Supplementary Issue
Rethinking Urban Rivers

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Urban River Management

Riverfront Development

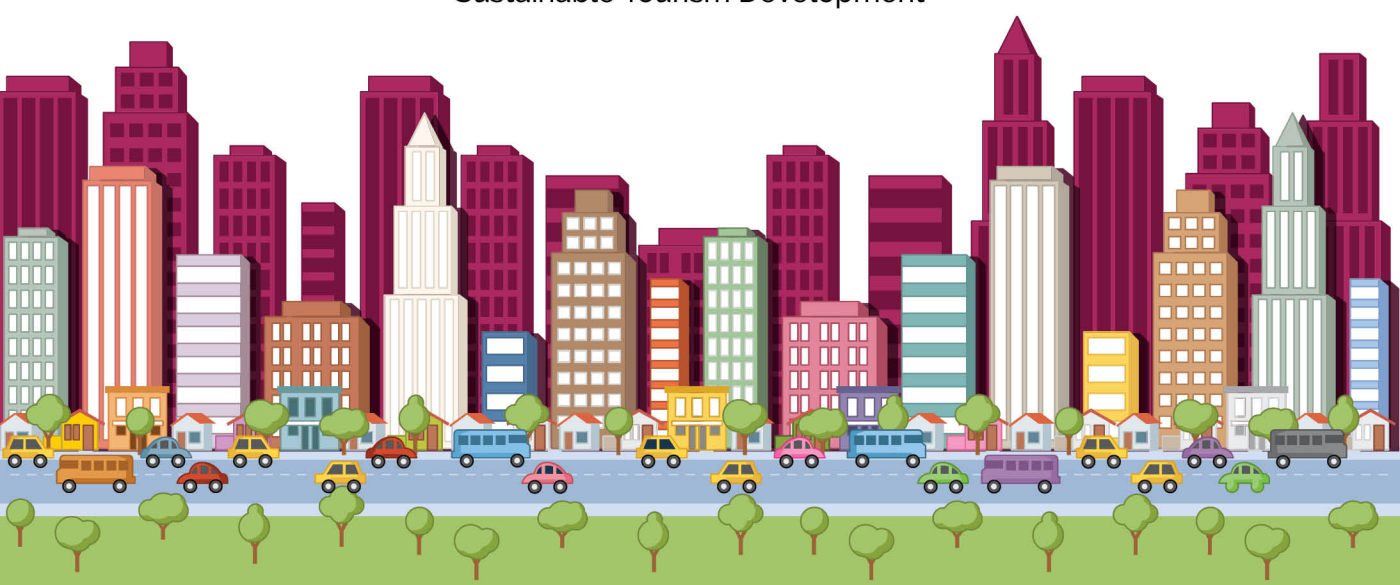
Rejuvenating Urban Rivers

Rivers in Mitigation of Urban Heat Island Effect

Revitalisation and Revival of Gangetic Dolphin Sanctuary

Traditional Water Systems

Sustainable Tourism Development



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Editorial

India is witnessing a paradigm change in urban development. There is a growing trend towards making urban habitations more climate-sensitive, environmentally friendly and resilient to disasters. In this backdrop, managing the river stretch in urban areas is assuming great interest. Academicians, policymakers and practitioners are looking into the possible areas of holistic and wholesome management of urban rivers and trying to address current challenges by effectively responding to imminent threats and issues. The most recent example is the effort of the National Institute of Urban Affairs (NIUA) and the National Mission for Clean Ganga (NMCG) (affiliated with India's Ministry of Jal Shakti) towards making river sensitive city master plans by developing and advocating for the "Urban River Management Plan (URMP) Framework". The purpose of the URMP is to provide a decision support system for river cities in India to systematically and holistically plan for interventions required to revive and maintain the rivers within sustainable limits. In this special issue of the Urban India journal on urban river management, the articles provide an in-depth analysis on the importance of rivers in city development and the present state of urban rivers, and explore the challenges faced thereby.

The first article by Victor R. Shinde, Rajiv Ranjan Mishra, Hitesh Vaidya and Uday Bhonde discuss the state of knowledge and research for urban river management in India. By calling the urban river management an emerging paradigm in India, they stress the importance of holistic urban river management that requires a systems approach which caters to multiple sectors and corresponding stakeholders and imminent threats in the face of climate change. Authors of this article have discussed in detail the development of Urban River Management Plan (URMP) Framework and showed the path to make river-sensitive city master plans.

In the second article, Rajorshi Banerjee, Nidhi Dandona, Suruchi Modi and Shivani Saxena have tried to reconnect the city to its riverfront by taking Kolkata city as an area of study. Kolkata, one of the major metropolitan cities in India, owes its creation to its strategic location along the east bank of the river Hooghly, a distributary of the river Ganges. The banks of the river,

once the lifeline of the people, remained bustling with different activities. In the recent past, the riverfront has become the backyard of the city, derelict of any desired activity leading to escalating environmental and urban issues. The river-edge precincts and neighbourhoods have died out their social association with the river. In light of the above, this paper argues for finding a suitable solution to revive the lost values of the Hooghly river. It also explores the principles of building a framework of developing tools for redefining the value of an urban riverfront through strengthening its cultural and social bonds with the city.

The presence of water bodies in an urban environment is considered an important part of infrastructure and plays a critical role in enhancing the quality and development of urban spaces. With increasing urbanisation however, rivers and water bodies in urban areas are subjected to exploitation through several anthropogenic activities resulting in their degradation. The case worsens when the river is non perennial as these are often considered a limited source of water that is renewed unpredictably. In this context, Alvina Habib Khan, Imaad Nizami and Shivani Saxena have called for enhancing the urban water experience and explored the rejuvenation of Kaliasot river in Bhopal. The paper attempts to understand, through a review of literature, the value provided by a non-perennial river and its importance. It also developed strategies and recommendations for transforming the existing, neglected urban river into a centre for social, cultural, and recreational activities in the city, by improving the water quality and developing a riverfront.

An attempt has been made by Aman Sharma, Vishakha Kawathekar and Nikita Madan to understand the traditional water systems of Govardhan in Braj Bhoomi (a cultural region spanning Mathura, Bharatpur, and Hodal in India) is the state of Uttar Pradesh. The paper aims to highlight the traditional knowledge embedded in the design and construction of these water systems.

The role of rivers in mitigation of urban heat island effect and climate change in Delhi has been discussed by Ritu V. Sharma, Chetan R. Patel and Lovlesh Sharma. The article examines the role of rivers in the urban environment and proposes a prototype for an effective riverfront that maintains a balance in the ecosystem by reducing the effects of 'Urban Heat Islands' (UHI).

Microbial activity has been around on this planet since time immemorial, contributing to the emergence of numerous renowned plagues, epidemics and pandemics. In light of this, Manju Rajeev Kanchan, Minakshi Jain, Jyoti Verma argued that the microbial activity required for environmental sustainability has become an eminent cause of concern as almost 60–75 per cent of the documented infections that affect man are of zoonotic or of animal origin. Studies have further identified a link between zoonoses and factors like habitat fragmentation, biodiversity loss, agriculture etc.; however very few have actually attempted to link them with the discipline of landscape architecture. This article makes an attempt to understand how zoonotic resilience can be achieved in an urban riverine landscape using the case of Vikramshila Gangetic Dolphin Sanctuary, Bhagalpur, Bihar.

Muddukrishna A.S., Karan Barpete and Lovlesh Sharma have explored the concept of integrated sustainable tourism development using Ayodhya City as a case study. This paper attempts to formulate an integrated sustainable development approach that collates the 5A's (Accessibility, Accommodation, Attractions, Activities, Amenities) and the travel trade using Ayodhya as a case study.

In the perspective Rajiv Ranjan Mishra and Puskal Upadhyay argues that the process of "Reimagination-Rejuvenation-Reconnection" has evolved as a completely new paradigm, simple to understand and easy to implement. This is especially relevant to complex objectives like the conservation of environmental assets which do not make immediate commercial sense in a superficial manner. This paradigm can be appropriately termed "#Ganga3R" which is not difficult to understand with 3 Rs and Ganga signifying all or any environmental assets. This is relevant to the conservation of any other river (as in the case of Ganga) but can also be deployed with equal effectiveness in case of any environmental assets like water bodies and wetlands (lakes and ponds), forests, springs, mountains, and to more complex issues like air pollution and oceans as well.

I hope that this supplementary issue of Urban India journal will trigger fresh enthusiasm among scholars, planners and practitioners to mainstream river management in riverine cities. This will help in strategising methods of sustainable development of these cities in the wake of the climate crises and attainment of the Sustainable Development Goals by 2030.

Prof. Debolina Kundu
Editor

State of Knowledge and Research for Urban River Management in India

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Abstract

Urban river management is an emerging paradigm in India. Much of the previous endeavours in this domain has been in the area of pollution control. While this is unquestionably important, there has been burgeoning evidence that holistic urban river management requires a systems approach that caters to multiple sectors and corresponding stakeholders. Only then will it be possible to achieve holistic and wholesome management of urban rivers that is not only able to address current challenges but is able to effectively respond to imminent threats and issues. The objective of the paper is two-fold. First, to collate and report existing work on urban river management in India. Second, to identify and highlight key research needs in this domain where emphasis must be placed on current times in order to ensure healthy rivers in the future as well.

Key words: Climate Change, Environment Planning, Floodplain, Master Plans, River Management, Urban Rivers

Introduction

River management is a complex process. The complexity stems from the fact that there are multiple issues that need to be addressed. Likewise, there are multiple stakeholders, often with conflicting agendas, and dynamics between these stakeholders keep changing rapidly. As Moore (2021) points out 'among the many difficult problems in environmental governance, cooperatively managing a shared river basin is one of the most complex—and elusive'. The need for this cooperative management is vital to ensure a holistic response to the planning objectives and paradigms. The complexity of river management is more pronounced in urban settings compared

to their rural counterparts for a number of reasons. First, the competing users of the river, and more importantly of the river zone, are larger in number. Second, very often these users have contrasting mandates. For example, the stakeholders concerned with tourism typically focus on the economic value of the river without much thought of the environmental aspects. Contrarily, the government agencies tasked with environment protection by and large oppose any kind of development in the river zone.

Urban rivers, as one of the most important urban ecological corridors, supply diverse and critical ecosystem services, including provisioning, regulating, cultural, recreational, and aesthetic services (Guo et al., 2021). The competition for urban rivers and the river zone is, therefore, understandable. However, it is vital that this competition does not result in a condition where: (a) urban rivers are exploited beyond their carrying capacity, or (b) the rivers are underutilised and are prevented from providing their full range of ecosystem services. Avoiding this condition is a matter of arriving at optimal solutions as opposed to perfect solutions, which accentuates the importance of holistic and inter-disciplinary urban river management.

Urban river management is an emerging paradigm in India. For far too long, the ambit of urban river management has solely focused on pollution control. This skewed approach is also found in scientific literature with several recent studies focusing on it (e.g. Bao et al., 2022; Tramoy et al., 2022; Kuwimba et al., 2021; Yin et al., 2021, Thiebault et al., 2017 etc.). To be fair, there are examples in literature that view urban river management from a lens other than that related to pollution. For example, in 2010, Zander et al. (2010) carried out a study to compare and contrast the willingness of urban Australians to pay for the sustenance of three aspects of urban rivers—river development, river culture, and river conservation. More recently, Guo et al. (2022) have focused on the demand for recreational services for sustainable urban river management. Through this work, they have proposed a comprehensive framework for supply-demand analysis of urban river recreation and apply this framework to the Jinjiang River. Likewise, Vian et al. (2021) studied the recreational interface between rivers and cities and classified urban riverfront parks and walks vis-à-vis seven Spanish urban rivers. However, such examples are few and far in between.

Human kind is already facing threats from multiple quarters—pandemics, climate change, loss of biodiversity, food insecurity, among others. Healthy urban rivers have the potential to alleviate these threats significantly, and make cities more livable for their inhabitants, while at the same time contributing to reversing debilitating trends. However, achieving the goal of making rivers healthy will require more than mere pollution control. The knowledge in this domain is still evolving, especially in terms of what is needed to continue to maintain healthy rivers in the light of anticipated drivers of change. The objective of the paper is two-fold. First, to collate and report existing work on urban river management in India. Second, to identify and highlight key research needs in this domain, where emphasis must be placed on current times in order to ensure healthy rivers in the future as well.

Relevance of Healthy Urban Rivers in National and International Development Agenda

Urban rivers have a central role to play in the overall socio-economic development of a city. This has been directly and indirectly alluded to in the global as well national narrative for sustainable development. In 2015, the member states of the United Nations adopted the 2030 Sustainable Development Agenda that required all countries to take actions against 17 Sustainable Development Goals, commonly called SDGs. The SDGs are a universal call to action to end poverty, protect the planet, and improve the lives and prospects of everyone, everywhere. Interestingly, many of these SDGs are intrinsically related to healthy rivers, and achieving the targets under these SDGs will require taking action to maintain the health of rivers. For example, target 6.6 of SDG-6 directs all nations to "protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes", which is directly related to healthy rivers. Likewise, SDG-11 emphasises "making cities and human settlements inclusive, safe, resilient and sustainable". Notice the words "resilient" and "sustainable" in this statement. As already stated, healthy rivers provide a wide range of ecosystem services to a city. Among these, services such as erosion control, flood mitigation, carbon storage, and climate regulation all improve a city's resilience. Similarly, healthy rivers are an important avenue for provisioning services like drinking water, food, and transport of timber, which are vital from a sustainability point of view.

The link between healthy rivers and SDG-6 and SDG-11 is quite direct. The link may not be as direct for some other SDGs but is equally relevant and significant. For example, SDG-1 talks about "ending poverty in all its forms, everywhere". Healthy rivers provide tangible and useful avenues for supporting livelihoods of people that depend upon them, and help mitigate poverty. Another example is SDG-13, which is centered on "taking urgent action to combat climate change and its impacts". Contemporary research suggests that a vital component of any climate change adaptation strategy is social cohesion. This is based on the notion that when things become really critical, people will have to rely on other people for help. In such times, technology may not be so helpful, neither will finances. What will actually help people deal with crises and shocks is their interaction with other people. Unfortunately, society is losing that personal connection between one another in this digital age. Healthy rivers provide an avenue for people to socialise and get together, and in the process, help re-establish that personal connection that is so important for climate change adaptation.

Healthy rivers are also directly relevant to the New Urban Agenda (UN Habitat, 2016) that was endorsed at the 68th Plenary Meeting of the 71st Session of the General Assembly of the United Nations held in December 2016. The New Urban Agenda called for the development of cities that "protect, conserve, restore and promote their ecosystems, water, natural habitats, and biodiversity, minimize their environmental impact and change to sustainable consumption and production patterns". It is quite clear therefore that healthy rivers have a vital role in implementing the New Urban Agenda.

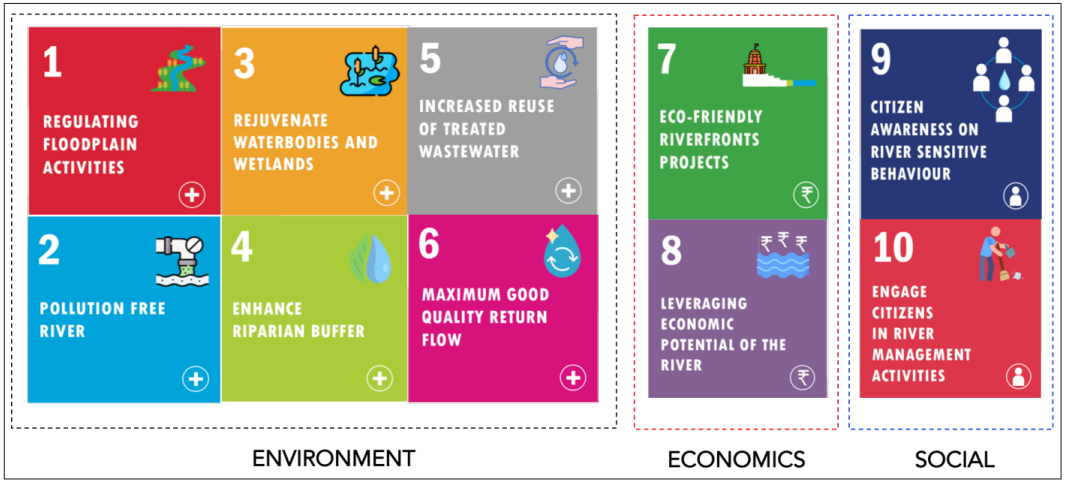
Current Ecosystem of Knowledge on Urban River Management in India

As already indicated in the previous section, the work in urban river management is relatively new in India. Most of the work in this domain has been carried out by the National Institute of Urban Affairs (NIUA) (affiliated with India's Ministry of Housing and Urban Affairs) and the National Mission for Clean Ganga (NMCG) (affiliated with India's Ministry of Jal Shakti). The two organisations have taken several initiatives to promulgate river-sensitive development in Indian cities.

Urban River Management Plan (URMP) Framework

In 2020, NIUA and NMCG launched a framework for managing urban river stretches, called "Urban River Management Plan" (URMP). The purpose of the URMP is to provide a decision support system for river cities in India to systematically and holistically plan for interventions required to revive and maintain the rivers within their limits in a sustainable manner. The URMP is embedded in the central idea that maintaining healthy rivers is crucial to enhance livability and productivity in the cities. At the heart of the framework is a ten-point agenda (Figure 1) that every river city would need to adopt in order to prepare their city-specific URMPs.

Figure 1: 10-Point Agenda of the Urban River Management Plan Framework



These agenda items are grounded in the principles of sustainable development, and advocate interventions under the environment—economic, and social categories. The URMP framework has been developed for all river cities in India and hence the framework is generic enough for it to be relevant to all these cities. However, all the cities are not the same. They have different characteristics, different needs, and different aspirations. Therefore, while the agenda items are the same for all river cities, they have the flexibility to choose the specific actions/interventions under each agenda item in line with their context and priorities. For example, objective 8 of

the framework leverages the economic potential of the river. As an intervention to achieve this objective, one city may decide to run a river cruise, while another may decide to create provisions for water sports. Yet another may opt for a river market. A city can choose what it thinks is best for its context and needs.

Strategic Guidelines for Making River-Sensitive Master Plans

Another initiative taken by NIUA and NMCG was to develop strategic guidelines for making river-sensitive Master Plans (NIUA and NMCG, 2021). The need for this document stemmed from the fact that a number of interventions required for rejuvenating urban rivers cannot be achieved by infrastructural projects and engineering solutions alone. A typical case in point is regulating, and if required, restricting development activities in the flood plains of rivers to ensure 'room for the river'. Likewise, conservation of water bodies and wetlands, which are deeply interlinked to the river anyway, requires a different management approach. A large number of these 'softer' solutions can be incorporated through sound city planning, i.e. through a city's Master Plan. The purpose of this guidance document is to help city planners across the country at large understand how to integrate river-sensitive thinking into a Master Plan. It seeks to leverage on the legal sanctity of the Master Plan to ensure a harmonious relationship between cities and rivers. The document highlights a set of planning instruments and tools that planners can use to plan for and manage different river-related aspects in the city. These include:

- *Localising national policies and instruments:* a number of national policies (e.g. National Water Policy 2012; National Policy on Faecal Sludge and Septage Management, 2017; The Water (Prevention and Control of Pollution) Act 1974; National Tourism Policy 2002; River Ganga (Rejuvenation, Protection and Management) Authorities Order, 2016; among others) have provided key river-related directions for cities to adopt. It is important for the Master Plan to acknowledge and incorporate these.

- *Developing city-specific sectoral strategies:* elaborates on specific key strategies (e.g. for riparian buffer development; for relocating encroachments in the river zone, among others) that are required in the city for sustainable management of the river.

- *Land use assignment:* includes the appropriate land use categories; use zones; use premise; and associated permissible/non-permissible activities in the flood plain as well in areas in other parts of the city that have a bearing on river management.

- *Development control regulations:* manages the FAR; and ground cover and height restriction in the relevant areas.

- *Norms and standards:* such as set-back distances; buffers; width of no development zones; discharge standards; among others, that are required to conserve and protect rivers and their associated elements.

- *Recommendations and directions:* to influence aspects that the Master Plan cannot directly control (e.g. citizen engagement in river management; CSR activities for river rejuvenation; among others).

- *Special projects:* for key big-ticket iconic endeavours that a city should undertake in order to enhance the river-city relationship (e.g. riverfront development project; reviving historic water bodies; developing a constructed wetland; among others).

Guidelines for Management of Urban Wetlands/Water Bodies: A Toolkit for Local Stakeholders

This toolkit is developed by the School of Planning and Architecture, Delhi, and NMCG (SPA, Delhi and NMCG, 2021). The main objectives of the toolkit are to: (a) protect the ecological processes that sustain water resources in urban settings; (b) mainstream protection of water bodies in the urban planning process; and (c) provide a step by step approach to identify, prioritise and prepare an action plan for protection of water bodies in urban areas.

The toolkit advocates a two-stage process for management of the urban wetlands/water bodies. The first stage focuses on identification of these features for conservation. It begins by requiring cities to prepare a detailed documentation of city-level information of natural resources such as temperature, humidity, soil, hydro-geology, ground water level, land use and land cover, which together provide a better insight into the water regime of wetland/water bodies. Next, cities are required to prepare interactive Geographic Information System (GIS) maps identifying and mapping of urban water bodies at city scale. This may also include the peri-urban areas. This part will not only cover the demarcation of urban wetlands, but also the zone of influence and the catchment area. This is done collectively from a primary survey and with the help of local stakeholders and Urban Local Bodies (ULBs). Next, the toolkit provides a simplified approach for identifying the ecosystem services of urban wetlands/water bodies. The ecosystem services include provisioning services, regulating services, cultural services and supporting services. The fourth step is to make a scientific assessment of the groundwater resources, estimation of ground water draft, estimation of ground water recharges during monsoon and non-monsoon seasons. This is to be followed by a land suitability analysis for ground water recharge based on whether the situation is semi-critical, critical or over-exploited. The last step of this stage is to identify drivers of changes in the hydrological regime of wetlands/water bodies. Assessment of impact is carried out at the level of zone of influence of wetlands/water bodies, catchment of wetlands/water bodies and within a 200 meter buffer area of wetlands/water bodies. The assessment will provide a basis for formulating synergy between wetlands/water bodies and urban development within the city.

The second stage of the process begins by developing an action plan for identified urban wetlands and water bodies. The plan should include a comprehensive listing of activities required to be implemented. These include boundary mapping and delineation, removal of encroachment at site level, afforestation activities, selective dredging and desilting, diversion and treatment of point sources of pollution, maintenance of breeding and spawning grounds for key species, management of invasive species, setting regulatory regimes, and development of a monitoring and evaluation

system at institutional level. This is followed by developing a management plan that defines all the indicative actions, core and non-core activities to be undertaken, along with a complete costing (activity wise) for the entire tenure of the plan using the existing norms of the state and central government, as may be the case.

Guidance Note for Environmentally Sensitive, Climate Adaptive and Socially Inclusive Urban Riverfront Planning and Development

This document is developed by the World Resources Institute (WRI) and NMCG, 2021. Riverfront planning and development in India is heavily skewed towards the built environment (construction, landscaping and beautification) and the potential economic benefits that can be derived from these projects. However, it is equally important that these projects give due consideration to their social, hydrological, environmental and ecological impacts as well as impacts on the project itself caused by erratic climatic events like flood and droughts. Failure to acknowledge and account for these aspects will only lead to failed outcomes, hydrological/ecological/ environmental stresses and disasters like floods with loss of life and property. This guidance note has been developed to help riverfront planners and developers help integrate water, ecology, environment and climate resilience related considerations within the existing framework of urban riverfront planning and development.

The document covers three broad objectives. The first is as an appraisal tool to support decision-making on urban riverfront development based on environmental and social indicators. The second is to inform project proponents and decision makers and other stakeholders about environmentally sensitive, climate adaptive and socially inclusive riverfront development. The third is to provide guidance to various service providers on design and planning and implementation of ecological riverfront development projects.

Research Needs for Urban River Management in India

Floodplain Protection in Dense Settlements

Even in ordinary circumstances, floodplain protection in rapidly urbanising cities is a challenge, given that the urban sprawl typically engulfs such government-owned vacant areas. The problem becomes particularly challenging when this results in informal unauthorised dense settlements that typically have very limited waste management and sanitation facilities. The preferred option in India to deal with such challenges is to carry out a court-backed eviction drive from time to time. However, such measures are counter-productive in the long run. They merely transfer the problem to some other part of the city, and since the river is a system of interconnected elements across the city, this will eventually have a cascading and detrimental effect on the river itself.

On the one hand, solving such problems requires dedicated research to understand the social and economic dynamics in the floodplain, and the kind of effect it will have on the river when the dynamics is disturbed. For example, what are the social ramifications of forced evictions? What should an empathetic and sensitive relocation strategy for informal settlements be comprised of? On the other hand, it is vital to carry out research on design transformation solutions that may take time to implement but are grounded in the pursuit of long-term sustainability. One

area of specific research is how to mainstream floodplain protection into a city's long-term plan (e.g. Master Plan or City Development Plan) through the intelligent use of planning instruments? Likewise, it would be worthwhile to explore economic models to incentivise floodplain protection so as the optimise the ecosystem services returns from the river.

Naturalising Existing Channelised Rivers and Concretised Riverfronts

It has been established that channelling river banks causes a disconnection between city dwellers and rivers (Che et al., 2012). However, for much of the nineteenth century, channelising river banks was seen as the norm, mostly to ensure quick removal of floodwater to a downstream location. While this was successful in mitigating the flood threat, it had quite the opposite effect on the aquatic biodiversity and the ecosystem at large. As environmental awareness started to grow in the 1970s, it became quite apparent that channelising river banks was detrimental to the overall health of the river. Likewise, with advances in scientific knowledge, it emerged that concretised riverfronts impede the river from performing its natural functions such as groundwater recharge, flood regulation, micro-climate regulation, among others. As a result, a number of cities like Singapore, Amsterdam and Los Angeles took up initiatives to naturalise their riverfronts through demolition and redevelopment activities. However, these have been cost- and resource-intensive endeavours.

Based on physical observations by the authors, a number of Indian cities like Agartala, Ahmedabad, Jaipur, Lucknow and Patna have also channelised their river banks and pushed for concretised riverfronts. While there is growing awareness among the cities about the benefits of naturalised features, the costs for transformation are quite significant, particularly since heavy investments were made in the first place.

There is need for urgent research on how Indian cities can naturalise existing channelised rivers and concretised riverfronts in a cost-effective way. This includes research on developing new technologies, innovative business models, and flexible governance mechanisms to support the transformation.

Estimating the Optimal Return Flow that a City should provide a River

One of the most important requirements in river management is ensuring the required environmental flow. Poff and Zimmerman (2010) defined environmental flows as one approach to setting science-informed water management goals, by quantifying the hydrological regime necessary to support aquatic ecosystems. Recognising that in-stream habitat requires more than a simple minimum level of flow they suggested that environmental flows incorporate a more comprehensive view of the magnitude, timing, variability and quality of streamflow.

In India, environmental flow is typically dictated by releases from dams and barrages that are built of rivers, and may not necessarily lie within the administrative jurisdiction of a city. In such cases, the onus is on the city to earmark an appropriate return flow into the river to ensure its

environmental flow is not comprised. Ensuring this return flow is far easier in the monsoon where the stormwater drainage system carries the runoff from the city into the river. However, providing this return flow is far more challenging in the non-monsoon months, especially in the dry season when the river requires the environmental flow the most. The only option, it would appear, is to earmark a portion of the treated wastewater as return flow. However, given the current thrust on wastewater reuse (some cities are even targeting 100% reuse), how does a city juggle between the two? More importantly, how does a city arrive at an optimal return flow value? These are very real and practical research questions that need to be answered in order to provide cities with a systematic and clear plan to make a contribution to the environmental flow of the river that passes through or beside it.

Linking Valuation of Urban River-Related Ecosystems to River Management

As highlighted in the introduction section, urban river management is never about perfect solutions but rather about optimal solutions, given the range of competing users and use sectors. Urban river managers are, therefore, forced to make choices and trade-offs about river ecosystems on a continuous basis. These imply valuations. The concept of evaluation of ecosystem services, introduced in the 1990s, has seen significant scientific traction in subsequent years. It involves assigning a monetary value to natural ecosystems (in context of this paper, river and its associated elements) and the services provided by the ecosystem.

Literature is abound with examples of the different modalities of valuation of riverine ecosystems in India. For example, Sinclair et al., (2018) developed an economical valuation tool using crowd-sourced data to: (a) map nature-based recreation patterns; (b) create value recreational ecosystem services; and (c) investigate how recreational benefits are affected by changes in ecosystem quality. They applied this model to the Vembanad Lake in the state of Kerala. Similarly, Sannigrahi et al. (2020) estimated the ecosystem service value of six eco-regions of the Sundarbans biosphere reserve.

The translation of scientific research findings into practice has, however, been very limited. One possible explanation could be lack of awareness among decision makers about the philosophy of ecosystem valuation and its application. However, a more plausible reason is that ecosystem valuation is treated as a theoretical subject matter with limited practical implications. Action research is needed to change this narrative. There is a need for more evidence-based studies that provide tangible avenues and channels to mainstream ecosystem valuation in decision making.

Sustainable Models for Enhancing River-Related Economy

Rivers have an intrinsic economic value. Throughout history, civilisations have flourished along the banks of rivers. For such civilisations, rivers were the main avenues for economic and social activities. To not tap into the economic potential of rivers will essentially be a lost opportunity. The challenge, however, is to do so without breaching the threshold of disturbance that the river can handle naturally.

Research is needed to identify quantity and explain this threshold of disturbance. This is closely related to the much touted term 'carrying capacity', which was originally an index of physical mechanics, describing the maximum load that an object can sustain without damage. Gradually over time, the philosophy of carrying capacity found application in natural resource management and land ecological protection to help define the extent of permissible socio-economic development (Hu et al., 2022).

There are good references in literature where the concept of carrying capacity has been applied in the water sector. For example, Hu et al., (2022) used water supply-demand analysis and temporal threshold analysis to estimate the regional water resource carrying capacity in Inner Mongolia of China. Sun et al. (2022) propose a marine ecological carrying capacity framework that uses the AHP-entropy based TOPSIS method to carry out a multi-angle evaluation of marine ecological carrying capacity, and applied this framework to the Shandong province of China. Likewise, Khorsandi et al. (2022) employed an earth observation method to develop an analytical tool to estimate the water resources carrying capacity for Iran.

The aforementioned studies and a number of others may be referred to to establish a methodology to estimate the carrying capacity of rivers under different development pathways, and identify means to boost this capacity through technological, economic and institutional mechanisms.

Addressing the Impacts of Climate Change

Climate change is easily among the greatest challenges for sustainable development. Water is the primary medium through which the impacts of climate change are manifested, which makes it all the more important to account for climate change in river management strategies of the future. Already across the globe, rivers are beginning to exhibit the impacts of climate change. Rivaes et al. (2022) carried out an assessment of climate change effects on the instream biota of the Lima River in Peru. Their results revealed that climate change-driven flow regimes will influence river hydraulics because of which all the assessed biological groups are prone to potential drastic changes. Likewise, studies have quantified the impacts of climate change on: (a) sediment load in rivers (e.g. Muto et al., 2022); (b) flow in rivers (e.g. Du Plessis and Kalima, 2021); (c) riverine aquatic species (e.g. Rivaes et al., 2022) sustainability of ecosystem services (Ashrafi et al., 2022), among others.

There is a need for research on how to integrate climate change in decision making for urban river management, linking climate-related considerations to planning strategies and management options. Some key research questions that need to be answered include: 1) How to address the variation in streamflow in light of climate change? 2) What kind of planning and management provisions should be made to account for large deviations in the course of rivers resulting from climate-induced change? 3) How to protect native aquatic and riverine species from the impacts of climate change?

Most importantly, however, is the question of how to keep rivers healthy in the face of climate change. This is a crucial aspect because already cities across the globe are bearing the brunt of climate change through increasing instances of floods, droughts, water-related pandemics, loss of

biodiversity, and other detrimental impacts. Healthy rivers are excellent avenues to help mitigate these impacts. For example, rivers with well-defined and well-maintained riparian buffers can reduce the threat of fluvial flooding significantly. Likewise, effective floodplain management can augment depleting groundwater levels, and subsequently enhance the overall water security in the city. The range of ecosystem services that a river provides—i.e. provisioning, regulating, supporting and cultural—are unparallel. However, many of these ecosystem services are likely to be compromised in light of climate change. Effective and sustainable management of healthy rivers is, therefore, a vital cog in the wheel of sustainable development in the context of climate change.

Conclusion

It is now well established that healthy rivers have a significant role to play in the overall livability and development of cities. It, therefore, is vital that cities invest their resources and time in maintaining healthy rivers. However, the management needs of the current times may be very different from those of the future. This accentuates the need for a dedicated stream of research on urban water management in the country, particularly because this domain is relatively new. The research required is more from an 'action' standpoint, where the emphasis has to be on creating a 'solution space' for addressing imminent and anticipated challenges.

The paper highlights a few areas of research that can be taken up in the near future. However, this list is not exhaustive. As the knowledge on urban river management improves, it will lead to both newer and deeper areas of research. The conventional cycle of research-to-publication-to-recommendation may have worked in the past. However, the current urgency to address the impacts of climate change demands embedded approaches to research that accompany the pursuit of massively scaled-up climate action. This calls for solution- and action-oriented research that is integrated into practice: from problem definition to solution implementation, from programme design to evaluation.

Conflict of Interest

Authors has no conflict of interest to declare.

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Reconnecting the City to its Riverfront: A Case of Kolkata

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Abstract
Kolkata, one of the major metropolitan cities in India, owns a great and heroic past, bearing its unique heritage and culture, owes its creation to its strategic location along the east bank of the river Hooghly, a distributary of the river Ganges. The banks of the river, once the lifeline of the people, remained bustling with different activities. They have become deserted areas, dotted with shabby old structures, disconnected with the city, and devoid of erstwhile scenic views. In the recent past, the riverfront has become the backyard of the city, derelict of any desired activity leading to escalating environmental and urban issues. The river-edge precincts and its neighbourhoods have died out in terms of their social association with the river. It is evident that the city has lost the social eminence of its riverfront because of the indifferent behaviour towards its revival. A discussion in response to the social issues of addressing the urban concern for finding a suitable solution or method to revive the lost values of an urban river has been elaborated within the paper. This research paper explored the principles of building a framework of developing tools for redefining the value of an urban riverfront through strengthening its cultural and social bonds with the city.

Keywords: Degrading Urban Landscape, Riverfront Development, Social Recognition, Cultural Exposure, Heritage Restoration

Introduction

Rivers have had great significance in the evolution of many civilisations and their sustenance, becoming an essential element of urban life. They serve as a visual and cultural resource, a life system, and a corridor of endless tales. Along with time, they become a memorandum capturing several impressions along their banks throughout their life, and are a reference for the future of humankind. They are a ground for recreation, an entire biological ecosystem, and an endless resource. The *Atharva Veda* (II, 3.6) says: "May the water bring us well-being!" There are many such references in literature about the quality, use, sanctity, and symbolism of water (Eliade, 1958). In ancient Hindu mythology, water has been described as the foundation of the whole universe, a basis for life and the elixir for immortality. (Singh, 1994).

Role of an Indian River

Though rivers are basic lifelines for cities in India, they have a bigger role to play as there is also a religious sanctity attached to them. Numerous beliefs and traditions become a part of the bond, whether tangible or intangible, that get enriched with rituals and daily life occurrences happening simultaneously on the river's edge. "According to the common saying, the Ganga River is the identity of the cultural history of India's civilisation since at least c. 2000 B.C., recording the history of Aryanisation. As a sacred entity, water is considered at once a purifier, a source of mystery, and a basic substance of life" (Singh, 1990). This importance given to Indian rivers has led to diverse forms of attachment to them in our lives. They take us through historical events, mythological references, and many traditional beliefs. They are socially considered to be 'holy', and accepted with faith, devotion, and worshipped. Indian cities evolved around them and nurtured various cultural meanings over time. These natural forms are believed to be embraced with the forms and processes of the cosmos, and mould the ecosystem in which they exist today. As stated by Prof. Rana P.B. Singh (1990), "The sacred bond between person and place is a reciprocal process illustrated in the realm of manifestation, visualisation (architecture and the symbolic meanings imposed upon) and the world of festivities (regulating and reawakening the spirit through rituals). The human relation with nature is realised primarily while narrating the place, understanding the place, and becoming part of the 'spirit of place' (genius loci)". Intangible bonds and emotional attachments pop up to define the spaces along a river, and activities are shaped in a respective manner, to stage a drama of life. People, in the form of the players of the ecosystem, construct societal values for themselves, and act within their own scripted role, giving birth to the cultural context of a place. 'The symbolic expression of place is the set of symbols that gives the people a cultural orientation in space and time" (Singh, 2009).

Alongside shaping the cultural dimension of a place, Indian rivers are vital resources with enormous potential for society with social and economic value in daily life. They become the central focus of urban form, especially for the communities living by a river. The bond becomes an emotional attachment for the city as a source of happiness, a resource for recreation, a medium to

serve as the 'third place' for the people, alongside a platform for revenue. All components involved within this synergy participate as entities of a single biome, a system of life that exists along with the natural flow. Their various roles function in a rhythmic harmony, where we see a priest purify himself with his 'holy' bath in the river water, the elderly stand submerged for 'Surya-namaskar' in the early mornings, the kids get a medium for their play, a dhobi washes clothes to earn a livelihood, and fishermen wander in for their daily catch. Ferries ply across the two sides carrying numerous passengers travelling for different purposes. Daily activities to annual performances and further lifetime accomplishments add to the identity of the place. Such public interaction happens in different ways along the river's stretch, depending on the cosmic atmosphere that surrounds the place.

Varied patterns of programming are constructed, shaping the local lifestyle and its needs. The banks are further determined for extracting resources for desired needs from the river. Despite their importance, the cities have sometimes come into conflict with the urban rivers in an undesired manner. Their existing potential is sometimes over-exploited and even in some cases under-utilised compared to the spaces in the city. However, these places always serve the urban form in a multitude of ways—may be as recreational open space, an attraction for tourists, a catalyst for trade, or an active booster for the local economy.

The North Kolkata precincts could be taken as an instance to observe the different layers of evolution of livelihood along with time and space. The Hooghly River passes by the urban edge, setting up a perfect example for exploring the correlation between the evolution of human society and its bond with the river. The riverfront here had been the epicentre of urban growth, ultimately resulting in a metropolis which grew from this very specific river-edge, carrying with it a handful of storylines associated with its growth, especially in the stretch from the Circular Canal till the Burrabazaar region. This urban edge possesses multiple expressions of defining a 'place', a mutual platform for different perceptions and activities.

Historic Background and Context

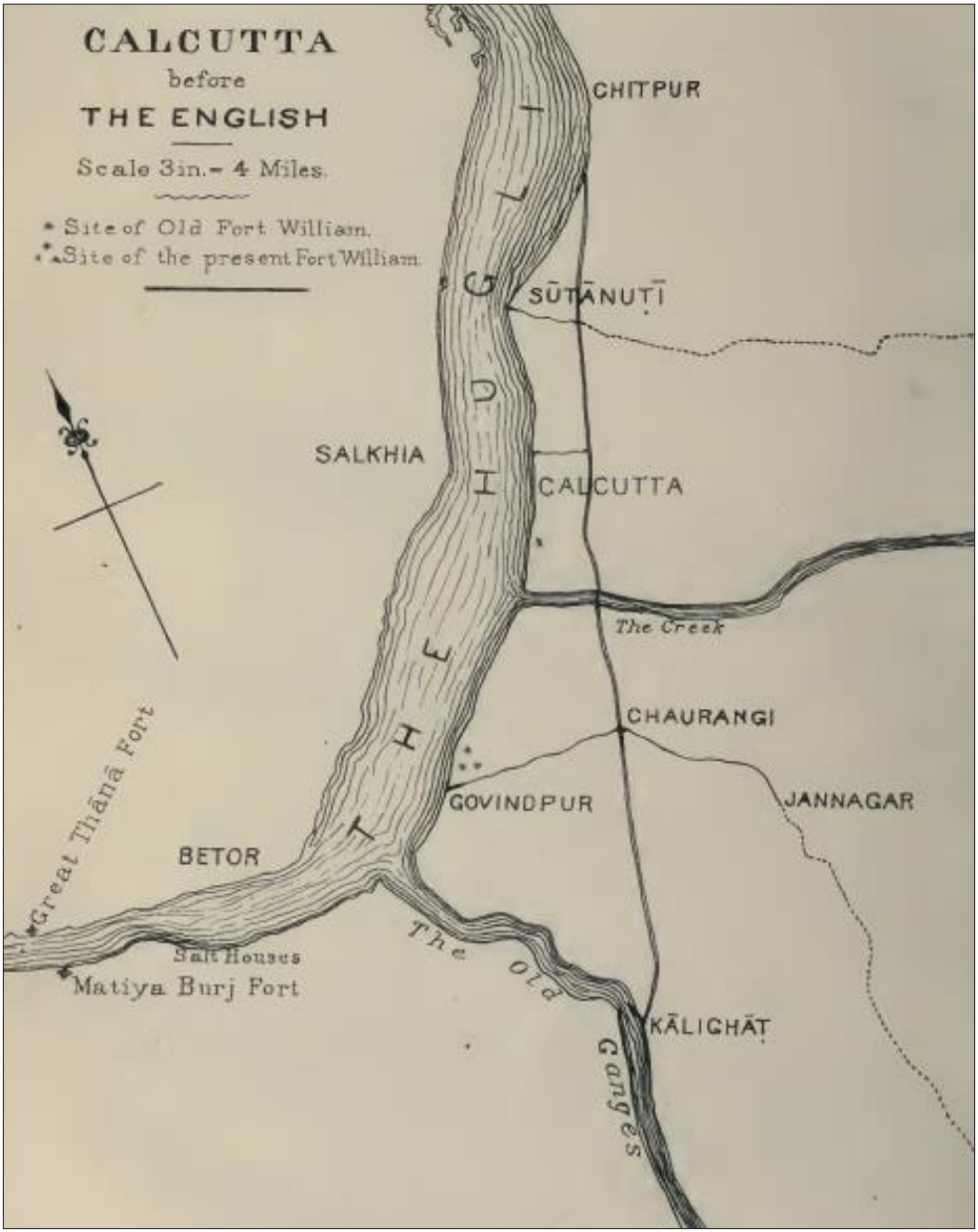
History records the pattern of growth of a civilisation during the last few centuries along the Hooghly River from a few hamlets to one of the most populous cities in the world. The city started to expand from the three villages of Sutanuti, Kalikata and Govindopore. With the arrival of the Europeans, Calcutta began a period of growth that would transform it into one of India's greatest cities and second only to London among the most important cities of the British Empire. "When Europeans sailed up the Hooghly for the first time in the early sixteenth century, they found a diverse population of ethnicities and faiths living along its banks" (Ivermee, 2017). Job Charnock, an agent of the East India Company, after several conflicting delegations and challenging confrontations with the then Mughal governor of Bengal, Shaishta Khan, had carefully selected the land near the village of Sutanuti to settle and expand trade. While Govindopore lies towards the south, where the British landed to build their superpower capital centering around Fort William, the major part of the urban growth comprising the native population took place within the northern grounds.

Figure 1: Hooghly River Running by the North Kolkata Region

Source: Google Earth map sourced on 20.08.2020

The dense morphology of north Kolkata relates back to the times when the city was emerging as a trading capital and an administrative power for the country. People from all over the state and beyond flocked within these areas in hope of a better economic opportunity. Rapid urban growth followed as a result. The British government imposed racist policies within the planning framework of the growing urban centre and the town was divided into three divisions—the black town (north Kolkata), the white town (south Kolkata) and the central business district area (Dalhousie and Chowringhee region).

Figure 2: Old Map Showing the Calcutta Region in 1680 before the British Arrived



Note: There were lot of creeks along the river where the settlements were mainly found. It proves how waterways played a major role of mode of transport. The map also shows the road linking Chitpur to Kalighat formed a major axis for the later urban growth of Kolkata.

Source: puronokolkata.com

Identity of North Kolkata Region

The native population was pushed towards north Kolkata or the Black Town. The gradual rise in trade and commerce of the city eventually showed a rise in the population index which also showed a similar pattern in the density of the growing urban fabric in an organic pattern. Flocks of migrants began settling in this region. It followed an uncontrolled densification of the neighbourhood without the provision of proper civic facilities. The streets were narrow and dingy, the shops and warehouses mean looking. The lower parts of the houses containing the bazaars, and the upper, the dwelling-houses, crowded with a heterogeneous population; many were half naked, while others were bedizened in tawdry and fantastic garments. Discordant noises of all sorts, and most offensive smells completed the repulsive character of this portion of Calcutta.

Figure 3: A Bewildering Mass of Billboards at the Corner of Harrison Street (Burrabazaar) and Strand Road

Source: Penn Libraries, University of Pennsylvania. Photo taken by Clyde Waddell most likely between 1945-1946.

Planning Framework

Though trade was the most important concern for the British Raj, the uncontrolled littering of the cityscape did not make for good scenery for the English residents. It compelled them to develop a planning framework for the township and establish a municipal body for basic services to the native people

'While E.P. Richards was drawing upon more concrete examples of town planning schemes from the Western world, Patrick Geddes, a Scottish sociologist and town planner, who produced several reports on Indian towns, believed that town planning was actually 'folk planning'. He (Geddes) believed that the plans for a future could only be drawn after unravelling the dominant social pattern of a community. To tackle the decay of urban settlements, Geddes invented a method that he called 'conservative surgery', which proposed minimum demolition and disruption to achieve maximum improvement in the city,' (Chakravarty, 2019). The urban blocks comprising

inclusive neighbourhoods evolved in an organic pattern. Wide roads meeting at right angles were developed to demarcate the irregular grid pattern urban blocks. It solved the purpose of better policing, easy layout of services and keep control over the native population.

Figure 4: Calcutta in 1792

Note: The concentration around the Old Fort, the Great Tank and Writer's Building is dense while the town is spreading. In the South, the new Fort William, the Maidan and the new English residential locality of Chowringhee have appeared.

Source: Map taken from Census of India 1951

The wide streets also served as busy commercial thoroughfares, thus increasing business and commercial activities within the city. Commercial veins proliferated within the native areas. Home-based industries emerged and a rise in mixed-use typologies came into the picture. The steep rise in the influence of trade generated a high demand for infrastructure by the riverside. The surrounding precincts emerged as a central focal point of economic significance for the urban form. The river's trade-oriented functionality gave rise to an expected commercial frontage on the river banks, thus, identified itself as a valuable urban edge and became the most bustling part of the city.

Development of the Riverline Cityscape

The Hooghly River served as the basin for connecting people and goods to different parts of the country and the world, as well, and thus gave rise to an urban centre which was aspiring to be the national economic and administrative capital. "Following the upheavals of the eighteenth century, it is suggested, Bengal entered a period of relative stability and peace under British colonial rule; the East India Company's monopoly on trade between India and Britain was lifted and replaced by free trade, as a result of which Calcutta was integrated into global networks of commercial exchange" (Ivermee, 2017).

The cityscape evolved from these activities, leading to the colonial built-up edge, with docking ports and ghat structures by the river banks. The Port Trust initiated large-scale infrastructural development in the 1870s. The exponential rise in trade between the 1850s and 1880s, trade in jute, cotton and tea led to a demand in more storage space within the port areas of Calcutta. The city was also the main centre for imports of cotton piece goods which were distributed throughout the hinterland comprising the provinces of Assam, Bengal, parts of northern India and central India. A tea warehouse on Strand Bank Road was constructed in the 1870s, to accommodate this increased volume of trade. Other warehouses were soon proposed along with need. "The trading activities at the port kept increasing, especially during World War I and its aftermath. The need for warehouse space was acutely felt in these years. More jetties and warehouses were ordered, and the port commissioners continuously put pressure on the government for adequate funds. In 1895, the average daily imported goods weighed around 1000 tons of which 300 tons were stored at the warehouses, the rest being carted away to other parts. In times of pressure, this amount doubled. In fact, a decade later, in 1906, the Secretary of the Bengal Chamber of Commerce mentioned that due to the increase of trade there was hardly any space at the jetties for the imported goods that were coming in; new jetties and a modern crane system were being constructed at the port but those were not enough; new warehouses were needed" (Sengupta, 2017). Responding to the need, a new dockyard at Garden Reach was constructed to reduce the pressure over the existing ones.

A proper channel of transport facilities to move goods to and from the dock area was another challenging development that occurred by the riverfront. The railways played a crucial role in connecting Calcutta with other parts of the province and country. Calcutta was served by the East India Railway, the Bengal-Nagpur Railways, and the Eastern Bengal Railways. The development of the railways was crucial in facilitating the activities of the port. Major items like rice, coal and jute were transported to other parts of the subcontinent from the port via the railways. But in the immediate vicinity of the port proper roads and carriers were not suitable to handle the large bulk of cargo. For this, the Port Trust started constructing the Strand Road and the Bank as well as a tramway. The development of the tramways was directly linked to the massive increase in the net cargo handling in the port. It solved the problems created by the gradual extension of port activities by establishing crucial links between the docks and the city, and in turn with the hinterland. A bridge was built above the Circular Canal to connect the tramways to the Chitpore railyard, which opened the movement of cargo and goods to the rest of the country through the Eastern Bengal Railways.

Hooghly River as a Boon for the City

"Commerce plays an important role in modern history. It is one half of politics, for in the first place the importance of a nation greatly depends on commerce. A desire to expand commerce, rather than a merely scientific curiosity, has been the mainspring of adventures in quest of new lands" (Deb, 1905).

As stated above, the Hooghly River, a distributary of the holy river Ganga, played an eminent role for the growth of the metropolis of Calcutta. The geostrategic location of the urban centre by the side of the flowing river towards the Bay of Bengal, and thus, to international waters, gave the growing city the advantage of attracting foreign trade and commerce. It also played a vital role as an arterial link to other parts of the country, especially the Gangetic plains. The regional periphery from the delta of the Bay of Bengal attracted foreign communities to settle and reign over native society in this region. The British settled mostly by the marshy lands of the east bank of the river. The French settled more upstream on the west bank of the river at Chandernagore and Chinsurah areas, and the Danish in Serampore, while the Portuguese settled more upstream in the Bandel region. These settlements of the European powers reverberated with its growing importance as a regional hydrological network acting as a basic source for new opportunities to expand trade in the province of Bengal. It also attracted the local people of the region to migrate into growing urban centres for better employment and lifestyle opportunities.

Figure 5: Regional Map Showing European Settlements along the Hooghly River

Source: Map taken from "Genesis of the Metropolis" by Munsi (2020)

The river edges along the north Calcutta region faced a boom because of their ecological value, while the marshy lands of the Salt Lakes became the grounds for sewerage and drainage of the city, and the western urban edge facing the river became the most important urban profile, ultimately representing the face of the city. The area facing the river, comprising the bustling commercial centre of the city, stretching from the Dalhousie area and Burrabazaar markets till the railyards of Chitpore certainly, gave an image of a booming colonial city. Urban infrastructure planning and developmental goals followed. Parcels of religious and public buildings peeped out in front of the native residential colonies upon the river line, adding a flavour of intangible connections with humankind, along with value of commercial benefits. Thus the river-lining cityscape of colonial Calcutta gave the impression of being one of the most important cities in the world, second only to London.

Cultural Identity

"The Hooghly was venerated as the Ganges's original and most sacred route. Its alternative name—the Bhagirathi—evokes its divine origin and the earthly ruler responsible for its descent. From prehistoric times, the Hooghly attracted people for secular as well as sacred reasons" (Ivermee, 2017). Europeans arriving along the Hooghly were fascinated by the position that the river occupied in local life, and in particular its significance in Hindu religious practices and beliefs. Explanations of the growth of Calcutta usually focus on the forces of capitalism. The influence of trade also led the local sub-dominion powers to showcase their capabilities by building local infrastructure and structures within the city and along the riverfront. Zamindars and eminent personalities of the time took such initiatives with a desire to serve civil society. Several ghats built in different eras by different local heads still stand tall today. These places were among the first to connect society with local culture and traditions. Religious practices and ritual performances took place within these places and gave a new identity to the river's edge. The ambient atmosphere developed within these spatial modules, which connected civic society intangibly with traditional beliefs. Eventually such activities acquired more and more of a significance connected to the sacredness of the water along the ghats. Mandirs and associated built forms sprawled around the surrounding areas. The social attachment of these elements with the city people gave a cultural dimension to the riverfront. These cultural ties have remained along with the deterioration of these structures and passed on from generation to generation. The riverfront still attracts the city people and binds them to itself with these intangible connections even today.

Figure 6: Hooghly Riverfront during the Colonial Period

Note: The Hooghly River was lined with bathing ghats and temples, along with ports and dockyards with commercial built frontage comprising warehouses during the colonial period,

Source: Taken from monovisions.com

Issues of the Degrading Landscape

In the present day, there is a discernible rhythmic flow of activities along the nodes of the north Kolkata riverfront. The atmosphere changes from one junction to another, along with the urban character and forms of livelihood. Diverse characteristics are reflected in the lifestyle and activities of different communities living next to each other. But the riverfront, which was once a thriving junction for trade, no longer reflects the exalted position it once held.. It is now ridden with dilapidated forms of heritage structures that have little connection or importance for the city people.

The river banks of Bagbazaar only reflect specific daily activities, with very little footfall. Empty spaces between active zones have created gaps that have given rise to unsocial activities and uncontrolled littering of the river edge. A narrow riverside road lined with temporary built stalls leading to the ferry jetty is a common sight within the place. The rest of the area has become a dumping ground by the river. The festive seasons bring life to the place with a heavy footfall but are of little concern to people vis-à-vis their ecological relevance.

Figure 7: Degrading Landscape of the Hooghly Riverfront from Sovabazaar in the Present Context

Source: Author, photo taken on 02/02/2021

The sloping ghats along the Sovabazaar to Ahiritola stretch, mainly developed for daily local activities, is the only riverside precinct available in north Kolkata that can become an open space in the city and a recreational destination for visitors even though there is no attraction at present to boost the area into a city level tourist destination spot. The neighbouring ghats of Nimtalah get a high footfall of visitors from the city for their specific role of ritual activities performed after death with respect to their location beside the Nimtalah crematorium.

Figure 8: Intangible Bonds with the Hooghly River

Note: Intangible bonds with the Hooghly river persist but without any concern for the health of the river.
Source: Author, Photo taken on 29/01/2021

Such concentric active zones within their own perimeter have created different expressions of the riverfront in secluded form. The riverfront is adopted by users for very specific uses and not looked upon from a holistic perspective. These node-based landmarks could be the reason for partial enlightenment of the potential of the river, and not as a wholesome entity.

The Burrabazaar precincts showcase total negligence towards the river edge. The large warehouse facilities which were directly connected to their prior location beside the river edge have no more purpose for being there. The pattern of movement of goods has changed. The Howrah Bridge has enhanced connectivity across the river to Howrah Railway Station. Porters carry over the goods to the Howrah Station now across the bridge. Trucks line up along the Strand Bank Road beside the warehouses for the transportation of goods and the waterways are no more used for movement of goods and commodities. Thus, the value of the river has diminished. The Hooghly River which once held prominence has become a mere background to the built forms. Scenic views of dilapidated structures and a garbage dumpyard have come into existence by the river over the years.

Figure 9: Degraded Landscape Frontier Near the Warehouses of Burrabazaar

Source: Author, photo taken on 29/01/2021

A fall in visitor attraction is also evident. The local ecosystem of commerce and economics is thus affected hugely and the standard of living of the inhabitants has been showing no positive symptoms within the analytics of the recent past. The landscape of the city riverfront has become a regular scene of "dilapidated ruined structures lining a river edge with polluted ghats and unattended garbage dumping grounds". The river edge, which is supposed to be the face of the city, is no more what it used to be.

Figure 10: Approach to the Riverfront through a Commercial Burrabazaar Node

Source: Author, photo taken on 29/01/2021

Need Analysis and Suggestions

Revival strategies of the riverside precincts into a newly transformed riverfront development need to be formulated. Such strategies could help to reconnect the landscape of the riverfront with the city socially and culturally better, and enhance the structure of livelihoods within the local associated built forms with new programmes. Eventually the precincts could thrive to become a city magnet, further boosting socio-economic development of the place, especially the neighbourhoods along the river edge.

Figure 11: Holistic Approach for the Development of the Hooghly Riverfront

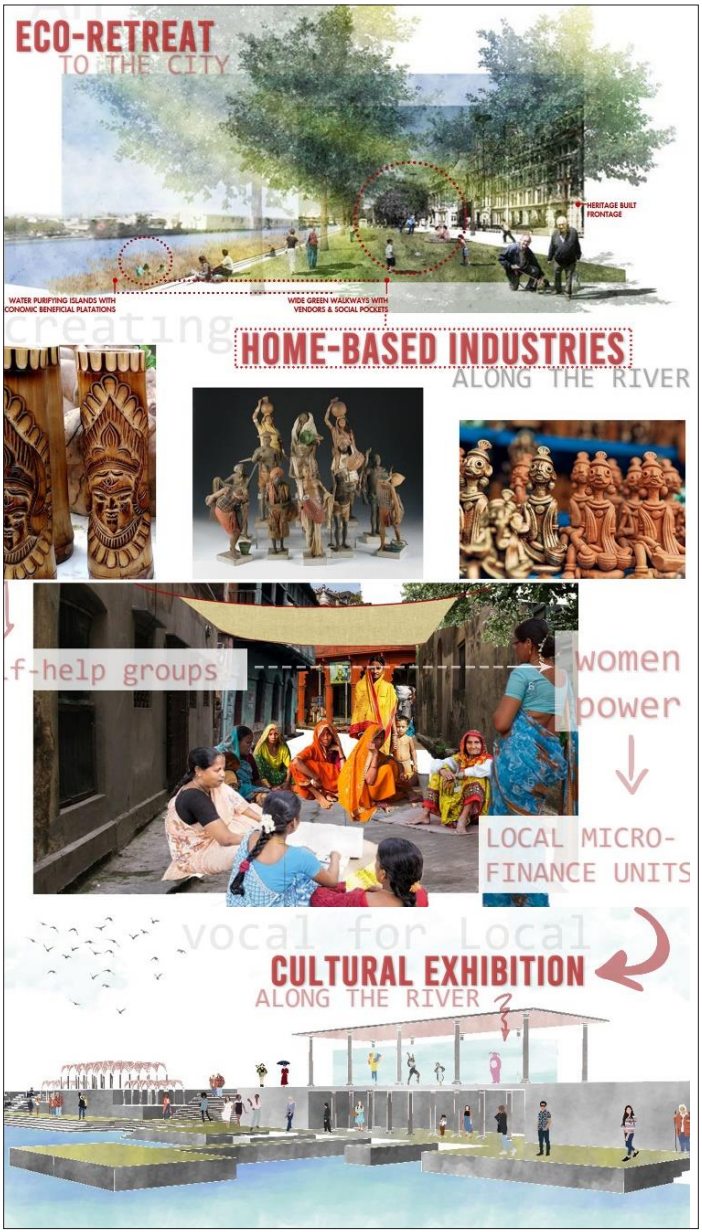
Source: Authors

Preserving the Culture

Creating a magnificent atmosphere along the river for a city recreational space should also be kept in mind. The paradigm of 'live-work-play' would give a beneficial thrust to the various lanes of improvisation when looking at the riverfront, and unleashing the potential that it can express.

Hosagrahar (2017) dissects the concept for considering the cultural context as the basics for shaping a community. She says, "Culture is who we are, and what shapes our identity. Placing culture at the heart of development policies is the only way to ensure a human-centred, inclusive and equitable development." She also demonstrates how 'culture' has a crucial role to play that makes cities and human settlements inclusive, safe, resilient, and sustainable (SDG-11 of United Nations). "Urban areas rich in cultural heritage and with a vibrant creative sector are more attractive for businesses. Promoting inclusive and sustainable economic growth through employment in culture and creativity encourages decent work. The economies of some cities draw significantly on intangible heritage such as crafts, music, dance, visual arts, traditional cuisine and theatre that are often an integral aspect of historic urban areas"' (Hosagrahar, 2017).

Figure 12: Strategies to Enhance Livelihood



Note: Strategies to Enhance the Structure of Livelihood Within the Local Associated Lifestyle with a New Programme to Enhance Social and Cultural Bonds

Source: Authors

Looking back at the importance of the Hooghly River that had once been a part of the glorious past of the city, the present state underestimates its heritage value and also its social association with the city people. A better outlook could be achieved through a social upliftment of the riverfront precincts through engaging them into regularised industry or commerce which is strongly culturally associated or becomes a promotional asset for the local cultural context; hence socially strengthening the intangible bonds of the river with the city will in turn impact in the revival of the health of such an urban river.

Figure 13: Developing a Cultural Hub

Note: A Cultural Hub with Associated Local Cultural Activities by Conserving the Heritage Warehouse Structures by the River Edge will help in retrieving the socio-cultural bonds with the river.

Source: Authors

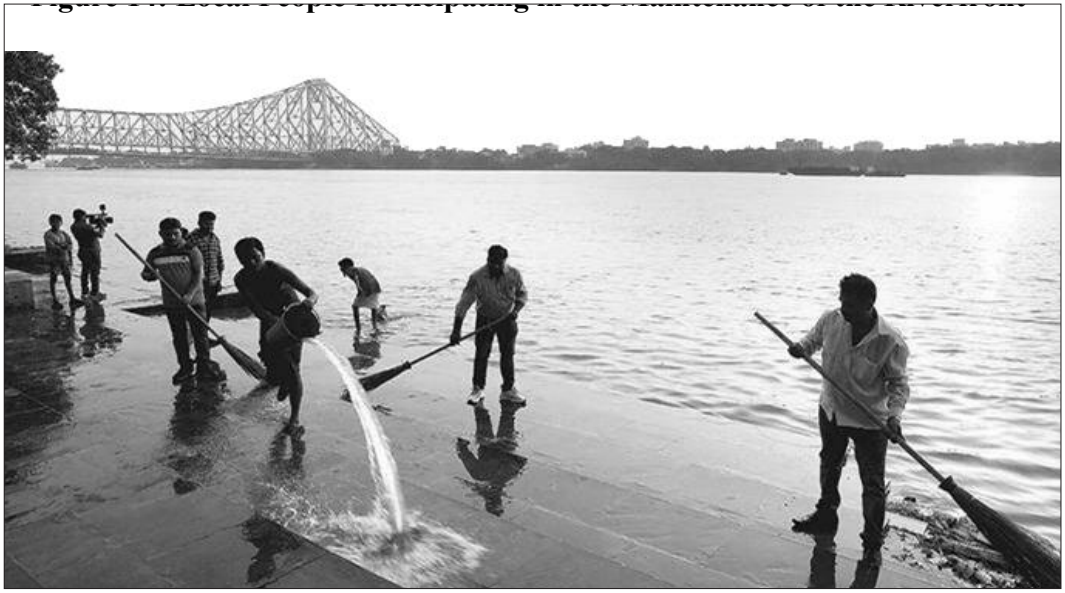
Improvised spatial management along with conservation of the heritage features of the ghats and other related structures including the colonial built-forms that contribute to their value need to be highlighted through careful description of their history. Narration of the storyline of the place and its background would create an immense impression in the minds of viewers. Built forms become potential assets for screening such an activity. They eventually reflect the need for exploring potential methods of improving their condition, and rejuvenate the atmosphere with an efficient and synergetic ecosystem that results in creating beautiful places and a public realm. Along with heritage conservation methods, strategies for utilising the heritage value for tourist attraction would deliver a much stronger sense of urban rejuvenation of the place. The old warehouses could be converted into museums, cultural workshops and exhibition centres which may be used to display the lost identity of the place.

Even the ghats could become a platform for newly introduced activities. Local associations and unions could be involved to organise such programmes, thus introducing the riverfront to the city with a new and fresh energy. This could also form a strategic way of attracting visitors and increasing the commercial activities of the region. Local neighbourhoods could benefit with the positive socio-economic upliftment.

Ecological Restoration

The ecological value of the Hooghly River could be brought back to life through public engagement and its social awareness among the local people of the region. The Swachh Ganga - Swachh Kashi Initiative is a role model for public engagement in the process of cleaning an urban river and maintaining it. Awareness campaigns on the need to clean the river Ganga and save its ecosystem by ensuring free flow of water, have been already successfully carried out in other Indian cities like Varanasi, Haridwar, Allahabad and Patna.

Figure 14: Local People Participating in the Maintenance of the Riverfront



Source: Author, photo taken on 02/02/2021

A better public understanding of the means of ecological restoration and the necessity for it through public engagement and awareness programmes can become an effective tool to control polluting agents and regulate the health of the free-flowing river.

Engaging the Local Community

Local communities could get engaged to extract their means of livelihood from the river and associate and exhibit their skills in the form of promoting their folk culture through new means within the riverfront precincts in a transformed public realm. Thus, the value of the Hooghly River can be enhanced and better connected with the ethos of the city people by portraying the local

cultural context and heritage background which is recognisable. It will help in retaining its societal value for nearby communities in a more sustainable manner, thus getting the interest of citizens in ensuring a cleaner environment along the urban river through strengthened bonds with city life.

Figure 15: Encouraging Local Association

Note: Local people could be encouraged to associate themselves with available ecological resources by the riverfront and protect it in favour of their daily means

Source: Authors

Better Developmental Approach

Development based on a node-based approach could further be adapted as a tool whereby people would be equally distributed along the riverfront. The major nodes that form the approach to the riverfront distinguish this fragmented character of development . These fragments of the stretch could then better respond to the present physical needs and the potential to deal with these needs from the adjacent neighbourhood, making the riverfront an economic resource platform and promotional ground for the locals. Communities could be exposed to the eco-friendly sustainable industries where the adjacent neighbourhoods get an opportunity to extract their needs from the natural resources of the riverfront. Furthermore, cottage industries can be based upon the regional Bengali folk cultural handicrafts, such as clay idol making from Krishnanagar, baked earth or terracotta items from Bishnupur, and bamboo and cane artefacts from Cooch Behar. They would represent and help in promoting the local Bengali folk culture. These would help in

the economic upgradation of the local livelihoods. As a basic resource ground for the locals the riverfront is expected to be maintained by them as well. This inclusive nature of inter-dependency of the locals with the riverfront would enhance the social integrity of the place and help to revive the social value of the river in the relevant nodes.

A Breathing Space for the City

The river also offers potential for being a recreational ground for the city. Spaces that serve this purpose in the present scenario are not well maintained or are utilising their utmost potential. Segregated ghats which form the major nodes of attraction and activities, give rise to ground for creation of unmonitored pockets along the river edge. These spaces attract unsocial behaviour or become solid waste disposal grounds, giving a negative impression of the place. Rather, a seamless corridor with varied activities might create a more interesting city space, with a better scope of management of the social issues, and create more space for adding value to the riverfront.

Potential for Future Development

The northernmost fragment of the stretch comprising the Bagbazaar region could be developed as an eco-retreat corridor for the city. The natural embankment of the river edge can serve as a resource platform for selective wood-based handicrafts industries. The natural embankment can also act as a platform to extract silt from the river for making clay items. These could serve the potters' colony in the precincts as a means of livelihood.

Figure 16: Developing Green Corridors

Note: Running Green Corridors to Act as a City Recreational Zone by the River Edges.
Source: Author, photo taken on 30/01/2021

The Sovabazaar-Ahiritola region could become a city recreational space with multi-dimensional utility of the spaces along the landscape. The present form of unplanned ghats could be unified. Spatial configurations could be made, along with planned segregation of activities according to the zoning of the unified stretch within the development of these ghats, which would then help in better management and policing of the riverfront.

Figure 17: Better Planning of River Ghats

Note: The development of the ghats could be better planned with associated activities by the riverfront and portraying local architectural elements.

Source: Author, photo taken on 30/01/2021

Different platforms for various activities within a fusion of each overlapping with each other would enhance the vitality of the place to become a vibrant environment for pedestrian activities along with recreational grounds, thus making it a tourist magnet. These places could be adapted to foster a huge amount of visitor footfall. Different tales of act is also expected at different times of the day as each space could be developed for multi-dimensional use. The different spatial configurations could give space for carrying out daily activities including rituals, evening aarti performances, weekly crafts bazaar, exhibition ground for local small industries and folk handicrafts all if which will eventually get reflected in the economic status of the adjacent neighbourhoods. The city's heritage style depicted in the existing built character with the unique Bengali style of architectural elements would even promote the local cultural context.

The fragment of the stretch leading from Ahiritala to Nimtalah could be envisaged as a place for city people to interact with the Hooghly River.Water-oriented activities such as viewing decks, boating facilities, bathing facilities and water sports activities are proposed here, making it a vibrant and active zone during the festive season. This could also act as an extension of the activities on the ghats and merge with the built character towards the south. The activities in Nimtalah, a landmark of the city, being a major city crematorium ground, could be authentically retained.

The warehouses along the riverbanks of Burrabazaar area could be rejuvenated and adapted for better use. The present warehouse activities can be relocated within the adjacent urban blocks. These heritage warehouse built forms could be conserved and retrofitted with features that express a city cultural hub, and be a venue for activities oriented to the research and promotion of Bengali culture. These heritage buildings could also house exhibition spaces, museums, cultural workshops and tutorial classes, cultural clubs, and theatre spaces. The re-adaptive use of these built forms could help them become a city magnet and nurture an appropriate cultural ethos in the surrounding areas. They would also serve to increase visitor footfall within the region. Broader pedestrian streets alongside the Strand Bank Road with large gathering spaces, performance areas, and open exhibition facilities would allow the cultural activities to unfold into extended public spaces, forming an open and permeable environment. The general public would

also be visually exposed to the activities of the cultural hub. There would be spaces for open street performances and open galleries too. It would become a culturally determined city space with the heritage background of the riverfront.

Figure 18: Exhibition Grounds in the River Promenade

Note: Development of Exhibition Grounds for Promoting Local Cottage Industries
Source: Authors

The Local Neighbourhoods

The local neighbourhoods could be encouraged to create new trade associations for promoting sustainable forms of agro-based industries and creating self-help groups for women, which would involve them in small-scale folk handicraft industries. Furthermore, exposure and promotion through community walks and dedicated theme streets, within a framework of a more attractive and commercially beneficial street network through the neighbourhoods would bring more interest within the whole region, to be explored by visitors. Local economic beneficiary strategies will open the economic potential of the area to outsiders.

Figure 19: Visitor-Oriented Community Walks Promoting Local Cottage Industries

Source: Author, photo taken on 19/01/2021

Conclusion

The idea of revival strategies for improving the ecological health of an Indian river needs understanding of the existing ecosystem for a sustainable model of redevelopment. A connection between the urban form and the natural body could be established after determining the social engagement of the living communities, their traditional beliefs and associated bonds with the river. Other local influential factors such as capitalist ideologies of development through the past and present, need to be given prior consideration for determining the necessities of different stages of development required within the vicinity. The physical outlook and social recognition of the ecological body are the key features expressing urban concern for its health.

In the case of reconnecting the Hooghly River with Kolkata, the socio-cultural ties between the river and city could be used as a tool for creating an adaptive model to enhance the social integration of the local community with the river. The riverfront could become a place of attraction at local as well as at regional level that values its heritage through a better use and social recognition of the place. It could then be blended with the neighbouring functionalities. Hence, the river could get the prior importance it deserves, and be treated with better care and maintenance if the surrounding place could be revived and upgraded in the image of the city. Increase in the influx of visitors would eventually cause an uplift in the livelihoods of the locals who should be solely responsible for taking care of the river in their own interest. The social upgradation of the Hooghly riverfront in north Kolkata could be strengthened through a better connection between the river and the human settlements alongside it within a sustainable framework of livelihood and cultural background.The strategies discussed involve an exaggerated engagement of the local communities living by the river. Such public interventions are socially sensitive and induce equal interest between the local community and the administrative authorities. Proper awareness and education of the locals through various forms of public engagement programmes needs to be held along with insights of experts in the whole process. The local version of concerned problems along with exchange of views in regard to a better solution for uplifting the local status will enhance the policy framework with more effective developmental strategies. Despite a controversial debate resulting in a discourse from the long-term vision, alternative urban design solutions and amendment of policy guidelines and bye-laws need to be adopted by administrative authorities. An integrated framework of institutions starting from the grass-roots level to the union level needs to be functional in uniformity. Their respective scope of actions needs to be put forward in an effective and sustainable administrative framework.

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Conflict of Interest

Authors has no conflict of interest to declare.

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Enhancing the Urban Water Experience – Rejuvenating Kaliasot River, Bhopal

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Abstract

The presence of water bodies in an urban environment is considered to be an important part of the infrastructure as it plays a critical role in enhancing the quality and development of urban spaces. However with increasing urbanisation, the rivers and water bodies in urban areas are subjected to exploitation through several anthropogenic activities thereby resulting in their degradation. The case worsens when the river is non perennial as these are often considered a limited source of water that is renewed unpredictably.

One solution to the conservation of urban rivers lies in rejuvenating the flow of water and developing waterfronts that can connect people to the river. Such initiatives could also aid in rectifying the decades of neglect by adding value to these urban waterbodies. What is lacking is a holistic approach.

This paper attempts to understand, through a review of literature, the value provided by a non-perennial river and its importance. The paper presents the case of the river Kaliasot in Bhopal tributary of the Betwa River, with the aim of exploring reasons for its degradation and arriving at solutions for its rejuvenation. The ultimate objective was to develop strategies and recommendations for transforming the existing, neglected urban river into a centre for social, cultural, and recreational activities in the city, by improving the water quality and developing a riverfront.

Keywords: Urban River, Urban Riverfront, Non-perennial Rivers, Recreation, Ecological, Sustainable Development

Introduction

The presence of waterbodies in an urban environment is considered an important infrastructural element and plays a critical role in enhancing the quality and development of urban spaces. Water bodies can provide social, environmental, and economic benefits but, with the dawn of urbanisation, in urban areas they are subjected to exploitation through several anthropogenic activities resulting in their degradation. The rapid pace of urbanisation has not only exposed water bodies to the stress of degradation, but also led to the loss of many. Frequently, the scale and size of the water body, the volume of water it holds or carries, influences the way it is perceived by the city.

Urban Rivers

When a river flows through an urban landscape it can be defined as an urban river. Unlike a pristine river, an urban river flows through densely populated areas and highly modified landscapes, experiencing some intense interactions between its bio-physical and social realities (Pradhan, 2019). Factors that contribute to the degradation of an urban river include channelisation, artificial banks/bed, dredging, removal of riparian zones, encroachment on riverbeds, pollution from untreated disposal of contaminated water and sewage discharge, solid waste disposal, lack of belonging and awareness, lack of river governance, etc. (NIUA[1], NMCG[2] , n.d.) According to India's Central Pollution Control Board (2015), 63 per cent of the urban sewage flowing into rivers (some 62 billion litres a day) is untreated.

The Plight of Non-Perennial Rivers

The case worsens when the river is non-perennial, seasonal in nature or small in scale. Non-perennial rivers are often considered a limited source of water; one that is renewed unpredictably. In an urban setting these rivers are often misinterpreted as drains. In the eyes of the city dwellers, the lack of volume of water flowing through them makes them generally less valuable and worthy of conservation than their perennial counterparts.

Waterfronts—An Urban Solution

A way to conserve urban rivers is through rejuvenating the flow of water and developing waterfronts that will connect people to the river. The value added by waterfronts can also help reverse decades of neglect urban water bodies have suffered.

With increasing environmental awareness seen in the last decade as a consequence of the pressure to upgrade urban areas, waterfronts are being rediscovered in the city. (Anand & Basak, 2020) The value of the river and other water bodies is being realised and several waterfront development projects have commenced in different cities. But so far, they appear focused more on being a means of generating economic benefit, that is, as real estate projects with the objective of sprucing up the city's image for recreational and commercial value, rather than as river restoration and revitalisation projects (SANDRP, 2014). These projects are being undertaken without due consideration of the social, environmental or ecological aspects. The ecological aspects are lost in the concretisation of the riparian zone, channelisation of river, etc.

[1] *NIUA (National Institute of Urban Affairs)*

[2] *NMCG (National Mission Clean Ganga)*

What is lacking is a holistic approach that considers ecological, recreational, social, aesthetic and economic aspects while keeping in mind the needs of context and people. Each water body has a unique, exclusive relationship with its people irrespective of its scale, and thus, one solution cannot cater to all aspects.

This paper aims at understanding the values provided by non-perennial rivers and rejuvenate the same by using an environmentally sensitive approach to developing eco-friendly riverfronts.

It addresses the following research questions:

- Why is there a need to conserve non-perennial urban rivers, what purpose do they serve? (macroscale)
- How can we develop a nature-based riverfront without compromising on the ecological aspects? (microscale)

Methodology

The study is carried out on two scales. At the macroscale it focuses on understanding the importance of non-perennial rivers and the need to conserve them, the value provided by such rivers and how the scale of a river and the city are interrelated in order to justify that smaller or non-perennial rivers are also worthy of conservation. At the microscale the research focuses on a neglected stretch of Kaliasot River in Bhopal, by attempting to understand the reasons for its neglect and proposing strategies and recommendations to rejuvenate it.

A qualitative approach based on case study analysis, literature reviews, primary surveys, interviews, etc. has been followed here.

Several techniques were incorporated in the data collection process, including secondary data sources from archival data for understanding the role and importance of non-–perennial rivers, as well as the evolution of a river with urbanisation. This was based on the understanding derived from studying literature in the form of relevant papers, journals, articles and guidelines from across the world. Several relevant case studies were analysed to understand, learn and identify best practices being followed in similar contexts.

For the primary data collection (conducted from January to March in the year 2021), field study tools included visual surveys, observations, site documentation through photographs, preparing field notes and activity mapping. The primary survey was based on a questionnaire that was prepared to get an insight on the perception of people about the river and their expectations from the water body. The questionnaire ensured a community-based approach, one that involved primary stakeholders from the initial stages. These were essential aspects in addressing the research questions of the study.

Literature Review

Non-perennial Urban Rivers

Rivers and streams that cease to flow at some point in time or space are referred to as non-perennial. Alternatively, the term non-perennial refers to streams and rivers that do not flow continuously and includes intermittent rivers and ephemeral streams. (Busch, et al., 2020) Such rivers are globally prevalent and hydrologically diverse, providing many ecosystem services such as agricultural and domestic water supply while sustaining the ecological integrity of river networks (Busch, et al., 2020; Stubbington, et al., 2020).

The characteristic of a non-perennial river include a temporary absence of surface flow, resulting in isolated pools or dry channels. (Busch, et al., 2020). By some estimates these rivers constitute 50 per cent of the total global river network length (Zipper, et al., 2021; Datry, et al., 2017).

With a continuous change in climates, anthropogenic activities such as construction of dams, altered land-use patterns and abstraction of water to meet human demands, the occurrence of non-perennial rivers is expected to increase in the future (Steward, Schiller, Tockner, Marshall, & Bunn, 2012).

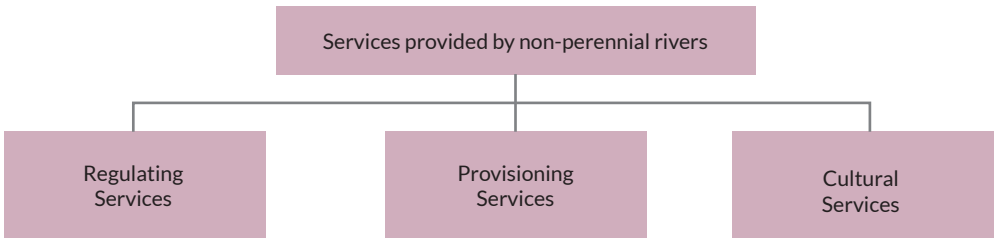
Such rivers usually undergo three phases over the course of a year – ponded, flowing and dry (Stubbington, et al., 2020). These three phases result in different habitats. Thus, ecosystems of non-perennial rivers create a diverse habitat mosaic—the shift in space and time between aquatic and terrestrial phases rendering an aquatic–terrestrial ecosystem.

Despite constituting 50 per cent of the total global river network length, non-perennial rivers are much neglected as a subject. Being undervalued by society threatens their restoration or protection as researchers and government policies are predominantly focused on perennial waters and biased towards larger rivers.

Value and Services Provided by Non-Perennial Rivers

Non-perennial rivers provide regulating, provisioning and cultural ecosystem services (Stubbington, et al., 2020).

Figure 1: Types of Services Provided by Non-perennial Rivers



Source: Adapted from Stubbington et al., 2020

Regulating ecosystem services include:

- Regulating the flow of water by mitigation of floods
- Regulating water quality by storing ground water
- Regulating erosion control
- Regulating the microclimate
- Regulating the water quality

Provisioning ecosystem services include:

- Provision of fresh water that is high quality subsurface water and ponded water
- Provision of livelihood by supporting fisheries, agriculture and livestock
- Provision for extracting sediments during the dry phase

Cultural Ecosystem services include:

- Recreational opportunities such as boating, fishing, walking, tourist hotspot, etc.
- Educational purpose as these ecosystems represent a research gap that creates interdisciplinary opportunities for researchers, stakeholders, and students to develop their knowledge and skills
- Spiritual connect and benefits depending on the region and local traditions

Non-perennial rivers, big or small, have a lot to offer in terms of ecological and socio-cultural value and are thus, worthy of conservation. Several studies (Stubbington, et al., 2020; Acuna, et al., 2014; Datry, et al., 2017) infer that non-perennial streams constitute a higher regional biodiversity compared to their perennial counterparts. It is necessary to understand their ecology as well as their character in order to bridge the huge gap in research regarding the same. Despite the numerous services provided by these rivers they are poorly understood and hardly considered as part of the water management system at all (Acuna, et al., 2014; Zipper, et al., 2021). In order to preserve the many valuable aspects recognised here, the identification, protection and conservation of non-perennial rivers should be incorporated into river management plans. Appropriate indicators should be developed for the continuous monitoring and assessment of the health of these ecotones. The health of the entire river network could be assessed based on the combined wet-dry-ponded phases of the river. Most importantly, non-perennial rivers must be incorporated into policy and legislation.

Background and Context

Kaliasot River

The Kaliasot is a non-perennial urban river in northern India. The river flowing from June to October is dry and ponded from November to May, lies in the Ganga River basin and is a tributary of the river Betwa. It originates in Bhopal, Madhya Pradesh and travels 29 km before joining the Betwa at Bhojpur, Madhya Pradesh. The catchment area of the Kaliasot in Bhopal district is 18.16 sq km covering 8.2 per cent of the total area of Betwa basin in the district (Ministry of Water Resources, 2013). In Bhopal, the Kaliasot flows from Kolar Road till Samardha village near Mandideep, Raisen, covering approximately 16 km. In different parts of its course, the river water is used only for irrigation; there is no water supply from the river in the entire stretch.

Figure 2: Map of Bhopal Locating Kaliasot River

Source: Block Map of Bhopal, District Geoportal – Bhopal (https://bhopal.nic.in/en/map-of-district/)

Historical Importance of Kaliasot River

According to folklore, also quoted by the historian and archaeologist W. Kincaid, when Raja Bhoj (reigned c.1010–1055 CE) of Malwa fell sick, a holy recluse prophesied that the raja's illness would be cured only when he constructed a lake fed by 365 streams or springs and bathed in it (Verma, 2001). A vast triangular valley, now known as Bhojpur, was identified as a feasible location and a cyclopean dam of massive scale was initiated to block the valley from all sides. It was to be fed by the headwaters of the river Betwa and its tributaries. So it was that a lake covering an area of 650 sq km (65000 ha), was constructed in a valley in the Vindhyan range. However, when finished, the lake was fed by only 356 springs and streams.

Kalia, a Gond chief, pointed out a river 32 km to the west of the lake. This river with its eight tributaries made up the requisite number that would cure the raja and consequently, it was turned 90 degrees from its course to feed the Betwa valley lake. The river was appropriately named Kaliasot or Kalia's river, a name that it carries to this day.

From the storage lake thus obtained, the Kaliasot River flowed at a right angle to its former course and became a valuable feeder, carrying its surplus waters into the larger lake for three full months after the rainy season had ended.

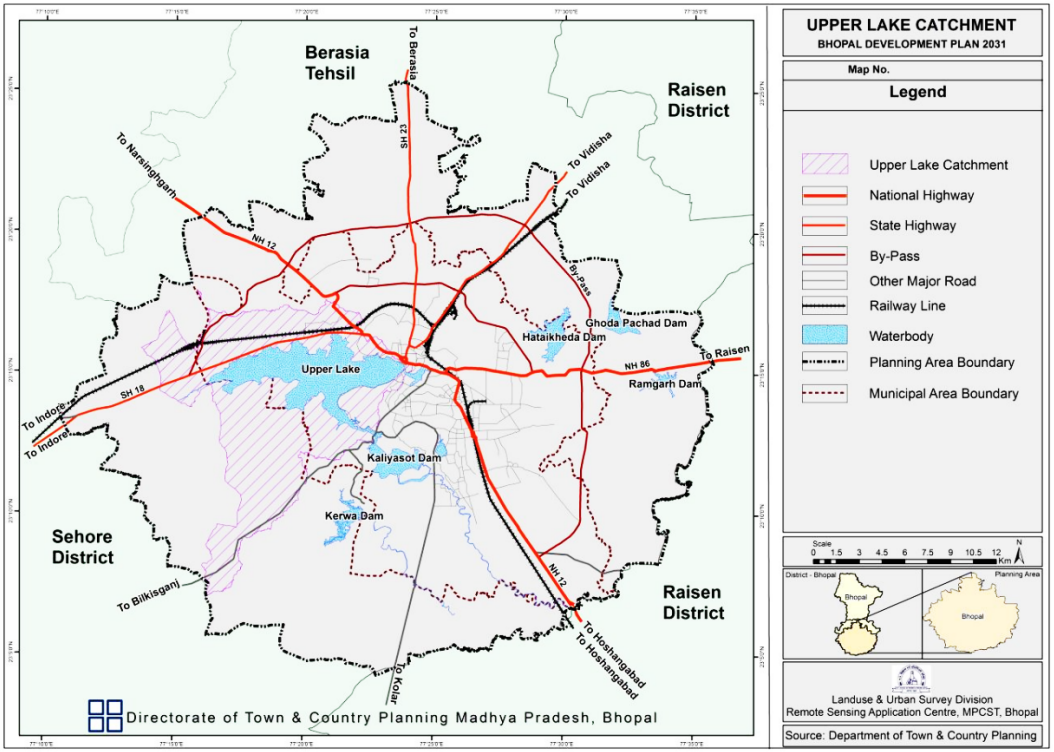
Later, in the early 15th century, the dam across the Betwa was destroyed by the armies of Hoshang Shah. The embankment at Bhopal is still preserved at Kamla Park and so is the lake, known now as Bhoj Tal or Upper Lake, but in a much-constricted size. In 1994, the Kaliasot Dam was constructed on the river for irrigation purposes, about three kilometres from its point of origin. Today, the river originates from Kaliasot Dam at Bhopal as overflow of the dam and flows south-east. The flow in the river from origin up to (river Betwa) Bhojpur is very meagre except for the monsoon season.

Bhopal—City of Lakes

Bhopal, the capital city of Madhya Pradesh, covers an area of 648.24 sq km with a population of 3,454,678 according to the census of 2011. It is also known as the 'city of lakes' because of numerous natural and artificial lakes that abound. The total area of water bodies, which includes lakes, rivers and streams constitutes 54.95 sq km, which is five per cent of the total planning area (Town and Country Planning, Madhya Pradesh, 2021). These water bodies majorly constitute lakes and water impoundments available in and around Bhopal, most of which are maintained and looked after. According to the Bhopal Development Plan – 2031 (draft), there are 18 such water bodies.

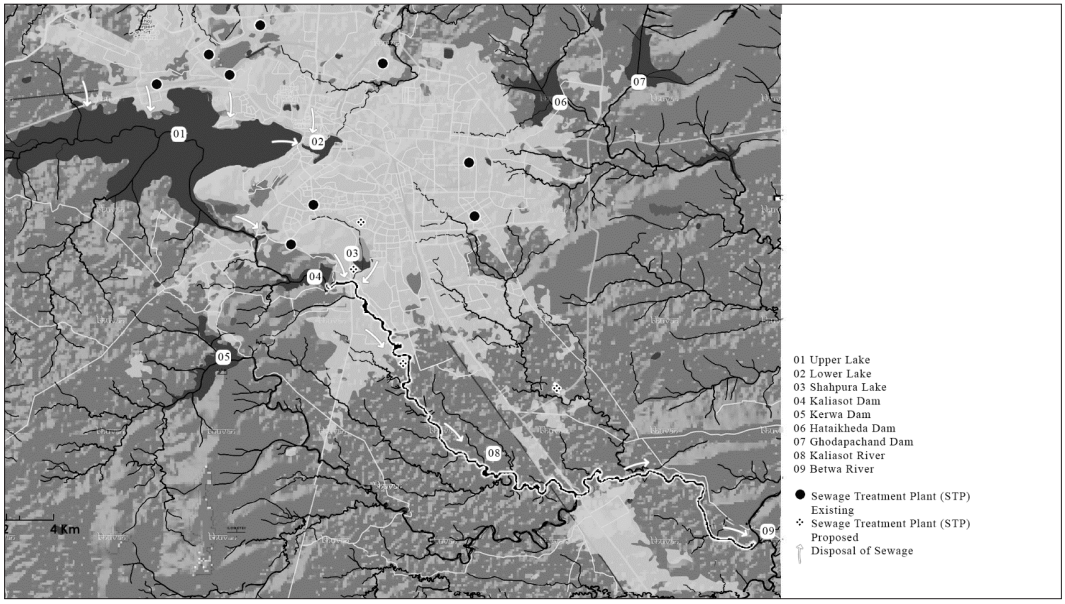
The major important water bodies are mostly lakes and dams—Upper Lake (Bhoj Tal), Lower Lake, Shahpura Lake, Kaliasot Dam, Hataikheda Dam—within the planning area of Bhopal. These water bodies are centres of recreational activity and a few of them also provide drinking water to the city. Kaliasot River and Halali River are tributaries of the Betwa that are non-perennial in nature. Of these, the Halali is outside the planning area.

Figure 3: Map Showing Water Bodies of Bhopal



Source: Bhopal Development Plan – 2031 (Draft), Volume I, Town and Country Planning, Madhya Pradesh, 2021

Figure 4: Map Showing Natural Water System—Rivers and Drains in Bhopal



Source: Bhuvan Image, accessed during March 2021

Natural Water and Drainage Systems

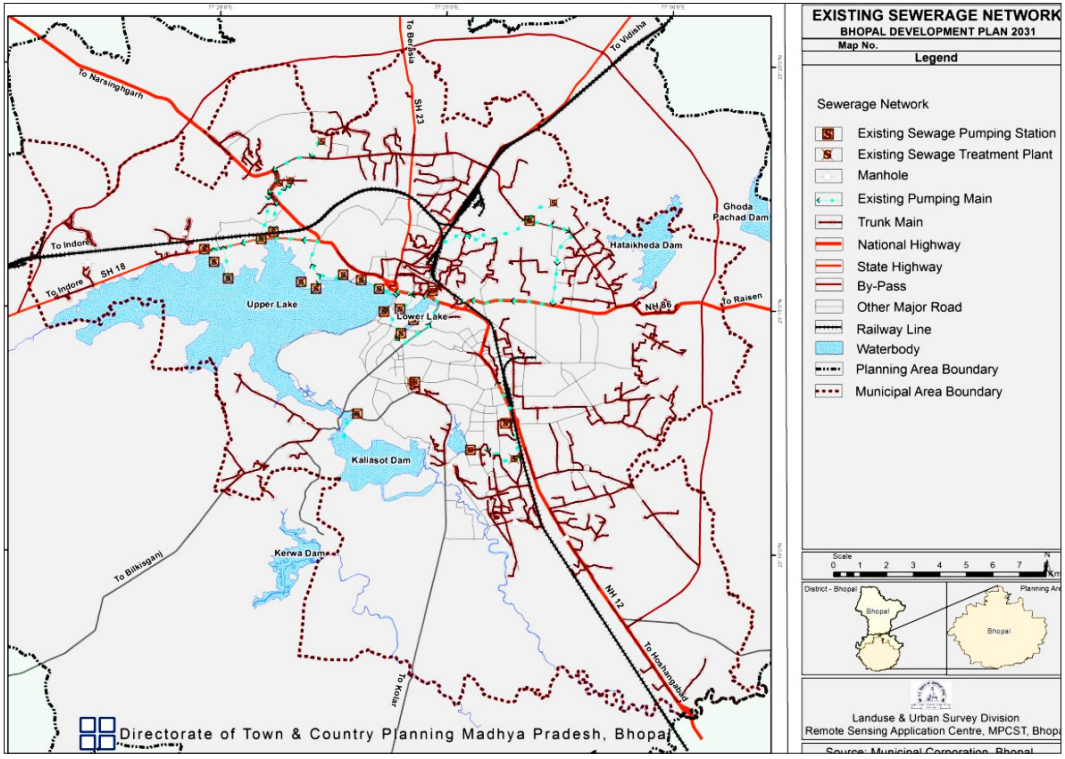
The topography of Bhopal is made up of hilly terrain, with the highest elevation at 640 m to the lowest at 420 m. Three major streams drain storm water from Bhopal. On the north-eastern side the drainage is carried by the river Halali and on the south-eastern side by the Kaliasot. Both these rivers drain into the Betwa River. During the monsoon, the Kaliasot carries surplus water from Kaliasot Dam, which is intercepted by Upper Lake or Bada Talab.

Pollution in Kaliasot River

In 2018 the Central Pollution Control Board (CPCB) identified 357 polluted river stretches in India that did not meet the water quality criteria. Madhya Pradesh ranked third with 22 polluted river stretches of which Kaliasot was one of them (Senapati, 2021).

Bhopal gets around 266 million litres (MLD) of water a day and generates 285 MLD of sewage, of which just 39 MLD is treated. Most of the sewage is discharged into the Upper Lake and drains, from where it eventually finds its way to the Betwa River through its tributaries, i.e. Kaliasot and Halali rivers (Ministry of Water Resources, 2013). A map of the existing sewage network (Town and Country Planning, Madhya Pradesh, 2021) published in the Bhopal Development Plan – 2031 (Draft), Volume I, clearly shows the absence of any treatment plant or sewage pumping station around Kaliasot River.

Figure 5: Map Showing Sewage Treatment Network in Bhopal



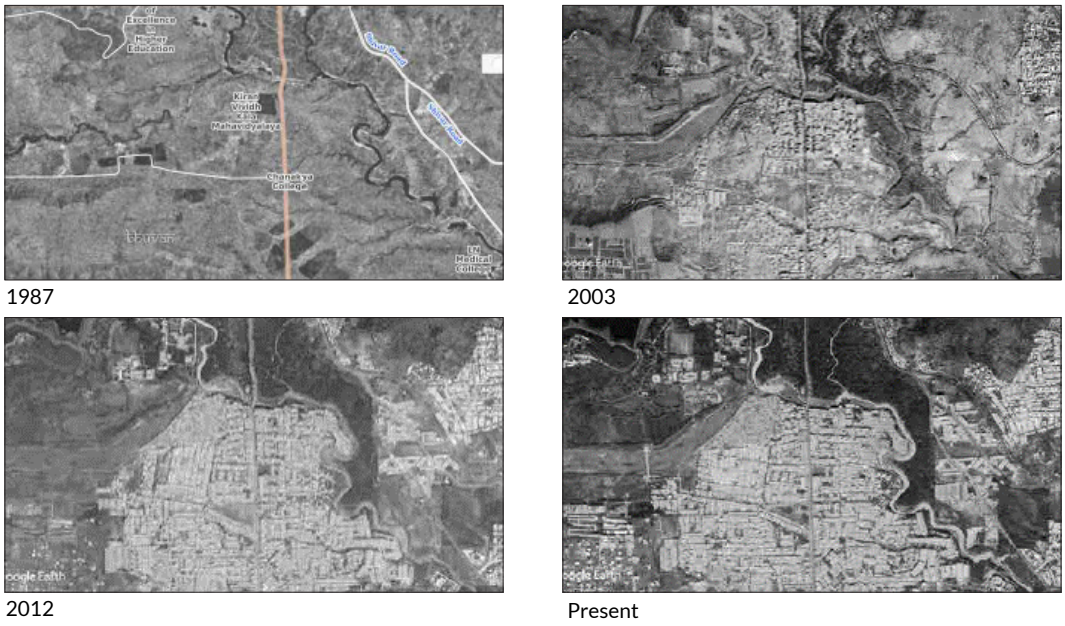
Source: Town and Country Planning, Madhya Pradesh, 2021, Bhopal Development Plan –2031 (Draft), Volume I

Apart from the major drains carrying sewage from Bhopal (Shahpura Lake spillage, Misrod and Mandideep regions) into the river, it is also subjected to domestic pollution as it receives sewage from the unplanned urban development around the river.

Water analysis carried out (M.P. Pollution Control Board, Bhopal, 2019) concludes that water quality that flows into the river falls in 'D' and 'E' categories throughout the year, except for the post-monsoon season when the quality upgrades to 'C' category. This infers that the water cannot be used for drinking or household purposes.

Administrative Boundaries and Kaliasot River

Figure 5: Urban Development Around Kaliasot River



1987 2003

2012 Present

Source: Google Earth Images, accessed during March 2021

Till 2014, the Kaliasot was seen as the natural edge of the new Bhopal development; therefore, initially it was not even in the planning area. Planning around the river was in the hands of governing bodies of gram panchayats with a very myopic vision. The Kolar municipality was included in the Bhopal Municipal Corporation area vide notification of state government on 20 November, 2014. Due to its location outside the planning area, the river was seen as a service water body that became a sink to drain the city's wastewater and sewage as mentioned earlier. As Bhopal expanded beyond its previous boundaries, the Kaliasot had already been subjected to unplanned development and urbanisation, especially along its edge.

According to the Bhopal Development Plan – 2031, Draft, (Town and Country Planning, Madhya Pradesh, 2021), Kaliasot River is identified as a landscape potential area for active recreation and conservation of water bodies and wildlife (birds and animal species). But this does not address the present condition of the river or how to revive it.

Study Area

The area of intervention is an approximate 2.5 km stretch of Kaliasot River, covering an area of 0.17 sq km (42.5 acre) and varies from 5 to 30 m in width across the site. The stretch is surrounded by unplanned urban development (Damkheda slums, Sarvadharam Colony, Sectors A and B till Mandakini Colony), predominantly residential housing on one side and a city forest (Swarna

Jayanti Park) sprawling over 2 sq km, on the other. As mentioned in the previous section, the study area was not inside the boundary of the planning area until 2014, thus, this urban development is accompanied by a lack of infrastructure facilities, proper sewage network, etc. This leads to discharge of solid waste, wastewater and faecal sludge into the existing water body.

Figure 6: Area of Intervention

Source: Google Earth Image, accessed in November 2020

The main purpose of selecting this stretch is to ensure that pollution is curbed right from the origin of the river and to ensure that what flows throughout the river is clean water. In the selected site, the river flows through a very contrasting landscape—on one side it is subjected to urbanisation, and on the other, there is a vast urban forest cover. The river can act as a bridge to connect the two and provide a place to coexist.

Data was collected through a primary survey (conducted from January to March in the year 2021). Field study tools included visual surveys, observation, site documentation through photographs, preparing field notes and activity mapping. A comprehensive questionnaire was prepared to gain an understanding of the perception people have about the Kaliasot River and their expectations from the water body. This questionnaire ensures a community-based approach, involving primary stakeholders from the initial stages. Several layers were documented and studied to understand the present situation, including – land use, open spaces, connectivity, accessibility, building heights, zoning, sewage infrastructure, income groups, activity mapping, etc. The data was analysed to understand the feasibility of developing an eco-friendly riverfront.

The strategic location of the site is an advantage as it provides rich biodiversity to the site throughout the year. Avian life found on the site was documented based on primary surveys and site visits to highlight the rivers ecological importance.

Birds listed included – Little Egret, Cattle Egret, White-browed Wagtail, Common Pigeon, Indian Peafowl, Laughing Dove, Rose-ringed Parakeet, Green Bee-eater, Common Tailorbird, Black-winged Stilt, Great Coucal, Pied Cuckoo, White-throated Kingfisher, Red-vented Bulbul, Jungle Babbler, Indian Silverbill, Purple Sunbird, Red-wattled Lapwing, Common Babbler, Water Hen, Sparrow, Double-crested Cormorant, Black-backed Forktail, Yellow-billed Magpie.

The presence of rich biodiversity on site is proof that non-perennial rivers also house rich biodiversity and need to be conserved to ensure ecological balance.

Factors Degrading the Kaliasot River

Based on primary surveys, site visits and observation, factors leading to the degradation of Kaliasot River were identified. These include:

- Untreated sewage discharge: A significant number of outfalls discharge untreated sewage along with storm water directly into the river, converting it into a polluted 'drain'.
- Solid waste disposal: Households nearby use the adjacent river as their dump yard and throw solid waste into it.
- Lack of accessibility: The river is not easily accessible. Along most of its length, the banks are lined by private properties. There are very few approach points, making the river inaccessible to citizens in general.
- Open defecation, bathing: The river is subject to pollution from anthropogenic activities such as defecation, bathing, washing clothes, etc.
- Lack of value, sense of belonging: Citizens are not sensitised towards the river, giving it the identity of a 'nala'.
- Flash floods: During heavy rains when Kaliasot Dam is filled to the brim, the sluice gates are opened to allow water through. At times, when all the gates are opened simultaneously, it results in flash flooding.
- Lack of governance.

Impact on the Kaliasot River

- Degradation of ecological value: Due to its non-perennial nature, the river acts as a wetland for most part of the year and is home to a variety of plants, birds, fish, etc. But, the insensitivity of residents towards the natural landscape, and the increase of pollutants in the river, make the water that flows through it during non-monsoon seasons incapable of supporting any aquatic life. This impacts the number of migratory birds that visit, etc.
- Erosion and loss of land: Flash floods lead to loss of land and property adjacent to the river.
- Danger to structures: Flash floods have rendered the structures prone to danger of collapsing.
- Unkempt and deserted: The river is underutilised and neglected. Over time, it has been transformed into a polluted drain that remains deserted and encourages illegal recreational activities.

Discussion

In addressing the issues, one solution to conserving Kaliasot River is by rejuvenating it and developing waterfronts that seek to connect people to the water and provide habitat for wildlife species, enabling them to coexist. The waterfronts are also essential to rectify decades of neglect, by adding value to the river through an ecological approach. The goal is to bridge the gap between the urban and ecological fabric through a series of large- and small-scale interventions that balance notions of site, context and ecology and so gain back its value.

Objectives and Strategies

Critical to addressing the issues identified in the previous section, objectives and strategies are formulated keeping in mind the social, economic and, most importantly, the ecological aspects.

Table 1: Objectives and Strategies for Development of an Eco-friendly Riverfront

	Issue	Objective	Strategies and Recommendations
1	Unkempt and deserted	Activate the river edges through multifunctional zones	1. Introduce different activities and programmes to engage the people. 2. Identify sustainable approaches for connecting people and river.
2	Degradation of ecological value	Preserve the ecology of the site	1. Document the existing flora, fauna and avian life present on the site. 2. Ensure sustainable practices are followed on the site. 3. Balance the interventions on site, ensuring ecology is given priority.
3	Untreated sewage discharge, solid waste disposal, open defecation, bathing	Curb the pollution and sewage flowing into the river	1. Increase the capacity of proposed STP and realign existing network. 2. Provide decentralised wastewater treatment plants for existing outfalls. 3. Incorporate treatment wetlands to ensure quality of water.
4	Danger to structures, erosion, loss of land (flash floods)	Minimise risk and impact of seasonal flooding on the neighbourhood	1. Build retaining wall or natural embankments along the residential edge. 2. Stabilise the embankment using soil bio-engineering. 3. Regulate the flow of water released from the dam.
5	Dry riverbed	Retain water in the river throughout the year through means of sustainable drainage systems	1. Retain water permanently by the means of: Engineered landforms Introducing check dams/nala bunds at regular intervals downstream 2. Maintain the flow of water through recycling wastewater.

	Issue	Objective	Strategies and Recommendations
6	Lack of accessibility	Enhance accessibility and connectivity	1. Create access points (entrance zones) to bring high footfall to the site and activate the river edges. 2. Draw up activity based zones that can have connections based on adjoining programme/activity. 3. Create visual nodes – junctions that provide a view of the river or river edge.
7	Lack of value, sense of belonging	Instil a sense of belonging and sensitise citizens about their roles and responsibility towards the river	1. Ensure community participation in the planning process. 2. Engage the locals into riverine ecosystem economic opportunities for their socio-economic upliftment and maintenance of the river. 3. Introduce awareness programmes for educating the locals about the ecological value of the river.
8	Lack of values, sense of belonging, degradation of ecological value, unkempt and deserted	Uplift the value of the river	1. Economic value: Engage slum dwellers with riverine ecosystem economic opportunities for their socio-economic upliftment and maintenance of the river. 2. Social value: Connect the river with the adjacent precincts to socially engage it with local settings as a part of their own space and social responsiveness. 3. Recreational value: Introduce active and passive recreational activities suitable for different age groups. Develop new, sustainable built forms for public recreation such as decks, watchtowers, trails, etc. Integrate the riverfront with existing recreational/ green spaces.

Proposal to Rejuvenate Kaliasot River

Water Treatment Strategy

The first problem that needs to be addressed before the design phase is the issue of water pollution. In order to improve water quality, this proposal suggests three water treatment strategies: wetland treatment, urban treatment, and household treatment.

Wetland Treatment proposed for the site caters to the sewage outfall from residential buildings along the river edge. It was observed during the primary survey that the sewage network proposed by the municipality does not include the Damkheda slums. Thus even after setting up a sewage network, waste from lower income groups will still fall into the river. The proposed wetland treatment plant will ensure that this wastewater and sewage acts as a resource. This

pilot treatment module will cater for 3000 individuals. The treatment involves a 4-step process: Settler (Septic tank); Anaerobic Baffle Reactor (ABR) + Anaerobic Filter (AF); Planted Gravel; and Polishing Pond.

Table 2: Calculations for Expected Wastewater Generation

No. Of Users	Rate Of Water Consumption (lpcd)	Total Water Consumption (L/Day)	Expected Wastewater Generation (L/Day)	Expected Wastewater Generation (Cum)
3000	135	405000	324000	324

Source: Authors' (calculations are based on Green Infrastructure published by the Centre for Science and Environment)

Table 3: Calculations for Area Required for Decentralised Wastewater Treatment Systems Module

DWWTs Module	Standard	Surface Area Required (Sq. m.)
Settler (Septic tank)	0.5 sqm/cum	162
ABR+AF	1.0 sq m/cu m	324
Planted Gravel	4.0 sq m/cu m	1296
Polishing Pond	1.2 sq m/cu m	388.8

Source: Authors' (calculations are based on Green Infrastructure published by the Centre for Science and Environment))

Once constructed, the proposed wetland will treat the effluents from the informal settlements and let the clean, treated water into the river. This water can also be used for landscaping purpose and in bio-toilets.

Urban Water Experience

An important characteristic of Kaliasot River is that it has meagre flow of water and, for most parts of the year, this flow is mainly sewage. In order to improve the water quality and ensure some flow of clean water throughout the year, several sustainable urban design elements can be introduced such as riparian buffers, floating wetlands, aeration fountains, retention basins (holding ponds), check dam (nala bund), swales/filter strips.

Riparian buffer: A 2.5-5 metre buffer on both sides of the water body will help in stabilisation of edges, providing habitat for semi-aquatic and terrestrial ecotone species, filter the run-off and act as buffer, etc.

Floating wetlands: These islands will clean the contaminated water and ensure clean water in the river. They will also build up a natural habitat for native species.

Holding ponds/waste stabilisation ponds/retention basins: Waste Stabilization Ponds (WSPs), often referred to as oxidation ponds, act as holding basins for secondary wastewater treatment where decomposition of organic matter takes place naturally. They also act as wetlands.

Aeration fountains: In several stretches the water is stagnant and is subjected to eutrophication. To avoid algae bloom and ensure sufficient levels of oxygen in the water, aeration fountains will be introduced to induce water currents and get the water circulating, thereby spreading oxygenated water and bringing oxygen starved water from the bottom to the surface.

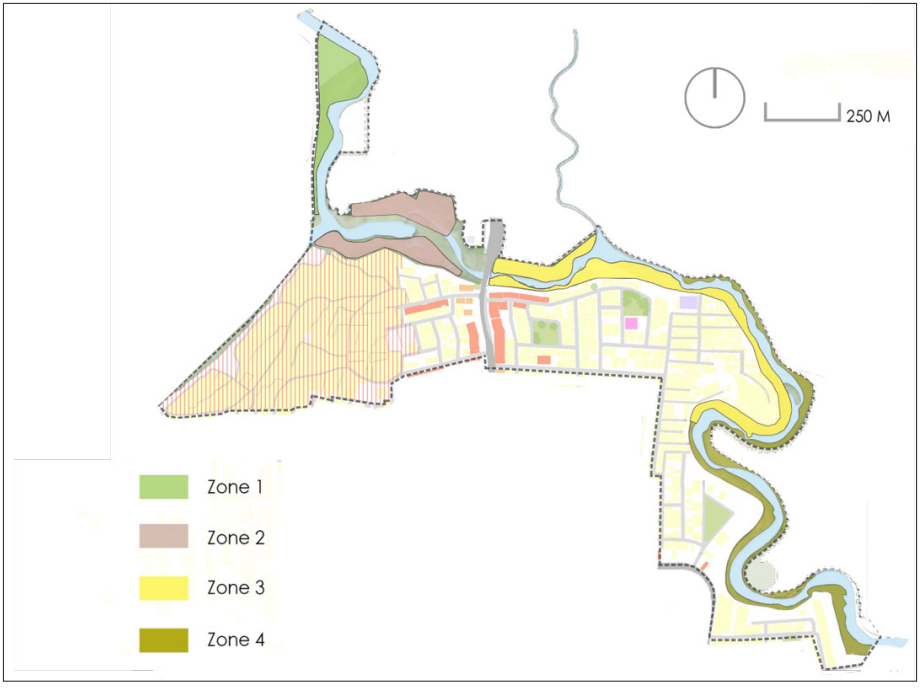
Nala bund/check dam: Small check dams, not more than a metre in height, can help retain water. In addition to providing habitat for aquatic life, this will also help in increasing aesthetic appeal.

Filter strips and swales: These will help in stormwater management, improve the ground water table and remove impurities from the water before it enters the river.

Rejuvenating the River and its Edges through Ecological, Socio-Economic and Recreational Values

The site can be divided predominantly into four zones based on topography, ecological value and strategic location to activate the edges of the river. Different activities and programmes could be introduced in each zone. The proposal will establish the site's identity as a public space and introduce a resilient, multi-layered recreational and social destination that connects its community to nature, the river and each other.

Figure 7: Site Zoning



Source: Authors

Zone 1 is proposed as the Ecologically Sensitive Area. This is the former course of the river, which is surrounded by forest and is home to native and migratory bird species. Passive recreation such as a pedestrian trail (permeable pathways) and resting points can be introduced in this area, while ensuring that the ecology of the place is not hampered. Decks and viewing points that encourage activities such as bird watching, along with awareness programmes can be introduced to educate the public about the river and bird life. This zone will serve as an opportunity to catalyse discussions on the ecological, recreational, and educational dynamics of the riverfront.

Zone 2 is the low lying, flat area, which could be anchored with different activities and functions for socio-economic and recreational values. The multipurpose space would act as an empty canvas that could be used for a series of recreation and socio-economic activities such as a recreational ground for outdoor games, fairs, weekly markets, exhibitions etc. A decentralised wastewater treatment system (constructed wetland system) of grey water for the informal settlement can be introduced across the river, to ensure a flow of clean, treated water into the river. The presence of a natural retention pond would act as a polishing pond for the DWTs. Its closeness to the informal settlement facilitates the introduction of bio-toilets, which will encourage safe sanitation. The treated water can also be used to irrigate the community gardens. This zone will provide valuable open space, protect and enhance the ecological systems and help elevate the socio-economic value of the river. In the social aspect, education and local culture are key tools to change not only communities but also the mentality that generated 'not my problem' responses to the increase in damage and neglect in the questionnaire.

Zone 3 is the recreational zone – spaces that would work as recreational pockets with movement corridors and neighbourhood green edges. This zone could incorporate trails and promenades to cater to recreational purposes—shaded viewing decks, look-out tower, boardwalk, entrance plazas, fishing area etc. are provided. These would ensure accessible and usable open space to all, with a balance of passive and active recreational opportunities within an environmentally enriched riverine setting for diverse ages and interests. This will foster recreational and aesthetic landscape experiences.

Zone 4 comprises the linear green edges that work as surfaces of visual interest to set the background. This zone is too narrow to introduce any anthropogenic activities. Thus, what could be introduced is a promenade along the embankment.

The proposal is low-maintenance, ecologically functional, and active. It will not only provide a recreational place for communities but also rebuild the ecological health of the river, leading to the recovery of biodiversity and native habitat around it. Eventually, it could become an attraction for the whole city of Bhopal.

Recommendations for an Eco-friendly Riverfront

Design and Construction Phase

- Construction
  - Use of natural materials such as stone, mud, mud bricks, lime, local species of timber and bamboo must be encouraged for construction activity. The use of cement should be kept to a minimum.
  - Surrounding natural physical features, habitats and biodiversity should not be disturbed during the construction process.

- Water Quality
  - Regulations must be put in place to ensure that untreated sewage is not allowed into the river.
  - STP network must be adequate and functioning.
  - Alternative sewage management systems should be evaluated and implemented. (Pilot testing must be done before implementation.)
  - All access points from which solid waste dumping into the river takes place must be identified and mapped, and appropriate design/planning solutions have to be suggested to prevent the same.
  - Water quality of the river must be maintained as per international/tropical standards (8PPM DO).

- Channelisation
  - River channelisation by increasing the depth of the riverbed at places will not only help retain water but avoid loss of land.
  - Channelising the river by engineering methods such as straightening and reinforcing the bed and banks must be strictly avoided.

- Retention Basin/Pond
  - Existing natural depressions must be preserved.
  - Soil bio-engineering techniques should be used to stabilise the edges of the basin/pond.
  - A riparian buffer should be maintained along the structure.

- Flood Control
  - A policy to stop further development on the banks of the river must be formulated.
  - All illegal debris dumped within river must be removed.
  - Retention/detention basins must be created along the river wherever sufficient space is available.

- Embankment and Slopes
  - A slope of 1:3 or 1:2 must be maintained to ensure stability of the slope.
  - Use of only sustainable, natural material should be encouraged.
  - Native species of plants should be selected for growing on site.

- Plant species must be suitable for the intended use and adapted to the site's climate and soil conditions.
- All installations should be maintained and inspected regularly, and provisions made for prompt repair if needed.
- Practices that must actively be discouraged include making of rock riprap, rock gabion etc.

Recreational Amenities

- The balance between recreational activities and ecology of the site has to be maintained.
- A balance between active and passive activities should be maintained.
- Recreational activities should respect the ecology of the site.
- No permanent structures should be built on the site that are not sustainable.
- No pollutants of any kind should be released through any recreational activity.

- Fishing
  - Fishing shall be permitted only after water quality and habitats are restored.
  - Fishing on site should be allowed for a limited time (monsoon period).
  - Walking/cycling pathways
  - Sustainable infrastructure should be used for enhancing recreational activities such as boardwalks, permeable pathways, viewing decks, etc.

- Nature trails, Birds/Insects/Flora walks
  - Restoration of the river ecosystem will boost the flora and fauna along the river. Thus, trails can be planned for studying plants, birds, insects, fishes etc.
  - Care must be taken to not disturb the hotspots while planning these trails.

- Multipurpose ground
  - Activities on the multipurpose ground such as weekly markets, fairs etc. must not disturb the ecology of the site.
  - A management committee should be set up to ensure that the site is maintained.
  - Cleaning of the site after an event must be the responsibility of the event organising party.

Socio-Economic Benefits

- Introducing awareness programmes to educate locals about the ecological value and local economic benefits from the river.
- Promoting a stewardship programme that encourages the coordinated participation of communities, government, organisations, stakeholders, and the private sector in rejuvenating Kaliasot River and in the riverfront development.
- Educating all involved parties, especially local communities on the sustainable development strategy for the river.
- Encouraging a sense of social responsibility among the locals to take care of the river in return of their economic benefits.
- Creating self-help groups to encourage women to come up with local economic benefits.

Conclusion

The paper attempts to understand through a review of literature the value of a non-perennial river and its importance in urban context. There was limited research on non-perennial rivers that could be found, especially in the Indian context. These rivers should be viewed as a separate type of water body from perennial rivers and lakes, and should be approached keeping in mind their limitations, the ecology they serve and services they provide.

An attempt was also made to study and analyse the different layers of Kaliasot River and to suggest recommendations to develop an eco-friendly riverfront. The proposal aims to be low-maintenance, ecologically functional and active. It aims not only to provide a recreational place for communities but also to rebuild the ecological health of the river leading to the recovery of biodiversity and native habitat around it, making it an attraction for the entire city of Bhopal.

Through an ecologically sensitive approach, the deteriorated urban river Kaliasot can be successfully transformed into a high-performance and low-maintenance front yard, which will retain water, clean contaminated water, provide public access to high quality open space, restore native habitats for biodiversity and attract residents and tourists. This waterfront can act as a catalyst in connecting the community to its context and sensitising them to become aware of the great potential this has for their future development, also stimulating a positive change towards the immediate environment.

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Conflict of Interest

The authors declares no conflict of interest.

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Traditional Water Systems of the Cultural Landscape of Govardhan, Mathura

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Abstract

The cultural landscape of Govardhan in Braj Bhoomi (a cultural region spanning Mathura, Bharatpur, and Hodal in India) is the legendary humble adobe of Lord Krishna. The area has a magnificent blend of nature and a cultural connect. Around 49 *kunds* can be found in and around a 21 km (7 *kos*[1]) *parikrama* of Govardhan. *Kunds* have always been a part of the people of Braj for ages. They provide essential services to the community as well as pilgrims, such as water for bathing, domestic use, cattle rearing, drinking purposes. They are a space for social gathering, performing religious rituals, and they provide protection from flood and water scarcity at the same time. This paper aims to highlight the traditional knowledge embedded in the design and construction of these water systems. The paper presents the documentation of the key architectural features and natural components of the *kunds*. They are part of the larger water system in Govardhan that used to provide sustenance for entire settlements in such semi-arid climates. For the protection and conservation of these water systems it is important to visualise *kunds* as a system of multiple elements coming together. The outcome of this research can help in guiding initiatives for future management and conservation of *kunds*.

Key Words: *Kunds*, Water Bodies, Traditional Knowledge Systems, Cultural Heritage, Water Systems, Braj

[1] *According to the Arthashastra, a kos is approximately 3000 metres or 1.8 miles.*

Introduction

Water has always been a central concern for humans. The history of water management can be found in ancient practices and community cultural traditions. Water is regarded as the source of life, and the elixir of eternity in Hindu mythology. The Atharva Veda (2.3.6) prays: "May the waters bring us well-being!" There are several similar explanations of water's purity, usage, sacredness, and symbolism. Water is considered to be a purifier in many religions. In mythology, water's ability to "wash away sins" is linked to the power of sanctity and cosmic meaning (Eliade, 1991). A sequence of consecrations, religious rituals such as pilgrimages and holy baths are required to reach the source and achieve the merit of "living water" (Singh, 1994). All traditions across the world have a special reverence for water, which has led to patronage of building and managing water bodies by communities (Mishra, 2011).

People have often settled along rivers, lakes, and coastlines to guarantee access to vital water resources. In arid to semi-arid regions, which face scarcity of water owing to the environmental conditions and highly varying rainfall patterns, those inhabiting these regions have developed several traditional techniques to harvest rainwater, that has proved to be sustainable over centuries (Ramineni & Bharadwaj, 2021).

Traditional water conservation and management techniques exist in every region of India. For instance, groundwater recharging has been practised traditionally in parts of Delhi, Gujarat, and Rajasthan as a result of low rainfall and extreme weather patterns. Water systems were developed specifically to store water in regions where run-off is relatively higher and more widely distributed. Traditional water management knowledge is based on different usage trends, the soil state of the field, the rainfall pattern of the city, and inter-surface soil fractures. Communities used to choose rainwater harvesting sites based on these characteristics by first planning an outline of anticipated rainwater run-off slopes or directions, and then building drainage outlets for the region's excess water to evacuate. The outlines, elongation, height, and breadth measurements were sketched out to elevate the barriers laterally opposing the water flow-in ditches. The material excavated was used to construct the fences. Hydro-experts preferred this approach because it was the easiest (Husain & Arif, 2014). These systems are still vital and functional in many places and are now under threat with the thrust of urbanisation. Traditional knowledge for water harvesting and management in various forms has developed in India based on various processes of the hydrological cycle, evaporation, condensation, rainfall, streamflow, physiography etc. Religious associations not only provided cultural significance but also long-term protection.

Depending on ecological differences, many trends of rainwater harvesting systems in India have been developed. The northwestern Himalayas make up India's high-land ecological zone, where rain harvesting systems like zings and *kuls* are often used. *Kuls* are small tanks used to collect melting glacial water, whereas zings are used to divert water from glaciers to settlements. India's arid ecological zone include3 the southwestern parts of the Haryana and Punjab states, the Kuchch peninsula, the western parts of Rajasthan, and the northern portion of Gujarat state's Kathiawar peninsula. Rainwater harvesting systems such as *kuis* and dakeriyan are used in the western part of Rajasthan. *Kuis* are subterranean 10-12 metre-deep tanks used for water storage.

Irrigation techniques such as *khadins/dhora* are also used in western Rajasthan. The northern plains, Gujarat, the central highlands, and the Deccan plateau make up the semi-arid ecological area, where *virdas*, which are shallow wells, is practised in low depressions. For groundwater recharge, other rainwater irrigation methods are used, such as *johad*, *baandh*, *nada* (Kavarana, n.d.). In this series of semi-arid traditional water systems, *kunds* are the source of sustenance for the people of Braj and are also symbols of religious significance (Saha et al., 2010).

The cultural landscape of Govardhan is a synthesis of cultural and ecological dimensions blended with a religious belief system. This entire cultural set-up is framed around the Govardhan hill, an elongated geographic natural feature, which changes its visual nature as climate changes. Other elements of this system comprise forests (*vans* and *upvans*) and gardens in small patches abutting water bodies, neighbouring settlements, and *kunds* around which the settlements grow and which feed the locals and pilgrims in the area, and the fertile land serving both as agricultural and grazing lands where human-nature interactions are manifest. The *parikrama* of Govardhan hill and Radha Kund is a sacred dynamic loop holding each of the above components together. Each of these elements is deeply connected, forming a singular system. For the early and childhood years of Krishna's legendary existence, Govardhan was a stage. The Vaishnavites anchored on the floor, designating particular sites for numerous incidents in the life of lord Krishna and creating the countryside from memory and religious scriptures where he performed many *leelas* etc. (Thakur, 2011), making it an associative cultural landscape.

This paper comprehensively documents the traditional water systems of Govardhan, Mathura, in Uttar Pradesh. It also shares some architecture, ecological and cultural practices to revive these water resources.

Research Methodology

This study was undertaken to understand and document the ecological and cultural aspects of water systems from the architectural to the regional level. The following methodology was followed:

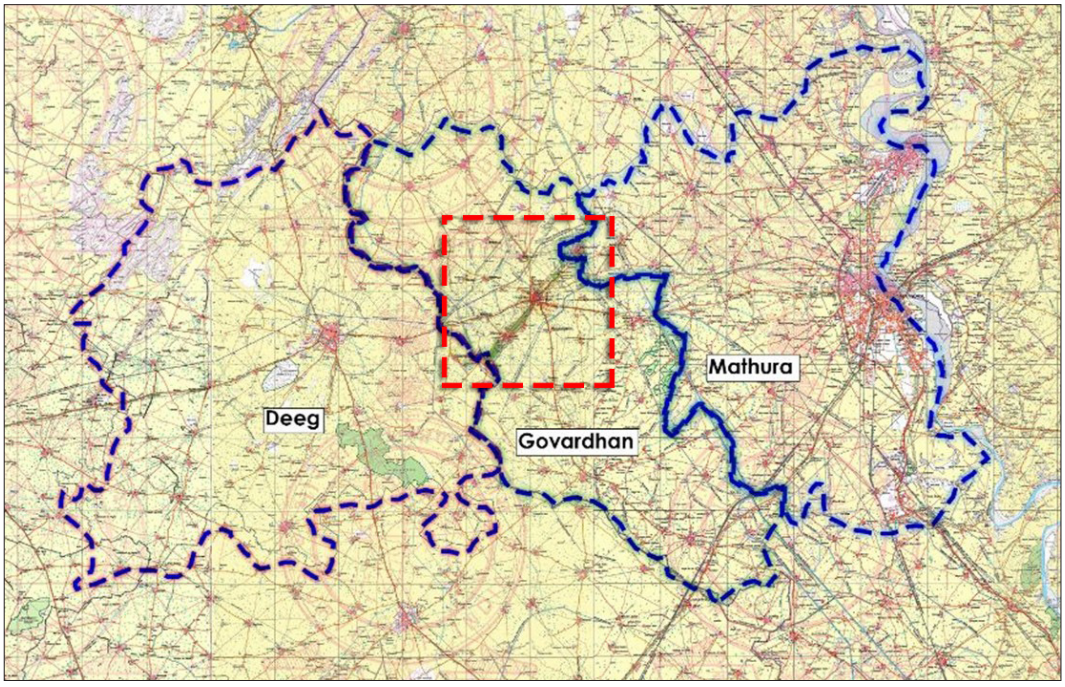
1. To understand the context of the study area, the research began with data collection and documentation of built and natural components. Primary and secondary surveys, as well as literature studies and interviews with various stakeholders have been used to acquire the necessary data for the study.
2. Mythological and cultural associations of *kunds* in terms of Govardhan, Braj, and the larger Krishna myths which also have a ritual based on significance were identified through religious texts and from primary data collection.
3. Based on the primary observation, scaled drawings were prepared by integrating site measurements with GIS mapping.
4. Assessment of the geographical character and watershed delineation was firstly done through secondary data collection using books and reports by the Central Ground Water Board (CGWB), the Ministry of Environment, Forest and Climate Change (MoEF&CC) etc., and using digital tools like GIS, Bhuvan etc. Then these gaps in data were identified and resolved by primary data collection and site visits.

5. Community-participatory traditional water management systems were developed over a period through local knowledge sources and by conducting interviews with community members and experts.
6. Along with this, the perspective through which *kunds* were observed and studied is broadly divided into three heads: architecture, water, and geography. *Kunds* were visualised as a system of multiple elements coming together—as trends observed on site, the conservation of built fabric is done extensively, but the ecological and cultural continuum of practices is not taken into consideration.

Study Area

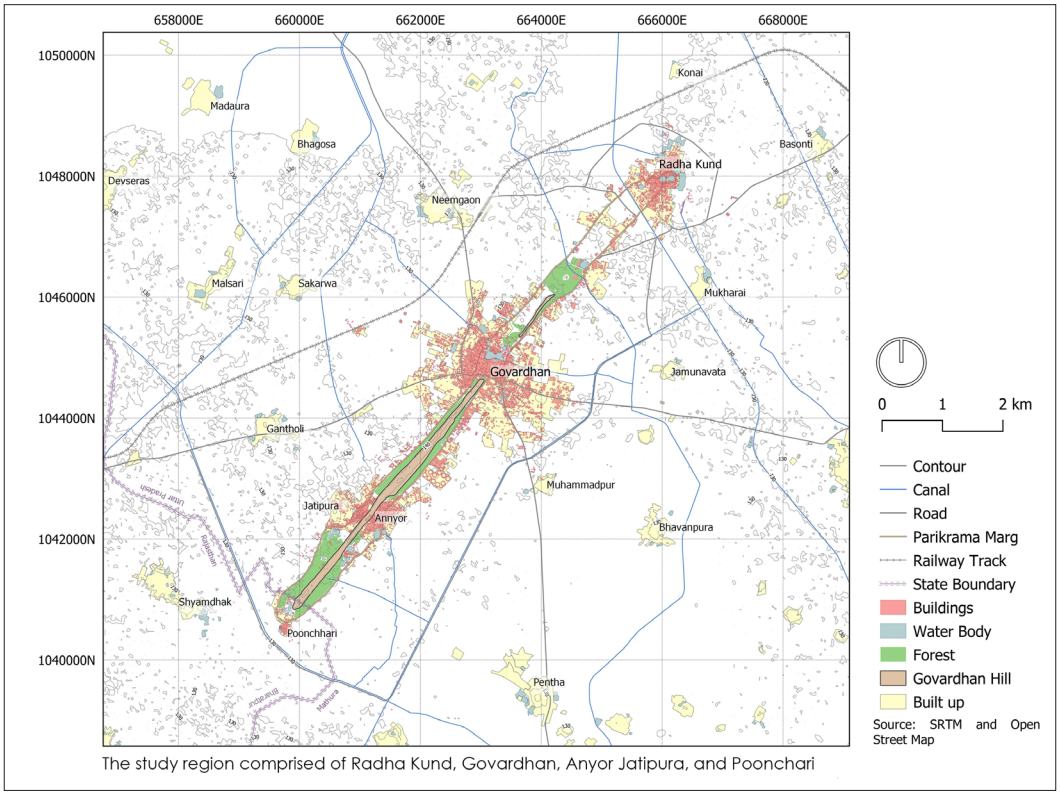
The cultural landscape of Govardhan sprawls around the Govardhan hill (also known as Giriraj Parvat) and Radha Kund, located in the Mathura district of Uttar Pradesh, and a small fraction in the Bharatpur district of Rajasthan. The study area is in the Govardhan and Mathura tehsil in Mathura district of U.P., and in the Deeg tehsil of Bharatpur district of Rajasthan (Figure 1). It comprises seven villages: Poonchari, Anyore, Jatipura, Sakitara, Govardhan Brahman, Govardhan Gorwan, Radha Kund Rural, Govardhan and Radha Kund Nagar Panchayat (Figure 2). Considering the census data, the area has a population of 46,000 (Census & Operations, Uttar Pradesh, 2011). However, being a prime centre for Lord Krishna worship, Govardhan is visited by approximately 1 crore (10 million) pilgrims annually (Udyoh Bandhu, n.d.). In order to sustain this footfall, there is always a need for water management for the residents as well as the visitors.

Figure 1: Study Area, Govardhan Tehsil of Uttar Pradesh and Deeg Tehsil of Rajasthan



Source: Survey of India. Modified by the authors

Figure 2: The Study Region: Seven Villages and Two Nagar Panchayats



Source: Space Shuttle Radar Topography (SRTM) and OpenStreetMap (OSM). Modified by the authors

The Govardhan hill and associated *kunds* are a natural built form, whose origins can be found in the mythological interpretations of the Vaishnavite legend, which is central to the Indic culture, where lord Krishna takes centrestage in his various forms as the protagonist. The mythic stories of the conflict between Indra and lord Krishna implored the people of Govardhan village to look towards spiritual means of worship, rather than the sacrificial or materiality of worship. The image of lord Krishna lifting this very hill with the tip of his finger to shield the villagers and animals from the wrath of Indra in the form of rain and lightning is of large significance in the Braj Mandal and the larger Indic culture.

The Ecological Context of Govardhan

Govardhan is a part of the western fringe of the Ganga alluvial plain. It lies in an older alluvium plain geomorphological unit. This unit is mainly characterised by yellow clay, kankar and reh. It is represented by alluvium plain, salt affected plain and waterlogged plain. Here the slopes are

very high and they mostly form run-off zones (Gupta, 2019). Govardhan lies in the Yamuna middle sub-basin and the slope of the land is towards the Yamuna from north to south and the southeast direction. Govardhan lies at an average height of 180 metres and the Yamuna at 150 metres. Many seasonal streams pass and originate from Govardhan, which eventually get connected to the Yamuna River.

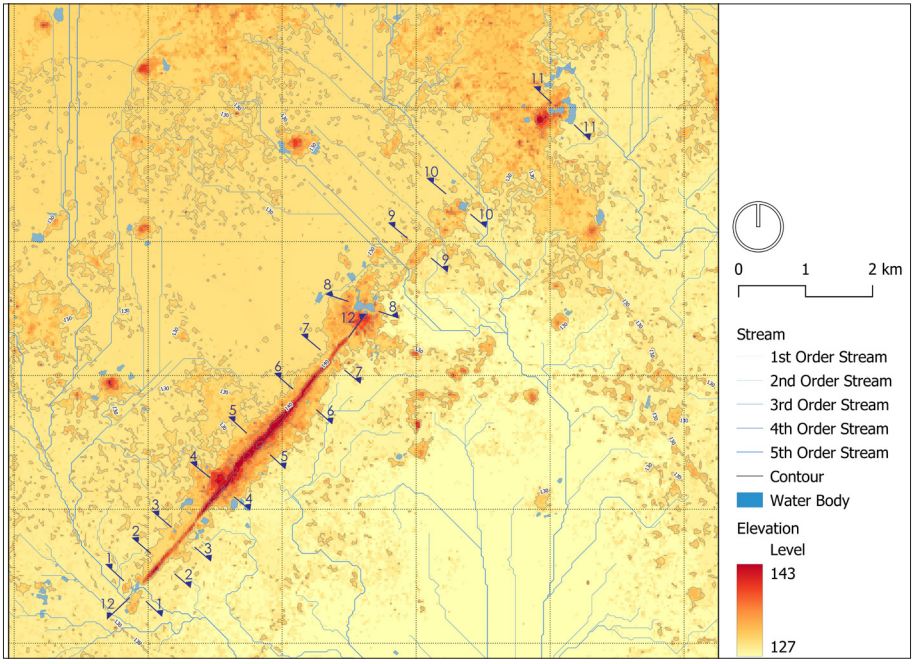
The study area lies at 27°27'22.0"N, 77°25'40.7"E to 27°31'56.7"N, 77°29'55.0"E. The Govardhan hill is a long, low ridge, of an ancient quartzite, part of the Aravalli mountain range (Figure 3) and is the largest in this region. It looks like a huge collection of small rocks due to the metamorphosis of the sandstone, and extends altogether for about 8.1 km (Figure 4), rising up to 30 m above the surrounding plain (Figure 5) (Sinha, 2015). The Aravalli, as a geological feature, is a rain-catcher, directing the rain-laden winds from the Western Ghats towards Govardhan, contributing more to its ecological, agricultural, and cultural ethos.

Undulating topography around the hill allows rainwater to get collected into natural depressions, resulting in ponds, lakes, and wetlands formation. These also act as natural groundwater recharge zones. These natural phenomena make this region suitable for water-centric cultural development and it has been so since ancient times, taking place in mythology and history as well.

Figure 3: Govardhan Hill Aerial View of the Southwest Tip

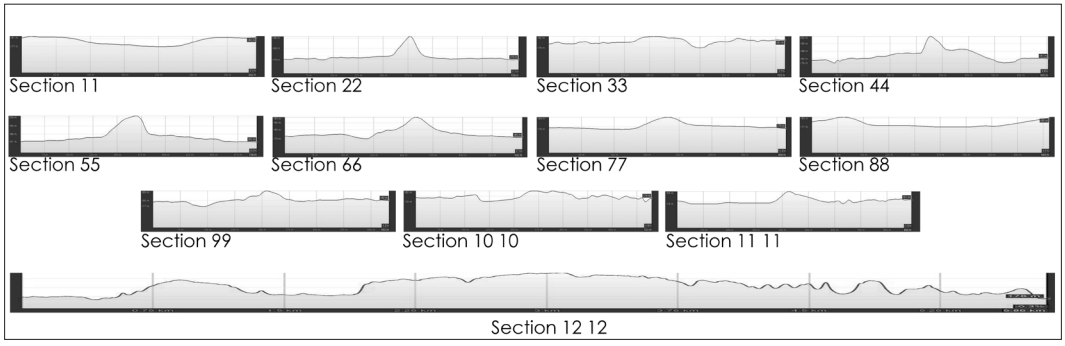
Source: https://youtu.be/iKHK1g13t1U

Figure 4: Elevation Map Govardhan Hill



Source: STRM and OSM. Modified by the authors

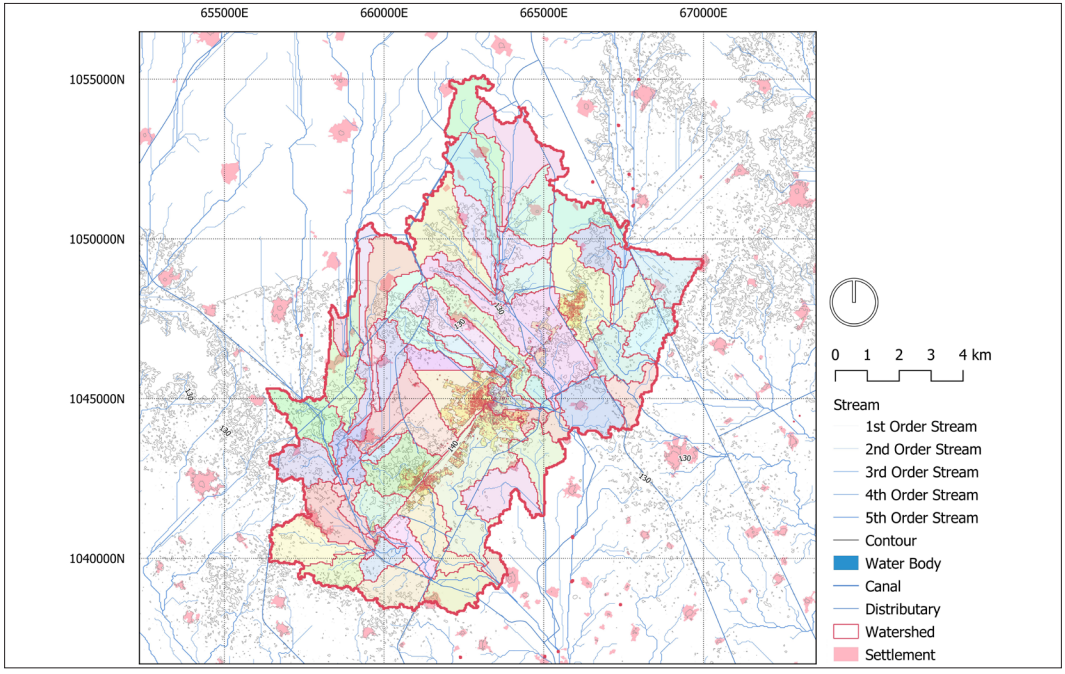
Figure 5: Sections of Govardhan



Source: Google Earth

Due to the natural alignment of the terrain, ample rainfall and the river system, the rainwater run-off is also directed towards the river Yamuna, which results in the formation of many seasonal streams and channels in these areas. With time, some of these streams are lined and converted into small canals (Gupta, 2019). It is observed that these channels also act as sources of water for many of the *kunds*. At times when water overflows from the *kunds*, specially during the rainy season, water gets released into these channels. Some *kunds* are not linked to any channel, and instead depend on much larger catchment areas. Many orders of streams are found in the catchment areas around the Govardhan hill, from where the surface run-off is carried to the *kunds*. The map below shows the unique interconnected system of water flow and collection (Figure 6).

Figure 6: Map Showing Watershed of Govardhan



Source: STRM and OSM. Modified by the authors

The Cultural Context of Govardhan

Govardhan is located in Braj Bhoomi which is the most significant centre of Krishna Bhakti and Vaishnavism. Braj culture is mostly a forest culture. Numerous transcendental lush groves and hills on both sides of the Yamuna are mentioned in the *Braj Bhakti Vilasa* (Gosvami, 2018). According to the *Shrimad Bhagavat Gita*, Braj is lord Krishna's birth and childhood place.

Govardhan is one of the most recognisable features in Krishna mythology, wherein Krishna lifts the hill to shield an entire village from the wrath of the rain god Indra (Entwistle, 1987). Braj, which has been interpreted in many forms, as in the Mathura Mandal (Figure 7) and in the shape of a lotus or the Braj-Kshetra (Figure 8), and Govardhan are believed to be in the very heart of the sacred land of Braj (Rana & Dubey, 1988).

Figure 7: Govardhan Location in Mathura/Braj Mandala

Source: Singh, Rana P.B. and Dubey, Devi Prasad, 1988, Mathura Mandala, Territory and Sacrality

Figure 8: Govardhan's Location, the Very Heart (Hrdaya) of the Sacred Land of Braj

Source: https://vrindavanactnow.com/maps/braja-mandal/

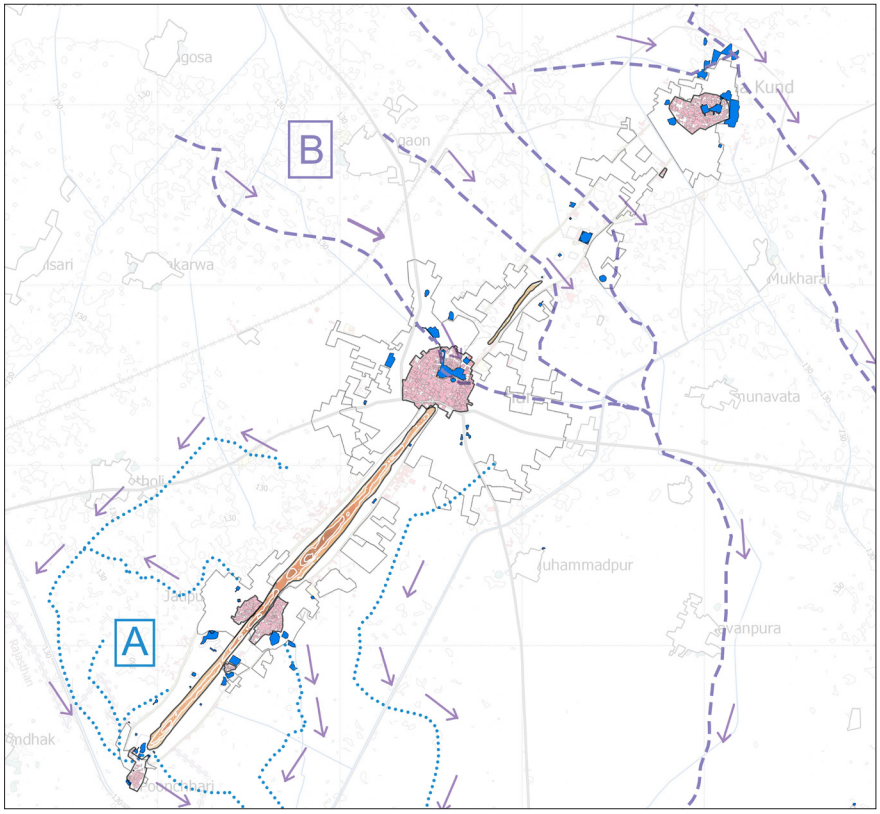
Traditional Water System

Traditional knowledge pertinent to *kunds* and ancient water management systems in Govardhan was tacit knowledge and had to be decoded from the existing architecture and practices. An understanding of this knowledge was developed as a result of the field survey and interviews with experts and residents of the place. Glimpses of this system have been prepared upon interpreting the collective consciousness of the people.

Macro Level

To understand and conserve these *kunds* an understanding of geography and gravity is required, and broadly, there are two types of streams in this area. Stream A represents the flow of water from the top of the hill, eventually forming smaller streams that flow away from the feature. Stream B represents the flow of the water from sources other than the hill, that flows through and around Govardhan (Figure 9). There are three major sources of water to feed the *kunds*, including water from the catchment areas, subterranean water, and canals or channels.

Figure 9: Types of Streams in Govardhan



Source: STRM and OSM. Modified by the authors

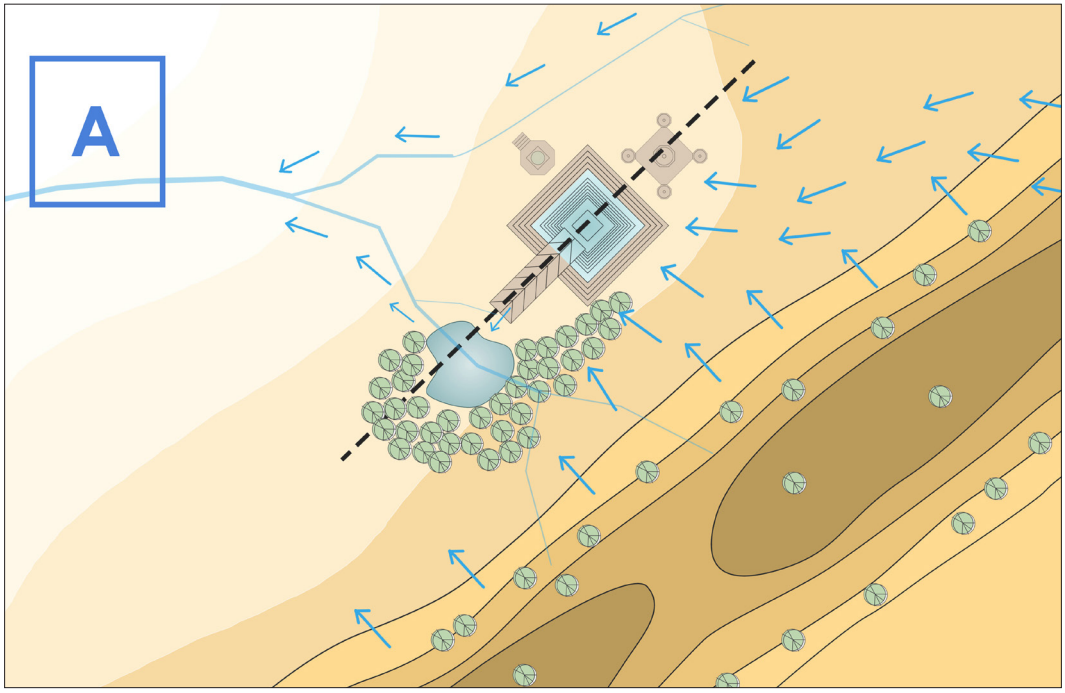
Meso Level

Based on the topography and nature of rainwater run-off, the design of the kund also changes. Two types of water systems have been developed, depending on the patterns of the stream flow.

Type A

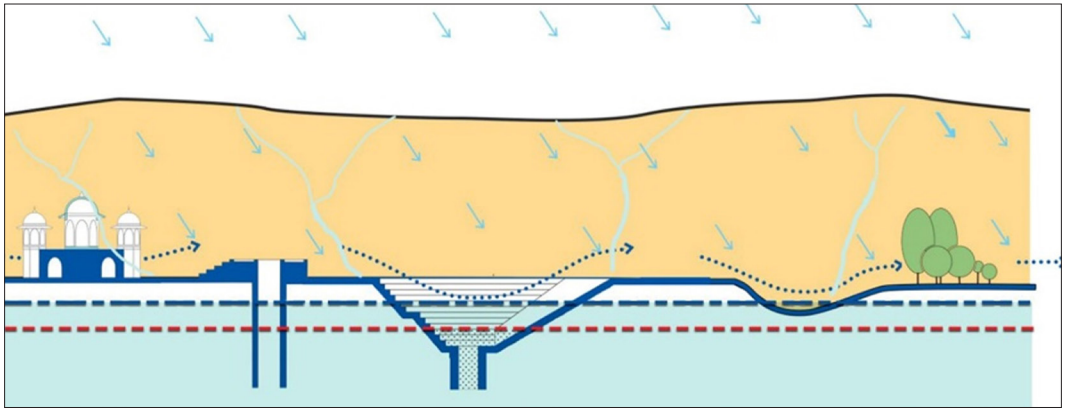
This type of water system is found in the *kunds* near higher terrain or built near the hill. A majority of these *kunds* are used for both religious as well as utility purposes, and also designed to facilitate ground water recharge (Figure 10). At the time of rainfall, water from the catchment gets collected in the *kunds*, leading to ground water recharge in this area. The water overflowing from these *kunds* exits to the *pokhar* towards a lower elevation. During the dry season when water level decreases in the *kunds*, the water quality deteriorates due to an increase in micro-organisms and silt deposits, making it appear slimy. As a security measure, the recharged water can then be extracted from wells adjacent to the kund, making it a critical component of these water systems. In Figure 11 the red dotted line represents the pre-monsoon underground water level while the blue line represents the post-monsoon level. Within the study area, the Apsra Kund, Naval Kund, Hariju Kund, Rudra Kund, Sankarshan Kund, Govind Kund represent this category of *kunds*.

Figure 10: Schematic Plan of Type A Stream Water System



Source: Authors

Figure 11: Schematic Section of Type A Stream Water System

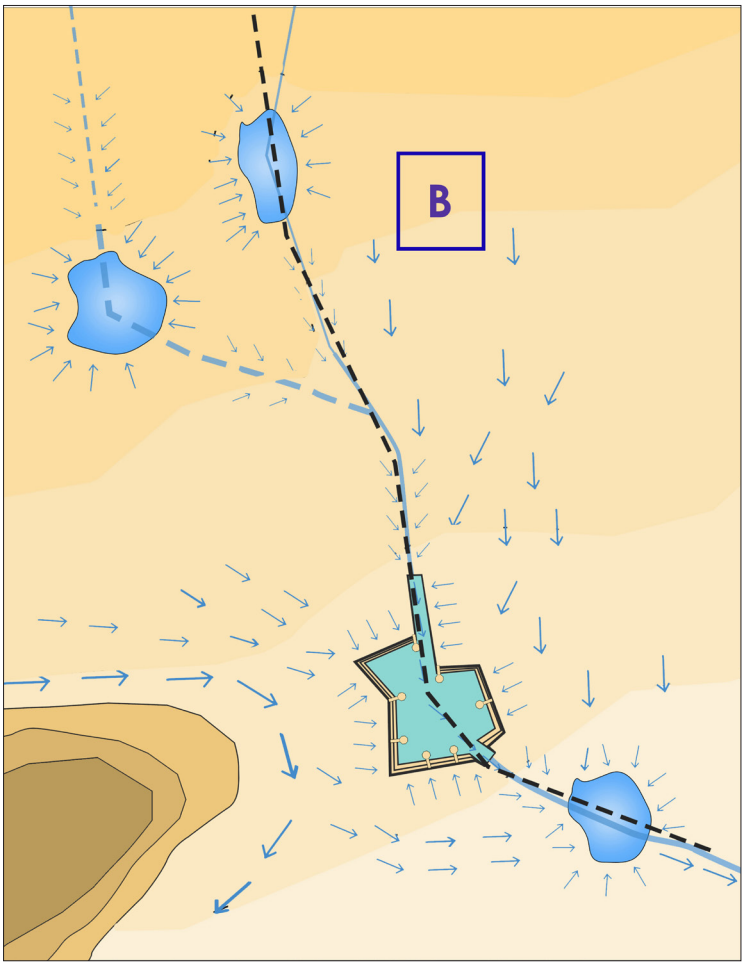


Source: Authors

Type B

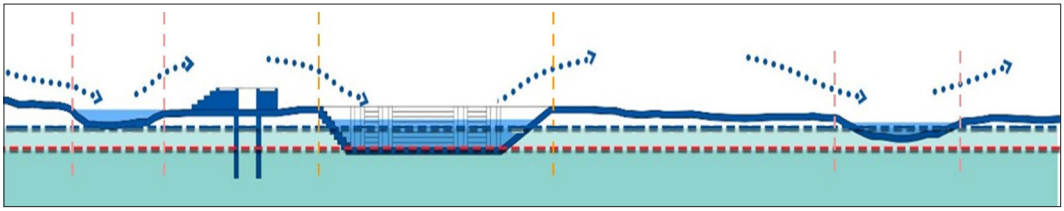
The water systems in the *kunds* which are away from the hill and spread along the Parikrama Marg till the Radha Kund are fed by the water streams formed on flatlands during rain, by canals and subterranean water. This particular type of system is mostly seen where post-rainfall rainwater gushes into the streams and channels that fill the *kunds*. The size of these water systems, in terms of the number of water bodies connected to each other, as well as the size of the *kunds*, is comparatively larger. Within the study area, rainwater collected in the water bodies situated on the northern offshore of Govardhan flows towards the *kunds*. The water further flows towards lower areas on the southern side. This creates an interconnected network of water bodies within the area (Figures 12 & 13). Radha Kund, Kusum Sarovar, Narad Kund, Uddhav Kund, Mansi Ganga and Ratna Kund are of this type.

Figure 12: Schematic Plan of Type B Stream Water System



Source: Authors

Figure 13: Schematic Section of Type B Stream Water System

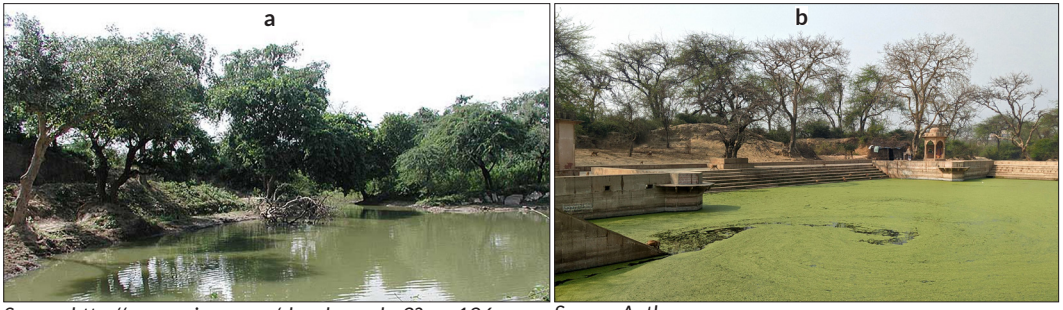


Source: Authors

Micro Level

Each water system is composed of a number of different kinds of *kunds*, connected to each other through the existing channels. Even within a system, these *kunds* vary in terms of their usage and size, which practically determine their architectural design. As its definition states, a kund is a stepped tank of a particular architectural design and can also be looked at as an expression of a cultural landscape. In Govardhan, *kunds* are like architectural elements designed in balance with nature, which not only allow human interaction with ecology but also act as an interface to connect with the Divine (Figures 14 &15). *Kunds* also facilitate essential community services like provision of drinking water, rainwater harvesting and flood control. *Kunds* have played an essential role in the growth of settlements since the Vedic era, resulting in their inclusion in the mythical Vaishnavite narrative that took form in the 15th century.

Figure 14: (a) Saurabhi Kund in its Natural State; (b) Saurabhi Kund Post Building Ghat

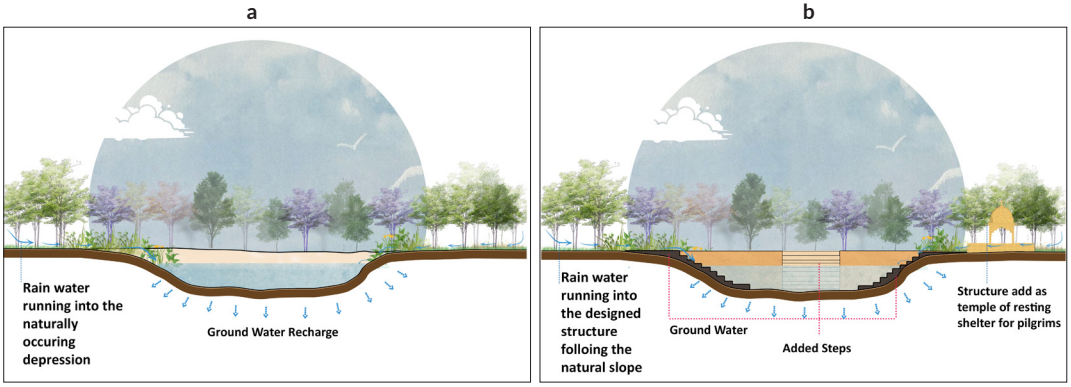


Source: http://www.vaisnava.cz/clanek_en.php3?no=186 *Source: Author*

Over the years, *kunds* have proven essential for the sustenance of living systems of the towns, making their place in the architectural vocabulary of the Mughal, Rajput and Jat eras of the region, and becoming instigators of artistic and creative forms of expression (Entwistle, 1987). The location of *kunds* around the Govardhan hill and parikrama, indicates their direct association with the mythological and religious practices.

Being an essential component of the social infrastructure, these have become places of social gathering and interaction among the local and pilgrim communities. With their multiple built and unbuilt components, *kunds* have become an integral part of the ecosystem. They create an environment that has an equilibrium, and a stage for a unique ecological setting for flora, fauna, and human growth.

Figure 15: Typical Kund Design Approaches Adopted in the Region

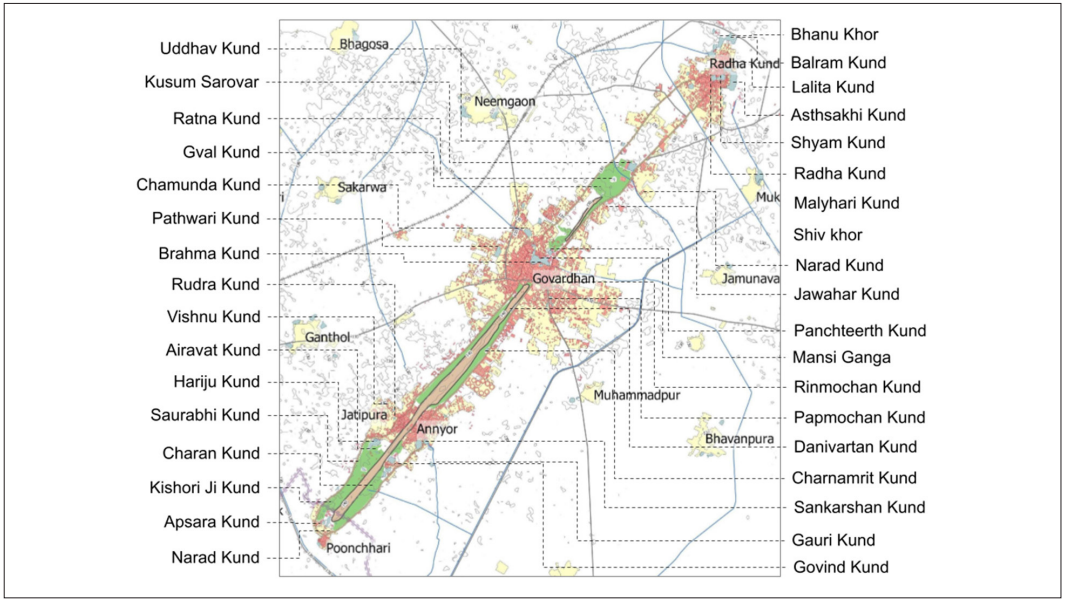


Note: (a) In a natural setting where rainwater is getting collected into the depression, with naturally occurring flora and fauna. (b) Designed architectural elements creating space for human interaction with the ecosystem.

Source: Authors

The extensive use of these *kunds* over ages reflects their religious, social, and infrastructural significance in sustaining the population, cultural relationships, and artistic imagery within the Govardhan region. At present, there are around 49 *kunds* of different shapes and sizes, in and around the 7 kos (mile) or 21 km parikrama of the Govardhan hill and Radha Kund (Figure 16).

Figure 16: *Kunds* Sprawled in the Cultural Landscape of Govardhan



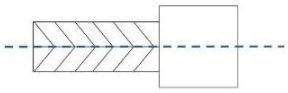
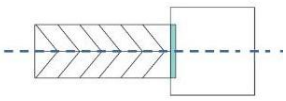
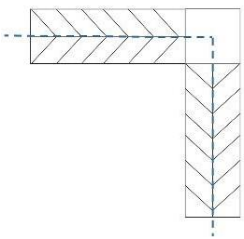
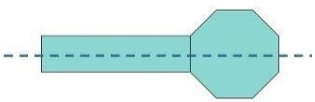
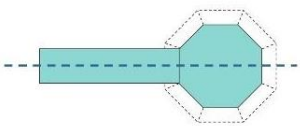
Source: STRM and OSM. Redrawn by the authors

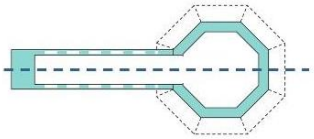
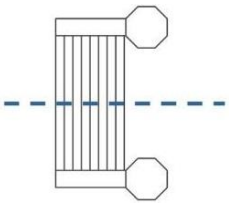
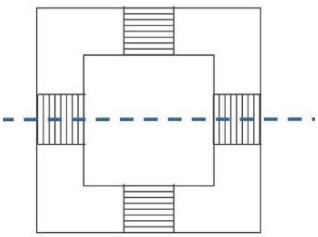
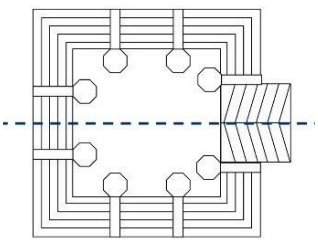
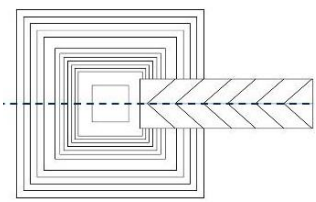
Identified Architectural Component of Kunds

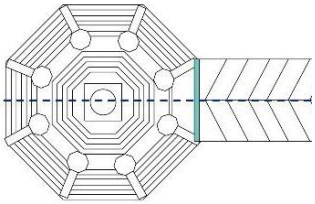
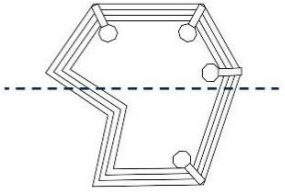
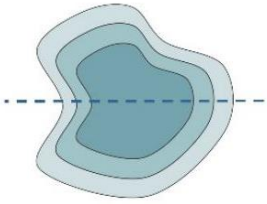
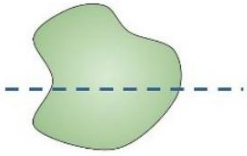
These *kunds* are built out of red sandstone and locally backed lakhori bricks, which are abundantly available in the adjoining areas of Rajasthan. Some of the tanks are built using boulders all around. They are generally used for drinking, bathing, and cattle use.

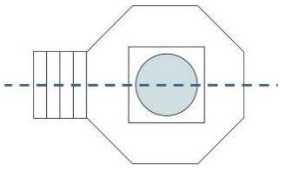
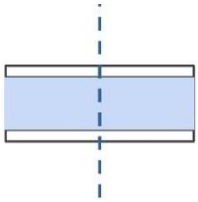
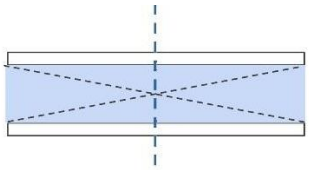
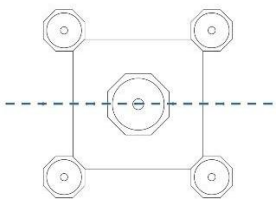
The different components found in the *kunds* of Govardhan along with their schematic, are detailed out in the table below.

Table 1: Architectural Components of *Kunds*

Component	Schematic Drawing	Description
Ghat and Burj are the key components of any *kund*.		
Gau Ghat Type 1		It is an architectural element in *kunds*, which is used by cows and other animals to access water. Its design depends on the depth of the kund. Majorly three types of *Gau ghat* design are seen in Govardhan, primarily depending on the depth of water: (1) where the depth of water and bed is comparatively less, (2) where the depth of water and bed is enough for drowning, (3) where the depth of water and bed is large, but access to the depth of water is also required. The most common material found in the design of this component is sandstone framing with lime mortar and bricks.
Gau Ghat Type 2		
Gau Ghat Type 3		
Burj Type 1		This is constructed with bricks and sandstone, is comparatively smaller in size, and is the most common type of burj.
Burj Type 2		This is larger in size when compared to Type 1, and provides more space on top of the surface for use.

Component	Schematic Drawing	Description
Ghat and Burj are the key components of any *kund*.		
Burj Type 3		This is the most ornate design among all three, with a number of structural considerations for access within the burj itself, making it a unique form in the architecture of *kunds*.
Ghat Type 1		This is a common design of a ghat, which is easily accessible by anyone, and is constructed with two burjs on either side.
Ghat Type 2		This is a different design of a ghat with an edge developed on all sides, and is filled with brick and lime concrete.
Ghat Type 3		This is lined all around the kund, providing structural integrity within the system. The burjs are interspersed through the horizontal stretch, creating one single kund.
Ghat Type 4		This follows the same principle as the above ghat, however on an irregular polygon shaped kund. It follows the natural edge of a kund, without changing its natural form, on which the construction is done.

Component	Schematic Drawing	Description
Ghat and Burj are the key components of any *kund*.		
Ghat Type 5		This type of ghat is designed on the principle of a simple well, with a lot of depth. It depends on the underground water sources and water from natural aquifers, rather than on rainfall or water percolation from the surface. The architectural detail, material used and design is like other ghats, except that it has much greater depth. Most of the *kunds* in the proximity of Govardhan hill are of this type.
Ghat Type 6		
Kaccha Ghat		These are manually dug ghats, with no specified built edges, and usually constructed in brick or stone.
Pokhar		These are naturally dug depressions, developed in and around the ghats. The overflowing water from the ghats goes into the *pokhars*, which essentially act like overflow sluices.

Component	Schematic Drawing	Description
Ghat and Burj are the key components of any *kund*.		
Well		These are commonly found across Govardhan. They act as a security measure for the *kunds* with degrading water quality. In such cases the wells are used to get water.
Canal		Artificially built by man, these are used to feed water into the *kunds* and *pokhars*. Most of the canals are open in nature, carrying water across the region.
Culvert		Culverts are commonly found, either in between a pokhar and a kund, or sometimes between two *kunds* for exchanging or levelling of water to ensure equitable distribution.
Chattri		These are found in various *kunds* of Govardhan. They act as a shelter for the people using them. These are usually constructed with bricks, lime concrete, and sandstone, and are composed of arcuated structural systems.

Source: Authors

Kunds are an important part of the socio-cultural fabric of Govardhan, and essential for the local communities and pilgrims visiting the area. Activities such as bathing, religious rituals, social and religious gatherings, domestic usage of water, washing etc. are heavily dependent on the local *kunds*. They also play a significant role in the social fabric of any place, by becoming catalysts for communication and recreation, on serving as activity spaces in a locality.

Discussion

During this research, an attempt was made to comprehend and document Govardhan's traditional water systems. The *kunds* of Govardhan are an important part of the ecological setting of the Yamuna basin. Govardhan itself is offshore of the Aravalli ranges, making it a significant setting

for restoring the crucial balance between nature and settlements. These *kunds* are a part of the larger water system in Govardhan, and have been serving as an essential component for sustaining large settlements, especially in such semi-arid climates. They are a part of the mythic narratives of Braj and Govardhan, as an archetypal setting of imagined cultural landscapes. *Kunds* are also integrated in the routes of cultural and religious *parikramas* and ensure their continuum. These systems help in the sustenance of a large number of people, flora and fauna, and their associated living systems.

However, the rapid urban sprawl and encroachment in present times is reducing the size of these water bodies and disrupting the natural interconnected network of water flow. Catchment areas used to be covered with sacred groves or vans, that are an integral part of the ecosystem, but are now vanishing, causing soil erosion during rainfall. This causes a large quantity of silt, mud, and pollutants to get deposited on the surface of the kund, further reducing the ground water percolation and rendering these water bodies unsuitable for use. When it comes to development and restoration of the urban water bodies, the traditional techniques are usually not followed, and non-scientific approaches are adopted around these sacred and ecologically sensitive sites. As a result, the symbiotic relation between heritage, the ecosystem, and community has been completely disrupted. The *kunds* were once part of the open space system of the town, but now their degradation is heavily impacting their function as a community space.

Conclusion

Water resources are an essential part of our ecosystem. By protecting this system, we are addressing a serious concern, which is adequate availability of good quality water. Traditional knowledge of designing these water systems is helpful in the design and revival of *kunds* and other traditional water systems. In the case of Govardhan, the topography of the landscape is such that it allows rainwater to be captured in shallow depressions with large catchment areas. Religious association with these water bodies has led to multiple initiatives for their improvement. It has also led to architectural developments. To further utilise these water bodies, *kunds* were built all around the *parikrama* of Govardhan. They have been serving the water requirement of the local residents and pilgrims for generations, and have also played a key role in development of the cultural landscape of Govardhan. Regular protection and proper management are required to keep the water free from pollutants and ensure adequate quantity of water, which is essential to maintain the ecosystem balance. These structures also served as rainwater recharge zones. They have evolved using the age-old wisdom and knowledge of geography, developed over hundreds of years. The *kunds* are a significant built component of the landscape, as they are a signature of an enduring, rooted, and culturally thriving environment, and are also in confluence with the natural environment.

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Conflict of Interest

Authors have no conflict of interest to declare.

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The Changing Paradigm of Urban Riverfronts: The Role of Rivers in Mitigation of Urban Heat Island Effect and Climate Change – A Case Study of Delhi

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Abstract

Human settlements have always been strongly linked to and evolved around rivers. Ancient civilisations such as Egyptian, Mesopotamian etc. all flourished near rivers. But today, due to anthropogenic activities, rivers are drying and moving towards extinction. It is very important to identify the crucial role of rivers in sustaining the well-being of humans as well as other biodiversities. The study aims to examine the role of rivers in the urban environment and to propose a prototype for an effective riverfront that maintains a balance in the ecosystem. This has been done by addressing the challenges which urban rivers endure, and suggest aids in reducing the effects of 'Urban Heat Islands' (UHI) in cities in general, and in the study area in particular. At present, cities along the Ganga basin are in a dilapidated stage and unorganised, which attracts climate vulnerability. UHI is one of the causes for increasing the demand for artificial cooling and discourages the culture of local interaction. The present study will focus on creating or restoring a riverfront that promotes a 'social connection' between the river and built-up interface and evaluates the ecosystem benefits. The proposal shows that the model has potential for creating value of approximately INR 60 crore in the initial two plus years. This study will help the city administration and government to take proactive steps in future and save mankind from the ill effects of climate change.

Key words: Land Surface Temperature (LST), Ecosystem Valuation, Urban Heat Island (UHI) Effect, Climate Change, Riverfront Development (RFD)

Introduction

Human beings as part of a large community are but a small part of the ecosystem in a biome which in turn is a part of the largest biosphere that helps in maintaining ecological balance. Rivers being a vital part of the ecosystem sustain millions of lives that help in maintaining the ecological balance. The river connects the culture, livelihood, environment, economy to the people and creates value. This case study has been done to understand the relationship between the changing river course of the Yamuna with the dynamic city of Delhi and its people by addressing the challenges which urban rivers endure and to propose a prototype for an effective riverfront.

There are many challenges that rivers are facing today due to urbanisation. Due to activities such as deforestation, dumping industrial waste, sewage waste into rivers, river pollution, diverting the river water or obstructing its flow by building various barriers, the overall ecological balance has been affected leading to the drying up of rivers and their moving towards extinction. The growth of cities near rivers with the fast pace of urbanisation has put immense pressure on limited natural resources like land, forests, rivers etc. The continuous depletion of resources has outpaced the regenerative capacity which has disturbed the natural healing process of nature and is leading to the phenomenon of climate change. As a result, the fast-changing land cover due to urbanisation is responsible for the 'urban heat island' effect. The riparian zone along the rivers is part of floodplains that acts as a buffer between city and river by storing excess water during flood situations and maintaining the ground water level. This is slowly being encroached upon by development activities leading to disasters.

The study by Sharma & Dikshit (2016) states that changes in the use of land such as replacing the pervious layer with an impervious layer have a direct impact on the overall carbon sink. Another study by Voogt and Oke (2003) has studied UHI relative to its size in terms of population in a city. This study gives us the relationship between the changing land cover and carbon sink which is an important factor in the discussion of climate change. Also, the land use and land cover change (LULCC) is associated with increasing population and the UHI effect. The present study is done in the context of Delhi and it forecasts a scenario where Delhi's developing populace and changing landscape is probably going to encounter a higher UHI impact. Another study in the context of Delhi by Mohan M., Kikegawa Y., Gurjar B., and Bhati S. (2013) observed that the dampness present on the green cover surfaces has a lower temperature, indicating the role played by healthy green vegetation in balancing the temperature. It also observed that the open regions (without trees) have less distinction among ambient and skin temperature because of the absence of impenetrable and canopy layers (trees) which is closely identified with LULCC, and is responsible for unbalancing the ecosystem. The implications of anthropogenic activities are economically very serious. This has led to the extinction of many bio-diversities and placed many others in the critically endangered category.

Climatic impacts have more harmful results, for example, restructuring of ecological systems, inhibited growth of creatures and plants, expansion in pandemic like situations, increase in human medical problems, and so forth, as per the study by Veena, Parammasivam and Venkatesh (2020). It was also noted that variations in a population's age structure can indeed lead to economic growth potential, especially when the working-age population (15 to 64 years) is larger than the non-working-age population. It refers to the ongoing population growth, as well as the trend toward increasing savings and investment, which can help drive the creation of additional goods and services using non-renewable energy sources (in developing nations where clean technologies are not readily available). The use of non-renewable sources for energy further exemplifies the climate change phenomenon. If rivers disappear or degrade, the dependent population will lose its cultural identity and way of life resulting in alienation, loss of livelihood opportunities, loss of biodiversity, leading to economic and environmental implications. The environmental implications are larger and will result in the extinction of biodiversity, ecosystem services, and at later stages human beings themselves. The revival of rivers will help in reimagining the urban river and re-establishing its social, economic, cultural, environmental connection to its people. The benefits will help in re-acquainting environmental loss which in turn will help in reviving rivers and realising economic potential through ecosystem services.

In the present context of Delhi on the Yamuna bank, the observations made by Sharma and Kansal (2011) have shown that 100 per cent divergence of the Yamuna River for water purposes in Delhi leads to a declining groundwater table. This decreasing discharge of groundwater has a substantial impact in the long term on agriculture, biodiversity, soil fertility, water flow, water volume, river pollution and the overall ecosystem. The divergence of water also has effects on the Albedo with the overall energy balance being disturbed. With disturbance in the water cycle and land use cover, the city is experiencing the UHI effect. A study by Masson-Delmotte,V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.) (2018), found that globally there is an overall increase in temperature by 1-2 degrees. Other observations concerning the heat index of Delhi specifically, indicate immediate danger throughout the late spring (March-June) and rainstorm (July-September) seasons since 2016 according to the study by Somvanshi A. (2019). The latter also shows the relationship between increasing air pollution and increasing temperature. The study has additionally presumed that this factor has necessitated raising power interest by 1,856 GWh over the base power necessity of the city with a relating expansion in CO2 discharges by 1.52 million tons. The study also emphasises increasing human deaths resulting from the soaring heat index killing thousands of people every year.

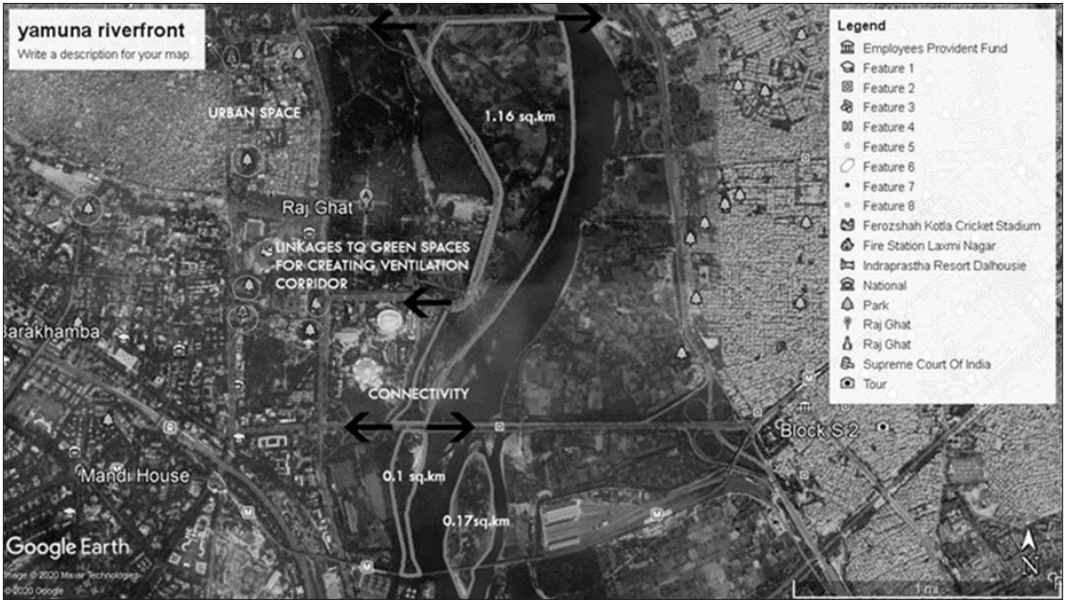
In the present context, the research was carried out with the help of satellite data to study the changing river course and urbanisation trend over 30 years to identify the urban heat island effect. Also, the data has helped in establishing the connection between increasing built-up activity with decreasing green cover and other LULC over the years, which has immensely helped in designing a prototype for ecological riverfront development. The analysis has brought clarity to the issue regarding mitigation efforts needed in this direction. The present study will help in identifying the reasons for a shrinking river and detached riverfront and proposing a design which caters

to the challenges of the urban heat island effect in cities and climate change in the long term. The prototype addresses the river's waning condition by addressing aesthetic (city identity), social, climatic, economic, and environmental challenges by creating spaces for social connection, addressing climatic aspects with the creation of a ventilation corridor, addressing environmental aspects with various design approaches that add value to the ecosystem and generate economic value, and achieving an effective riverfront development. This research and design will provide policymakers with a paradigm study for effective riverfront development from an ecological standpoint.

Site Context and Background

The Yamuna River is the largest tributary of the Ganges River. It is also considered a sacred river in India. The source of the Yamuna is located at an average elevation of about 6,387 meters above sea level in the Uttarkashi region, starting from the Yamunotri glacier near the summit of Bander Punch in the Mussourie mountains at the bottom of the Himalayas. The main tributaries of this river are Tons, Betwa, Chambal, Ken and Sindh, which together account for 70.9 per cent of the basin area, and the remaining 29.1 per cent constitutes the direct drainage of the main river and smaller tributaries. Depending on the region, the Yamuna River Basin accounts for 40.2 per cent of the Ganges River Basin and 10.7 per cent of the country as per the study by Sharma and Kansal (2011). During the 1,370 kilometre journey from Yamunotri (birthplace) to the sea, the Delhi section of the Yamuna River occupies only 22 kilometres. Although it only represents 2 per cent of the length of the basin, it contributes more than 80 per cent to the pollutant load of the entire stretch of the river as per the study by the Delhi Urban Art Commission (DUAC, 2015).

Figure 1: Study Area Site for Yamuna Riverfront



Source: Google Earth (Access date 28-10-2020)

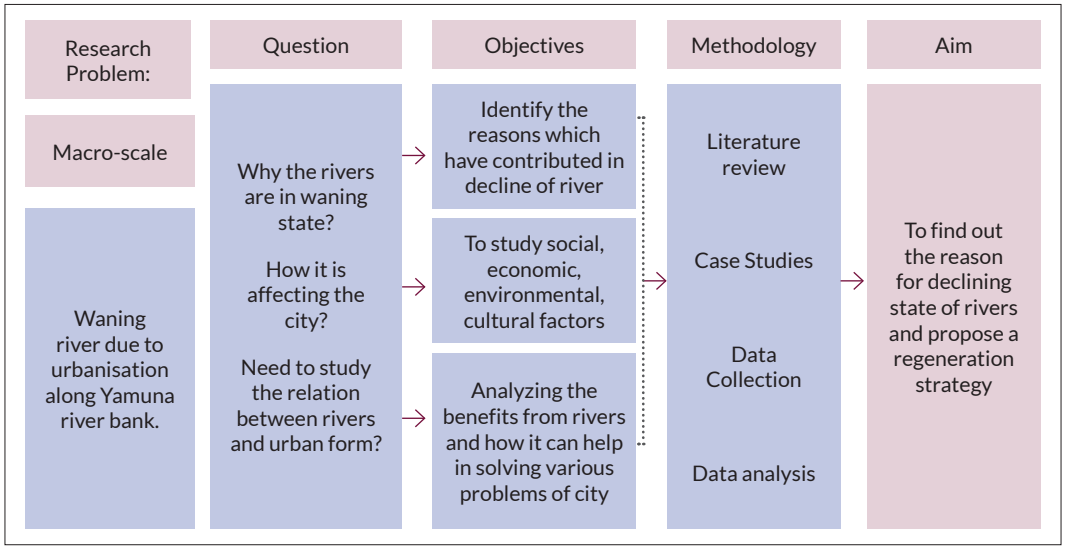
The site is already under proposal for Yamuna riverfront development by Delhi Development Authority (DDA). However, it does not address the concerns of the UHI Effect and the role the river can play in reducing it by establishing a social connection culturally through the positioning of green spaces. This can be done by connecting it with a proposed ventilation corridor which will result in environmental benefits and subsequent economic benefits. The economic benefits will help in the self-sustainable riverfront development model in the long term and the positive environmental impact will help in restoring the degraded ecosystem due to anthropogenic activities. This study will help policymakers with the paradigm case study for effective riverfront development from an ecological approach. These factors were missing in various proposals given till now for Yamuna riverfront development. The present context has potential for creating a ventilation corridor and also has heritage value (Feroz Shah Kotla and Khooni Darwaza) lying in the close proximity to selected site which will help in creating an identity for the riverfront. The agricultural land in existing patch of the site can be useful in creating value for the environment. Lastly, evaluating the addition of green spaces through economic appraisal will create value for ecosystem services that will help government, policymakers in understanding the ecological approach benefits from the economic angle. Further, the replication of the model will create awareness among people and more people participation will make this sustainable model a community project.

Study Methodology

The research was carried out at two scales: macro and micro. At the macro level, the research problem was focused on understanding the shrinking condition of the river and various other factors responsible for causing it in the context of the river covering the entire Delhi region. At the micro scale, it addressed the forgotten and detached riverbank by proposing a regenerative strategy covering a radius of about 5 km (area of 25 sq. km) from the site as shown in Figure 2. After analysis through various primary and secondary studies, an effective riverfront prototype was proposed specifically to this context.

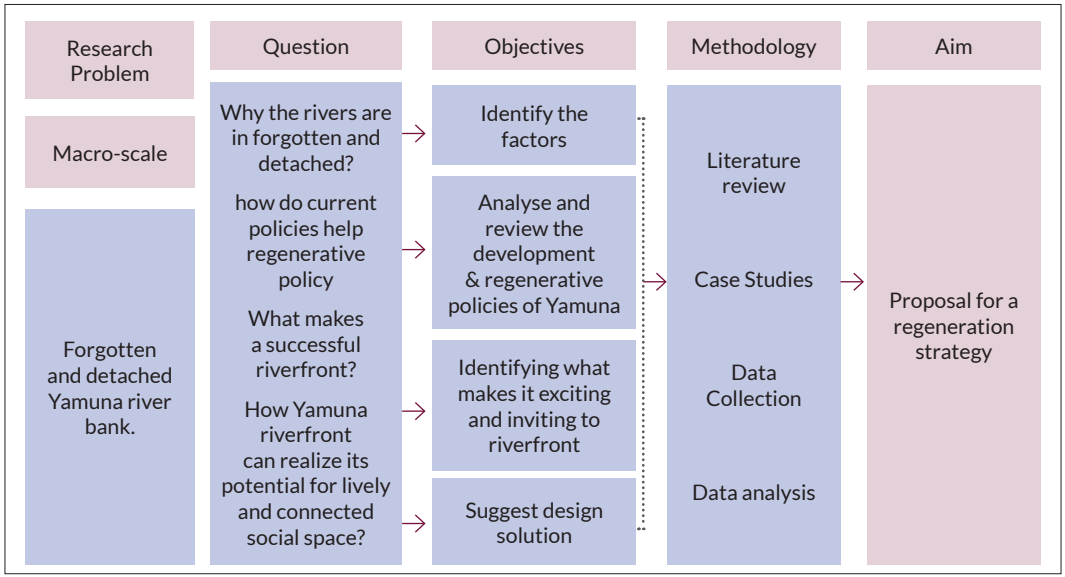
To understand the scenario at the macro level, the satellite images were used for analysing the land cover change, preparation of land surface temperature maps and detecting UHI and overall change of temperature across different land use, flood mapping, Normalised Difference Vegetation Index (NDVI), Normalised Difference Built-up Index (NDBI) maps, etc. To perform analysis at the micro scale, formal and informal surveys were conducted, site analysis was done, a land use map was prepared, and analysis like computational fluid dynamics was observed for this location as shown in Figure 3. The secondary data over the years for different places in Delhi was collected, which included statistics for air pollution, heatwaves, the number of deaths due to air pollution, flooding history, energy consumption and its relation to UHI, identifying the wind corridors near rivers and their effects in reducing UHI effect, the contribution of vegetation in the context of ecology and economy, and other data specific for the Delhi region. This data has immensely helped in building a prototype ecological riverfront addressing the context-specific challenges of the study area.

Figure 2: Macroscale Research Analysis



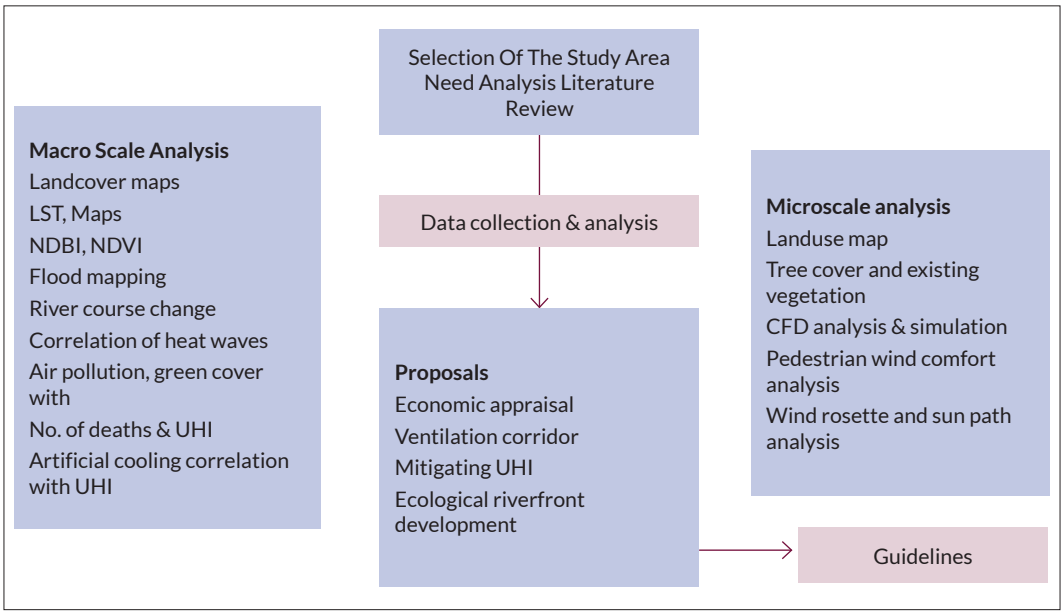
Source: Authors

Figure 3: Microscale Research Analysis



Source: Authors

Figure 4: Study Methodology



Source: Authors

Data Collection

The data was collected for the past 30 years to understand the climate behaviour by analysing the UHI effect, rainfall pattern, heat index, land cover change, air pollution and deaths due to it, UHI and its correlation with artificial cooling specific to major issues concerned with runoff water, floods, heating of the areta. The vulnerability analysis was carried out based on the existing data in GIS, which helped in computing the economic loss to the city. For the preparation of surface temperature maps and land cover maps, Landsat imagery was used for the same month (May), same date (14 May) and different years (1990, 2000, 2010, 2020). Similarly, the analysis through secondary studies indicated the ill effects of UHI on local people by analysing the health data as UHI also worsens the effects of some natural events like heat waves. Primary data was collected by carrying out site surveys, questionnaire surveys, informal questioning. Secondary data was collected from multiple development plans. The data collected through various literature has helped in analyzing the groundwater potential, decadal and annual fluctuation in groundwater, depletion of groundwater, loss of floodplains, change in seasonal and annual rainfall patterns, drought frequency, heat index correlation with the rise in electricity demands and the increasing number of deaths due to it, increasing heat stress and air pollution in the cities and its correlation with UHI, and the overall carbon footprint of the city.

The data collection for the research work is carried out at macro and micro scale to understand the situation holistically. For collecting primary data in a proper format, a questionnaire was generated which included questions investigating the perception of riverfront development in Delhi. The

survey was conducted on May 20th, 2021 online by getting information from inhabitants of Delhi communities. A total of 49 (simple random sampling) responses were recorded to understand the perception of people about RFD and River from Delhi locals through online mode, while offline inputs (from those living along the river) were acquired by visiting nearby slums. Because all slums around the river could not be covered due to COVID-19 constraints, the slums that fell under the micro scale (25 sq. km) were considered. Forty responses were recorded on site to understand the viewpoint of the informal sector working in the Indraprastha area, and were captured through a Google questionnaire form for holistic analysis.

Data Analysis

Data analysis was performed to better understand the area. Few factors cannot be judged by direct observation, and more graphics and statistics need to be analysed to relate them to other factors. The primary and secondary data collected were analysed to propose a regenerative strategy for the Yamuna river bank.

Primary Survey Results

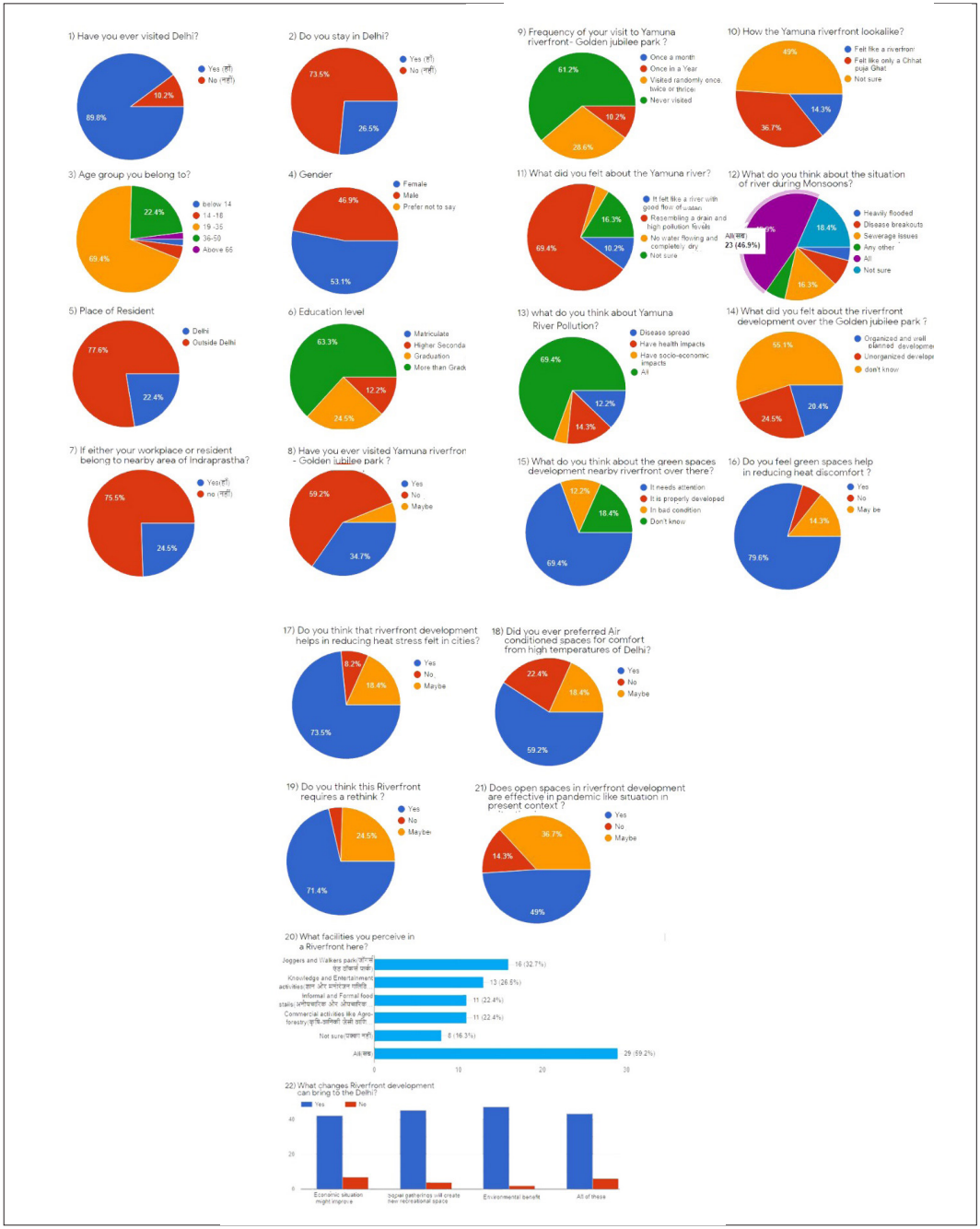
The primary data was collected with the help of a questionnaire to understand the public perception of riverfront development (RFD). The formal survey aimed to analyse the perception of the Delhi localities and how they connect with the river.

The survey result shows the positive perception of people for riverfront development along with environmental concerns as they connect strongly with the river's deteriorating condition and river pollution. It was an attempt to understand the perception of regional localities living near this area and the frequency of the inhabitants' visits to the river. The responses recorded show that 69.4 per cent were not able to relate to it as a river but as a drain. The perception of 71.4 per cent was in favour of rethinking riverfront development. The survey also tried to capture the facilities the people are looking forward to in riverfront development to capture the social and economic angles in order to propose a prototype for this area as the site is already under proposal for RFD. Also, the survey showed that 74.5 per cent of the people felt a thermal comfort as compared to the city due to greener areas in the vicinity. The survey has helped in understanding the potential of the site to be developed, along with the constraints.

Secondary Survey

The satellite images were downloaded for the years 1990, 2000, 2010, 2020 from the USGS website from the LANDSAT 5 TM, LANDSAT 8 OLI sensors of the study area for date 14-05-2020 and were used for analysing LST, NDVI, and NDBI and were classified into five classes (agriculture, bare soil, vegetation, built-up areas, water body/river for LULCC detection. The entire process is described below in detail. The maps were corrected with the Kappa accuracy assessment method to avoid any discrepancies, showing 75 per cent results. The land cover change analysis was performed in the GIS through dissolve function and it showed the maximum change in built-up areas, agriculture and vegetation land use. Building activity from the 1990s to 2020s increased from 16.43 per cent to 50.33 per cent for overall Delhi.

Figure 5: Perception of Surveyed Individuals about River, Green Spaces and Riverfront Development, 2021



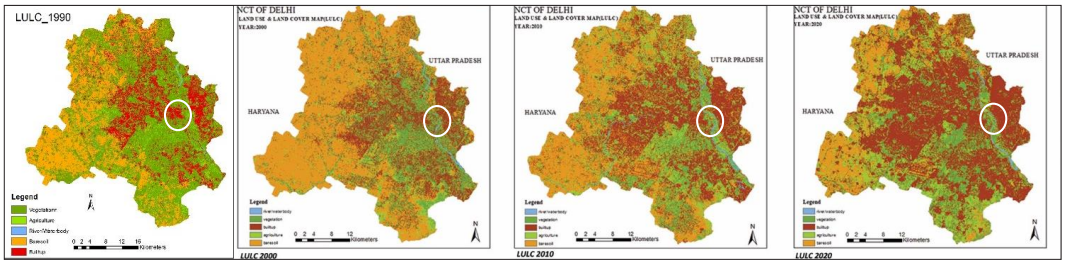
Source: Primary Survey, 20 May, 2021

Vegetation area decreased from 53.18 per cent to 13.79 per cent in 30 years. Agriculture activity increased from 4 per cent to 18 per cent. This suggests divergence of vegetative land for built-up and agriculture activities. Apart from this, the water body surfaces have shown a fluctuation in increasing or decreasing trend. After the land cover change analysis, the same maps were analysed for the five classes (agriculture, bare soil, vegetation, built-up areas, and water body/ river) for land surface temperature change for the last 30 years.

Land Surface Temperature (LST) represents the temperature of the ground surface and is one of the important parameters that affects the energy balance of the ground surface, the local climate, and the exchange of heat flux and energy.

i) Land cover change analysis from 1990-2020

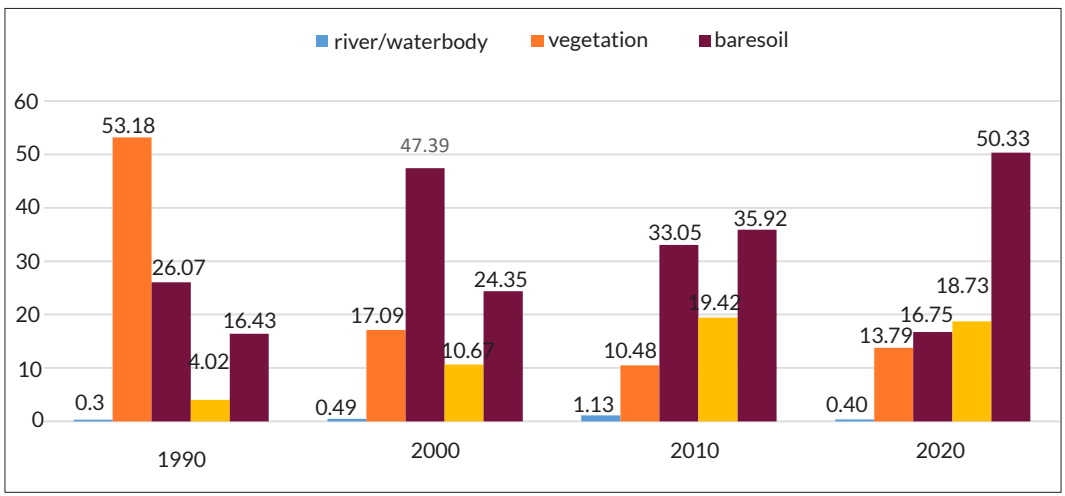
Figure 6: LULCC Change Detection, Indraprastha Area, Delhi



Note: Site of Microscale Study, Indraprastha area (25 sq. km)

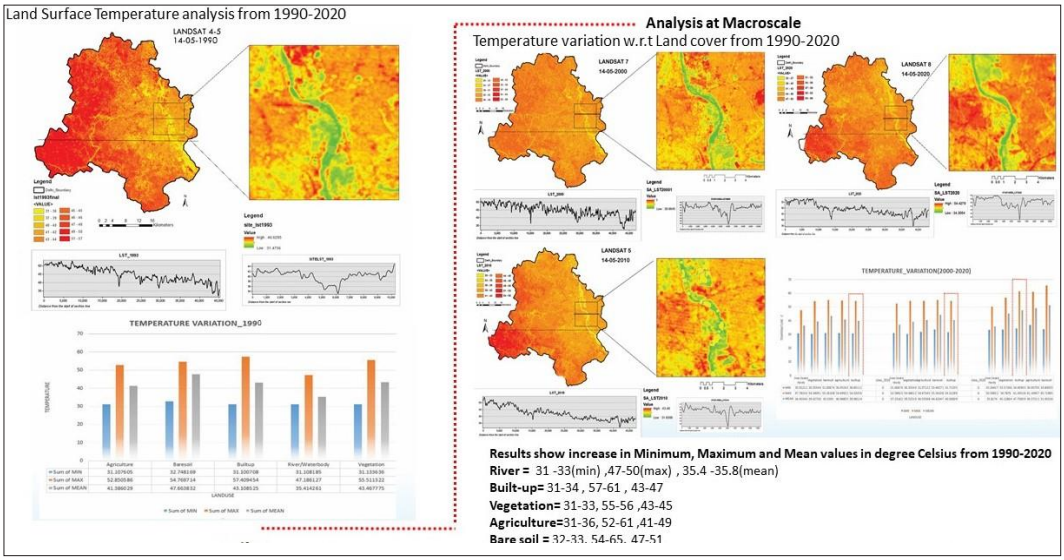
Source: USGS website, Landsat Imaginary 5 TM, LANDSAT 8 OLI sensors

Figure 7: Change (in %) in Land Use and Land Cover, Indraprastha Area, Delhi



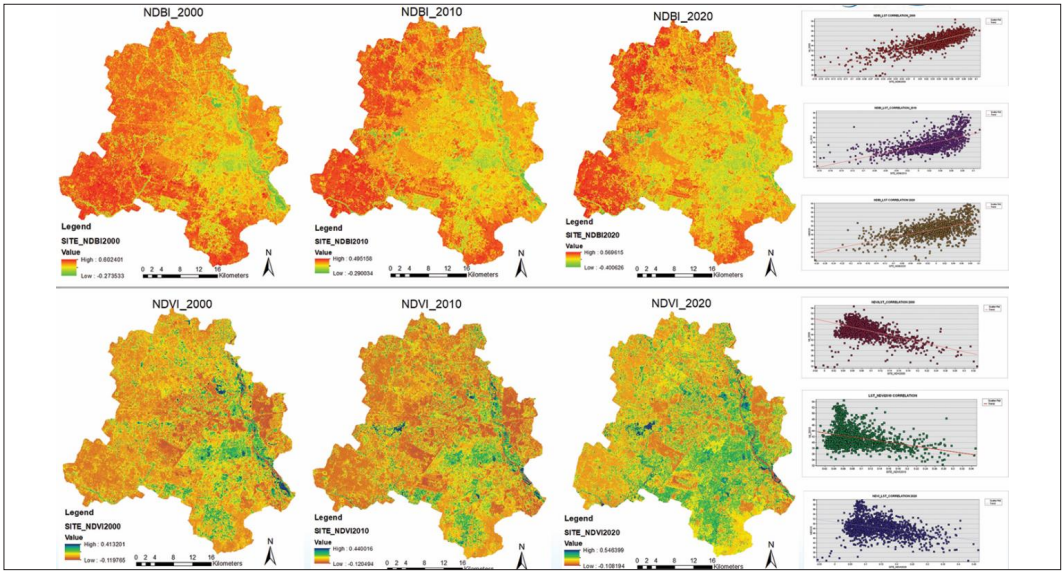
Source: USGS website, Landsat Imaginary 5 TM, LANDSAT 8 OLI sensors

Figure 8: Land Surface Temperature Maps for Delhi (14th May 1990-2020) and the Corresponding LULCC



Source: USGS website, Landsat Imaginary 5 TM, LANDSAT 8 OLI sensors

Figure 9: NDBI and NDVI Maps for Delhi (14th May 1990-2020) and Corresponding LST and LULCC



Source: USGS website, Landsat Imaginary 5 TM, LANDSAT 8 OLI sensors

The NDVI and NDBI analysis was performed further to confirm the effect that built-up activities are having on escalation of temperature whereas vegetation, river/water bodies help in pacifying the rise of temperature.

ii) Results

The results show an increase in minimum, maximum and mean temperature for the last 30 years due to land cover change.

Table 1: Results of Temperature Change Due to Land Cover Change

Land use	Temperature		
	Minimum range (degree Celsius)	Maximum range (degree Celsius)	Mean range (degree Celsius)
River/ water body	31- 33	47-50	35.4-35.8
Built-up	31-34	57-61	43-47
Vegetation	31-33	55-56	43-45
Agriculture	31-36	52-61	41-49
Bare soil	32-33	54-65	47-51

Source: Calculated by Authors using ArcGIS sectional analysis

The NDBI correlation analysis shows a positive scatter plot graph indicating the rise of temperature with increasing built-up activity. The NDVI correlation analysis shows a negative correlation of land surface temperature with vegetation and water surface indicating that vegetation, water bodies and rivers play a role in cooling the spaces.

Limitations

The CFD analysis which helps in determining the wind direction and wind velocity at the local scale was not performed due to time constraints and COVID restrictions for the site visit. It would have helped in confirming and strengthening the proposal results at the micro level.

Results and Discussion

Detection of changes helps to quantitatively analyse past impacts of events by applying Remote Sensing information and determining changes in the properties of LULCs referenced from various satellite data sets. After analysing changes at the macro level and understanding different factors responsible for river deterioration, the study was focused on the micro scale for proposing a regenerative strategy by proposing an effective riverfront development plan. The confusion matrix was prepared for the site covering the 5 km radius (covering approx 25 sq. km area) to understand the land cover changes surrounding the site from 2000 to 2020.

Table 2: Confusion Matrix for 25 Sq. Km Riverfront Development Site

Confusion Matrix Agriculture		Area(ha)_2020					
		Bare soil	Built up	River/ Waterbody	Vegetation	Total	
Area(ha) in 2000	Agriculture	3872.25548	1262.64	6705.92	24.78	3948.70	15814.30
	Bare soil	17144.8263	21190.10	26679.37	11.03	4638.51	69663.84
	Built up	3206.56706	1049.03	28602.69	49.35	3292.24	36199.87
	River/ Waterbody	53.206563	139.05	157.74	243.31	140.77	734.067
	Vegetation	3407.33426	1121.43	12253.06	255.63	8357.12	25394.59
	Total	27684.1896	24762.26	74398.78	584.10	20377.34	147806.7

Source: Authors' (ArcGIS raster calculations of land cover change)

The confusion matrix shows the area change inland cover from the year 2000 to 2020. Out of the 15,814 ha that was agriculture area in 2000, 3872.25 ha still remained agriculture area in 2020 but 1262 ha was converted to bare soil/rocks, and the rest to vegetation and built-up Area. Out of 25,394 ha in year 2000, vegetation area lost mainly to agriculture, bare soil/rocks and built-up area, and retained 3407.33 ha of the total in 2020. Built-up area increased from 36,199 ha in 2000 to 74,398 ha in 2020. It retained 28,602 ha of it and was mainly replaced by agriculture and Bare soil/rocks. The category which built-up area mainly replaced in 2020 was bare soil and vegetation (12,253 ha). This study elucidates the importance of integrating GIS with remote sensing studies to detect changes in local land cover/land use to provide important information about spatial distribution as well as the changing nature of land cover. The water category in 2020 retained only 243 ha of the total 734 ha in 2000.

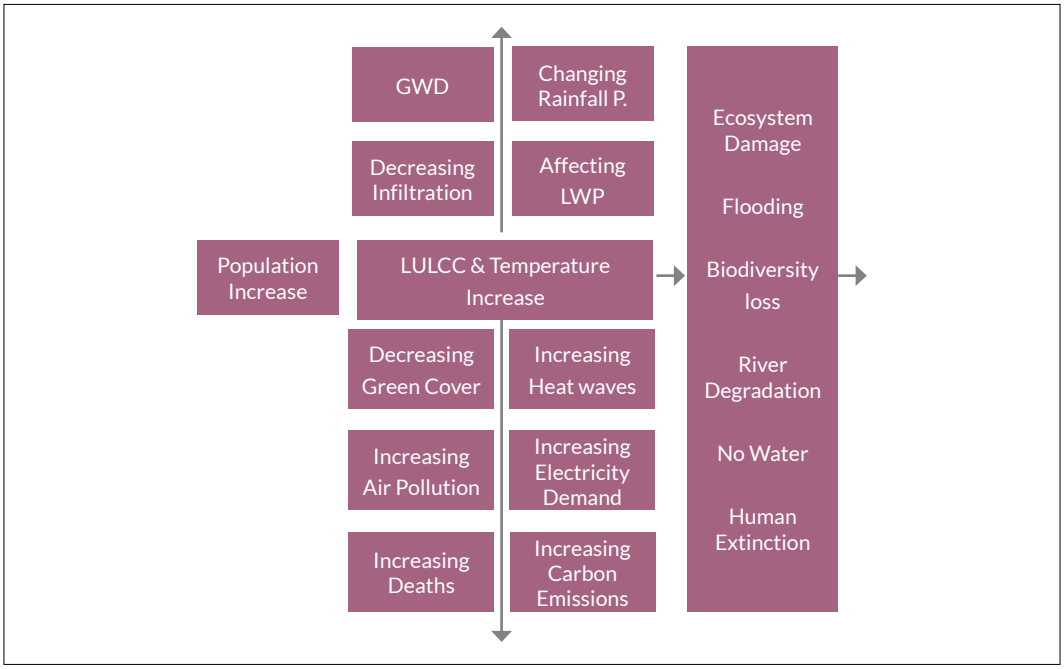
The temperature variation across different land use in LST shows the increase in minimum and maximum values of temperature. This indicates the UHI effect. Moreover, the temperature across built-up area is rapidly changing, indicating the change of land cover leading to a rise in temperature. To validate the above change taking place in the city of Delhi, the average ambient temperature of the city was compared with this rising temperature to analyse the difference. The ambient temperature in any case has not extended beyond 41-42 degrees Celsius overall for Delhi, whereas the LST shows the variation observed in temperature difference for different land cover in more than two decades.

For NDVI, the Scatter Plot was plotted to analyse the relationship between NDVI and LST. It shows a Negative correlation between NDVI and LST. It indicates that the less vegetative area is associated with high temperature whereas the high vegetation area is associated with low temperature. Thus, vegetation helps in keeping the temperature low. Similarly, for NDBI, the

Scatter Plot was plotted to analyse the relationship between NDBI and LST. It shows a Positive correlation between NDBI and LST. It indicates that the high built-up area is associated with high temperature (in the city too) whereas the low built-up area is associated with low temperature.

The above maps from the year 1990 to 2020 indicate the increase in built-up area. This increase has changed the land use pattern. Pervious open land has been converted to an impervious layer. This has decreased the infiltration rates to the groundwater table. It was observed that the area under vegetation also decreased indicating less evapo-transpiration. All this has contributed to raising the overall temperature of the city in general. This suggests that in future the temperature will further increase causing discomfort to all living beings along with various other consequences.

Figure 10: Consequences of LULCC and UHI Effect on Rivers



Source: Authors

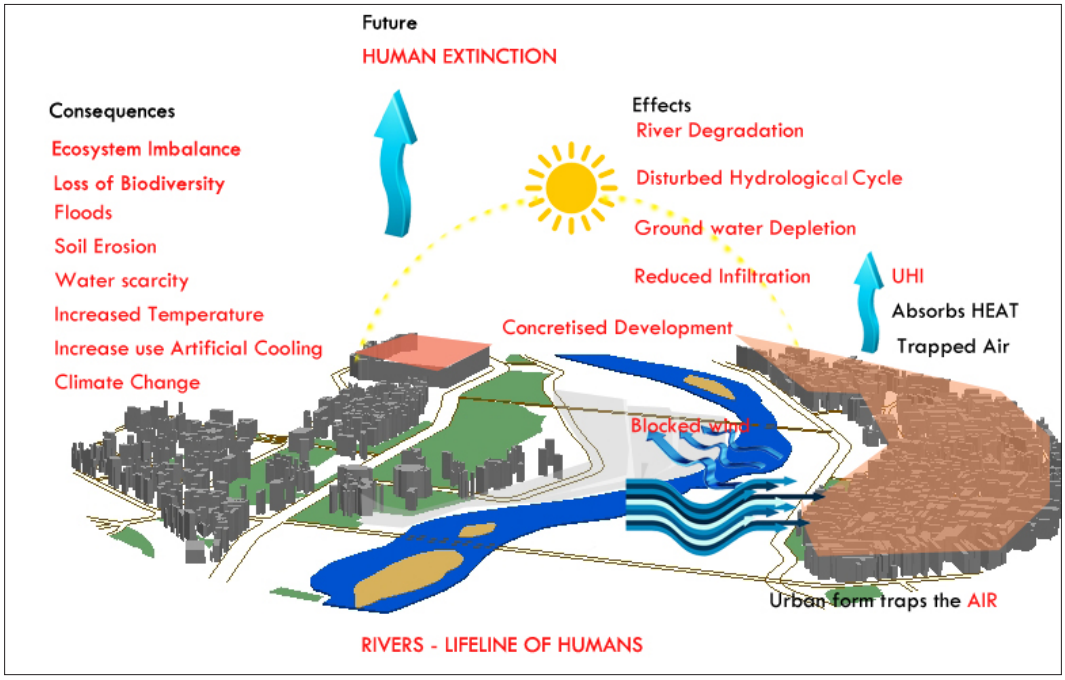
Urbanisation is increasing because of the rising population leading to LULCC and temperature increase has many consequences as shown in the above Figure 10. The LULCC leads to decreasing green cover which intensifies air pollution and is one of the causes for increasing deaths in Delhi as per the observation of the department-related standing committee on Science & Technology, Environment & Forests (2018). The temperature increase adds to the heatwaves which drive the demand for artificial cooling, leading to an increase in carbon emissions.

The LULCC, with more and more addition of impervious layers due to increasing population leads to decreasing infiltration rates which exacerbate groundwater depletion. All these processes disturb the natural hydrological cycle vertically with the atmosphere and horizontally with the ground leading to changing local weather patterns, which further affects rainfall intensity and its distribution. This has wider implications on the health of the ecosystem and contributes to the degradation of the rivers. The situation currently is such that there is no water flowing through the rivers in the dry season and only sewerage flows through it.

Recommendations

The regenerative strategy is proposed to revive the ecosystem. The design concept was worked out on the principle of a water-sensitive design strategy, which in the long term will help in reviving the ecosystem.

Figure 11: 3D View of Site in Business as Usual (BAU) Scenario

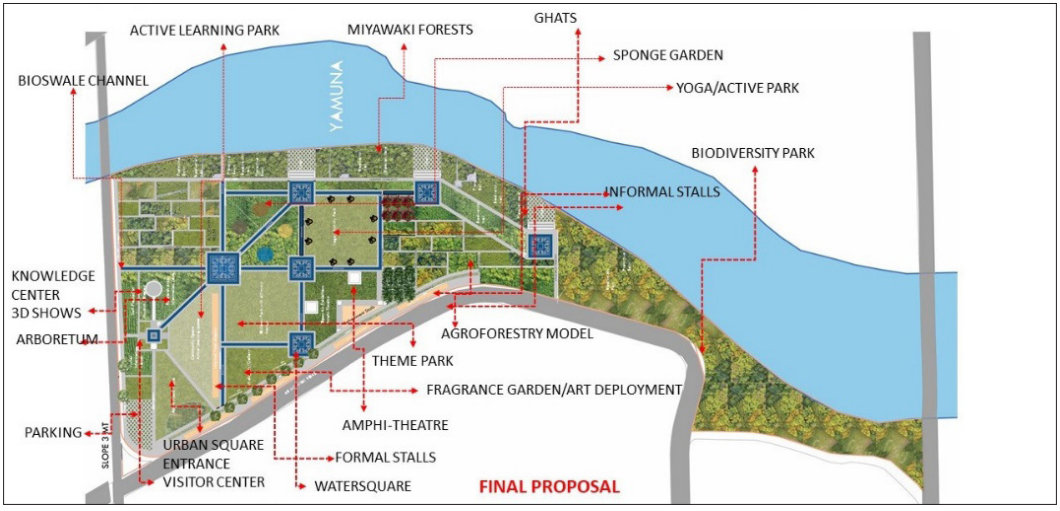


Source: Delhi Master Plan 2021

Figure 12: Proposed Site (Indraprastha) through an Ecological Approach

Source: Delhi Master Plan 2021

Figure 13: Final Proposal for Riverfront Development



Source: Delhi Master Plan 2021

The 3D visual of the site explains the BAU scenario of concretised development and the consequences leading to river degradation. But if the site is developed as a ventilation corridor as shown in Figures 11 and 12 it helps in pushing the cool river breezes towards the core of the city. These breezes from the river help in connecting the river to the city physically and mentally by establishing a social connection. The ecological approach to the riverfront development further helps in realising environmental, cultural and economic value.

The final proposal for a regenerative strategy was proposed keeping in mind the potential of the site. The macro- and micro-level analysis in GIS software further helped in the determination of existing water streams and headwaters in the site which play an important role in water storage and maintaining a continuous flow of water in the rivers. The concept was to establish a connection by addressing Climatic, Environmental, Economic, Cultural and Aesthetic factors which address a water sensitive based regenerative strategy. The proposal will help in mitigation of the UHI effect by building a ventilation corridor (the RFD is conceived as a form that will help in promoting the cool breezes from rivers to the city core and in establishing a connection). The water streams helped in identifying ideal locations for urban squares, water squares and other landscape activities around the riverfront. The design has been proposed keeping into consideration the strategies of Master Plan Delhi 2041 and differentiation proposed by DDA around rivers in the sensitive, protected and interactive zones, and accordingly activities are proposed. The site falls under Zone O, an interactive zone as a recreational zone for development. The proposal addresses the 'No Water' scenario in rivers and proposes recharging of *kunds* which will help in situation improvement in the long term. The theme for the riverfront development was based on the traditional architecture in order to give it character, and where people can connect with the architecture and tales of the river Yamuna. The motive was to capture responsible behaviour patterns of people through sensitisation and to increase awareness towards maintenance of the ecosystem.

a. **Economic Appraisal:** To capture the economic value in the proposed model, different strategies were employed as shown in Table 3.

i. Total economic value of riverfront development

Table 3: Total Economic Value Generated in Initial Years

Ecosystem service	Type of service	Valuation technique	Total value (INR) (crore/ year)	% Contribution of total economic value
Conservation	Non-use value	Contingent valuation	27	43. 3
Education and research	Indirect-use value	Market price	1.4	2.25
Carbon sequestration	Indirect-use value	Market price	7.4	11.89
Recreational and cultural	Indirect-use value	Individual travel cost method	12.4	19.9
Water potential Value		Market price	14	22.5
Total			62.2 cr	100
Surrogate value of land	Non-use value	Opportunity cost	25 cr (one time cost)	
The land value of the Delhi zoo	Non-use value	Market price (benefit transfer)	12281.5 cr (one time cost)	

Source: Referred and modified from Economic Valuation of Ecosystem Services, National Zoological Park, New Delhi, 2020.

The detailed calculation for deriving these values has been discussed below. The values for education and research and environmental conservation were derived from the report[1] of the survey done for the National Zoological Park by TERI, New Delhi, and Central Zoo Authority in the vicinity of radius 1 km and accordingly, it was extrapolated for the entire population.

ii. To calibrate the water potential added to the site, the following method was used:

Table 4: Water Potential Value

Proposal for Riverfront Development			
Class	Stock added (ha)	Storage potential	water value
Agroforestry	32.4042	171105	4510327.8
Urban Forest (Biodiversity)	36.1082	186660	4920357.6
Water Estimates (Rainwater Harvesting)			9430685.4

Source: Authors' (calculations as per design area).

[1]*Report on Economic Valuation of Ecosystem Services, National Zoological Park, New Delhi, 2020.*

Monetary Potential

The water tariff rate per 1000 liters (1 cu.m) in Delhi is 26.36. For Delhi, peak hourly rainfall is 90 mm (based on 25-year frequency) and 15 minutes peak rainfall is between approximately 22.5 mm/hr and 25 mm/hr, according to Central Ground Water Board (CGWB) norms.

For proposed recharge kund = Large kund = 10368 x 0.025 x 0.85 = 220.3 cu.m; Small kund = 5950 x 3 = 17,850 = 379.3 cu.m. Total A = 599.6 cu. m of water stored.

Design of recharge trench: Assuming a void ratio of 0.5, the required capacity of a recharged tank is 29,073 x 0.025 x 0.85 /0.5 = 1235.6 cu m = Total B. TOTAL = A+B = 1835.2 cu.m.

Annual water harvesting potential: Delhi average rainfall = 611 mm. Total site area (1000,000) x 0.6 x 0.85 = 518,500 cu. m x 26.36 = 13667660/- (13 crore).

iii. Environment conservation (willingness to pay)

Table 5: Environmental Conservation Valuation

Range (INR)	Percentage of people willing to pay	Number of people	Average value (INR)	Value of biodiversity conservation (INR)
free	10	330,096		
0-50	59	2,025,589	23	46588547
50-100	14	480,140	93	44653020
100-200	10	360,105	150	54015750
200-500	4	150,044	440	66019360
500-above	3	90,026	700	63018200
Total				274294877=27 cr

Source: Referred and modified to the context from report on Economic Valuation of Ecosystem Services, National Zoological Park, New Delhi, 2020.

The surrogate value of the land is circle rate x area. The circle rate for the riverfront location is 106400/sq. m (Indraprastha). The land value of the site is INR 12281.5 crore. The surrogate value of land is estimated to be around INR 250,000,000 or INR 25 crore. The values are directly assumed from the survey done for the National Zoological Park which estimated ecosystem services valuation after the park was made. The zoological park lies in the influence zone of 1 km of the site and hence a minimum of 5 per cent visitors was assumed to be visiting this site after it was completed.

iv. ***Education and research (willingness to pay):*** As per the survey of the National Zoological Park, lying in the influence zone of Riverfront Development, it was assumed if 5 per cent tourists out of the total tourists coming to the National Zoological Park visit this riverfront, it would have the potential of generating a value of INR 14 crore approximately.

Table 6: Education and Research Valuation

% of people subscribed to wildlife and environmental information programme	Total assumption of visitors	Value incurred annually	Annual cost (INR) invested by visitors
4% (Offline)	100000	INR 2333	9332000
72%(Online)		INR 75.11	5472000
24%(None)			0
Total			14.804000 cr

Source: Referred and modified to the context from report on Economic Valuation of Ecosystem Services, National Zoological Park, New Delhi, 2020.

Carbon Sequestration: The rate of carbon sequestration depends on the growth characteristics of the tree species, the conditions for growth where the tree is planted, and the density of the wood of the trees. It is greatest in the younger stages of tree growth, between 20 to 50 years. The native species were identified for the site and above breast diameter was identified. The following steps were followed as per the study by Sharma Richa et al. (2020).

Step 1: Tree Height and Girth at Breast Height (GBH)

Step 2: Estimation of Above-Ground and Below-Ground Biomass (AGB and BGB)
AGB = 34.4703 − 8.0671D + 0.6589D2 (1) where D is the DBH (cm). BGB = AGB × (15/100)

Step 3: Estimation of Total Biomass (TB) = Total Biomass = AGB + BGB

Step 4: Estimation of Carbon Content = 0.5 × Total Biomass

Step 5: CO2 equivalent is then calculated using the equation given below : CO2 (eq.) = (carbon content × 44)/12

The results of this study as shown in Table 7 illuminate the value of urban trees as well as their aesthetics, which mitigate the effects of climate change at the local level. It is important to study the potential for carbon sequestration in the centre of the city to understand and emphasise the role of urban green spaces in offsetting carbon dioxide emissions at the regional level.

Table 7: Carbon Sequestration (Equivalent Tons)

Native species	At breast diameter avg (cm)	AGB (kg)	BGB (kg)	Total biomass	Carbon content	CO2 equi. (kg)	CO2 Equi. (tons)	The total number of trees (Appro.)	Total Co2 equi. (tons)
Neem	80	3606.1	540.9	4147.0	2073.5	7602.8	7.60	100	760.27
Axle wood	50	1278.4	191.8	1470.1	735.1	2695.2	2.70	50	134.76
Eucalyptus	120	8554.6	1283.2	9837.8	4918.9	18035.9	18.04	50	901.79
Babul	30	385.5	57.8	443.3	221.6	812.7	0.81	50	40.63
Bottle brush	4.5	11.5	1.7	13.2	6.6	24.3	0.02	50	1.21
Peepal	150	13649.7	2047.4	15697.1	7848.6	28778.0	28.78	50	1438.90
Banyan	200	24777.1	3716.6	28493.6	14246.8	52238.3	52.24	50	2611.91
Laurel fig	90	4645.5	696.8	5342.3	2671.2	9794.3	9.79	100	979.43
weeping fig	60	1922.5	288.4	2210.9	1105.4	4053.2	4.05	100	405.32
Indian Laburnum	60	1922.5	288.4	2210.9	1105.4	4053.2	4.05	100	405.32
Indian Mahogany	80	3606.1	540.9	4147.0	2073.5	7602.8	7.60	50	380.13
Bambusa vulgaris	10	19.7	3.0	22.6	11.3	41.5	0.04	50	2.07
Terminalia arjuna	150	13649.7	2047.4	15697.1	7848.6	28778.0	28.78	50	1438.90
Yellow Trumpet Tree	40	766.0	114.9	880.9	440.5	1615.0	1.62	50	80.75
Alstonia scholaris	90	4645.5	696.8	5342.3	2671.2	9794.3	9.79	100	979.43
Total		83440.1	12516.0	95956.2	47978.1	175919.6	175.92	1000	10560.87

Source: Referred and modified from Sharma, 2020.

The committee's report was presented to a Supreme Court bench led by Chief Justice of India S.A. Bobde, which had asked the committee to assess the monetary value of the trees in January 2020 based on the cost of oxygen released and other environmental advantages. Based on the report, a guideline on tree valuation for the first time in India was prepared, stating that a tree's monetary worth is its age multiplied by rupees 74,500.00 per tree year. This was presented to a Supreme Court bench. Out of this the cost of oxygen alone is rupees 45,000.00 and of biofertilizers, rupees 20,000.00.

Table 8: Carbon Sequestration Valuation

Trees year (age)	Monetary worth of one tree (INR)	No. of trees	Monetary worth (INR)
1	74500	1000	74500000
5	372500	100	37250000
10	745000	100	74500000
15	1117500	100	111750000
20	1490000	100	149000000=14.9cr

Source: Author

There would be 175 tons of carbon equivalent in a year sequestered if just one tree of each native species is planted (total 15 trees). Initially, trees will take an average time of 4-5 years in attaining maturity. To arrive at the monetary value, total native species were assumed that are to be planted initially. The assumed number of trees' monetary value with age was found out by multiplying it with 74,500 rupees per tree year.

Conclusion and Way Forward

The ecological riverfront prototype with ecosystem valuation is the first study of its kind in the Indian context undertaken in order to understand the role of rivers in the mitigation of urban heat islands (UHI) and climate change in the long term. So far, the studies done on UHI in the international context were focused on mitigation planning and monitoring whereas most of the studies in the Indian context were in the analysis stage, with mitigation guidelines being listed but attempts not yet made for implementation. In the international context, the studies have been done wherein the role of cool breezes from the rivers in urban areas have been observed through various experiment as helping in mitigation of UHI. A study by Akashi (2008) evaluates the effectiveness of reducing the UHI effect by creating 'wind corridors' in dense urban areas. This study describes how wind paths create chains of wind over the ocean, facilitating the ventilation of naturally heated air. The study by Kagiya & Ashie (2009) discusses the creation of ventilation paths along rivers or the seafront as a measure for mitigation of UHI. Another study by Hathway & Sharples (2012) identified the possible impact of small urban rivers in reducing the UHI effect and studied the role of urban morphology on the riverbank in the propagation or reduction of potential cooling. In the Indian context, the study by Veena, K M Parammasivam and T N Ventakesh (2020) sudden climatic changes and the rise of temperature in the urban area, that is the formation of Urban Heat Islands (UHI pointed out that more than 70 per cent of the research is related to the analysis of LST and surface temperature (ST) (that is, the study of surface heat islands), and about 30 per cent of the research is only in AHI (atmospheric heat island). Also, research work is limited to UHI testing and its findings but the implementation of mitigation efforts is missing. Other studies are by L. Vailshery, M. Jaganmohan, and H. Nagendra (2013) and Aslam M.Y., Krishna, K.R., Beig, G., Tinmaker, M.I.R. and Chate, D.M (2017) for UHI w.r.t air quality, R. Sharma & Joshi (2014) for LULCC and UHI, and The Energy and Resources Institute, (TERI, 2017) for urban planning and UHI. The study on The Economics of Ecosystems and Biodiversity (TEEB, 2010) demonstrates an ecosystem valuation technique that can be applied in different ecological contexts but it is still in the experimentation stage.

The present study of UHI in the context of Delhi to give a proposal for ecological riverfront development was unique as it involved not only identifying the UHI in a particular context but also the results obtained have given clarification concerning mitigation efforts needed to reduce ill effects of UHI or vice versa. The study focuses not only on the identification of the problem of UHI and various factors responsible for it but also on how to solve it through various mechanisms to be adopted and for its implementation at ground level. The design approach of the ecological riverfront addresses social, cultural, economic, environmental, aesthetical factors which will cater to the sustainable development of the model in the long term. The economic appraisal shows that the model in the initial two plus years only has the potential of creating a value up to approximately INR 60 crore which is very rare in investment model returns. The tangible and intangible benefits such as employment generated and improvement in air quality have not been calculated over here. If all this is added up its value will further increase. Further, the valuation of ecosystem services will create awareness among the people and will motivate them to promote and adapt to such development models in future. If such a development prototype is further implemented on a large scale, the tangible and intangible benefits to people would be ten times more than estimated. Such modelling in future will help in debating the issue of development versus environment by balancing development objectives particularly in the context of achieving SDG goals 2030.

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Conflict of Interest

Authors have no conflict of interest to declare.

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The Sombre Case of an Odd Triad — Dolphin, Man and Zoonoses: Revitalisation and Revival of Vikramshila Gangetic Dolphin Sanctuary, Bihar

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Abstract
Microbial activity has been around on this planet since time immemorial, contributing to the emergence of numerous renowned plagues, epidemics and pandemics. What was once a means to sustain the environment today has become an eminent cause of concern as almost 60–75 per cent of the documented infections that affect man are of zoonotic or of animal origin. Studies have further identified a link between zoonoses and factors like habitat fragmentation, biodiversity loss, agriculture etc.; however very few have actually attempted to link them with the discipline of landscape architecture. This research therefore is an attempt to understand how zoonotic resilience can be achieved in an urban riverine landscape using the case of Vikramshila Gangetic Dolphin Sanctuary, Bhagalpur, Bihar. The research outcome is a prototypic design approach and framework that may be scaled and adapted into any ecosystem, followed by a cemented understanding of the fact that landscape architecture is indeed capable of curbing zoonoses at the initial phases itself. However, a combination of design interventions, proactive planning upon consultation with inter-disciplinary experts and policy formulations is needed for success to prevail. Mimicking the natural environment as much as possible is the core strategy to keep zoonotic spillover at bay.

Key words: Landscape Architecture, Zoonoses, Vikramshila Gangetic Dolphin Sanctuary, Braided Rivers, Zoonotic Resilient Landscapes

Introduction

"The clash of human and animal interests may also create friction when wild species from the peri-urban hinterland are attracted to feeding or nesting opportunities in the ever-expanding suburbs." (Atkins, 2016, p. 6)

The above excerpt perfectly highlights the contextual gist behind the research intent in this paper. Zoonoses[1] is slowly turning into a predominant issue of concern within the public health sector as studies indicate around 61 per cent of all human diseases and around 75 per cent of emerging infectious diseases to be of zoonotic origin (Taylor, L. H. , Latham, S. M. , & Woolhouse, M. E. (2001)). The transfer of malignant zoonotic pathogens from sylvatic reservoirs[2] into the human population is truly a rising concern; especially with the ongoing COVID-19 pandemic (Morens, D.M. & Fauci, A.S., 2020).

Generic research studies[3] identify the prominent causes of zoonotic development within the human community to be closely linked with degrading environmental status and the health of our blue–green network infrastructure as well. Studies reveal water bodies as an equivalent pathogenic reservoir for pathogens (Thomas, 2020, September 13 'Potential sea animal reservoirs for coronaviruses') that are either endemic or reach the waters due to improper anthropogenic practices such as open defecation etc. Additional research further recognised the natural presence of human pathogens in wild fauna, inclusive of gregarious species such as dolphins (Thomas, 2020, September 13) and migratory avi–fauna[4] that can turn into potential zoonotic vectors as well.

This calls for effective monitoring and preservation of these water bodies to prevent onward transmission to other wild, domesticated or human species via direct or indirect contact. Understanding the working of predator–prey relationships and existential food webs can help devise strategic design solutions to minimise biodiversity loss without compromising on food security or development.

In a diverse nation such as India, the floodplains of rivers such as the Gangetic watershed are socio-ecological systems, supportive of both man and a plethora of wild species. However today, Indian riverscapes are competing with human interests to sustain a diverse riverine ecology, evident from the degrading quality of these rivers.

The Gangetic riverscape comprising the Ganga – Brahmaputra – Meghna river system is the main habitat of the national aquatic animal of India—the Indian Gangetic dolphin (Platonista gangetica); a key indicator species whose presence indicates the purity of the Ganga River and vice versa.

[1]*World Health Organization (WHO) defines zoonosis as any disease or infection that is naturally transmissible from vertebrate animals to humans.*

[2]*Sylvatic reservoirs indicate natural reservoirs wherein these pathogens are hosted. Only upon encounter with humans do they turn pathogenic in nature. Else they are harmless to their host vectors.*

[3]*An in-depth understanding of zoonotic spillover into the human community was explored in Kanchan (2020), 'Role of landscape architecture in curbing zoonoses—developing a design framework and approach (unpublished Master's dissertation). School of Planning and Architecture, Vijayawada.*

[4]*Avi–fauna/avian fauna refers to bird population.*

Apart from occupying the apex position in the aquatic food chain (a mark of increased biodiversity, hence healthy riverine ecosystem), the downward movement of this species is another indicator of receding water during floods for the local people as well. Additionally, these beautiful blind and semi-gregarious species are known to orient their entire life via echo-location. Upward water movement, a combination of deep and shallow riverine segments are two major character traits of these river dolphin habitats. Within an overall population wavering around 4000–5000, these species have been occupying the International Union for Conservation of Nature (IUCN) endangered list since 1996 (Table 1). Massive sightings in addition to the year-round dwindling dolphin count and vanishing of the species from the majority of previous Gangetic dolphin hotspots have led to the establishment of the Vikramshila Gangetic Dolphin Sanctuary (VGDS).

Despite being a notified sanctuary, the dolphin count here has drastically decreased over the years, which is a huge predicament for the health of the Gangetic Riverine system is closely linked to the survival and presence of the Gangetic dolphins. Moreover, their semi gregarious nature does hold a massive potential for them to host potential zoonotic pathogens, thereby acting as a harbinger of probable global zoonotic pandemics. The project shall provide immense scope for exploration of creating a sustainably enhanced built environment in a natural dolphin habitat with the result being a healthy and zoonotic resilient landscape.

Additionally, the sanctuary is also home to various migratory fish and avi–fauna as well, such as the red-crested pochard, greater adjutant etc. However today, VGDS is in a sorry condition and fails to maintain the ideal habitat needed for any of these species owing to excessive pollution, anthropogenic interferences and intense eutrophication. Which is why it is also important for the design proposal to not just ensure riverine biodiversity protection but also the zoonotic resilience of surrounding landscapes, keeping in mind both the potential scope of a pathogenic spillover into the human community, in addition to affecting the sacred and historic relevance of Ganga.

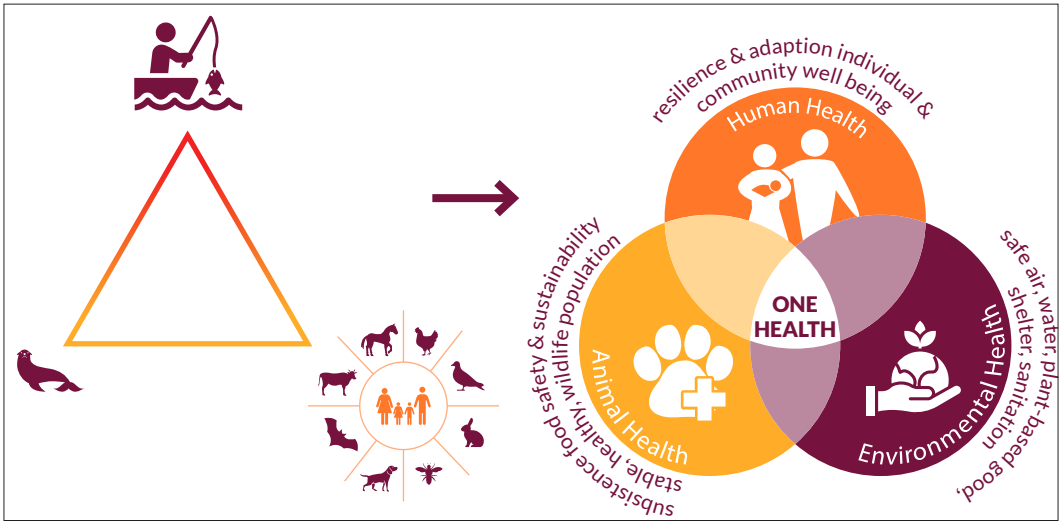
This research paper is a comprehensive document that elucidates the past and present of Ganga River in the context of the Vikramshila Gangetic Dolphin Sanctuary in addition to providing a detailed account of how this sanctuary may be restored and conserved to its best possible glory through strategic design interventions, policies and guidelines. Efforts were made to consider the various aspects associated with a holistic yet sustainable river sanctuary management for the benefit of both the river, its associated dynamics with biodiversity, and the local regional community, while also attempting to establish a consensus between the key unconventional project stakeholders—dolphin, man and zoonoses—each symbolic of a wider canvas (Figure 1).

Table 1: Stretch in the Ganga River System in India Where Gangetic Dolphins Have Been Reported

River systems of Ganga Plain	"Stretch where dolphins have been reported"	Estimates of population size
Ganga River	Between Haridwar, Uttarakhand and Bijnor barrage, Uttar Pradesh	"Completely disappeared WII (2018)"
	Between Bijnor and Narora, Uttar Pradesh	"35–39 (Behera and Mohan 2005; Behera 2006) 56 (Behera et al., 2013)"
	Between Anupshahar and Narora `Barrage, Uttar Pradesh	28 (Bashir et al.,2010)
	Between Narora and Kanpur, Uttar Pradesh	"Nil (Sinha 1999) 3 (Behera et al.,2013)"
	"Between Allahabad, Uttar Pradesh to Buxar, Bihar "	204 (Sinha 1999)
	Vikramshila Gangetic Dolphin Sanctuary, 60 km stretch between Sultanganj to Kahalgaon, Bihar	"81–92 (Sinha et al., 2000) 88–174 (Chaudhary et al., 2006)"
	Between Buxar and Maniharighat, Bihar	808 (Sinha et al., 2010a)
	"Between Maniharighat and Farakka, West Bengal"	115 (Sinha 1999)
	River Hooghly (250 km stretch from Mayapur to Ganga Sagar) in West Bengal	170–180 (Sharma 2010)
	"Waterways in the Sundarbans forest, India-Bangladesh"	196–225 (Smith et al., 2006)

Source: Aggarwal, D., Kumar, N. & Dutta, V. (2020). 'Impact on endangered Gangetic dolphins due to construction of waterways on the River Ganga, India: An overview'. Environmental Sustainability, 3(2), 127. https://doi.org/10.1007/s42398-020-00104-2.

Figure 1: Adapted One Health[5] Diagram – Animal (Dolphin), Human (Man) and Environmental (Zoonosis) Health



Source: Developed and adapted by authors from WHO recognised One Health diagram

Aim

To develop a prototypic zoonotic resilient landscape where humans and fauna (both wild and domesticated) can coexist within the same environment without fear of a pathogenic spillover.

Objectives

To create a safe haven for the endemic species of the region, thereby simultaneously increasing the population count of the Indian Gangetic dolphins.

To design a zoonotically resilient riverine infrastructural landscape for an ecosystem as unique and sensitive as that of the Ganges that exists within the layers of religion, natural sanctum and rapid urbanisation—this can further be adapted to similar Indian riverscapes.

Research Question

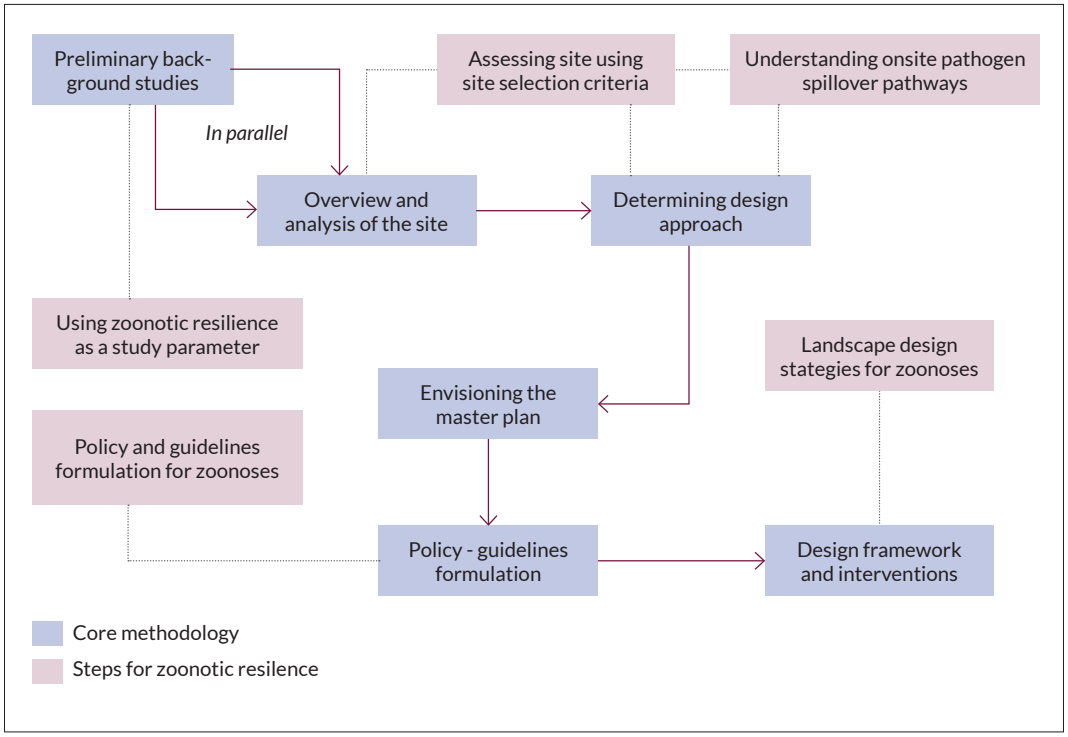
How can we develop a blue-green infrastructural riverine urban landscape, inclusive of the diverse species that exist within the habitat as well as hold potential for a zoonotic spillover into a zoonotically resilient landscape?

Research Methodology

A focused research technique was adopted in order to better understand how such a massive yet critical developmental change such as zoonotic resilience may be brought about within practical limits. This is primarily a descriptive and qualitative approach in order to better influence outcome and empower change through opening a platform for future discussions and research (Figure 2).

[5] *One health approach stands for the unification of the health of the triad namely animal health, human health and environmental health.*

Figure 2: Methodology



Source: Author

Owing to the novelty of research as well as limitations with respect to time and geographical issues, most data presented here is secondary in nature. Therefore, a holistic look at the issue at a macroscopic level was carried out by addressing the zoonotic infections based on vector typology and also limited to the local site context.

Google Scholar was utilised wherein keywords searched were limited to include a combination of 'zoonoses', 'landscape architecture', 'design interventions', 'framework', 'design guidelines' 'Vikramshila Gangetic Dolphin Sanctuary'(VGDS) 'Gangetic dolphins' for research papers and reports published within the domains of landscape architecture, ecology, and health. Searches were carried out from start to end. Likewise individual familiarity of the scientific literature was also relied upon, adding the relevant inputs wherever possible on the basis of generic primary knowledge of the subject.[6] Data search was mostly limited to the recent time frame of 5-10 years, however older relevant publications were not excluded. Likewise, an attempt to understand the origin of the Gangetic River stretch within VGDS dating back to 200 years was undertaken

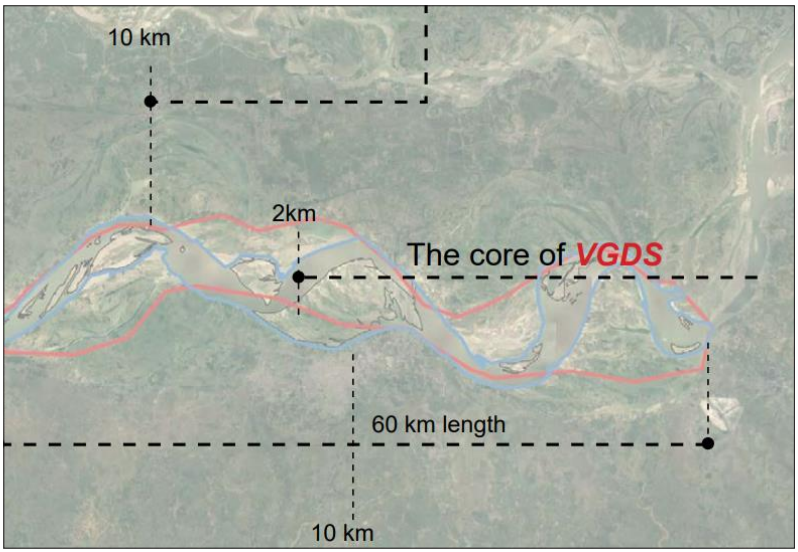
[6] *A major portion of the data with reference to the concept of zoonotic resilience in landscapes was derived from Manju Rajeev Kanchan (2020), 'The role of landscape architecture in curbing zoonoses—developing a design framework and approach' (unpublished Master's dissertation), School of Planning and Architecture, Vijayawada. This paper could be treated as a continuation of the concepts developed from the former cited source.*

through means of Google Earth Historical Imagery and old literature articles so that a site specific solution could be developed. Simultaneously, a reference list of papers identified as a part of the study were also searched of which a few were shortlisted to review further, based on prioritisation and relevance with respect to the study.

Scope and Focus

The actual extent of VGDS (Figure 3) in addition to the novelty associated with the entire topic clearly indicates a wide repository of options to research and work upon. This, owing to the academic research timeline, acts as a constraint, as a result of which the emphasis shall be more towards a holistic outlook of the study at a macroscopic level.

Figure 3: Aerial Extent of Vikramshila Gangetic Dolphin Sanctuary



Source: Modified by the authors from Google Earth. (n.d.). Vikramshila Gangetic Dolphin Sanctuary. Retrieved December 15, 2020, from https://earth.google.com/web/search/Vikramshila+Gangetic+Dolphin+Sanctuary,+Bhagalpur,+Bihar, OpenStreetMap. (n.d.). Vikramshila Gangetic Dolphin Sanctuary. Retrieved December 15, from https://www.openstreetmap.org/#map=11/25.3487/86.8696, Behera, Mishra, & Sinha. (n.d.). Vikramshila Gangetic Dolphin Sanctuary. BirdLife Data Zone. Retrieved December 15, from https://datazone.birdlife.org/site/factsheet/vikramshila-gangetic-dolphin-sanctuary-iba-india

Analysis

In order to propose a viable solution that addresses the three stakeholders of concern as cited in the title, it is imperative to start from scratch. Therefore, the studies undertaken may be categorised under the following subheads:

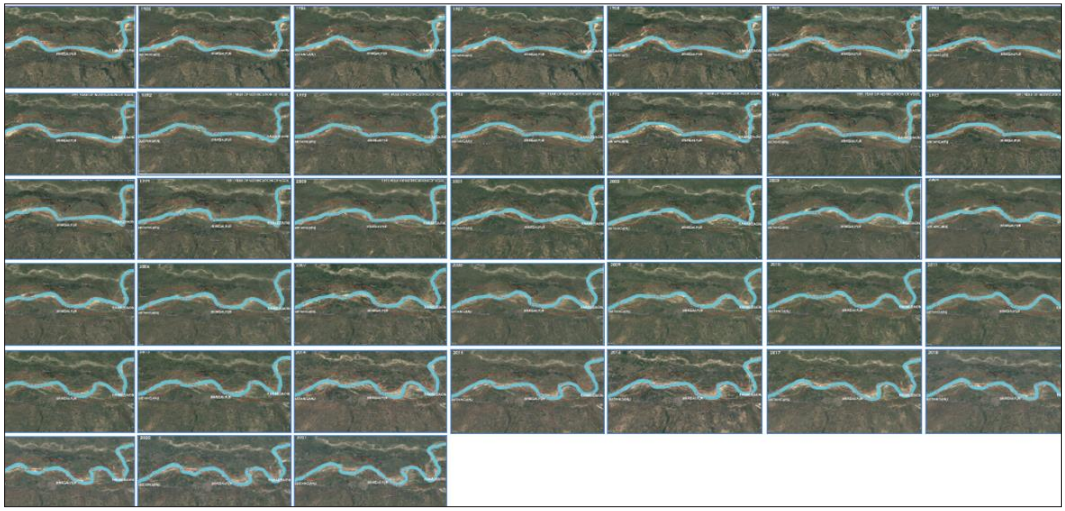
- Fluvial studies and dynamics
- A Gangetic perspective
- A holistic overview of zoonosis

Each subhead critically addressed the organic scenario of how natural ecosystems functioned in an environment devoid of human interventions, which ultimately paved the way for some critical understandings. These studies were utilised as a stepping stone to critique selected case studies that were near similar to the proposed site extent and this generated fruitful inferences for taking forward the entire study.

To start with, the stretch of Ganga from Bhagalpur (Bihar) to Jangipur (West Bengal), inclusive of the site extent, adopts a braided river character, forming a series of mid-Channel Islands or diaras (local terminology) which are primarily landscapes in flux, always changing with time. These diaras are separated by a series of interweaving channels or 'braids' which together form the main river channel of the Ganga. In a process that continues to date, when there is an increased and fast-paced flow of water during periods of intense precipitation, these braids fuse and leave behind a network of riverine and sand-gravel islands that reveal themselves with the recession of water.

To the common man, this process may seem like regular floods, however it is not, as it is this phenomenon that defines the very essence of what a braided river is all about. A braided river in its natural form is four-dimensional, i.e., unlike other lotic water systems, this river does not stay confined within relatively stable banks and a similar width–depth range over long periods of time. Rather, it is a landscape feature of flux known for changing its form, location, channel depth and diara planforms within a short span of time (Figure 4). This phenomenon is dependent on a variety of parameters both natural and anthropogenic.

Figure 4: Evolution of Ganga in VGDS from 1984–2021 (Left to Right)



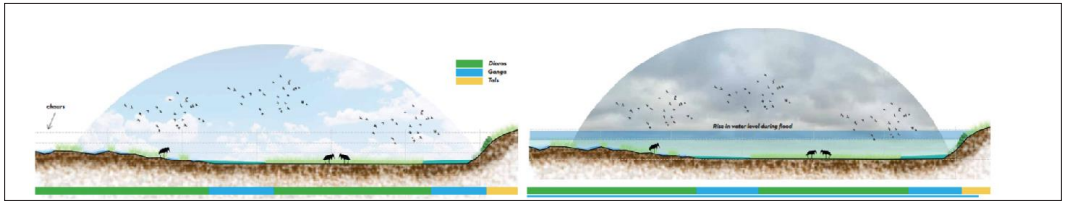
Note: This clearly indicates the evolution of braided character.

Source: Adapted from Google Earth by authors (Google Earth n.d.). Vikramshila Gangetic Dolphin Sanctuary. Retrieved December 26 2020, from https://earth.google.com/web/search/Vikramshila+Gangetic+Dolphin+Sanctuary,+Bhagalpur,+Bihar/@25.30462976,86.93091181,32.14081942a,52122.55085729d,35y,0h,0t,0r/data=CigiJgokCSfh6U9lJTNAESjh6U9lJTPAGa4pHvubUT9AIQZx5aVPLVHA,

Each braided river is unique. It is easy to demarcate the extent of braid plains within higher elevations as they are majorly confined by glacial valleys but as the river flows on to the region of plains, there is no factor that confines the river channels, as a result of which they carelessly wander across the area, thereby further complicating the regional dynamics (Figure 5).This behaviour causes these rivers to be recognised as being wild and largely untameable, owing to which they need to be looked at from a different lens and therefore provided with alternative levels of protection and conservation.

Due to the mobile nature of braided rivers, as they shift both laterally and longitudinally, figuring out the exact extent of a specific braid plain with respect to a river is complicated and, in some cases, not even possible for a myriad reason.

Figure 5: Generic Schematic Section of How the Site Extent Functions in Dry vs. Monsoon Periods



Note: Landscapes like diaras, chaurs and tals are a result of fluvial/riverine processes whose constant state of flux implies a healthy riverine ecosystem.

Source: Author

Braided river plains are unique fragile ecosystems (Braidplains: Habitat Loss, n.d.) that offer numerous life supporting ecosystem services; some of which even act as buffers against some of the drastic impacts of climate change. Many times, their natural presence defines the critical infrastructure in addition to maintaining the equilibrium of the surrounding lands. Yet, a lack of clear demarcation makes it difficult to preserve the braided rivers and their plains the way they ought to be as these ecosystems often succumb to a state wherein they compete against versatile human interests and evolving anthropogenic needs. Coupled with a lack of defined riparian boundaries, the resultant scenario is pretty obvious yet catastrophic as the anthropogenic functions like rapid urbanisation, intensive agriculture etc. slowly encroach over the very systems that offer the core ecosystem services vital to our sustenance, thereby destroying the equilibrium of the processes that drive the functioning of braided river ecosystems. This calls for a need to strike a balance between anthropogenic needs and conservation of these eco-sensitive systems.

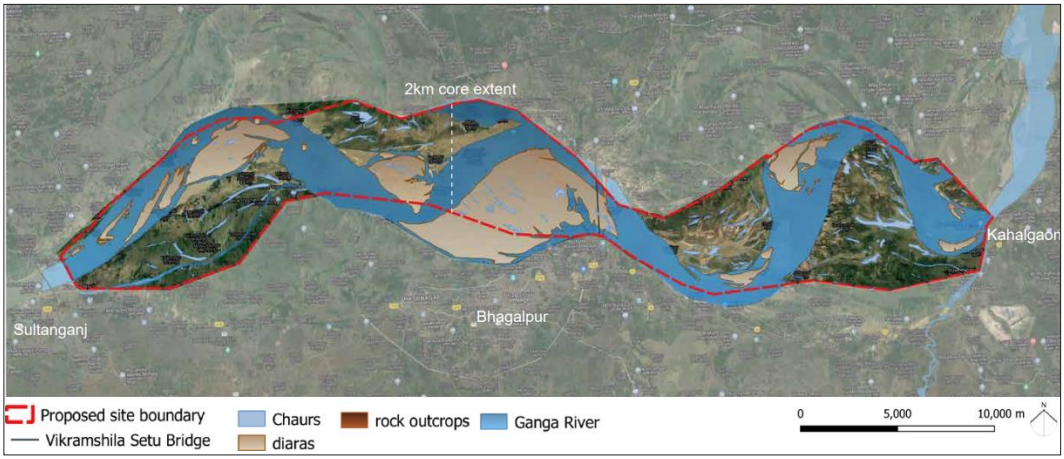
One way of defining the aerial extent of these braid plains is to look back over the course of a century to see how much space these rivers and their plains have actually occupied when devoid of any anthropogenic interventions—also referred to as active floodplain zones. This can help us carve out an average extent that has to be preserved on a priority basis for the healthy sustenance of the braided river ecosystems.

Meanwhile zoonotic spillover in its actual form alone is a serious predicament on its own, as seen in the case of the ongoing COVID pandemic. So, in the case of a fragile ecosystem such as a braided river the outcomes are only going to magnify tenfold. To and fro pathogenic transfer between humans and faunal species is a product of a multitude of factors, namely, climate, ecosystem ecology, changing land use, deforestation, habitat destruction and fragmentation, agriculture and food insecurity, socio-economic factors and landscape interventions. This makes it all the more important to have a clear understanding of the same before attempting to resolve any of the existing site issues. Adopting a nature-based design approach with ecological interventions is the ideal way to control the magnitude of a zoonotic spillover while preventing potential pandemics or epidemics in the future. It is not about the number of interventions or barriers proposed to counter the issue but rather the time and space in which the favourable barriers may coincide. Likewise, the nature and character of the intervention site also plays a relevant role in determining the degree of zoonotic spillover or ensuring zoonotic resiliency through means of strategic ecological interventions.

Likewise, the extensive literature studies were taken forward to critique some of the existing site similar case studies, which proved quite instrumental in delivering a few characteristic inferences of which the core takeaways would be the omnipresent understanding that things happen for a reason in addition to strengthened emphasis on the fact that the relationship between healthy landscape and resilient species are correlated.

Vikramshila Gangetic Dolphin Sanctuary — An Overview

Figure 7: Base Map Showing the Extent and Natural Landform Diversity of the Proposed Site



Source: Modified by the authors from Google Earth (n.d.). Vikramshila Gangetic Dolphin Sanctuary. Retrieved December 15, 2020, from https://earth.google.com/web/search/Vikramshila+Gangetic+Dolphin+Sanctuary,+Bhagalpur,+Bihar/@25.30462976,86.93091181,32.14081942a,52122.55085729d,35y,0h,0t,0r/data=CigiJgokCSfh6U9lJTNAESjh6U9lJTPAGa4pHvubUT9AIQZx5aVPLVHA, OpenStreetMap. (n.d.). Vikramshila Gangetic Dolphin Sanctuary. Retrieved December 15, from https://www.openstreetmap.org/#map=11/25.3487/86.8696, Behera, Mishra, & Sinha. (n.d.). Vikramshila Gangetic Dolphin Sanctuary. BirdLife Data Zone. Retrieved December 15, from https://datazone.birdlife.org/site/factsheet/vikramshila-gangetic-dolphin-sanctuary-iba-india

The actual extent of VGDS spans a radius of 10 km from the Ganga River edge. However, here the research shall only deal with the sanctuary core that covers a radius of 2 km from the Ganga River edge (Figure 7). The actual core of the sanctuary spans a distance of 60 km from Sultanganj to Kahalgaon within Bhagalpur district, Bihar, covering an aerial extent of approx. 5000 ha (12355.27 acres). Being a braided riverine habitat, its boundary and expanse undergo constant change due to the altering geomorphology of the Ganga River.

A Zoonotic Perspective

The diverse biological profile of the region accompanied by a juxtaposition of biological diversity and intense urbanisation right at the river edge makes the region of Bihar a natural reservoir of pathogen carrying zoonotic vectors, and therefore a potential zoonotic spillover. A careful overview of the Annual Communicable Disease Surveillance Report, 2011, Bihar, and National Vector Borne Diseases Control Programme clearly showcase an ever-increasing graph of multiple zoonotic cases of both vector and waterborne diseases of which a greater percentage has only resulted in subsequent deaths in the region of Bihar (State Health Society, 2011).

Additionally, Gangetic dolphins are also host to human pathogens that may not be limited to Cyclorchis campula, Echinochasumus andersoni, Anisakis simplex, and Contra caecum lobulatum (Swinton, J., & Gomez, W. (n.d.)). This in addition to improper anthropogenic practices and inferior sewage (anti pollution infrastructure) renders the proposed site extent capable of a zoonotic pathogen spillover into the riverine ecosystem.

However, keeping in mind the vast diversity of zoonotic diseases and their vectors, this paper shall address those infections predominant in the region, namely:

- Vector-borne (Malaria, Acute Encephalitis Syndrome, Japanese Encephalitis, Kala-azar, Chikungunya, Dengue, Filaria)
- Enteric, Food and Waterborne Diseases (Acute Diarrhoeal Disease, Bacillary Dysentery, Typhoid fever, Cholera Shigellosis)

Route to Solutions

"Sometimes not intervening is also landscape architecture."

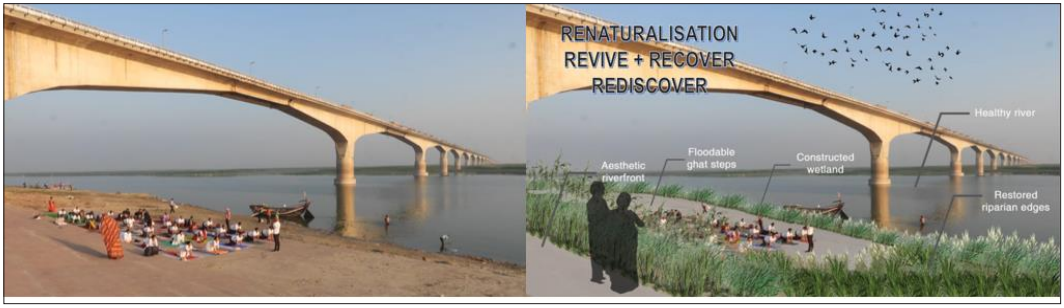
The above statement explains the approach chosen so as to combat the prevailing issues in the proposed site extent.

The Ganga is a dynamic river with a personality that is strong, fluid and expressive Allowing her to express herself to the fullest is perhaps the best way to ensure that natural equilibrium is restored. The sustenance of braided river ecosystems is heavily dependent on the proper equilibrium with which the associated ecological processes such as abrasion, siltation, erosion etc. take place. Making room for the river is the ideal way to ensure the proper sustenance of the braided river ecosystem while minimising extensive loss of life and property during floods.

One of the major methods of achieving a unified health resilient Gangetic riverscape within the VGDS area is to increase the population of Gangetic dolphins and similar such key indicator species for this will help strike a solution with respect to a majority of the problems faced by the different Gangetic riverscapes. By revitalising the river stretch, not only will the biodiversity thrive but at the same time the project shall also help tourists and locals understand the relevance of the presence of Gangetic Dolphins in the river.

The design proposal therefore pitches the concept of rewilding—a package theme comprising three sub themes: Renaturalisation, Revive + Recover, and Rediscover (Figure 8). Rewilding is an innovative yet quite a simplistic approach of resolving perhaps the most complex of problems prevalent in the region by allowing the natural ecological processes to take over and etch the destiny of the fluvial landscapes, as a result of which the braided river ecosystem can thrive and prosper. Further, this shall also help tackle and therefore resolve practically all the urban challenges faced by the proposed site extent such as improper / absent tourism infrastructure, urban encroachments, urban floods, arsenic and fluoride poisoning, declining fisheries etc. while creating aesthetic yet functional open spaces to be used in harmony by both humans and other species prevalent in the region—therefore a win-win situation for all.

Figure 8: Photomontage Showing Before and After Implementation of Strategies under the 3Rs Concept at Barari Ghat under the Vikramshila Setu, Bhagalpur

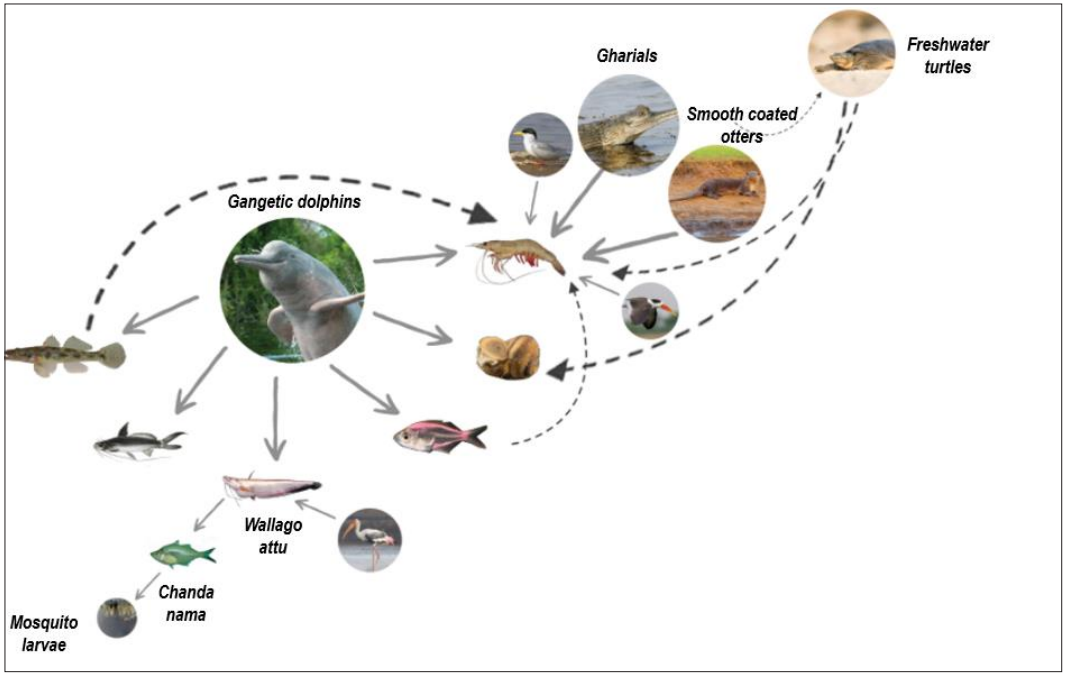


Note: The photo has been captured by Deepak Kumar. The photomontage on the right side has been prepared by the authors over the photo

Source: VGDS biodiversity conservator, Deepak Kumar

Each of the proposed sub themes strategically target the prevalent challenges associated, thereby effectively revitalising the area of the sanctuary. Additionally, this proposal adopts an indirect approach towards establishing a sanctum for the Gangetic dolphins (Figure 9) as sometimes the key to resolving multiple problems might lie in fixing just one instead of trying to find many solutions for all. Rather than purely focusing on developing just the dolphin habitat, the design proposal focuses on restoring the habitat of key indicator species (gharials, smooth coated otters etc.) and those species that these dolphins depend upon as bottom feeders which are a major prey source for them. This way the river's health also improves while simultaneously improving the quality of life for all the species in question.

Figure 9: Gangetic Dolphins as the Apex Predator



Note: A food web representation indicating the importance of Gangetic dolphins as the apex predator in the food chain and how it indirectly contributes to escalating or reducing zoonotic spillover. Its presence and absence alone can modify the natural equilibrium equation drastically

Source: Author.

Project Implementation and Stakeholders

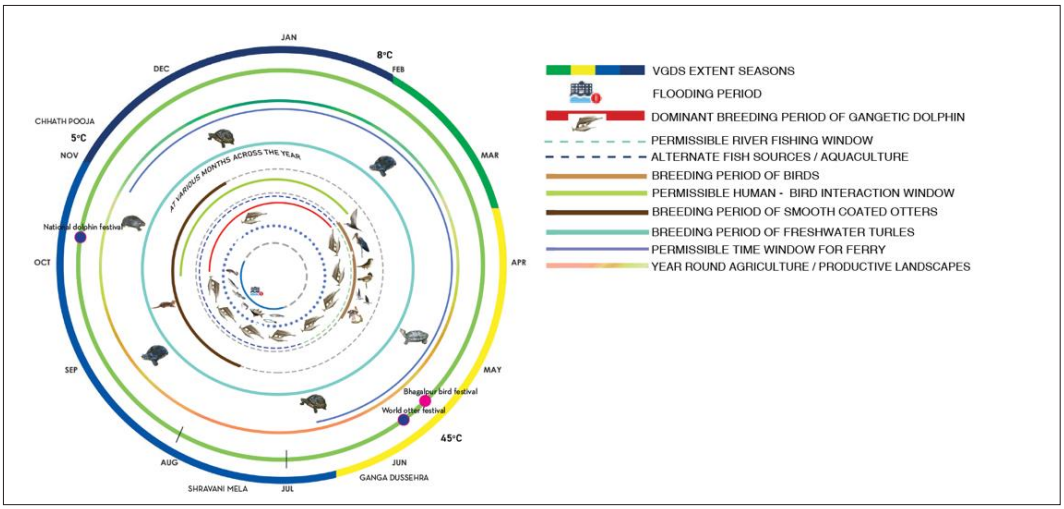
The proposal envisages three major phases in line with the 3Rs concept so as to achieve an output for the holistic health and functioning of the VGDS. To extort the fullest site potential, the entire proposal has to be executed in a strategic and careful manner on the basis of annual monitoring, evaluation and implementation of key lessons learnt. The strategies proposed as part of the design proposal are also aligned with the SDGs proposed by the UN which is an added benefit. The main areas of work that shall be addressed as a result of this proposal include:

- River health protection, environment preservation and landscape conservation
- Recreation, religion and sustainable tourism
- Local livelihood and awareness
- Management and organisation

The proposal further visualises the setting up of a Programme Steering Committee (PSC) at both national and state level. The holistic project however shall be governed by National Mission for Clean Ganga (NMCG) and National Institute of Urban Affairs (NIUA) , who will each follow their own pre-established mechanisms of governance and if need arises may constitute their own monitoring and steering committees for overseeing the project. At a micro level, the local communities need to be made a part of the entire project execution for it is only their involvement that determines the success or failure of this project. Active involvement by the local communities can help conserve the natural landscapes through means of best practices to be incorporated as part of their livelihood routines, in addition to being active role-players in imparting awareness of the local biodiversity to the visitors accessing the river.

As discussed above, a comprehensive landscape development master plan (Figure 11) based on the 3Rs concept has been conceived along with a design programme that decides the permissible and proposed activities within the sanctuary extent (Figure 10).

Figure 10: Design Programme Wheel on an Annual Basis



Source: Author.

Core strategies proposed as part of Renaturalisation:

- Establishing a designated active floodplain region.
- Restoring and daylighting the natural hydrological connections to the main river channel.
- Conservation, preservation and diversification of the natural mid-channel islands or diaras.
- Establishing riparian corridors with effective soil erosion control and bank stabilisation strategies.
- Introducing subtle modifications of faunal habitats of species such as smooth coated otters, fishes etc.

Core strategies proposed as part of Revive + Recover:

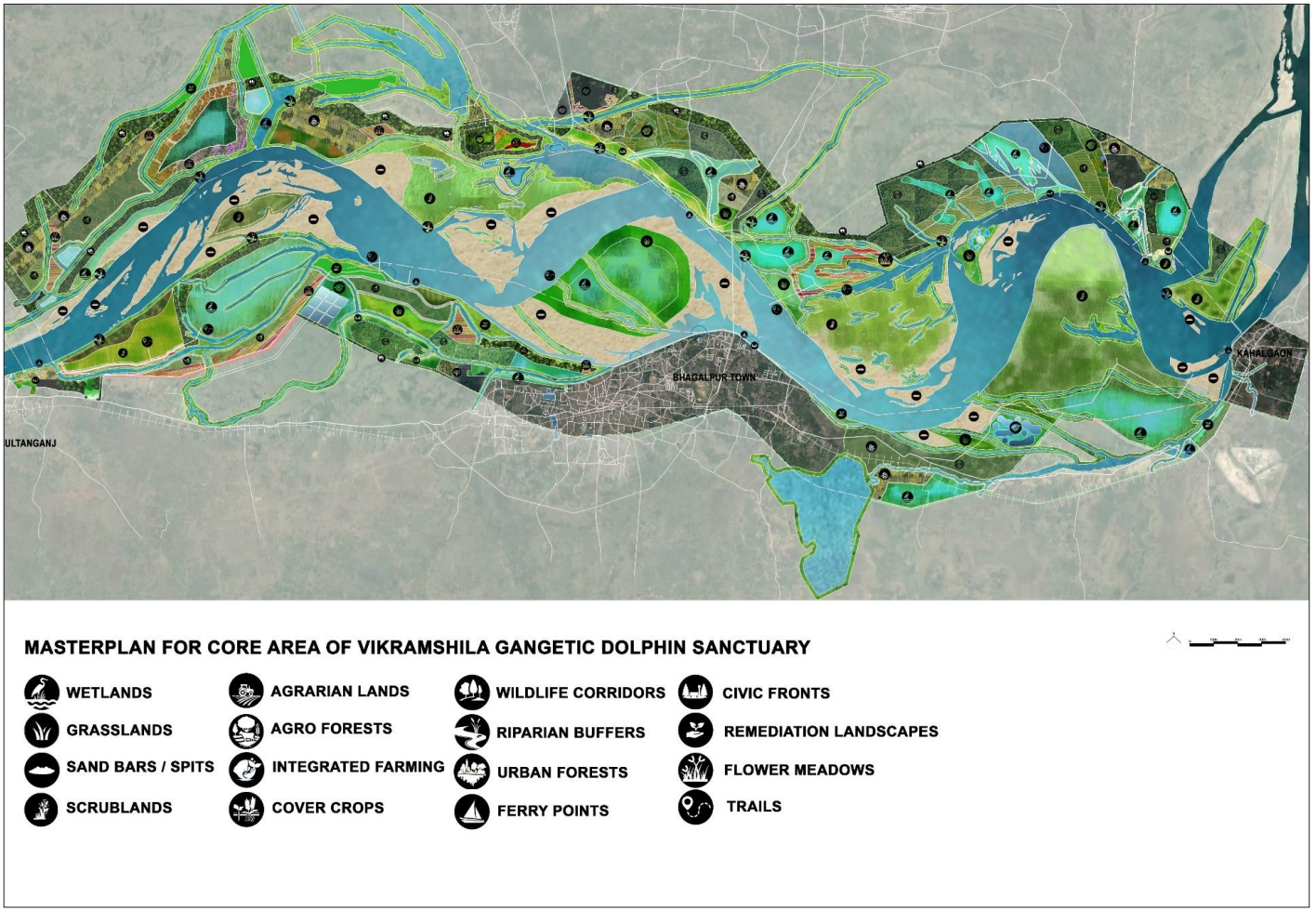
- Installing trash boom barriers at the mouth of the meeting points of lower order water channels with the main river channel to counter solid waste accumulation.
- A series of remediation glades, riparian buffers and natural and constructed wetlands with phytoremediation abilities to counter issues like arsenic and fluoride poisoning.
- Revamped agro site zoning for the entire sanctuary extent considerate of the site ecological sensitivities.
- Designated 'No Fishing' zones and natural hatchery ponds on diaras in an attempt to develop sustainable fisheries in the region.
- A scientific design-oriented approach to control prevalent zoonoses in the region through strategic planting and interventions such as urban forests, flower fields and pollinator fields based on the two core concepts—zooprophylaxis, and introducing floral species with higher sugar level content.

Core strategies proposed as part of Rediscover:

- Modified ghats design.
- Eco-sensitive nature trails and floating footbridges.
- Ferry points.
- Watchtowers.
- Innovative signages as part of species awareness programme.

The design proposal is based on ideologies like adaptive reuse and retrofitting of the natural environment owing to which the strategies proposed are majorly cost-cutting in character through measures such as incorporating native regional species majorly etc

Figure 11: Comprehensive Landscape Development Master Plan



Source: Author

Zoonotic Resilient Landscapes

The paper has already addressed the basics of zoonosis and the extent to which zoonosis is prevalent in the site as well, however this is yet to be explored further on the concept of turning an environment into a zoonotically resilient landscape. Although the design proposed is carried out with a penchant for ensuring a balance within the eco-sensitivity associated with the site of concern, yet it is imperative to explore the extent to which zoonotic resilience has or hasn't been achieved through means of strategic design interventions. At the same time, it is also essential to understand the benefit of these interventions in the grander scheme of things.

Ensuring a continuous landscape ecosystem with minimal human intervention and interferences contributes a great deal to zoonotic resiliency. However, that alone is not sufficient to achieve an ideal zoonotic resilient environment as there still persists a chance for a potential zoonotic spillover as the urban towns of Bhagalpur, Kahalgaon and Sultanganj are quite close to the sanctuary core. To control this spillover, strategies like urban forests, wildlife corridors, flower fields, pollinator hotels etc. were proposed. But this too will work only to an extent within the sanctuary core.

What about the urban settlements then? How can accidental spillovers be controlled there?

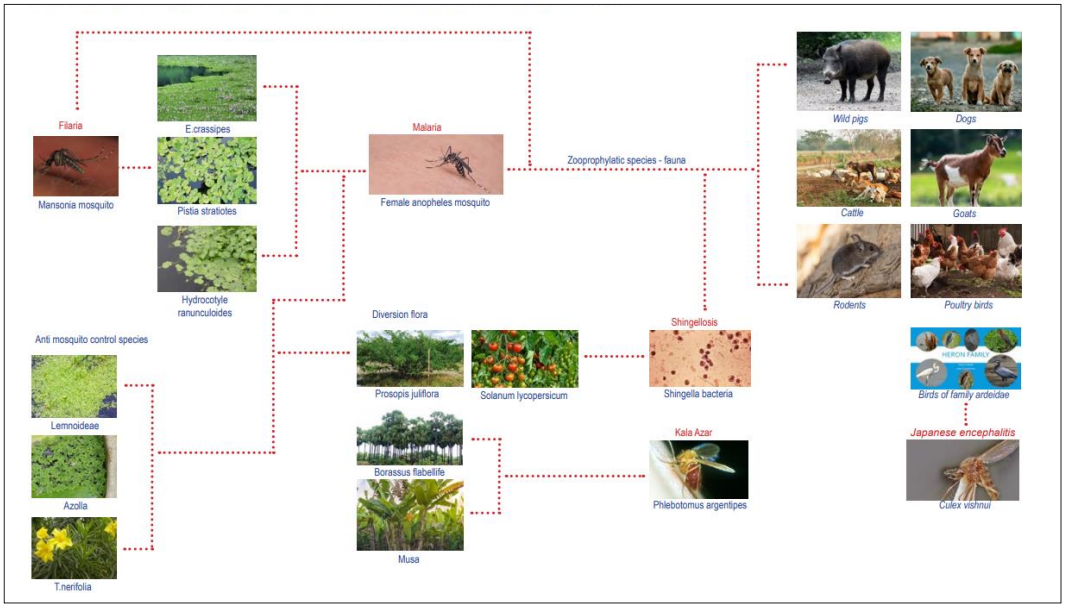
What needs to be understood here in this context is that more often than not humans are not the primary meal option for most zoonotic vectors like mosquitoes (the dominant zoonotic vector in VGDS). Rather they end up as a meal due to lack of options mainly in addition to other influencing parameters. This is quite a valuable piece of information that landscape architects and designers may exploit in the design and this is exactly what has been attempted here as well. An environment for alternate faunal species and natural reservoirs of zoonotic vectors have been established as a zooprophylaxis[7] control strategy to redirect the mosquitoes away from humans (Figure 12). Likewise, a planting palette composed of species with high sugar levels can help to redirect the mosquitoes away from humans by offering another optional meal source as mosquitoes are known to feed on sugar rich plants and flowers in the absence of human presence in the region. Spraying sugar solutions on plants such as banana (musa) is also a tried, tested and proven technique (Poché, D. M., Torres-Poché, Z., Garlapati, R., Clarke, T., & Poché, R. M. (2018)).

Further, in the urban centres, it is important that the plant species be based on a carefully curated palette as there are species known to be quite essential just for the mosquito lifecycle alone to be completed! For instance, plants like water lettuce, floating pennywort, water hyacinth etc. are known to be favourable for the survival of female anopheles mosquitoes responsible for malaria (Stone, C. M., Witt, A. B. R., Walsh, G. C., Foster, W. A., & Murphy, S. T., (2018)) while dense planting of duckweed, aquatic ferns or using anti plasmodium plant sources like T.nerifolia (Hien, D. F. d. S., Dabiré, K. R., Roche, B., Diabaté, A., Yerbanga, R. S., Cohuet, A., Yameogo, B. K., Gouagna, L.-C., Hopkins, R. J., Ouedraogo, G. A., Simard, F., Ouedraogo, J.-B., Ignell, R., & Lefevre, T., 2016)

[7] *Zooprophylaxis is the use of wild or domestic animals, which are not the reservoir host of a given disease, to divert the blood-seeking malaria vectors from human hosts. Basically a diversion strategy.*

can hinder mosquito growth. Simultaneously it is important to be aware of the ecology that gets established as a result of a certain environment before proposing landscapes like fragmented urban forests etc. so that sylvatic species may be avoided. Sylvatic species are infamous as vector hosts of numerous zoonotic infections and they thrive in coexistence with human life and resources. This, when supported by non-design strategies like vaccination etc. is what zoonotic resilient landscapes are all about.

Figure 13: Schematic Flowchart Citing Examples for Planting and Animal Reservoirs



Note: This schematic flowchart is used to understand how zoonotic resilience may be achieved in the proposed site extent.
Source: Author

Discussion

"Maybe zoonoses are like animals—fighting to be the survival of the fittest trying to face the man who is devastating their homes." (Mallavolu, 2019)

The primary aim of the study was to explore and identify if the idea of developing a zoonotically resilient landscape is possible or not with a site as dynamic as Vikramshila Gangetic Dolphin Sanctuary and it can be safe to say that it is possible. However, it can be effective only if the proposals and interventions are based on inputs from professionals of various disciplines, supplemented with policies at a regional level. It is essential to recognise and elucidate the causal zoonotic drivers so as to adapt the landscape epidemiology knowledge into effective public health interventions. Strategic and prioritised calls need to be taken in addition to ecological

interventions that complement the conventional interventions for attaining higher success rates. The case studies carried out have made it transparent that the zoonoses are mostly an outcome of anthropogenic drivers.

Although notified in 1991, VGDS remains a protected sanctum for the Gangetic dolphins only on paper. The proposed findings are a result of a deep and intensive study of the natural ecological conditions of the entire VGDS site keeping in mind the socio-economic-cultural scenario as well. Therefore, the solutions so proposed also majorly focus on ecological river sustenance, its associated systems and biodiversity, which indirectly can help promote a better quality of life for humans as well. The outcome is a prototypic design approach and framework that may be adapted into any manner of waterscapes across the country or lay a foundation for advancements at a global scale.

Incorporating the element of zoonoses into the research paradigm only assists in further exploring a river-sensitive development prototype that is resilient to potential pandemic or epidemic scenarios, which in the light of the ongoing COVID-19 global pandemic makes further investigation and study imperative. The strategies covered here follow the One Health approach that credits the positive health of our planet to the health of humans, animals and the environment, which offers multiple benefits such as increased blue-green infrastructure, enhanced quality of life, improved river health and increased awareness of man of the existence and importance of nature and its ecosystem services.

Likewise, another integral component of this study is an attempt at documentation of the existing research relevant to the maintenance of Vikramshila Gangetic Dolphin Sanctuary, thereby acting as a database for future research in this region and for similar databases to be developed for the river in its entirety. The solutions offered in this paper are merely a starting point which, when implemented shall offer an environment with resilience as its foundation for existence. Only so much can be covered within a constricted frame of time and words. Yet it is anticipated that the successful implementation of the strategies and interventions cited here would be seen as a trailblazer for many similar waterscape projects to unfold at both a national and a global scale in the immediate future.

Owing to the novelty associated with the chosen topic of research, a sliver of possibility persists with respect to developing an ideal design output as this is an ongoing area of research. However, a key limitation that lies in the fundamental understanding of disease emergence is the complexity involved because of the unknown ecology in unknown hosts. This is quite a fundamentally ecological problem that demands large-scale field studies in addition to interdisciplinary collaboration between ecology and health. The spillover is an outcome of a series of barriers that a pathogen overcomes from the host reservoir to human settlements. Although our knowledge about mosquitoes and other potential vectors is increasing by the day when it comes to disease ecology basics, strategies to control and manage the spillover in humans is quite limited. There may be a multitude of ways to achieve zoonotic resilience apart from all that is proposed here but understanding pathogen persistence in abiotic environmental reservoirs provides scope for introducing simple interventions that operate on multiple interacting levels to manage zoonotic

spillover risk in a landscape. However, targeting the interface of contact can perhaps offer solutions in the most unexpected ways. Which is why the question here is how we can integrate ecology, health and a multitude of other parameters that influence a zoonotic spillover because that is the way to design landscapes resilient to zoonotic attacks.

Further, as discussed earlier, the stretch of Ganga that passes within the VGDS site is of braided character. Effective sustenance of such ecosystems is possible only when the natural ecological processes happen in the way it should be. Also, most of the issues experienced in the proposed site extent are a result of a multitude of activities that occur both upstream and downstream, which is why, if the proposed site is to truly tap into its potential, it is imperative to resolve those issues such as damming rivers, sewage influx into the rivers, construction of barrages on rivers such as the Farakka Barrage etc. prior to dealing with the proposed site challenges. Moreover, it is now more important than ever to look at alternative solutions to those already proposed as a means to resolve current problems as for each intervention so proposed, there may be issues that may be arising somewhere outside of the intervened zone. Last but not least, the key to protecting the Gangetic dolphins through the development of a sanctum lies in the holistic revitalisation of the region to support the key indicator species of the region as this will indirectly help sustain the habitat of the Gangetic dolphins by ensuring that the factors essential for their survival such as clean river water, necessary amount of fish supply, residential areas such as river meanders etc. are present. This is a classic case of hitting multiple birds with a single stone, or rather, a motive in this case. The biggest advantage of the same being the fact that the proposed idea is scalable and can be adapted along the other stretches of the Ganga or anywhere in the world. Further, almost all the Sustainable Development Goals (SDGs) can be achieved upon the successful completion of the project interventions.

The vast repository of data waiting to be uncovered and the complexity associated with living systems is in itself a boon and a limitation in this research. There are multiple directions in which this research may be taken forward in future. The solutions offered here are only a mere possibility of the scope and potential of this project and there may be numerous ways in which this idea may be explored further while keeping the essence intact.

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Conflict of interest

The authors declare no conflict of interests.

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Integrated Sustainable Tourism Development: A Case Study of Ayodhya City

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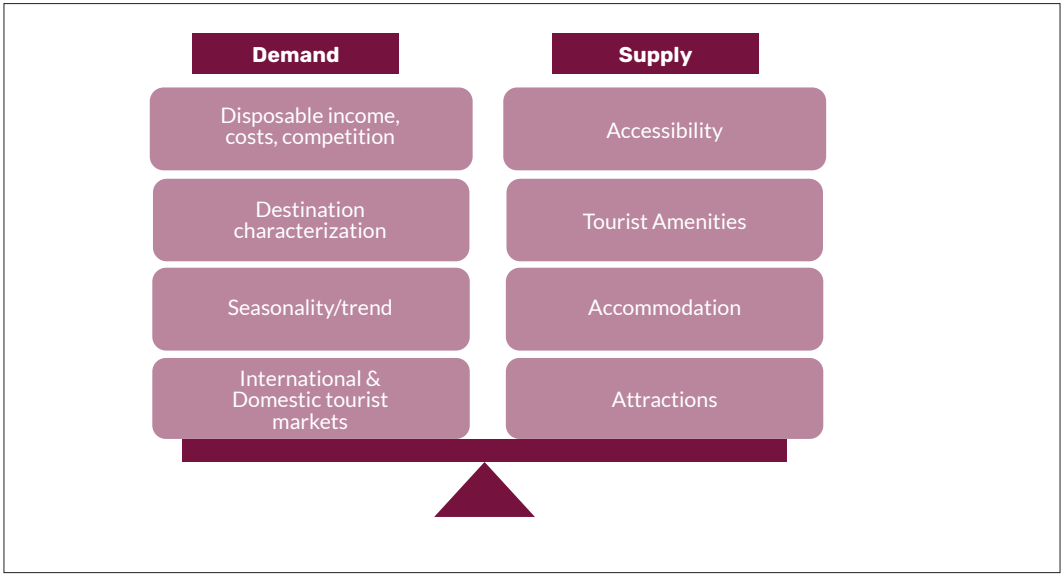
Abstract

The cross-cutting nature of tourism that connects multiple facets of the 17 UN SDGs has resulted in it evolving globally from being a tool of leisure to being a tool of comprehensive development. This change has propelled planners and public policymakers to adopt the concept of 'Destination Development through Tourism'. This, in turn, has led to the development of multiple approaches, ranging from an issue-oriented approach that ponders on the principle that addressing existing infrastructural gaps would automatically develop tourism destinations, to a thematic approach that hypothesises the theme/character as central to the tourist's decision making, acknowledging that addressing infrastructural issues/gaps in destination development is not just a need but a necessity. Although these approaches foster a broader tourist base leading to greater market capitalisation, the exclusion of social and environmental dimensions calls out for an inclusive, sustainable approach to tourism that is integrated in nature. This is the context within which this paper attempts to formulate an integrated sustainable development approach that collates the 5A's (Accessibility, Accommodation, Attractions, Activities, Amenities) and the travel trade using Ayodhya as a case study.

Introduction

Travelling, once viewed as an essential tool for survival that served the crucial needs of food, water and shelter, in the modern world, has transformed into a need driven by the desire for experiencing– a change that can be attributed to psycho-sociological proponents. The entry of the middle class across the broader spectrum of the consumer market in the post-neoliberal era has given rise to a significant multisectoral industry generating USD 8.9 trillion globally (i.e. 10.3% of global GDP, (Suri, n.d.). With one out of ten people employed in a tourism affiliated industry, the need to channelise the sector through planning for a sustainable world is clear (World Tourism Organization (UNWTO) & United Nations Development Programme (UNDP), 2017).

Figure 1: Demand and Supply Factors of Tourism



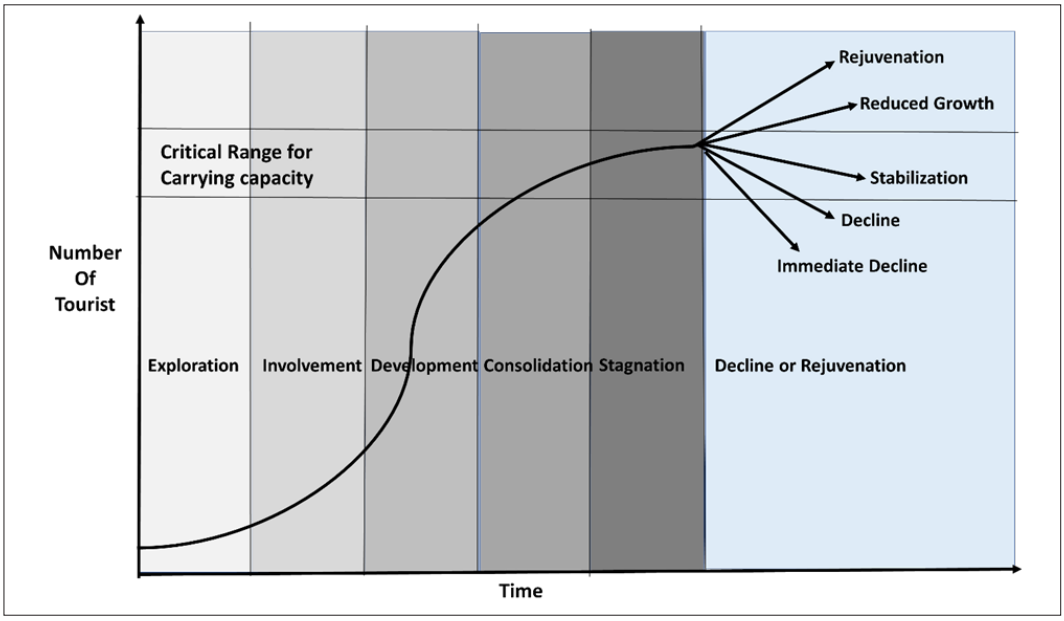
Source: Authors summarised from contemporary research

The tourism industry, like every other industry, also operates on the micro-economic principles of supply and demand as depicted in Figure 1. Supply is determined by tourist attraction, accessibility, tourist amenities and accommodations, whereas aspects such as disposable income, cost competition, seasonality/trends, destination characterisation, as well as the international and domestic tourist markets comprise the demand that frames tourist choices at a broader level.

Butler's model (Sahli,2020) namely, exploration, involvement, development, consolidation, stagnation and decline or rejuvenation. In each stage of the life cycle, the destination undergoes a series of changes defined by the author. The purpose of this study is to apply the TALC model to the tourism destination Hammamet (Tunisia tries to capture the life cycle of tourism through phases from exploration to decline/rejuvenation by analysing its relationship with time and number of tourists. The model suggests that when a destination evolves on its own, there comes a stage when intervention is required to sustainably channelise tourism development based on critical carrying capacity, while suggesting that the direction the destination takes towards rejuvenation or decline is determined by the approach adopted.

The evolution of approaches to tourism in modern planning began with an issue-oriented planning approach, wherein it was assumed that tourist destinations would spontaneously develop when core infrastructural issues were resolved. However, it failed to stand the test of time because of dynamism in the sector. In the late 1990s it was realised that there was a need to emphasise an approach based on 'character' or the attraction, around which a thematic approach was developed, where the market caters to the demand created by special interests (Gunn, 1994; WTO, 1994; Wilkinson, 1997; Timothy, 1999).

Figure 2: Butlers' Tourism Development Model



Source: Butler's model (Sahli, 2020)

The significant issue with this approach is that it emphasises only financial benefit in catering to market demand, characterised by tourist wants over destination area development. As such, it overlooks the local community and other stakeholders and, as a result, ignores social and environmental costs. Further, because it is market-driven without a cap or threshold, it turns out to be exploitative in the long term as it fails to include the factor of sustainability.

Tourism sector, acknowledged for its valuable contribution towards achieving the 17 SDGs (UNDP, 2017), It becomes even more crucial to develop a comprehensive perspective, beyond the secluded thematic tourism approach, which could lead to the formulation of an integrated, sustainable tourism development approach by integrating the 5A's (Access, Accommodation, Attractions, Activities, and Amenities) through enabling actions.

This research intends to develop a planning approach that is inclusive and integrated in nature, acknowledging interdependencies in channelising the mass religious tourism potential of Ayodhya with river tourism and ensuring sustainability through an integrated tourism approach.

Significance and Need for the Study

Located on the banks of the river Sarayu, the city of Ayodhya extends its significance over the social-cultural, environmental, as well as the economic spheres. Socio-culturally, the city is recognised as one of the seven (sapta puri) sacred cities of Hinduism and is the gateway of the government of India's most ambitious Ramayana circuit. Being an ancient historic capital, of the kingdom of Kosala and also the nawabs of Awadh, its significance is recognised across religions

and cultures with more than 105 Hindu religious and historic heritage structures concentrated in the Ayodhya zone (UP Tourism). Ayodhya also stands out as pivotal to Jainism, as it was the birthplace of five tirthankaras and visited by Mahaveer himself, and so its Jain heritage goes back 2500 years. Built upon as the first capital of the nawabs of Awadh, it is a vital destination of the Sufi sect of Islam encompassing significant places such as Bahu Begum ka Maqbara, Gulab Bari, Imam Bara and others. It is also of significance to Sikhs with gurudwaras such as Bramha Kund and Nazarbagh whose establishment can be traced to Guru Nanak Ji and Guru Tej Bahadur Ji. In addition, cultural links between Ayodhya and Korea that date back to AD 48 through Queen Huh Hwang-Ho, have initiated the development of an inter-cultural repository in the form of a memorial and Korean cultural centres.

Ayodhya is the first major city on the banks of the river Sarayu, and it is urbanising at a tremendous rate. There is a critical need to sustain and channelise the resources that support the mass tourist influx through necessary action plans mindful of its environmental significance. The Sarayu's rich natural landscape, across which lies a heart of faith and heritage with more than 25 ghats each engulfed in historical and spiritual significance, has to be conserved while increasing the potential of developing river-based tourism. The city, transforming at a stage of development and consolidation on Butler's tourism development model scale (as depicted in Figure 2), makes essential the need to look into the critical range for carrying capacity.

Looking at economic significance, with the construction of the Ram temple, Ayodhya is projected to be the epicentre of mass religious tourism, with an expected tourist footfall of around 3.96 crore/ year by 2031 as per UP Tourism (Anon, n.d.). The state and center government have proposed spending more than INR 2000 crore to comprehensively develop Ayodhya as a religious-cultural hub and the epicentre of the Awadh circuit. Additionally, the expected growth of tourists is set to increase by three-fold over the next 11 years (Anon, 2020), which makes channelising a strategy for effective implementation of feasible solutions critical.

Study Area Profile

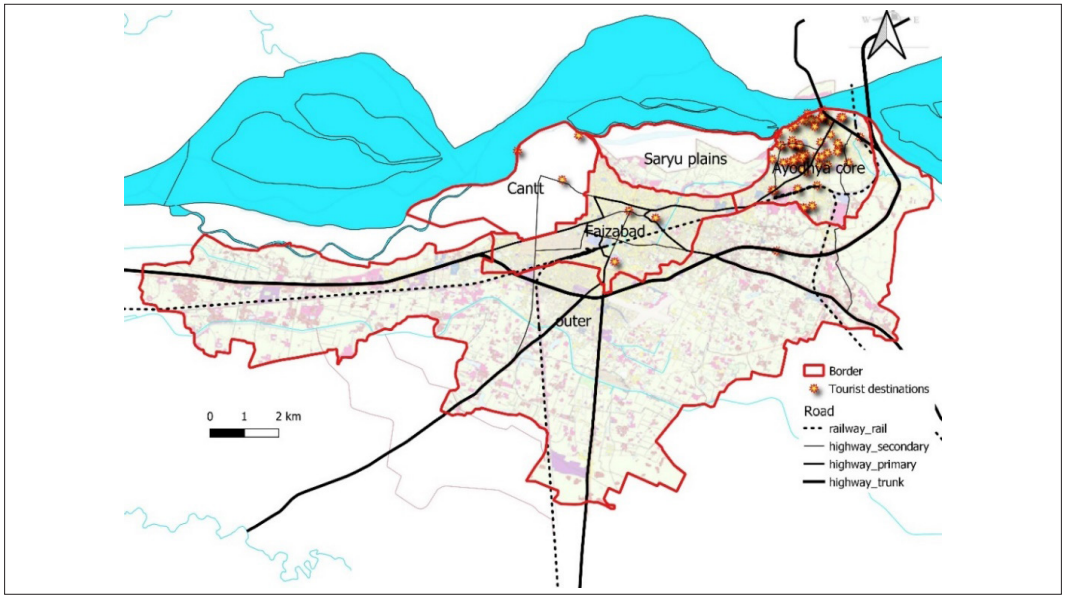
Location and Regional Connectivity

The city of Ayodhya, located in the state of Uttar Pradesh on the banks of the river Sarayu, has emerged as a regional hub with regard to the transportation sector because of its historical and current significance. Situated at the cross junction of roadways connecting Lucknow, Gorakhpur, Prayagraj and Varanasi, the city already has well-established road and rail connectivity. The international airport, currently under construction, will make the town an ideally connected tourist destination. It has frequent bus and tempo services, catering to not just tourism but also industries, including the agricultural sector. With rapid urbanisation of the city, connectivity can act as a boon for both tourism and investors.

Destination Profile

The study area encompasses the jurisdiction of Ayodhya Nagar Nigam and the Cantonment area. It is classified into five different zones (Figure 3) with varied characteristics for analysis-based destination characteristics as briefed below:

Figure 3: Zonal Profile of Ayodhya



Source: Ayodhya Development Authority.

- **Ayodhya core:** Located in the north-eastern part of Ayodhya, the zonal boundary was previously administered as Ayodhya. The zone covers most tourist spots and heritage structures, and the built structures can be categorised as high-density, low-rise developments.

- **Faizabad:** Administered previously as Faizabad Nagar Palika Parishad, this zone encompasses major Islamic shrines, commercial spaces and Awadhi style structures. The built structures here are noted to be high-density, medium-rise developments.

- **Cantonment:** Located on the north-western boundary of Ayodhya, the zone encompasses touristic places of religious and cultural significance with serene landscapes such as Guptar Ghat and Military Mandir. Entry is restricted, with all rights reserved by the army.

- **Sarayu Plains**: The zone has the lowest population density and is located in the central stretch of the study area along the Sarayu River. Notably, the sparse agricultural landscape with village settlements is linked to the fact that the zone was not previously under development.

- **Outer zone:** The outer zone comprises areas newly added to Ayodhya Nagar Nigam, which were previously under the Ayodhya Development Authority. It is majorly agricultural in use, and the increasing urbanisation observed can be attributed to commercial, industrial uses across transits.

Methodology

The study seeks to develop an integrated, sustainable approach for destination development through tourism by analysing the active and passive impacts of factors such as attractions, activities, amenities, accommodations, accessibility, geophysical character, demographic trends, land use, tourist profiles, destination profile, as well as psychometric profiles of both tourists and locals. With Ayodhya as a case study city, a framework consisting of primary and secondary surveys was formulated to capture the data. Secondary data was captured through reports of the Ayodhya Development Authority, Town and Country Planning Organisation, statistical data from UP Tourism, the Sarayu Action Plan Report, as well as Bhuvan satellite imagery, and open street maps. The primary survey captures the strengths, challenges and potential of tourism in the city from multiple stakeholders through:

- **Departmental survey:** Here development prospects with respect to destination and tourism were captured from Ayodhya Nagar Nigam, Ayodhya Development Authority, UP Tourism and the police department.
- **Local resident survey:** Around 100 local residents across all the five zones were surveyed to assess the impact of tourism on the daily lives of locals along with place attachment, from a conservationist's perspective.
- **Commercial establishment survey:** This was conducted for 50 establishments across major markets of Hanumanghari, Ghanta Ghar and the weekly Thursday market to understand the dynamics of travel trade profiling of tourist markets and tourism products.
- **Accommodation survey:** This was conducted across 40 ashrams, hotels and dharamshalas, the survey captures occupancy and stay patterns along with consumption and generation trends across water, power, sewerage and solid waste.
- **Accessibility survey:** This was conducted to capture the travel pattern and plight of auto rickshaw/e-rickshaw/bus/car/taxi/boat from the operators' perspective.
- **Tourist survey:** Between February 2021 to March 2021, 120 tourists were surveyed to characterise the profile of tourists based on nature of a tourist, experiences and perspective andissues based on which tourist characterisation, service quality assessment, image intensity analysis was developed.
- **Non-participant survey:** This survey was conducted online with a sample size of 120 across multiple states and age groups to identify and analyse issues faced by potential tourists, and to assess their awareness, perceptions and preferences from a psychological perspective.

Analysis

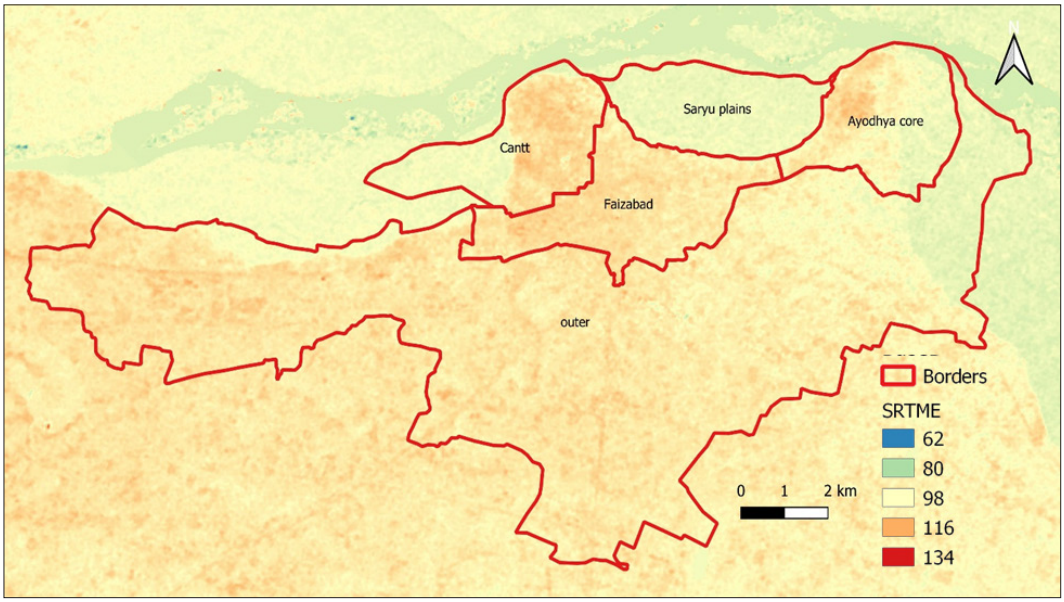
The components with active and passive correlation to the aspect of tourism were identified with an intent to capture the destination's profile in terms of challenges, potential opportunities and gaps through comprehensive integration (cross-analysis of components), underlining the concept of sustainability in approach.

Geophysical Character

An objective analysis was carried out of geophysical components that indirectly impact the city's ecological and tourist character. This analysis considered elevation analysis, state of thermal discomfort, and an overview of solar potential and rainfall trends to derive sustainable strategies to cater to the predicted drastic growth in demand.

Elevation

Figure 4: Elevation Map, Ayodhya

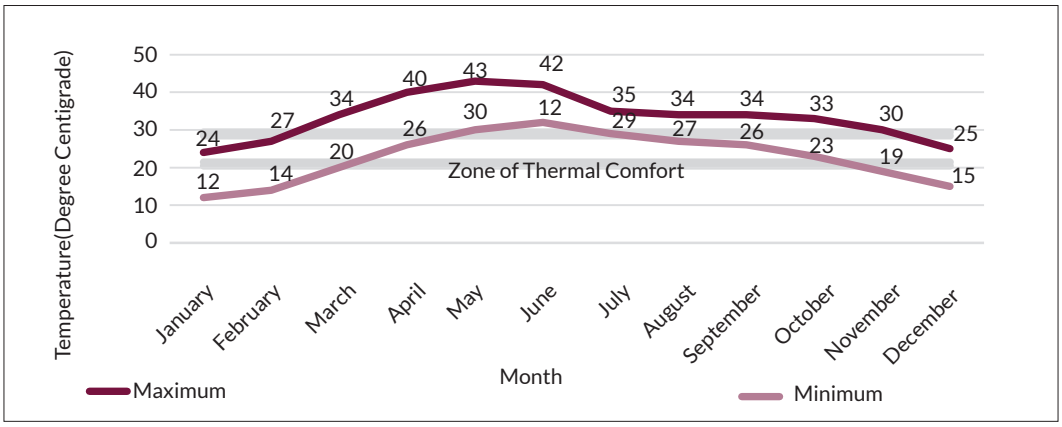


Source: Prepared from bhuvan-app3.nrsc.gov.in (Anon, n.d.)

The city slopes from west to east (Town and Country Planning Authority, UP, n.d.). The eastern part of Ayodhya and Sarayu plains are prone to flooding because of the lower elevation and, as depicted in Figure 4, the prominent tourist destinations of the Ayodhya core, Sarayu plains and Cantonment lie within this region. Hence, the need to develop a flood-resistant strategy to conserve the tourist destination as well as maintaining the beautiful landscapes.

Temperature

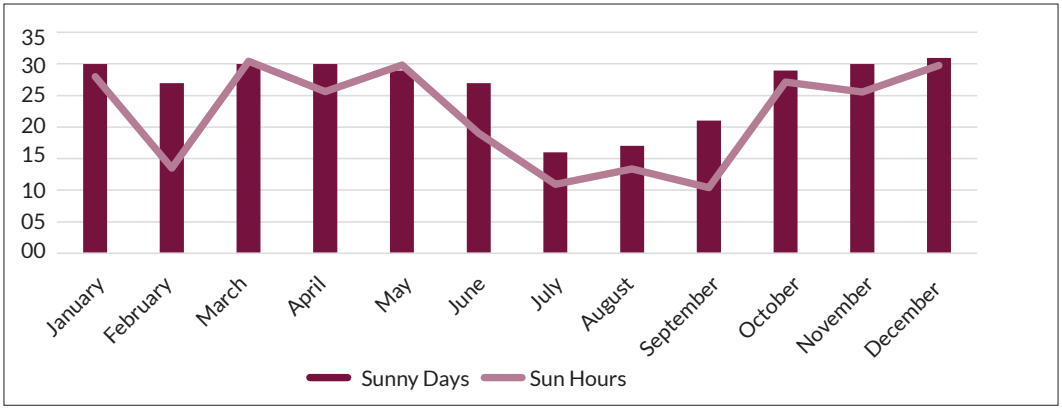
Figure 5: Average Temperature Graph for Ayodhya



Source: worldweatheronline.com (average of 2010–2020)

The average temperature was analysed over the thermal comfort zone to derive inferences as to the correlation between thermal comfort and tourism (Wang et al., 2022). The impact on tourist decisions on visiting season, duration of stay, and mode of intracity travel was clearly visible. Tourist influx and thermal comfort can be seen to be interdependent where tourist influx dropped during months with higher temperatures. During April to June, high temperatures and humidity rise to 43°C, resulting in thermal discomfort, but this coincides with the tourist season (Ram Navami, Hanuman Jayanthi, Holi), which leads to a need for dynamic shading and heat proofing techniques. There exists a high potential to tap solar energy. Ayodhya has up to 240 hours sun hours (Monthly average) with higher sunny days distributed across the year as shown in Figure 6.

Figure 6: Average Sun Hours Graph for Ayodhya



Source: worldweatheronline.com (average of 2010–2020)

Rainfall

Figure 7: (a): Rainfall Trend by Months in Ayodhya

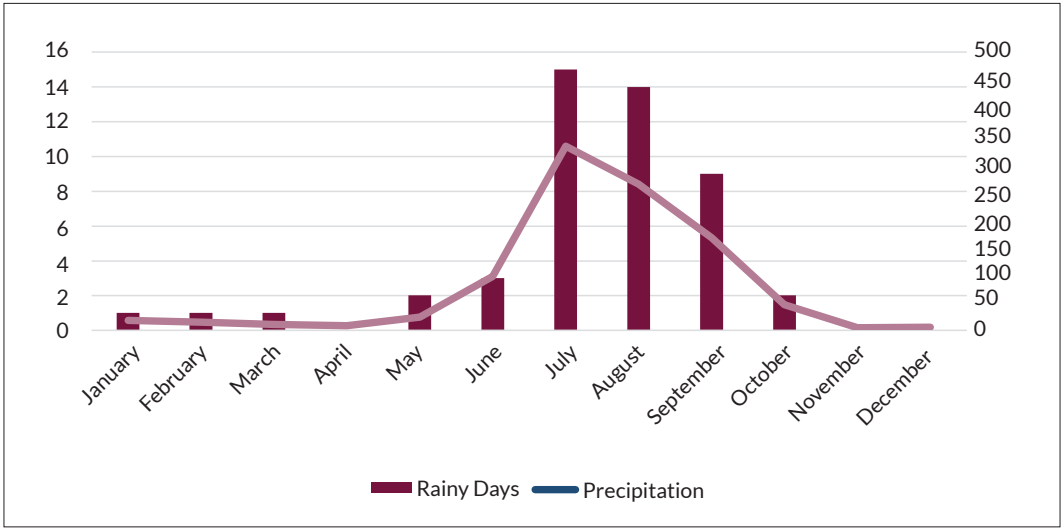
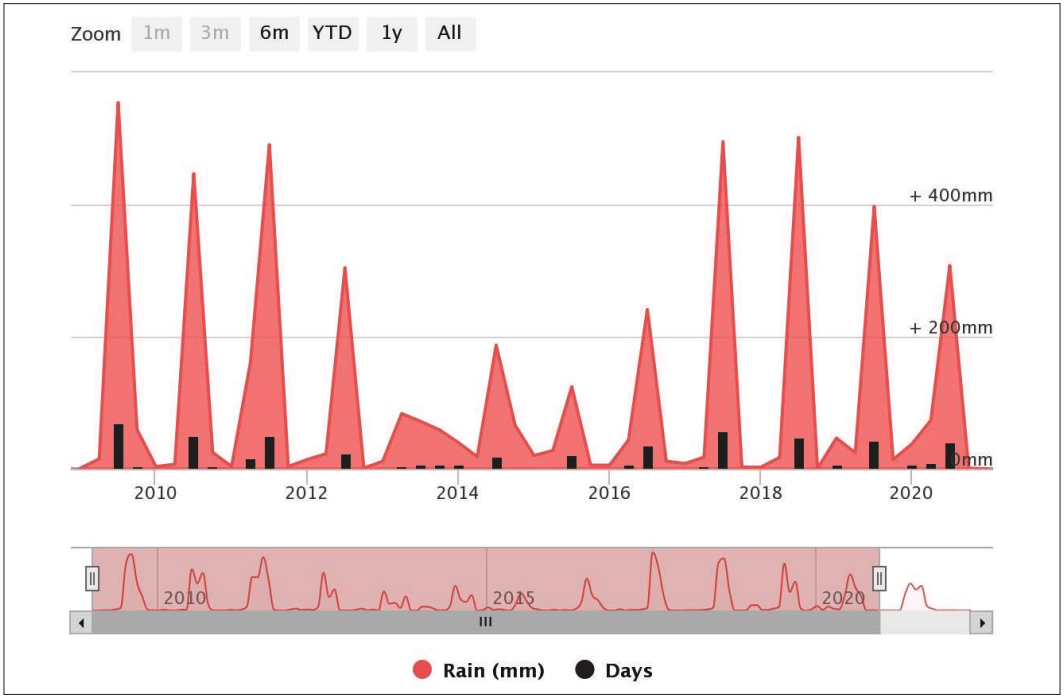


Figure 7(b): Average Rainfall Amount (mm) and Rainy Days



Source: worldweatheronline.com (average of 2010–2020)

An inconsistent and decreasing rainfall trend is observed. with July and August having the highest precipitation, followed by flood-like scenarios emerging across the Sarayu plains. The increasing dependency on groundwater to meet the increasing demand for water underlines the need to conserve rainwater as a sustainable practice.

Land Use Analysis

A qualitative analysis of the impact of tourism on urbanisation and required land use intervention is depicted in Table 1.

Table 1: Land Use Analysis in Comparision with URDPFI's Ideal Developable Area in Ayodhya

LAND USE	Area (in ha)	Percentage Area (Ayodhya)	Ideal Developable Area % (URDPFI)
Residential	1531.21	11.46	35–40
Commercial	21.14	0.16	5–7
Industrial	216.55	1.62	4–5
Institutional	299.37	2.24	-
Public & Semi Public	37.16	0.28	10–12
Recreational	254.42	1.90	10–12 (includes water bodies)
Public Utilities	2.10	0.02	-
Transportation	583.67	4.37	12–14
Other	107.76	0.81	-
Agricultural	7417.29	55.49	-
Rural	605.92	4.53	-
Specific Land Use	4.75	0.04	7–10
Vacant Land	870.60	6.51	-
Waste Land	842.68	6.30	-
Water Bodies	539.18	4.03	10–12 (Includes iecreational use)
Wetlands	33.19	0.25	-
Total	13367.00	100	-

Note: Land Use Analysis based on (Urban and Regional Development Plans Formulation and Implementation) (URDPFI) comparing URDPFI's ideal developable area percentage in a tourist city with Ayodhya

Source: URDPFI (Urban and Regional Development Plans Formulation and Implementation) and Ayodhya Report TCPO UP.

The impact of tourism on urbanisation and required landuse intervention was derived from the land use analysis above. Notably, agricultural land use stands out as significant, primarily due to newly added areas reflecting the state of urbanisation and future scope of expansion.

'Specific land use' can be increased to conserve the core heritage zones, which are currently not covered under zonal restrictions. Wetland degradation attributed to rapid expansion and urbanisation remains a crucial concern. Existing recreational use classification is limited. However, an expanding user base driven by internal casual tourists from the sub-regional areas and expectations of a more significant influx are indicative of the excellent potential of increased recreational use. Hence, increasing recreational land use would cater to the existing population and diversify tourism in the city. It would expand the stay and trickle-down economic benefits to a larger local economy.

With traditional water conservation in the form of kunds gradually declining, kund rejuvenation and reconstruction would add environmental benefits and socio-cultural value. Additionally, accessibility being a concern specially across the Sarayu plains and the outer zone developing transportation networks use would positively change tourism sector.

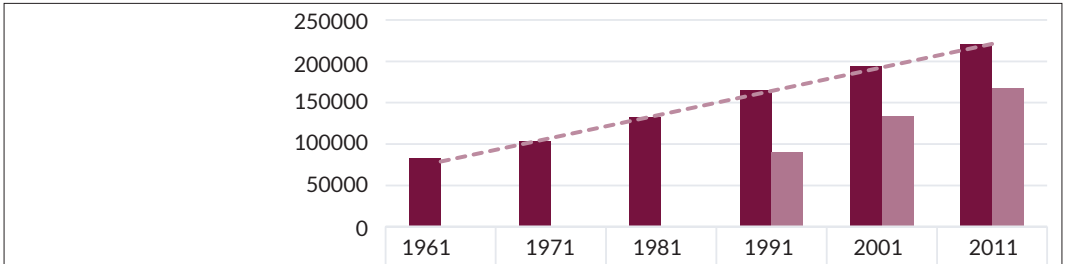
Administrative Structure

A functional profile of administrative organisations involved in Ayodhya's touristim development was carried out wherein crucial administrative, organisational and financial issues were inferred:

- The authority was excessively dependent on grants because of low revenue generation. What this means is that there is a need for newer revenue-generating models.
- Zonal regulations/restrictions were absent in and around heritage sites.
- Land acquisition issues and a need for dynamic pricing models had arisen primarily due to rapid expansion due to acquisition of land in and around the city.
- Interdepartmental coordination issues and limitations of PMU (Project Management Unit) are listed.

Demographic and Tourist Trends

Figure 8: Population Trend, Ayodhya



	1961	1971	1981	1991	2001	2011
Population of Ayodhya Nagar Nigam	83177	102835	132373	165079	194122	221118
Ayodhya Rural Area (Under Development Area)	0	0	0	90500	134292	167216

Source: Town and country planning authority UP (n.d.)

The analysis is based on census and UP Tourism data showing the drastic growth rate of local and floating population promoted by tourism, reflecting potential in terms of international tourists. It could help to develop an activity-based strategy for tourist redistribution and deal with quantum of challenges that could emerge in future.

Up until 2011, the city of Ayodhya witnessed gradual growth (as depicted in Figure 8). This growth rate is set to increase in upcoming years because of the opportunities generated by urbanisation. According to the 2011 census, the population of 65 villages within the Ayodhya Development Authority boundary was 1,67,216. Of these, 41 villages have been merged into the Nagar Nigam. The steady growth of 8.2 percent can be observed from 2009 to 2019 in tourist influx, as depicted in Figure 11. The sudden dip of -234 per cent observed in 2020, can be attributed to the COVID-19 pandemic should be temporary.

Figure 9: Tourist Footfall, Ayodhya

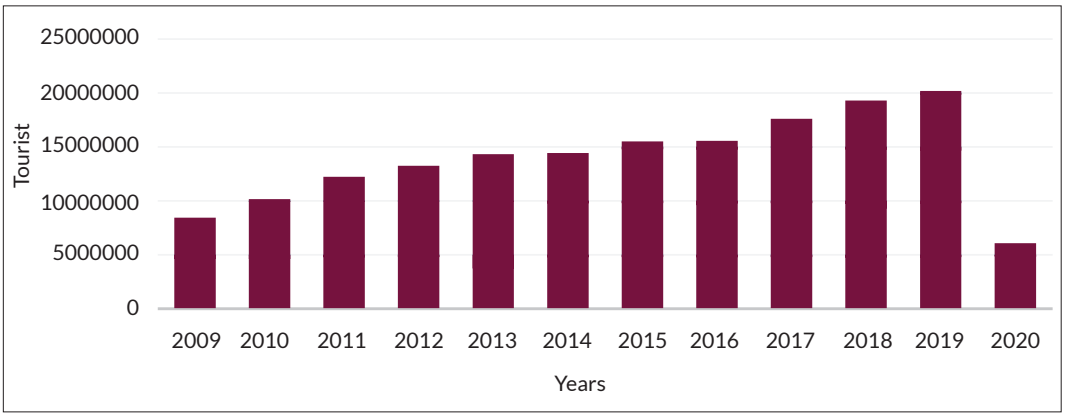
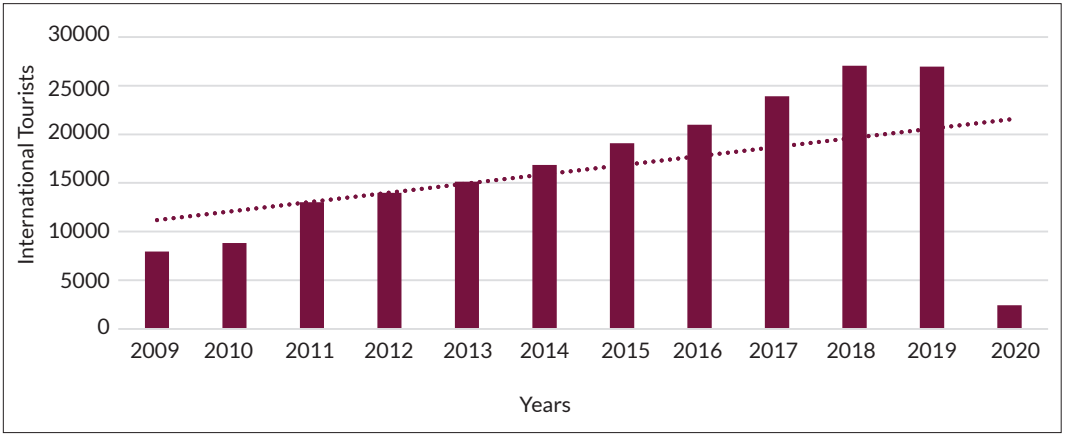


Figure 10: International Tourist Footfall, Ayodhya

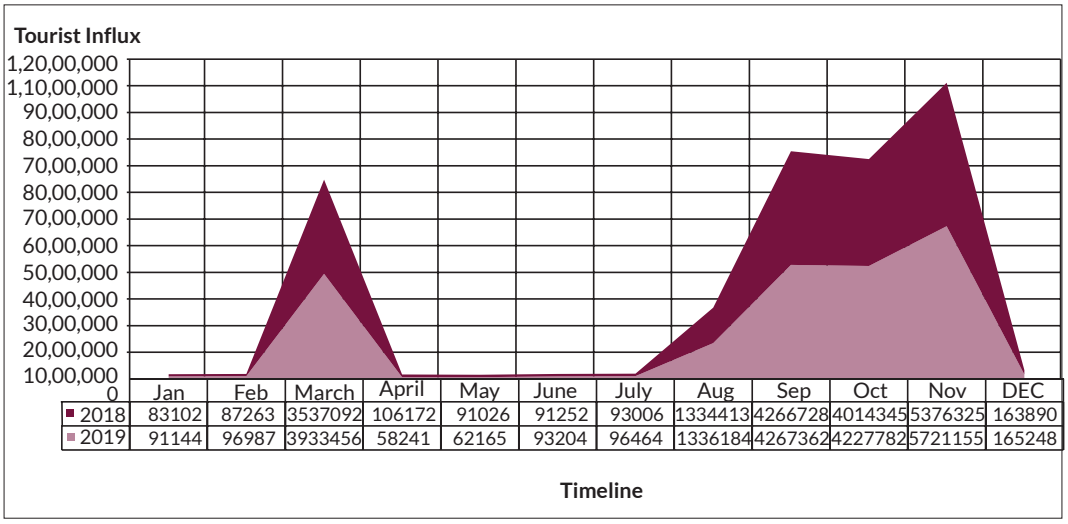


Source: Tourism Directorate, UP Tourism

International tourists comprise less than 0.2 per cent (Figure 10), which indicates that the city's tourism is entirely driven by the domestic religious tourist. However, an average rise of 11.1 per cent points at a considerable potential to be tapped, to which the regional integration of Varanasi and the mainstreaming of existing locations with diverse character would provide a boost.

The major tourist spikes were observed across the months of February to March (attributed to Holi, Mahashivaratri and Ram Navami) and September to November (Dussehra, Deepotsav and Parikrama) as Figure 12 shows. The dip months in between can be attributed to less important events and the scorching heat.

Figure 11: Tourist Influx—Monthly Variation, Ayodhya



	Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	DEC
2018	83102	87263	3537092	106172	91026	91252	93006	1334413	4266728	4014345	5376325	163890
2019	91144	96987	3933456	58241	62165	93204	96464	1336184	4267362	4227782	5721155	165248

Source: Tourism Directorate, UP Tourism

Tourist Destination Profile

Destinations are profiled for the zones in line with intracity travel patterns. Divided in zones, the places are characterised based on the nature of the place, issues and potential opportunities. The destination profiles are created through a lens focusing on how tourism centres around the Sarayu River contribute to the socio-cultural character of Ayodhya and make the river more than just a component in the city's tourism profile.

Tourist destinations in the study area are categorically profiled based on their character into the Ayodhya core, Faizabad zone, Cantonment, outer zone and Sarayu plains.

Ayodhya Core

The core of Ayodhya city is located on the north-eastern side of Ayodhya on the banks of the river Sarayu. This zone acts as the epicentre of tourism with significant places of touristic, religious and heritage significance, such as Ram ki Paidi, Hanuman Ghari, Dashrat Bhavan, Ram Janam

Bhoomi and Kanak Bhavan. With the religious and cultural character being the attraction, new development along the river stretch also caters to leisure activities for locals and others..

The issues inferred from primary surveys prominently revolved around (i) parking (ii) pedestrian and vehicle conflicts, and (iii) accessibility issues for the elderly and differently-abled. These issues call for design interventions. There have been concerns about heritage loss around the essential part of the temple ecosystem. Also of concern is the lack of public toilets, while the absence of public drinking water facilities in market spaces leads to a dependency on bottled water.

It is observed that despite Ram ki Paidi being developed for bathing purposes, certain devotees still prefer to take a holy dip at Naya Ghat in the main-stream flow of the Sarayu, causing an overlap between the ghats and boat docks. The lack of changing room facilities at Ram ki Paidi pushes ladies to use only Naya Ghat, which is 200 metres away, negating the usefulness of a ghat that was primarily constructed for that purpose. Design elements such as steep steps and lack of ramps at Ram ki Paidi lack inclusivity towards the differently-abled, propel this section of people towards the main stream as well.

Faizabad, Cantonment and Outer Zone

Located away from the core zone, Faizabad caters to tourists seeking heritage/leisure/shopping through places such as Gulab Bari and Bahu Begum ka Maqbara. Tourists often spill out from the core with an interest in exploring the cultural heritage, as well as for other leisure activities.

The Cantonment with all entry rights reserved with the army consist of Guptar Ghat, Military Mandir and Company Gardens, and cater to religious, nationalistic and leisure audiences.

Sarayu Plains

This area comprising more than 25 ghats and different heritage structures in the form of ashrams, dharamshalas and havelis remains the most under-explored place in the city.

The primary issue is accessibility with only Faizabad zone easily accessible through IPT. The areas inside Cantonment and the outer zone are highly dependent on private transport. The Sarayu zone is the most inaccessible, resulting in a smaller trickle down of tourists from the zone, although they remain culturally integrated.

Non-Mainstream Places

It is to be noted that with greater influx come greater challenges for which redistribution should be adapted as a strategy for destination development. The destination is predominantly characterised by non-mainstream places at local and regional levels, which plug in to a high potential for expansion of the itinerary provided the required intervention is made.

Many of these non-mainstream places were identified through primary surveys and are usually left out in the mainstream tourist itinerary. They have excellent potential to redistribute and retain tourism to ensure social and economic sustainability, while simultaneously acting as a tool for conserving heritage and boosting tourism.

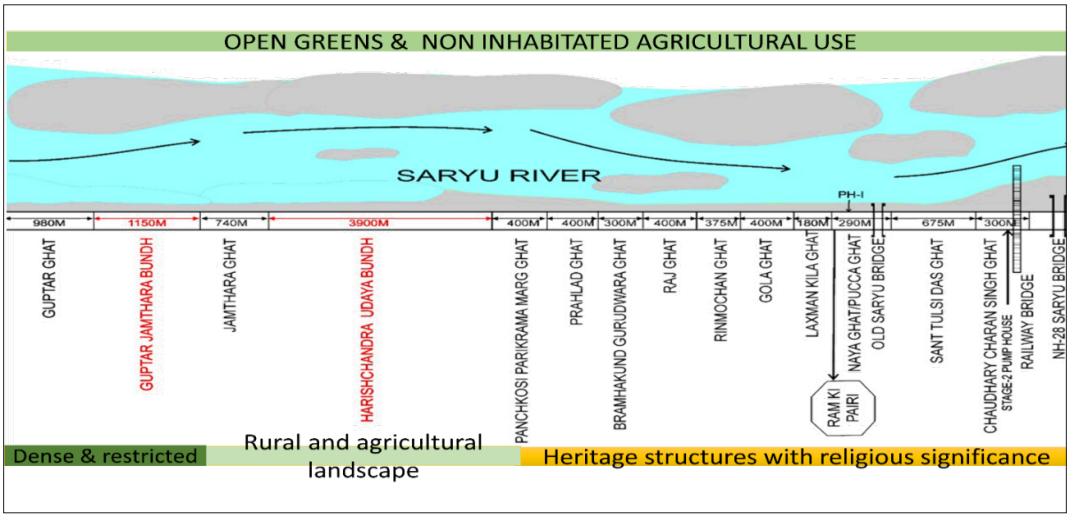
These sites consist of the galis of Ayodhya, heritage ashrams of Ayodhya, Korean Park, tomb of Bani Khanam, Gumnami Baba's resting places across the zones along the river, along with Mani Parvat and Chowk Mosque (the base of Ahmadullah Shah, known as the maulavi of Faizabad, one of those who spearheaded the revolt of 1857) within the city limits, and Kamakhya temple and Imambara at regional level bridging the Gaghra and Gomti rivers.

Sarayu Characterisation

The various features of the river Sarayu across Ayodhya's city stretch were analysed.

Activity Mapping

Figure 12: Line Diagram of Riverside Activities, Ayodhya

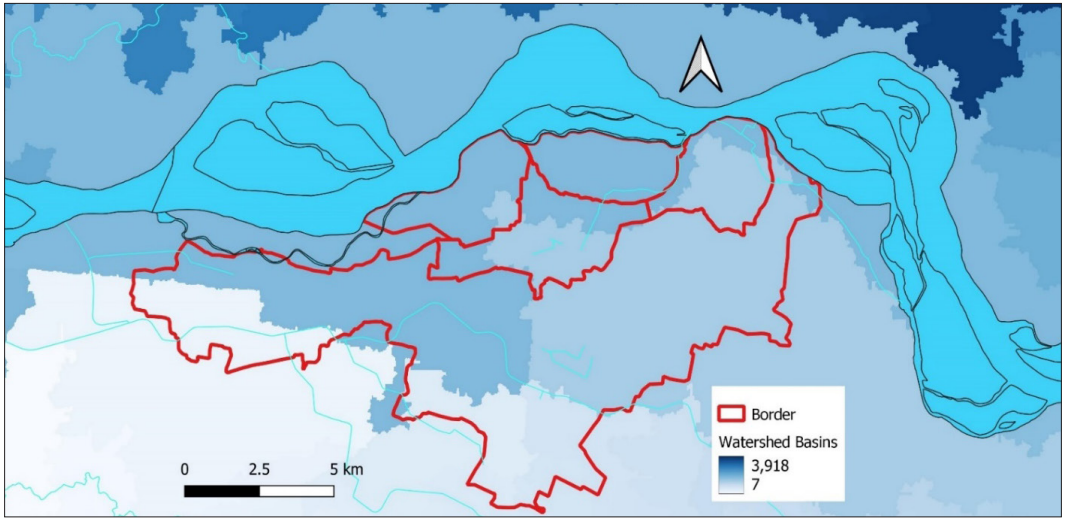


Source: Primary Survey & Irrigation Department, UP

The river Sarayu creates varied landscapes along the zone of interactions that have been developed simultaneously with Ayodhya's rich socio-cultural spaces. Ancient heritage-rich elements can be observed till the stretch of Prahalad Ghat along the core zone. From here till Cantonment, the landscape transitions towards natural heritage against a rural and agricultural backdrop, with settlements of the fishermen community at Rajghat. The Cantonment has a backdrop of denser vegetation and cultural richness, with places such as Company Garden and Guptar Ghat while the northern bank is primarily agricultural. The upper bank remains uninhabited with the Sarayu changing its basin over the years, as depicted in the line diagram.

A catchment area profile was analysed to derive conservation strategies. It was observed that increasing urbanisation was a cause for concern in the watershed across the Sarayu plains, with the northern banks being of primary concern. There is a need for policy and spatial interventions to conserve these areas.

Figure 13: Watershed Basin of Ayodhya



Source: bhuvan-app3.nrsc.gov.in (Anon, n.d.)

As a part of capturing the cultural approach towards water conservation, the status of canals and kunds that sprawl across the city was observed. It was noted that despite the kunds being acknowledged not only for harvesting water and from a religious perspective, they continue to face extinction, creating a need to conserve them.

Rapidly changing flood lines across the year remain a critical concern. With tourist spots, the major tourist and local ecosystem being most vulnerable, there is an urgent need to stabilise the flow of the river The hydrological profile shows areas where difficulty in navigation indicates a need for desilting. Solid waste disposal and sewage were identified as the primary concern. A recent Sarayu action report (UP-PCB, 2019) identified dumping sites and sewerage as cause water pollution. With tourism as a significant contributor, these issues must be addressed at inception itself.

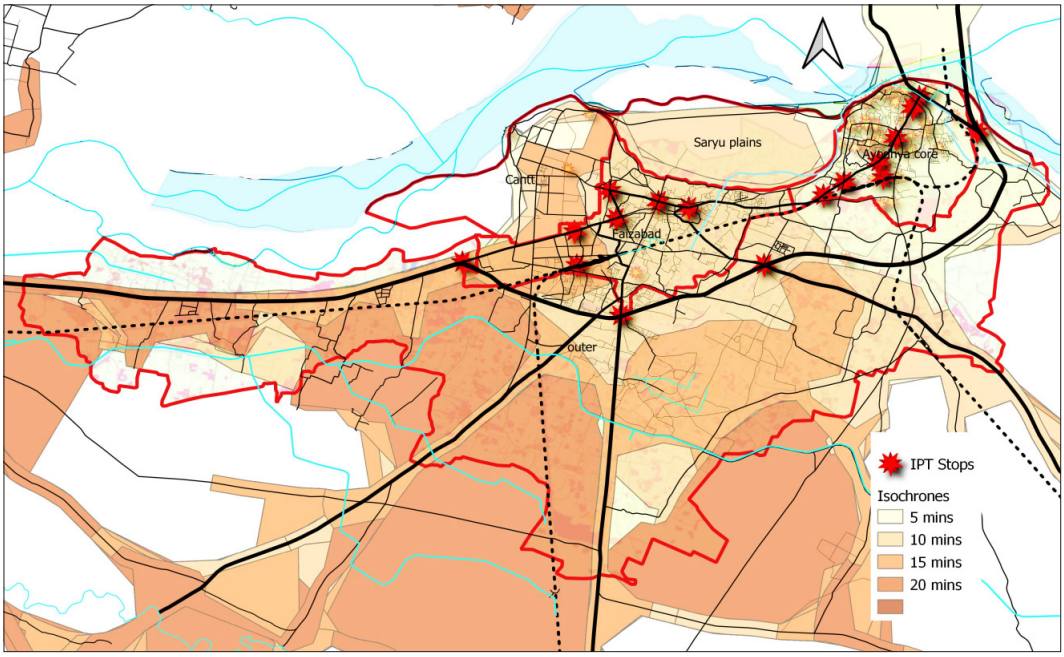
Accessibility

A detailed profile of existing connectivity in Ayodhya in terms of modes of transport and routes such as personal transport, IPT encompassing Vikram autos (diesel-powered), general auto rickshaws (CNG), e-rickshaws, walking etc. were analysed. The character and issues of each mode were identified through primary surveys and secondary analysis.

Isochronal Network Analysis was done based on 17 significant stops of IPT. Ayodhya core zone was observed to be the most accessible. The outer zones and Sarayu plains where IPT was found to be least accessible can be cross-interpreted with the tourist approach towards Guptar Ghat and Bharath Kund.

IPT routes majorly covered Naya Ghat towards Shahadat Ganj, Shahadat Ganj towards Sohawal, Naka towards Sultanpur, Naka towards Bara, Devkali to Maya, Naya Ghat to Nawab Ganj.

Figure 14: Isochronal Network Analysis, Ayodhya



Source: Authors (bhuvan-app3.nrsc.gov.in) (Anon n.d.)

Further, it was observed that IPT acts as the central spine of intracity transport in Ayodhya, and the increasing trend of residents moving towards private modes of transportation indicates a need to strengthen the public transport system.

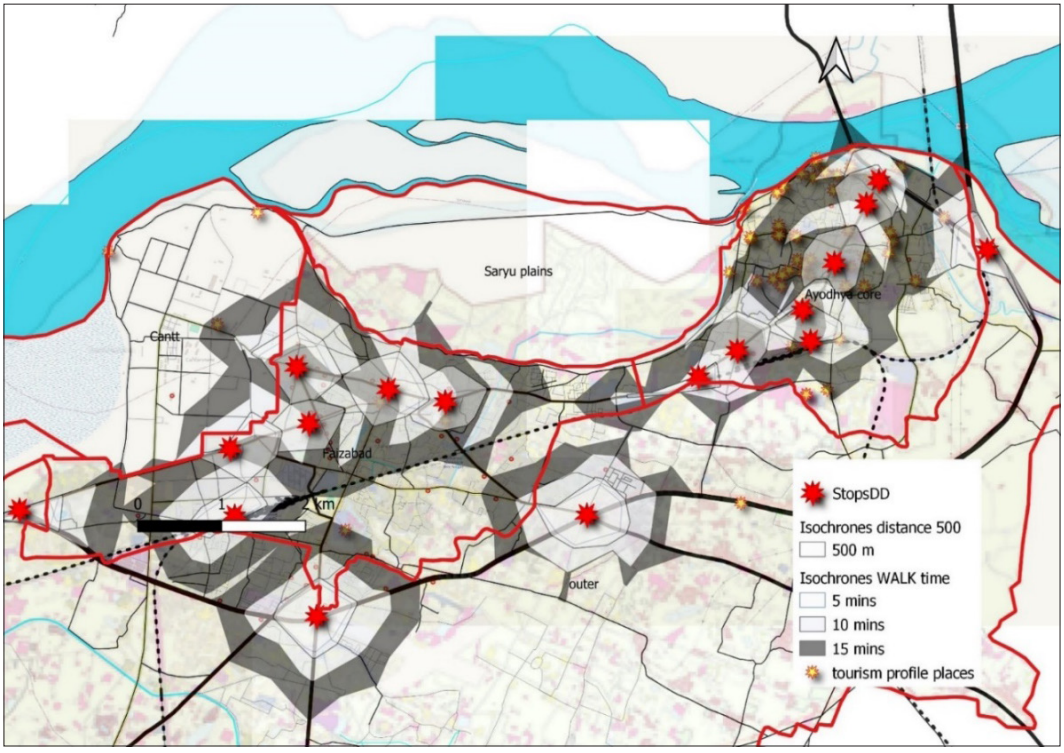
Walkability assessment: The assessment (Figure 17) was done on the standard that destinations should be under 500 metre reach and under 10minutes overlay. The areas where walkability needs to be improved are shown by the overlay method in grey. Scorching temperatures, lack of shade and shelter further affect an already low walkability that needs to be approached through design interventions and planning strategies.

Accommodation

Tourist accommodation is majorly concentrated in the Ayodhya Core in the form of ashrams, dharmshalas and hotels. The state of tourist accommodation was picturised through primary survey and secondary data in terms of:

- **Affordability:** Establishments are mostly non-starred and budget in nature, with ashrams and dharmshalas remaining universally accessible to all. Most charge nothing or a nominal amount and so remain most affordable.
- **Occupancy:** Average occupancy lies between 25 to 50 per cent during the lean season, going up to more than 75 to 100 per cent during the peak season (primary survey).
- **Resource management:** This aspect leaves a significant footprint in Ayodhya's environmental profile. Water consumption ranges from 50 kl to 300 kl per month (primary survey), and is majorly dependent on groundwater. Sewerage, primarily dependent on self-cleaning soak pits, also remains a point of concern. Solid waste, mostly comprising plastic bottles and kitchen waste, contributes to the major unsustainable practices affecting the land and water ecosystem. Around 5000–6000 units of electricity remain the average consumption, increasing during summer months for which the source needs to be decentralised and diversified through sustainable clean energy to cater to the increasing demand.

Figure 15: Walkability Assessment , Ayodhya

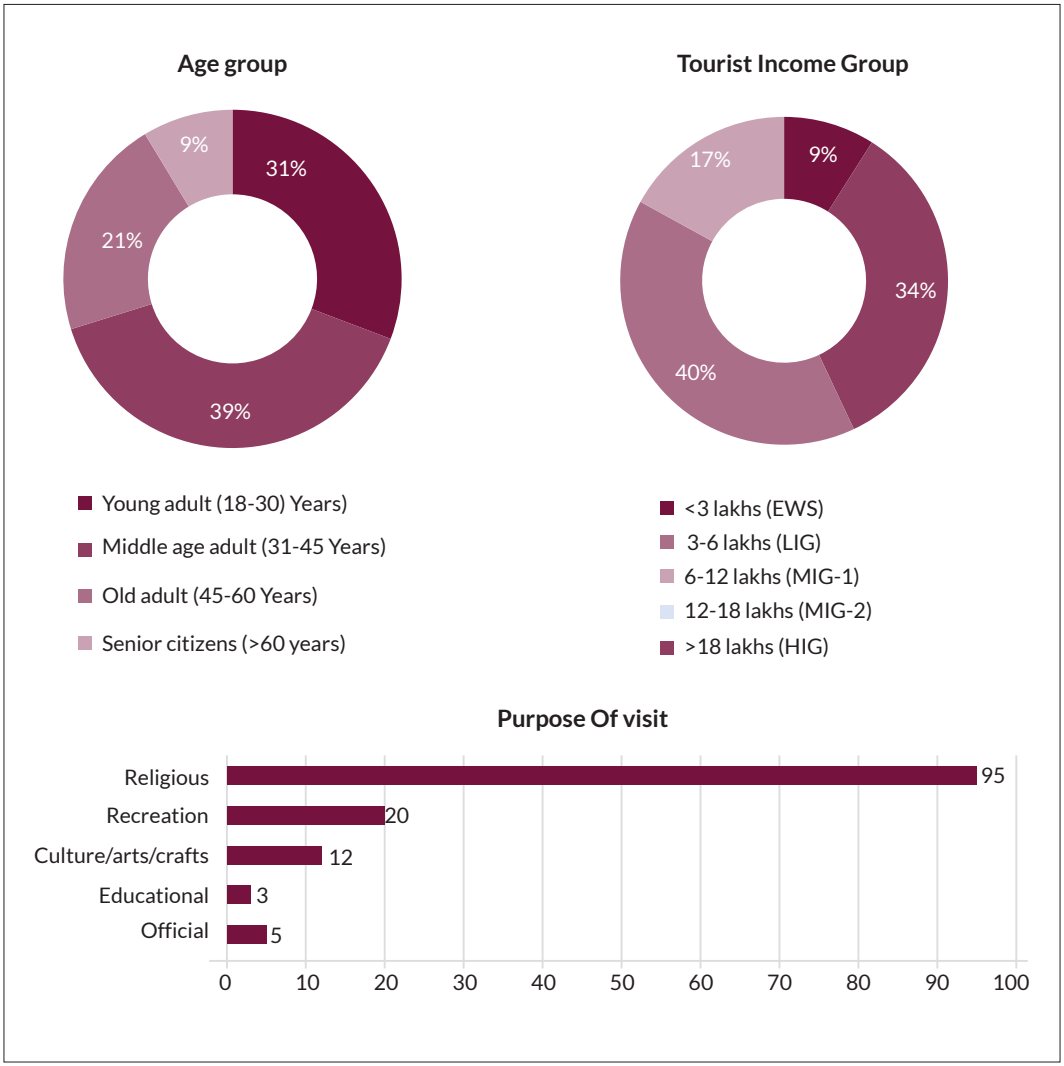


Source: Primary Survey & open street maps, March 2021

Tourist Characterisation

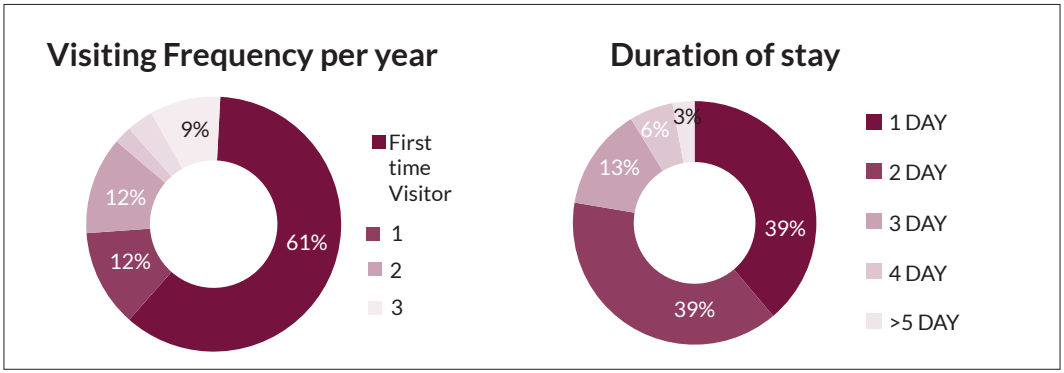
The tourist profile was captured through cross-analysis from primary survey data, which encompasses nature of a tourist and issues perceived. It was observed that: Average grouping was between 2-4, with a considerable proportion of bigger groups as well. The purpose of the visit was predominantly religious and cultural. Locals and a multitude of visitors from surrounding districts subscribe to recreational use alongside religious reasons.

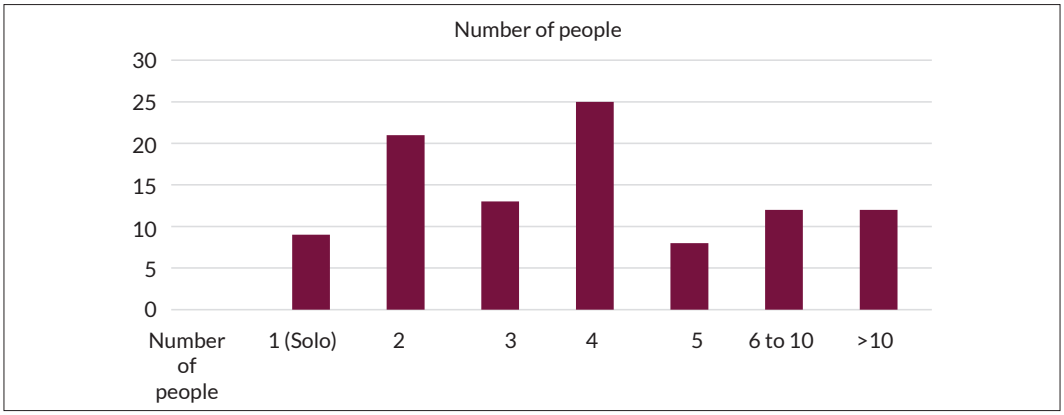
Figure 16 A: Characteristics of Tourists in Ayodhya



Source: Primary survey, February–March, 2021

Figure 16 B: Characteristics of Tourists in Ayodhya



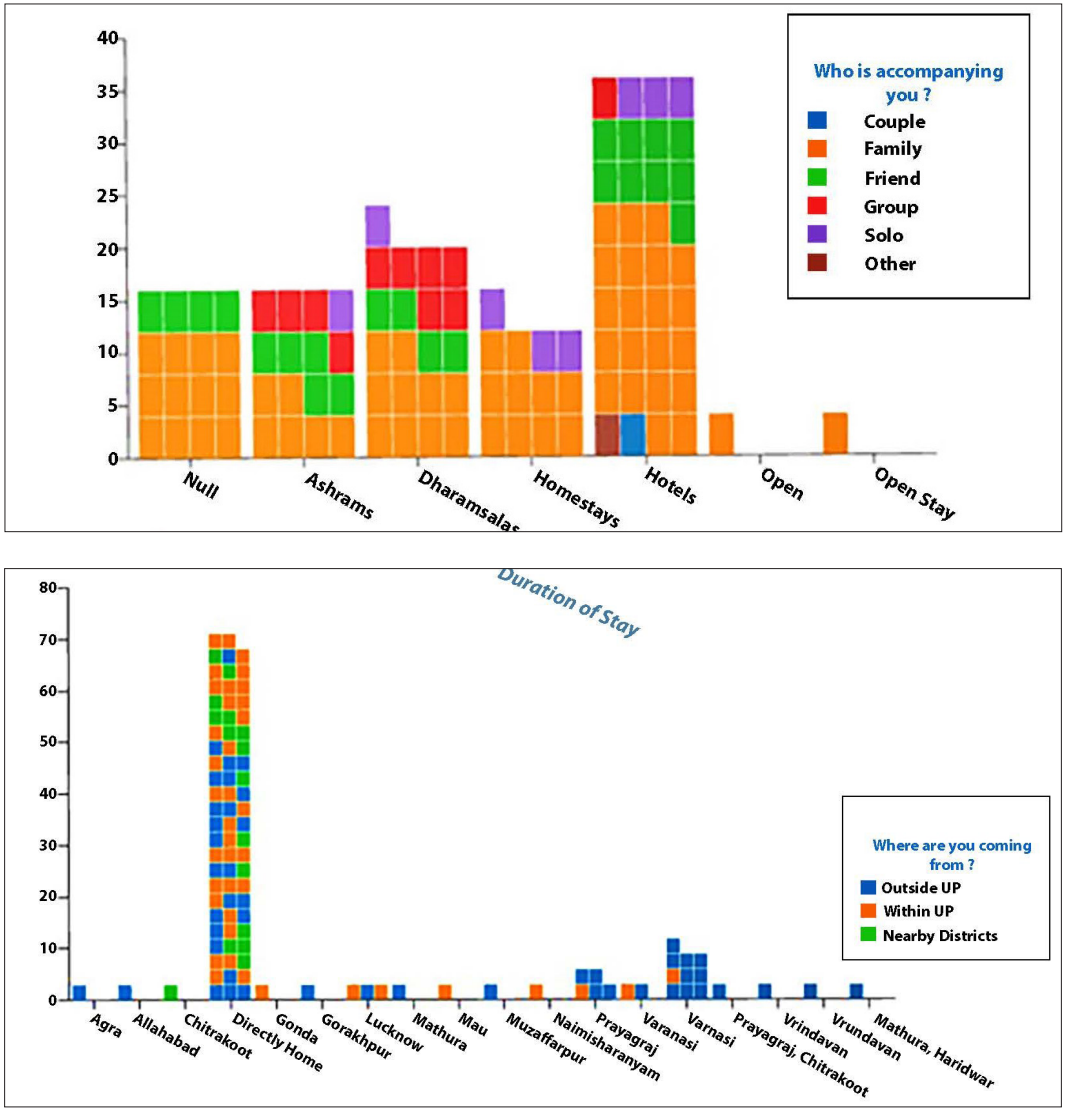


Source: Primary survey, February–March, 2021

Family tourists comprised a significant number, followed by friends and groups. Further classifying the family group based on accommodation, younger couples preferred staying in a hotel; senior citizens and older adults preferred ashrams and dharmshalas. In contrast, middle-aged adults were split between both types.

Tourists belonging to other states tend to cover the regional circuit travelling to Varanasi, Prayagraj and other places. Their duration of stay is limited to a day or two, covering mainstream places. A willingness to explore Ayodhya further was primarily expressed by first-time visitors. Lack of information regarding non-mainstream places was what deterred a major proportion of first-time visitors, revealing a potential for regional integration. The need for redistribution to tackle congestion, as well as solid waste sensitisation issues were majorly highlighted.

Figure 17: Cross Analysis of Tourist Characterisation, Ayodhya



Source: Primary survey, February–March, 2021

Image Intensity Analysis

Image intensity analysis was done to understand the psychological footprint of imageability of spaces and places in Ayodhya. The city's tourism is characterised at a stage between development and consolidation on Butler's scale; there is a higher potential to utilise the places by mapping the unmapped places in people's minds. The analysis could be a basis to formulate redistribution as a sustainable tool to tackle congestion alongside enhancing user experiences.

Figure 18: Image Intensity Analysis

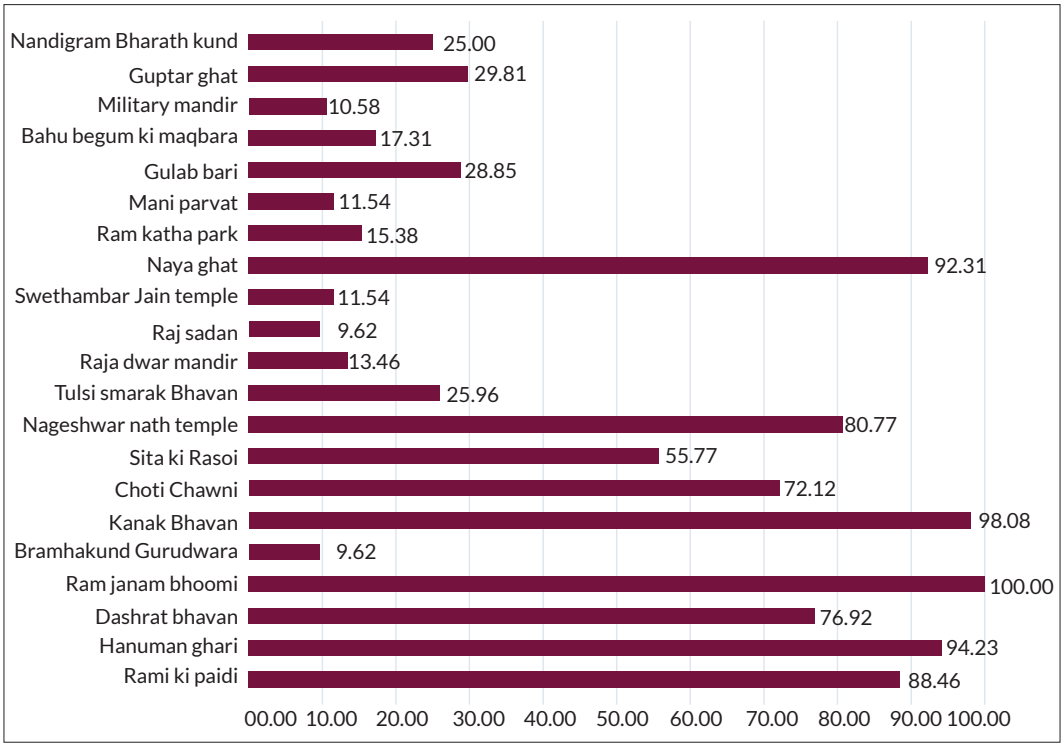


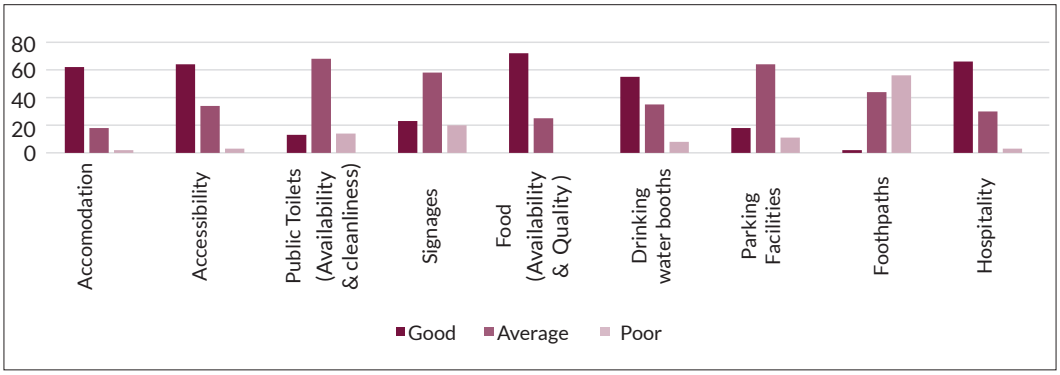
*Image analysis=Recall frequency*100/sample size*

Source: Primary survey, February–March, 2021

Service Quality Assessment

A perception-based service quality assessment was done to identify the critical shortage in services. Issues pertaining to footpaths, signage, parking facilities and public toilets, among others, were identified to be of concern.

Figure 19: Service Quality Assessment

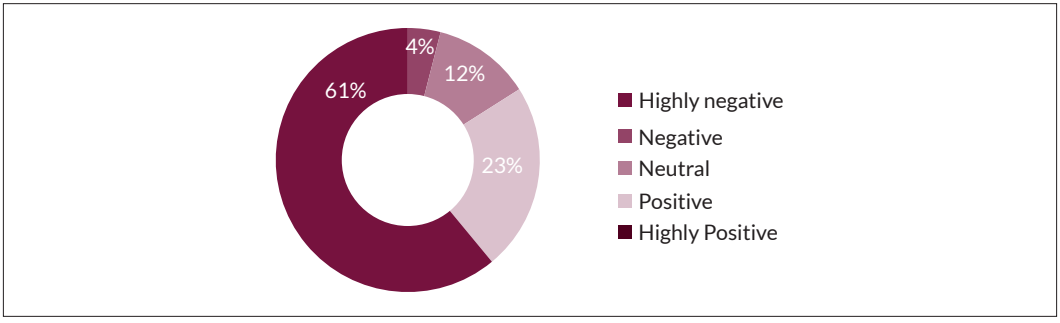


Source: Primary survey, February–March, 2021

Local Resident Characterisation

A local resident survey was conducted across different zones to understand the influence of tourism on quality of life. The majority perceived the influence of tourism as highly positive attributing to socio-economic proponents.

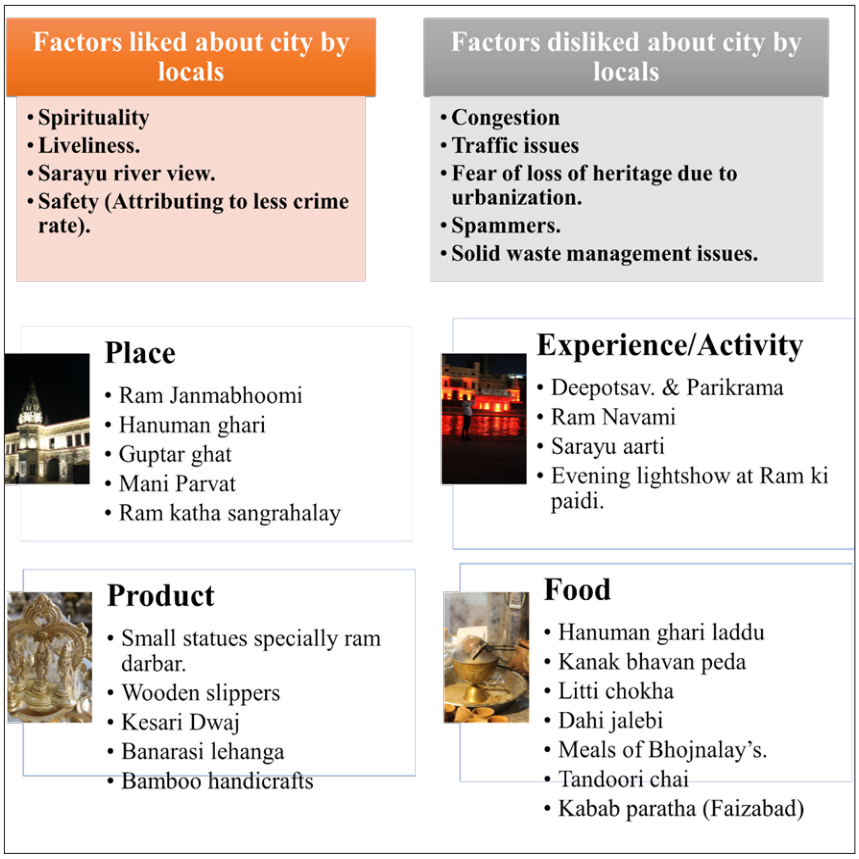
Figure 20: Influence of Tourism on Locals



Source: Primary survey, February–March, 2021

Core characterisation of Ayodhya was done by capturing the attributes locals like or dislike about the city. The Must-Do catalogue depicts a necessary experience a tourist should have from the perspective of the locals and core nature of tourism that must be conserved.

Figure 21: Must-Do Catalogue

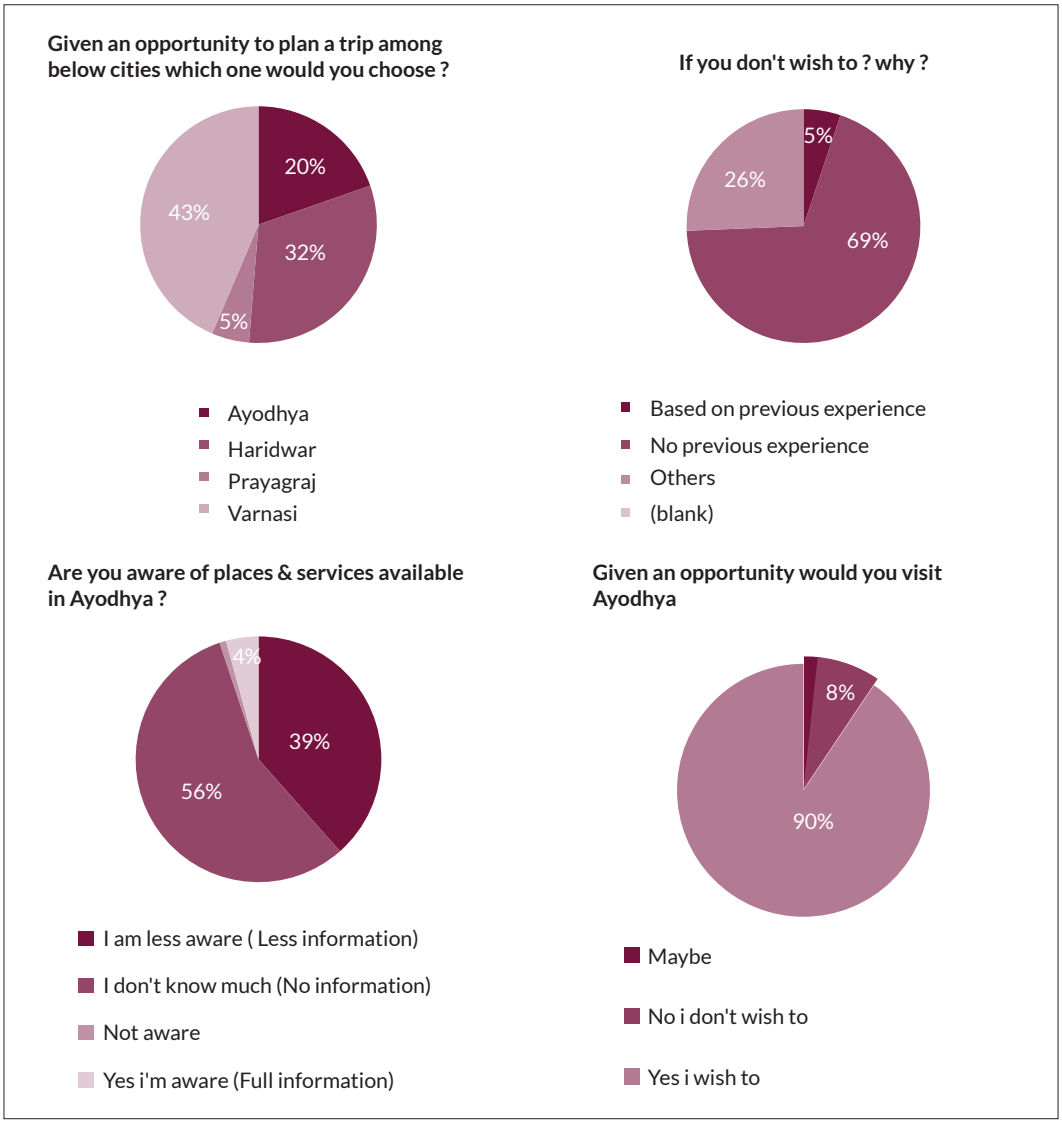


Source: Primary survey, February–March, 2021

Non-participant Survey—Identifying potential tourists (outside Ayodhya)

A non-participant survey was conducted to analyse and extract issues faced by potential tourists based on the psychological paradigm. The issues were captured in terms of: awareness, perception and preferences. Through the non-participant analysis, it was observed that Varanasi is the preferred choice followed by Ayodhya on the basis of spirituality, landscapes, experience and mainstream information availability. From another perspective it can be inferred that tourist integration through regional development is a possibility, as visitors of Varanasi and Prayagraj are potential tourists if the drawbacks are addressed. It is also observed that the lack of information and uncertainty regarding services were among the prime deterrents, pointing to a need to revisit the tourism promotion strategy along with a need to induce a transparent system.

Figure 22: Analysis of Non-Participant Survey



Source: Primary survey, February–March, 2021

Amenities

Amenities such as sewerage, stormwater drainage, water supply, solid waste were individually assessed to capture existing status as well as the contribution of tourism to demand, gaps and potential.

Sewerage

The rapidly increasing tourist influx and its ripple effect on tourism-allied industries, combined with local generation majorly propelled by sugar refineries, oil extracting mills in and around Ayodhya have redefined the challenges. With the existing state of wastewater treatment observed to be managed unsafely as per a study conducted by the Centre for Science and Environment (CSE), the situation poses a catastrophic risk to the Sarayu's riverine ecosystem in the future.

Drainage

The state of drainage was analysed with the help of the Sarayu Action Plan Report and the existence of both open and closed drains was observed. However, along with regular cleaning/ maintenance of drains, underground drainage systems and decentralised treatment plants are required in the city to maintain hygienic conditions and enhance the aesthetics of the tourist city.

Figure 25: State of Drains, Ayodhya

Number of Drains	Type of Drain			Status of Drains			Industries		Sewage Discharge (MLD)			Total Discharge in the river (MLD)
	Domestic	Industrial	Mixed	Tapped	Untapped	Partially Tapped	Number	Treated Effluent	Treated	Untreated	Total	
18	16	2	0	0	18	0	2	7.9	0	23.14	23.1	31.04

Source: Sarayu Action Plan Report, 2020

Water Supply

Tourism activities, often correlated to hydric stress, pose a challenge to the growing demand arising out of increasing influx. Analysis reveals that despite the city being located on the banks of the river Sarayu, it is majorly dependent on underground water, which is supplied through overhead tanks. Though groundwater resources are abundantly available with water tables varying from 20 to 150 feet within the city, the concern of overexploitation persists due to rapid urbanisation.

Tourist demand was estimated to be more than 14.79MLD (Becken, 2014)this research analysed tourism-related water use in 21 countries and compared it with other municipal use. Tourists' water use on a per guest night basis was found to differ substantially, with water usage being highest (up to 956 l per guest night in China (calculated from individual demand based on consumption studies and influx). The need to introduce a sustainable supply system through a conservation approach was derived correlating to this projected demand.

Solid Waste Management

A correlational analysis was done to pinpoint the relation between impact of tourism and solid waste management. Calculated on the basis of a study that states that the Indian tourist, on average, generates 0.9 kg waste (source: Sustainable Tourism Promoting the Environmental Public Health, University of Copenhagen, per day, tourist waste generation was estimated to be 49.31TPD. This constitutes the major proportion of total generated waste in the city, making tourist activity the top solid waste generator. Ayodhya Nagar Nigam (ANN) practises door-to-door collection of MSW, but due to lack of processing facilities, unsegregated solid waste is dumped in open plots or ponds and ow-lying areas. This results in waste toppling down into the riverine ecosystem, additionally contributing to air and groundwater pollution. The plastic waste generated by increased tourist influx was analysed as a major contributor contaminating the river's health, underlining the need for an alternative waste management plan.

Recommendations

The recommendations are derived based on the inter-relational analysis where the multitude of factors analysed and their implications were stitched together to draft sustainable solutions on the lines of:

Administration

It is said that the success of any scheme or project lies in the spirit of implementation. The concerns of coordination and capacity building are addressed by the formulation of a Joint Coordination Committee (JCC) consisting of representatives appointed by the line department and headed by the commissioner, formed under Section 5, The Uttar Pradesh Municipal Corporation Act, 1959. Along with promoting the existing project management unit, in its hierarchical placement under the Joint Coordination Committee, by expanding its scope through creation of sub-units. The project management cell looks into status monitoring, daily reports and benchmarking to set standards and targets. The issue management cell is to be a one-stop destination with respect to any stakeholder issue addressal with regard to to all line departments. The data management cell acts as the centralised data base for all details pertaining to line departments. The tourism and heritage cell is entrusted with short- term action plan preparation, tourist management, heritage conservation, assessing and coordinating line department projects on tourism and heritage. The environment and disaster cell- works on environmental conservation, flood plain conservation, dynamic activity monitoring and, coordinating with line departments' units, acts as an innovation cell introducing sustainable practices through dynamic strategic plans and action reports among line departments.

Land Value Capture

As a part of revenue resource mobilisation to reduce the dependency on grants and increase fiscal autonomy, the introduction of a betterment charge is proposed to reap the benefit of urbanisation and development activities in Ayodhya. Betterment charges proportionate to land value are to be levied on non-agricultural land: on residential plot sale, 0.5 per cent of market value per square

metre; on commercial plot and development, 1per cent of market value per square metre; on industrial plot and development, 1.5 per cent of market value per square metre; on other plots and development, 0.5 per cent of market value per square metre. This is authorised to be levied under the JCC by the UP Municipal Act,1959, where the revenue is deemed as a joint transaction.

Spatial Proposals in River Abutting Zones (Attractions & Activities)

An extended buffer of 500 metre width and 10 kilometre length towards the offside/northern bank of the Sarayu is proposed. This will be a riparian buffer where reforestation caters to the local ecosystem and flood mitigation. The funding drive will be undertaken through CAF (Compulsory Afforestation Fund) along with a remodelling of the Sarayu's riverscape, developing scope for open space sports activities. A voluntary participatory model can be adopted in the creation phase as part of a service to Ayodhya in coordination with other major stakeholders. With Ayodhya being epitomised as a symbol of civilisation, an open sports park of 330 meter*1500 forming 111 acre is proposed, to promote display and practice of ancient as well as with modern sports, adding touristic value and activities towards the northern bank.

As a part of riverfront activity development on the embankment being constructed from the Naya Ghat to Guptar Ghat stretch, a cycle track is proposed, with docks at Lakshman Ghat and Guptar Ghat and activity encouraged through permitting rural cafes and food points though in limited numbers. The stretch would help to redistribute tourists, exposing several non-mainstream heritage structures to recreational and cultural tourists. The growth in tourist influx would increase accessibility to the Sarayu flood plains and also add a mode of revenue generation in the form of viewpoints and cycling through Public Private Partnership (PPP).

Design intervention is proposed at Ram ki Paidi, where soft-scaping is proposed to develop shades and shelters to tackle scorching temperatures, keeping to a coherent design that is inclusive of women and the differently-abled through changing rooms, ramps, audio-visual signages, tactile braille signages, etc.

The normal poles are proposed to be replaced by smart poles in the major tourist destinations to make available facilities such as Wi-fi hotspots, charging port, CCTV monitoring and dynamic billboards for tourists.

A special heritage zone is delineated in the Ayodhya core (abutting the river) to conserve heritage structures. Supervised building destruction and construction permits will be given. A Special Area Heritage Plan has to be prepared to promote adaptable reuse of heritage structures, for example, deteriorating and abandoned heritage buildings can be conserved and used as heritage accommodation in the PPP1 model.

Kund rejuvenation is proposed and as part of the effort to revive ancient water conservation techniques seven kunds have been identified, adding both socio-cultural and environmental value.

[1]*Public Private Partnership*

Accessibility

The upgradation of three docks is recommended (Naya Ghat, Guptar Ghat, Raj Ghat) and two new dock (buffer view and open sports park) are proposed to facilitate better accessibility to different attractions via the river. This will increase the scope of boating from a leisure activity to a mode of transport connecting the Sarayu plains, Guptar Ghat and offside areas once activities are introduced. Additionally, it is proposed that, as in Varanasi, the existing diesel-powered boats be converted to solar, in association with The Energy and Resources Institute (TERI) under CSR.

Accommodation

Based on SDG 12, highlighting the priority of responsible consumption, it is proposed that in commercial accommodation with kitchens, a kitchen waste composter, decentralised waste water treatments (such as an anerobic baffled reactor and planted gravel filter) and the installation of solar power units should be made mandatory to getting permits. A centralised data base of accommodation, hotels, dharmshalas and ashrams, maintained in Realtime by PMU together with a private partner as a part of the open data initiative would ensure transparency.

Amenities

The introduction of Lootels, similar to those in Rameswaram, under PPP is proposed, where tourists, and vendors can avail access to toilets, bathrooms and food at minimal cost. For any new property beyond 1200square feet to be given building design approval it must provide for rainwater harvesting. The enforcement of a strict plastic bottle ban in a phased manner is also recommended. Plastic bottles can be gradually replaced with earthen pot/bamboo/brass bottles. The chronology of phasing out could be, accommodations, restaurants, and then street vendors.

Conclusion

The tourism sector's significance in achieving the 17 Sustainable Development Goals has propelled a development planner to view it as an unparalleled tool for destination development. Prompted by this, the research has attempted to develop a new integrated approach for destination development through tourism. It captures challenges, potential opportunities and gaps through comprehensive integration (cross-analysis of components) by analysing factors such as attractions, activities, amenities, accommodations, accessibility, geophysical character, demographic trends, land use, tourist profiles, destination profile, as well as psychometric profiles of both tourists and locals. As the essence of the proposal is both active and passive, the recommendations are focused on achieving integration by resolving issues through inclusion and ensuring sustainability through being proactive by addressing the issue at its source and predicting its future course.

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PERSPECTIVE

Ganga 3R-A New Paradigm for Conservation of Environmental Assets

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The book Ganga: Reimagining, Rejuvenating, Reconnecting authored by Rajiv Ranjan Mishra and Puskal Upadhyay has recently been published and gives a detailed and firsthand account of the conceptualisation, implementation and future prospects of the largest river conservation programme in modern times. This is not just a memoir, though a few personal experiences have been incorporated to make the context clear. In fact, it is a chronicle of the aspiration of a developing country to be in sync with its natural assets, leveraging its cultural connections and ensuring a better future for its coming generations.

Not many countries have set themselves the agenda of cleaning their rivers and making them sustainable at par with their basic needs like hunger, health and employment. India has done so. Rivers are fundamental to us and mean much more than just a resource. Since the establishment of the National Mission for Clean Ganga (NMCG) in 2011 and the launch of Namami Gange in 2014, significant efforts have been made. The challenge of Nirmal Ganga has been primarily addressed by creating the required sewage treatment capacity in cities along the river, apart from tackling other sources of pollution. Many other facets of rejuvenation, like clean villages, ghats and crematoriums, improving ecology and flow, biodiversity and wetland conservation, plantation, strengthening the people-river connect, research, knowledge dissemination and public participation have been initiated with a holistic approach. In one strategic approach, the mission combines Nirmal Ganga (unpolluted flow), Aviral Ganga (improving ecology and flow), Jan Ganga (strengthening the people-river connect), and to support all, Gyan Ganga (knowledge co-creation, research, developing policies and improving governance). The book describes these interventions along with a brief outline of the processes of their evolution. These efforts aim to make the river not just clean but also rejuvenated, a concept still new to many countries.

This achievement is phenomenal for any river conservation project in modern India, especially by an entity that grew and continued with the programme. In the process, its human capital, i.e. its employees, kept growing. They produced tangible outcomes and laid the foundation of a model for other rivers. It makes an exciting story of aspiration, struggle and zeal, deriving lessons

in management, project execution, and planning. It also signifies the emergence of a new India, conscious of its natural assets and its drive to make them sustainable forever.

The Namami Gange programme is unique on multiple counts. It not only provided the necessary political and financial commitment but also facilitated a review of its implementation procedures. The usual procedures would have led to usual results and hence, the review was naturally necessitated if the desired goals were to be achieved. However, whether by design or by sheer logical evolution the programme has been able to achieve results normally unseen in recent times. In the process, the "agile mode" has been reflected in its true form to handle an otherwise "wicked problem" where the solutions have been evolved to meet the ever-changing nature of the issue. This evolution had been the result of a complete 360-degree review of the problem, actually amounting to a "reimagination" of the river and its relevance. The rejuvenation process has been naturally taken off from this reimagination exercise. That is how a series of steps like the Hybrid Annuity Model (HAM), One City One Operator concept, and focus on reuse and sale of treated water have been made an integral part of the process. Some of the chapters in the book give specific cases of the first HAM projects in Haridwar and Ramana in Varanasi, their challenges and successes. "Rebuilding Kanpur for Ma Ganga" gives an elaborate story of rationalisation of old and new sewerage infrastructure and putting in place HAM and the One City One Operator approach. There is also a reference to mainstreaming rivers in the urban planning process and developing the first Urban River Management Plan (URMP). A new and innovative framework for managing urban rivers has emerged and an institutional framework such as River-City Alliance is evolving supported by the National Institute of Urban Affairs (NIUA). Prayagraj comes up again as the story of HAM and One City One Operator, but more significantly to point out how an ephemeral city develops and is managed during the Kumbh Mela. Varanasi is the eternal connection between Ganga and Kashi. But most significantly, the reconnection with the river through a mass public linking has been the real game-changer, which is realised and demonstrated throughout this rejuvenation story in the book.

From the beginning, the organisation had realised the importance of a radically different and holistic approach to resolve the "wicked problem", which not only included stakeholders from different strata of society with their needs and aspirations, but also the clash of ideas on the road ahead from different intellectuals and well-wishers. Hence, the scope of the mission was expanded to include afforestation, tributaries clean-up, nurturing of wetlands and natural springs, and redevelopment of old ghats. The book throws light on the interesting as well as the challenging process of consulting stakeholders and also persuading and negotiating to develop consensus and commitment.

This includes the journey of the NMCG so far, overcoming challenges of over-exploitation of its waters for development and other purposes, age-old beliefs and traditions, their collaboration with the central and state government and district administrations to achieve their goals. More importantly, it has brought back some of the love and respect of the people for its Mother Goddess.

This process of "Reimagination-Rejuvenation-Reconnection" has evolved as a completely new paradigm, simple to understand and easy to implement. This is especially relevant to complex objectives like the conservation of environmental assets which do not make immediate commercial sense in a superficial manner. Such efforts in the past had not been able to achieve much. The reasons had not been far from understanding. The efforts looked at the entire exercise in a myopic manner, normally focusing on the immediate asset value of the resources. This put a block on its perceived value, future relevance and consequent resources invested. Such limitation compromised the achievement of results and disconnection of the associated population from the asset, and its conservation compromised its sustainability.

This paradigm can be appropriately termed "#Ganga3R" which is not difficult to understand with 3 Rs and Ganga signifying all or any environmental assets. This, of course, is relevant to the conservation of any other river (as in the case of Ganga) but can also be deployed with equal effectiveness in case of any environmental assets like water bodies and wetlands (lakes and ponds), forests, springs, mountains, and so on. This will not be difficult to apply to more complex issues like air pollution and oceans as well.

The first element of this paradigm is "Reimagination", which has a slightly different connotation from its literal meaning. The term is more broad-based and actually signifies a 360-degree view of the asset or problem not only in its current context, but inclusive of its past significance as well as future value, criticality for future generations and its more innovative usages in the modern digital age. For example, in the case of Ganga, the Reimagination process would consider its past and its religious-cultural value, conventional economic usages like strategic-military concerns, transportation, drinking water and fishery. This would go beyond and take into account how it is perceived by people in this internet age, the evolution of cities on its banks and possible entertainment-recreation spaces in its catchment. It will continue further to consider its criticality in the overall ecosystem, how it affects other components like biodiversity, groundwater, other landforms and possible damages from its wastage. Whether the future generations would have an alternative to River Ganga or not, would complete this Reimagination process and would lead to a completely new understanding of the river which will be much more than its superficial religious-economic-ecological value. This Reimagination process has only caused the government to take efforts with a new sense of urgency and commit large sums of project funds along with a political will. The process would not only include the river but the problem of its degradation too, the causative factors for its swift transition from "river to sewer" in many places and why the efforts failed to yield results. The urge to change the processes and introduce new concepts of project implementation are a direct result of the same.

The next process is "Rejuvenation" which is a novel concept in itself, signifying the improvised understanding of the concept moving further from the original "cleaning" and "restoration". These terms are still operational in most of the western world. Rejuvenation is conceptually different because it does not limit the conservation processes to visual and technical purity or improve to make them as before but sets the objective as "bringing them to their pristine states", as

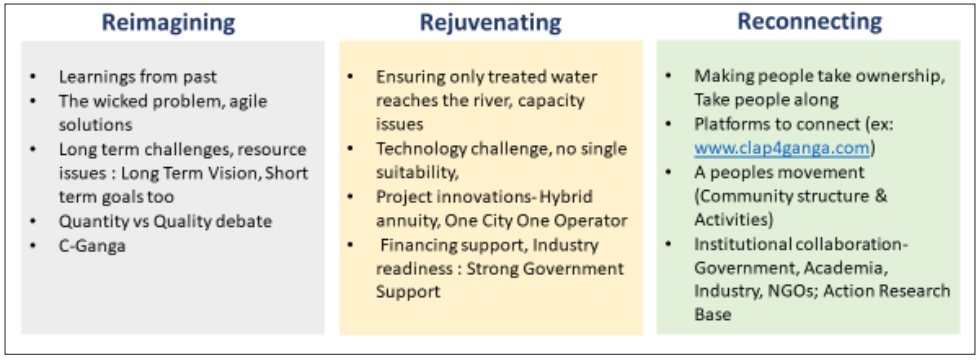
they had been, not in the recent past, but as they had been in known memory, untouched and unadulterated. This raises the benchmark much higher and makes the objective far more difficult to achieve but makes our priorities right and sound helping us take appropriate decisions. Infusion of this new concept in the Namami Gange programme helped expand the scope exponentially to include "Aviral Dhara"—environmental flows, longitudinal and geological connectivity, as also components of biodiversity conservation, research and communication. Rejuvenation is a long-term commitment and not a short-term objective. It not only warrants immediate results but also presupposes sustainability of efforts, institutions and finances and an inbuilt understanding that this is a continuous process.

The term "Reconnection" emerges from the fundamental concept of symbiotic evolution of environment and civilisation. Every society has evolved in its environmental context mostly in favourable habitats which made them remain in sync with the environmental assets, understand its demands and adjust their needs accordingly. This trait can still be observed in most tribal and rural communities where the socio-religious customs reflect built-in conservation practices. However, with the advent of industrialisation and non-environment-based economic activities this understanding gradually diminished leading to a severe "disconnect" between people and their habitat. Its most significant reflection is seen in the rivers turning into sewers and wetlands being usurped by urbanisation processes or even encroaching and diminishing these for unsustainable cultivation in rural areas. No one can stop the rivers and water bodies from extinction when people turn their backs on them.

"Who owns Ganga?" is a question we need to address and the answer to that is "the people" and then the task is how to make them realise it and own it. We need catalysts and we need to develop champions. Several models tried out in this process for reconnecting people with the river are discussed. These are diverse, ranging from virtual platforms to cleaning at banks, tree plantation, saving aquatic life, adventure sports, runs, walkathons, and audio-visual mediums, all to be sustained through community structures and the institution of District Ganga committees (DGCs). In fact, DGCs reflect institutionalisation of a decentralised approach to river rejuvenation.

An illustrative list of activities under these 3 Rs is given in Figure 1.

Figure 1: A New Paradigm, the 3 R Model: Reimagining, Rejuvenating, Reconnecting



That makes people's reconnection a strong component of the reversal paradigm of degraded environmental assets. Recent public efforts in Bengaluru and many other places to reclaim and revive their ponds are a glaring example of its effectiveness. Reconnection is not difficult to understand. Essentially, it expects people in an area to be aware of their environmental assets, use them effectively and stand up for their protection. This includes raising a voice to attract attention of all concerned, including media and government, and prevent any degradation process. In case of the Yamuna in Delhi, it can be seen that apart from some religious compulsion, no one wishes to visit its banks for recreation or otherwise. This realisation helped the Namami Gange programme to build this component in their overall aims and its success has been observed in a large number of public action activities emerging on its banks, both with and without government support. These arrangements are catalysts of public awakening and have become the nucleus of a much larger process creating a new generation conscious of its rights and responsibilities, capable and willing to consider themselves the owners of Ganga and to fight for its sustenance. A river-based Jan Andolan, a new awakening, is not far behind. Such public awareness and involvement is the most conducive environment for a successful conservation programme.

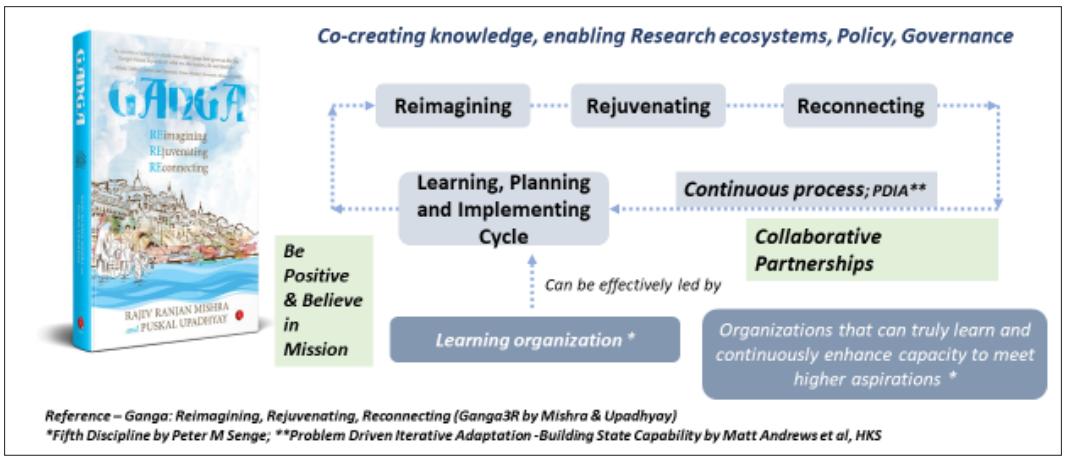
The application of this paradigm, 3R, to any other environmental component would not be difficult with some understanding of its various aspects. If we take the example of air pollution, the efforts would start from reanalysing the role of air in our lives, which may not be difficult considering its criticality for our survival, but the realisation of limitations on the creation of fresh air, the continuous increase in pollution levels, the increasing cost of air purification, exponential impact of consequential health hazards, huge cost of health care, and impact on future generations would help us reimagine air much differently from an ignored ubiquitous asset. This would consider its large reach and ability to disperse, as also capacity to attract pollution from distant areas, making it impossible to tackle it at a local level, and may warrant a global effort. The Rejuvenation aspect would involve the new technologies available and the need for the creation of new agencies, or capacity building of existing institutions to factor in air pollution control measures with a new sense of urgency and significant commitment of resources. Public connection would be relatively difficult to relate to since air has always been perceived as something ubiquitous and would necessitate a massive awareness programme and enriching of healthy clean habits among people through an attitude correction programme.

A simplified and higher-order version of this model is presented in Figure 2. This shows the cyclic nature of the 3 Rs. It is not possible to complete the exercise/phase of Reimagining and then work on Rejuvenating or Reconnecting. We need to be dynamically looking at them and also be agile and adaptive to make suitable adjustments to the situation, change realities and evaluation of the outcome. One is reminded of the concept of PDIA (Problem Driven Iterative Adaptation), which is needed to understand and work on complicated public management issues (Matt Andrews et al, Building State Capability, Harvard Kennedy School). Developing a comprehensive understanding of the problem is essential for finding a real and sustainable solution. Mishra and Vogel (2020) in their book has described river rejuvenation, basin management, and natural resource management as "wicked problems" associated with the enormity and unpredictability. Reimagining is fundamental to the solution with a deeper understanding of the continuous nature

of this process. This becomes even more important in light of the impacts of climate change on several of these interventions and existing models.

Knowledge co-creation and developing a conducive ecosystem for research is an important element of a strategic approach to understaning future challenges along with the present issues. A balance can be brought between Science and Practice. One needs to go beyond the modes of interaction such as separation or even cooperation and proactive co-creating of knowledge in a transdisciplinary manner and also taking advantage of experiential knowledge (Regeer, B. & Bunders, J., Knowledge Co-creation, Interaction Between Science & Society).

Figure 2: #3R Model of River Rejuvenation



As explained throughout the book, Collaborative Partnership is a core principle in all the thought processes as well as interventions. Achieving such goals would only be possible if we understand the process of building an institution and organisational dynamics and develop a "learning organisation". In the book is described this journey in one of the initial chapters, "From Vision to Mission: the ebb and flow of the Start-up journey", and again towards the end in the chapter "Sustaining Ganga". Learning organisations are those organisations that can truly learn and continuously enhance their capacity to meet higher aspirations (Senge Peter M., The Fifth Discipline). Such organisations can help in knowledge co-creation, develop enabling research ecosystems and lead to an effective learning, planning and implementation cycle of the 3 Rs.

Proper application of this paradigm would need further research in this area and development of a framework for its application in different areas. On a simpler scale this can be applied by all researchers and policy practitioners. It would be interesting to watch further progress in this regard and how people make use of this concept. A separate policy paper on a deeper scale is already undergoing to work out a clear policy prescription of this model for complex problems, especially environmental ones. In the meantime let #Ganga3R become the global buzz on all environmental concerns.

Note: This paper is the initial conceptualisation of a detailed research study being pursued by the authors on "Applications of #Ganga3R paradigm to environmental assets". The authors have written Ganga—Reimagining, Rejuvenating, Reconnecting, a book published by Rupa Publications. (Visit www.ganga3r.com)

Conflict of Interest

Authors have no conflict of intrest.

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