within a 10 km radius of the project site, as per their TOR. Based on our field studies and understanding of river ecosystems, particularly the River Ken, we looked at the potential impacts of the project on the ecosystem services of the river and their economic value.

We note that the provisioning services of River Ken's water supply for irrigation and domestic use would be fully exploited by diverting the flow at Daudhan, but this will deprive the downstream people in Panna, Chhatarpur and Banda of the same services. These people will rely on the flows contributed by downstream tributaries, such as Kutni, Urmil and Chandrawal, which have also been impacted by dams constructed recently. Since Banda relies largely on the river for domestic water supplies and some of its lift irrigation, the reduced flows will affect the supplies and increase the costs. Another major impact of reduced flows would certainly be groundwater recharge in areas along the river, evidenced by the fall in groundwater level during dry years.

We have assessed fisheries to be a major biodiversity-linked ecosystem service that also supports human livelihoods. The downstream fish catch will certainly decline along with gradual changes in species diversity after the reduction in river flows. The upstream fisheries will also be adversely affected by the high dam and the submergence of areas inhabited by a few rare, endangered and vulnerable fish species.

8.1. Impacts on Sediment Transport

As is common to all other storage reservoirs, a large volume of sediments will be trapped behind the 78-metre-high dam proposed at Village Daudhan. The river downstream will be deprived of these sediments, causing several kinds of economic losses, such as the loss of habitats for fish, gharial, and other wildlife, as well as the loss of agriculture. Sand is a directly-utilised economic resource that will be lost partly to the extent it is trapped upstream and partly to the extent its transport downstream will be affected by the reduced flows.

The EIA Report of the proposed K-B Link project has estimated that, on the basis of long-term average sediment load of the river at Banda gauging site, the total sediment transported by the River Ken per year is 96,10,518 tonnes, which equals 83,93,465 m^3, or 8.39 MCM, with the average density of silt being 1.145 t/m^3. Out of this sediment load, about 6.5 MCM are estimated to be trapped annually behind the dam. Thus, at a conservative price of sand at the mines in Banda – ₹14,000 for 19 m^3 truckload, or ₹737 per m^3 – the value of sediments trapped behind the dam is estimated at ₹4790.5 million, or ₹479 crores per year. The reduced availability of sand downstream will have its own economic costs.

It is important to note that it will be wholly impossible to dredge out the sediments from the 78-metre-deep reservoir spread over the more than 100 km2 area, and then to transport them to downstream areas. Even if it were possible technologically, the costs would be phenomenal, and downstream damage would have already been done.

8.2. Loss of Ecosystem Services of the Tiger Reserve

It is interesting to estimate the loss of ecosystem services solely due to the proposed dam at Daudhan's projected submergence of the 125 km2 area of the PTR, which includes its core habitat. The loss, in simple terms, would be ₹85 crores every year, even if the consequent downstream effects of the reservoir on the remaining area of the Tiger Reserve were not accounted for.

9. Summary of Discussions with the Community

During the study period we interacted with several thousand people from all sections of the society – from the common man on the street, to the poorest villager, to the landless labourer; from farmers to business people, to college and school teachers, to government officers and peoples' representatives. We interacted with tourists visiting Khajuraho, Panna National Park and Raneh Falls, as well as a wide range of people engaged in the tourism industry. It is not possible to report all these conversations and discussions in detail. Major salient points are only summarised here. These are categorised into two groups: (1) the views of the stakeholders regarding the River Ken and its benefits; and (2) the views concerning the proposed Ken-Betwa Link project.

9.1. Views of the Communities on River Ken and its Benefits

1. We were surprised that many people were not aware of the river or its course. Some had never even seen it. However, most of the people knew a lot about it and its tributaries, and provided useful information during our surveys.
2. People in general did not attach any special significance to the river, except that they associated it with the Pandavas of the Mahabharat period, who were supposed to have stayed in this region for some time during their exile – at Pandava Falls, for example. The people around Pandavan narrated a belief that the Pandavas had tried to stop the river at that place, but the river water passed under their feet by turning itself into a fish. This incidence is used to explain the sinkhole and the subterranean flow of the river downstream of this site for more than one km.
3. Practically all people in the villages along the river, along its tributaries, and throughout the basin, thought of the river as only a source of water, mostly for agriculture. For them, at first thought, the river had no other benefits, while it had a negative, often disastrous impact on their lives when it caused floods. Almost every one had vivid memories of the devastating floods of 2004, when the river rose by over 20 meters and washed away their hutments. At Madla, the river flowed well over the railings on the bridge over NH 75.
4. The irrigational benefits from River Ken have accrued mostly to the people in U.P. over more than century. The canal system from Bariyarpur

In general, the communities on River Ken knew a lot about the river and its tributaries yet did not attach any special significance to it. Almost all people in the villages along the river thought of the river as just a water source, primarily for agriculture

Many benefits of the river were appreciated only by those directly concerned with that benefit, and most people claimed no direct benefit from the river. No commercial fishing leases exist, and almost all tourists to the region were unaware of the River Ken

Barrage served only the farmers in Banda. Other reservoirs, such as Ranguwan, are also controlled by the Irrigation Department of U.P. The left bank canal from Bariyarpur completed recently serves parts of Chhatarpur District, but people do not see of much advantage because they have to use pumps to lift water to their fields. Many people use pumps to lift water directly from River Ken and its tributaries.

5. After little hints were provided regarding their drinking water sources, people readily linked the groundwater recharge with the river flows. They reported seasonal changes of 3 to 6 metres or more in the groundwater table, with drastic differences between dry and wet years. However, most people also knew from their experiences about the large variability in geology and permeability of the soils over even short distances. For example, in village Ujreta, in District Banda, hand pumps drilled within 25–30 m of each other yielded different results.
6. Other benefits from the river were perceived and appreciated by only those directly concerned with that benefit. Thus, drawing water for drinking or domestic use, or using the river for bathing or washing clothes, was appreciated by only a few people, and that too as a compulsion because of non-availability of water near their homes.
7. There are no commercial fishing leases. In a large stretch passing through the Panna National Park, fishing is prohibited but occurs illegally. Throughout the Madhya Pradesh part of the River Ken and its tributaries, fishing is done by individuals for their own consumption or for sale in the market. Within the Uttar Pradesh part, at Banda and downstream, fishing occurs on a larger scale, though still by individual fisherfolk. Our studies are reported in a separate section on their valuation.
8. Sand transported by the river is a major resource and is highly valued. In the middle reaches of River Ken, which pass through the Panna National Park and Ken Gharial Sanctuary, sand is extracted from the tributaries. In Chhatarpur, sand is extracted largely from River Dhasan. In a downstream reach over about 100 km in Panna, Chhatarpur and Banda districts, sand mining is a major activity. Details are discussed in a separate section of this report. People engaged in sand mining are aware of the variations in sand transport in relation to the flows of the river. When sand is not renewed by fresh transport from upstream areas, miners exploit the deeper deposits. However, many farmers complained of its adverse impacts on groundwater, and the loss of agricultural use of floodplains.
9. Almost all tourists to Khajuraho, Raneh Falls, and Panna Tiger Reserve, were unaware of the River Ken. In general, they were unaware of the Ken Gharial Sanctuary before they arrived to see the Raneh Falls, and none had known about the opportunity for boating on the river inside the Park or near the Gharial Sanctuary. Other attractions on the river, such as the fall at Gehrighat, the large wide gorges, or the site at Pandavan, are not known even to the local people, and are not well publicised.
10. In the absence of significant riparian vegetation, and because of the morphological features of the river, which include steep, vertical banks, people do not appreciate any direct benefits from the river.

9.2. Communities' Views Concerning the Proposed Ken-Betwa Link Project

1. In order to understand the impacts of flow storage and diversion on the ecosystem services of the river as perceived by the people, we asked specifically about the likely impacts of the proposed Ken-Betwa Link project. Again, to our greatest surprise, the vast majority of people did not have any idea about the project. Some people did say that such a

project was planned more than ten years ago, but that nothing has happened since then. Only a few educated people and those living in the area that would be immediately affected by the project were aware of it.

2. It is important to place on record that the Special Secretary of the U.P. Forest Department, who is also the Member Secretary of the U.P. State Biodiversity Board, was unconcerned with the project. She told Dr Brij Gopal on 10 October, 2014, that as the project is not on their land, they need not worry about it.
3. Most of the people to be affected by the project, due to the submergence of their villages at the project site, had resigned to their fates and were concerned about the quantum of compensation. Because these villages, such as. Daudhan and Palkhowan, lie inside the Panna Tiger Reserve and have to be relocated, people were not concerned about the impacts of submergence.
4. Coincidentally, the Public Hearing on the EIA report of the proposed K-B Link project was conducted during our study period – on 23 and 27 December 2014. It gave us an opportunity for interaction with many stakeholders and a large number of people from the neighbouring areas. Because of our ongoing interactions with the downstream communities in Banda, Panna, Mahoba, Hameerpur and Chitrakoot, several people from these areas came to the Public Hearing.
5. It is interesting that the Collector of Chhatarpur, who attended the Public Hearing in Silon on 23 December, publicly admitted about his being not fully aware of the project and having not widely publicised about it to the public in the district as required. The Additonal DM of Panna was aware of it, had prepared a separate file, and agreed to show it to Dr Brij Gopal. It was only after some reluctance that he provided a copy of the EIA report on a CD to us on 26 December, 2014.
6. The stakeholders and participants at the Public Hearing, especially on the 27th, were divided into two camps: those for and against the project. Clearly divided on political lines, participants were in general unwilling to discuss the technical, social and economic aspects of the project and its impacts. Even researchers like us, directly engaged in the study of the river, were shouted down as outsiders.
7. Of greatest relevance to the present study on ecosystem services of River Ken is the fact that the EIA report did not consider the impacts of the project on the river downstream, even up to 10 km downstream of the proposed dam. Nor did it consider the entire projected area of submergence. Many people from Banda and Panna raised these issues, but were not heeded.

10. Conclusions and Recommendations

Whereas some ecosystem services of a few wetlands in India have been assessed and valued in economic terms, the rivers have never been examined for their ecosystem services and their economic valuations. The present short-term study, from September 2014 to April 2015, was undertaken as the first attempt of its kind to assess and value the ecosystem services of River Ken in relation to its aquatic biodiversity. River Ken was selected for the study in spite of the paucity of scientific information on most aspects of the river, out of consciousness of the fact that it is a nearly pristine river which will be subjected to the first major storage and diversion of its flows by a 78-metre-high dam for the Ken-Betwa Link project, which will fall within the core zone of the Panna Tiger Reserve. The river therefore offered a rare opportunity to examine the ecosystem services of a pristine, nearly unregulated river, of which only a small part of flow had been diverted more than a century ago for irrigation, with the additional purpose of providing some baseline data for assessing the likely impacts of the project later on. Such chances are scarce in the worldwide race for development. The River Ken provides a moment in which India may choose to implement informed, pragmatic policies.

We wish to emphasise that the present study cannot be and should not be compared with other studies on economic valuation of ecosystem services of wetlands or other ecosystems that have been investigated over decades, in some cases over a century, and for which long-term time-series data are available for many ecological, economic and social variables. The present study of ecosystem services of a river was greatly constrained by its short duration, which did not allow field observations for the full year. These time constraints were especially restrictive in that they excluded monsoon. We could not obtain time-series data to analyse the relationship of various ecosystem services with the inter-annual or seasonal flow variability. Another major constraint was the non-accessibility of long-term data on river discharge because of the fact that it is classified information especially for the Ganga basin and other Himalayan rivers.

Therefore, from our study over 7 months in the post-rainy season of a coincidentally dry year, 2014, we are unable to draw significant and bold conclusions and offer recommendations for policy and management.

River Ken – a north-flowing tributary of R. Yamuna – forms a single-thread channel with a rocky or boulder bed and flows through deeply incised, undulated terrain, which results in steep rocky banks and poorly developed riparian fringes. It passes through several gorges, making scenic falls. The river owes its near-pristine state to an almost-total lack of urban or industrial development and to largely rainfed agriculture in its basin, as well as to the fact that its 50-km-long middle stretch, passing through the Panna National Park – a tiger reserve and a gharial sanctuary – is fully protected against anthropogenic pressures. Banda, the only major town along the banks of the Ken, located in the last reach of the river, has a human population of only 1.6 lakhs, as of the 2011 census.

The water quality of River Ken can be appreciated by the fact that at Banda, the domestic water supply is drawn directly from the river and requires no treatment except chlorination. In several upstream reaches and in tributaries, the water has a very low conductivity, even less than 10 3S – an indicator of the near-absence of dissolved salts.

We identified sand formation and transport, and fisheries, along with water supply for domestic use and irrigation, as major provisioning services. Groundwater recharge is a major regulating service, and ecotourism is a cultural-recreational service. Riparian agriculture has been found to be of considerable significance from the viewpoint of supporting livelihoods of the poor. The river is currently able to assimilate an un-estimated amount of wastes from non-point sources, as the water remains of potable quality throughout its course.

We assessed the extent and economic values of sand and fisheries using standard market prices and the value of recreational services through Travel Cost Method. Other ecosystem services are described in qualitative and semi-quantitative terms. We laid more emphasis on the approximately 120-km-long stretch of the river through Banda, Panna and Chhatarpur districts, downstream of the century-old diversion at Bariyarpur. We estimated the following economic values:

Sand extraction from the leased mines	₹2500 crores per year
Sand extraction by individuals in villages	₹75 crores per year
Fish	₹2 to ₹17 lakhs in different stretches (based on winter season survey only)
Ecotourism value of PTR	₹7.69 crores (Travel Cost method)
Total Economic Value of PTR	₹369 crores per year (based on average economic value of other tiger reserves in India; Verma et al. 2015)

It is worth stressing that at present less than 10% of irrigation and domestic water supplies depend on the River Ken, except for the irrigation provided by the Bariyarpur canal system in Banda. The dependence on groundwater indicates the potential of groundwater recharge from the streams of the Ken River system. The value of groundwater recharge potential could not be assessed because of very high variability in groundwater levels within a short distance caused by geological factors, and non-availability of long-term data on river flows, groundwater levels, and groundwater abstraction.

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The water quality of River Ken can be appreciated by the fact that at Banda, the domestic water supply is drawn directly from the river and requires no treatment except chlorination. In several upstream reaches and in tributaries, studies show a near-absence of dissolved salts

In the absence of any point source of pollution and the high water quality, even during the dry season, it was not possible to estimate the value of the river's pollution abatement or waste assimilation. The value of livelihoods associated with river-dependent activities such as sand extraction, fishing, boating, and riparian agriculture, has also not been assessed quantitatively. It may be added that the ecotourism potential of the River Ken for its geological heritage value has not yet been explored.

This preliminary study shows that storage and diversion of flow to the extent proposed in the K-B Link project is likely to cause considerable long-term economic loss of the ecosystem services. The sand trapped behind the dam every year will itself be a significant cost. The economic and social cost of reduced water availability downstream – both surface and groundwater – need to be examined in view of the future developmental needs of the region. Only a comprehensive valuation of all important ecosystem services will show if the economic losses would exceed the short-term gains – besides the irreversible loss of biodiversity, in the forms of fish species, gharials, and vultures, as well as degradation of water quality because of the lower waste assimilation potential of the decreased flow – after making huge investments over a decade or so.

10.1. Recommendations for Policy and Management

Whereas the protection of rivers, their water quality, and biodiversity, is a duty of every citizen, the State and Central Governments exercise control over them as the trustees of the nation's natural resources. Yet there are multitudes of stakeholders who try to maximise different ecosystem services of the rivers – water for human uses; water for energy; fisheries; mineral resources, such as gravel and sand; navigation; recreation; and other economic activities. Our preliminary study of a small river using the ecosystem service approach should be of interest to everyone concerned with rivers. In the absence of adequate data and analysis over sufficient time, it is difficult to make prescriptions or specific targeted recommendations.

While we appeal to the research community to get involved in more studies on a wide variety of rivers, the following recommendations are addressed to the Ministry of Water Resources, River Development and Ganga Rejuvenation (MoWR), and the Ministry of Environment, Forests and Climate Change (MoEF-CC), who have the first stake in the rivers and need to function in tandem, as the regulatory powers rest with the latter to ensure water quality, ecological integrity and biodiversity.

First and foremost, we emphasise the need for comprehensive studies of the ecosystem services of different kinds of rivers. River Ken, for the reasons stated earlier, deserves detailed studies and appropriate economic valuation, with adequate inputs of flow data, before the proposed K-B Link project is approved and implemented.

Next, it is noted with serious concern that the current EIAs of water resource development projects do not examine their impacts on the entire river stretches affected by the project both upstream and downstream. We strongly recommend that all water resources development projects in river basins must take into consideration the impacts on the entire upstream and downstream stretches which will be affected by flow alteration, in the form of submergence or flow reduction. Detailed studies should be undertaken to assess various ecosystem services and their values, which must be considered in the cost-benefit analyses of the water resources development projects in river basins.

We are aware of the current policy that requires a provision for environmental flows in the rivers while according approval of the water resource

First and foremost, we emphasise the need for comprehensive studies of the ecosystem services of different kinds of rivers. River Ken, for the reasons stated earlier, deserves detailed studies and appropriate economic valuation before the proposed K-B Link project is approved and implemented development projects (Ministry of Water Resources, March 2015). However, as suggested by the hypothesis stated in the present study, the environmental flows should be determined on the basis of an analysis of ecosystem services. It has indeed been proposed that the environmental flows can be determined by the threshold of flow diversion or abstraction at which the total losses of ecosystem services of the river are fully compensated by the benefits from diverted water, after taking into consideration all ecological, economic, and social aspects, including livelihoods (Gopal 2015, communicated).

It is very well established in published literature that large reservoirs or water storages sites and diversions, which result in reduced flow downstream, have long-term impacts on water quality as well as nutrient availability downstream. These impacts often affect the fertility of floodplain soils. There is an urgent need for such studies in India in the wake of many large water resource projects.

Any suggestion or recommendation for the management of groundwater in relation to projected flow alterations in the Ken River basin requires detailed investigation. It must be reiterated that the River Ken flows in a deep channel with 5- to 20-metre-high banks in rocky substrata. Available studies suggest only a poor to moderate groundwater recharge potential in most of the Ken River basin (Ram Avtar et al., 2010).

Often called mining, sand extraction from the rivers is a common practice, as sand is a major requirement in all construction activity. The formation of sand by fluvial crushing and grinding and its transport by the river flow has been a major though unrecognised ecosystem service of the rivers. The sediments transported by the river also carry nutrients, provide habitats for riverine biota, and contribute to riparian productivity.

During the past few years, extraction of gravel and sand from the rivers has been intensified, as machines are used for extracting old fluvial deposits from deeper layers of the riverbed. This has caused concern about impact to riverine biodiversity, as well as the shifting of river channels.

It is important to distinguish between the provisioning of sand and its transport as an ecosystem service of the river, and to assess the impacts of its over-extraction before maximising one benefit at the cost of others. We consider sand extraction as an essential activity in order to prevent the aggradation or rise of the riverbed, and under some circumstances to alter the shifting of river channels. Adverse impacts arise when sand extraction is indiscriminate and excessive. A human-induced decrease in river flows reduces the supply of sand to downstream areas and is expected to result in over-extraction that is in excess of the annual supply.

There is an urgent need for a policy on sand and gravel extraction from the rivers, keeping in view the importance of this ecosystem service as well as the adverse impacts of unregulated over-exploitation on riverine biodiversity, riparian agriculture, groundwater, and river morphology. At this stage, we recommend that the extraction of sand and gravel from the rivers should be strictly regulated, and that the annual variation in supplies transported by the river and the distribution pattern on the river bed, determined by the river morphology, must be taken into consideration to determine the amounts and locations for extraction by the lesees.

The activities must be strictly monitored to prevent over-extraction and misuse of floodplains. Detailed studies are required to assess the potential of different river reaches for exploitable sand.

The forests and the wildlife therein also depend upon the river as much as the river depends upon the forests. Forests regulate the flow and water quality, and indirectly the biodiversity of the rivers, and the rivers contribute to the sustenance of the forest. The benefits from the forest should therefore be accounted for in the ecosystem services of the rivers.

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ANNEX I

Distribution of Faunal Aquatic Species in the River Ken

FISH DIVERSITY

Table 20. Fish species recorded during this study at Banda and downstream, along with comparison with earlier studies (Y = present)

	This study at Banda to Chilla	Johnson et al.	Dubey et al.
S.N.	Order- Osteoglossiformes		
	Family: Notopteridae		
1	Notopterus notopterus		Y
	Order- Clupeiformes		
	Family: Clupeidae		
2	Gudusia chapra		
3	Goniolosa manmina		
	Familty: Engraulidae		
4	Setipinna phasa		
	Order- Cypriniformes		
	Family: Cyprinidae		
5	Aspidoparia morar		
6	Barilius vagra		
7	Chela laubuca		
8	Catla catla		Y
9	Chagunius chagunio		
10	Cirrhinus mrigala	Y	Y
11	Cirrhinus reba	Y	Y
12	Cyprinus carpio communis		
13	Labeo bata		
14	Labeo boga		
15	Labeo calbasu	Y	
16	Labeo dero		
17	Labeo rohita	Y	Y
18	Osteobrama cotio cotio		
19	Puntius chola		
20	Puntius conchonius		
21	Puntius sarana sarana	Y	Y
22	Puntius sophore	Y	
23	Puntius ticto	Y	

24	Salmophasia bacaila	Y	
25	Tor tor	Y	Y
	Order-Siluriformes		
	Family:Bagridae		
26	Sperata aor		
27	Sperata seenghala		Y
28	Mystus cavasius	Y	
29	Mystus vittatus		
30	Rita rita		Y
	Family: Siluridae		
31	Wallago attu	Y	Y
	Family: Schilbeidae		
32	Ailia coila		
33	Clupisoma garua	Y	Y
34	Eutropiichthys vacha		Y
35	Eutropiichthys murius		
	Family: Clariidae		
36	Clarius batrachus		
	Family: Heteropneustidae		
37	Heteropneustes fossilis	Y	
	Order-Perciformes		
	Family: Ambassidae		
38	Chanda nama		
39	Pseudambassis ranga	Y	
	Family: Mugilidae		
40	Rhinomugil corsula		
	Family: Gobidae		
41	Glossogobius giuris	Y	
	Family: Anabantidae		
42	Anabas testudineus		
	Family: Belontiinae		
43	Colisa fasciata		
	Family: Channidae		
44	Channa marulius	Y	Y
45	Channa punctatus	Y	
46	Channa striatus	Y	
	Family: Mastacembeldae		
47	Mastacembelus armatus		
	Family: Cichlidae		
48	Oreochromis niloticus		

Table 21. Fish species reported by Dubey et al. (2012) but not encountered during this study in downstream areas of River Ken

Bagarius bagarius	Ompok pabda
Chitala chitala	Sperata aor
Clupisoma garua	Wallago attu
Eutropiicthys vacha	Gudusia chapra,
Garra gotyla	Amblypharingodon mola,
Labeo boggut Labeo	Rasbora daniconius,
gonius Mastacembelus	Chanda nama,
armatus Mystus tengara	Puntius chola
Ompok bimaculatus	Glyptothorax brevipinn

Table 22. Fish species reported by Dubey et al. (2012) but not encountered during this study in downstream areas of River Ken

Cyprinidae
Bangana dero
Barilius bendelisis
Gibelion catla
Danio rerio
Devario aequipinnatus
Devario devario
Esomus danricus
Garra gotyla Garra
mullya
Crossocheilus latius
Labeo angra
Labeo pangusia-
Osteobrama cotio
Rasbora daniconius
Puntius amphibius
Puntius conchonius
Salmophasia balookee
Salmophasia boopis

Balitoridae
Acanthocobitis botia
Nemacheilus denisoni

Cobitidae
Lepidocephalichthys guntea

Bagridae
Rita gogra

Siluridae
Ompok bimaculatus
Ompok pabda

Schilbeidae
Clupisoma montana

Sisoridae
Glyptothorax telchitta

Claridae
Clarias magur

Ambassidae
Pseudambassis baculis

Nandidae
Nandus nandus

Channidae Channa gachua
Mastacembelidae Mastacembelus armatus

Belonidae
Xenentodon cancil

Fish Species of Concern: (from Joshi and Biswas 2010)
Endangered fish species:
Tor tor (Mahseer), Chitala chitala, Eutropiichthys vacha, Ompok pabda.

Vulnerable (VU) species:
Gonialosa manmina; Catla catla; Puntius sarana sarana; Rhinomugil corsula; Mystus bleekeri; Clarias batrachus; Heteropneustes fossilis; Clupisoma garua; and
Bagarius bagarius

Table 23. Distribution of Phytoplankton at different stations of the River Ken in Banda district. (B1; Bhuraghar, B2; Chotapurwa, B3; Chilla)

Phytoplankton	B1	B2	B3
Bacillariophyceae			
Achanathes	+	+	
Achnanthedium	+	+	+
Adlafia	+	+	+
Amphora			
Brachyasira	+	+	
Caloneis	+		+
Ceratoneis	+		+
Cocconeis	+	+	+
Craticula	+		
Cyclotella	+	+	+
Cymatopleura			
Cymbella	+	+	+
Cymbopleura	+		
Denticulata	+		
Diadesmis	+	+	+
Diatoma	+	+	+
Diploneis	+	+	+
Encyonema	+	+	
Encyonopsis		+	
Epithema	+	+	
Eunotia	+	+	
Fallacia			+
Fragilaria	+	+	+
Frustulia			
Geissleria	+	+	+
Gomphocymbelopsis		+	
Gomphonema	+	+	+
Gyrosigma	+	+	+
Hantzschia	+		
Luticola		+	+
Melosira	+	+	+
Navicula	+	+	+
Neidium	+	+	
Nitzschia	+	+	+
Pinnularia	+	+	+
Placoneis	+		
Planothodium	+	+	+

Reimeria	+	+	+
Rhopalodia	+		+
Sellaphora	+		
Stauroneis		+	
Stephenodiscus			+
Surirella	+	+	+
Synedra	+	+	+
Tabellaria	+		+
Chlorophyceae			
Ankistrodesmus	+	+	+
Actinastrum		+	+
Closterium	+	+	+
Characium		+	+
Closteridium	+	+	+
Cosmarium	+	+	+
Cladophora	+		+
Desmidium	+	+	
Oedogonium	+	+	
Protococcus	+		
Pediastrum	+	+	+
Scenedesmus			+
Selenastrum	+	+	+
Spirogyra	+	+	+
Ulothrix	+	+	+
Volvox	+	+	+
Zygnema			
Cyanophyceae			
Anabaena	+	+	+
Aphanocapsa	+		
Lyngbya	+	+	+
Merismopedia	+	+	
Microcystis	+		
Nostoc		+	+
Oscillatoria	+	+	
Spirulina	+	+	+
Phormidium	+		+
Euglenophyceae			
Euglena	+	+	+
Phacus	+	+	+

Table 24: Longitudinal variation in the generic composition of epilithic diatoms in the Ken River (from Nautiyal and Verma 2009).

GENERA	K1	K2	K3	K4
CENTRALES				
THALASSIOSIRACEAE				
1. Cyclotella	1	1	1	1
2. Aulacoseira	1	1	1	1
Total species	2	2	2	2
Total genera	2	2	2	2
PENNALES				
FRAGILARIACEAE				
3. Diatoma	1	2	1	2
4. Fragilaria	0	1	0	1
5. Staurosira	1	1	1	0
6. Synedra	11	11	7	10
7. Tabellaria	1	1	1	0
Total species	14	16	10	13
Total genera	4	5	4	3
EUNOTIACEAE				
8. Eunotia	2	1	1	3
Total species	2	1	1	3
Total genera	1	1	1	1
ACHNANTHACEAE				
9. Achnanthes	1	1	1	1
10. Achnanthidium	8	7	7	4
11. Planothidium	2	3	2	3
12. Cocconeis	5	6	4	2
Total species	16	17	14	10
Total genera	4	4	4	4
NAVICULACEAE				
13. Amphora	9	8	8	7
14. Brachysira	1	1	1	1
15. Caloneis	4	5	4	4
16. Cymbella	18	17	20	16
17. Cymbopleura	9	9	10	9
18. Diploneis	5	5	5	3
19. Encyonema	4	4	3	2
20. Frustulia	1	0	0	0
21. Gomphocymbelopsis	1	1	1	1
22. Gomphonema	10	9	7	7
23. Gyrosigma	1	1	2	2

24. Mastogloia	1	0	0	0
25. Navicula	27	27	26	28
26. Navicula sensu lato	2	2	1	0
27. Craticula	4	3	4	4
28. Diadesmis	1	1	1	1
29. Adlafia	1	1	1	1
30. Fallacia	1	1	1	1
31. Geissleria	1	1	1	1
32. Hippodonta	1	0	1	1
33. Luticola	5	5	5	5
34. Placoneis	1	2	1	1
35. Sellaphora	4	4	4	4
36. Neidium	1	2	1	1
37. Stauroneis	2	2	1	1
38. Pinnularia	3	3	1	2
Total species	118	114	110	103
Total genera	26	23	24	23
BACILLARIACEAE				
39. Denticula	1	1	1	1
40. Hantzschia	1	1	0	0
41. Nitzschia	21	19	17	13
Total species	23	21	18	14
Total genera	3	3	2	2
SURIRELLACEAE				
42. Surirella	7	7	4	6
Total species	7	7	4	6
Total genera	1	1	1	1
TOTAL SPECIES	182	178	159	151
TOTAL GENERA	41	39	38	36

Table 25: Plankton density at different stations of the River Ken in Banda district (B1; Bhuraghar, B2; Chotapurwa, B3; Chilla)

	B1	B2	B3
Bacillariophyceae	592 u/l	354 u/l	432 u/l
Chlorophyceae	355 u/l	238 u/l	209 u/l
Cyanophyceae	104 u/l	123 u/l	109 u/l
Zooplankton	186 u/l	98 u/l	106 u/l

Table 26: Distribution of Macroinvertebrate at different stations of the River Ken in Banda district. (B1; Bhuraghar, B2; Chotapurwa, B3; Chilla)

Macroinvertebrate	B1	B2	B3
Other Diptera	+	+	+
Chironomids	+	+	+
Coleoptera	+		+
Gastropoda	+	+	+
Odonata	+		+
Trichoptera	+	+	+
Ephemeroptera	+	+	+

Table 27: Variation of benthic macroinvertebrate fauna along the course of the River Ken (from Nautiyal and Mishra 2012)

Orders/Family	S1	S2	S3	S4
Ephemeroptera				
Caenidae	29	37	0.4	-
Neoephemeridae	41	27	1	-
Leptophlebiidae	-	3	30	-
Baetidae	-	4	13	-
Trichoptera				
Rhyacophilidae	1	1	-	-
Brachycentridae	1	3	7	-
Hydropsychidae	-	-	14	-
Hydroptilidae	-	-	1	-
Diptera				
Chironomidae	11	3	8	16
Thiaridae	10	3	3	26
Tabanidae	-	1	-	5
Heleidae	-	4	1	10
Dytiscidae	-	-	0.3	4
Gomphidae	-	2	11	10
Agrionidae	-	-	-	2
Oligochaeta				
(Glossoscolecidae)	2	2	-	4
Polychaeta (Nephthydae)	3	2	-	16
Pelecypoda (Corbiculidae)	1	2	5	6
Miscellaneous groups	1	3	2	1

Table 28. Distribution of zooplankton at different stations of the River Ken in Banda district

Zooplankton	B1	B2	B3
Cladocera			
Bosmania	+		+
Diaphanosoma	+	+	+
Moinodaphnia	+		+
Copepoda			
Cyclops	+	+	+
Diaptomus	+		+
Rotifera			
Asplanchna	+		+
Brachionus		+	+
Filinia	+	+	+
Keratella	+		+
Lecane	+	+	
Protozoa			
Paramecium	+	+	+
Amoeba	+		+
Euglena	+	+	+

ANNEX 2

Aquatic Plants in the River Ken

Table 29. Macrophytes recorded from River Ken, its shallow pools, riparian areas and adjacent wetland habitats

Free Floating macrophytes
Salvinia molesta
Pistia stratiotes
Eichhornia crassipes
Spirodela polyrhiza
Lemna minor
Azolla pinnata

Submerged macrophytes
Chara sp.
Nitella sp.
Ceratophyllum demersum
Hydrilla verticillata
Vallisneria spiralis
Najas sp.
Zannichelia sp.
Potamogeton pectinatus
Potamogeton natans
Potamogeton crispus

Floating leaved macrophytes
Marsilea minuta
Nelumbo nucifera
Trapa bispinosa (cultivated)
.Nymphoides indicum
Nymphaea species

Emergent macrophytes
Typha angustata
Eleocharis sp
Cyperus sp. (several species)
Scirpus sp. (several species)
Carex sp.
Polygonum sp.
Bacopa monieri
Hygrophila spinosa
clipta alba
Alternanthera sp.
Ludwigia sp.
Rumex sp.
Vetiveria zizanioides
Echinochloa colona
Paspalum distichum
Sagittaria guayanensis

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India a biodiversity hotspot

India is one of the megadiverse countries in the world. It faces unique circumstances as well as challenges in the conservation of its rich biological heritage. With only 2.4% of the world's geographical area, her 1.2 billion people coexist with over 47,000 species of plants and 91,000 species of animals. Several among them are the keystone and charismatic species. In addition, the country supports up to one-sixth of the world's livestock population. The rapid growth of her vibrant economy, as well as conserving natural capital, are both essential to maintaining ecosystem services that support human well-being and prosperity.

To demonstrate her empathy, love and reverence for all forms of life, India has set aside 4.89% of the geographical space as Protected Areas Network. India believes in "वसुधैव कुटुम्बकम" i.e. "the world is one family".

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