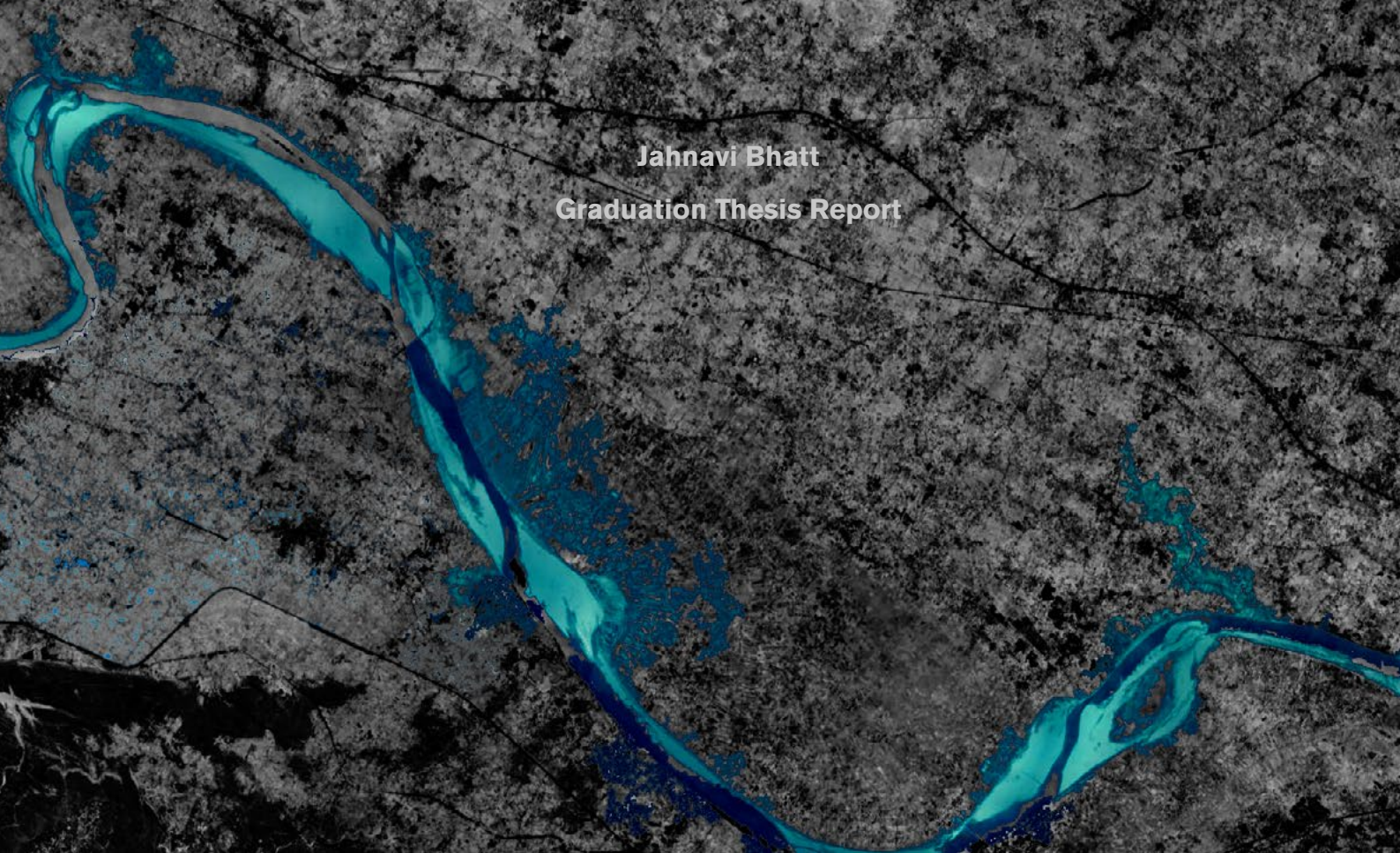


# **BEYOND CLEANSING**

**Transitioning Towards Socio-Ecological  
Resilience in the Ganges River Basin through  
an Adaptive Spatial Planning Model**

**Jahnvi Bhatt**

**Graduation Thesis Report**





## Beyond Cleansing

Transitioning Towards Socio-Ecological Resilience  
in the Ganges River Basin through an Adaptive  
Spatial Planning Model

Graduation Thesis Report  
MSc. Architecture, Urbanism and the Building Sciences  
Department of Urbanism,  
Faculty of Architecture and the Built Environment,  
Delft University of Technology

 Department of Urbanism  
**BK Bouwkunde**

Research Studio: Transitional Territories

Student: Jahnvi Bhatt  
Student No. 4794516  
Email id: jahnvi.bhatt17@gmail.com

Thesis Mentors  
First Mentor: Dr. D. A. Sepulveda Carmona  
Second Mentor: Dr. ir. Claudiu Forgaci

Delegate of Board of Examiner:  
Dr.ir. E. Mlecnik

Delft, Netherlands | 26-06-2020

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EFL STICHTING

 | Global Initiative

*\*All drawing unless specified are done by the Author*



.... ભવસાગર ના નિમિત્ત બની ને પાપ જગ ના ધોયા મેં,  
તારા કર્મોના વલોપાત માં મેં મુજના ખોયા શૃંગાર રે!!  
કહેવાઉં છું નિર્મળતા ની દેવી ગંગા,  
કયા ખૂણીયે જઈ ક્યાં રોઉં! યાઈ ઘેલી કોને પંપાળું!  
મૂકી વિષાદમાં તે માનવ, તારા ભીતર ના અલંકાર ને કંડાર્યા રે!!  
રહીયે એકમેક સહ રાખીને મર્યાદા ના બોલ,  
છે આજીજી તુજને ચાલ વાવીએ સાથે નમ્યતાને પ્રગતિ ના બોર!! ....

*In the transformation of your deeds, I have lost my adornment!!  
Which corner should I go to and where should I cry?  
Put that human in melancholy, the ego within you is shattered!!  
I beg you to make a move with meekness, not boredom of progress!!*

---

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To friends, especially Prinka Choesin, Joanna Demetriou, Shuangyun Chen and Kavya Kalyan for never-ending critical discussions and many more memories, Thank you.

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To professors at NIT Patna, Officers in Patna Municipal Corporation, and NIC Patna, thank you for insights and sharing your knowledge.

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### **Abstract**

The capitalistic and economy-driven approach towards urbanization in India has led to a great disparity between different socio-cultural groups as well as a huge pressure on the ecological systems. Further, with the changing climate, these groups are increasingly vulnerable to hazards. This can be observed even in the Ganges River Basin where unplanned urbanization has caused a fragmented river system that puts several local settlements at increasing risk.

The approach to planning water-centric projects has not been a holistic approach in the past, and with uncertainties of changing times, the planning approach needs to be more adaptive. The project aims to re-look at the current development trend within the existing system and derive a possible adaptive spatial planning model for design, that would include local communities and governing bodies into the planning process. The focus lies in emphasising the importance of a holistic approach to planning for the Ganges River Basin and bridging the gap between the national mitigation policies and local adaptation to climate change, to alleviate social, economic and ecological vulnerabilities.

Designing for resilience for the Ganges River Basin is based on the understanding of the relationship between the human systems and the ecological systems. The notions of SES (Adger 2003-2009), and the panarchy of adaptive cycles from Holling (1986) are used to derive the process of designing infrastructure and interventions within the river basin. The derived framework of Adaptive Spatial Planning enables a flexible approach to plan for uncertainty, integrating local communities in the planning process. Local adaptation of multi-scalar strategies along with local knowledge from the community allow early testing of strategies and informing policies simultaneously, with results and local knowledge, reducing the time-line compared to traditional planning where policies are derived at a central level without an in-depth understanding of local context. The new adaptive spatial planning allows a shift of pathways in times of uncertainty, making the system more flexible and resilient.

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## GLOSSARY

1. Hazard: A possible occurrence of an even that would have an impact on exposed population.
2. Exposure: Location of the population in the area where hazard may occur.
3. Vulnerability: The inability to counter the adverse effect of a hazard. (Not all exposed population group are vulnerable since vulnerability is an virtue of ability)
4. Mitigation: The act of reducing agents that cause or accelerate climate change
5. Adaptation: The adjustments within natural and/ or human systems in response to actual or expected climate risks or their effects, which moderates harm or exploits beneficial opportunities.
6. Resilience: Ability to adapt and transform in order to survive from difficulties. An process that involves both mitigation and adaptation at the same time.
7. Social Capital: The networks and relationships between people within a community that enables functioning off a society.
8. Adaptive Spatial Planning Model: A planning model, that allows participation form local actors and regional governing bodies to develop a flexible framework for planning towards resilience.

Source: IPCC Report, 2012

## ABBREVIATION

SES - Socio-Ecological System

GRB - Ganges River Basin

RS - Regional Scale Strategies (for Ganges River Basin in India)

MS - Metropolitan Scale Strategies (for Patna Metropolitan Area)

NMCG - National Mission for Clean Ganga (Nammai Gange)





# 1. Introduction

The following section informs about the general context of The Ganges River. The river has held a high ecological, social and environmental significance for the country and its people. With the rapid growth and development of urban areas along the river, the pressure on agriculture in the river basin and the water demands are constantly increasing. The unregulated urban development and growth of industries along the river bank have lead to extreme degradation of the river. The current state of the river is severely impacting the communities directly or indirectly dependent on the river.



## MOTIVATION

Coming from India my greatest motivation lies in helping to improve the livelihoods of developing nations through sustainable development. Looking at the current condition of urban growth in India, the development is highly economy driven, drastically increasing the differences in social and cultural groups. The economy driven development has tremendously stressed the ecology of the region. There is an urgent need for good urban design and planning strategies, employing integrated governance, and cross-disciplinary strategies to solve complex challenges.

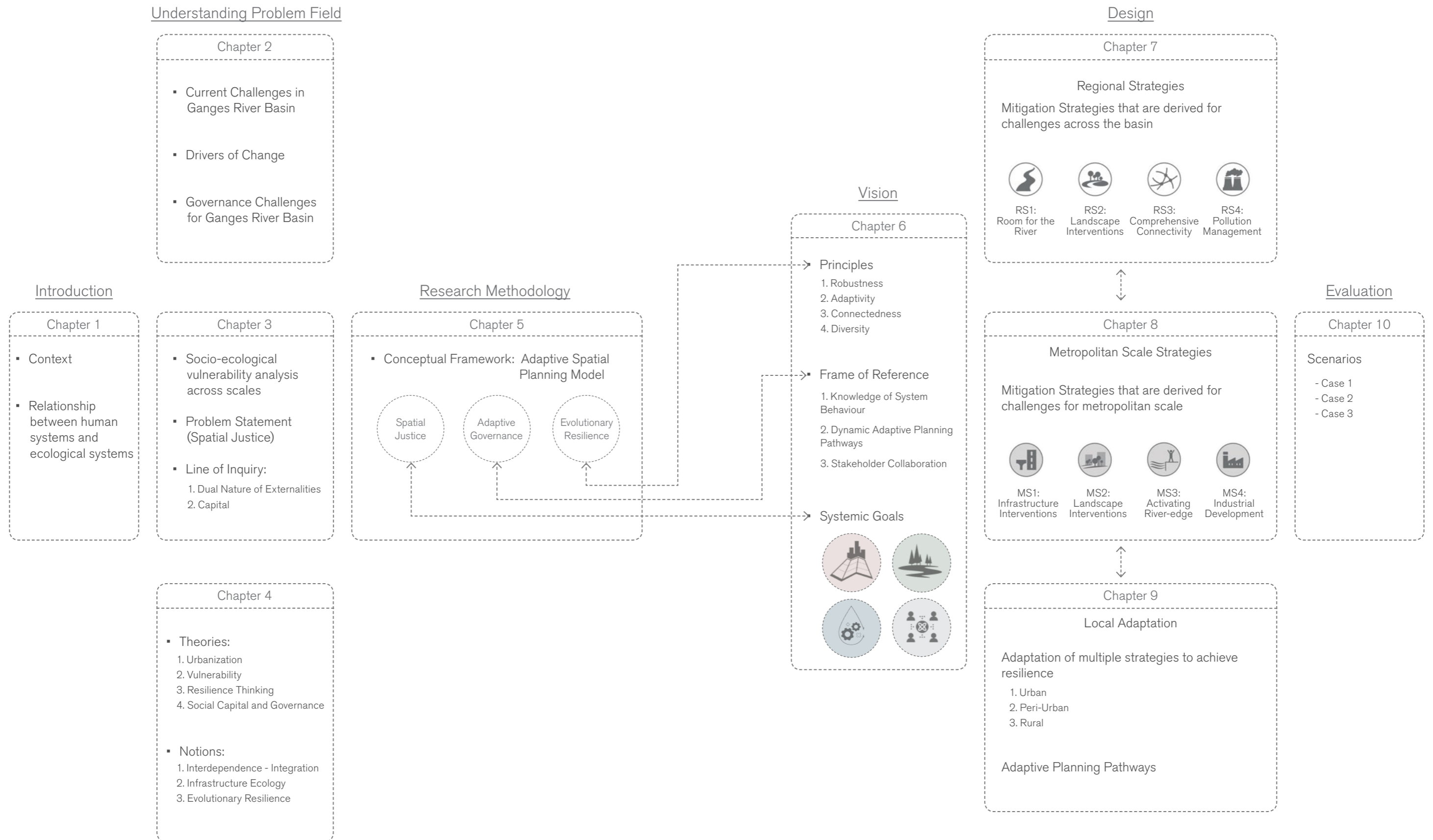
I want to positively impact vulnerable communities by helping them become more liveable, equitable, and sustainable. I would want to influence change in favour of communities and eventually empower them to help others and become agents of change within their own communities.

Understanding, researching and resolving complexities faced by rapidly developing cities is highly necessary for creating smooth transitions between the urban and the rural; formal and the informal; rich and poor. This with the overlapping issues of housing and public realms in the developing countries has led to issues of spatial justice. The possibility of being able to create a difference in the lives and lifestyle of people by altering and designing the built and the unbuilt environment intrigues me the most.





# Report Structure:



# 1.1. INTRODUCTION

## 1.1.1. Context: Location

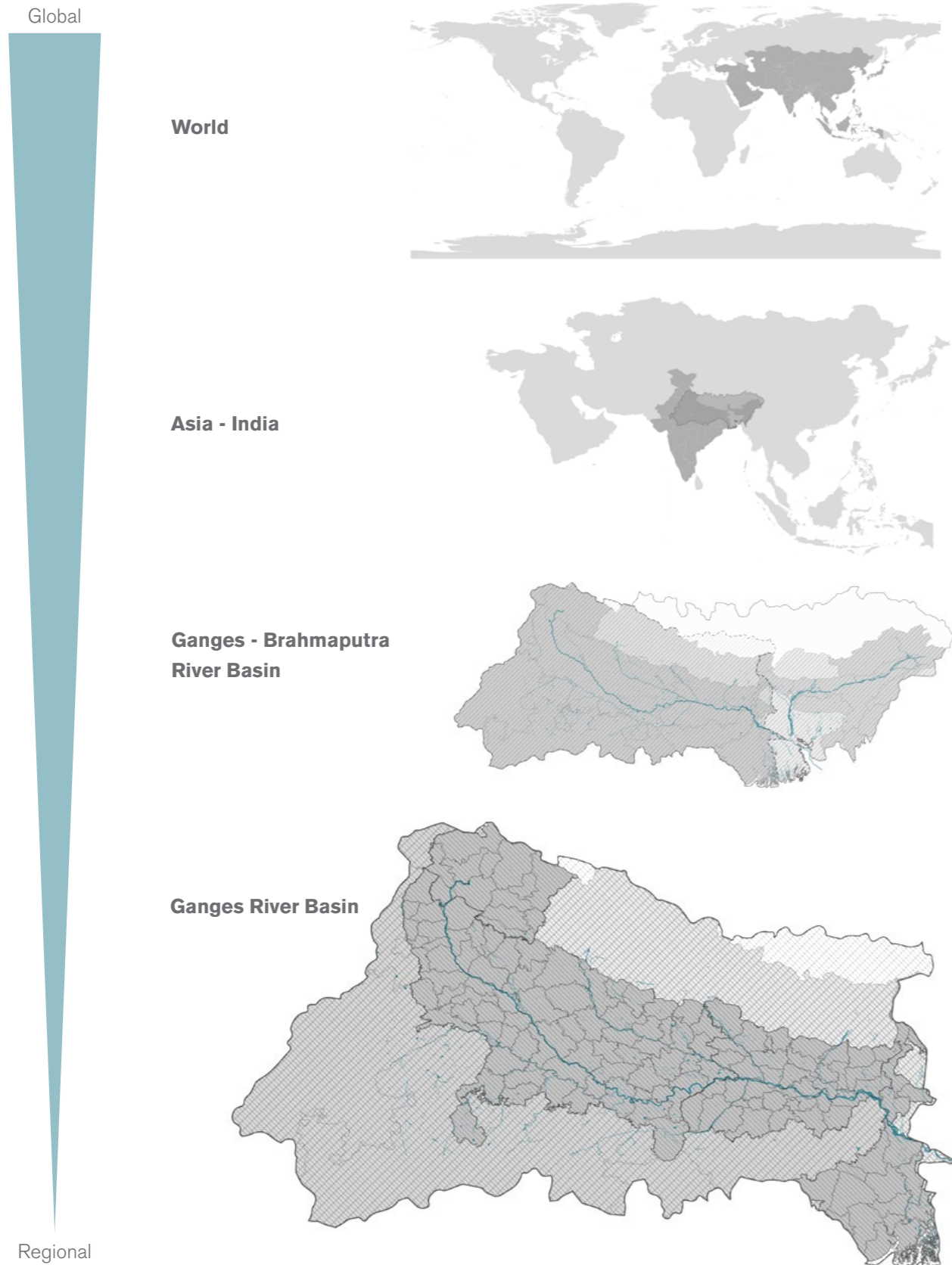


Fig. 01. Geographical context of Ganges River Basin

## 1.1.2. Major River Basins across the world

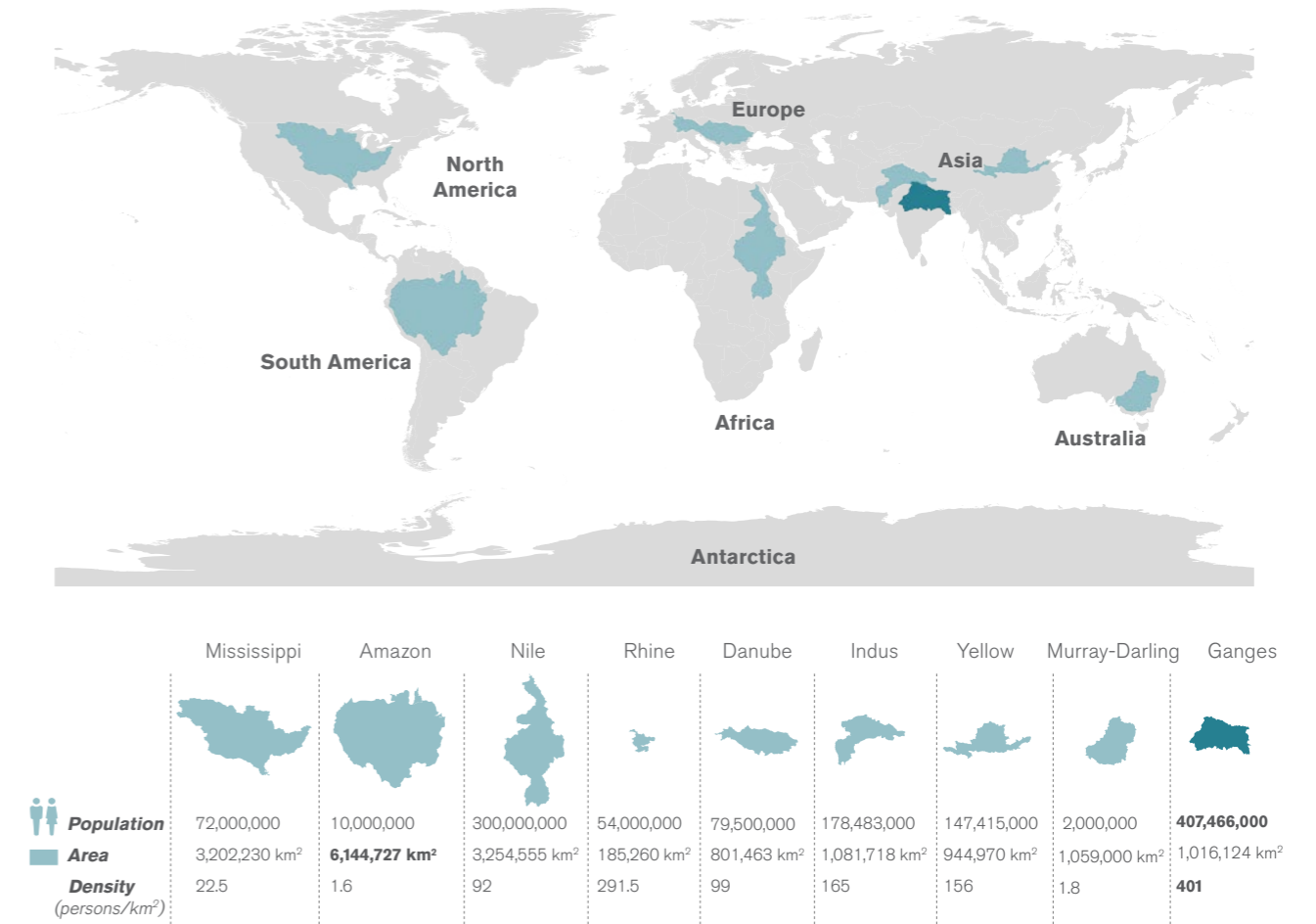


Fig. 02. Major River Basins across the World  
Source: Anthony Acciavatti, 2015

Catchment **basins are vital elements of the ecosystem** in which soil, plants, animals and water are all interdependent. Thus it is extremely important to understand, study and develop strategies at basin level.

“As of 2019, **17** countries in total are now experiencing **"extremely high"** levels of baseline water stress, according to recent data from the World Resources Institute (WRI).”

“The Ganges River flows through **29 cities** with population over **100,000**, and **23 cities** with population **between 50,000 and 100,000**, and about **48 towns.**”

Source: "Interesting facts about River Ganges | Just Fun Facts", 2020



### 1.1.3. The Ganges

The Ganges River basin is a lifeline to millions of people (approximately 40% of India's population), sprawling through the great plains of India. The river Ganges upholds unique geographical, historical, socio-economic and environmental importance. Due to its high importance, the river was declared "National River" on 4th Nov 2008 by the government (Our National River Ganga, 2014).

The Ganges basin consists of hilly terrains with dense forests in the Himalayas, the fertile plains and the delta. The upper portion of the river within Himalayan Range consists of a wide range of biodiversity, the middle section of the river is the most densely occupied part of the river and hence is highly polluted due to human activities. The lower section of the river consists of the deltas of Sundarban with high eco-sensitive regions.

The river water is widely used for agriculture, irrigation, human consumption (domestic and industrial), tourism and recreation purposes. Over the years there has been a major shift in the hydrology and the quality of river water due to several human activities. The river is facing water challenges because of construction of huge barrages and dams for hydroelectricity and irrigation, unmonitored industrial use of water and intensive unplanned development of the cities and towns on its bank. Secondly, climate change is affecting the biophysical characteristics of the basin, leading to shifts in the monsoon regimes, which results in increasing floods and droughts that cause massive human destruction. The contamination and shortage of water are leading to more exploitation of groundwater for irrigation and domestic use (Luna Bharati, 2016).

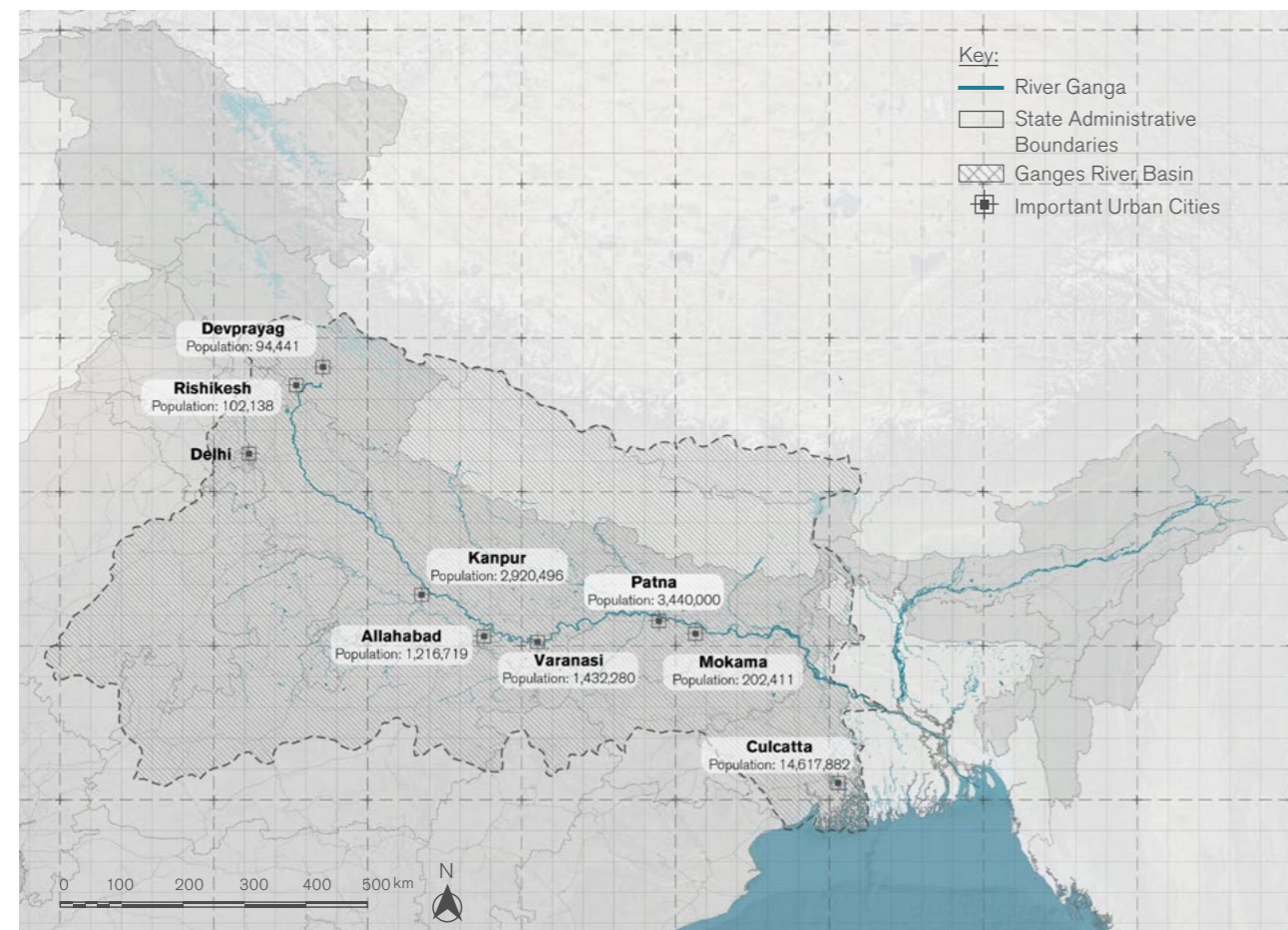


Fig. 03. Map showing the water network in Ganges Basin with the river and important cities along the river.

Source: GIS Data, Bhuvan, NIC Bihar, Census data 2011

### A. Environmental Significance of the Ganges



Image (c): Photograph of Gharial (fresh water crocodile) in the Ganges

Source: Photograph by Sandeep Behera, WWF - India, River Basins & Water Policy Team, 2012

As the river flows from the Himalayas in the north to the Bay of Bengal in the east, creating one of the world's biggest delta, it is home to a diverse range of biological wealth distributed over forests, wetlands, fresh river channels and within marine areas.

About 31% of National parks in India and 15% of wildlife sanctuaries, protecting some of the most endangered species of animals and birds are located in the Ganges River Basin. There are almost 70 species of freshwater aquatic animals and around 140 types of fishes, birds and animals like The Indian Tiger with the river basin area. (Isha Foundation, 2019)

Earlier the river water was significant because of its high ability to retain oxygen with 12ppm count. This high count of oxygen made it possible for the river to eliminate concentration and accumulation of small pollutants, helping it in hosting the biodiversity.

## B. Economic Significance of the Ganges



Image (d): Hooghly Port  
Source: Hooghly Dock & Port Engineers Ltd, 2019

The river supports over 565,000 sq km of cultivated land, representing almost a third of the agricultural area in India.

The river water in higher altitudes of the Ganges, in the Upper Ganga Region, is used for generation of hydro-electricity.

The Ganges was once an important navigational route. Even today, West Bengal uses the river to transport jute, tea, grain and other agricultural products. The Kolkata port, one of the major ports in India, is located on the Hooghly, a tributary of the Ganga (Isha Foundation, 2019). Several small scales business related to culture and traditions are carried out along the banks of the river because of the cultural significance of the river.

## C. Social Significance of the Ganges



Image (e): Morning prayers at river Ganga  
Source: © Jedraszak/iStock.com, www.britannica.com, 2019

The river holds a highly sacred position in the Hindu Religion. It is worshipped by Hindus, who believe the river can bring their spirits closer to salvation.

Thousands of pilgrims visit places on the banks of the river, to bathe in the Ganga, to worship and perform various rituals and cultural functions. The river water is highly used for domestic purposes like bathing and washing of clothes. The Ghats on the river have had high social importance and are a place of gathering for the communities.

The river holds an emotional, spiritual, socio-cultural and historical place in Indian civilization and hence finds its mention in many ancient books and scriptures. Though the river holds high significance in the Hindu religion, the river water and system is extremely important to the entire society. Hence the religious aspect of the river is not accounted within the scope of this thesis.



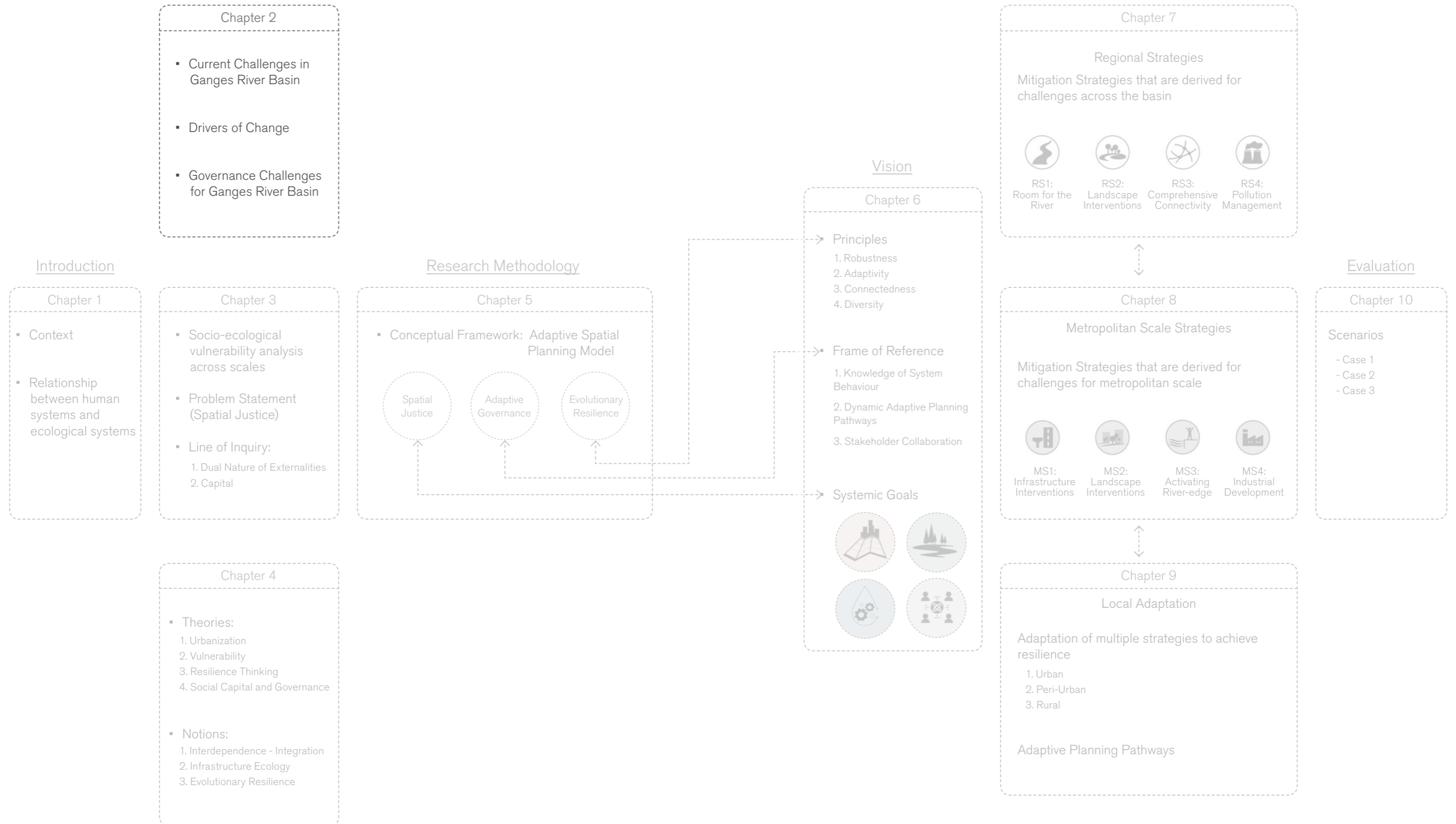


## 2. Problem Field

The following chapter focuses on the constantly increasing pressures on the river due to urbanization and climate change. The current economic, environmental and social conditions of the river require urgent assessments of the mounting risks on the communities along the river. The 3 important problem focus areas namely, Urbanization, Infrastructure Development and Climate Change are scrutinized within the Ganges River Basin context. Further, the problem is understood concerning to the UN Sustainable Development Goals to assess their importance and funding possibilities.

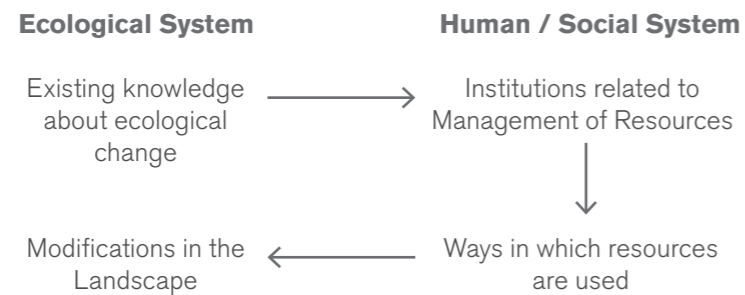


Understanding Problem Field





## 2.1. UNDERSTANDING RELATIONSHIP BETWEEN SOCIETY AND ECOLOGY



Source: Resilience thinking meets social theory: Situating social change in socio-ecological systems (SES) research, Cote & Nightingale, 2011

The relationship between human systems and ecological systems has always been co-dependent, yet constantly evolving. For the longest time in history these two systems were analysed independently. With evolution of SES, there began a shift in understanding of the 2 systems and its interdependency.

In current Anthropocene times human actions dominate the ecological systems, causing imbalances (Goymier, 2014). To maintain balance and gain from ecosystem services it is necessary to adopt sustainable uses. Targets within policies often segregate social and ecological goals making the process more imbalanced.

Moreover, with changing climate it is extremely necessary to look at the approach of SES, considering interlinks between the 2 systems. With the approach of Ecosystem based adaptation both societal and ecological goals can be achieved together (Munang et al., 2013).

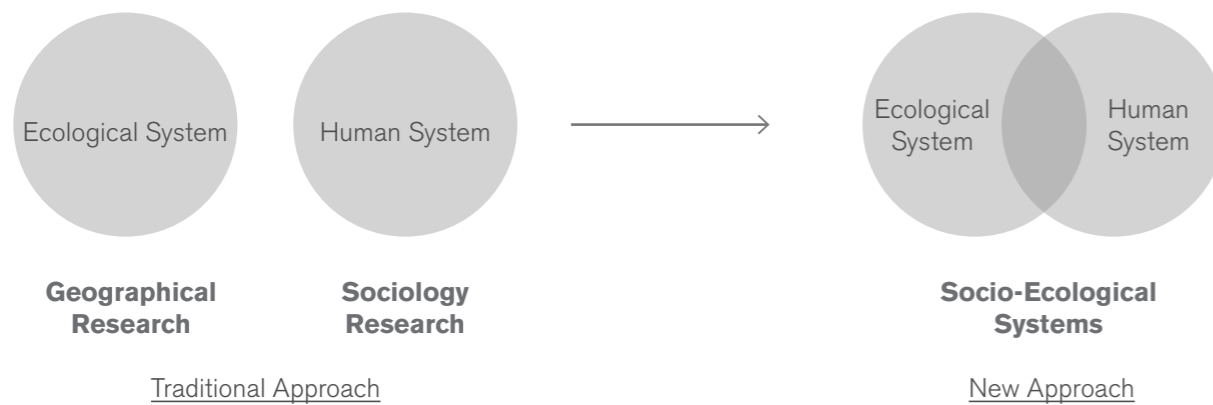


Fig. 04. Paradigm change in approach of planning

## 2.2. WATER CHALLENGES

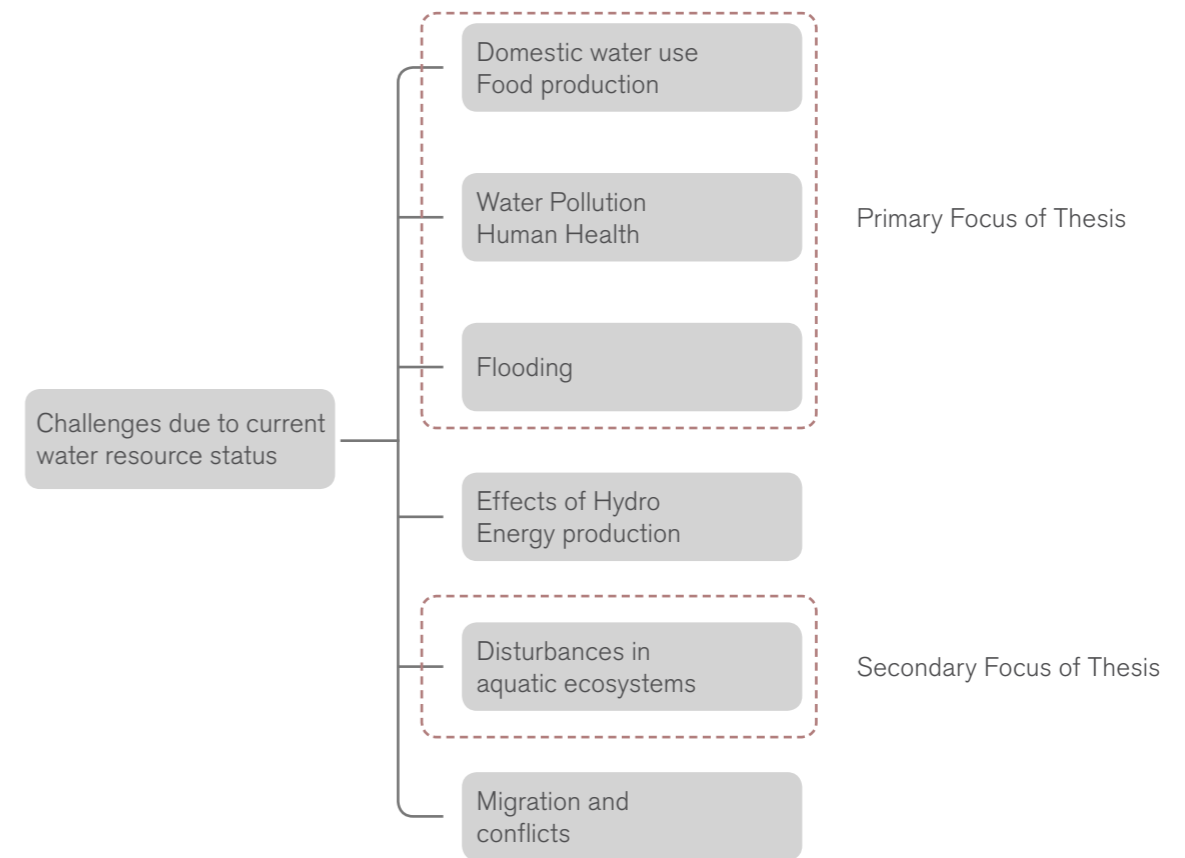


Fig. 05. Challenges due to current water resource status  
Source: Ligtvoet et al., 2020, Adapted by author

Water is a key resource for survival, yet it is one of the biggest threat to human system. With constant population rise, unregulated development and changing climate the treats on water system are high. Challenges cause due to quantity and quality fluctuations of water, leads to 6 main challenges mentioned in the figure above.

Impacts on water systems are observed across boundaries and scales. Thus addressing these challenges require an systemic approach, considering all directly and indirectly dependent systems.

All of the above mentioned challenges are observed in the Ganges River Basin. Effects of these challenges lead to income loss, life losses and pushing communities to high vulnerability.

The project primarily aims to address challenges do Water Pollution, Domestic and Agricultural use of Water, Flooding and Drought. Moreover it aslo focuses in reducing disturbanes in the aquatic ecosystems.



## 2.3. CURRENT CHALLENGES IN THE GANGES

### A. Environmental Challenges



Image (g): Dead fishes due to water pollution.  
Source: Hindustan Times, Kanpur

Construction of dams and barrages along the river and its tributaries has resulted in a fragmented water network, leading to deterioration of the environment of the Ganga river basin.

Two major species of freshwater animals: the gharial – a species of crocodile and the Ganges Freshwater Dolphin are facing extinction are. (Isha Foundation, 2019)

Due to imbalance in the food web of fishes in the river, there has been an invasion by exotic fish species.

The growth of industrial activities in 1960 -1970 has lead to unprecedented destructions in the flora and fauna of the river basin.

Mining of sand further leads to loss of biodiversity at river bed impacting population and habitat of other fishes.

### B. Economic Challenges



Image (h): Outflow of waste water form Tanneries  
Source: © WWF, India

The Ganges is experiencing cycles of drought and floods creating catastrophic impacts on agriculture.

These cycles of drought and flooding also cause massive human and economic losses.

The increased level of arsenic due to the pollution from industries and agricultural pesticides and the increased amount of salinity due to the construction of barrages and reduced water flow is impacting the agricultural produce in the river basin.

The plastic wastes and waste from tanneries make the river water unfit to use for agriculture or other small scale business practices.



### C. Social Challenges



Image (i): Degraded condition of river due to religious practices.  
Source: The Wire, 2017

The lack of proper water infrastructure the poor population is becoming excessively vulnerable to natural disasters (Luna Bharati, 2016).

The degraded conditions of water due to pollution makes the availability of clean water impossible, leading to the injustice of water.

Urban meeting and gathering spots are highly polluted with plastic waste and bio-waste, making them unfit for use. This impacts the kinship within the communities.

### 2.4. UN DEVELOPMENT GOALS

To ensure that people around the world achieve prosperity by 2030, the United Nations Member State adopted The Sustainable Development Goals (SDGs) in 2015. These SDGs also known as Global Goals were designed to take action to protect the planet and eradicate poverty. These 17 SDGs are integrated to achieve social, ecological and economic sustainability.

This research aims to contribute mainly to the 9 out of 17 SDGs stated below.

- SDG 3:** Ensuring good health and well being of people living in The Ganges River Basin.
- SDG 6:** Access to clean water and sanitation facilities.
- SDG 8:** Opportunity to work, jobs and economic growth.
- SDG 9:** Innovative development of infrastructure and industries that does not impact the environment.
- SDG 10:** To reduce inequalities within communities.
- SDG 11:** Sustainable and liveable communities.
- SDG 13:** To take action against climate change; flooding and water crisis.
- SDG 14:** Improve water conditions to sustain life in water.
- SDG 15:** To create environment that caters biodiversity



Source: UN Development Goals

## 2.5. DRIVERS OF CHANGE IN GANGES RIVER BASIN

### 2.5.1. Pattern of Urbanization

#### A. Urbanization in India

The process of urbanization increased at a tremendous rate in India after independence as the country adopted the policy of a mixed economy. This gave rise to the development of several industries in the private sector. With economic liberalization in 1991, the growth of the private sector in urban areas increased at a high pace. This led to the process of rapid urbanization in major cities. As per The World Bank reports, the population in urban India is expected to increase to 35% by 2020, compared to merely 11.4 % in 1901 and 27.8% in 2001. The 11<sup>th</sup> 5-year plan (2007-2012) was aimed at the process of further urbanization to achieve economic development. While these policies help in the economic growth of the country, it creates more gaps between urban-rural area, promoting migration and creating pressure on urban areas.

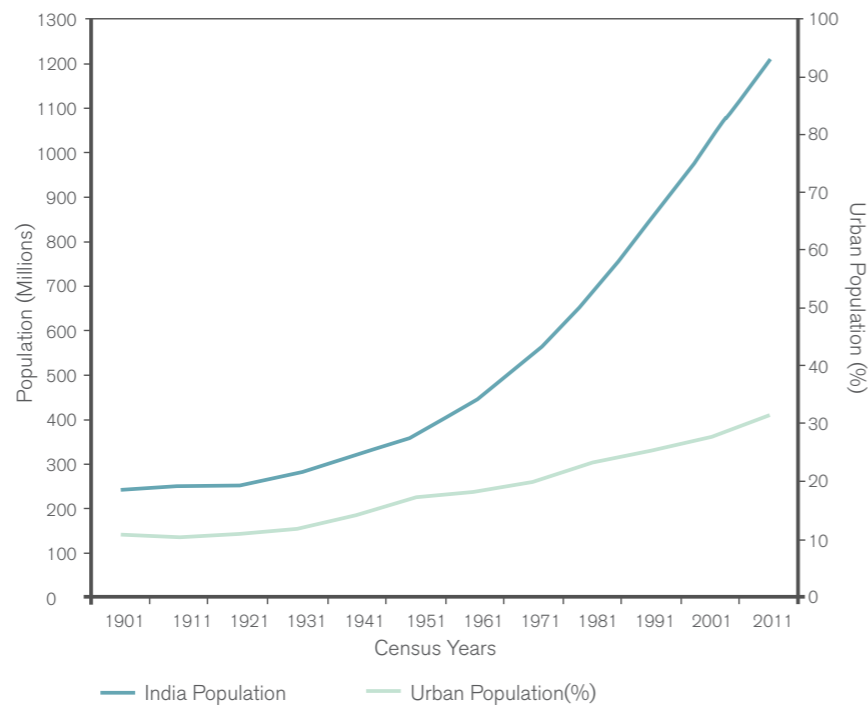


Fig. 06. Urban Population Growth of India  
Source: Denis and Marius-gnanou, 2010

#### B. Impact of Rapid Urbanization

The impacts of rapid urbanization can be seen in environmental, economic, social and government sectors of the country. With the movement of industrial capitalism, the phenomenon of spatial polarization started to become predominant. The rapid urbanization in India leads to the following consequences.

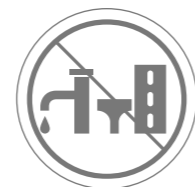
(A) Shortage of Houses - The lack of housing and the continuously increasing demand for about 22 million houses, forced more than 50% of the population in cities to live in slums, with extremely low quality of living.

(B) Critical Inadequacies in Public Utilities - The rapid urban growth of major cities of Prayagraj, Kanpur, Varanasi and Calcutta along the bank of river Ganga, did not correspond to the growth in urban infrastructure causing problems of clean drinking water and lack of sanitation facilities.

(C) Deteriorating Urban Environment - With increased migration from rural to urban and urban population growth, the pressure on resources increased tremendously. The increased pressure not only increased environmental degradation but it also increased vulnerability for several communities (Amit Kumar, 2014).



Housing Demand



Lack of Public Utilities



Environmental Challenges

### C. Rural - Urban Migration in India

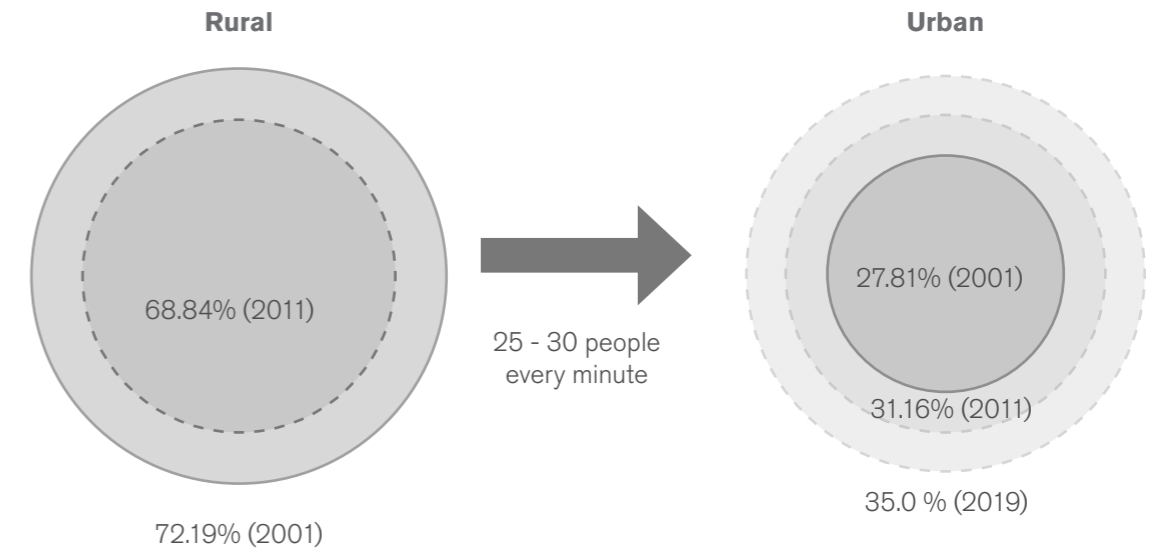
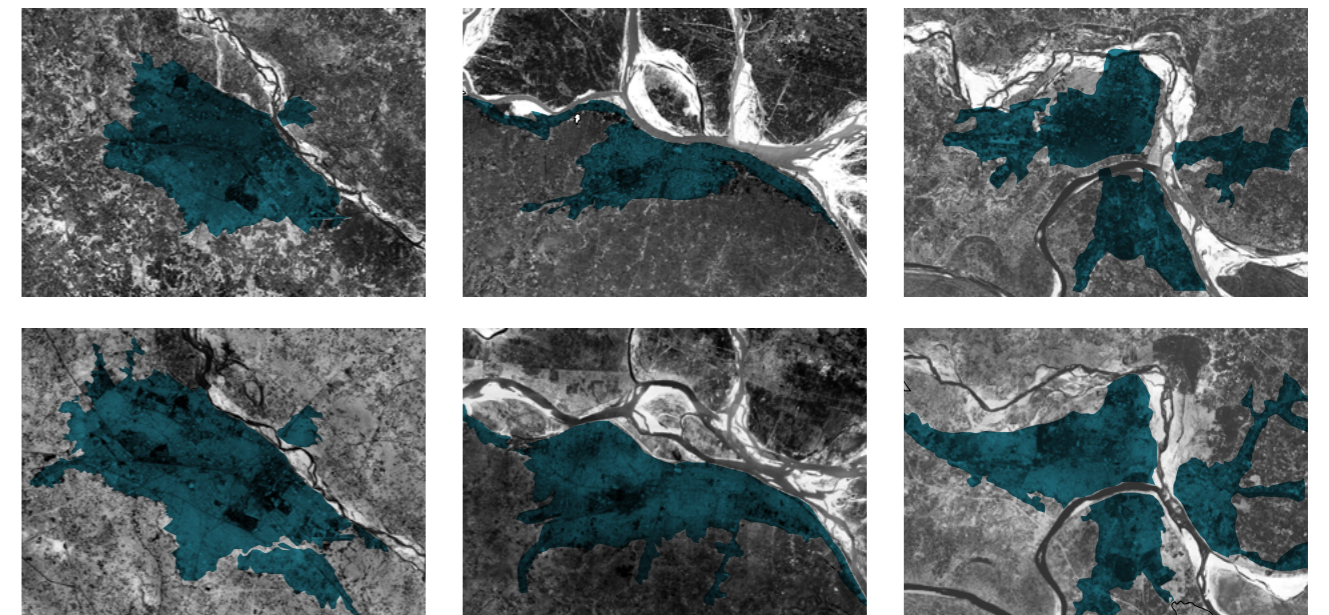


Fig. 07. Rural to Urban Migration in India  
Source: "India Population (2020) - Worldometers", 2020

### D. Expansion of Urban Centers in Ganges River Basin



Kanpur: 1990 (top), 2019 (bottom) Patna: 1990 (top), 2019 (bottom) Prayagraj: 1990 (top), 2019 (bottom)  
Image (j): Growth of Urban Centers in Ganges River Basin  
Source: Google Earth Images

The increasing growth of cities in India leads to the creation of environmental degradation, economic inequality, unachieved standards of living affecting the marginalised and the vulnerable groups of people within the city. This made questions about justice specifically **Spatial Justice** more evident.



## 2.5.2. Infrastructure Development

### A. Water Infrastructure and Society

Construction of Water Infrastructure has an important social and economic dimension. Water Infrastructures in The Ganges River Basin are mainly constructed to achieve the following benefits:

1. Domestic Water Supply
2. Industrial Water Supply
3. Irrigation
4. Hydro-Power Generation
5. Sanitation
6. Flood Defence

While most developed industrial countries harness over 80% of hydro-power potential, India, despite huge hydro-power sites, is currently utilizing on 20% of the available potential.

In the Ganges River Basin, the distribution of water supply and access to water infrastructure is not just. Most marginalised communities still lack the supply of clean drinking water and sanitation facilities. The huge infrastructure of canals for irrigation in the basin has been constructed yet, farmers are forced to build bore-wells for groundwater extraction.

The societal perception for flood defence infrastructure still lies in the construction of concrete embankments for safety.

### Future Capacity of Water Infrastructure in India

200 billion m<sup>3</sup>  
Water Storage Capacity

30,000 MW  
Hydro-Power Generation Capacity

90 million Ha  
Irrigation Capacity

Source: World Bank Report, WRI 2013

### Future of Water Infrastructure and Society in Ganges River Basin

With changing climate and increasing water needs it is important to understand the value of water infrastructure in the basin. There needs to be a shift in designing of water infrastructure, to make it sustainable, efficient and spatially just for all communities. Building and monitoring optimised water infrastructure is necessary to create economic opportunities, job generations and liveable conditions.

### Current State

Basic Water Supply (2015)    Basic Sanitation (2017)

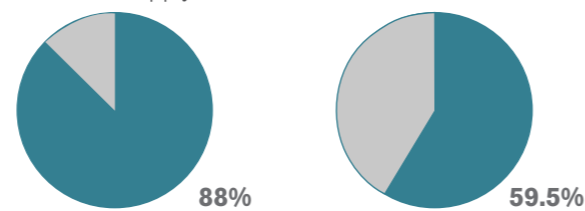


Fig. 08. Water supply and Sanitation Access in India

Source: World Bank Report



Image (k): Unjust distribution of Water Supply Infrastructure

Source: UNICEF India, 2017, Flickr.com



Image (l): Tehri Dam, Uttarkashi.

Source: Pete McBride, nature.com 2018

### B. Water Infrastructure and Space

All water infrastructure finished/unfinished, small and big have spatial implications due to their presence. Large scale infrastructure like hydropower dams, barrages, irrigation canal, usually constructed over a large span of years has spatial implications like soil erosion, change of water flow, and submergence of land. While these infrastructures are necessary for social and economical benefit of the society, it is important to understand the spatial results, intended or unintended, caused due to these structures. Several protests have been carried out by locals against the construction of such infrastructure projects to protect themselves from issues of land submergence and biodiversity loss.

Small scale infrastructures like recharge well, rainwater harvesting tanks and flood-able landscapes when planned holistically, have a low spatial impact in terms of space occupancy and can make a huge impact in achieving resilience. The ownership and maintenance of these low spatial impact infrastructure can be distributed amongst the communities. Hence, by understanding the dynamics between space and water infrastructure, suitable infrastructures can be built and maintained.



Image (m): Spatial dimension of Water Infrastructure

Source: Arjun Swaminathan, idronline.org

### C. Water Infrastructure and Ecology

During the second half of the 20th Century, various water infrastructures like dams, hydropower projects, irrigation canals, barrages were constructed to on The Ganges River and its tributaries. These projects hampered the longitudinal, lateral and vertical connectivity of water networks in the basin, hampering the ecological integrity of the river.

Moreover, the government promotes embankments, as the only flooding measure suitable and available for flood protection, encouraging people to construct concrete walls, confining the dynamic river and water movements between walls. Thus, to date, the engineered grey infrastructure in The Ganges River Basin, has created more ecological disturbances than benefits, making it necessary to move towards new green infrastructure that promotes resiliency.



Image (n): Ganges Canal at Haridwar

Source: Google Earth

### 2.5.3. Climate Change

#### A. Rising Temperatures

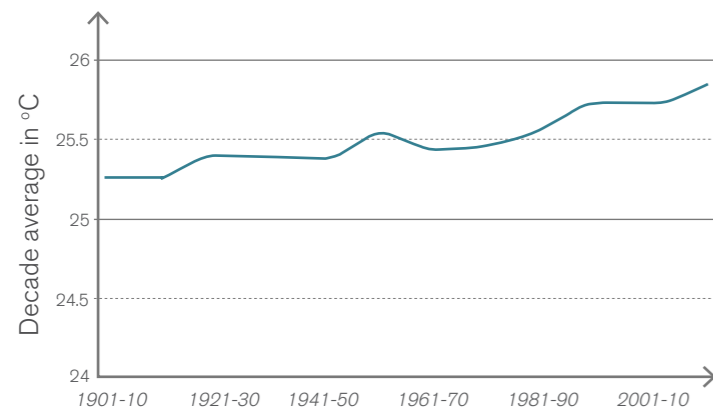


Fig. 09. Average Decade Temperature in India  
Source: Environment Statistics 2019, MOSPI (LiveMint, 21 Jul 2019)

The impacts of global warming are clearly visible in India. India has been experiencing an increase in its average temperature, reaching as high as 26.2°C in 2016. This constant increase in temperature has resulted in changing patterns of rainfall, leading to loss of economy.

Due to increased temperatures, the glacial sources of Himalayan rivers are melting at irreversible rate. 30% of water source in The Ganges River is currently formed by the Himalayan Glaciers. With the rising temperature and melting of glaciers, there is an expected rise in the temporary water flow of the river. Although in the long term, as there will be loss of glacier formation due to high temperatures, the river might experience loss of water due to decreased water source. This understanding of fluctuated water source makes it important to re-look at water cycles to maintain them and if required modify and adapt to reduce future water crisis.

#### B. Flooding Risk

15 Countries account for 80% of population exposed to river flood risk worldwide

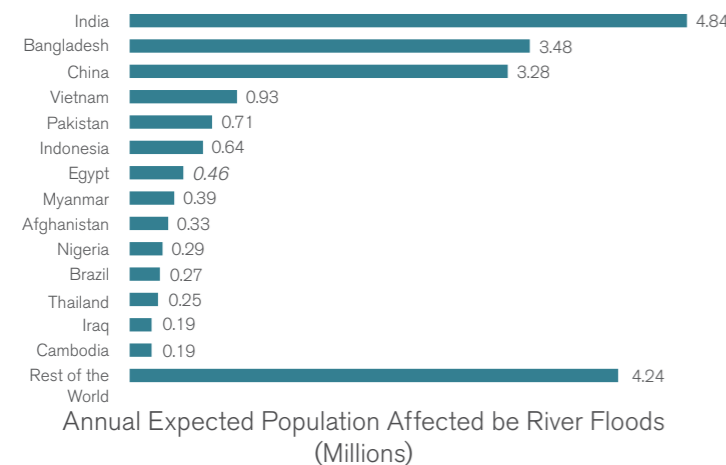
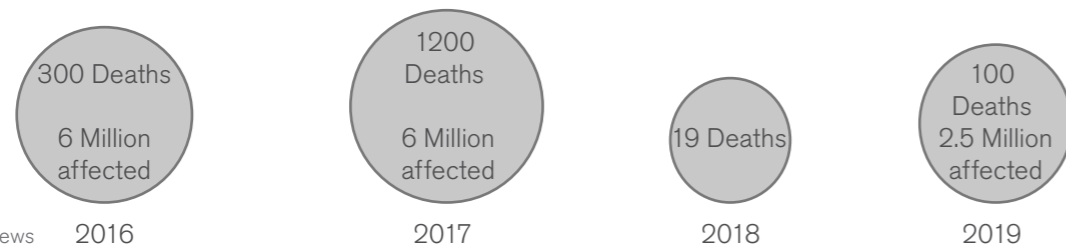


Fig. 10. Impact of Flooding around the World  
Source: World Resource Institute, 2013

Changing precipitation patterns and unplanned development has led to increased flooding occurrences around the world. India becomes the most impacted country with about 4.84 million people being affected by river flooding annually.

The Ganges River Basin has also been highly impacted due to flooding of the river and its tributaries. In the past few years, the thousands of people have died and millions have been impacted with the loss of households, jobs and income. Thus, planning for adaptation to flooding is extremely necessary today.

#### Deaths and Affected Population due to flooding in The Ganges River Basin



Source: BBC News 2016

#### C. Water Crisis

Climate change has impacted millions of people around the world with increasing temperatures, water crisis and natural disasters. In 2019, more than 2.3 billion people (approximately 31% of the world's population) were affected due to water availability crisis, and the numbers are increasing every second.

Farming accounts for 70% of the world's water usage and with constant depletion in water levels, the pressure on existing water resources is increasing. The water level in The Ganges River is depleting at a rate of 38.1 cm/year compared to 0.5 cm in 1999. At this rate, by 2050, 115 million people may face food scarcity due to the water crisis.

Source: 10 Most Important Water Scarcity Facts, 2019



Fig. 12. Population within countries under Water Stress  
Source: World Bank Statistics, Dormido, 2019

#### D. Climate Disaster Risks Map of India

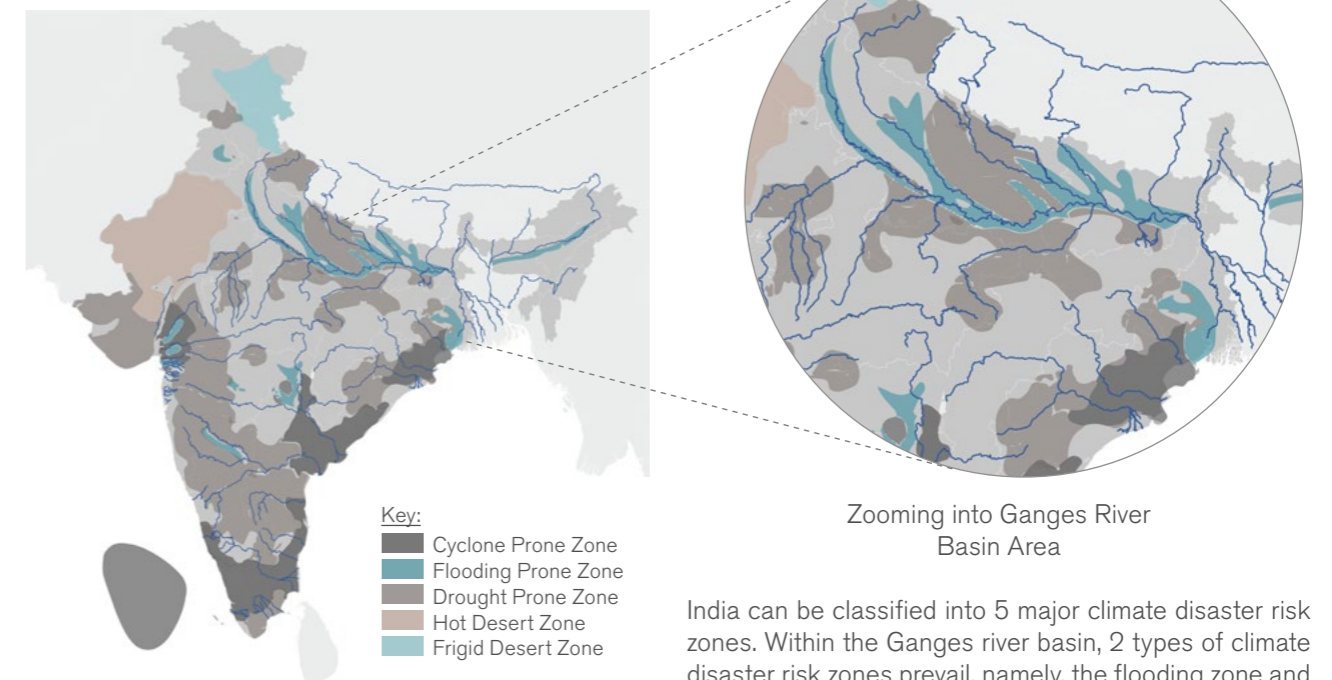


Fig. 11. Climate Disaster Map of India  
Source: Atlas of India

Zooming into Ganges River Basin Area

India can be classified into 5 major climate disaster risk zones. Within the Ganges river basin, 2 types of climate disaster risk zones prevail, namely, the flooding zone and the drought zone. Hence while designing and planning for such zone it is important to understand the hydrology and the water cycles of the region with respect to the changing climate and monsoon cycles.

To conclude, Urbanization, Infrastructure Development and Climate Change act as drivers of change in the Ganges River Basin. These drivers of change also create **externalities**, that are both positive and negative for the communities in social, economic and environmental aspects.



## 2.6. CURRENT GOVERNANCE MODEL

### 2.6.1. Actors and Hierarchy

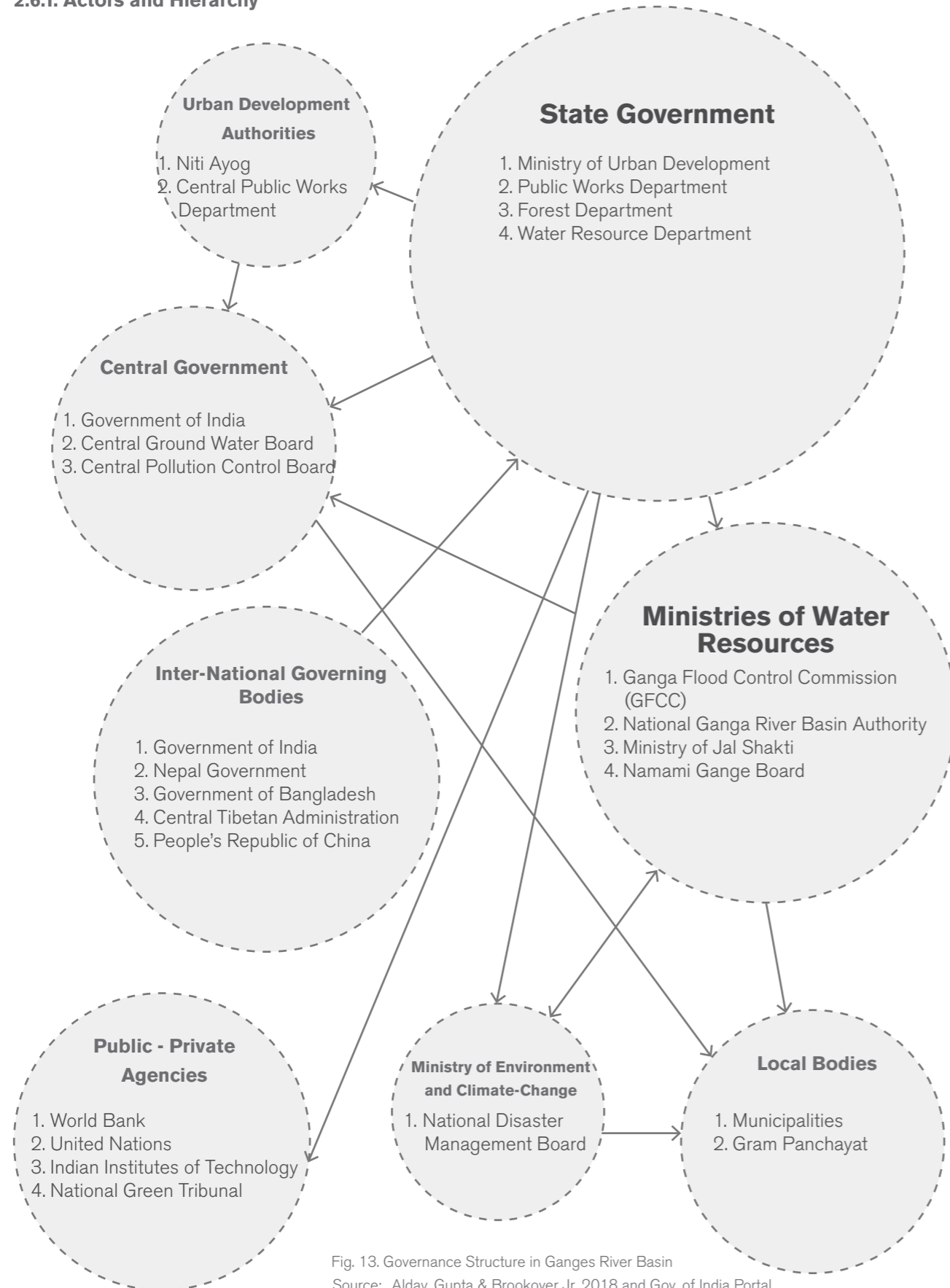


Fig. 13. Governance Structure in Ganges River Basin  
Source: Alday, Gupta & Brookover Jr, 2018 and Gov. of India Portal

### 2.6.2. Governance of The Ganges River Basin



Image (o): Ganga Rejuvenation project, led by National Government  
Source: Press Information Bureau, Government of India, 2019

The river basin of the Ganges lies in three countries namely, India, Nepal and Bangladesh. For the sustainable planning and implementation of projects there need to be an cross-country governing agency.

Within India the river passes through 5 states. With different government bodies at National, State, City and Rural Administrative areas there is need to establish multi-level governance dialogue. The co-ordination between various ministries dealing with problems related to water, the state governments and the national government is not sufficient. Also, the current model of Governance is a top-down approach with National policies playing the front rule in determining the type of development and projects within states. The state governments further determining planning projects for water without integration with adjacent state governments or local bodies.

It has been observed globally, that water quality and its management can be improved with local actions. There is a need for shift of action from the central and the state governments and also change in planning models to achieve optimum water management. Moreover, with no proper R&D institutes and lack of multidisciplinary teams development and implementation of integrated water and resource management in large river basins become more challenging. Concepts of participation, community empowerment and institutional development have remained unclear and unexplored.

### 2.6.3. Lack of Integration

There has been a lack of knowledge and exploration regarding tools and strategies for the interaction of various water management bodies, urban planners, central and state governments, local municipalities and environment bodies.

In India, water has been listed under the state government, and hence the responsibility of the management of water resource, flood risk management and development of strategies for economic mobilization of water comes under the state authority. With competitions amongst the state to achieve regional benefits, the interest of water management at the river basin scale is failed.

Most of the water management planning and projects are carried out in isolation. To achieve sustainable development, it is necessary to establish interactions between society, economy and ecology, and the numerous sectors that share the common resource of water.

Water management department in most states in the river basin was initially established as irrigation departments, thus the approach still remains oriented to engineering and construction of dams and canals to achieve irrigation benefits. With the domination of engineering, there is a lack of social perspectives, environmental cost and co-management of resources.

Also, due to the lack in the integration of different departments and sectors, the approaches lack integration and diversity within strategies to deal with climate change adaptation, vulnerability, and resource management in the basin.

As issues of water management affect all sectors and sections of society, it is important that the process of management includes ideas and thoughts from all stakeholder and also the civil societies into consideration (Singh, Saha & Tyagi, 2019).

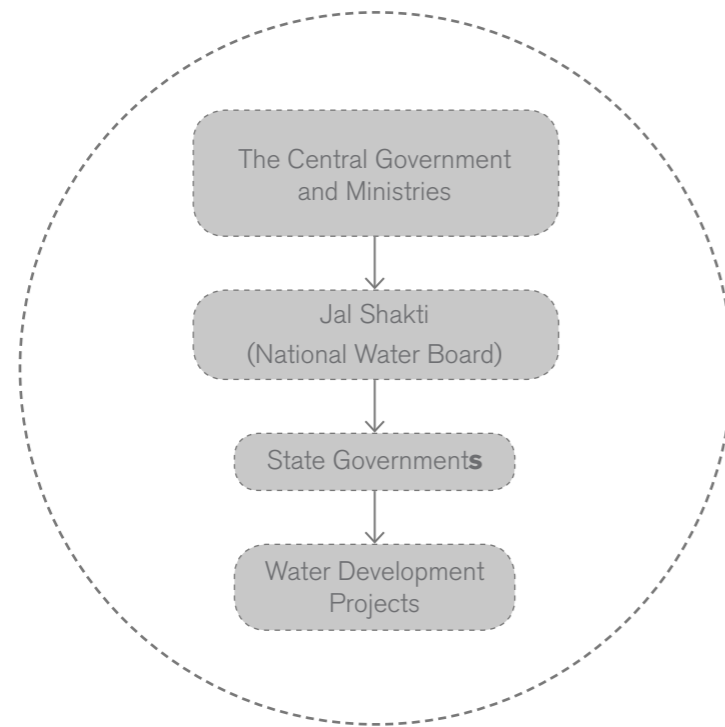


Fig. 14. Current Model for Water Development Projects, in isolation, for each state in the river basin.

### 2.6.4. Need for Paradigm Shift in Planning and Governance

India is undergoing rapid urbanization and industrialization, changing demands of water and adding new challenges in water development. This demands for change in manner water policies and management is carried out.

The approach of dealing with problems in The Ganges River Basin have been focused on reducing pollution and fulfilling irrigation demands. Apart from this, several projects for flood and disaster risk management are carried out in the basin. But, with changing climate and increasing vulnerability and risks, there is a need to develop a new paradigm and institutional framework of adaptive governance and resilience building.

The current condition of The Ganges River and the basin is dominantly due to anthropogenic activities carried out in the basin over the years, the urbanization and industrialization. Strategies and tools to counter these

challenges need to be based on the culture and attitudes of the people. Thus, it is important to include communities in the development of policies and designs related to water. The civil societies can help play an important role in bridging the gap between governance policies, strategies and execution.

The water disputes, due to the inter-state river basin of the river, continue to hamper the progress of development in the basin. Secondly, several individuals and NGOs are working in the river basin to relieve water stress in the region. These individual approaches when working in isolation fail to attain desirable results. Apart from that, there is a need to establish a science-based evaluation system, at local levels to give feedback loops to the regional and national level, for the holistic development of the river basin.

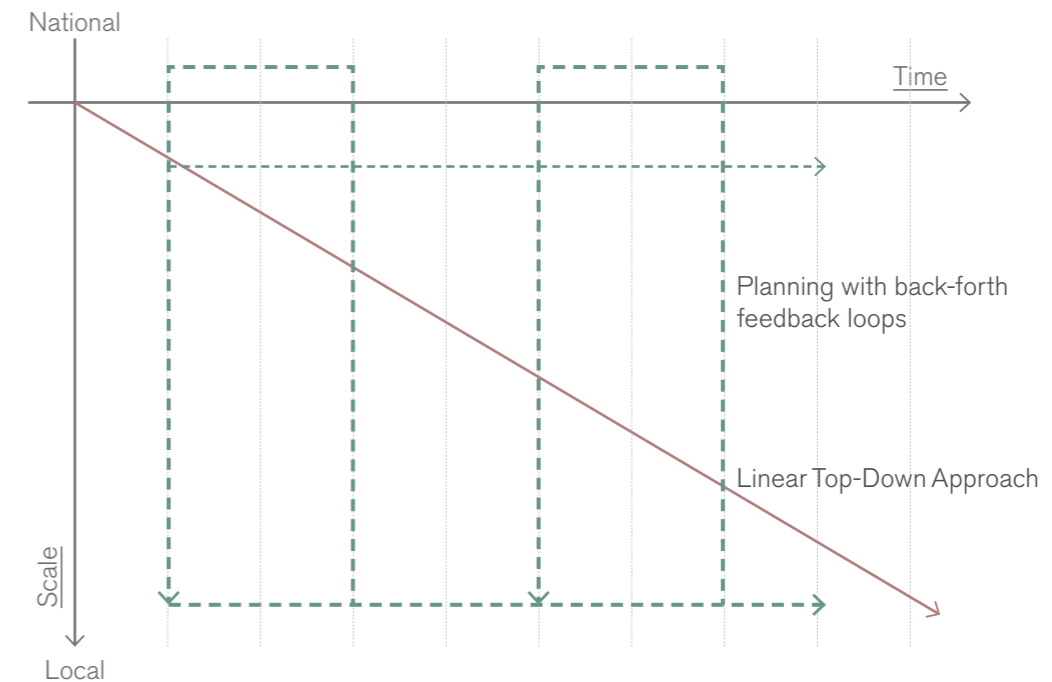


Fig. 15. Shift in Planning Approach





# 3. Problem Analysis

This section of the report emphasises on problem analysis in The the Ganges River Basin to understand the issues. The analysis aims to learn about the geographical context and determine socially, economically and ecologically vulnerable areas in the region. Further, the analysis is carried out zooming into the state of Bihar for specific design interventions. This area will be studied to develop strategies, that can be developed and tested throughout the basin.



Understanding Problem Field

Chapter 2

- Current Challenges in Ganges River Basin
- Drivers of Change
- Governance Challenges for Ganges River Basin

Introduction

Chapter 1

- Context
- Relationship between human systems and ecological systems

Chapter 3

- Socio-ecological vulnerability analysis across scales
- Problem Statement (Spatial Justice)
- Line of Inquiry:
  1. Dual Nature of Externalities
  2. Capital

Chapter 4

- Theories:
  1. Urbanization
  2. Vulnerability
  3. Resilience Thinking
  4. Social Capital and Governance
- Notions:
  1. Interdependence - Integration
  2. Infrastructure Ecology
  3. Evolutionary Resilience

Research Methodology

Chapter 5

- Conceptual Framework: Adaptive Spatial Planning Model

Vision

Chapter 6

- Principles
  1. Robustness
  2. Adaptivity
  3. Connectedness
  4. Diversity
- Frame of Reference
  1. Knowledge of System Behaviour
  2. Dynamic Adaptive Planning Pathways
  3. Stakeholder Collaboration
- Systemic Goals

Design

Chapter 7

Regional Strategies

Mitigation Strategies that are derived for challenges across the basin

Evaluation

Chapter 10

Scenarios

- Case 1
- Case 2
- Case 3

Chapter 8

Metropolitan Scale Strategies

Mitigation Strategies that are derived for challenges for metropolitan scale

Chapter 9

Local Adaptation

Adaptation of multiple strategies to achieve resilience

1. Urban
2. Peri-Urban
3. Rural

Adaptive Planning Pathways



### 3.1. VULNERABILITY ANALYSIS

#### 3.1.1. Vulnerability Assessment

**Definition:** The inability to counter the adverse effect of a hazard. (Not all exposed population group are vulnerable since vulnerability is an virtue of ability)

#### Vulnerability Assessment

Social Vulnerability	
Age	High 0 ----- Low 15 ----- Medium 65 ----- High 100
Gender	Females Transgender
Vulnerable minorities	Low income Caste Classification
Immigrants	High
Family Structure	High 0 ----- Low 4 ----- Medium 6 ----- High 10
Literacy Rate	High 0 ----- Low 100
Population Density	Low 0 ----- High n

Ecological Vulnerability	
Flooding	Low ----- High
Drought	Low ----- High
Ground Pollution	Low ----- High
Soil Erosion	Low ----- High
Surface Water Runoff	Low ----- High
Agricultural Practices	Low ----- High
Loss of species	Low ----- High Increase ----->

Economic Vulnerability	
GDP per capita	High ----- Low
Average monthly salary	High ----- Low
Economic sector	Agriculture Fishing Energy

Table: Variables for vulnerability assessment

Source: Adger, 2005-2009

Global

<b>Social Vulnerability</b> <ul style="list-style-type: none"> <li>Vulnerable minorities</li> <li>Population Density</li> </ul>	<b>Ecological Vulnerability</b> <ul style="list-style-type: none"> <li>Flooding</li> <li>Loss of Species</li> </ul>
---	---

<b>Social Vulnerability</b> <ul style="list-style-type: none"> <li>Population Density</li> </ul>	<b>Ecological Vulnerability</b> <ul style="list-style-type: none"> <li>Flooding</li> </ul>
--	--

<b>Social Vulnerability</b> <ul style="list-style-type: none"> <li>Literacy Rate</li> <li>Population Density</li> </ul>	<b>Ecological Vulnerability</b> <ul style="list-style-type: none"> <li>Flooding</li> <li>Rainfall</li> <li>Groundwater Pollution</li> <li>Soil Erosion</li> <li>Surface run-off</li> </ul>	<b>Environmental Vulnerability</b> <ul style="list-style-type: none"> <li>GDP</li> </ul>
---	--	--

<b>Social Vulnerability</b> <ul style="list-style-type: none"> <li>Functional Distribution</li> </ul>	<b>Ecological Vulnerability</b> <ul style="list-style-type: none"> <li>Flooding</li> </ul>	<b>Environmental Vulnerability</b> <ul style="list-style-type: none"> <li>Economic Sector</li> <li>Per Capita Income</li> </ul>
---	--	---

<b>Social Vulnerability</b> <ul style="list-style-type: none"> <li>Vulnerable minorities based on area of residence</li> </ul>
--

Local

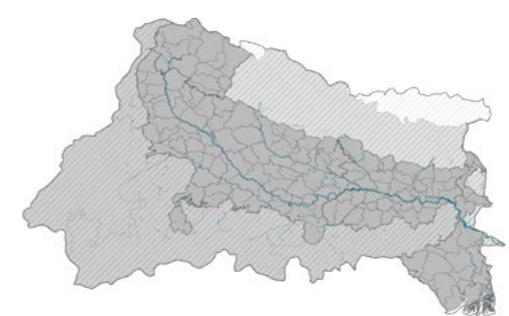
World



Asia - India



Ganges River Basin



Bihar State



Patna Metropolitan Region



Fig. 16. Vulnerability assessment across scale

### 3.2. RISK ANALYSIS: MACRO SCALE

#### 3.2.1. Social Vulnerability

The social vulnerability can be determined with parameters like population density, growth development product (GDP), literacy rate, age, income, gender, family structure. Of the above criteria, population density, growth development product and literacy rate have been identified and mapped in The Ganges River Basin Area to identify socially vulnerable areas in the region. The rest of the parameters are used at the zoomed-in scale in the next section of the chapter.

#### A. Population Density

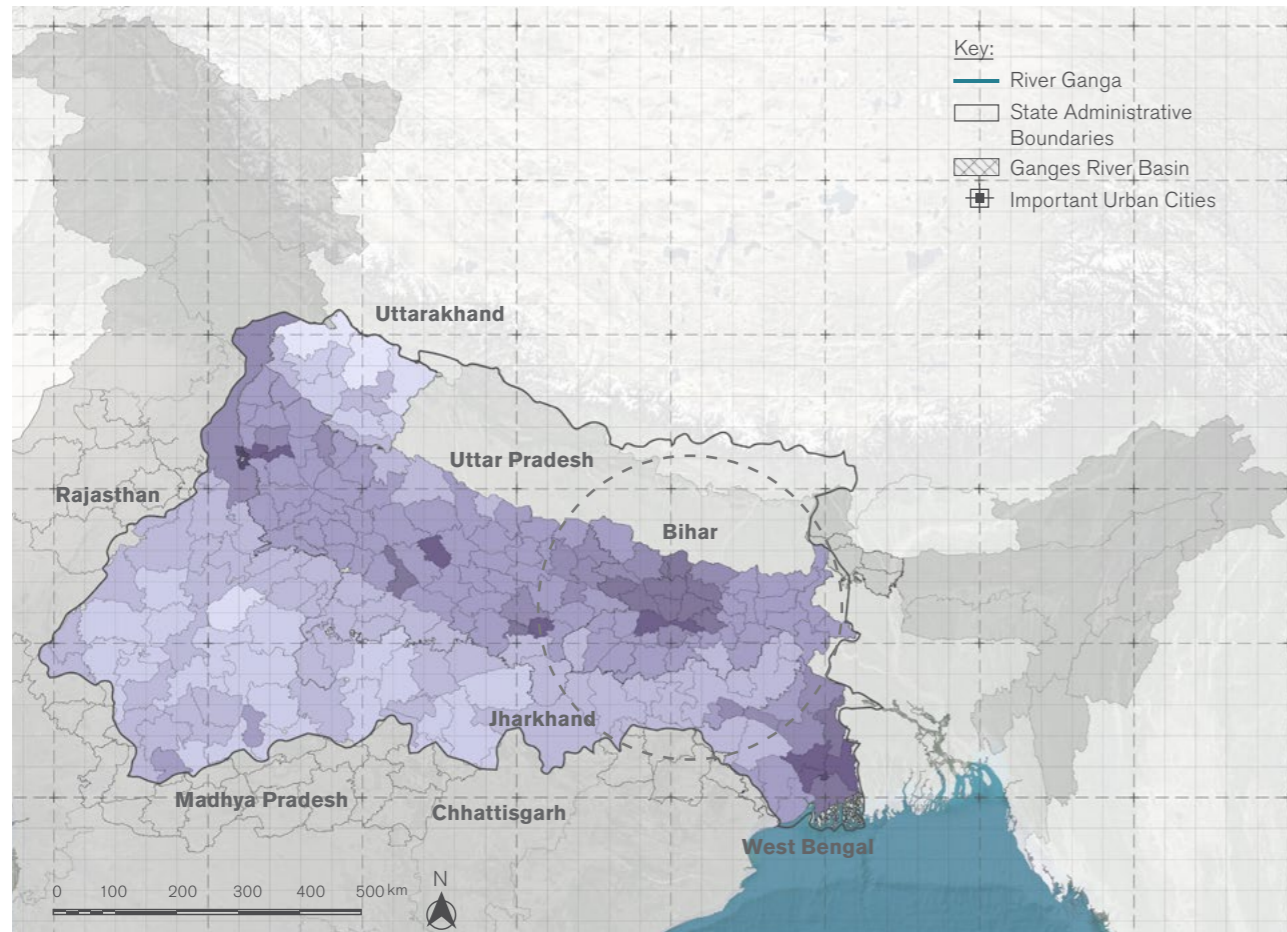


Fig. 17. Map showing population density within The Ganges River Basin  
Source: GIS Data, Bhuvan, NIC Bihar, Census data 2011

The above map shows the distribution of population density within The Ganges River Basin. The range of density varies from 25 persons per sq km to as high as 1500 persons per sq km. Most high-density districts are in the state of Bihar. With density as high as approximately 900 persons/sq km, the areas become highly vulnerable as the infrastructure and amenities are not built to cater to the high number of persons. Also, in case of disaster and calamities, a huge amount of people are exposed to the risk.

**1,106 persons / sq km**  
Bihar State Average

**382 persons / sq km**  
Density Average India

**25 persons / sq km**  
World Density Average

Source: Census Data 2011

#### B. Gross State Domestic Product (GSDP)

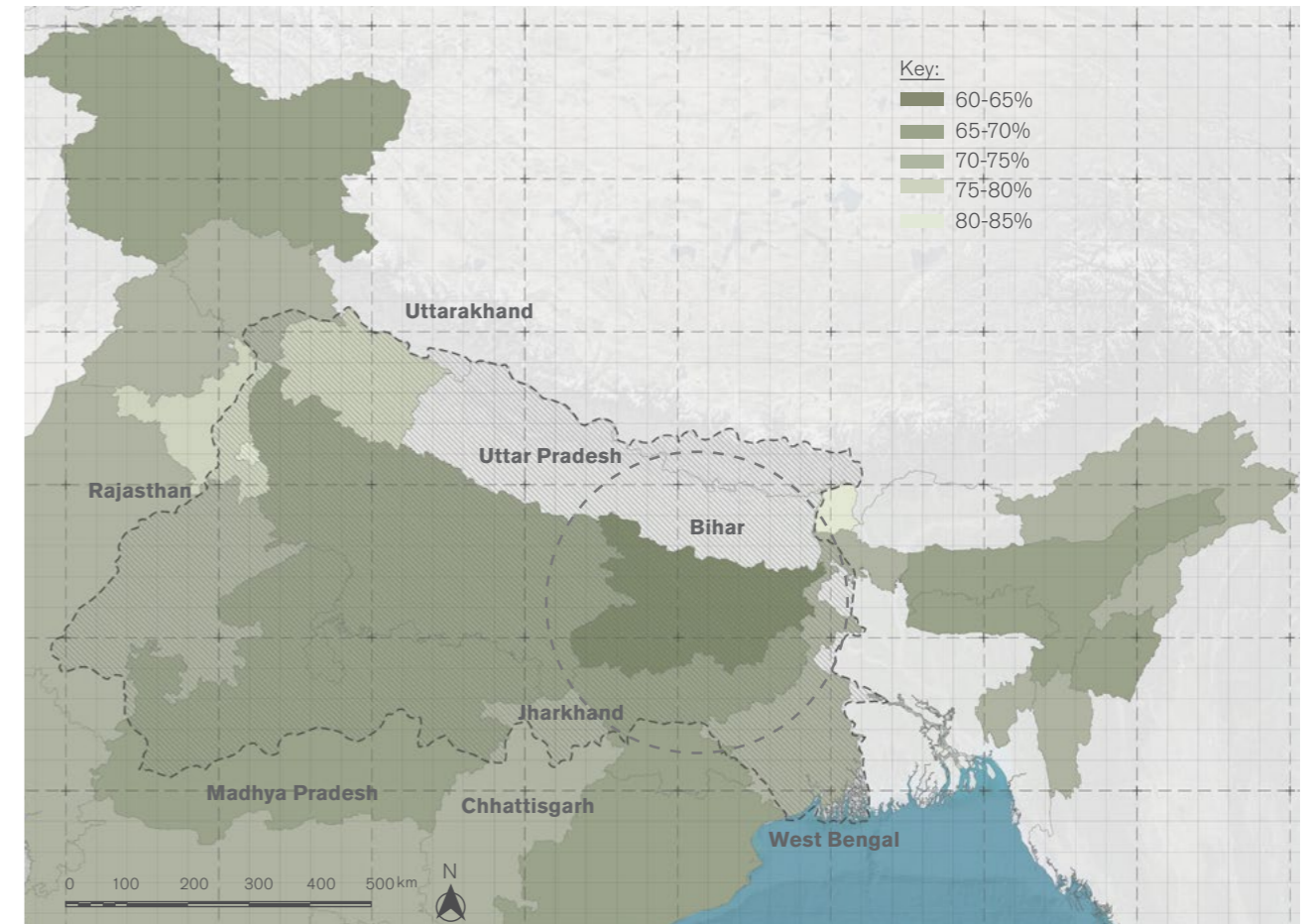


Fig. 18. Map showing Gross State Domestic Product for states in Ganges River Basin  
Source: GIS Data, Bhuvan, NIC Bihar, Census data 2011

The Gross State Domestic Product (GSDP) is defined as a measure, in monetary terms, of the volume of all goods and services produced within the boundaries of the State during a given period, accounted without duplication (Data.gov.in). This measure is used to compare and analyse the growth and production by different states in India. Currently, the state of Bihar, with GSDP of INR 47,541 is the state with lowest GSDP. This makes the state economical more vulnerable in the country and the basin.

**INR 502,425**  
Highest GSDP, Goa

**INR 47,541**  
Lowest GSDP, Bihar

Source: Census Data 2011



### C. Literacy Rate

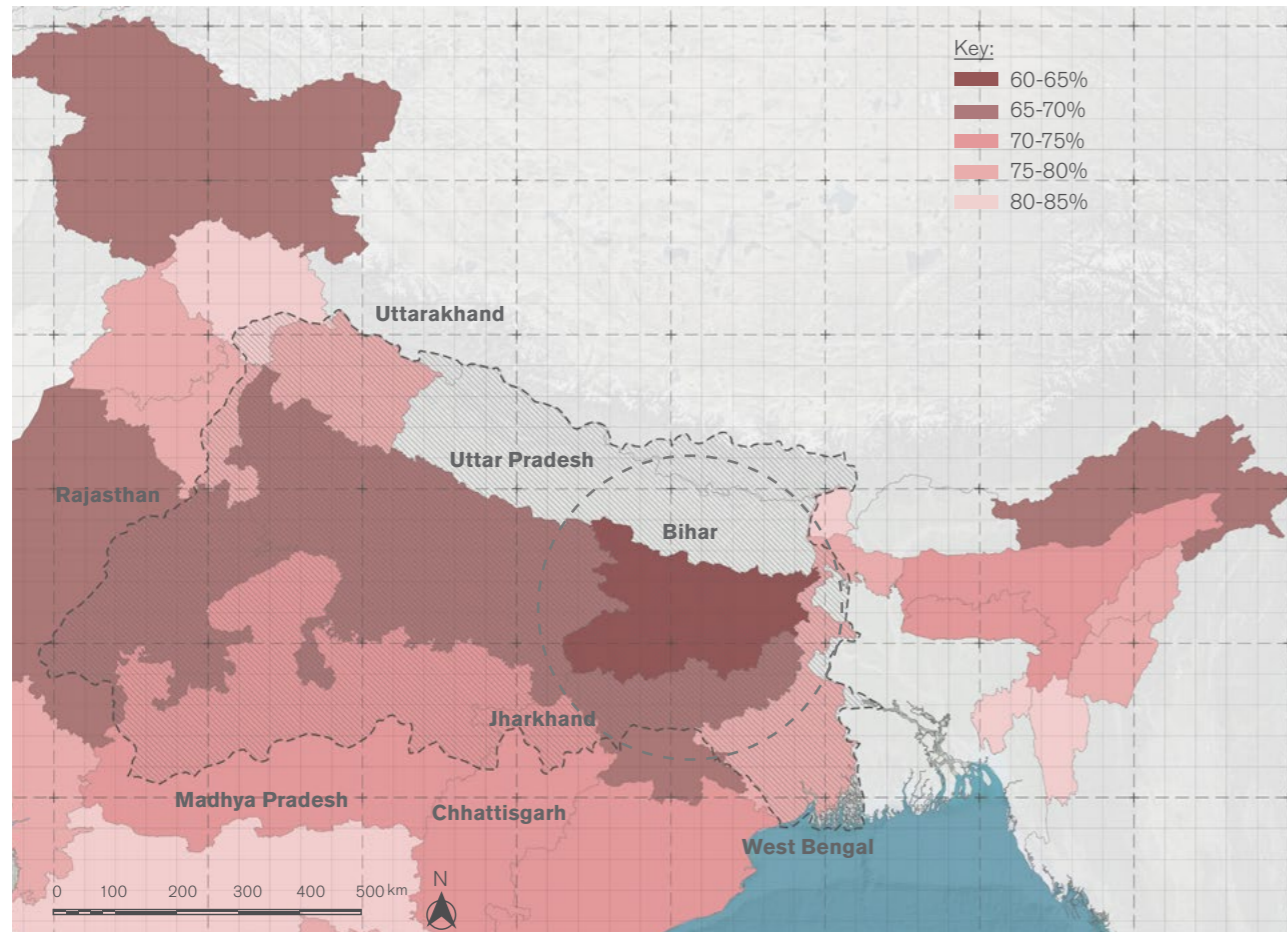


Fig. 19. Map showing the Literacy Rate within different states in The Ganges River Basin  
Source: GIS Data, Bhuvan, NIC Bihar, Census data 2011

Literacy rate average of different states is mapped above to understand the social vulnerability parameter of the river basin. As per the 2011 census data, literacy within India the highest literacy rate is in the state of Kerala with 91.58 and the lowest literacy rate is in the state of Bihar with 63.82%. With less access to knowledge and awareness, people within the state of Bihar become highly vulnerable to risk and hazards.

### Social Vulnerability Map of Ganges River Basin

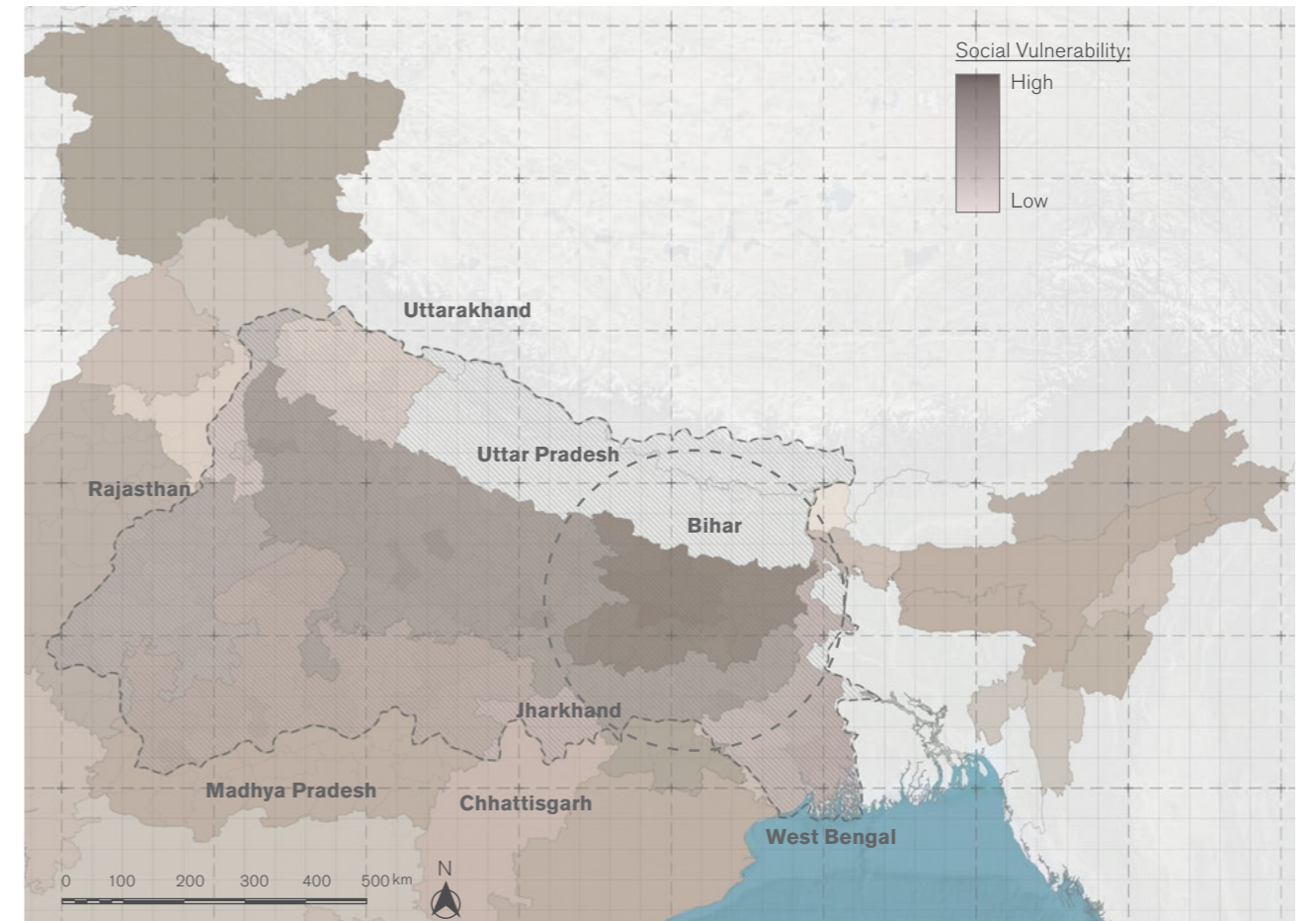


Fig. 20. Map showing Social Vulnerability in The Ganges River Basin  
Source: GIS Data, Bhuvan, NIC Bihar, Census data 2011

### Conclusion:

Overlaying data from the population density map, GSDP and literacy rate within The Ganges River Basin, it can be concluded that the Bihar state is one of the most vulnerable area socially within the basin. Further analysis is carried out to analyse ecological vulnerability in the basin, to determine the area for intervention.



### 3.2.2. Ecological Vulnerability (Anthropogenic)

The ecological vulnerability can be analysed by understanding first by analysing impacts of anthropogenic activities on the ecosystem and second, by understanding the impact of climate change on the ecosystem and the society. To analyse the ecological vulnerability due to anthropogenic activities, construction of dams, industries, surface run-off due to highly paved areas and deforestation. Sensitive zones are marked based on the mapped data.

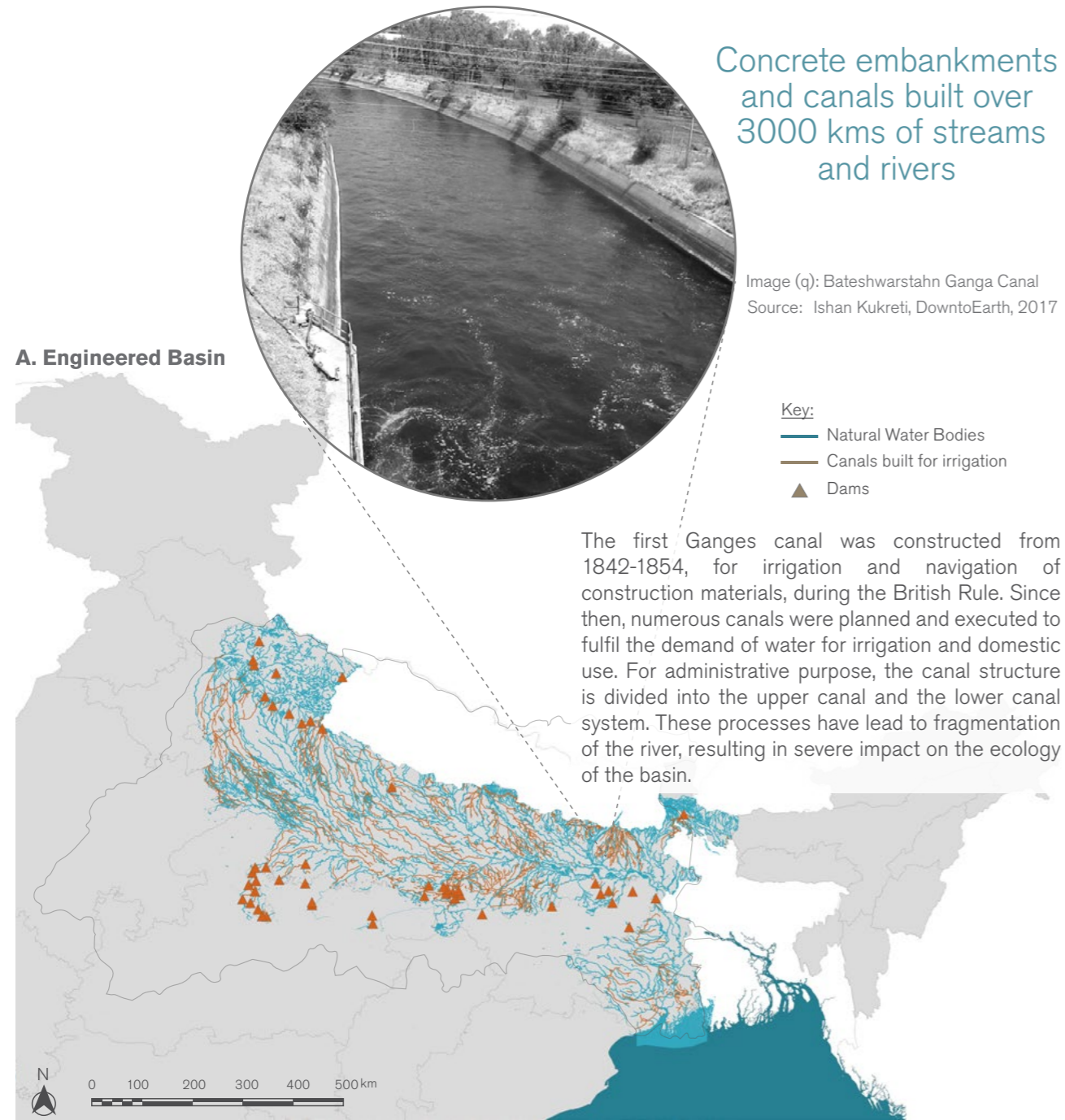


Fig. 21. Map with Natural and Engineered water bodies in the river basin  
Source: GIS Data, Bhuvan, NIC Bihar, Census data 2011

### B. Industrial Pollution

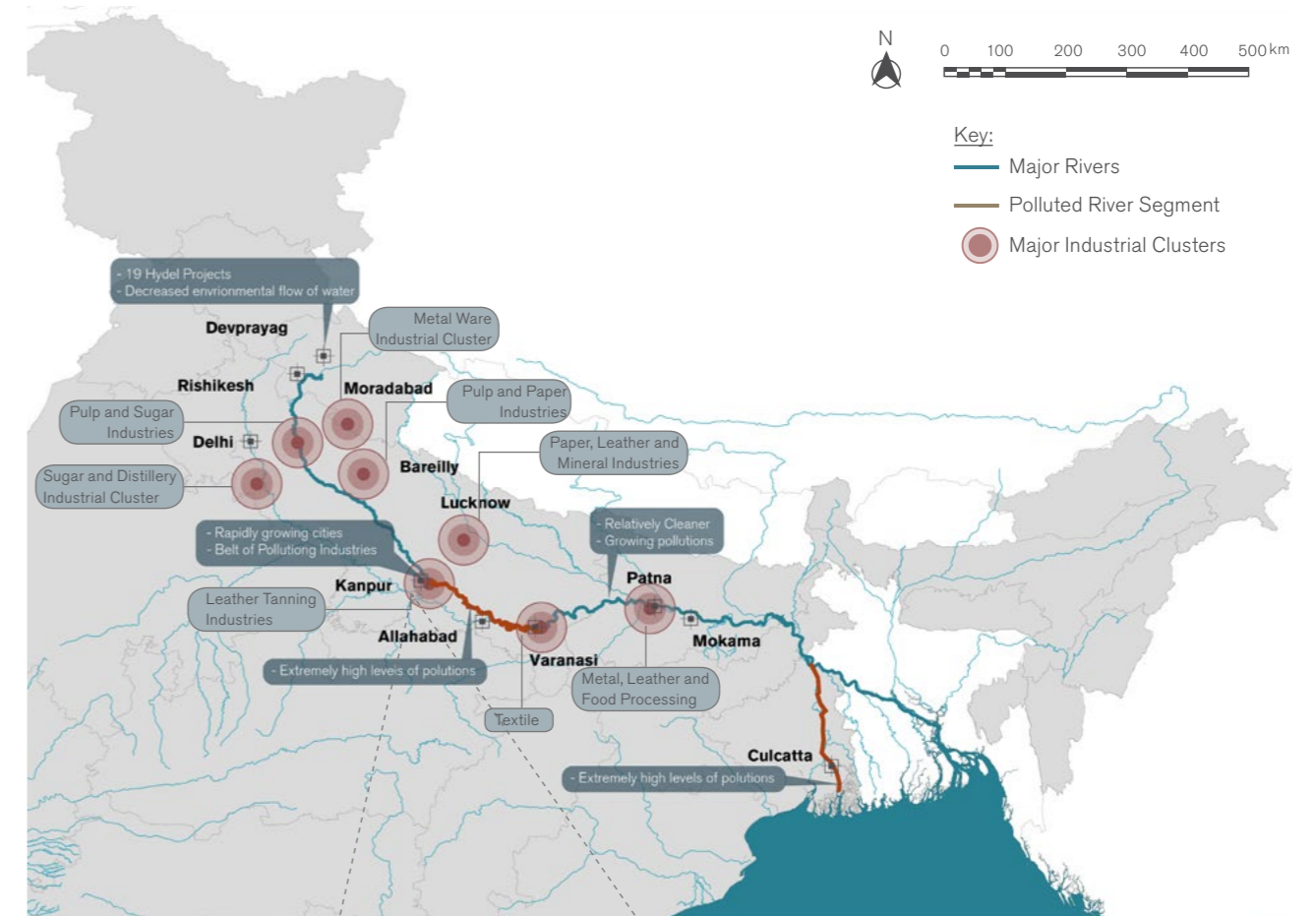


Fig. 22. Map with Major Industrial Clusters along the River  
Source: GIS Data, Ganga River Basin Management Plan, 2015



Industrial clusters of most urban centres on The Ganges River depend on the river for its water to manufacture items. These industries are often built on the outskirts of cities next to the river bank. The untreated polluted water from the industries is flushed into the river, causing water pollution. The chemicals in the wastewater, makes The Ganges River water unsafe to use.

Image (r): Unregulated working conditions in tanneries along The Ganges  
Source: Image by George Black. India, 2015.



### C. Surface Run-off

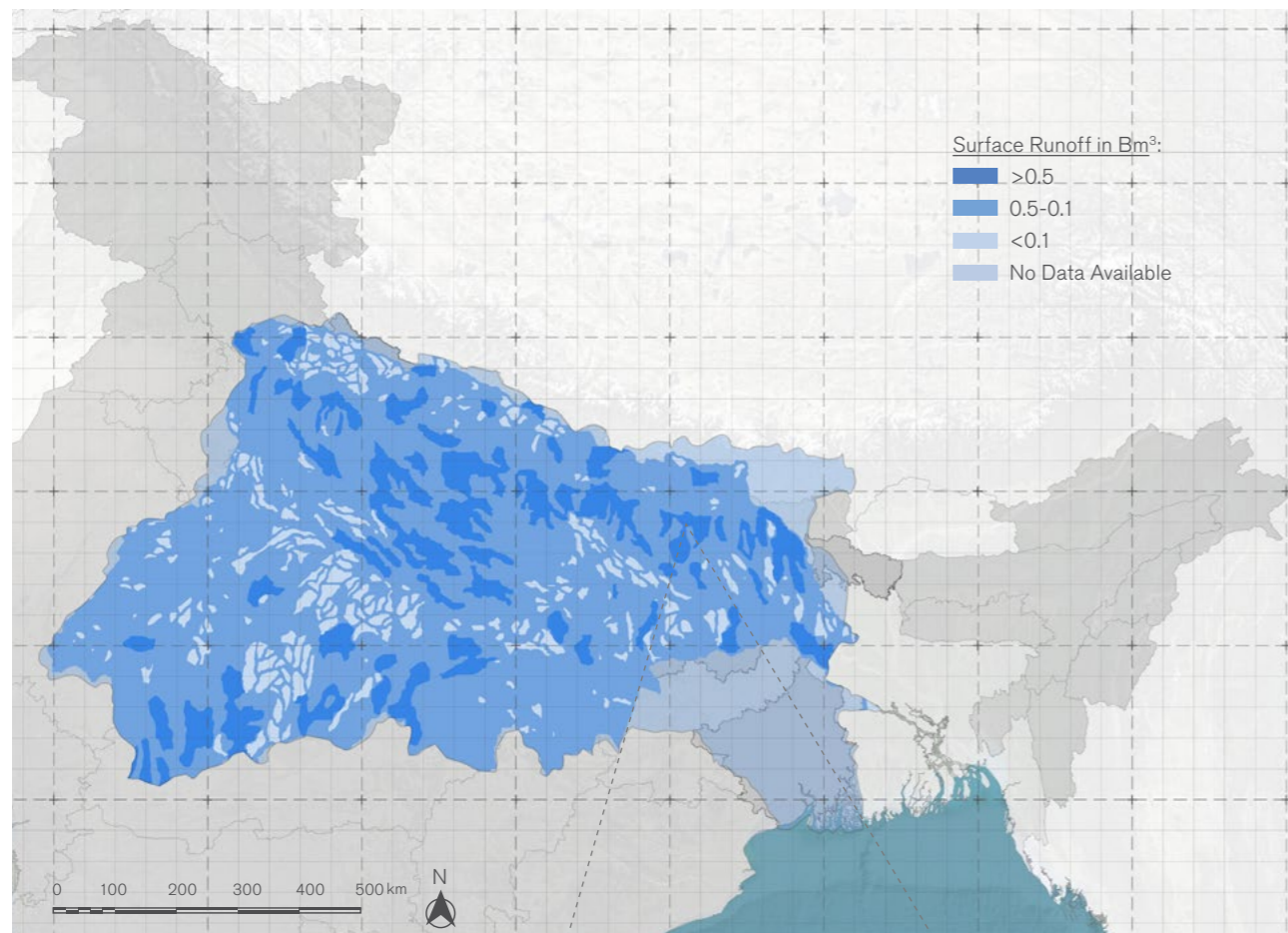


Fig. 23. Surface run-off water map  
Source: GIS Data, Bhuvan, Reviving the Ganges Water Machine, 2016

Areas in the basin, are divided into sub-basin areas to analyse the surface run-off water during monsoon. Nature-based, local solutions shall be adapted to hold this water. Holding water locally in small pond structure made with temporary bunds can help recharge groundwater.

In urban areas, the surface run-off is high due to intense paving of roads and the built environment. These paved areas shall be reduced or complemented with recharge tanks to allow local harvesting of rain-water.



Image (s): Temporary bunds to store rain water  
Source: Nandita Singh and Om Prakash Singh, 2018

### D. Groundwater Conditions

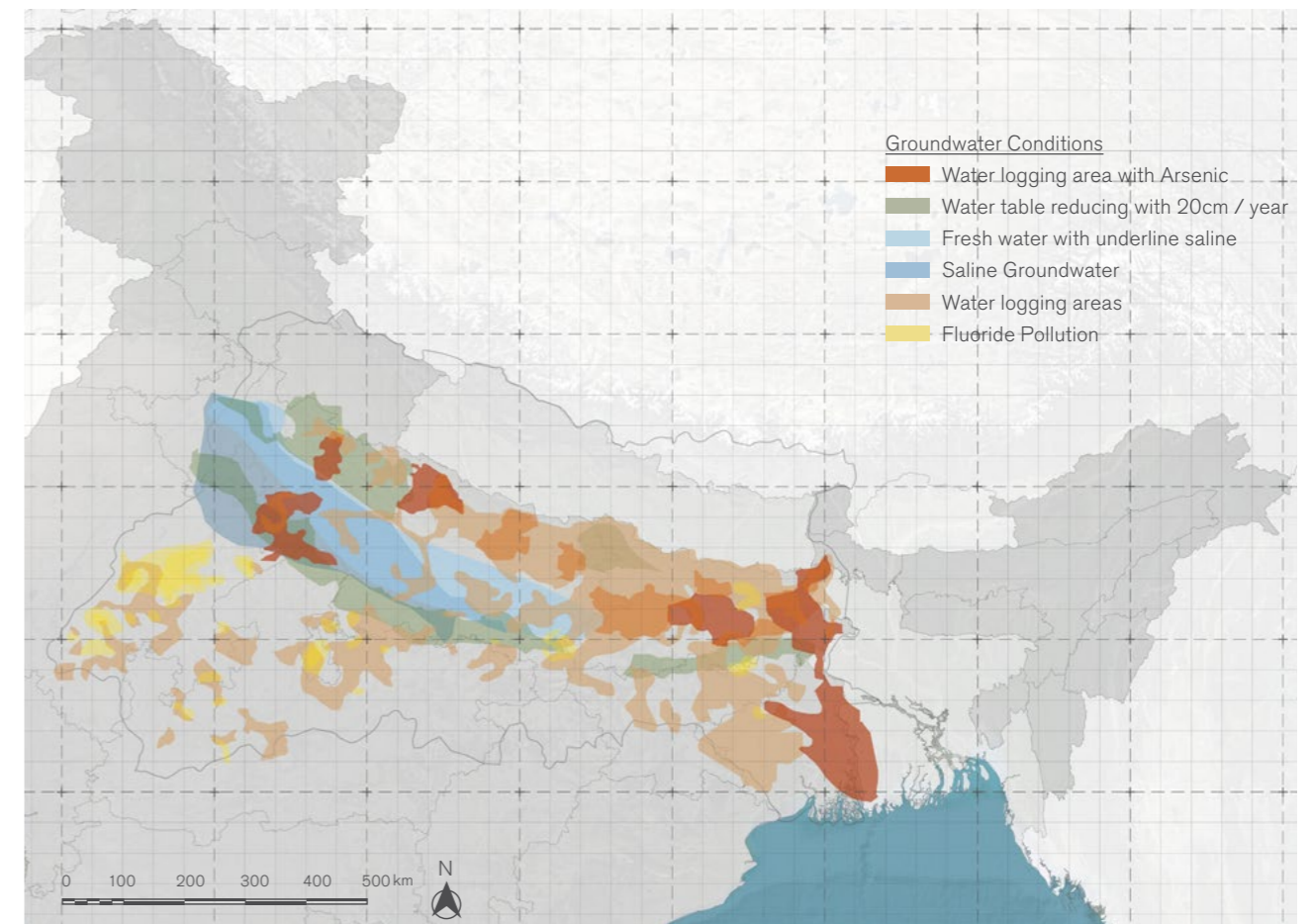


Fig. 24. Groundwater conditions in The Ganges River Basin  
Source: GIS Data, Bhuvan, NIC Bihar, Ganga River Basin Management Plan, 2015

With untreated waste from industries being directly flushed into the river, the pollution levels in the river have been alarming high. These pollutants further contaminate the groundwater in the region. Traces of fluoride and arsenic are found in groundwater as deep as 100m. These contaminations have impacted the health and living conditions of vulnerable people and also impacts the diversity of flora and fauna.



Image (t): Effects of Arsenic Pollution in Ground Water



### 3.2.3. Ecological Vulnerability (Climate Change)

#### A. Rainfall Pattern in The Ganges River Basin

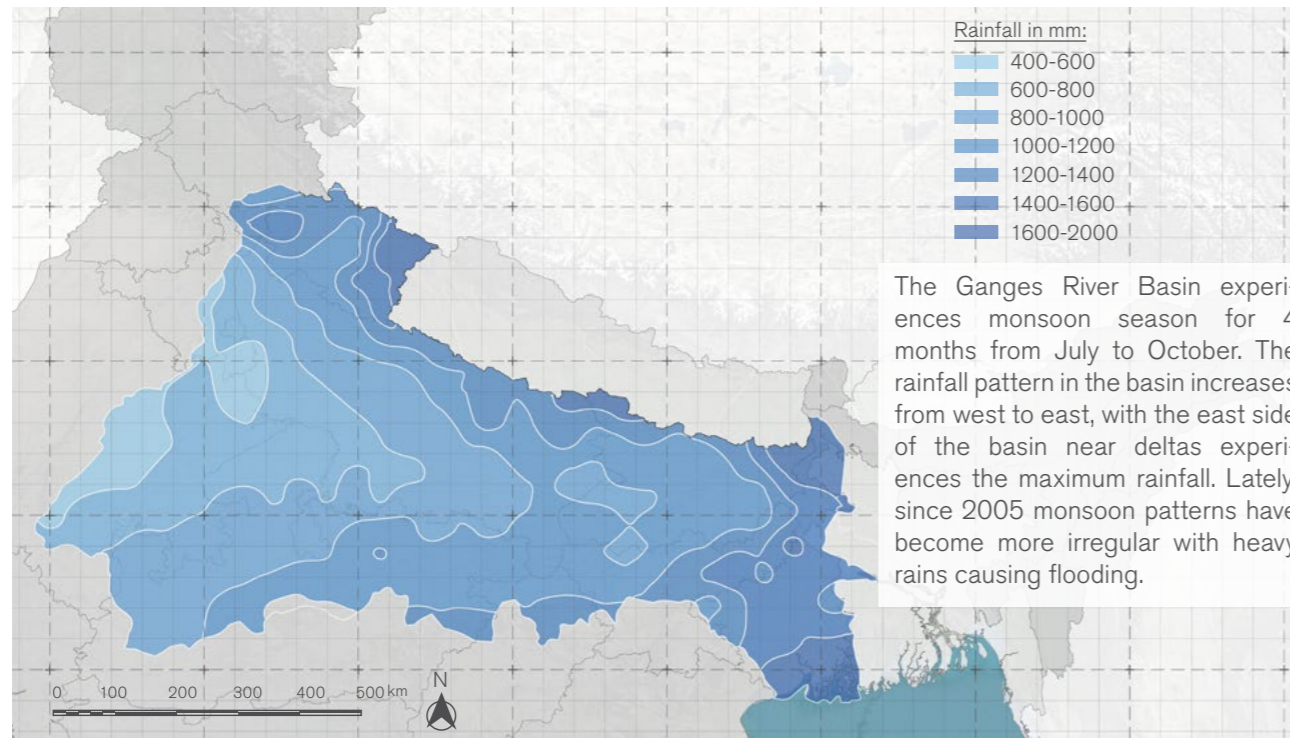
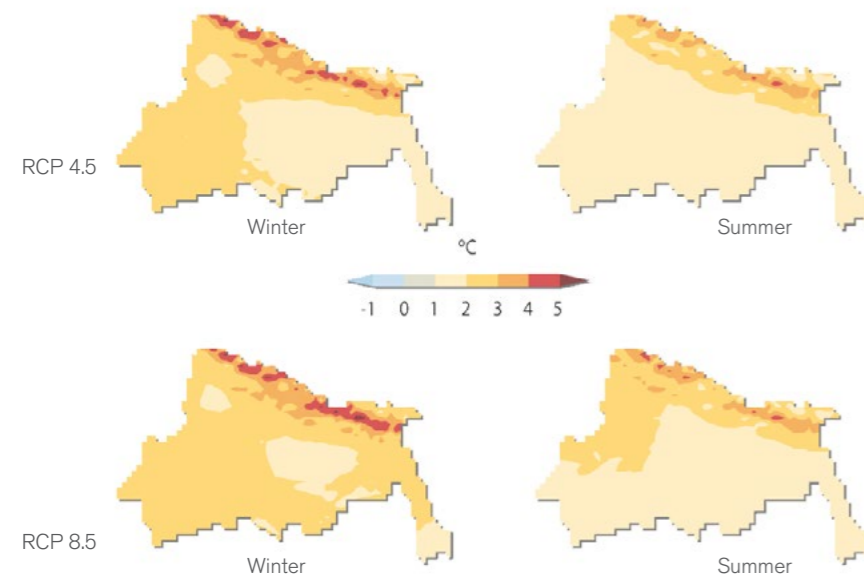


Fig. 25. Map depicting rainfall in The Ganges River Basin  
Source: GIS Data, Bhuvan, NIC Bihar, Ganga River Basin Management Plan Interim Report, 2013

#### B. Increase in temperature

Change in average temperature, 2021-2050  
(baseline (1961-1990))



The future temperature increase scenario is predicted with RCP of 4.5 and RCP of 8.5. In both scenarios, the average temperatures in the winter are increasing, while the temperatures in summer are pretty constant, with the increase in the Himalayan mountains. This increase will impact on the size of glaciers and water flow in the river due to the melting of snow.

Fig. 26. Scenarios of temperature increase based on Greenhouse gas prediction  
Source: The Himalayan Climate and Water Atlas, 2015

### 3.2.4. Ecological Vulnerability (Existing Conditions)

#### A. Soil Erosion in The Ganges River Basin

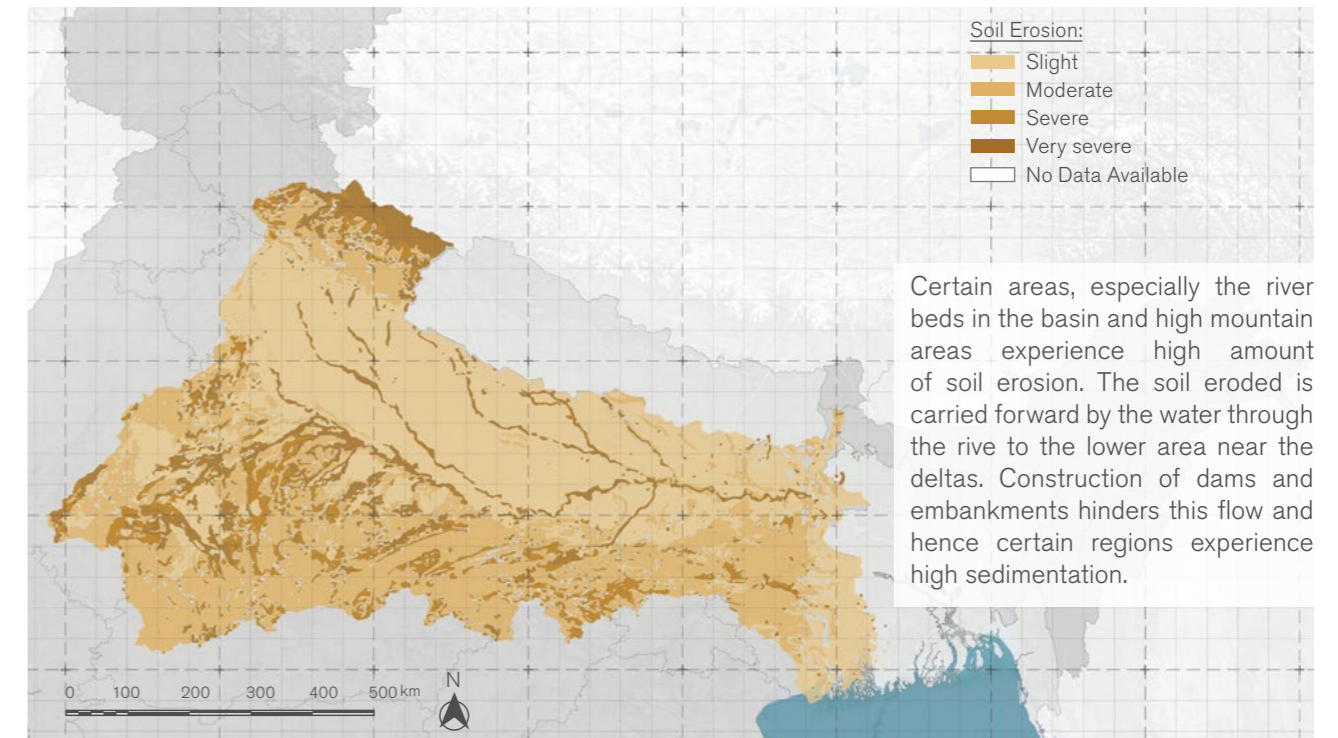


Fig. 27. Map with Soil Erosion.  
Source: GIS Data, Bhuvan, NIC Bihar, Namami Gange

#### Conclusion:

The impact of climate change within the basin varies across the basin as per the topography and the geographical locations. It will be critical understanding the differences in the context, for the development of strategies and testing its application later throughout the basin.



### 3.3. MESO SCALE ANALYSIS: BIHAR STATE

#### 3.3.1. Bihar State Context

##### A. Location within Ganga River Basin

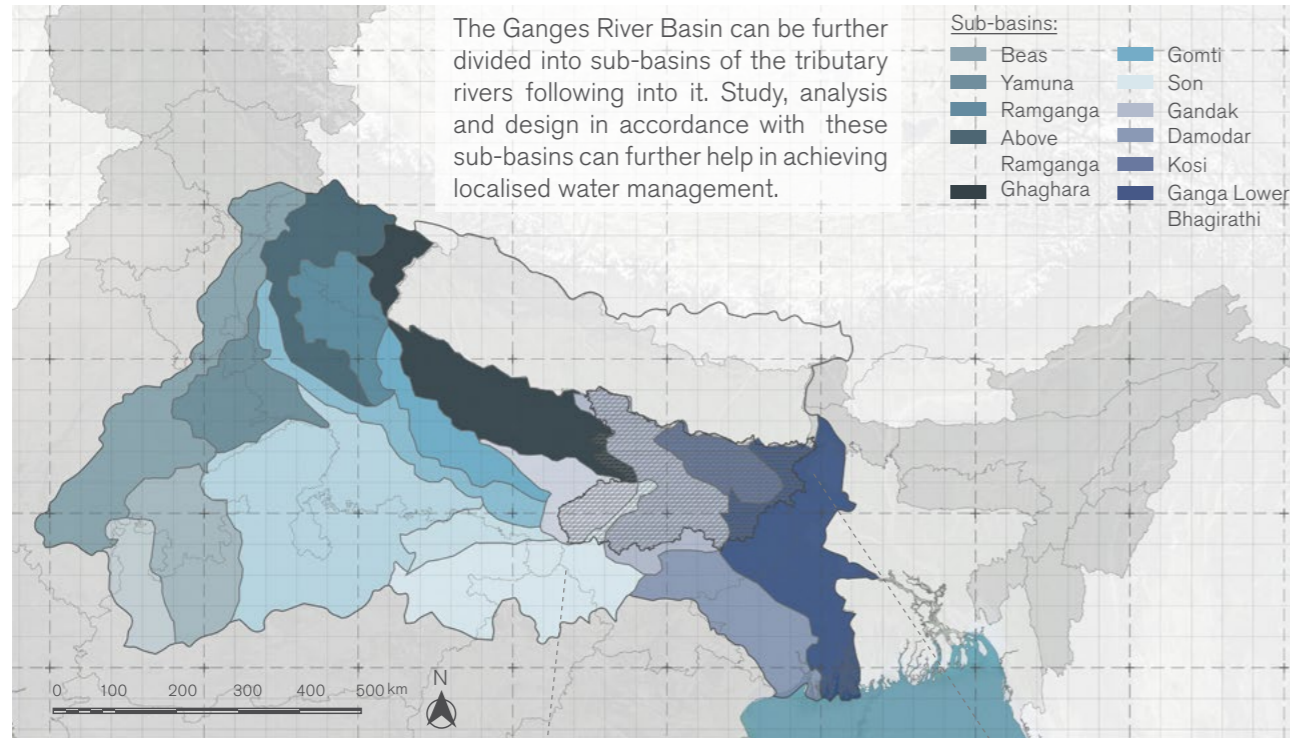


Fig. 28. Map showing Location of Bihar and Sub-River Basins within The Ganges Basin  
Source: GIS Data, Bhuvan, NIC Bihar, Reviving the Ganges Water Machine: potential, 2016

##### B. Land-use Distribution

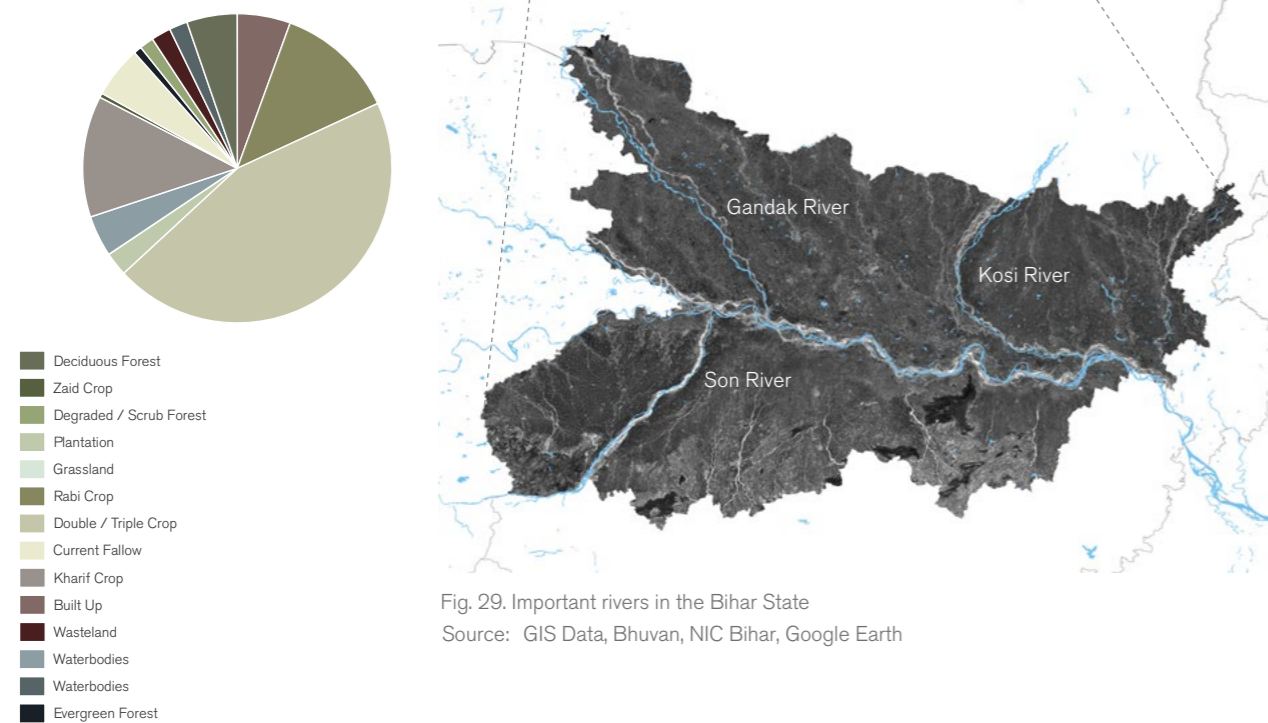


Fig. 29. Important rivers in the Bihar State  
Source: GIS Data, Bhuvan, NIC Bihar, Google Earth

#### 3.3.2. Bihar State and the River

##### A. Flooding



Fig. 30. Possible Flooding Areas in Bihar  
Source: GIS Data, Bhuvan, NIC Bihar, UNDP India

##### Deaths due Flooding

Year	Human	Animal
2019	130	No Data
2017	521	192
2016	254	5383
2013	201	140
2008	434	845
2007	1287	126
2006	36	31
2005	58	4
2004	885	3272
2003	251	108
2002	489	1450
2001	231	565
2000	336	2568
1999	243	136
1998	381	187
1997	163	151
1996	222	171
1995	291	3742
1994	91	35
1993	105	420
1992	4	No Data
1991	56	84
1990	36	76
1989	26	No Data
1988	52	29
1987	1401	5302
1986	134	511
1985	83	20
1984	143	90
1983	36	21
1982	25	14
1981	18	11
1980	67	42
1979	14	50

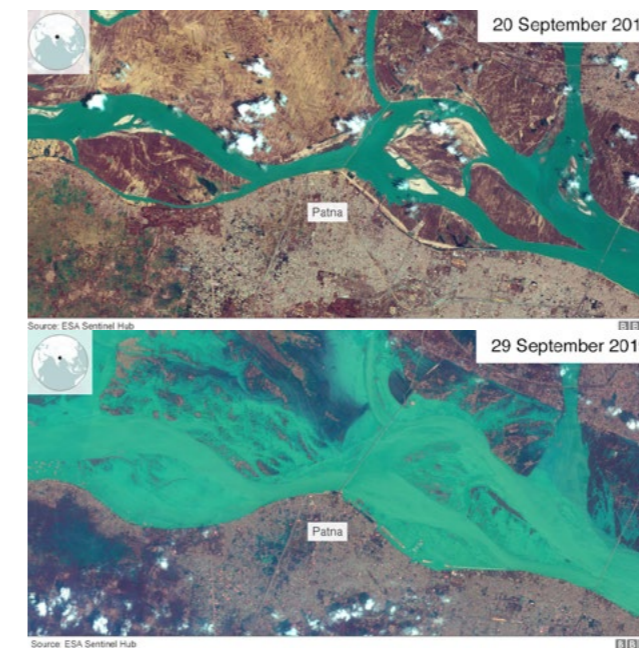


Fig. 31. Satellite Image of 2019 Flooding  
Source: BBC News, 2019

Flooding has been a serious challenge in the state of Bihar with 2 tributaries of the Ganges, Gandak and Kosi, along with The Ganges often overflowing during the monsoon season. These flooding have caused major damages to the economy, crop, humans and animals.

Source: Disaster Management, Bihar Government



### 3.3.3. Bihar State Economy

#### A. Per Capita Income Distribution

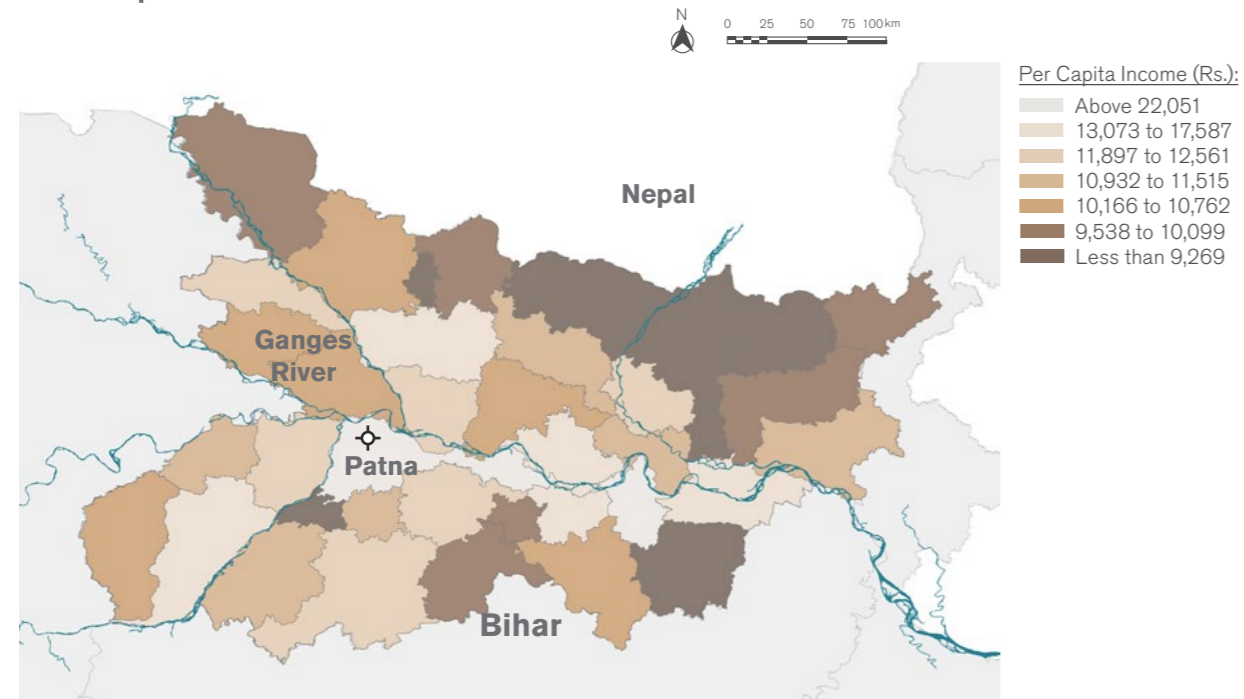


Fig. 32. Per Capita Income Distribution for Districts in Bihar  
Source: GIS Data, Bhuvan, NIC Bihar, Department of Economics and Statistics of Bihar Government

#### B. Source of Economy (Agricultural Distribution + Industries)

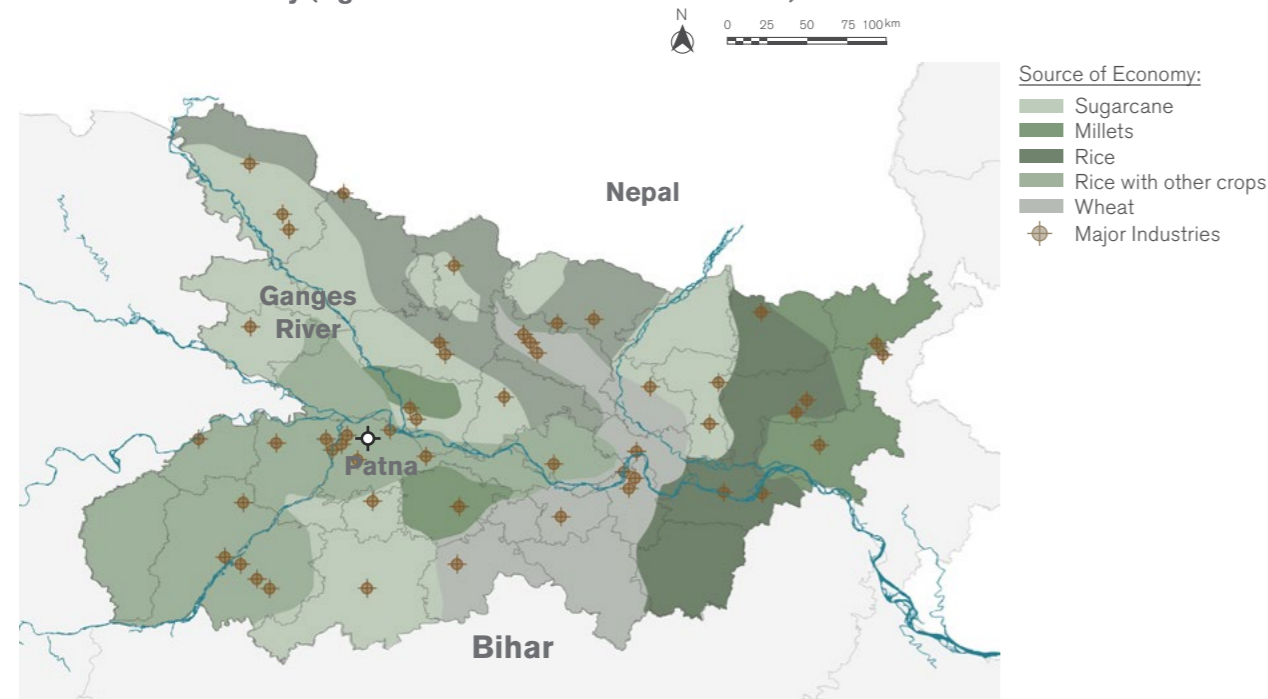


Fig. 33. Agricultural Produce Zones in Bihar  
Source: GIS Data, Bhuvan, NIC Bihar, Bihar Government, Teri Report, BIADA

### 3.3.4. Urbanization in Bihar

#### A. Urban Agglomerations within the State

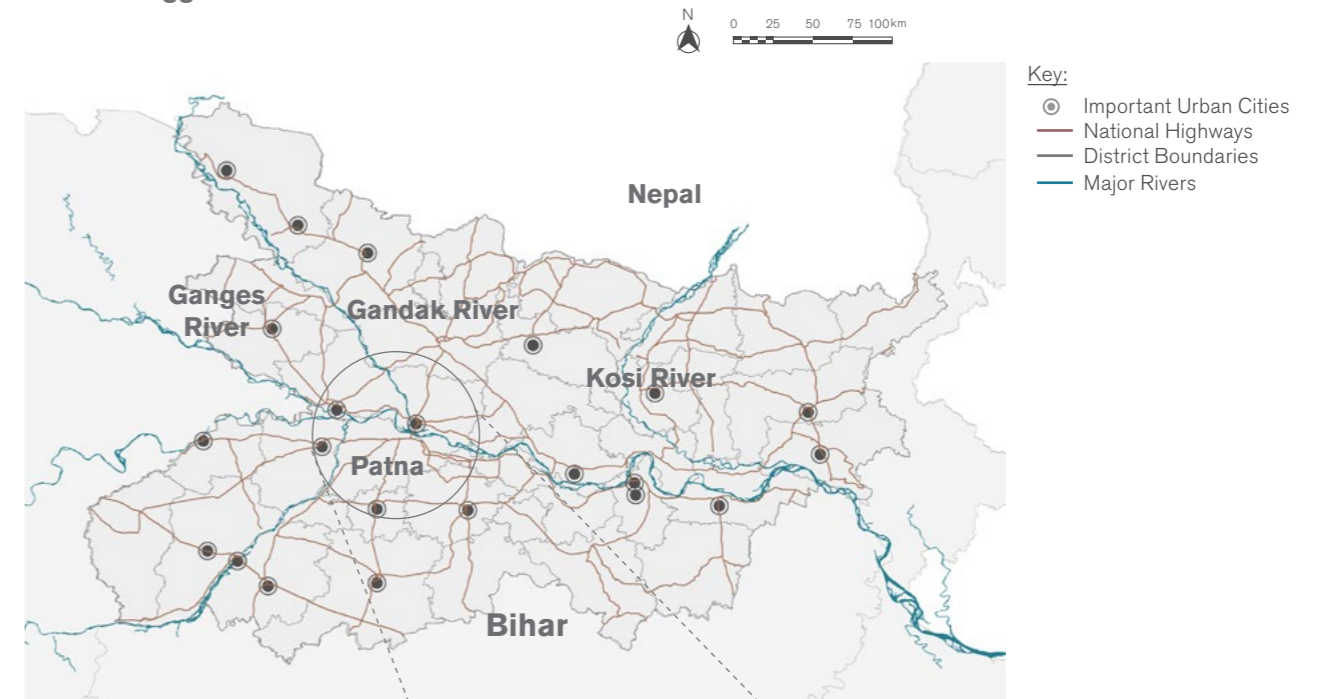


Fig. 34. Urban Center and Agglomeration in Bihar State  
Source: GIS Data, Bhuvan, NIC Bihar, Department of Economics and Statistics of Bihar Government

In the census of India 2011, an Urban Agglomeration has been defined as follows: "An urban agglomeration is a continuous urban spread constituting a town and its adjoining outgrowths (OGs), or two or more physically contiguous towns together with or without outgrowths of such towns. An Urban Agglomeration must consist of at least a statutory town and its total population (i.e. all the constituents put together) should not be less than 20,000 as per the 2001 Census. In varying local conditions, there were similar other combinations which have been treated as urban agglomerations satisfying the basic condition of contiguity." There are 14 urban agglomerations in the Bihar State.

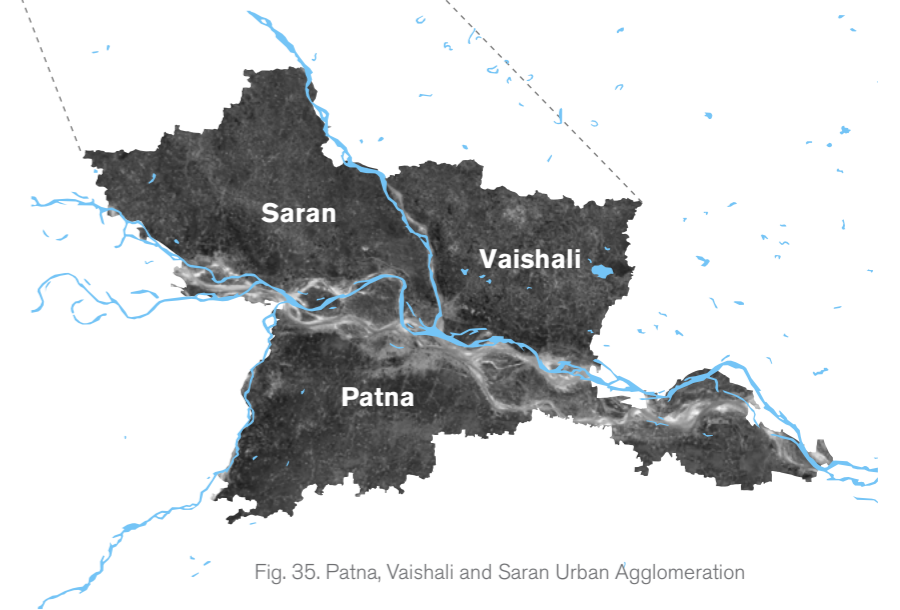


Fig. 35. Patna, Vaishali and Saran Urban Agglomeration



### 3.4. MICRO SCALE : PATNA, SARAN AND VAISHALI DISTRICTS

#### A. Position of Patna within Bihar State

Patna is a metropolis and has a designated regional development area that covers 234.70 sq km and includes outgrowths within Patna district – the Patna Urban Agglomeration (Danapur, Khagaul and Phulwarisharif) – Saran district and Vaishali district.

The process of urbanization in the state of Bihar is centred to Patna. The divide in population amongst urban centres within the state is extremely unbalanced. The Class 1 cities in the state are highly populated, compared to other Class of cities. The manufacturing industries essential for the process of urbanization are mostly placed in and around the city of Patna. This generates migration from rural areas to Patna.

The functional linkages observed in the region are mainly flows of construction labours and raw materials from rural to urban areas. Construction and manufacturing industries have provided job opportunities to rural migrants.

The percentage of workers engaged in the manufacturing sector in the state of Bihar is extremely low. Most towns with people are still working in the agricultural profession, living in town sizes of 10,000-50,000 people, do not qualify as urban areas due to the definitions of urban towns defined by the census of India. This classification deprives the towns from funding and amenities of urban category, leading to more imbalance in the urban-rural divide.

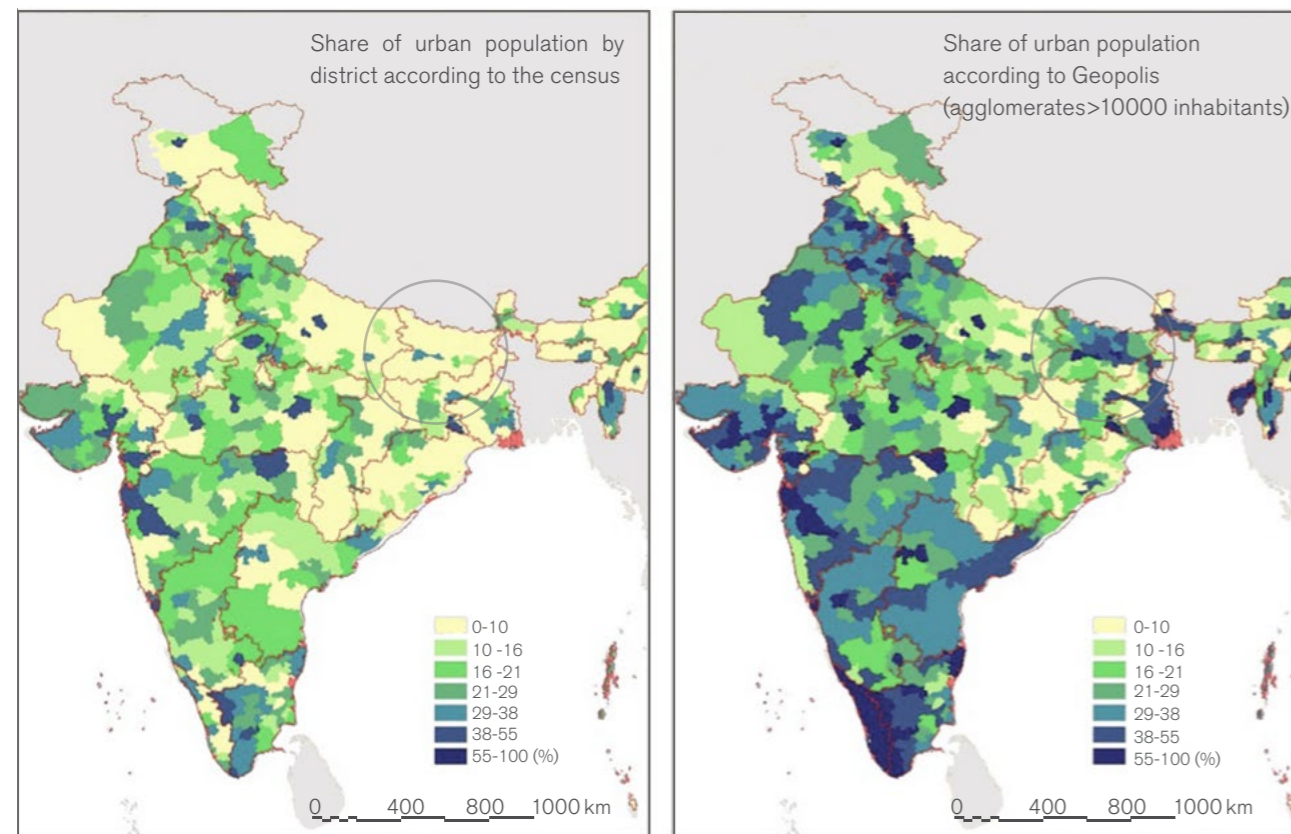


Fig. 36. Map showing difference in Urban Areas due to different mapping definitions  
Source: Denis and Marius-gnanou, 2010 as per 2001 census

#### B. City's Urban Growth and the River

The Patna Regional Development Area (PRDA), that includes district of Patna, Saran and Vaishali, is undergoing urbanization. This process of urbanization has led to a huge transformation in its land-use and land-cover. The built-up area of Patna district has expanded from 80 sq km to 141 sq km. in 20 years.

Due to the location of the city near the confluence of 2 major rivers, the city has become an anchor for industrial growth and cater to diversity in functions. The urban sprawl of the city is achieved by the invasion of vegetation cover and agricultural land. The city has been expanding towards the south and in the west.

The expansion of built-area has affected the hydrology of the region. It has also affected the morphology of the river due to disturbances in rainwater discharge into the river. Due to major urban influences, there has been a change in the stream channel size and shifting in the location of the river. The changes in the river hydrology and climate changes have triggered several floods. The current expansion of the river is happening in low-lying areas, further increasing vulnerability to flooding.

#### C. Future Expansion Scenarios

Lack of Public Participation

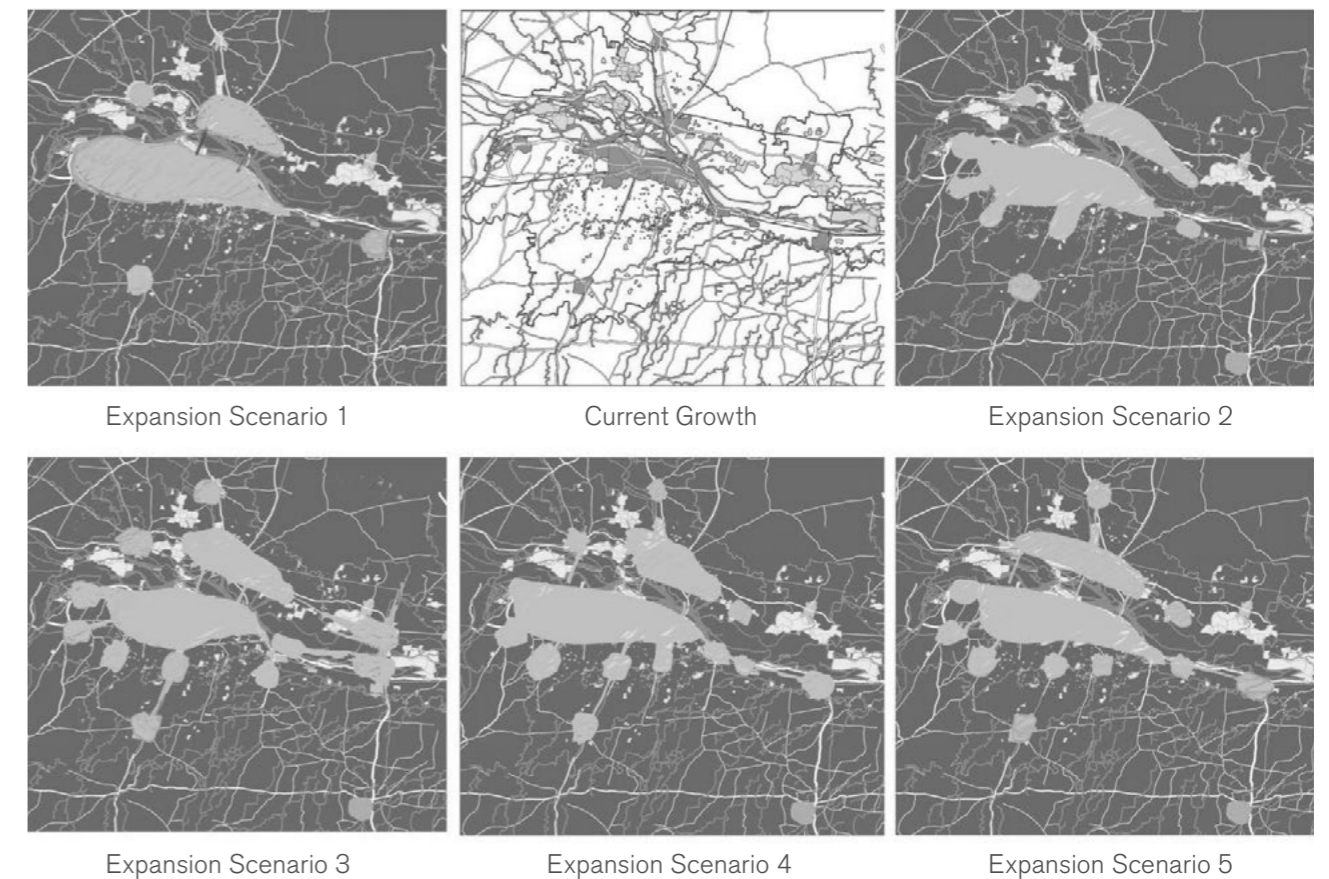


Fig. 37. Patna Future Expansion Scenario

Source: Master Plan for Patna 2031, CEPT

### 3.5. PROBLEM STATEMENT

#### 3.5.1. Rapid Urbanization in India



Image (u): India's Rapid and Chaotic Urbanization  
Source: Picture by Lars Mortensen

Urban expansion in India is happening at a tremendous rate, with over 400 million people expected to live in cities by 2030. India is attracting investments for growth but has failed to deliver high liveability index (Mckinsey, 2010).

Unplanned urban growth in India has caused several negative consequences like the growth of slums, environmental degradation and increased burden on existing infrastructure. (Amit Kumar, 2014)

Urban growth and construction of buildings in India account for 40% energy use, 30% raw material use, 20% water use and 20% land use; they also generate 30% of solid waste and 20% of water effluents (World Economic Forum Annual Meeting, 2019).

#### Impact of Rapid Urbanization: The Ganges

The current policies of development along the river are highly focused on rapid urbanization and economic gains, unfortunately neglecting a large part of the population. The complex governance system with several sectors and actors lack integration. The inconsistent policies for river development have resulted in severe degradation of the river's water and ecosystem. (Irengbam et al., 2019)

While huge infrastructure projects along the river are planned to obtain economic gains, the vulnerable communities whose living is directly or indirectly dependent on its water are facing most of the water challenges. Due to these water challenges, they are driven further into poverty. Moreover, this increasing urbanization and poverty are causing further negative impacts on the water in the river and the surroundings. (Sanghi, 2014)

Majority of river Ganga's flow is diverted for hydropower generation and irrigation, compromising the ecology and hydrology of the river. This has led to a fragmented river system. With unregulated industries and unmanaged sewage systems, the water in Ganga has become highly polluted and unfit for domestic use or drinking. (Irengbam et al., 2019)

#### 3.5.2. Governance and Planning Challenges: Current Model of Adaptation

The project on the revival of the Ganga River first began in 1985. Since then the approach to the project is focused highly on reviving the water quality, meeting the shortage of water demand and development of new infrastructure. Even though the region is now facing more and more risk from climate change and human-induced hazards, the concept of resilient planning is loosely dealt within the current planning framework. The current planning for water management works in isolation, excluding development and analysis of current urbanization models. The governance excludes participation of stakeholders, communities and citizens in planning. The strategies and policies made for climate change are highly engineered, with the focus on restoring conditions and returning to equilibrium. With continuously rising social and ecological vulnerabilities, a new method of integrating social and ecological resilience and participation is needed.

To conclude, the disconnect between various governing bodies and planning sectors, the current development model fails to achieve spatial justice for all. Lack of communication, information sharing and need-based short term solutions create more challenges. Although there are several NGOs, environmentalist and agencies working towards the problem of water and its scarcity, there is a lack of integrated holistic approach towards water planning and management.

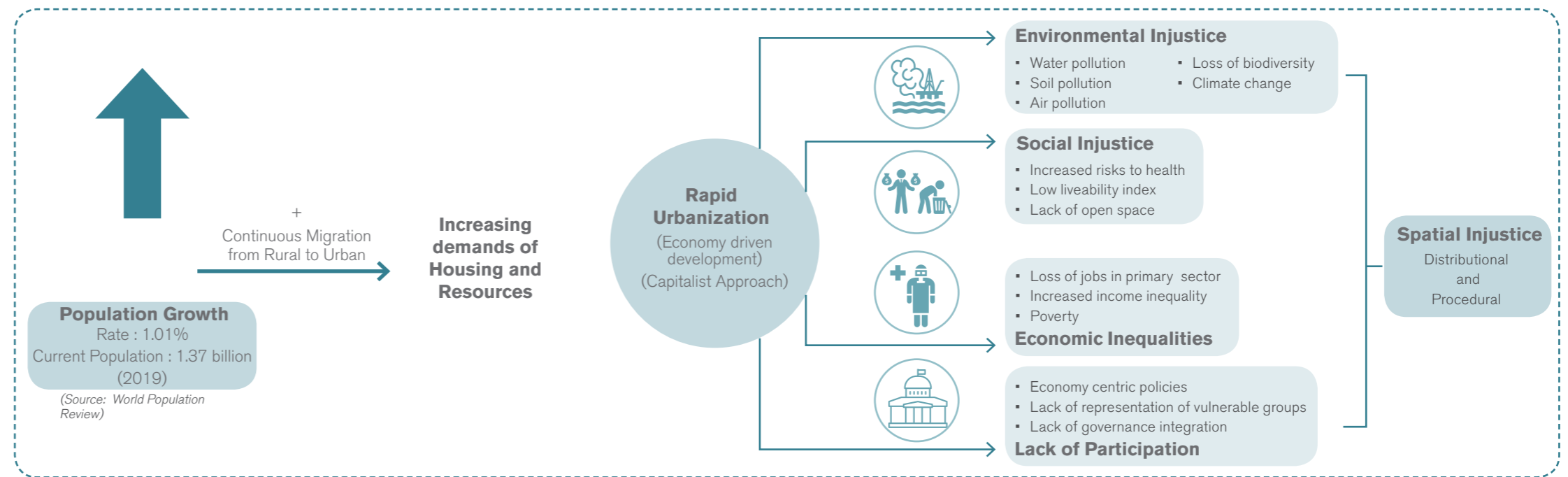


Fig. 38. Diagram representing population growth, urbanizations and its impacts



### 3.6. LINE OF INQUIRY: THE DUAL NATURE OF EXTERNALITIES

#### 3.6.1. Definition

Externalities of the drivers of change mapped in the problem field are further elaborated here.

**Externalities:** a consequence of an industrial or commercial activity which affects other parties without this being reflected in market prices, such as the pollination of surrounding crops by bees kept for honey. (Dictionary, 2019)

**The Dual Nature:** a theory that considers reality to consist of two irreducible elements or modes.

For instance, an industry set up in the city can be highly beneficial for the residents with the generation of new jobs, but on the other hand, the great amounts of waste and pollution released by the industry will impact the environment and the future society. These externalities are the third party on which the subject does not have control. The major externalities in this research are *Pollution* and *Infrastructure Development*, both of which are a human-engineered intrusion into natural systems. To understand the impacts of these externalities it is important to understand risk.

#### 3.6.2. Understanding Risk

##### Hazard

Hazard refers to the possibility, future occurrence of natural or human-induced physical events that may have negative effects on vulnerable and exposed communities.

The intensity or recurrence of hazard events can be partly determined by impacts of human intervention in natural ecosystems and degradation rate of the natural system (IPCC, 2012).

##### Exposure

Exposure refers to the location of elements in an area in which hazard events may occur. Thus, if population and economic resources were located in (exposed to) potentially dangerous settings they may experience impacts of disaster risk.

It is possible to be exposed but not vulnerable. However to be vulnerable exposure is necessary (IPCC, 2012).

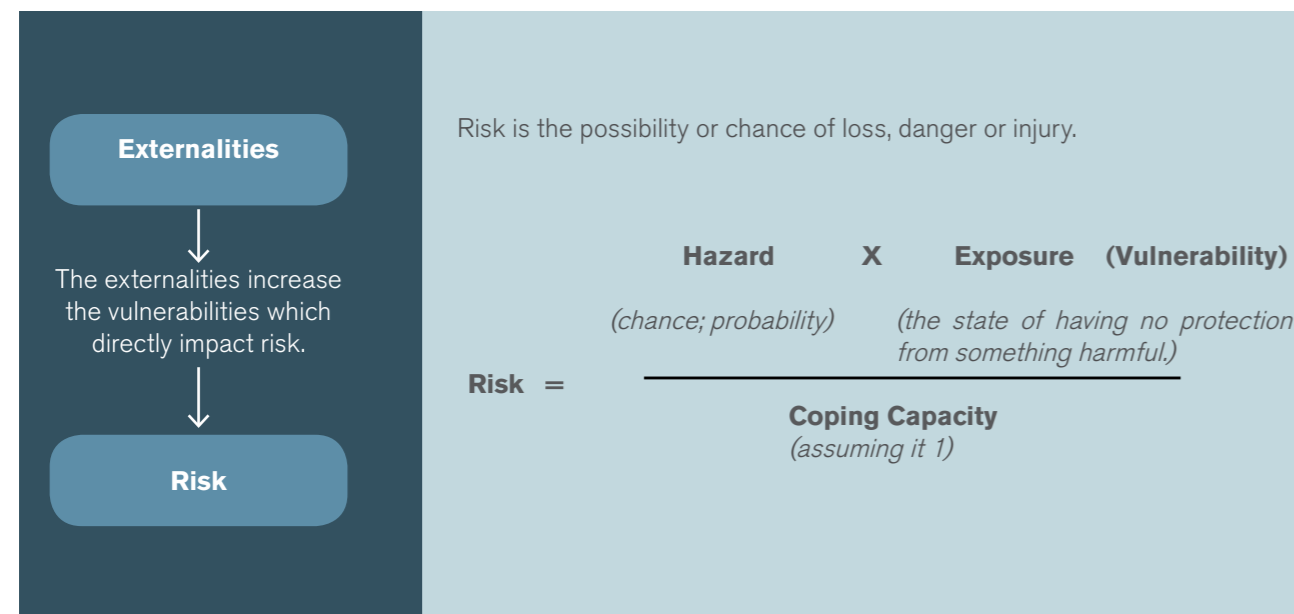


Fig. 39. Externalities and Risk

Fig. 40. Formula to calculate risk  
Source: Adger (2003-2015)

##### Vulnerability

Vulnerability is termed as an inability to counter-act the adverse effects on the exposed elements. The vulnerability can be seen as situation-specific and location-specific, interacting with a hazard event to generate risk Adger (2003-2015).

#### 3.6.3. Human-engineered Externalities

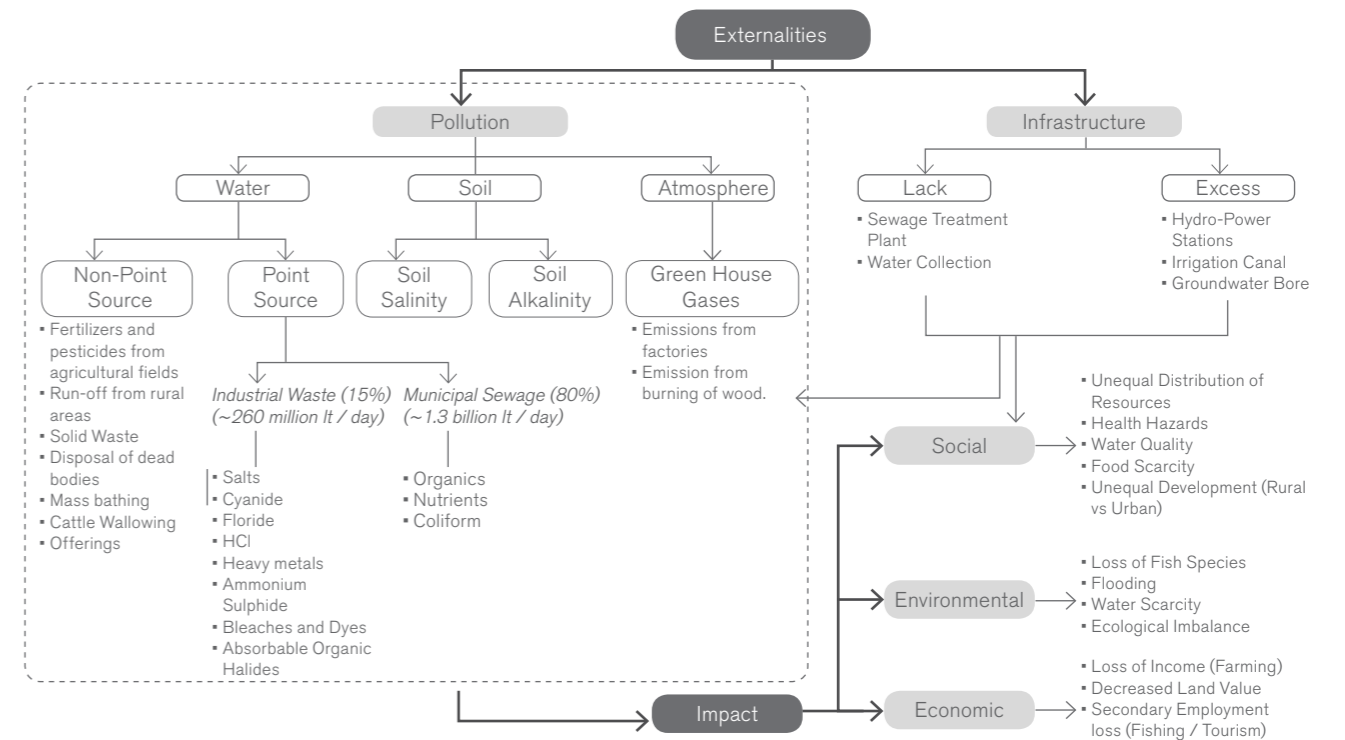


Fig. 41. List of Externalities and Impacts on the River Ganga Source: Gangapedia and Our National River Ganga, 2014

#### 3.6.4. Nature-Induced Externalities

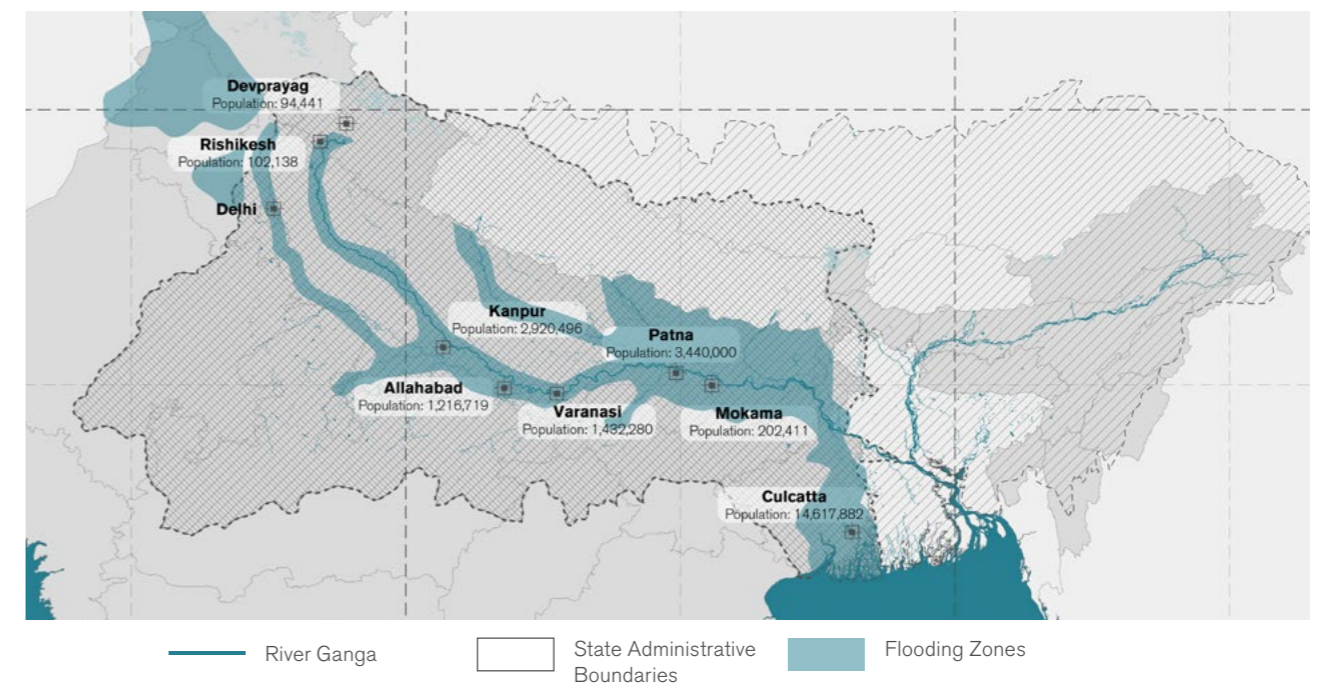


Fig. 42. Map of (flooding/drought) environmental risks in The Ganges Source: National Water Grid for Bharat (2017)

The Ganga is experiencing alternate flood and drought cycles. In May 2016, the Ganga was dry at Prayag, Uttar Pradesh to allow people cross the river bed and three months later, the river's monsoon floods, affected more than 4 million and displacing 650,000 people from their homes (Isha Foundation, 2016).





# 4 • Theoretical Framework

This chapter deals with the theoretical framework of the research. Literature review on concepts of urbanization, vulnerability, resilience, social capital, informal institutions and adaptive planning is carried out to formulate nexus of ideas for the project. The theoretical framework helps to derive the conceptual framework of Adaptive Spatial Planning.



Understanding Problem Field

Chapter 2

- Current Challenges in Ganges River Basin
- Drivers of Change
- Governance Challenges for Ganges River Basin

Introduction

Chapter 1

- Context
- Relationship between human systems and ecological systems

Chapter 3

- Socio-ecological vulnerability analysis across scales
- Problem Statement (Spatial Justice)
- Line of Inquiry:
  1. Dual Nature of Externalities
  2. Capital

Chapter 4

- Theories:
  1. Urbanization
  2. Vulnerability
  3. Resilience Thinking
  4. Social Capital and Governance
- Notions:
  1. Interdependence - Integration
  2. Infrastructure Ecology
  3. Evolutionary Resilience

Research Methodology

Chapter 5

- Conceptual Framework: Adaptive Spatial Planning Model

Vision

Chapter 6

- Principles
  1. Robustness
  2. Adaptivity
  3. Connectedness
  4. Diversity
- Frame of Reference
  1. Knowledge of System Behaviour
  2. Dynamic Adaptive Planning Pathways
  3. Stakeholder Collaboration
- Systemic Goals

Design

Chapter 7

Regional Strategies

Mitigation Strategies that are derived for challenges across the basin

Evaluation

Chapter 10

Scenarios

- Case 1
- Case 2
- Case 3

Chapter 8

Metropolitan Scale Strategies

Mitigation Strategies that are derived for challenges for metropolitan scale

Chapter 9

Local Adaptation

Adaptation of multiple strategies to achieve resilience

1. Urban
2. Peri-Urban
3. Rural

Adaptive Planning Pathways



## 4.1. THEORETICAL FRAMEWORK

To understand the concepts of Urbanization, Vulnerability, Resilience Planning, Social Capital and Governance used in the research, the following is the list of literature refereed. Further understanding and use of the literature in the context of the project is explained in detail. Apart from these core theories, secondary literature is refereed for context specificity. They are listed in the reference list at the end of the document.

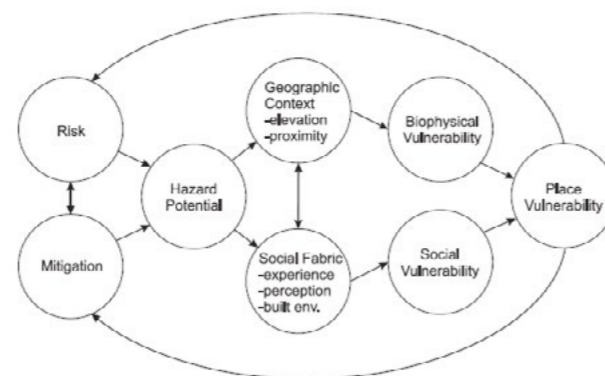
### 1. Urbanization (Why?)

▪ Unequal Development and Spatial Justice	<i>Regions in context: spatiality, periodicity, and the historical geography of the regional question</i> , E W Soja (1985)
▪ Urban Change and Industrial Capitalism	<i>The World City Hypothesis</i> , John Friedmann (1986)
▪ Urbanisation Economies and Metropolitan Governance	<i>Beyond Polycentricity: Does Stronger Integration Between Cities in Polycentric Urban Regions Improve Performance?</i> , Evert Meijers, Rodrigo Cardoso, Marloes Hoogerbrugge (2017)
▪ Macro-Urban Regions	Interact Study: Making the most of macro-regions, Dominic Stead, et al. (2017)

### 2. Vulnerability (What?)

▪ Social Vulnerability and Environmental Hazards	<i>Social Vulnerability and Environmental Hazards</i> , Susan Cutter, Bryan Boruff, W. Lynn (2003)
▪ Risk, Exposure and Vulnerability	<i>Determinants of Risk: Exposure and Vulnerability</i> , Book: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (2012)

The Hazards-of-Place Model of Vulnerability (Modified from Cutter, 1996)



“Geographically uneven development thus becomes part of the material framework of capitalism, linked directly to the labour process, to economic exploitation and political domination, to the accumulation process and attendant class struggles, to the making of concrete capitalist geography and history”-E.W. Soja 1985

The existing patterns of Urban Development is putting to more pressure on Societies and Eco-systems, increasing fragmentation, leading to increased **Vulnerabilities**.

Vulnerability can be examined complex interaction of **Social and Biophysical Phenomenon**.

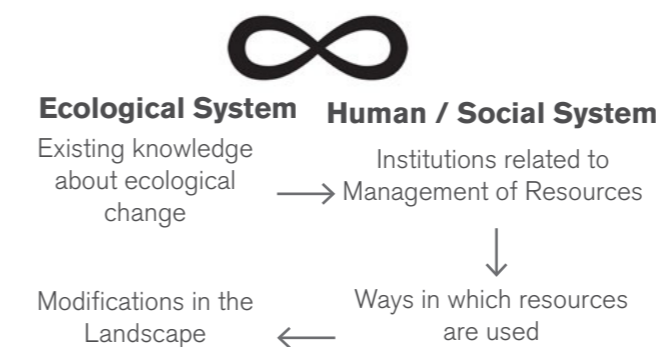
These theories of urbanization and capitalism are used to understand the exiting on-going development in the region that has lead to conditions of risk.

The following theories help to understand the interconnectivity of social and ecological vulnerabilities and will help define variables for vulnerability.

### 3. Resilience Thinking (How?)

▪ Socio-Ecological Resilience	<i>Resilience thinking meets social theory: Situating social change in socio-ecological systems (SES) research</i> , Muriel Cote, Andrea J. Nightingale (2012)
▪ Resilience Strategy	<i>Evolutionary Resilience and Strategies for Climate Adaptation</i> , Simin Davoudi, et al. (2013)
▪ Adaptation and Scales	<i>Successful adaptation to climate change across scales</i> , W. Neil Adger, et al. (2004)
▪ Adaptation and Developing Countries	<i>Adaptation to climate change in the developing world</i> , W Neil Adger, et al. (2003)

Socio-Ecological System (SES) Research



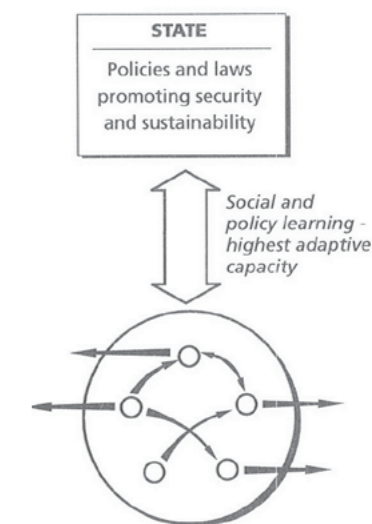
(Resilience thinking meets social theory: Situating social change in socio-ecological systems(SES) research) (Cote & Nightingale, 2011)

Adaptation to climate change is a **continuous, forward looking process of small and large adaptive cycles** under the Evolutionary Resilience Framework.

The theory list on resilience helps in defining resilience as an adaptive process rather than disaster risk management which is short term reactive approach.

### 4. Social Capital and Governance (Who?)

▪ Social Capital and Collective Actions	<i>Social Capital, Collective Actions and Adaptation to Climate Change</i> , W. Neil Adger (2003)
▪ Actor - Relational Planning	<i>Theorizing Practice and Practising Theory: Outlines for an Actor-Relational-Approach for Planning</i> , Luuk Boelens (2010)
▪ Adaptive Capacity Wheel	<i>The Adaptive Capacity Wheel: a method to assess the inherent characteristics of institutions to enable the adaptive capacity of society</i> , Gupta et al., (2010)



“Social capital is a necessary “glue” for adaptive capacity, particularly in dealing with unforeseen and periodic hazardous events, but the prevalence of different type of social capital is important at different times to different social groups.”  
- W. Neil Adger, 2003 (Social Capital, Collective Action, and Adaptation)

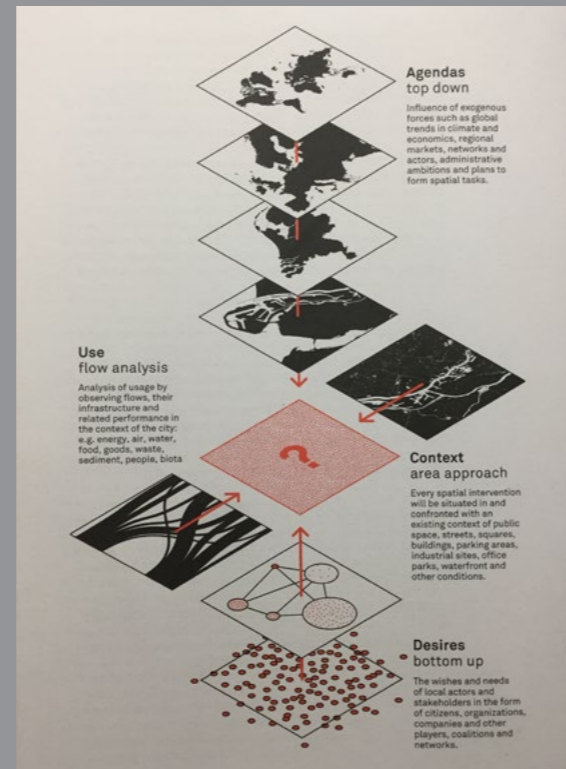
From Inside - out planning process to Outside - inward, **Actor Relational - Approach**

The above theory papers will help develop an adaptive spatial planning model to achieve resilience. The theory helps to determine institutions and social capital as key for Actor-Network Planning.

**Interdependence - Integration**

Every element in a system has its own infrastructure, every scale has its own flows within the system. For a system to function, integration of flows is necessary rather than optimum use of infrastructure.

- Sandra van Assen, T. v. (n.d.). Urban Challenges, Resilient Solutions . Future Urban Regions.



The field of activity - four angles

**Infrastructure Ecology**

**“Infrastructure ecology views urban systems as complex adaptive systems; the sustainability and resilience of which emerge from the complex interactions and co-evolution of a city’s interdependent engineering, ecological, and socio-economic infrastructure through time and space.”**  
- A. Pandit (2017)

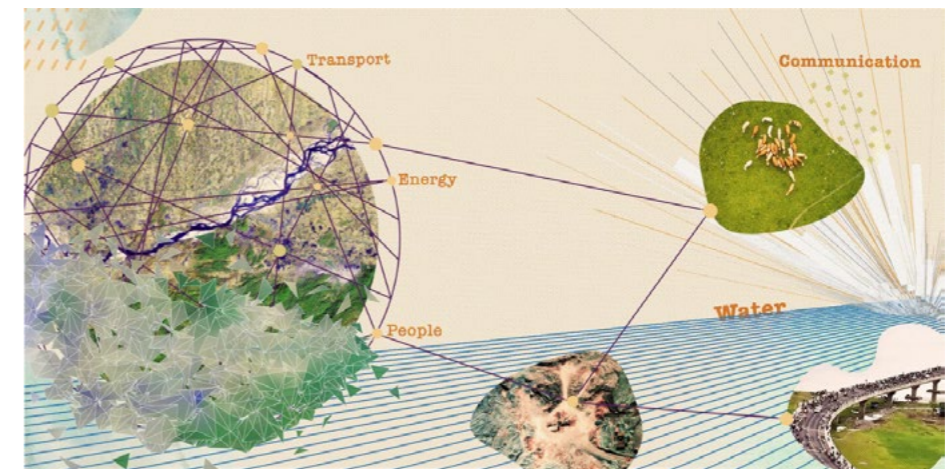
Endless Rhythm, Robert Delaunay, 1934



**Evolutionary Resilience**

**The social and the ecological systems are interdependent systems. The system remains to continue in loops of adaptive cycles.**

- Davoudi, S., Brooks, E., & Mehmood, A. (2013). Evolutionary Resilience and Strategies for Climate Adaptation. *Planning Practice And Research*, 28(3), 307-322. doi: 10.1080/02697459.2013.787695
- Cote, M., & Nightingale, A. (2011). Resilience thinking meets social theory. *Progress In Human Geography*, 36(4), 475-489. doi: 10.1177/0309132511425708



Web dossier of infrastructure interactions  
- Heinrich Boll Stiftung

- Pandit, A., Minné, E., Li, F., Brown, H., Jeong, H., James, J., Newell, J., Weissburg, M., Chang, M., Xu, M., Yang, P., Wang, R., Thomas, V., Yu, X., Lu, Z. and Crittenden, J. (2017). Infrastructure ecology: an evolving paradigm for sustainable urban development. *Journal of Cleaner Production*, 163, pp.S19-S27.
- Wilbanks, T. and Fernandez, S. (2014). *Climate change and infrastructure, urban systems, and vulnerabilities*. Washington, DC: Island Press/Center for Resource Economics.



#### 4.1.1. Process of Urbanization

##### The Spatiality of Economies and Societies

The understanding of cities has changed over time, with new ways of looking at the forces that govern the cities. With the constantly changing and evolving economy, it is important to understand the impacts of these economic drivers on the cities. John Friedman in his paper, The World City Hypothesis (1986) talks about how class conflicts have become central with the way cities have evolved. Cities, from being social ecology, have been directly connected to the world economy, and are now a spatial representation of the economy. This linking of cities to the world economy leading to the spatial organization of the new international division of labour. Friedmann (1986) described world cities to be the basin points for accumulation of wealth and resources in capitalist development. The functionality of nodes in the network of the global economy will decide the structural changes occurring with the node.

In parallel to this Edward Soja (1985) talks about the dynamic of the new quest of regionalism. Capitalist development approach has lead cities to become geographically unequal development (GUD) of societies. In his paper, he states how geographically uneven development is an essential feature of capitalist spatiality. It is directly linked to the labour process, to economic exploitation and political domination. GUD has lead to the evolution of the core-periphery structure of development. The core areas can be described as the primary locales of capitalist accumulation and the periphery as the area supporting the core with resources and labour. Thus, it is important to understand that various social movements and regional political coalitions bring about regional restructuring.

Development in India	Spatial Justice
<p>The development in India is driven by the capitalist approach post industrialisation. The major cities, forming the core are mainly supported by the periphery of small cities and rural areas. The rapid influx of poor workers or migrants to these cores have put these cities on high pressure. Within the Ganga river basin cities like Kanpur, Allahabad, Calcutta are facing tremendous pressures with housing shortages, a constant fight for resources and low quality of living standards.</p>	<p>The thinking of space has changed drastically from the notions of space as container for human activities to an active force shaping human life. With the new emphasis on exploration of urban agglomerations, economic developments, social and environmental changes, social polarization and widening of income gaps it is highly important to understand the concept of spatial (in)justice. Spatial justice refers to an intentional and focused emphasis on the spatial aspect of justice (E Soja, 2009).</p> <p>With neo-liberal policies in India, the country is opening its markets for private developments. These private development are focused on super profits and have intensified the economic inequalities and social polarization. The growth of new infrastructures like roads, dams or industries is also meant to meet the demands of these private companies and elites. Hence, understanding and implementation of policies of justice, in spatial terms of resources and space has become critical.</p>

##### Polycentricity and Beyond

To reduce the constantly growing economic disparities, the model of polycentric planning can be thought of as a new strategy for urban development. The in-elasticity of housing supply in the core cities and resource pressure are good reasons to prefer the development of a network of smaller cities over one single megacity. For the model of polycentric development to be a success, the integration of networks within the cities need to be strong. (E Meijers et al. 2017) While the concept of polycentricity can be applicable in thinking of the new development of the Ganga river basin, aiming to achieve integrations to reduce pressures on big cities like Kanpur, Allahabad and Calcutta, and also to achieve institutional integration, but the implementation of the concept feels far from being achievable due to the large distances between the cities and huge patches of rural development. The current condition of the cities along the Ganges river can be best studied with the approach of "urban field" theory, Cardoso & Meijers (2019) describe as a zonal model where "socio-economic or environmental effects of urbanization, both beneficial and detrimental, can be seen as fluctuations of intensity of 'agglomeration externalities fields.'" But the assembly of the whole river basin as one single metropolis requires cultural and political integrations.

#### 4.1.2. Vulnerability

##### Understanding Vulnerability to Hazard

Vulnerability to environmental hazards means potential loss. These losses are specific to the geographical locations of the hazards. 3 methods have been developed so far to access vulnerability. The concept of understanding the social aspects of vulnerability is developed by Cutter (2003) with the hazard-of-place model of vulnerability. The model portrays how the hazard potential is either moderated or enhanced by a geographic filter and social fabric of the place.

To understand the vulnerability over a region like the Ganges, it is extremely important to develop a system to calculate the Social Vulnerability Index, based on the factor specific to the location of the region and social relations within the communities.

The hazard-of-place model of vulnerability developed by Cutter suggests that social vulnerability is a multidimensional concept and it helps in identifying the characteristics and experiences of the communities that enable them to respond to the risk.

Development of such model with the Ganges river basin will help in determining the social and natural hazards indicators, improving the method of hazard assessment and will help in determining the areas of high risk and concerns for immediate actions and mitigation. The representation below shows how can the Hazard-of-Place model be used to determine are the areas of intervention.

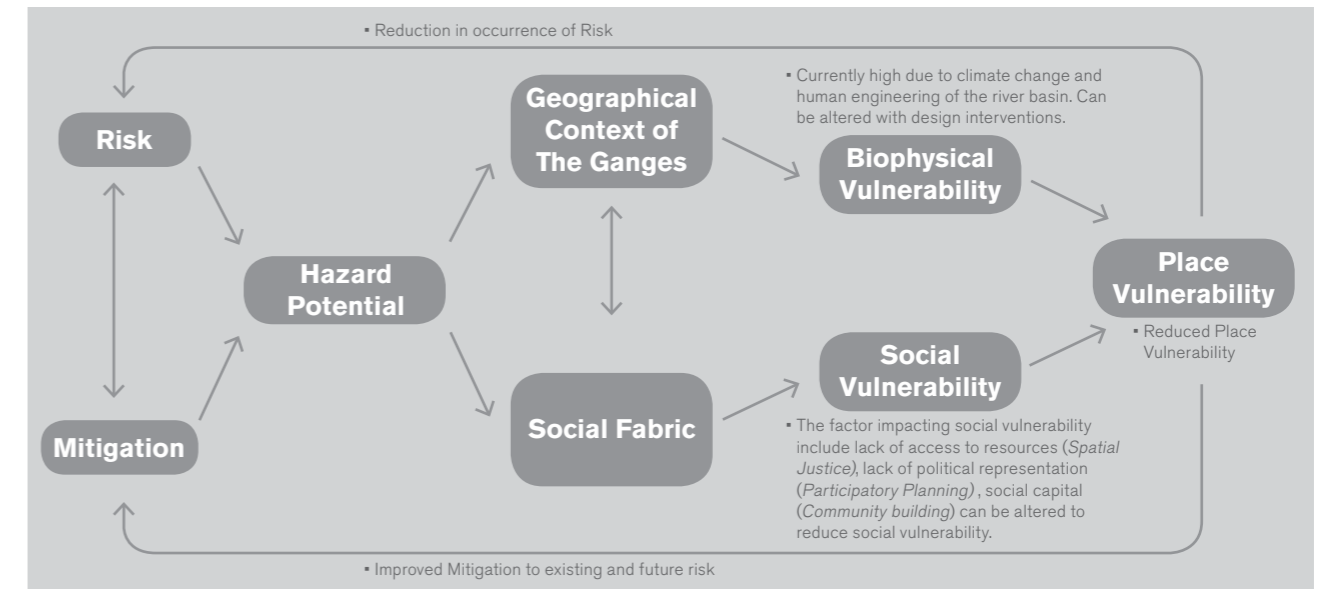


Fig. 43. Hazard-of-Place model for Ganges to identify area of interventions

##### Adaptation to Climate Change

The climate around the world is changing and is expected to change at an unprecedented rate. The risks associated with the changing climate are uncertain and needs the highest attention priority, to reduce future human and economic losses. The vulnerability of societies varies across the globe based on their location and coping capacity. As Adger (2003) mentions vulnerability is a socially constructed phenomenon and is influenced by institutional and economic dynamics. The adaptation strategies highly depend on the technological innovations and availability of resources, thus developing countries like India pose higher risks from climate change. As seen in the communities living on the banks of Ganges, the risk is high in the communities that are dependent on resources that are sensitive to climate change, though these communities have developed local techniques over the years to combat this change. This shows that a larger part of adaptation in developing countries will rely on past experiences. Therefore, planned adaptation in such countries requires a stronger bottom-up approach, across various scales of institutions to tackle climate change.

### 4.1.3. Resilience Thinking

Resilience refers to the ability of the socio-ecological system's ability to absorb disturbances without flipping into another state. But to understand resilience it is important to answer questions like the resilience of what and for whom?

#### Evolution of Resilience

The older models of ecosystem dynamics focused on the 'balance of nature', assuming that the biophysical system tends to reach towards stable equilibrium cycle with a single climax. Later in 1990s resilience was closely related to 'new ecology'. This system understood the dynamics of ecosystems as a system revolving around multiple equilibriums. Thus in this case, as explained by Holling (1973) ecological resilience was understood as the system's capacity to reach equilibrium rather than the time it takes to reach the equilibrium state. Further, study and research were carried out to understand the interactive dynamics between social and ecological

systems. Building on the theories of the co-evolutionary nature of human and biophysical stems the concept of a social-ecological system (SES) was developed.

This new concept places an important role in shifting the focus away from the quantitative availability of resources and moves towards the scope of available response options. (Cote and Nightingale, 2012). The SES Resilience helps to develop a framework to analyse human-environment dynamics. The approach is dynamic and forward-looking approach to human and environment change. The system still emphasises the role of physical shocks and reducing the role of political-economic factors. With the approach of focusing on human actions, the aspects of culture, indigenous knowledge can also play a role in the system to achieve resilience. Hence with human system knowledge, SES can help in analysing feedbacks and in determining which forms of environmental governance is best suited.

<p><u>Resilience and Climate Adaptation</u></p> <p>Promoting resilience involves planning not only for recovery from shocks but also cultivating preparedness and seeking transformative opportunities which emerge from it. Today, resilience is largely seen as a response to climate change uncertainties and socio-economic insecurities. Resilience for climate change can be looked at from the perspective of engineering resilience and ecological resilience. India's resilience policies are mainly focused on engineered design approach for disaster risk management, focusing on returning back to normal (pre-disaster) conditions.</p>	<p><b>Engineering Resilience</b></p> <ul style="list-style-type: none"> <li>Focuses on the systems ability to return back to equilibrium.</li> <li>How fast can a system return?</li> </ul>	<p><b>Ecological Resilience</b></p> <ul style="list-style-type: none"> <li>Focuses on the systems ability to take disturbance.</li> <li>How much can the system take ?</li> </ul>
	<p><u>Evolutionary Resilience</u></p> <p>The evolutionary resilience talks in favour of 'People and Nature' as an interdependent system. It shows the ability of the socio-ecological system to change, adapt or transform in response to stress and strains. In a complex adaptive system (Cities, Regions) there are continuous interactions between small-large, slow-fast subsystems depending on scales. These systems by going through adaptive cycles, self organise and maintain resilience. Thus resilience a conceptual framework can help thinking about the process like climate change as a dynamic and holistic process. (S Davoudi et al., 2013)</p>	

The concept of evolutionary resilience with, nested adaptive cycles with varying time-frames and scales help form a framework for the current dynamic need of climate adaptation and resilience. Davoudi (2013) talks about adapting the resilience framework in a social context. This allows intervening in the continuous system of persistence, transformability and adaptability with preparedness ( learning / reacting capacity of human systems). Thus the system of evolutionary resilience helps in moving forward from the old practice of engineered approach to climate change , promoting adaptability dynamics and future forward-looking transformations.

### 4.1.4. Adaptive Planning

#### Planning Process in India

In 1950, post-independence, the Planning Commission was set up by the Government of India. The Commission was assigned to develop Five Year Plans, the National strategy that orders and guides development at State and local District levels.

The setting of Planning Commission empowered the local governments to take the actions for strategy making and implementation of schemes but under the guidance of the National of Five Year Plans. As per the Indian Constitution, urban improvement is a state subject. The local government does not have the power to pass enactment on urbanization, urban advancement and urban arranging. While the National Planning Commission laid out detailed guidelines for development, funds were allocated state-wise to implement projects in the state.

With the 74th amendment bill in 1992, there came a shift in the planning process. Smaller towns and cities were granted their own governing bodies to carry out development. Though the decisions were still made at the centre, the implementation process was made simpler with smaller governing bodies of gram panchayats and municipalities working at local scales. This was indeed a major shift noted in the development process.

With the changing economic patterns and development of neo-liberal policies, new planning commission, called the Niti Aayog, was established in January 2015. The planning commission was aimed to achieve bottom-up approach of planning, though the term bottom-up is vaguely used. The power was now distributed to state governing bodies, to develop strategies and plans to achieve sustainable development. The local bodies and most importantly the stakeholders, the people are barely included in the planning process.

With the new development strategies, there are now points in the planning process where public meeting are carried out and public opinions reheard to achieve the actual demands of people. Though these formal moments of the public hearing are introduced in the planning process, informal institutes and networks with the development area, do not allow these processes to be carried out fairly.

#### Actor-Relational Approach in Planning

With the changing patterns of economy, neo-liberal policies the approach of planning also needs to be modified. Luuk Boelens (2010) in his paper talks about how planning in the Netherlands has been successful as it has always been carefully constructed and maintained by the planners. The planning has been well executed due to the institutional framework of national, provincial and local planning bodies. But in recent times the planning system started experience failure in promoting human environment perspective, and hence there was a need to further amend the planning framework.

He talks about how planning framework has always been developed from within the system, or from a government related perspective. Spatial planning had become bureaucratic and process-oriented. There existed a single-minded approach on land-use regulations to deal with the current multi-actor, multi-scaling network of society.

This led to the evolution of Actor Network Theory (ANT) in planning. ANT is based on the idea that the world is made up of multiple heterogeneous networks of actors. Considering the theory of ANT in planning, governance and spatial planning can become a more collaborative process, with informal partnerships between public, private and civic actors. Though there has been a question about the power distribution amongst various stakeholders and fair distribution of resources and decision making, since there still lies a possibility of powerful stakeholder overpowering the weaker stakeholders. The planning process under such framework can become a long process involving bilateral talks round table discussions, yet the process seems to be able to achieve a fruitful outcome for most. This planning framework is completely contradictory to the existing framework in India. For India to achieve socio-ecological resilience it is important to consider these aspects in planning.

Secondly, for a robust outcome, it is important to understand the role of social capital in collective actions of planning process and adaptation to climate change. Networking social capital with linkages with a "well-functioning" state can help achieve co-management of resources (Adger, 2003). Hence, co-management of resource with strong networks within social capital can help communities cope with the stress brought by climate change.



# 5. Methodology

The following chapter briefly describes the steps and methods used to carry out the project. The aim of the research and the intended output of the research are defined. Based on the research aim and problem analysis a conceptual framework of Adaptive Sustainable Planning to achieve spatial justice is conceptualized. A research framework, with main and sub research questions along with the methods used to approach the questions, has been formulated in this chapter. The Chapter ends with social and scientific relevance of the project along with conclusion and way forward for future steps.



Understanding Problem Field

Chapter 2

- Current Challenges in Ganges River Basin
- Drivers of Change
- Governance Challenges for Ganges River Basin

Introduction

Chapter 1

- Context
- Relationship between human systems and ecological systems

Chapter 3

- Socio-ecological vulnerability analysis across scales
- Problem Statement (Spatial Justice)
- Line of Inquiry:
  1. Dual Nature of Externalities
  2. Capital

Chapter 4

- Theories:
  1. Urbanization
  2. Vulnerability
  3. Resilience Thinking
  4. Social Capital and Governance
- Notions:
  1. Interdependence - Integration
  2. Infrastructure Ecology
  3. Evolutionary Resilience

Research Methodology

Chapter 5

- Conceptual Framework: Adaptive Spatial Planning Model

Vision

Chapter 6

- Principles
  1. Robustness
  2. Adaptivity
  3. Connectedness
  4. Diversity
- Frame of Reference
  1. Knowledge of System Behaviour
  2. Dynamic Adaptive Planning Pathways
  3. Stakeholder Collaboration
- Systemic Goals

Design

Chapter 7

Regional Strategies

Mitigation Strategies that are derived for challenges across the basin

RS1: Room for the River    RS2: Landscape Interventions    RS3: Comprehensive Connectivity    RS4: Pollution Management

Chapter 8

Metropolitan Scale Strategies

Mitigation Strategies that are derived for challenges for metropolitan scale

MS1: Infrastructure Interventions    MS2: Landscape Interventions    MS3: Activating River-edge    MS4: Industrial Development

Chapter 9

Local Adaptation

Adaptation of multiple strategies to achieve resilience

1. Urban
2. Peri-Urban
3. Rural

Adaptive Planning Pathways

Evaluation

Chapter 10

Scenarios

- Case 1
- Case 2
- Case 3



## 5.1. RESEARCH APPROACH

### 5.1.1. Research Aim :

#### Socio-Ecological Resilience and Spatial Justice

The research aims at assessing the current conditions of water and urban infrastructure, the policies that govern it and the impacts in terms of cost-benefit, caused by them, for the settlements on the banks of river Ganga.

Furthermore, it sets to derive the variables of social, economic and environmental vulnerability, to study the impacts of externalities generated due to the process of urbanization, development of existing water infrastructure and climate change on these variables, along with the governing policies to calculate risk.

The goal is to find institutional gaps in the current planning model and formulating a new adaptive spatial planning model. This new model of planning shall help in generating guidelines and tools that consider the environmental impact of the economic developments and water infrastructures, to achieve resilience integrating the formal and self-organized informal institutions (communities). The model shall consider the risks on communities especially, vulnerable communities to attain spatial justice for all.

### 5.1.2. Intended Output

The output of this research is directed to all the stakeholders (public, private companies, governments, local communities, civil societies and NGOs) who are now working or shall in future work towards adaptation to climate change and development of The Ganges River. This research aims to understand the challenges and counter the risks imposed due to urban developments that are doubled with the impacts of climate change, with an Adaptive Spatial Planning Model. As a strategic project, to formulate and analyse the new planning model, the urban agglomeration of Patna district is in the Bihar State of India, within the Ganges Basin is developed, and later the model and the strategies will be tested for different sections of the river to achieve integrated and holistic development of the river basin.

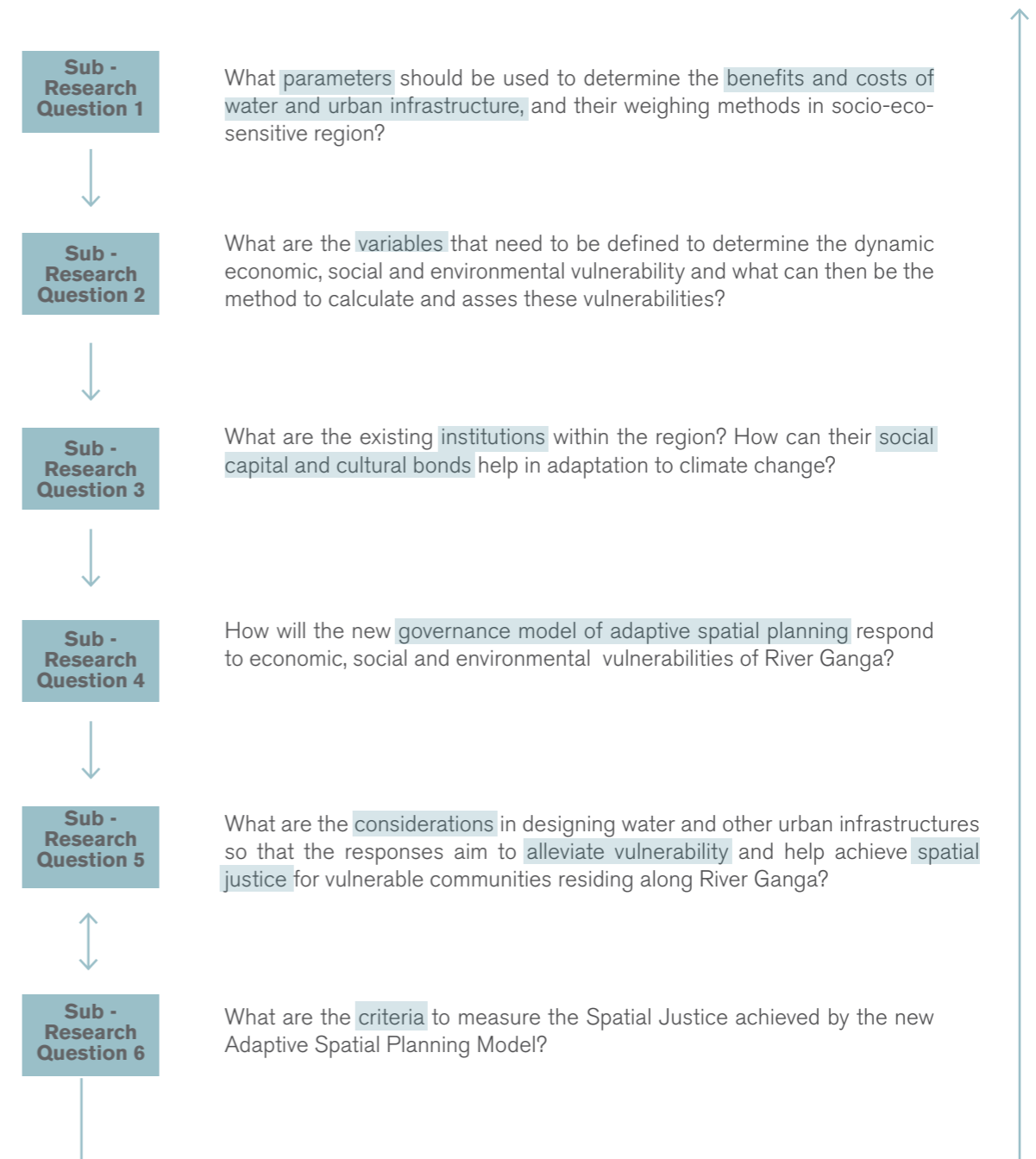
**For Governments:** The outcome of the exploratory adaptive spatial planning model shall help in changing the approach of planning policies, making it more participatory and reducing inequalities in resource distribution. The approach will include local adaptation with municipalities of the district, and the possibility of applying the strategies and providing basic and feedbacks for large scale regional planning as well (River Basin Governance). Thus, deriving a model for an alliance of different scales of government involved; local, state and national. (Macro to Micro Scale)

**For Communities:** The guidelines and tools developed by process of the research within new vision and strategies shall help in achieving bottom-up planning, strengthening the existing bonds and social capital, making communities more empowered to take independent steps towards resiliency and reducing socio-ecological vulnerability. (Micro Scale)

**For Environment:** With adaptive spatial planning model, the exploitation of natural resources will be reduced to achieve ecological balance. This in the long term shall help reduce negative externalities that are impacting climate change. (Macro to Micro Scale)

### 5.1.3. Research Question

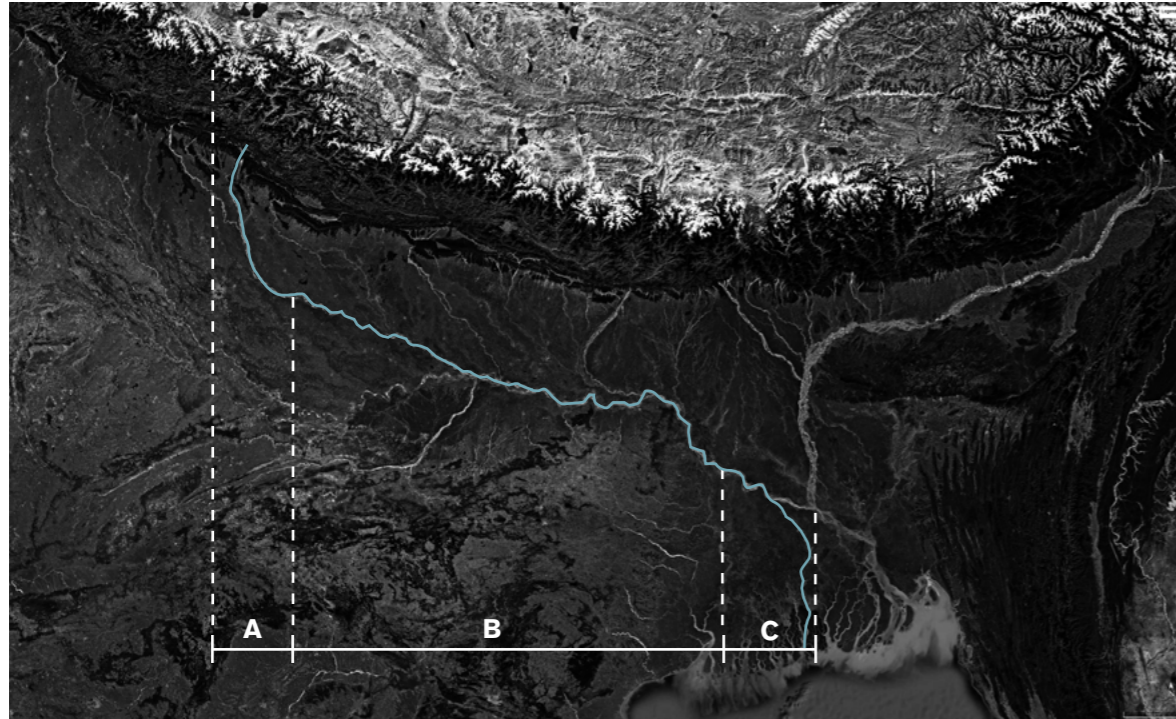
**How can the development of water centric infrastructures help to cope the dynamic economic, social and environmental vulnerabilities along the banks of River Ganga through an Adaptive Spatial Planning Model within the basin?**





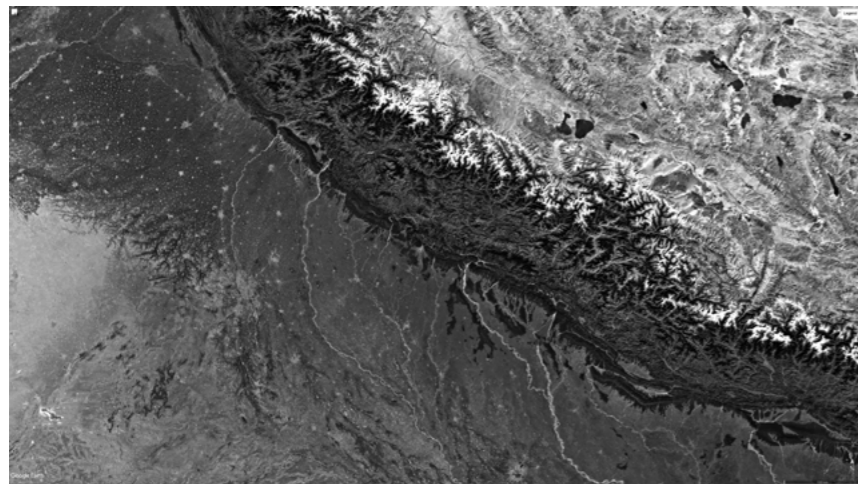
5.1.4. Analysis Process at Different Geographical Scales

Scale 1:  
Macro: Ganges River Basin

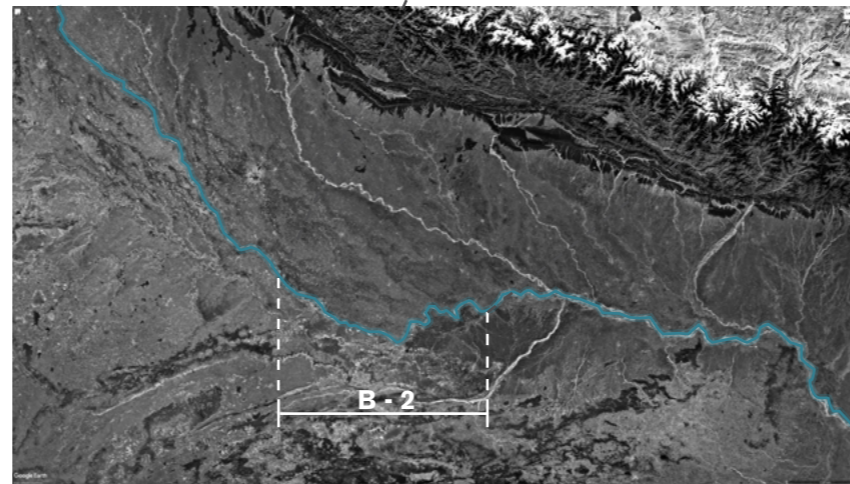


It is necessary to carry out a transcalar analysis and mapping to understand the relationship of river with cities, people and governance at different levels.

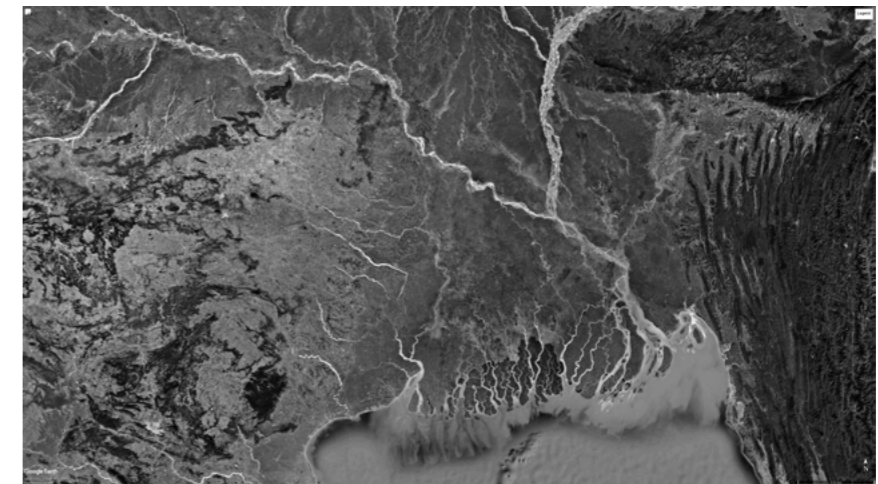
Scale 2:  
A. Hilly Section



B. Flat Plains

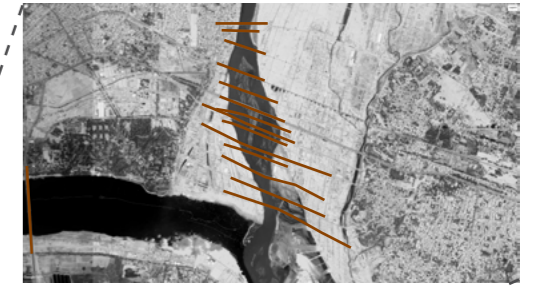


C. River Delta

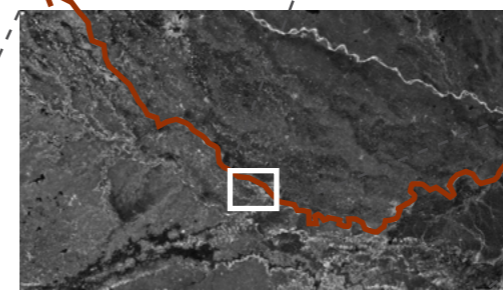
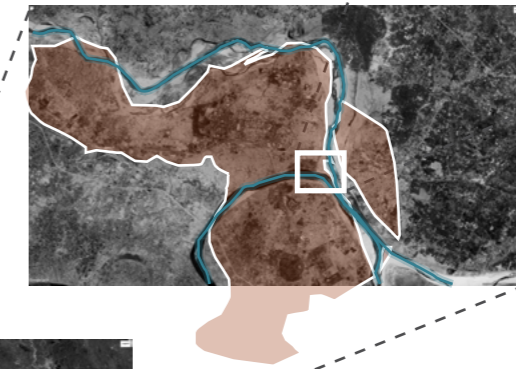


Sections of River

Scale 4:  
Micro: Zoom-in (Eco-Sensitive : Highly Engineered)



Scale 3:  
Meso: The City and The River (Understanding Relationships)



River Segment

← Designing and Testing at Different Scales →

Image (x): Mapping river Ganges at different scales: Understanding relationships between River and Human Systems  
Source: Google Earth Images



## 5.2. CONCEPTUAL FRAMEWORK

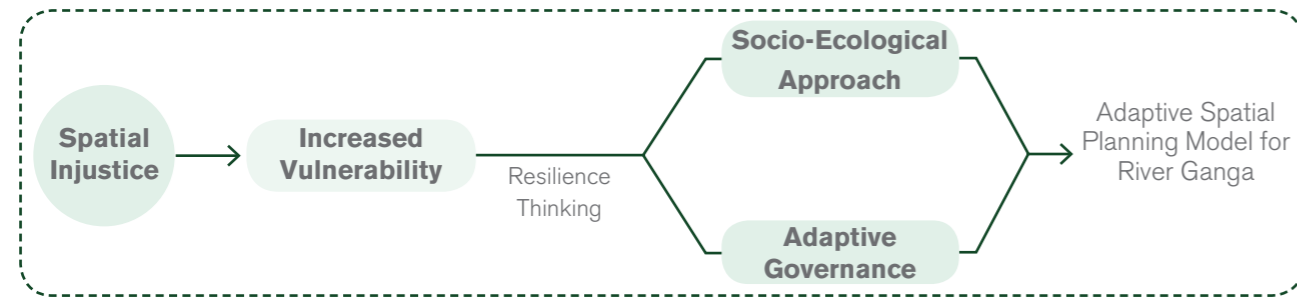


Fig. 44. Road Map from Spatial Injustice to Adaptive Spatial Planning

This thesis aims to achieve a framework for Adaptive Spatial Planning Model for development of The River Ganga. While the current planning framework fails to address the constant rising risks of climate change and uncertainty, it is important to adopt a system of resilient planning for now and future. The 3 core concepts considered for the Adaptive Spatial Planning Model are :

**1. Adaptive Governance:** The concept of adaptive governance highlights the importance of Actor-Network Theory aiming to achieve Actor-Relational Approach in planning. The process aims to achieve outside-inward planning rather than planning policies coming from inside of planning departments. This new model of Adaptive Governance emphasises on social capital and co-management of resources to achieve socio-ecologically resilient future (Luuk Boelens, 2010).

**2. Evolutionary Resilience:** The socio-ecological system is a framework to understand the dynamics of human-environment relation. Resilience has always been understood as the ability of the ecological system to reach back to equilibrium after a disturbance. While, evolutionary resilience, a forward-looking approach was developed to understand the integrated dynamic nature of human and biophysical systems to form adaptive cycles for resilient development (Muriel Cote and Andrea J. Nightingale, 2012).

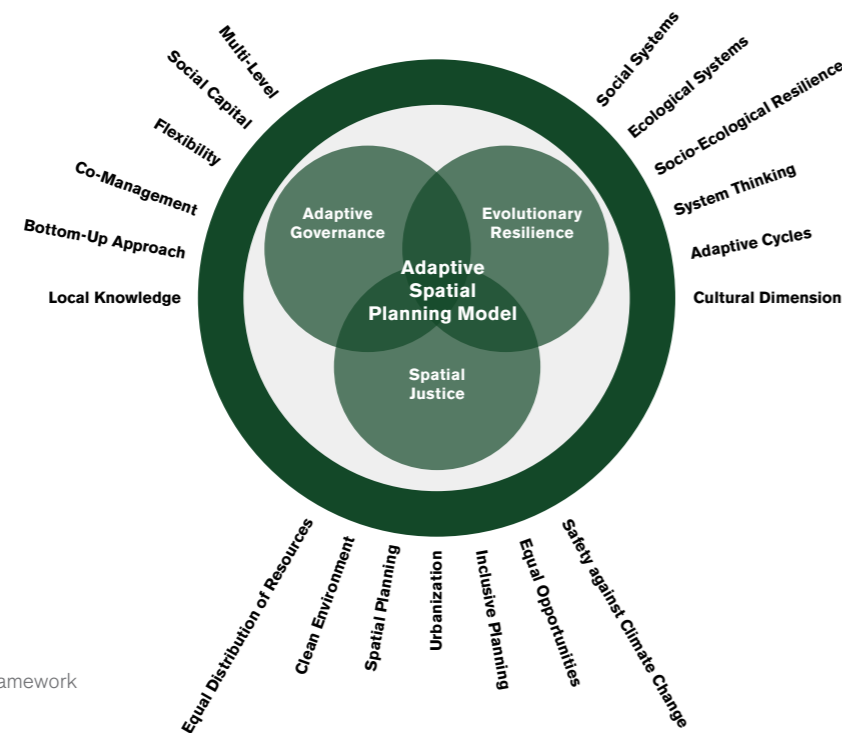


Fig. 45. Conceptual Framework

**3. Spatial Justice:** Spatial justice can be defined as fair and equitable distribution in space of socially valued resources and the opportunities to use them. (Soja,2009) To achieve an Adaptive Spatial Planning Model it is

extremely important to empower local communities and provide them with equal rights to participate and use resources.

**Theory:**  
 • Regions in context: spatiality, periodicity, and the historical geography of the regional question, E W Soja (1985)  
 • The World City Hypothesis, John Friedmann (1986)

**Theory:**  
 • Social Vulnerability and Environmental Hazards, Susan Cutter, Bryan Boruff, W. Lynn (2003)

**Theory:**  
 • Resilience thinking meets social theory: Situating social change in socio-ecological systems (SES) research, Muriel Cote, Andrea J. Nightingale (2012)  
 • Evolutionary Resilience and Strategies for Climate Adaptation, Simin Davoudi, et al. (2013)

**Theory:**  
 • The Adaptive Capacity Wheel: a method to assess the inherent characteristics of institutions to enable the adaptive capacity of society, Gupta et al., (2010)

**Theory:**  
 • Theorizing Practice and Practising Theory: Outlines for an Actor-Relational-Approach for Planning, Luuk Boelens (2010)

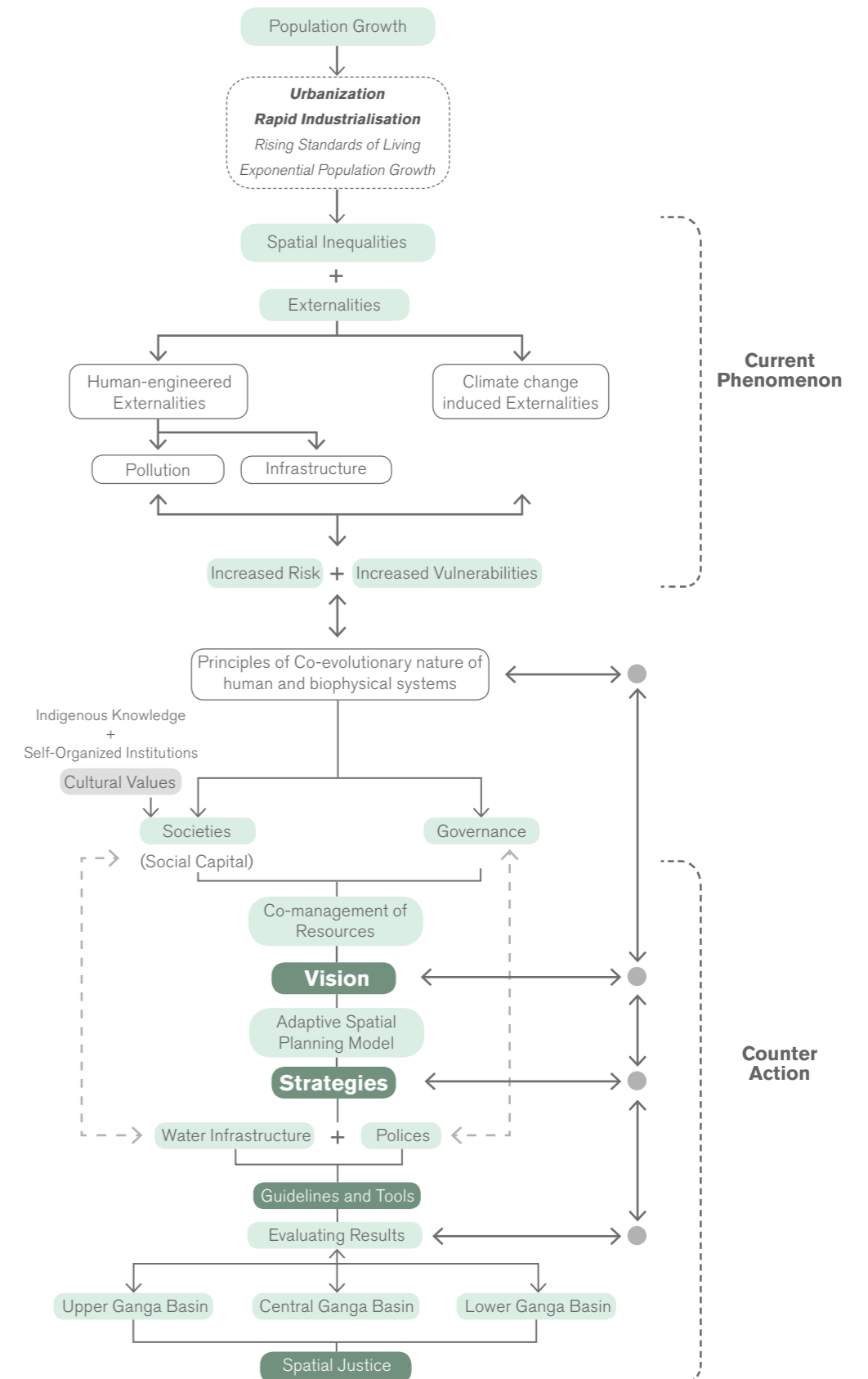


Fig. 46. Theories and Research Framework

### 5.3. RESEARCH METHODOLOGY

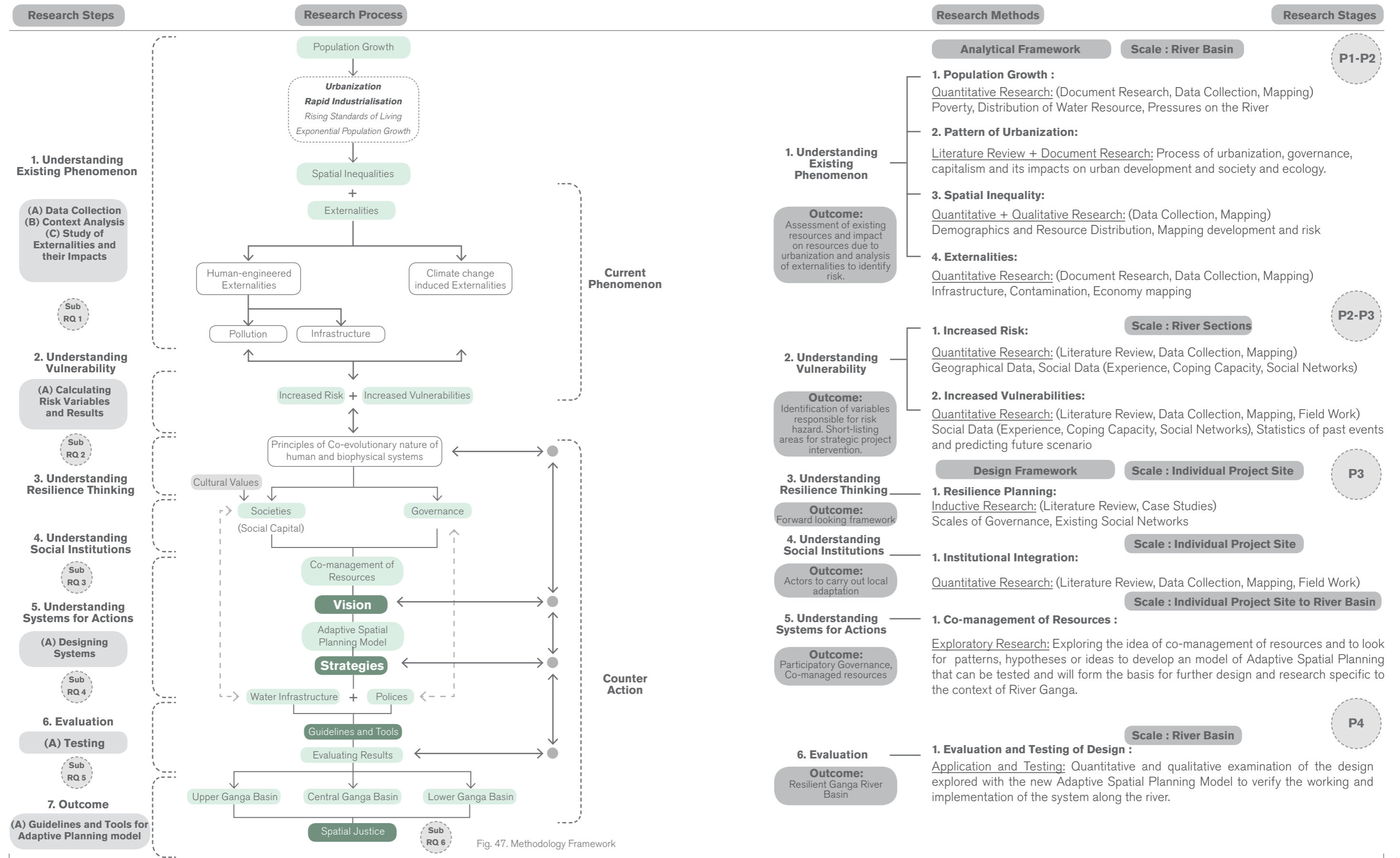


Fig. 47. Methodology Framework



### 5.3.1. Sub-Research Questions and Research Methods

#### Sub-Research Question 1 (Analytical Framework ; Context)

What parameters should be used to determine the benefits and costs of water and urban infrastructure, and their weighing methods in socio-ecological sensitive region?

#### Intended Outcome:

With this sub-question, an assessment of existing natural resources in the Ganges Basin Context shall be carried out. Further with analysis of the on-going process of rapid urbanization, the impact of externalities like pollution and infrastructure construction (and/or lack) due to this urbanization on the resources is determined.

#### What? (Elements) :

A. Context	B. Infrastructures Specific to the context	C. Benefit - Cost Assessment Specific to the infrastructure
<p><b>1. Natural: Mountains-River Plains-Delta</b></p> <p>Identifying and mapping the geographical conditions of the region. Understanding the terrain, and mapping historical evolution of climatic conditions and vegetation.</p>	<p><b>1. Water Infrastructure:</b></p> <ul style="list-style-type: none"> <li>Hydro-Power Dams</li> <li>Irrigation Canal</li> <li>Check-Dams</li> <li>Barrage</li> <li>Bore-wells</li> <li>Embankments</li> </ul>	<p><b>1. Ecological Assessment Parameters:</b></p> <ul style="list-style-type: none"> <li>Water Quantity / Availability</li> <li>Water Quality</li> <li>Flora and Fauna Diversity</li> <li>Vegetation Cover</li> <li>Frequency of Natural Disasters</li> </ul>
<p><b>2. Anthropogenic: Urban-Rural Areas</b></p> <p>Data collection of population growth, economic distribution, to understand the dichotomy of urban-rural areas in the region. This analysis will help identify the hot-stops of population concentration and patterns of neglected areas for intervention.</p>	<p><b>2. Urban Infrastructure:</b></p> <ul style="list-style-type: none"> <li>Railways</li> <li>Roads</li> <li>Built Development</li> </ul>	<p><b>2. Social Assessment Parameters:</b></p> <ul style="list-style-type: none"> <li>Economic Opportunities</li> <li>Living Standards</li> <li>Quality of Space</li> </ul>

#### How? (Methods):

Quantitative Research: (Document Research, Data Collection, Mapping) Population, Poverty, Distribution of natural resources especially water.

Literature Review + Document Research: To understand process of urbanization, governance, capitalism and its impacts on urban development and society and ecology.

Transcalar Mapping: (Document Research, Data Collection) Mapping of infrastructure elements locate the typologies of infrastructure projects.

Transcalar Mapping: (Document Research, Data Collection) Mapping of infrastructure elements over time to understand its impacts on society and ecology.

Literature Review + Document Research: To formulate a combined assessment rubric for benefit-cost.

#### Scales:



**Macro: River Basin**  
**Meso: River - Cities**



**National**  
**State**

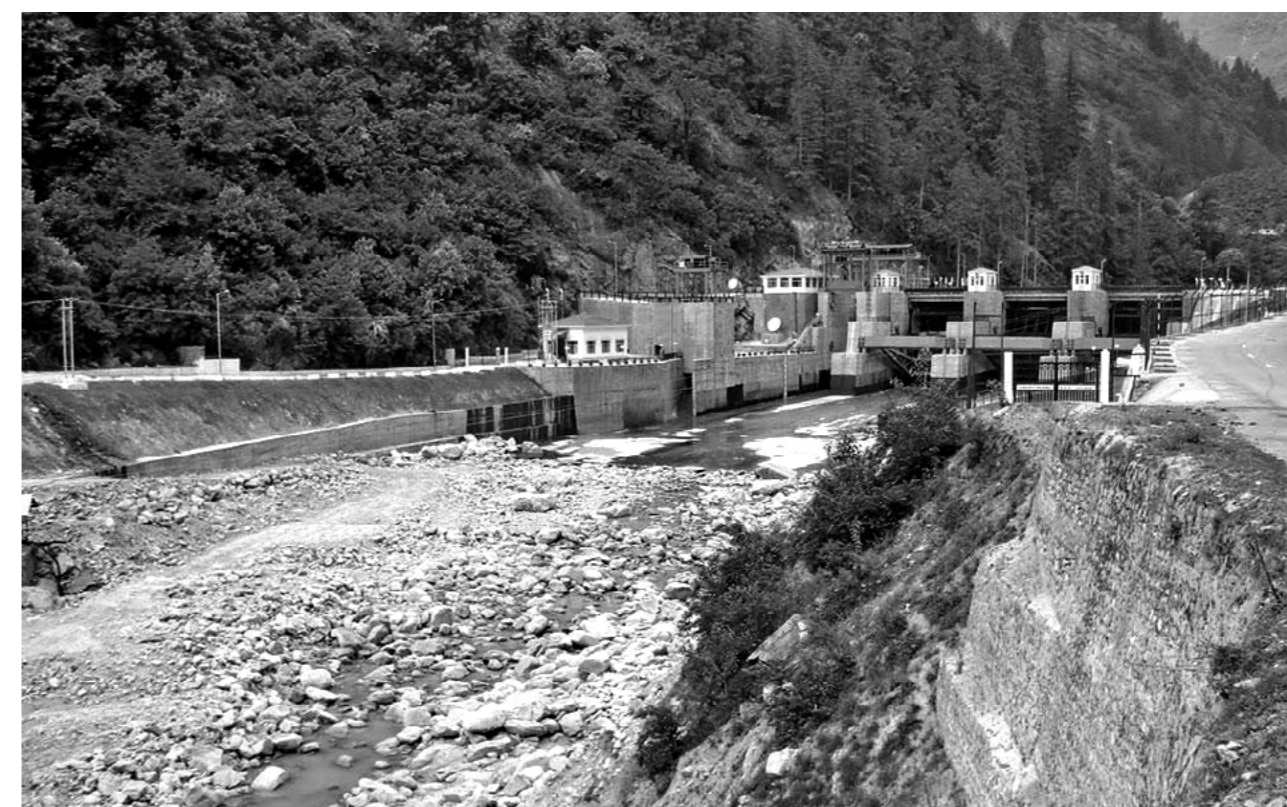


Fig. 48. Dams jeopardizing Ganga's free flow

Source: Ganga Matu Jansangthan, Down to Earth, 2019

#### Constrains:

The occurrence of benefit and cost varies according to the users. Some elements (infrastructure) that have high social benefit may have cost for the flora - fauna. Thus it is important to understand trade-offs between social, economic and ecological benefits and cost of a project.

Secondly, the availability of data for mapping of small scale infrastructures like bore-wells and embankments is difficult to obtain in India. The results shall be verified during fieldwork.

#### Conclusion:

Based on the initial analysis of world bank reports and several independent document research as seen in chapter 2 of this report, it can be noted that the construction of grey huge scale infrastructure has impacted the ecology of the region negatively and also the distribution and access of the majority of infrastructure are unjust.

**Sub-Research Question 2 (Theoretical - Analytical Framework ; Conditions)**

What are the variables that need to be defined to determine the dynamic economic, social and environmental vulnerability and what can then be the method to calculate and assess these vulnerabilities?

**Intended Outcome:**

Identification of variables responsible for risk. Mapping of the vulnerable area will help determine areas for strategic project intervention and also relate these variables to systemic design interventions.

**What? (Elements) :**

A. Social Vulnerability Parameters	B. Ecological Vulnerability Parameters	C. Economic Vulnerability Indicators
<ul style="list-style-type: none"> <li>▪ Age (proportion of youth and elderly population)</li> <li>▪ Gender (female)</li> <li>▪ Education</li> <li>▪ Special needs/disability population</li> <li>▪ Vulnerable minorities</li> <li>▪ Immigrants</li> <li>▪ Rapid population growth</li> <li>▪ Family Structure</li> </ul>	<ul style="list-style-type: none"> <li>▪ Biophysical Elements</li> <li>▪ System Functioning</li> </ul>	<ul style="list-style-type: none"> <li>▪ GDP per capita</li> <li>▪ Average monthly salary</li> <li>▪ Unemployment level</li> <li>▪ Number of economically dependent individuals/citizen</li> <li>▪ Occupation</li> <li>▪ Economic sector (e.g., resource extraction)</li> </ul>

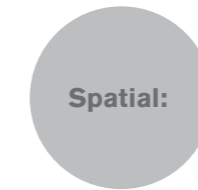
Source: Adger, 2005-2009

**How? (Methods):**

<p><u>Transcalar Mapping:</u> (Document Research, Data Collection) Mapping of social indicators, overlapping data to determine most vulnerable areas.</p>	<p><u>Transcalar Mapping:</u> (Document Research, Data Collection) Mapping of ecological indicators, overlapping data to determine most vulnerable areas.</p>	<p><u>Transcalar Mapping:</u> (Document Research, Data Collection) Mapping of economic indicators, overlapping data to determine most vulnerable areas.</p>
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Literature Review + Document Research: Understanding of Risk, hazard and vulnerability with respect to social, economic and environmental parameters, to formulate index for vulnerability.

**Scales:**



**Macro: River Basin**  
**Meso: River - Cities**



**State**  
**District Municipalities**



Fig. 49. Social, economic and ecological vulnerabilities in Ganges basin Source: NRC, nl , 2017

**Constrains:**

Analysis of certain parameters of vulnerability is feasible only at district or neighbourhood scale.

**Conclusion:**

Based on certain social, ecological and economic parameters at the river basin scale and zoomed-in areas of State of Bihar and UP are identified to carry out the second level of analysis. This 2-degree analysis will help in determining sites for interventions.



**Sub-Research Question 3 (Analytical Framework ; Actors-Institution)**

What are the existing institutions within the region? How can their social capital and cultural bonds help in adaptation to climate change?

**Intended Outcome:**

Study and assessment of how existing self-organized informal institution within the communities directly dependent on the water can contribute to adaptation to climate change and achieve resilience in the long term.

**What? (Elements) :**

**A. Self-Organized Informal Institutions**

- Fishermen's Communities
- Farmers
- Temple Associations
- Groups within Ghat Precincts
- Boatmen

**B. Adaptation to Climate Change**

**1. Indigenous knowledge:**

Most of the communities that have their livelihood directly dependent on the water have shown adaptation strategies in past. It will be important to understand small scale, context specific strategies from such groups.

**2. Technological Innovations:**

Technological innovations like glass-houses have helped achieve huge produce of food, in less area and water requirements. Thus incorporating such innovation with indigenous knowledge would help achieve resilience.

**How? (Methods):**

Quantitative Research: (Document Research, Data Collection) Mapping location and boundaries of communities directly dependent on river.

Literature Review + Document Research: Institution organization and working. Identify existing qualities within these institutions.

Literature Review + Document Research: To study how communities have adapted to changing dynamics of water in the past. Also identifying new technologies that can be implemented with local knowledge to achieve resilience.

**Scales:**

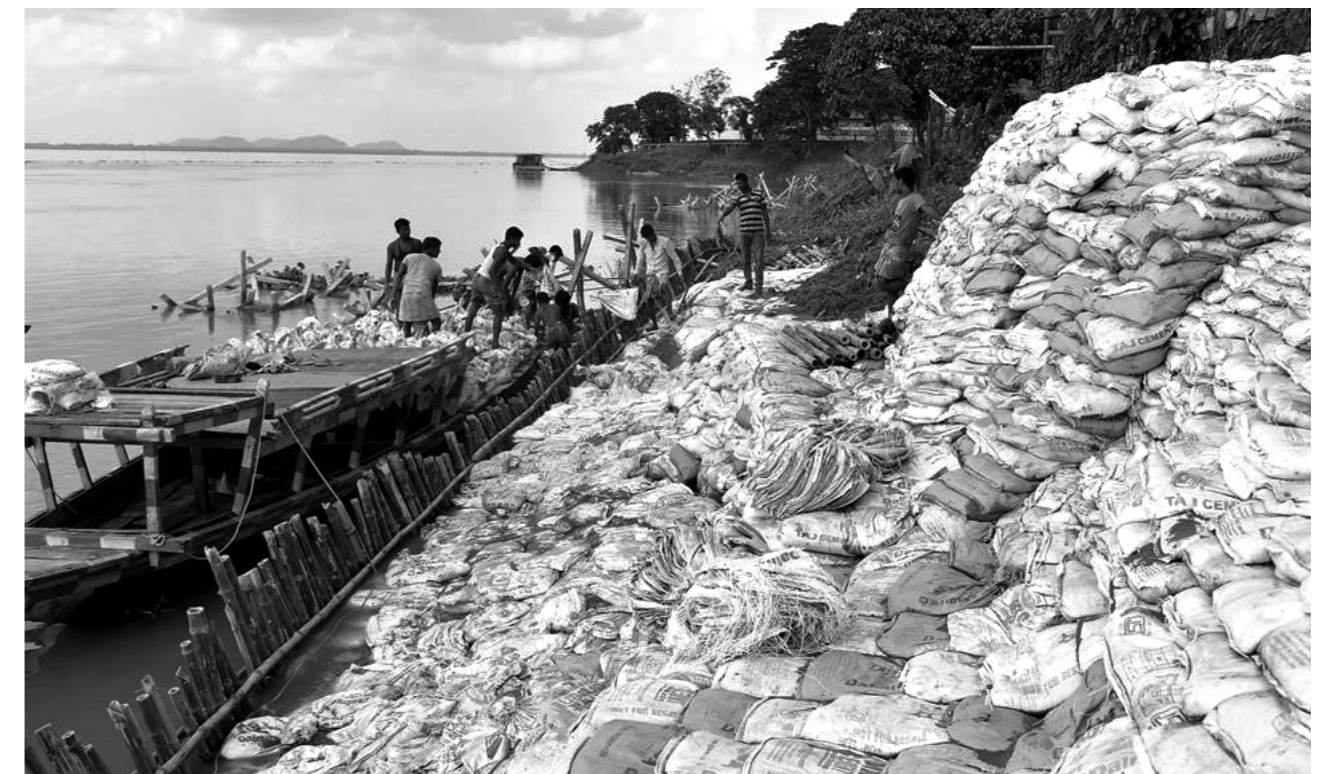
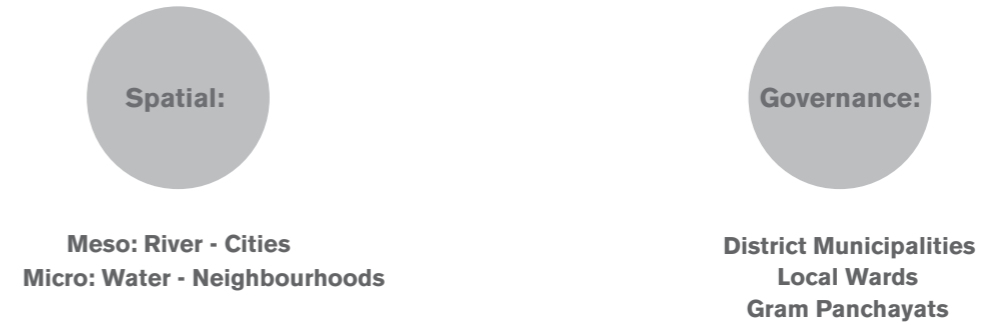


Fig. 50. Labourers piling sand bags to try to protect a bank (Sustainable method instead of concrete embankments, yet use of plastic bags pollutes the river and soil)

Source: Getty Images (BBC, 2018)

**Constrains:**

Self-organized institutions are often formed around economic activities, hence it is crucial to educate these institutions to look beyond short term economic gains, to achieve resilience to climate. Also, data for such activities and groups are not explicitly noted. Thus, the method and question were adapted to focus on ward offices (formal) institution.

**Conclusion:**

Local adaptation actions carried out by groups like fishermen, farmers etc when set within the a regional framework of adaptive planning can help achieve climate mitigation and resilience.

**Sub-Research Question 4 (Analytical Framework ; Actors)**

How will the **new governance model of adaptive spatial planning** respond to economic, social and environmental vulnerabilities of River Ganga?

**Intended Outcome:**

To analyse the current system of fragmented governance in the river basin, and formulate a new adaptive system that involves civil societies and local institutions to participate actively to achieve resilience. Exploring the idea of co-management of resources and to look for patterns, hypotheses or ideas to develop Adaptive Spatial Planning Model.

**What? (Elements) :**

**A. Actors**

**Global**

- World Bank
- United Nations
- International Union for Conservation of Nature (IUCN)
- Convention on Biological Diversity (CBD)

**National**

- Central Government
- National Ganga River Basin Authority (NGRBA)
- Namami Gange Board
- NGOs (Green Tribunal)
- Indian Institutes of Technology
- National Political Parties
- Ministry of Jal Shakti
- National Disaster Management Board
- Ministry of Environment and climate change
- Civil Societies

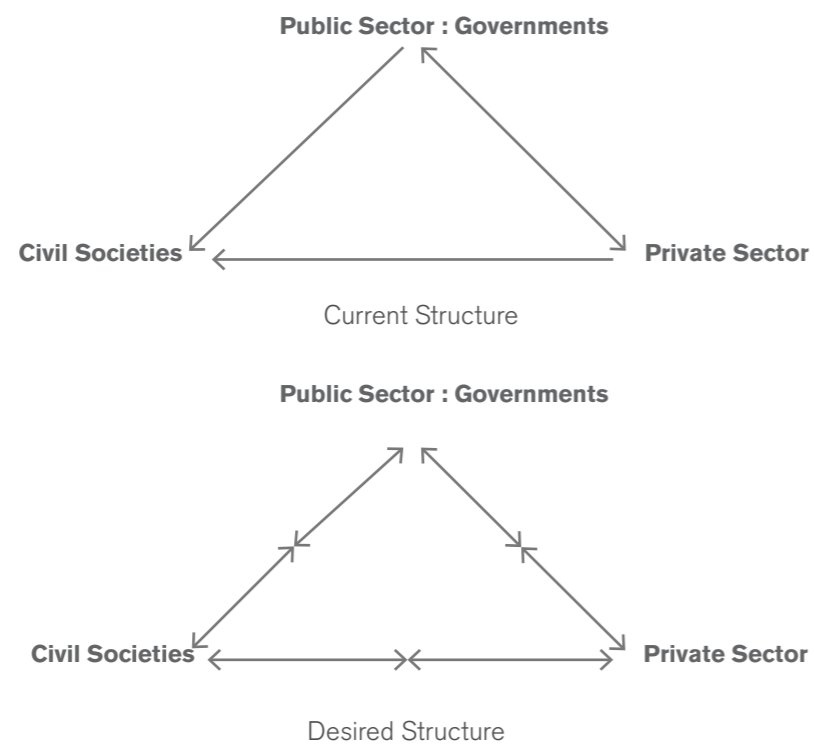
**Local**

- State Government
- Local Municipalities
- Gram Panchayat
- Private Companies like tanneries, energy companies
- Temple Associations

**How? (Methods):**

Stakeholder Analysis: (Document Research, Data Collection, Field work) Create matrix of actors currently involved and create power interest graph to analyse future desired relations for co-management of resources.

**B. Structure**



**Scales:**

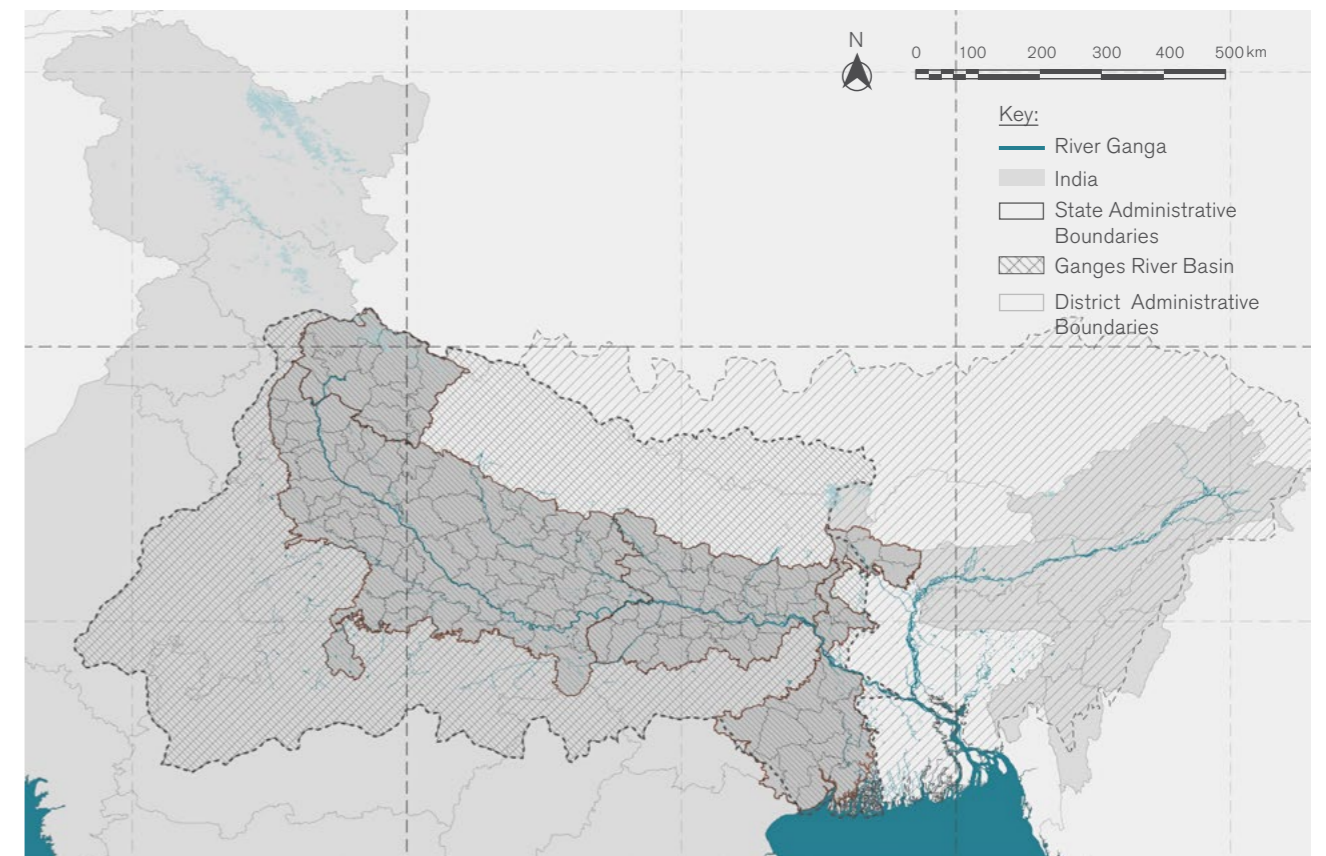


Fig. 51. Administrative and Ecological boundaries Source: GIS Data, Bhuvan, NIC Bihar

**Conclusion:**

Based on initial desk research and document review the power distribution amongst the stakeholders is in the top to bottom hierarchy. More in concrete conclusions shall be derived based on interviews with locals and government officials during the fieldwork.



**Sub-Research Question 5 (Design Framework ; Guiding Principles)**

What are the considerations in designing water and other urban infrastructures so that the responses aim to alleviate vulnerability and help achieve spatial justice for vulnerable communities residing along River Ganga?

**Intended Outcome:**

The design principles derived from answering this sub-research question would help in planning and designing of a resilient neighbourhood, district and a system that promotes adaptive thinking. Few projects that have been successful at achieving resilience at different scales have been studied to learn the implementation of these principles.



Source: The Resilient Design Principles | Resilient Design Institute (2020) and Tool-kit for Resilient Cities (2019)

**Bishan Park, Singapore**



Image (y): Transformation of Bishan Park in Singapore  
Source: Ramboll Studio Dreiseitl, Landezine (2012)

Bishan Park is one of the most popular parks in the country. The park was redesigned to improve the water holding capacity of Kallang River. The concrete utility canal running in the park was naturalised, creating urban river park. This transformation not only upgraded the park ecologically but also upgraded it socially.

**Rabalder Park in Roskilde, Denmark**



Image (z): Skating Rink, Rabalder Park  
Source: Wired (2013)

The new section of drainage canal at Rabalder Park in Roskilde, Denmark, is designed with skating rink recreational area. This was planned to cater to the increasing rainfall due to changing climate. The basic function of storm-water drainage is fulfilled exploring the possibility of the flexibility of space and recreational needs of the society.

**Water Square, Rotterdam, Netherlands**



Image (aa): Water square being used for gathering and water storage  
Source: DE URBANISTEN | Water Square Bentemplein (2013)

The Water Square in Rotterdam, next to a school is designed to fulfil the requirements of rainwater storage as well as public space need. The location and colour schemes were designed keeping in mind the function and users of the project. The project was built with community participation. Hence, it can be seen as one of the examples of resilient design at neighbourhood scale.

### Sub-Research Question 6

What are the **criteria** to measure the Spatial Justice achieved by the new Adaptive Spatial Planning Model?

#### Intended Outcome:

After exploration with design interventions, it is important to test if these design interventions have managed to achieve spatial justice. Thus, the intended outcome is to formulate a measurement strategy to evaluate the new Adaptive Spatial Planning model and its interventions (Strategies, tools and guidelines).

#### What? (Elements) :

Availability of Resources

Access to Opportunities and Resources

Opportunity for Participation

#### How? (Methods):

Quantitative Research: (Document Research, Data Collection, Mapping) Quantification of available resources with users.

Transcalar Mapping: (Document Research, Data Collection) Mapping of accessibility to the resources.

Quantitative Research: (Document Research, Data Collection) To understand and evaluate the ability of an individual to participate.

Case Studies, Discussions and Literature Review: To understand the theoretical aspect of spatial justice and looking at best practices of the practical implementations to achieve it.

#### Scales:

**Spatial:**

**Macro: River Basin**  
**Meso: River - Cities**  
**Micro: Water - People**

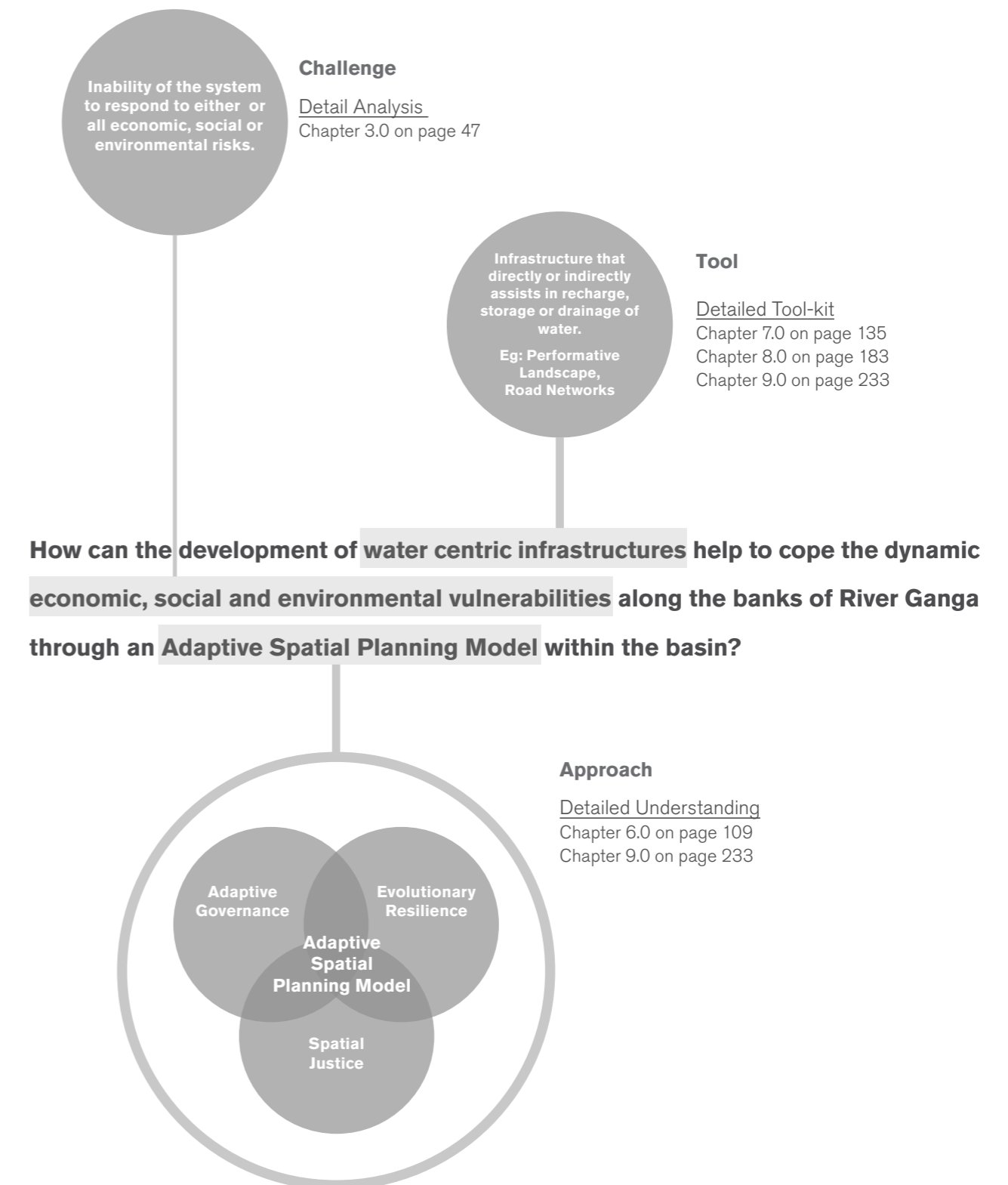
**Governance:**

**National State**  
**Local Municipalities**

#### Conclusions:

The aspect of spatial justice had main focus in the operability aspect of the project. The operability framework of planning process across scales and local adaptation focuses on the aspects of just distribution, equal access and opportunity for participation.

### 3 Main Components of Research Question







## 6. Vision for The Ganges River Basin

The following section describes the designing framework, moving from goals and principles to a spatial vision. The spatial vision is then elaborated to understand the operational framework of the project, analysing the existing socio-ecological system and the stakeholders within the Ganges River Basin. The chapter concludes with systemic goals at different scales for the co-management of resources between governance and society.



Understanding Problem Field

Chapter 2

- Current Challenges in Ganges River Basin
- Drivers of Change
- Governance Challenges for Ganges River Basin

Introduction

Chapter 1

- Context
- Relationship between human systems and ecological systems

Chapter 3

- Socio-ecological vulnerability analysis across scales
- Problem Statement (Spatial Justice)
- Line of Inquiry:
  1. Dual Nature of Externalities
  2. Capital

Chapter 4

- Theories:
  1. Urbanization
  2. Vulnerability
  3. Resilience Thinking
  4. Social Capital and Governance
- Notions:
  1. Interdependence - Integration
  2. Infrastructure Ecology
  3. Evolutionary Resilience

Research Methodology

Chapter 5

- Conceptual Framework: Adaptive Spatial Planning Model

Vision

Chapter 6

- Principles
  1. Robustness
  2. Adaptivity
  3. Connectedness
  4. Diversity
- Frame of Reference
  1. Knowledge of System Behaviour
  2. Dynamic Adaptive Planning Pathways
  3. Stakeholder Collaboration
- Systemic Goals

Design

Chapter 7

Regional Strategies

Mitigation Strategies that are derived for challenges across the basin

RS1: Room for the River    RS2: Landscape Interventions    RS3: Comprehensive Connectivity    RS4: Pollution Management



Chapter 8

Metropolitan Scale Strategies

Mitigation Strategies that are derived for challenges for metropolitan scale

MS1: Infrastructure Interventions    MS2: Landscape Interventions    MS3: Activating River-edge    MS4: Industrial Development



Chapter 9

Local Adaptation

Adaptation of multiple strategies to achieve resilience

1. Urban
2. Peri-Urban
3. Rural

Adaptive Planning Pathways

Evaluation

Chapter 10

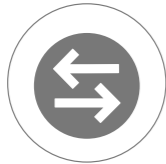
Scenarios

- Case 1
- Case 2
- Case 3



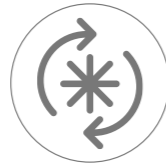
## 6.1. PRINCIPLES FOR RESILIENCE

### Robustness



**Responsive**

A responsive design intervention or a system is a system that responds and adjusts as per the current requirements.



**Renewable**

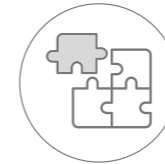
One of the key goals of the project is to maintain the renewable aspect of natural resources like water, agriculture, forest, etc. The most important aspect of this goal is to see that the rate of usage does not exceed the rate of renewal.



**Robust**

The principle of robustness in the design makes sure that the design interventions are derived by keeping in mind the tipping points of the system in case of hazards like flooding. The design of water infrastructure shall be strong to survive the crisis without failure.

### Adaptivity



**Flexible**

For a resilient system to function a system must adapt to shocks. An adaptive approach in system shall be able to provide multiple pathways and opportunities. Thus flexibility in design and planning is required to be able to cater multiple possible adaptation scenarios.



**Community Based**

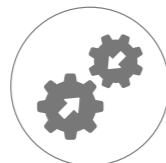
For adaptation against climate change, it is important to re-look at local scales. Thus, Community based design and public participation place a crucial role in designing for resilience.

### Connectedness



**Across Scales**

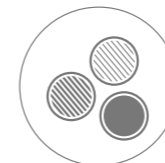
As the project deals with socio-ecological networks within the river basin it is important to understand several networks of layers involved within the system. Hence designing for all scales and analysing impacts of intervention at different scales is necessary to achieve resilience within the system.



**Co-ordinated**

The governance system in the river basin has remained fragmented across levels and in different sectors. For a resilient design intervention, it is important to establish co-ordination across levels and within different sectors like water management and urban planning to attain resilience.

### Diversity



**Diverse**

Diversity is a key component of resiliency. This diversity can be of 2 types, functional diversity and response diversity. Functional diversity addresses the different possible disturbances within the system while the response diversity aims to address single major disturbance with different solutions.



**Socially Just**

The design of water-centric infrastructure and planning should cater to the vast population irrespective of their income group. Also, the landscape shall remain accessible to all. Moreover the community shall play a crucial role in the planning process and decision making. Hence, the principle of socially just is required for the design.



## 6.2. VISION

The Vision for the Ganges River Basin is a spatial interpretation of the concepts, goals and values to achieve socio-ecological resilience, in the river basin through Adaptive Spatial Planning. The vision aims to incorporate the field of Urban Planning, Landscape Architecture, Water Engineering with Governance and Society to achieve procedural and distributive spatial justice.

*"By 2050, the project aims to achieve adaptation towards the on-going water challenges of flooding and drought in the Ganges River Basin, by enhancing, protecting and connecting various environmental sensitive areas, through re-arranging and re-programming of the existing urban landscape and urban morphology, by including local communities and actors in the planning process."*

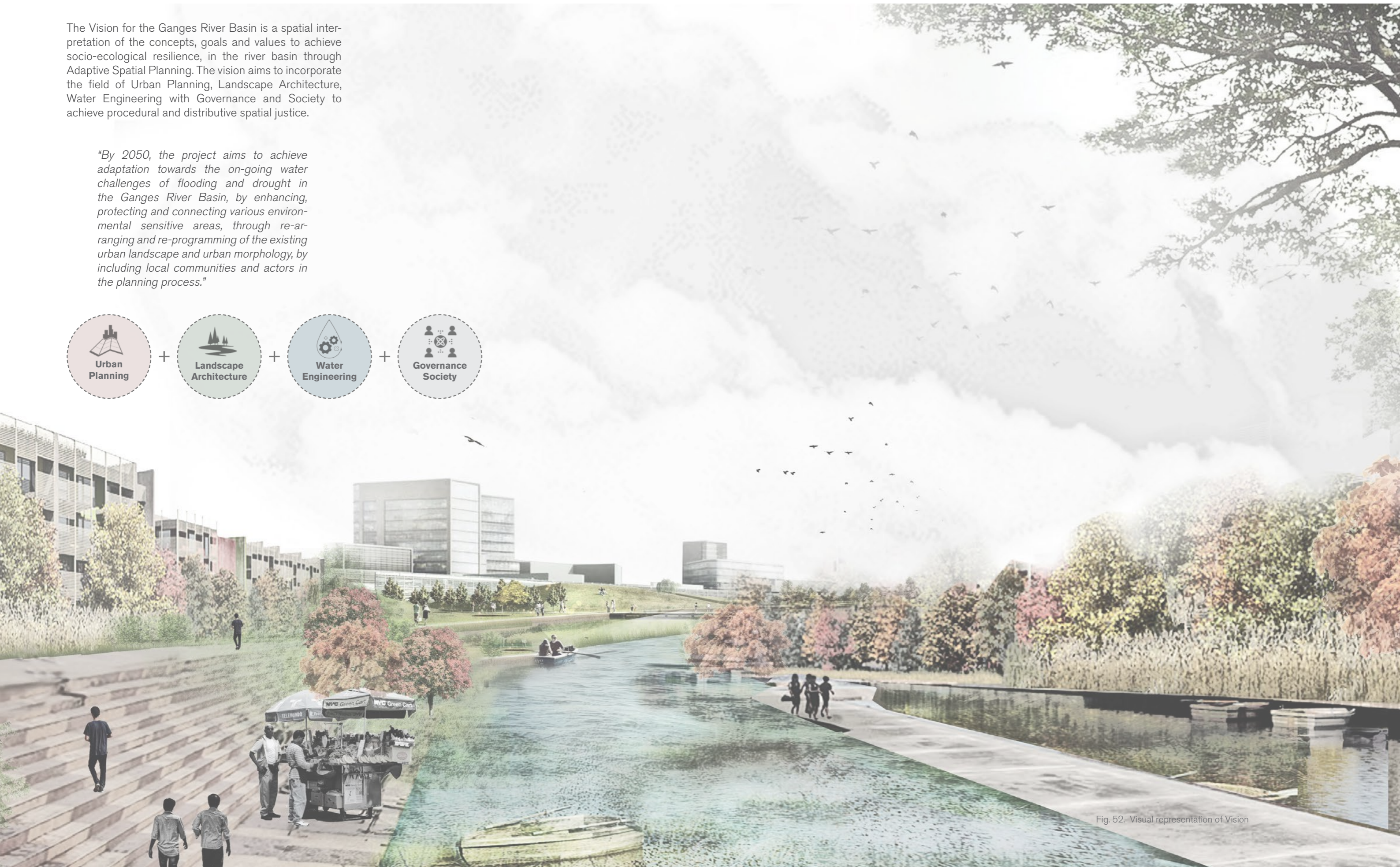
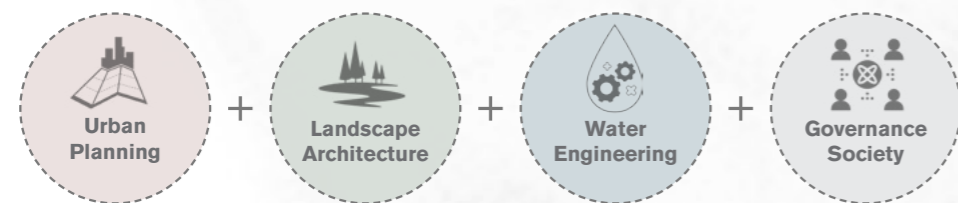


Fig. 52. Visual representation of Vision



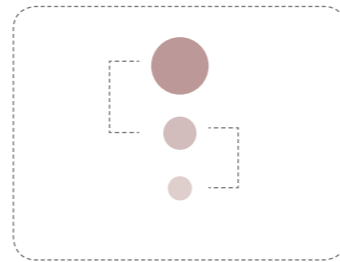
### 6.3. SPATIALITY OF RESILIENCE



**Urban Planning**

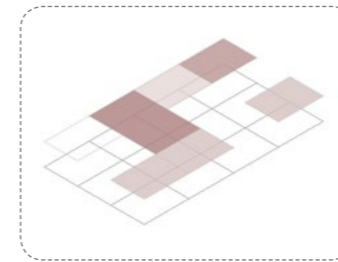
Urban planning plays a key role in designing the morphological fabric of the built and the unbuilt. The urban fabric further determines aspects like distribution of density and functions, connectivity infrastructures such as roads and railways. The design of these features attributes to social, ecological and economic development. Thus, the spatiality of principles of resilience with respect to urban planning will help in understanding how they can be translated and implemented across the basin.

#### Robustness



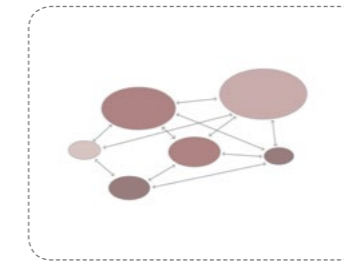
1. Systemic goals and vision

#### Adaptivity



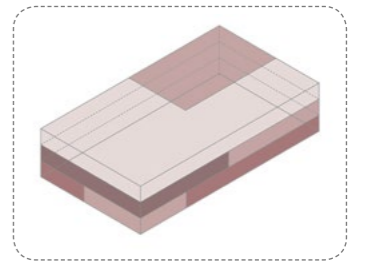
2. Flexible design framework

#### Connectedness

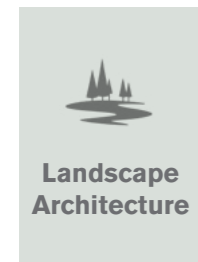


3. Connecting functions (Polycentricity)

#### Diversity



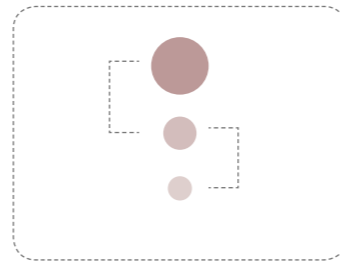
4. Mix-use development



**Landscape Architecture**

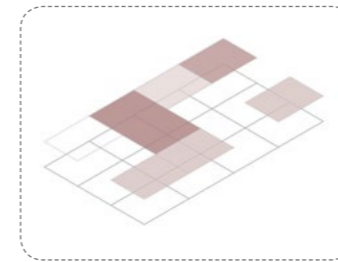
Translating the principles of resilience within the framework of landscape architecture helps in deriving soft, nature-based solutions to complex challenges of flooding, and water crisis. The aim here is to use landscape interventions such as multi-purpose patches, plantation of trees and native shrubs to alleviate social and economic vulnerabilities, and moreover balancing ecological systems to active short term mitigation and long term adaptation to the crisis.

#### Robustness



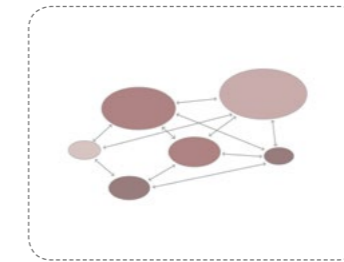
1. Systemic goals and vision

#### Adaptivity



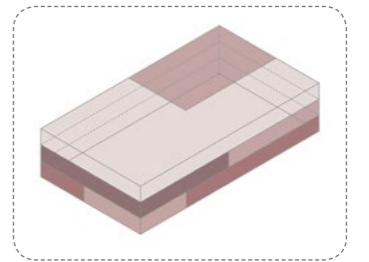
2. Flexible design framework

#### Connectedness

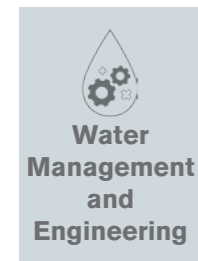


3. Connecting functions (Polycentricity)

#### Diversity



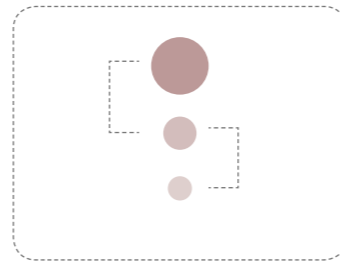
4. Mix-use development



**Water Management and Engineering**

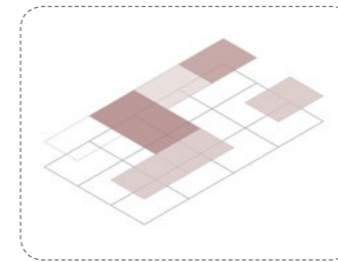
Water management and engineering deals with the designed water infrastructure of the cities, the supply and discharge of water. Since the project talks about achieving Socio-ecological resilience in the Ganges river basin, it is essential to understand the functioning of water infrastructure within the basin. Moreover, these infrastructures play a crucial role in mitigating disasters directly or indirectly related to the water.

#### Robustness



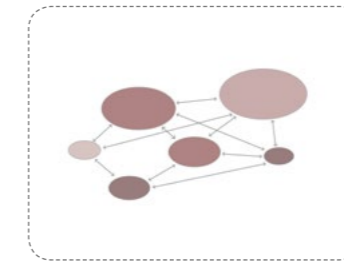
1. Systemic goals and vision

#### Adaptivity



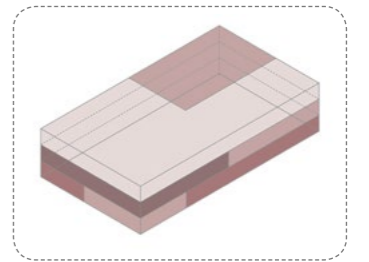
2. Flexible design framework

#### Connectedness

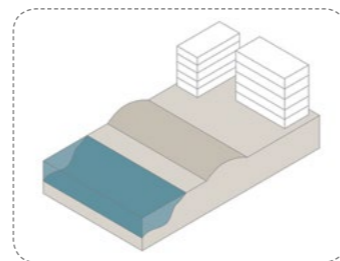


3. Connecting functions (Polycentricity)

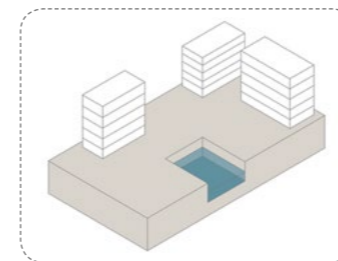
#### Diversity



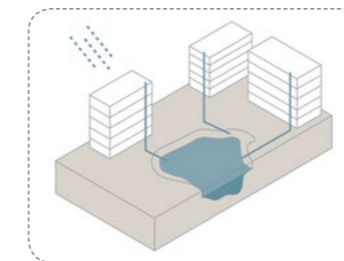
4. Mix-use development



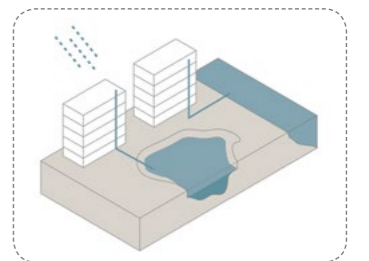
1. 100 year disaster protection



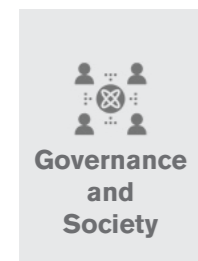
2. Flexible capacity system



3. Integrated water management



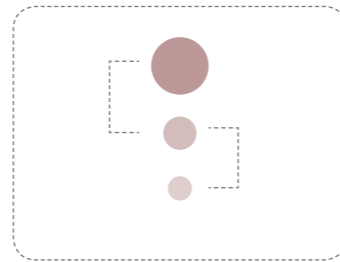
4. Multiple water source and storage



**Governance and Society**

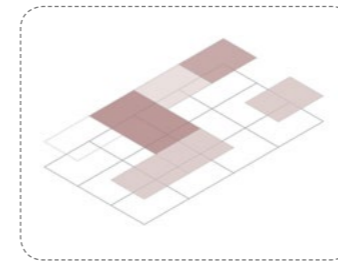
The resilience of governance functions and societal networks is extremely necessary to intervene in the above 3 aspects of urban planning, landscape architecture and water management. The planning framework, policies, approach and processes govern the implementation of these principles and their spatial translations. Hence it is extremely important to create a framework that can facilitate the change to achieve resilience.

#### Robustness



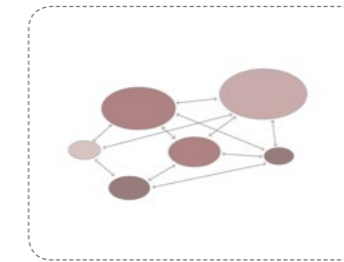
1. Systemic goals and vision

#### Adaptivity



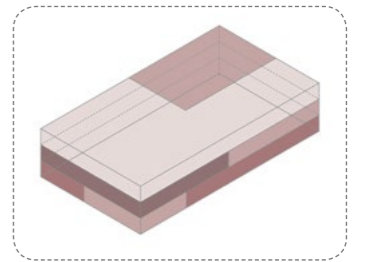
2. Flexible design framework

#### Connectedness

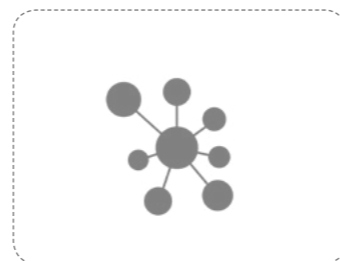


3. Connecting functions (Polycentricity)

#### Diversity



4. Mix-use development



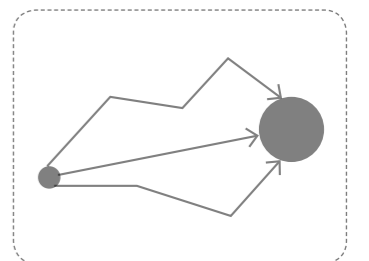
1. Stronger bonds between community and government



2. Flexible policies



3. Awareness and participation



4. Multiple approach route

Fig. 53. Spatiality of principles of resilience in the basin

## 6.4. ADAPTIVE SPATIAL PLANNING

### WHAT?

To achieve resilience to the crisis caused due to changing climate and continuous urban growth it is now important to re-look at the current planning framework and move towards an adaptive planning framework that offers the

possibility to change and adapt to the changing times. This new adaptive spatial planning is derived from understanding the four important aspects of it, explained below.

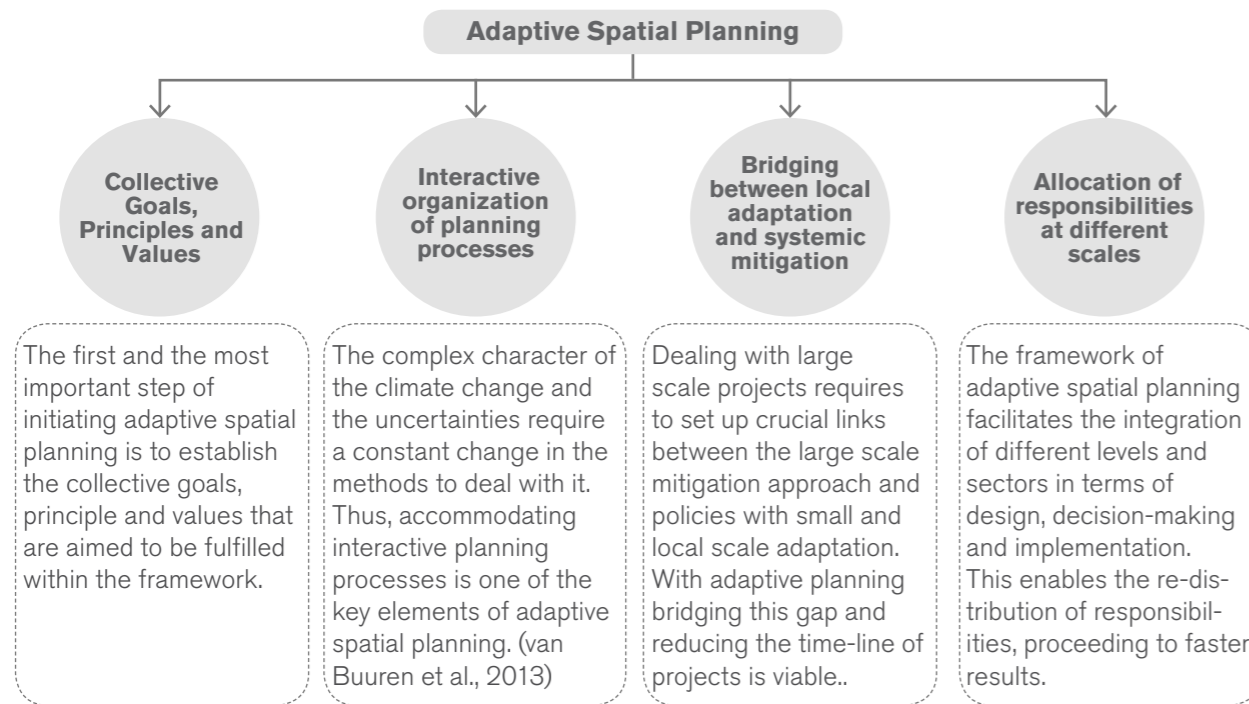
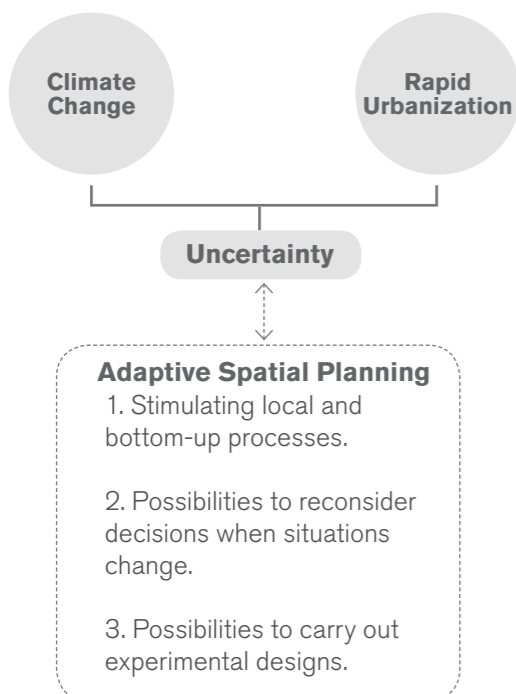


Fig. 55. Components of adaptive spatial planning

### WHY?



Climate change causes macro-scale effects like increasing temperature and rising sea levels. Moreover at a local scale, it creates disturbances like flooding, drought and storms. These disturbances result in uncertainties and hence require a possibility to reconsider the decision-making process (van Buuren et al., 2013). It is extremely important to stimulate processes that can cater to both scales, and can mitigate the national policies and local approaches. Within the adaptive spatial planning framework there lies a possibility to reconsider decisions when situations change.

Secondly with the constant growth of population and rapid urbanization has led to high pressure on the environment. This is further accelerating climate change. Thus with an adaptive spatial planning framework, which focuses on learning by doing, flexibility and resilience could be achieved.

Fig. 54. Reasons for employing adaptive spatial planning

## 6.5. FRAME OF REFERENCE

The Frame of Reference (van Koningsveld, 2003) is used to analyse and understand the interactions between the vision and its application.

The method is used within the adaptive spatial planning framework to establish a relationship between different stakeholders with a different state of knowledge, working on several scales for the same overall problem.

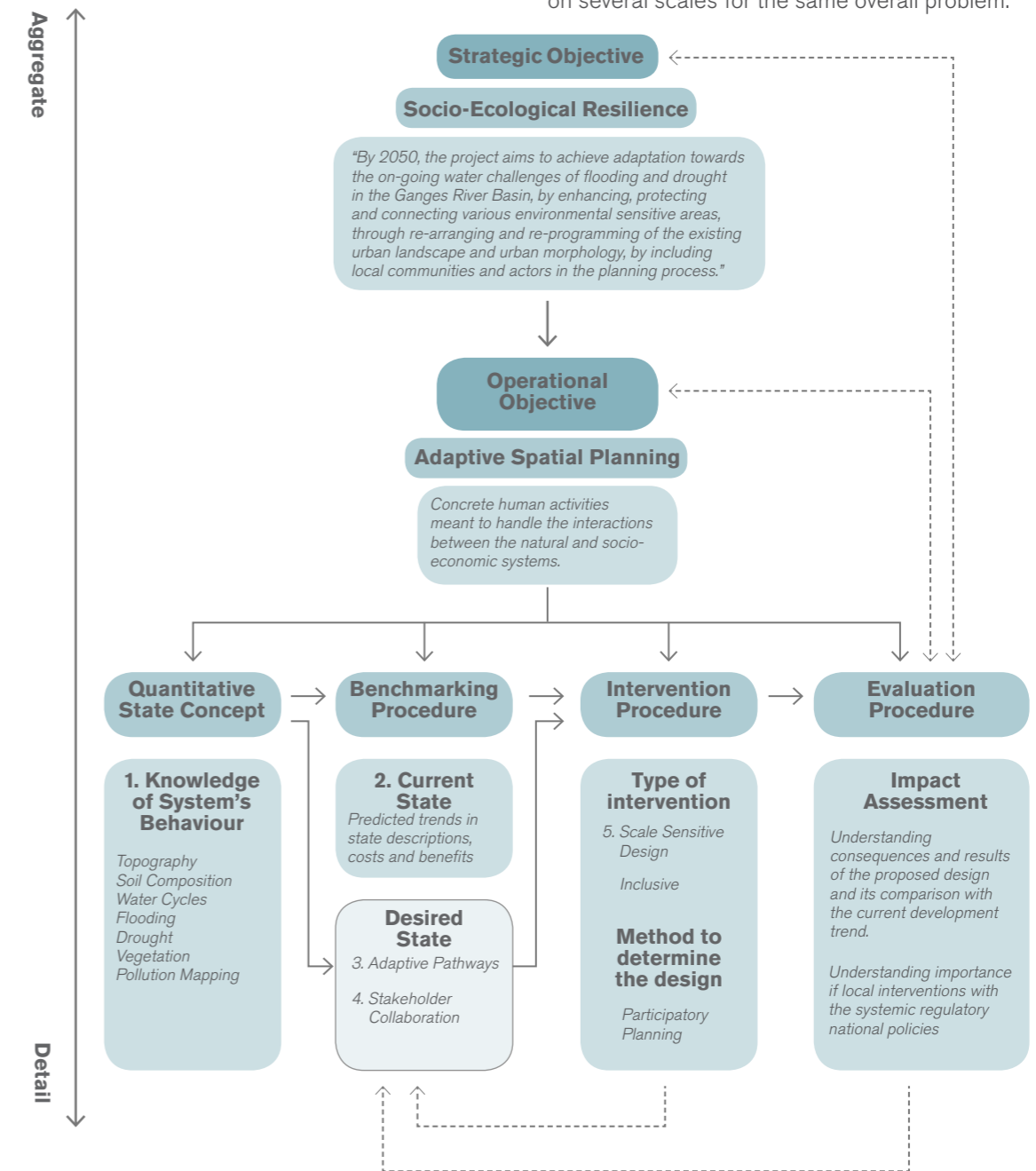


Fig. 56. Frame of Reference for design development  
Source: Van Koningsveld, 2003, modified by author



### 6.5.1. Knowledge of System's Behaviour

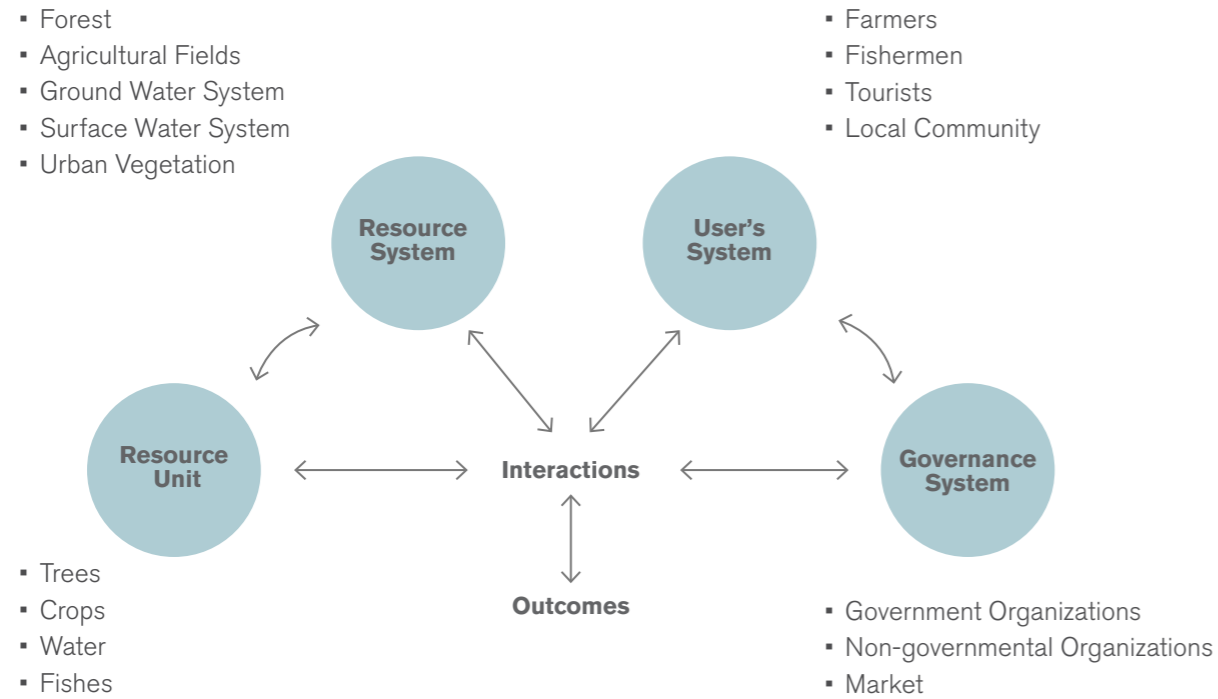


Fig. 57. SES System diagram for The Ganges River Basin  
Source: Ostrom, 2009, adapted by author

Socio-ecological systems are complex systems, dealing with the ecology and social actors and institutions governing or utilizing it. To achieve resilience in the Ganges River Basin it is necessary to learn about how the system functions and what are the variables or parameters with the system that helps in achieving resilience. Therefore to understand this complex system, Ostrom (2009) in his research further divides this system into 4 important sub-systems.

1. Resource System: These are different systems that are used to obtain benefits/gains by the user.
2. Resource units: These are the individual units or commodities that are traded/utilized within the system.
3. User System: The system fundamentally consists of the user groups that are involved with the resource system directly.
4. Governance system: The various organizations and rules that govern the actions carried out within the resource system form the governance system.

Establishing, and understanding of these sub-systems help in further evaluating relationships between different variables on which the functioning of the sub-system, and hence the system works.

### SES for the Ganges River Basin

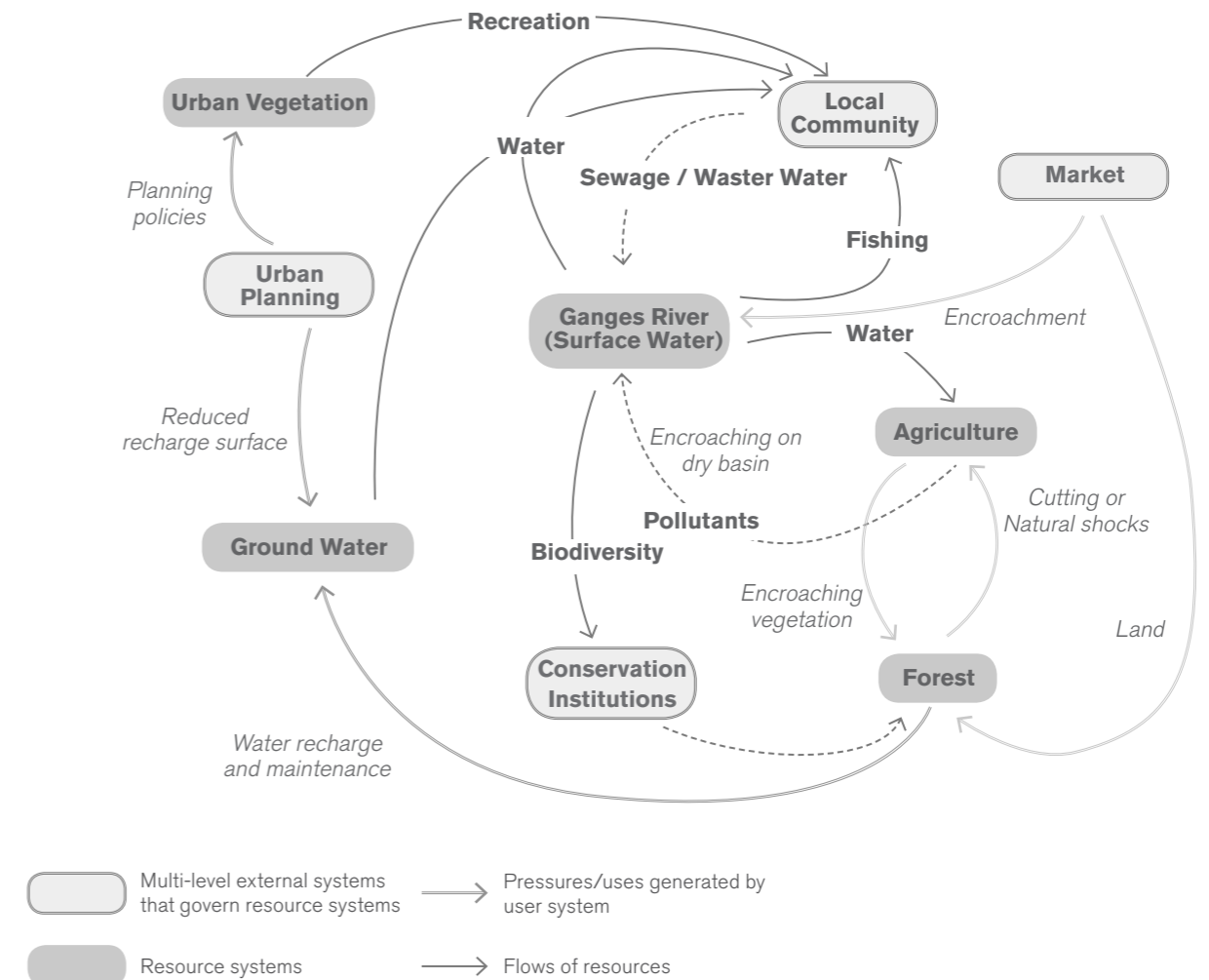

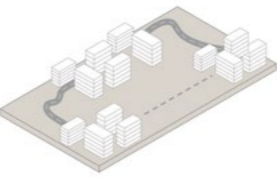


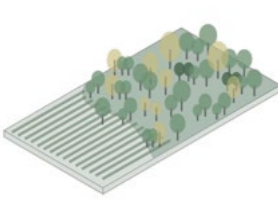

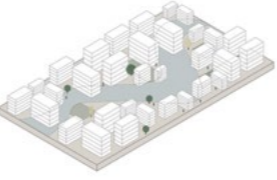

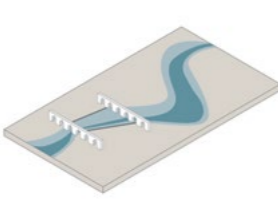
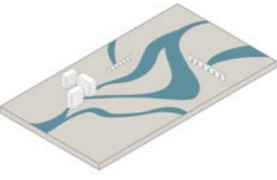







Fig. 58. Conceptual Expansion of current SES for The Ganges River Basin  
Source: Scale-Sensitive Governance of the Environment, adapted by author

The above figure is a conceptual representation of sub-systems ( Resource system, resource unit, user system and governance systems) currently prevailing in the Ganges River Basin. The representation showcases the aspects that are focused within the scope of the thesis. The diagram helps to determine relationships between different activities and its consequences, the external agents impacting the system, and how interventions at individual units within this system at smaller scales can change existing relationships to achieve resilience of the system.

**Challenges towards Socio-Ecological Resilience in the river basin**

 <p><b>Urban Planning</b></p>			
	<p>1. Rural areas and 2nd tier cities lack diversity in function and depend on urban centres</p>	<p>2. Lack of robust infrastructure networks</p>	<p>3. High population and dense urban fabric, leading to high pressure on land</p>
 <p><b>Landscape</b></p>			
	<p>1. Invasion of landscapes by cash crops and exotic species</p>	<p>2. Lack of priority and funding for ecology centric landscape development projects.</p>	<p>3. Insufficient land for ecological nature based interventions.</p>
 <p><b>Water Management and Engineering</b></p>			
	<p>1. Extreme engineering and privatization of water resources</p>	<p>2. Fragmented water system.</p>	<p>3. Multiple governance systems due to trans-state river basin.</p>
 <p><b>Governance and Society</b></p>	<p><b>Waste Generation</b></p>  <p><b>Pollution</b></p>		
	<p>1. Cultural practices and habits</p>	<p>2. Low public engagement capacity</p>	<p>3. Lack of education and awareness</p>

**Opportunities towards Socio-Ecological Resilience in the river basin**


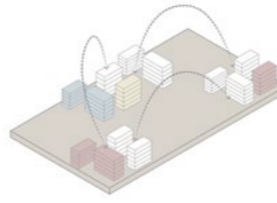



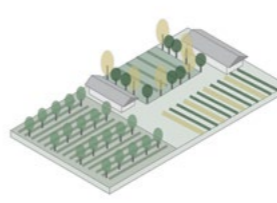
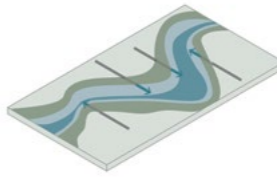


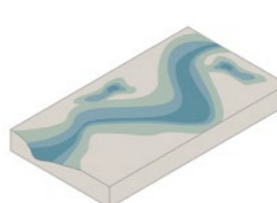
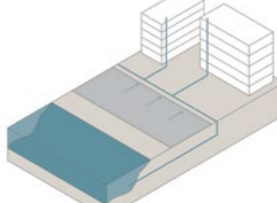
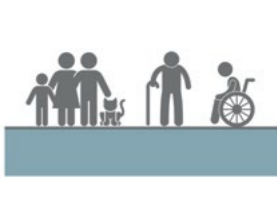

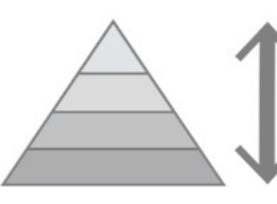
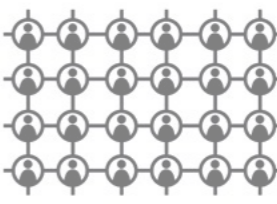

 <p><b>Urban Planning</b></p>			
	<p>1. Connecting 2nd tier cities and rural areas to reduce pressure on urban centres</p>	<p>2. Re-orienting cities towards river to establish relation</p>	<p>3. Diverse and ecologically integrated urban fabric.</p>
 <p><b>Landscape</b></p>			
	<p>1. Potential for development of agro-forestry for ecological and economic gains</p>	<p>2. Plantations to reduce ground and river pollution</p>	<p>3. Exploit potentials of social use of landscape</p>
 <p><b>Water Management and Engineering</b></p>			
	<p>1. Nature based, soft solutions to tackle flooding challenges</p>	<p>2. Integration of water management with new infrastructure.</p>	<p>3. Equal distribution and access to water resources</p>
 <p><b>Governance and Society</b></p>			
	<p>1. Bottom up planning to include local expertise</p>	<p>2. Existing social bonds and strong sense of community</p>	<p>3. Multi-sectoral and multi-level stakeholder collaboration and distribution of responsibilities.</p>

Fig. 59. Challenges and Opportunities towards socio-ecological resilience in the basin



### 6.5.2. Dynamic Adaptive Pathways

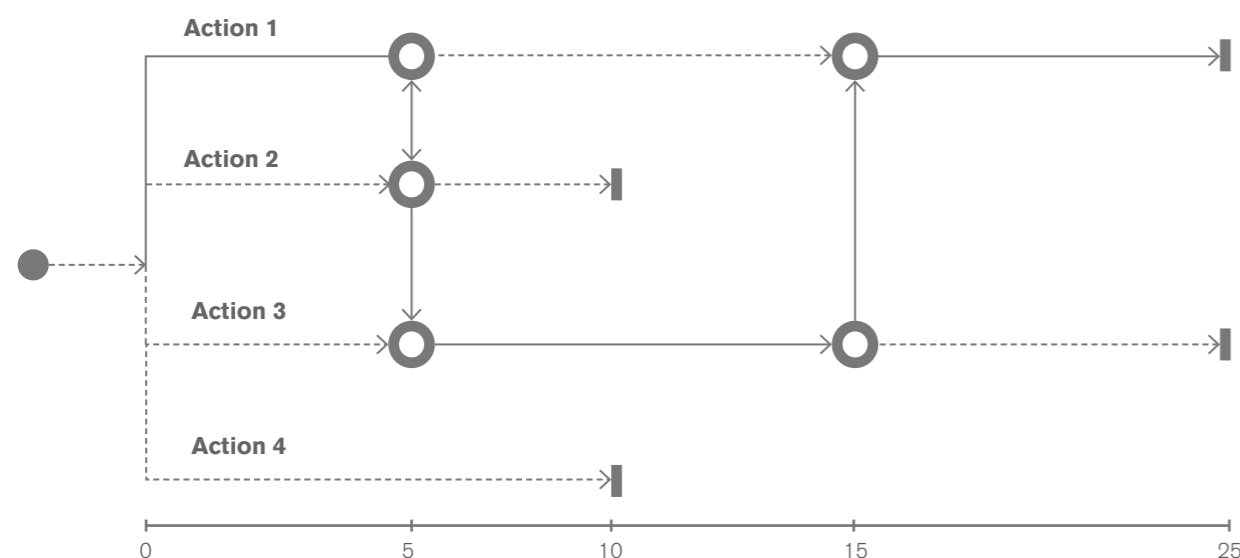


Fig. 60. Conceptual representation of adaptive planning pathways  
Source: Dynamic Adaptive Policy Pathways, Deltares 2020 adapted by author

Interventions in ecological layers especially project related to water management have long term visions and consequences. Often these projects need to be planned in advance or in a near time. Making decisions now for future uncertainties is quite challenging and also requires flexibility.

Thus, the dynamic adaptive pathways provide an opportunity to explore possibilities by sequencing a set of possible actions considering different external developments over time (Haasnoot, Kwakkel, Walker & ter Maat, 2013). The adaptive plan accommodates both the actions required to be taken now to prepare for the immediate future as well as the actions needed to keep future options open.

Within the adaptive pathways, there lies a need to derive a strategic vision for the future and then commit to short-term actions that can set up a framework for possible future actions. Within the framework, there are several tipping points, the points where the current actions may no longer be valid and hence additional actions are required. These are the points where there lies a possibility for new pathways to emerge with a shift in stakeholder and their actions.

Since the Ganges River Basin is extremely dynamic, with constantly evolving social and economic changes, along with impacts from climate change, there lies a need to derive a dynamic adaptive planning pathway.

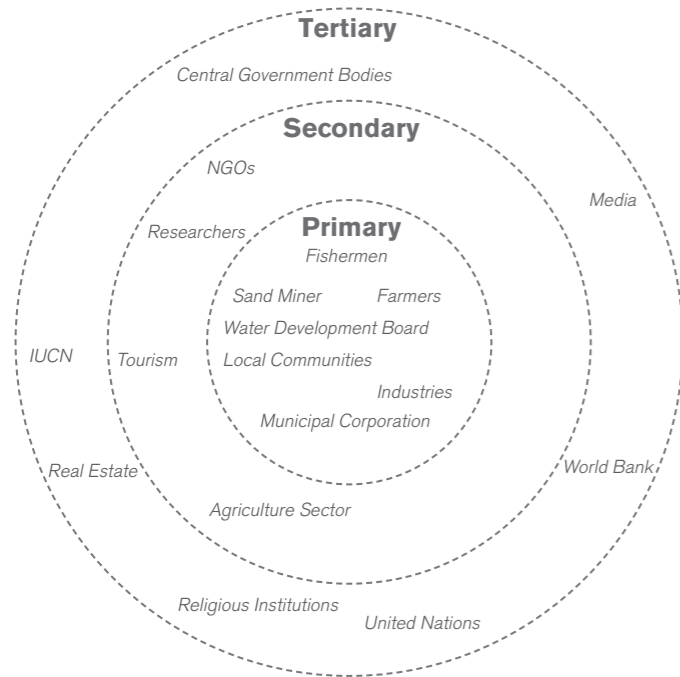
### 6.5.3. Stakeholder Collaboration

Level	Stakeholders	Interest
Global	<ul style="list-style-type: none"> <li>World Bank</li> <li>International Union for Conservation of Nature</li> <li>UN</li> <li>Bangladesh Government</li> </ul>	<ul style="list-style-type: none"> <li>Environmental sustainability</li> <li>Conservation of biodiversity</li> <li>UN sustainability goals</li> <li>Water sharing</li> </ul>
National	<ul style="list-style-type: none"> <li>Central Government</li> <li>Jal Shakti Board (National Water Department)</li> <li>National Mission for Clean Ganga</li> <li>National Ganga Council</li> <li>NGOs</li> <li>Researchers</li> <li>Ministry of Power</li> </ul>	<ul style="list-style-type: none"> <li>Tourism, Industrial development</li> <li>Monitoring of state policies</li> <li>Policy formulation for clean Ganga</li> <li>Policies for river development</li> <li>Awareness and advocacy</li> <li>Study and analysis</li> <li>Hydro-power generation</li> </ul>
Regional / State	<ul style="list-style-type: none"> <li>State Government (Water Resources)</li> <li>State Government (Urban Development)</li> <li>State Government (Agriculture)</li> <li>State Government (Animal and Fishery)</li> <li>State Government (Disaster Management)</li> <li>State Government (Environment &amp; Forest)</li> <li>State Pollution Control Board</li> <li>Agriculture Sector</li> <li>Real Estate</li> <li>Media</li> </ul>	<ul style="list-style-type: none"> <li>Water use and distribution</li> <li>Development plans for cities</li> <li>Policies for agricultural practices</li> <li>Policy and monitoring</li> <li>Relief and Management</li> <li>Protection and policies for forests</li> <li>Monitoring and regulating pollution</li> <li>Water use and production</li> <li>Construction in floodplains and cities</li> <li>Information and awareness</li> </ul>
Local	<ul style="list-style-type: none"> <li>Farmers</li> <li>Fishermen</li> <li>Religious Institutions</li> <li>Village (Gram Panchayat)</li> <li>Municipal Corporation</li> <li>Ward Offices</li> <li>Industries</li> <li>Sand Miners</li> <li>Tourism Industry</li> <li>Local Communities</li> <li>Students/Universities</li> <li>NGOs</li> </ul>	<ul style="list-style-type: none"> <li>Water use for farming and animals</li> <li>Fishing and aquaculture</li> <li>Water use for religious activities</li> <li>Water use and disposal</li> <li>Water use and disposal</li> <li>Execution and implementation</li> <li>Water use and waste disposal</li> <li>Sand mining from river bed</li> <li>Using river for recreational purpose</li> <li>Water use</li> <li>Research and awareness</li> <li>Awareness and mobilization</li> </ul>

Table: Stakeholders involved for socio-ecological resilience in Ganges River Basin  
Source: Sinha, Samir. (2014), updated by the author

The above table list important stakeholders and their possible interests with the Ganges river basin. Stakeholder analysis helps in determining who are potential benefiter, who amongst these are responsible for planning or on the other hand who are voiceless victims of the existing situations in the river basin. The stakeholders are classified based on the scale of their activities and the impacts, which enables them to understand the importance and impacts on governance and planning.

### Levels of stakeholders



Based on the assessment of how these stakeholders are either immediately affected or least affected, the stakeholders are classified as primary, secondary and tertiary stakeholders. The primary stakeholder is often the ones that are directly dependent on the resource system, while tertiary are the ones that govern these systems.

Moreover, further classification is carried out based on the power-interest of stakeholders. The analysis helps to identify the victims that need to be heard and empowered, and the influencers that need to be made more aware and responsible for their actions.

Fig. 61. Stakeholder assessment  
Source: Sinha, Samir. (2014), updated by the author

### Stakeholders: Power - Interest

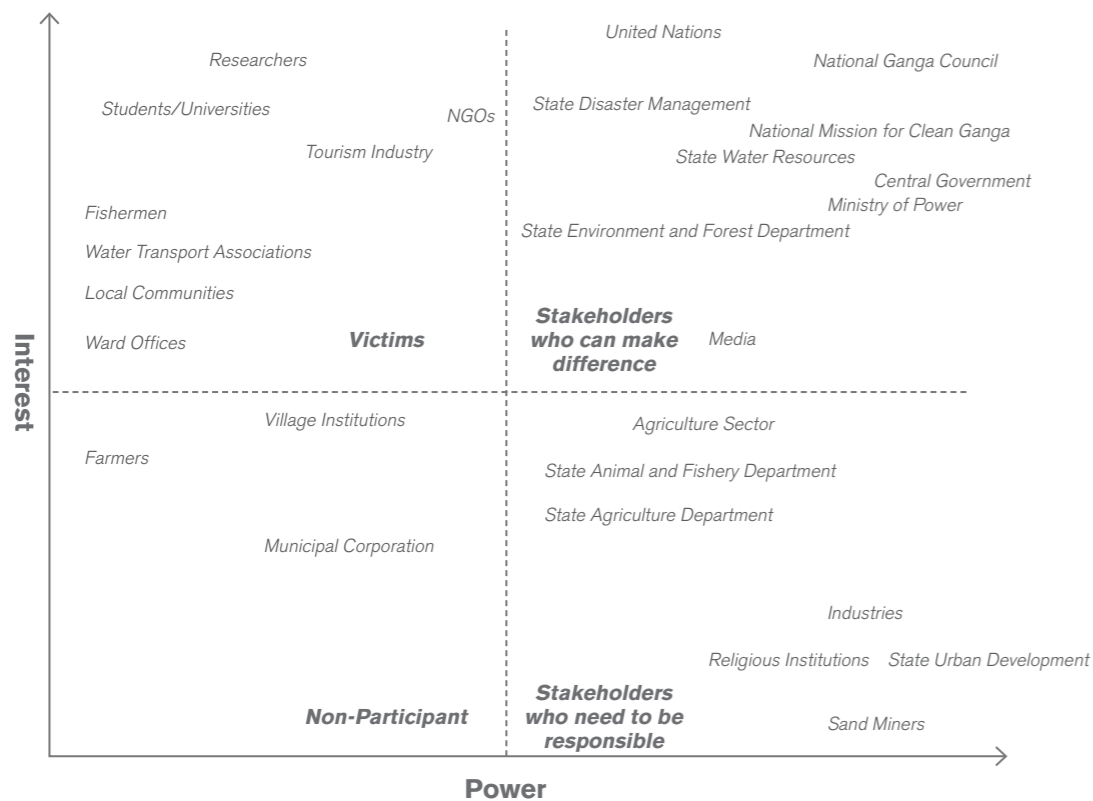


Fig. 62. Stakeholder analysis  
Source: Sinha, Samir. (2014), updated by the author

### 6.5.4. Scales of Socio-ecological Systems

#### System Scales

Below are systemic illustrations of scales and levels of the physical systems involved within the scope of this project in the Ganges River Basin.

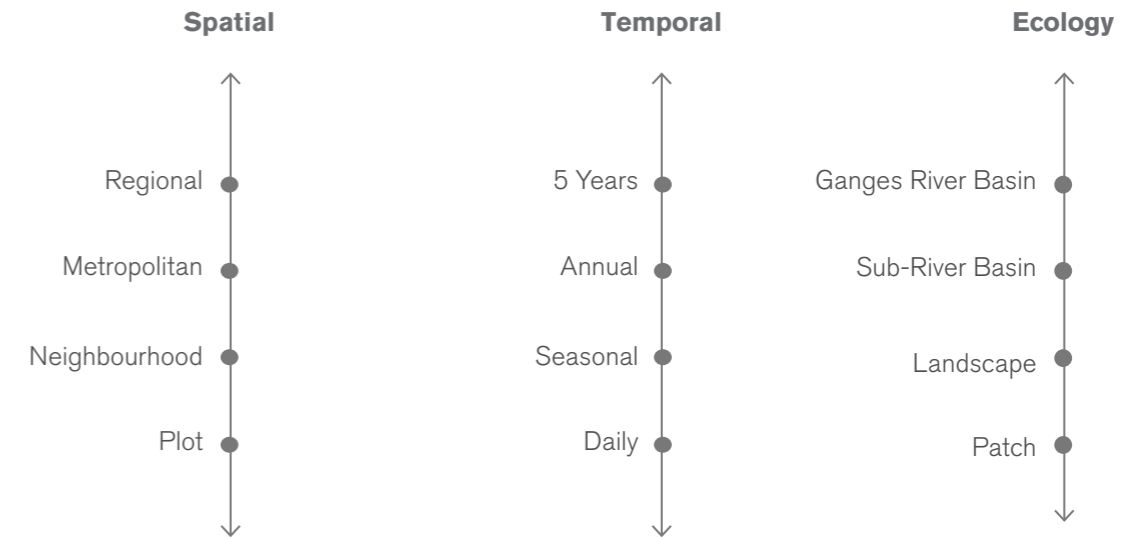


Fig. 63. Scales of System  
Source: Scale-Sensitive Governance of the Environment, modified by author

#### Administrative and Management Scales

The below illustrated scales represent the various levels of interventions required and carried out within the administrative and management aspect of the project for a holistic multi-scalar development.

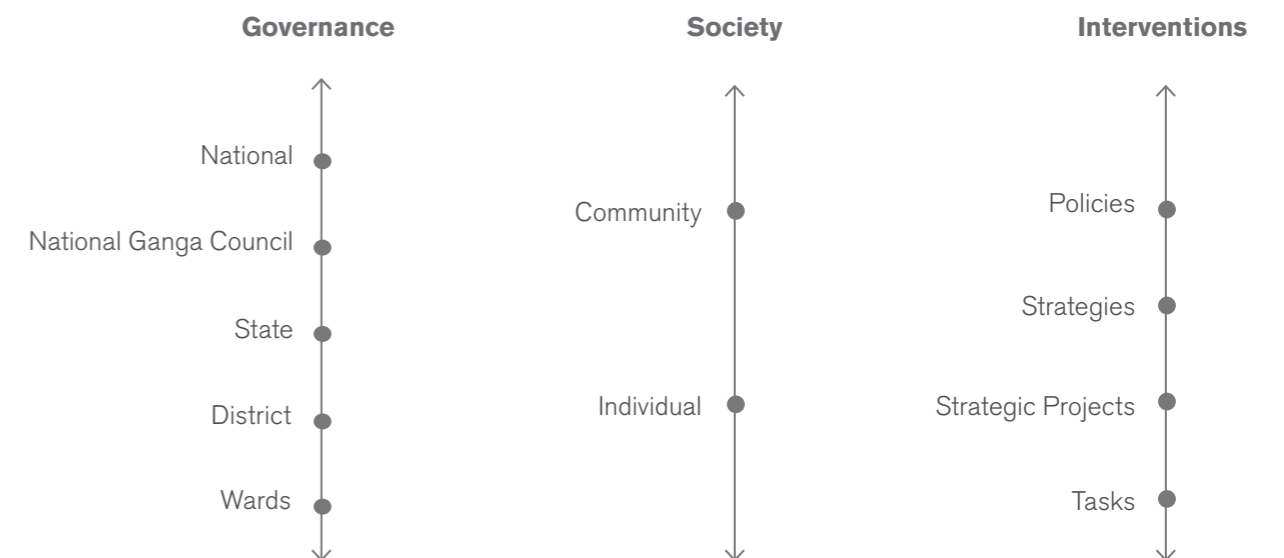
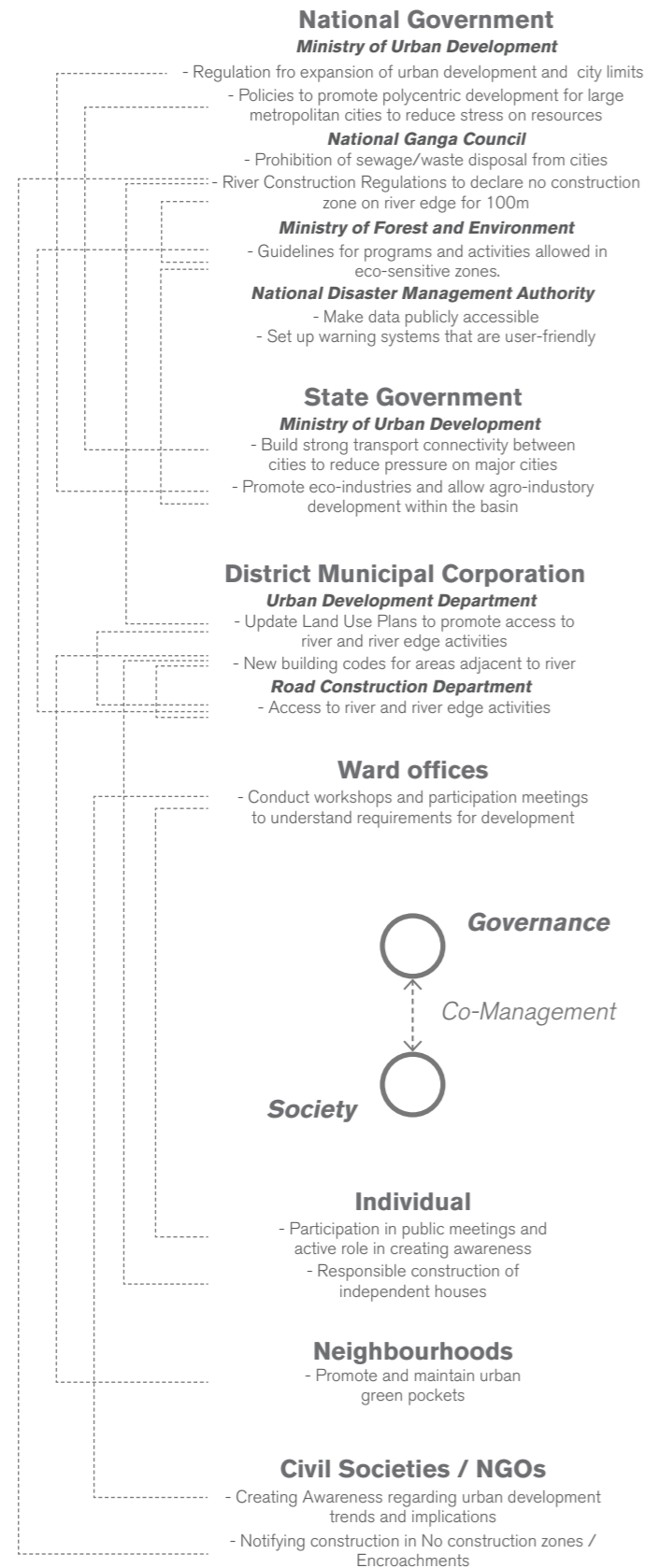


Fig. 64. Administrative and Management  
Source: Scale-Sensitive Governance of the Environment, modified by author

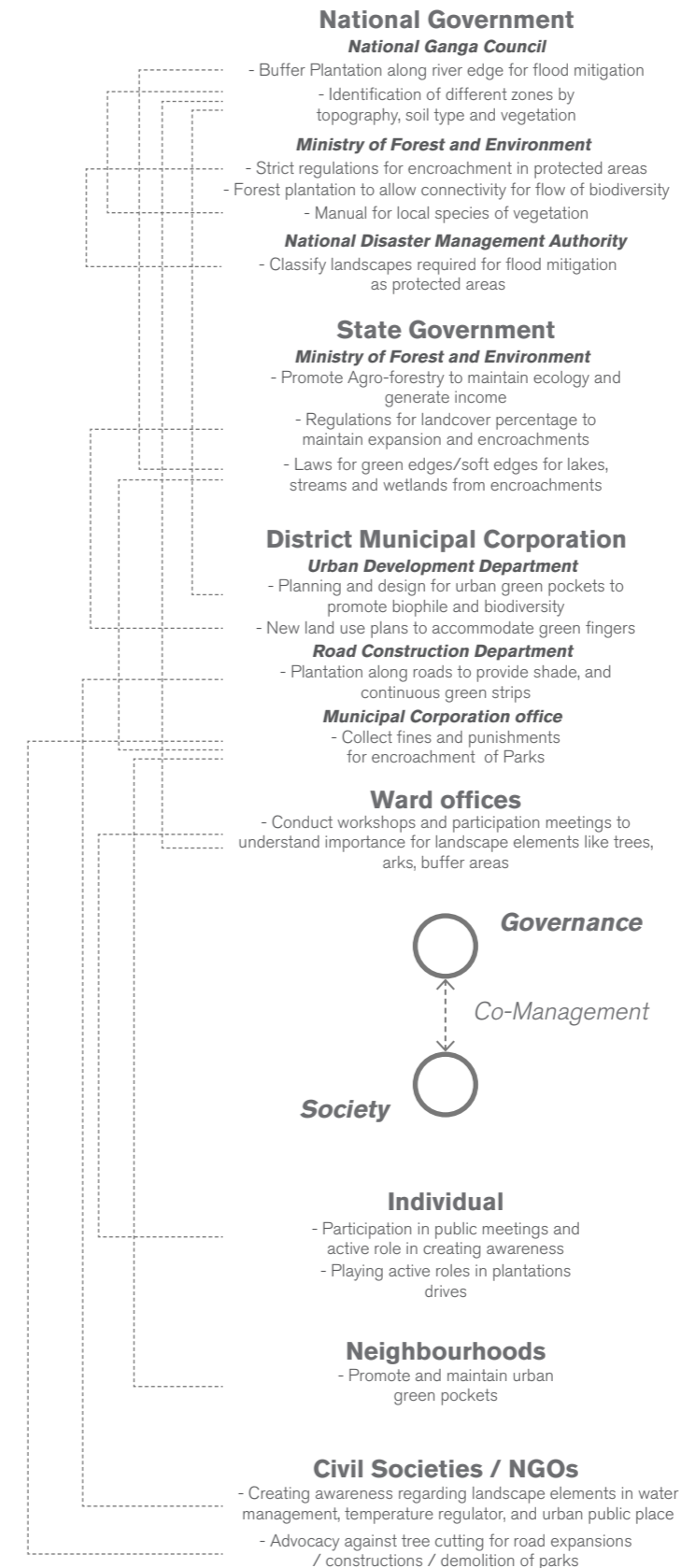


## 6.6. SYSTEMIC GOALS

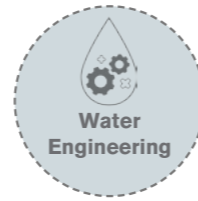
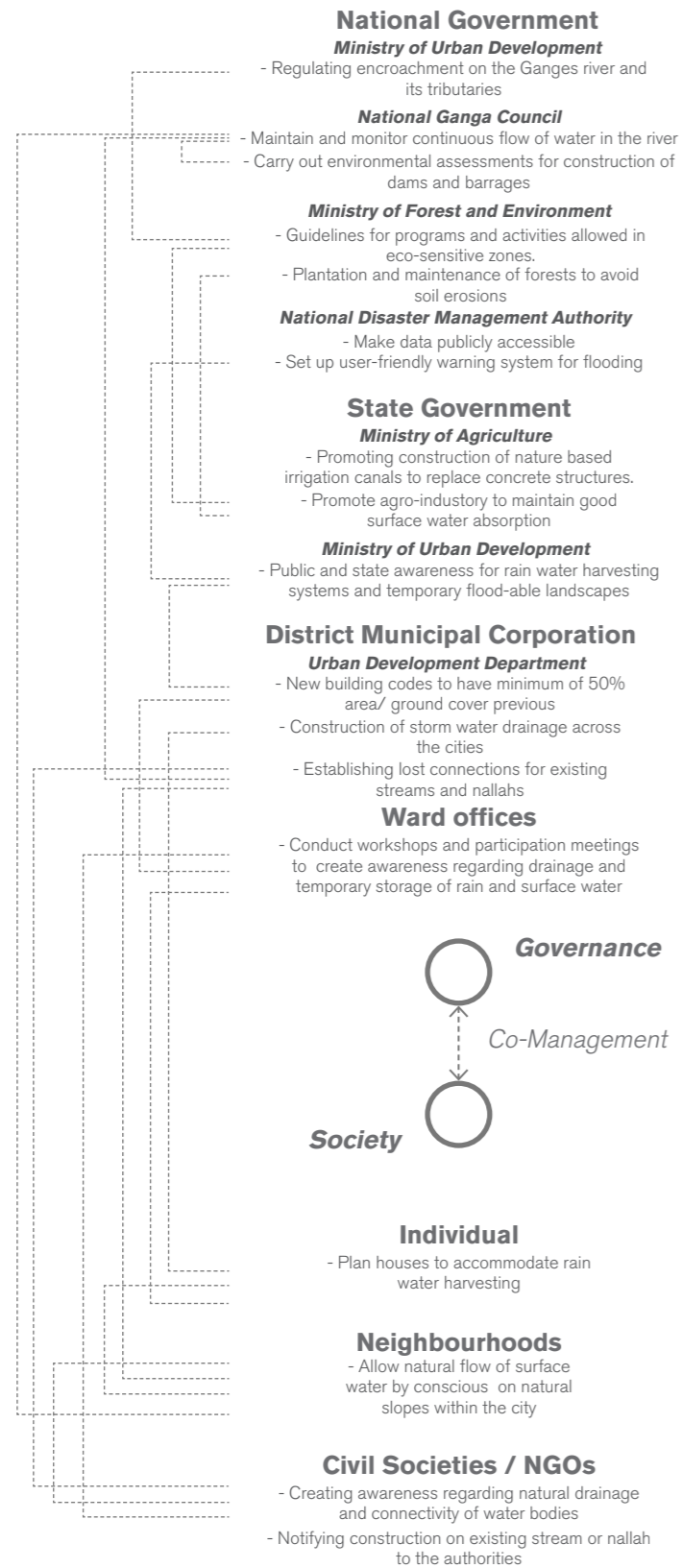
### 6.6.1. Urban Development in Ganges River Basin



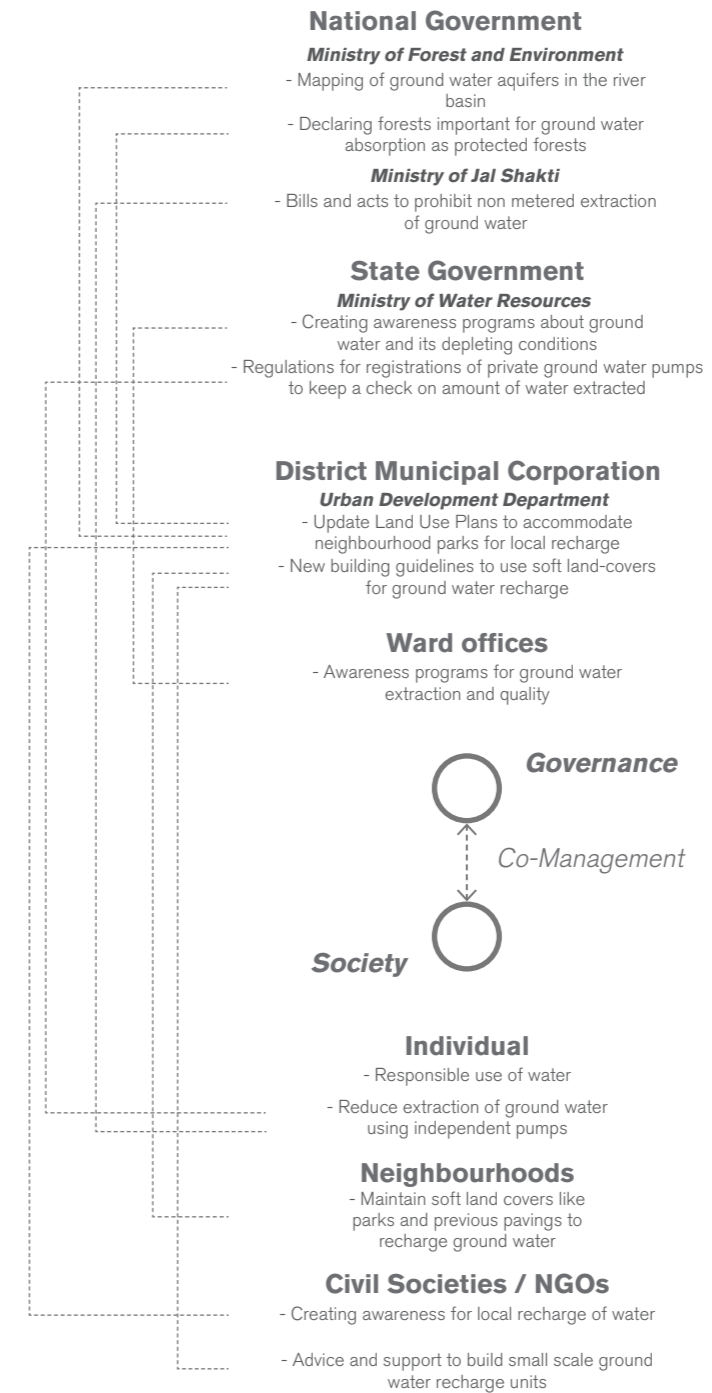
### 6.6.2. Landscape Architecture in Ganges River Basin



### 6.6.3. Surface Water in Ganges River Basin



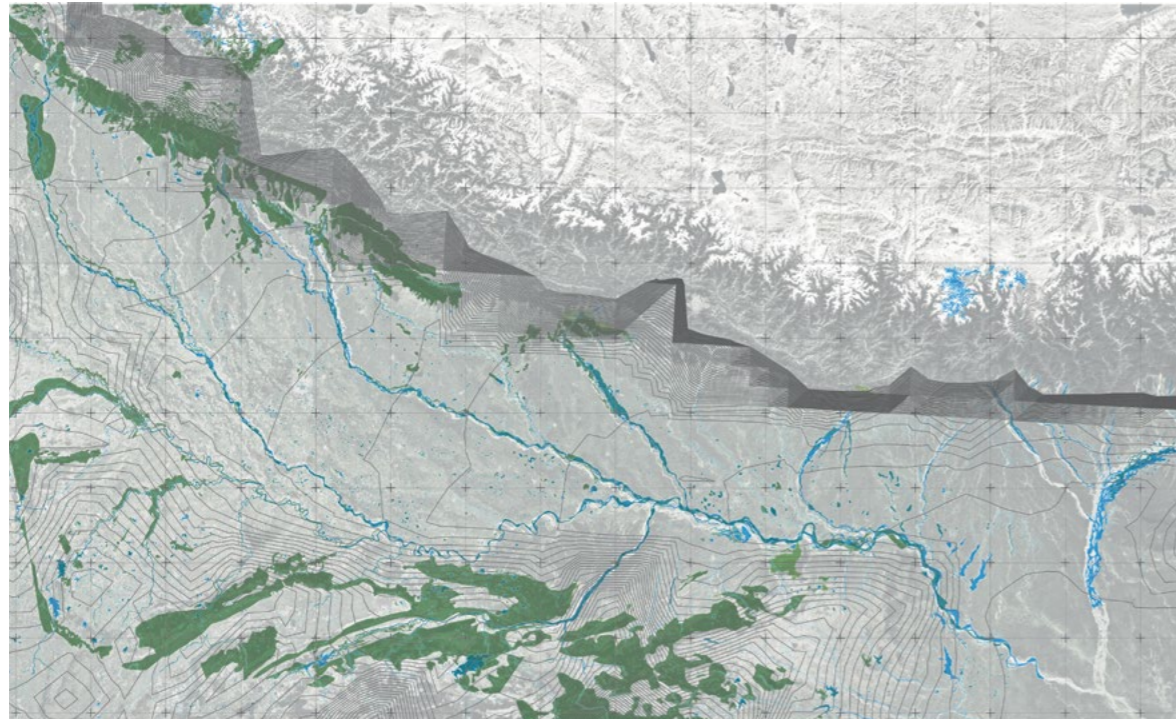
### 6.6.4. Ground Water in Ganges River Basin





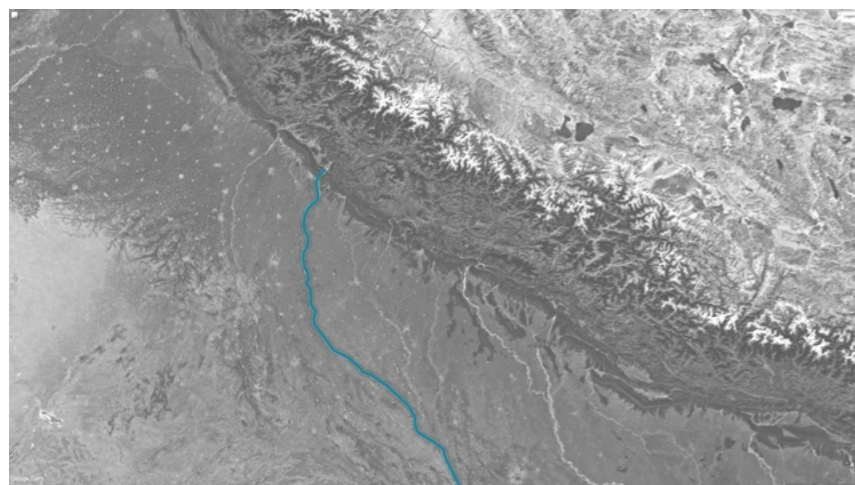
## 6.7. DESIGN FRAMEWORK

### Scale 1: Regional Strategies for Macro Scale:



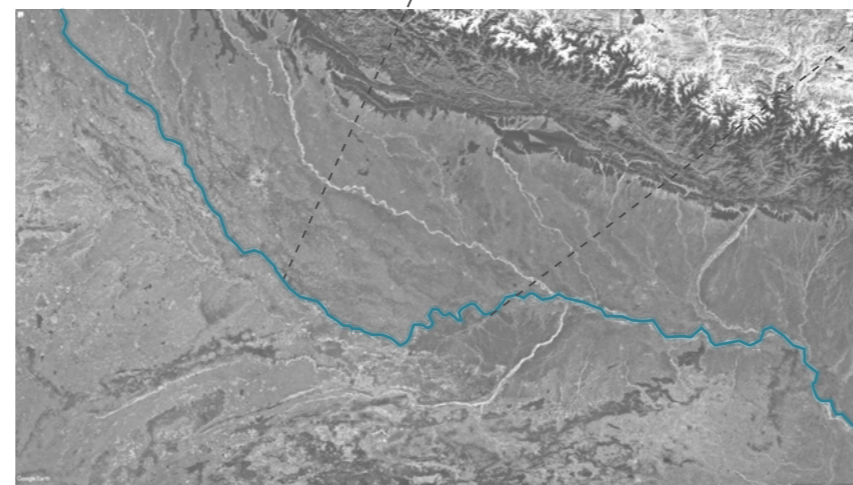
-   
**RS1:**  
Room for the River
-   
**RS2:**  
Landscape Interventions
-   
**RS3:**  
Comprehensive Connectivity
-   
**RS4:**  
Pollution Management

### A. Hilly Section



#### Sections of River

### B. Flat Plains



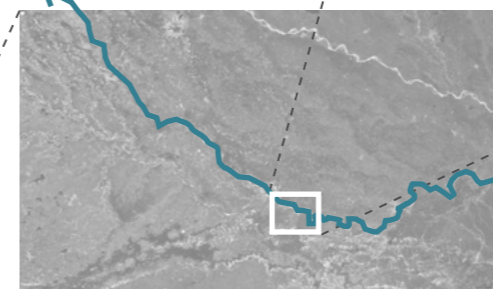
### C. River Delta



Designing and Testing at Different Scales

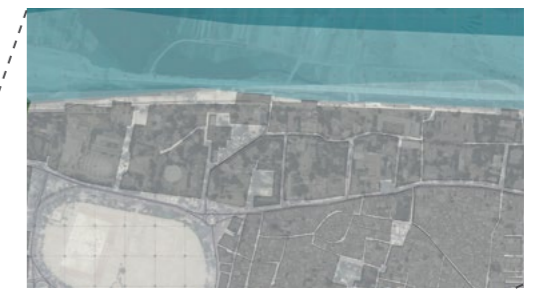
### Scale 2: Design Strategies at Metropolitan Scale

-   
**MS1:**  
Infrastructure Interventions
-   
**MS2:**  
Landscape Interventions
-   
**MS3:**  
Activating River-edge
-   
**MS4:**  
Industrial Development



#### River Segment

### Scale 3: Local adaptation of Strategies



1. Urban
2. Peri-Urban
3. Rural

Image (ac): Mapping river Ganges at different scales: Understanding relationships between River and Human Systems

Source: Google Earth Images





# 7 Regional Design and Strategies

This section introduces to set of Regional Strategies that are established to achieve socio-ecological resilience. The regional strategies set up a general framework that could be carried out at the basin level. These strategies are further elaborated with a set of possible actions that can be adopted. The set of possible actions within each strategy are alternative ways to implement the vision at various locations depending on the context and actors involved. To conclude an overall Strategic Plan for the Ganges River Basin is formulated.



Understanding Problem Field

Chapter 2

- Current Challenges in Ganges River Basin
- Drivers of Change
- Governance Challenges for Ganges River Basin

Introduction

Chapter 1

- Context
- Relationship between human systems and ecological systems

Chapter 3

- Socio-ecological vulnerability analysis across scales
- Problem Statement (Spatial Justice)
- Line of Inquiry:
  1. Dual Nature of Externalities
  2. Capital

Chapter 4

- Theories:
  1. Urbanization
  2. Vulnerability
  3. Resilience Thinking
  4. Social Capital and Governance
- Notions:
  1. Interdependence - Integration
  2. Infrastructure Ecology
  3. Evolutionary Resilience

Research Methodology

Chapter 5

- Conceptual Framework: Adaptive Spatial Planning Model

Vision

Chapter 6

- Principles
  1. Robustness
  2. Adaptivity
  3. Connectedness
  4. Diversity
- Frame of Reference
  1. Knowledge of System Behaviour
  2. Dynamic Adaptive Planning Pathways
  3. Stakeholder Collaboration
- Systemic Goals

Design

Chapter 7

Regional Strategies

Mitigation Strategies that are derived for challenges across the basin

RS1: Room for the River    RS2: Landscape Interventions    RS3: Comprehensive Connectivity    RS4: Pollution Management

Evaluation

Chapter 10

Scenarios

- Case 1
- Case 2
- Case 3

Chapter 8

Metropolitan Scale Strategies

Mitigation Strategies that are derived for challenges for metropolitan scale

MS1: Infrastructure Interventions    MS2: Landscape Interventions    MS3: Activating River-edge    MS4: Industrial Development

Chapter 9

Local Adaptation

Adaptation of multiple strategies to achieve resilience

1. Urban
2. Peri-Urban
3. Rural

Adaptive Planning Pathways

## 7.1. CHALLENGES AT REGIONAL SCALE

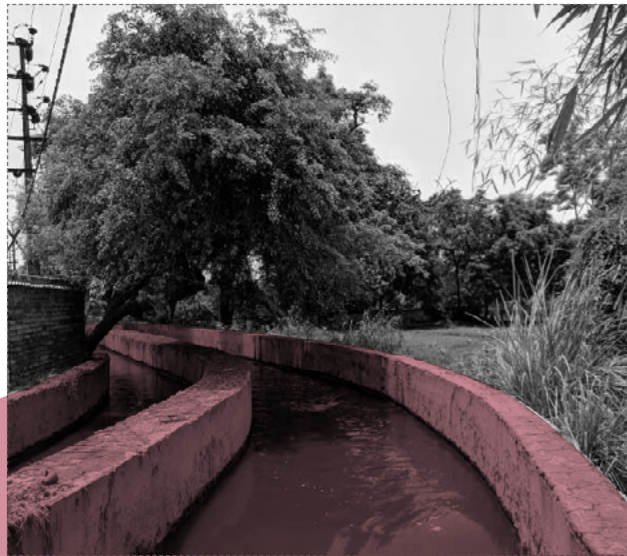


Image (ae): Concrete irrigation canal  
Source: gaonconnection, edited by author

### 1. Highly engineered river basin

The Ganges river basin is one of the most engineered river basins in the world (Anthony Acciavatti, 2015). Structures like dams and Upper Ganga Canal play a curial role in the economic development of the region. But on the other hand, their structures make the river system fragmented and confined between fixed concrete edges. While some structures are unavoidable and necessary to provide services, small irrigation canals and groundwater pumps within the basin can be altered to nature-based options. This shift would also help in reviving the nature and the local ecology.



Image (af): Floods in Bihar  
Source: ANI Commuters, DNA India, edited by author

### 2. Water Crisis and Flooding

Flooding of rivers during monsoon has been a constant challenge within the basin. With an uncertain pattern of rainfall and urbanization, the groundwater absorption has reduced. The reduced groundwater table is now causing a water crisis since most of the population within the basin depends on groundwater due to unsafe surface water. Understanding the water cycle as just not the surface water but part of the bigger, evaporation - condensation - rainfall-groundwater is extremely important to propose interventions for water crisis and flooding.

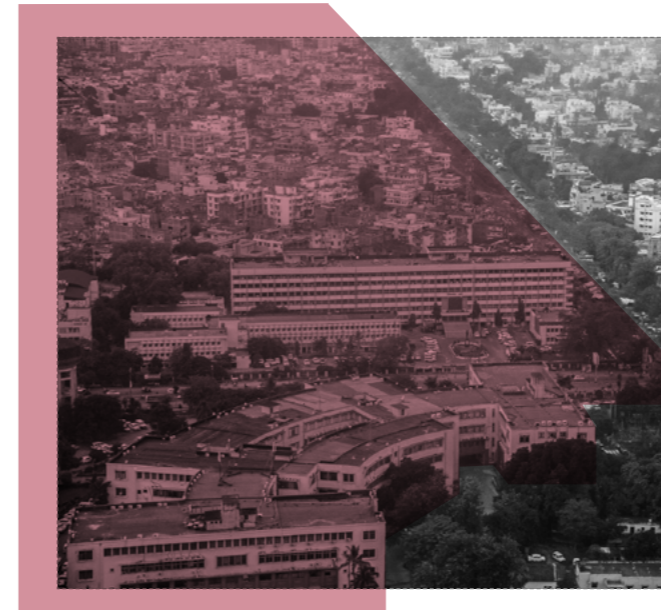


Image (ag): Dense Urban Centers  
Source: Saurav Anuraj, Patnabeats, edited by author

### 3. Pressurized Urban Centers

As derived from the initial analysis, there is a stark difference in functional distribution between urban and rural areas within the basin. This has led to increased migration to urban centres. Urban centres along the river are facing challenges of housing and transportation. The constant urban sprawl to accommodate housing and employment challenges is causing high pressure on the environment, and the river system.



Image (ah): Water Pollution at Kanpur discharged in the river  
Source: Daniel Bachhuber, Alliance for Water Stewardship, edited by author

### 4. Water Pollution

Pollution management has remained a challenge for the Ganges river since 1985. Most cities dispose of untreated sewage directly into the river. Secondly, polluted water from the agricultural farms due to chemical-based insecticides and pesticides also flows into the river. Furthermore, the industries established on the river banks also dump untreated water into the river. The pollution levels in the river are distinctly high, making the water unfit for drinking and domestic purposes. Thus, management of pollution is one of the key strategies for socio-ecological resilience.



## 7.2. STRATEGIES FOR SOCIO-ECOLOGICAL RESILIENCE AT REGIONAL SCALE



### 1. Creating room for the river

The Ganges River is one of the most dynamic rivers, as it gains its water from the melting of snow as well as monsoon rains. Moreover, with constantly changing weather there is a high fluctuation in water levels. Thus it is important to create enough room for the river water to accommodate flooding predictions of 50-100 yr risk., 2020). The room for rivers can be created by making more land available for temporary flooding.



RS1

(Room for the River | Rijkswaterstaat, 2020)

Image (ai): Room for the River, Nijmegen  
Source: Johan Roerink Aeropicture, Landezine, edited by author



### 2. Performative landscape strategy for water cycle management

Vegetation covers, especially forests play an important role in regulating the flux of atmospheric moisture and rainfall pattern. Furthermore, vegetation also plays a crucial role in the recharge and retention of groundwater (Ellison et al., 2017). This modification and designing for ecosystem services of performative landscapes and help in achieving resilience from the on-going water challenges.



RS2

Image (aj): Agro-forestry, Haryana  
Source: Surindar Singh Hara, thefarmstory, edited by author



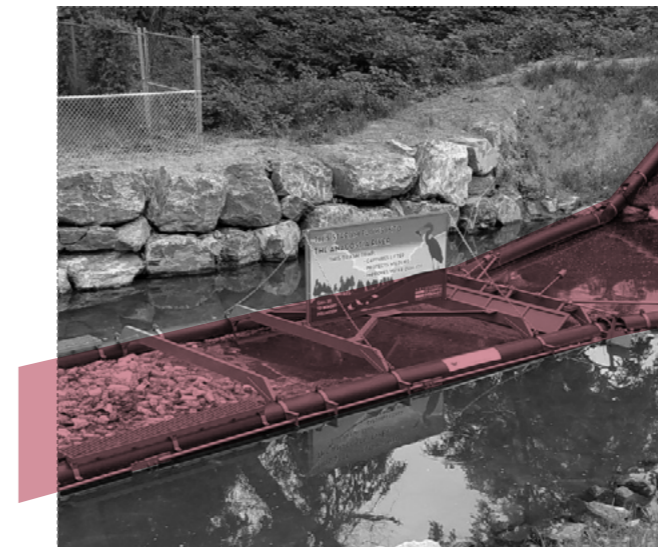
### 3. Comprehensive connectivity across the basin

To address the challenge of pressurised urban centres, the density and function need to be distributed to 2nd tier cities and rural areas. To distribute the functions and density, it is necessary to establish comprehensive connectivity, with different modes of transportation. With comprehensive connectivity across all modes of transport, a daily commute is encouraged and migration could be reduced. This connection would also be beneficial in the transportation of goods especially agricultural produce from rural-urban.



RS3

Image (ak): Comprehensive Connectivity  
Source: Author



### 4. Pollution Management

Different types of pollution enter the river from different points. Sewage and wastewater are termed as point source pollution because the source can be determined. Planning for sewage treatment plants and polishing ponds can help reduce the pollution levels before entering the river. Secondly, pollutants from agriculture field (run-off) also enter the river untreated. The source of this pollution cannot be determined and hence reed plantation should be carried out along the river and its tributaries.

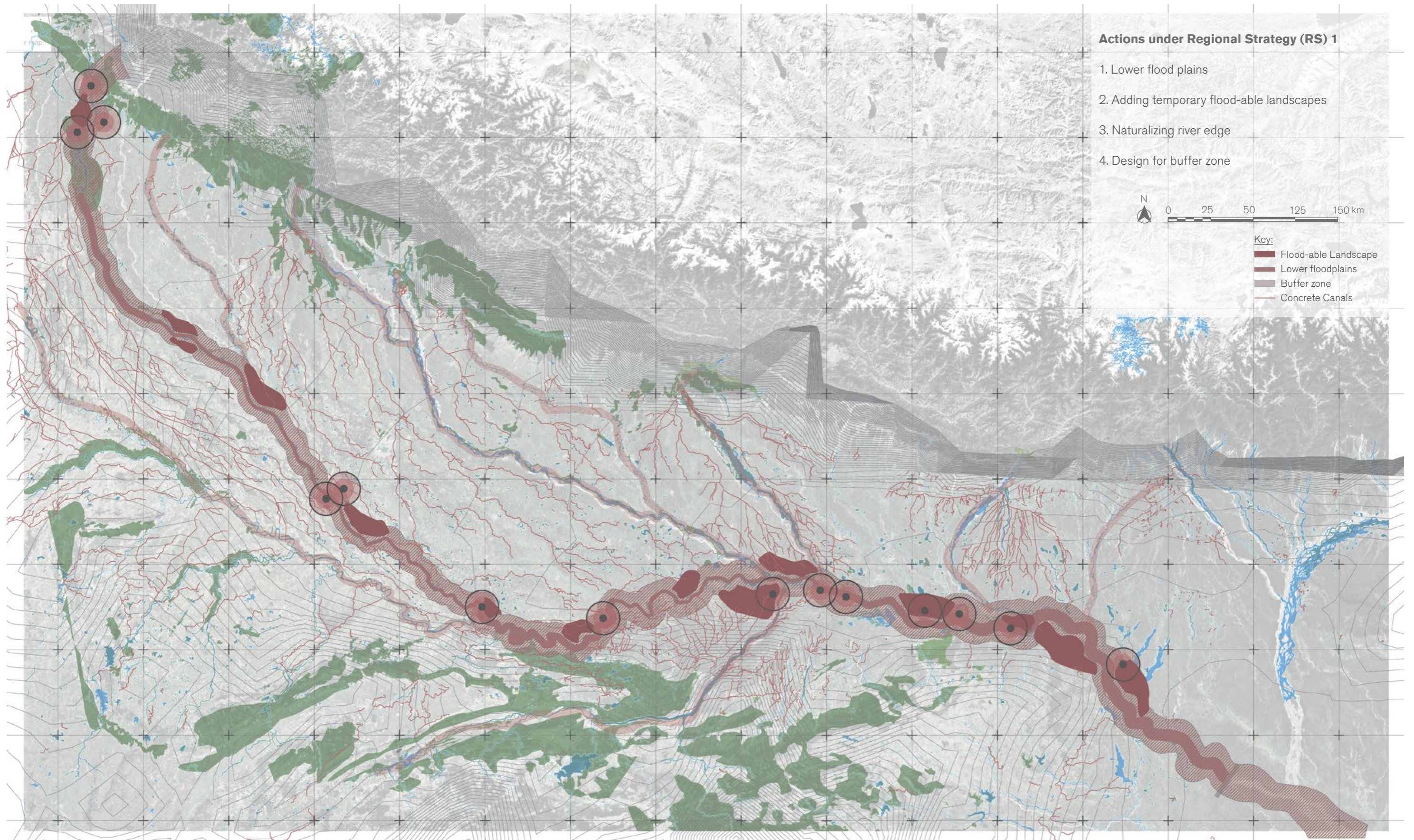


RS4

Image (al): Water Pollution Management  
Source: stormwatersystems, edited by author



7.2.1. Strategy 1: Creating room for the river





## Spatial Actions and Design Interventions

### 1. Lower flood plains

One of the most critical actions to create room for the river is to create more water holding capacity for the river. Lowering of the flood plains, creates more volume increasing capacity for predicted flooding situations. Additionally, the slit excavated from the river bed can be used to build embankments along the river for secondary protection.

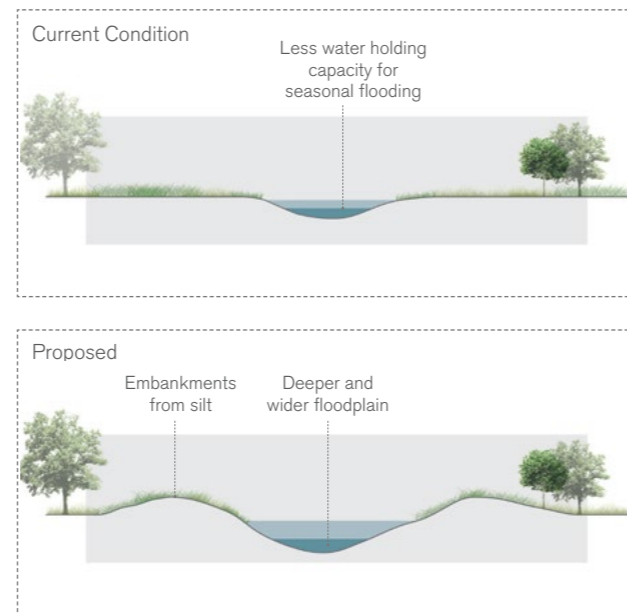


Fig. 65. Current - Proposed section for Action1 (Regional Strategy 1)

### What it means at Metropolitan Scale?

- Identifying the flow velocity of water to calculate adequate depth required based on sediment deposition throughout the year.
- Check and maintain the depth every 5 years so the capacity to accommodate excess rainfall and flooding is available.

### What it means at Local Scale?

- Involve fishermen and sand mining companies to facilitate the extraction process for extra depth in the floodplain and embankment construction.
- Setting up poles to check levels of sediments and depth of the river.

## Stakeholder Engagement

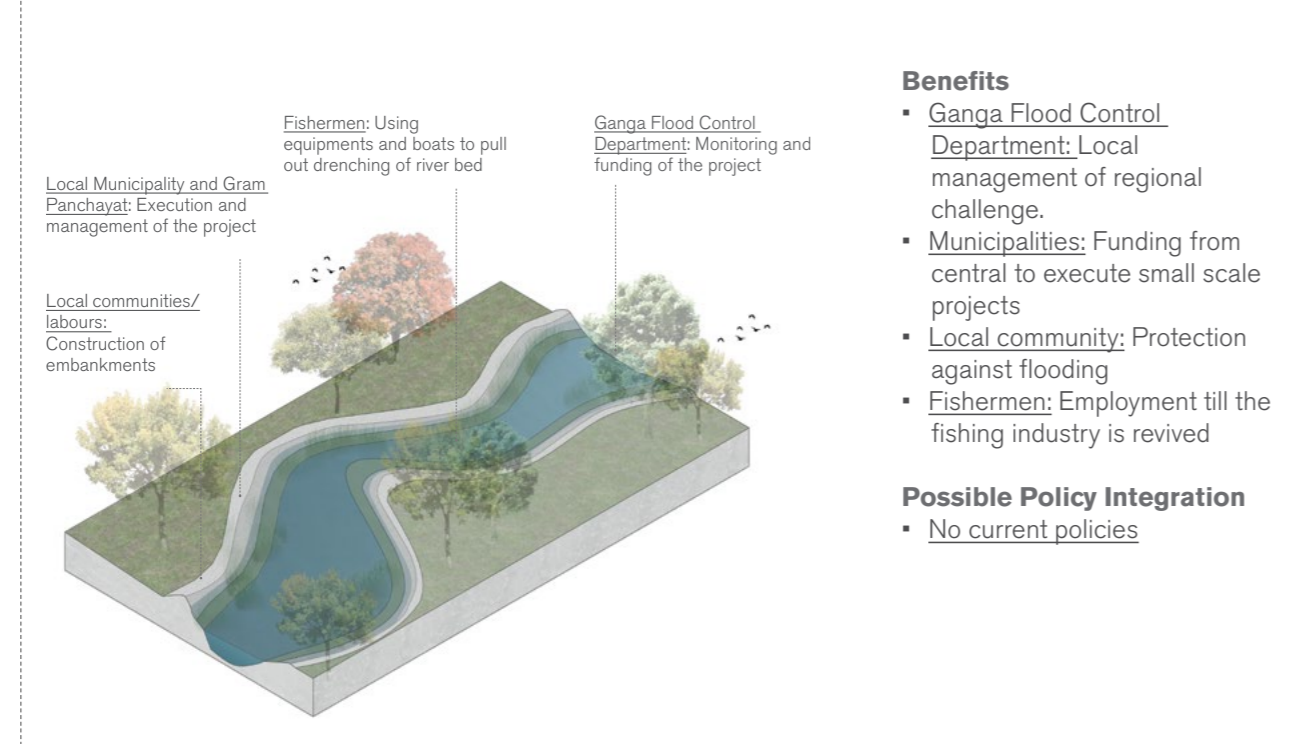


Fig. 66. Stakeholder Engagement for Action1 (Regional Strategy 1)

## Regional Plan for Action

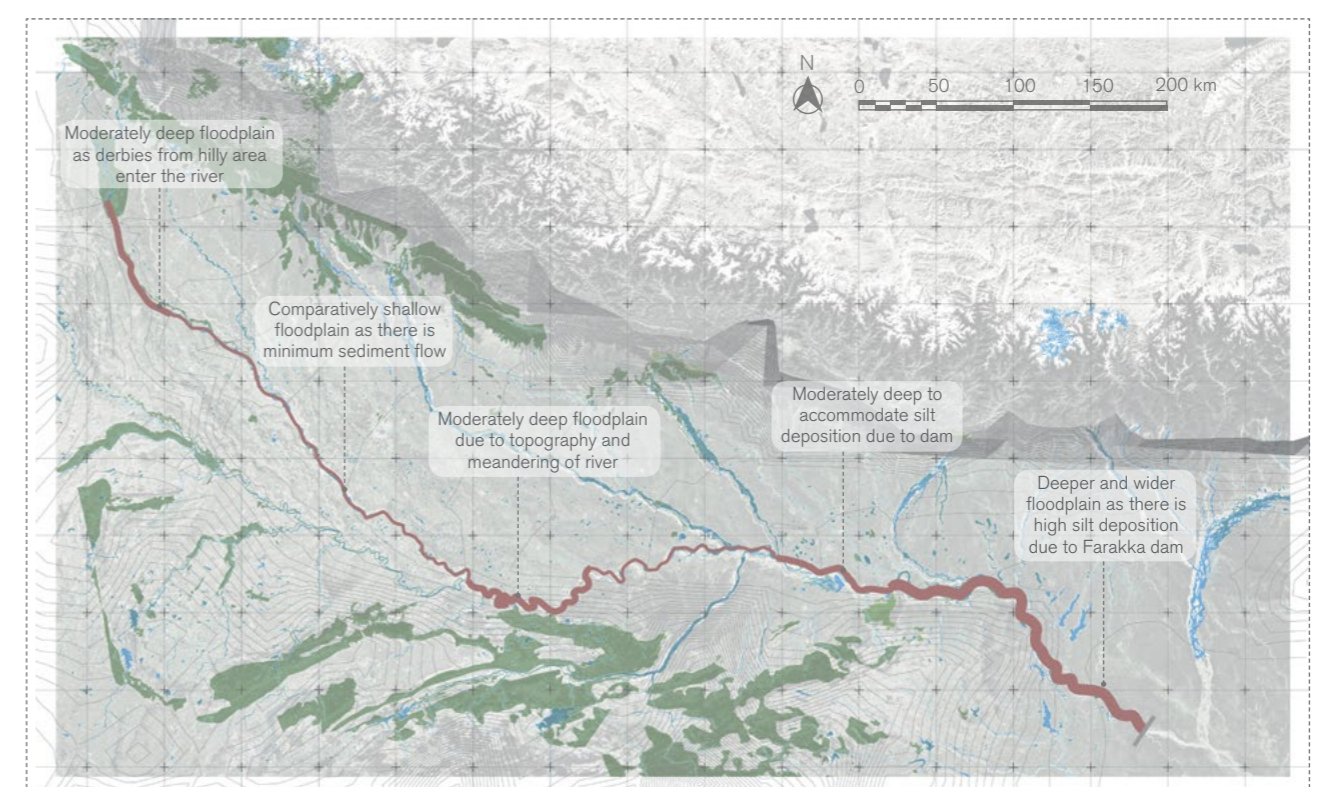


Fig. 67. Spatial Plan for Action1 (Regional Strategy 1)



## Spatial Actions and Design Interventions

### 2. Adding temporary flood-able landscapes

Since most flood occurrences last for a short period ranging from few days to a couple of weeks, temporary flood-able landscapes can correspond to accommodate the excess water. These flood-able landscapes can belong in rural areas, where the availability of land is more and if flooding is allowed in a controlled method, it can be an opportunity for farms to gain from sediment flows.

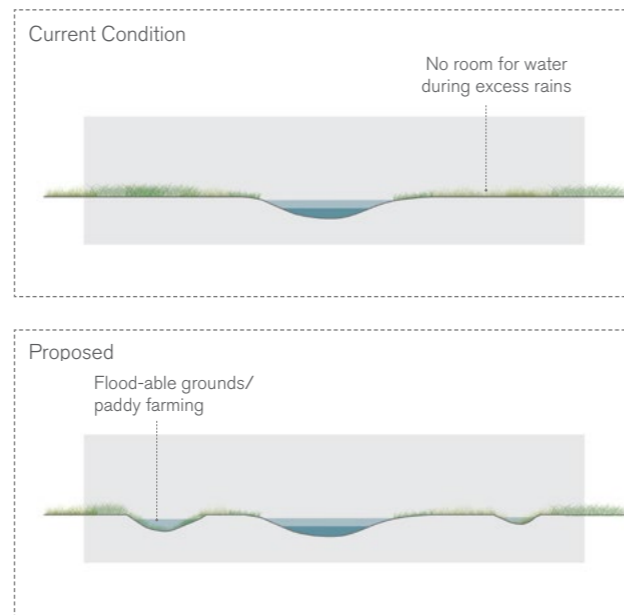


Fig. 68. Current - Proposed section for Action 2 (Regional Strategy 1)

### What it means at Metropolitan Scale?

- Updating Land-Use Plans to add special flood-able land use that can include temporary agriculture and other activities.

### What it means at Local Scale?

- Design embankments that allow controlled flooding of landscapes.  
- Collaborate with farmers to plan agriculture practices to gain nutrients from the flooded river.

## Stakeholder Engagement

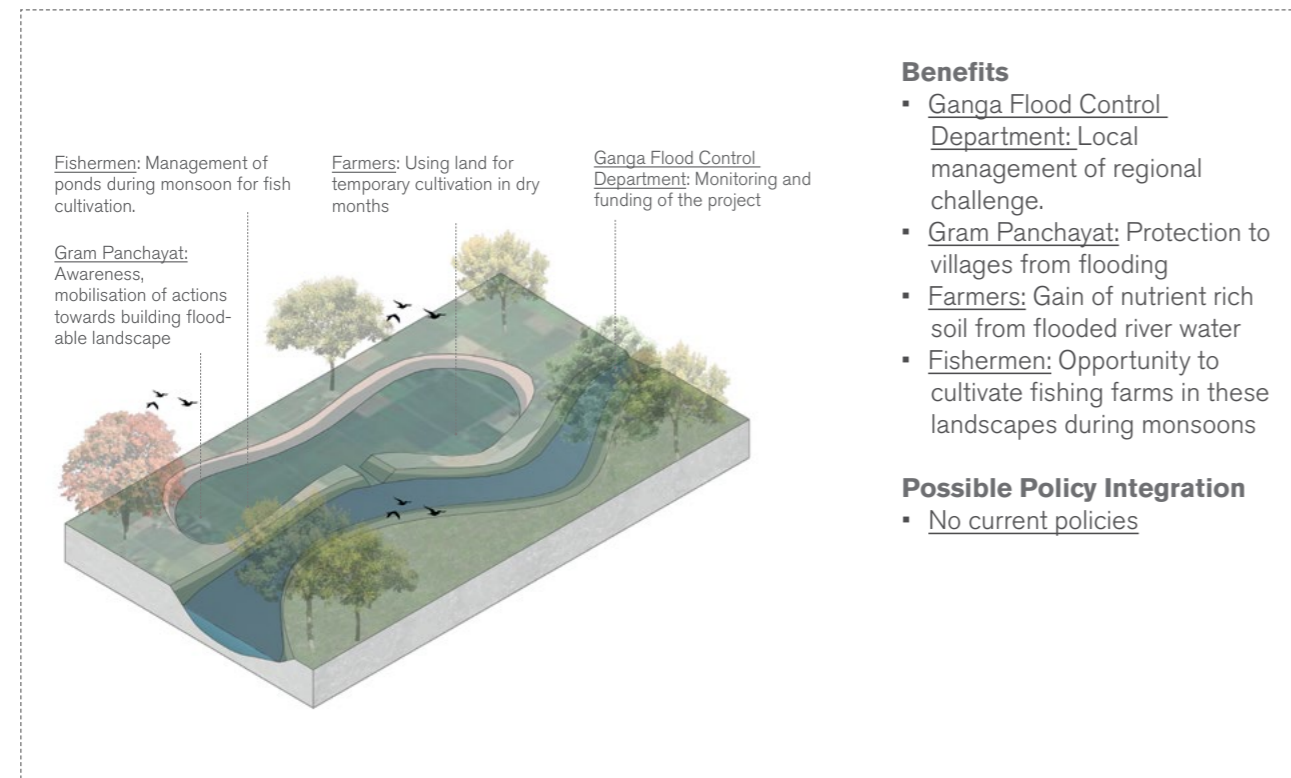


Fig. 69. Stakeholder Engagement for Action 2 (Regional Strategy 1)

## Regional Plan for Action

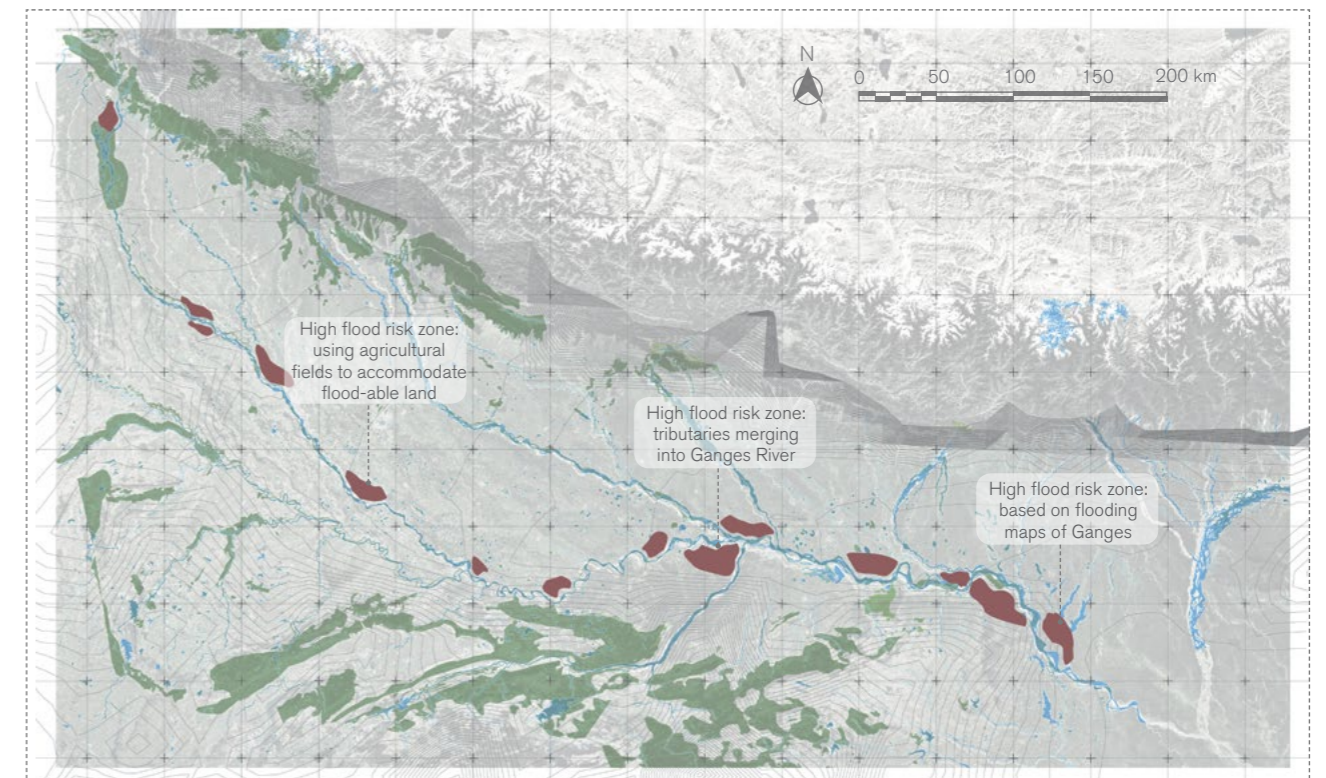


Fig. 70. Spatial Plan for Action 2 (Regional Strategy 1)



## Spatial Actions and Design Interventions

### 3. Naturalizing river edge

Almost 50% of water streams and river sections in the Ganges Basin are engineered. This engineering of the river edge causes harm to the ecological systems within the basin. It hampers the growth of water plants and vegetation and furthermore leading to loss of fishes and other living animals. With nature-based reinforcement techniques, the banks can be made stable as well as ecologically thriving.

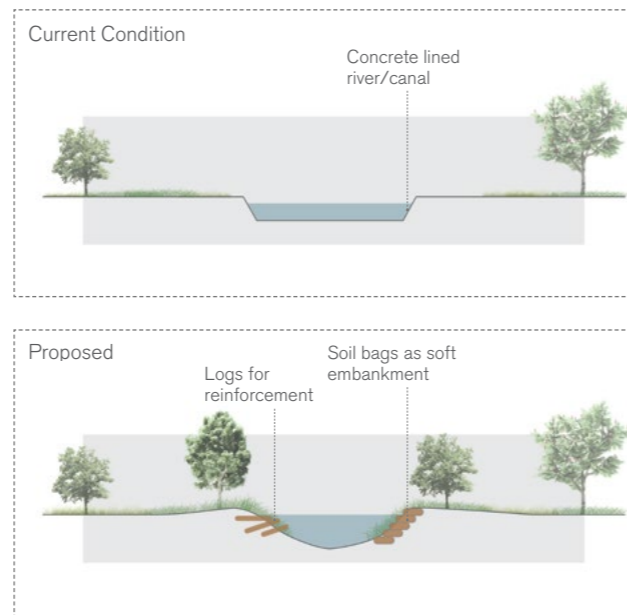


Fig. 71. Current -Proposed section for Action 3 (Regional Strategy 1)

### What it means at Metropolitan Scale?

- Mapping built edges of the river and irrigation canals.
- Overlapping built edge plan with activities along the river bank to decide and negotiate on what edges to keep built (eg: Ghats, Jetty/ Loading Areas).

### What it means at Local Scale?

- Monitor flow velocity and direction of water to identify what type of nature-based edge solutions to be used (Hard edge / Soft edge) interventions.

## Stakeholder Engagement

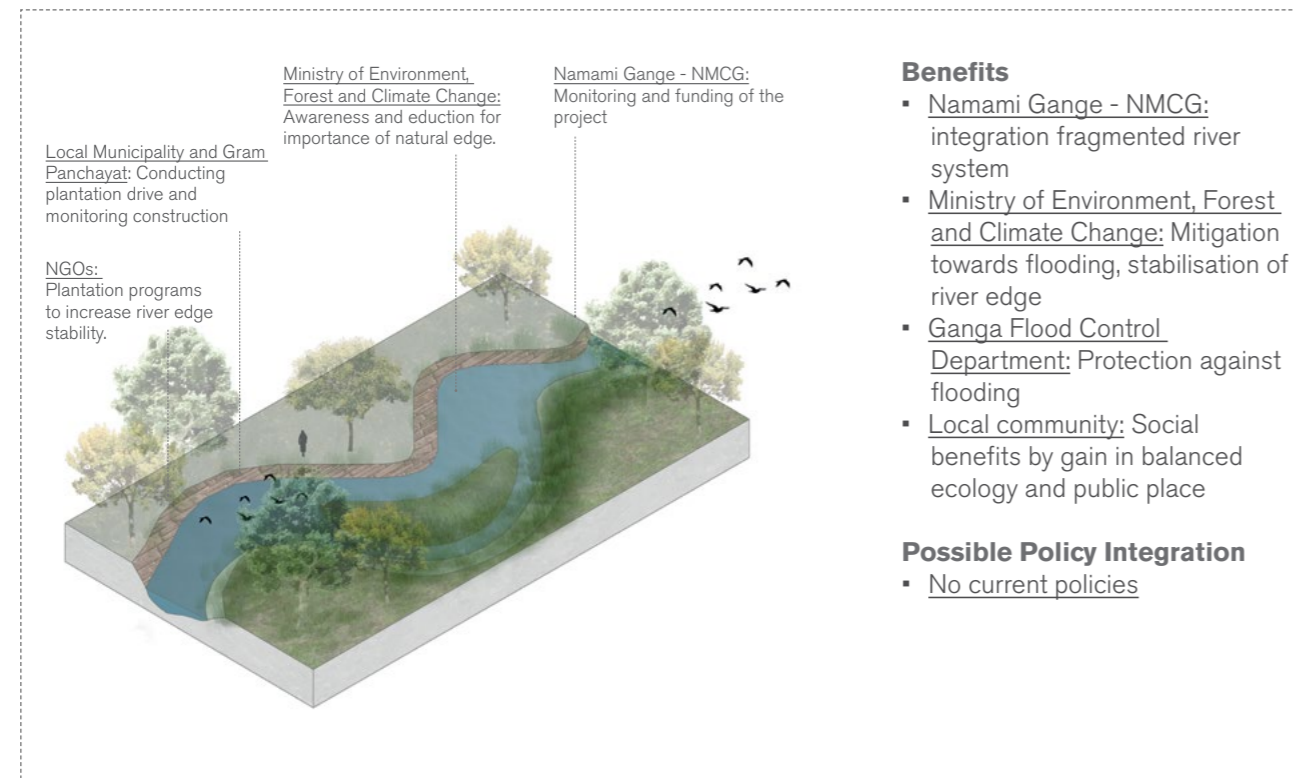


Fig. 72. Stakeholder Engagement for Action 3 (Regional Strategy 1)

## Regional Plan for Action

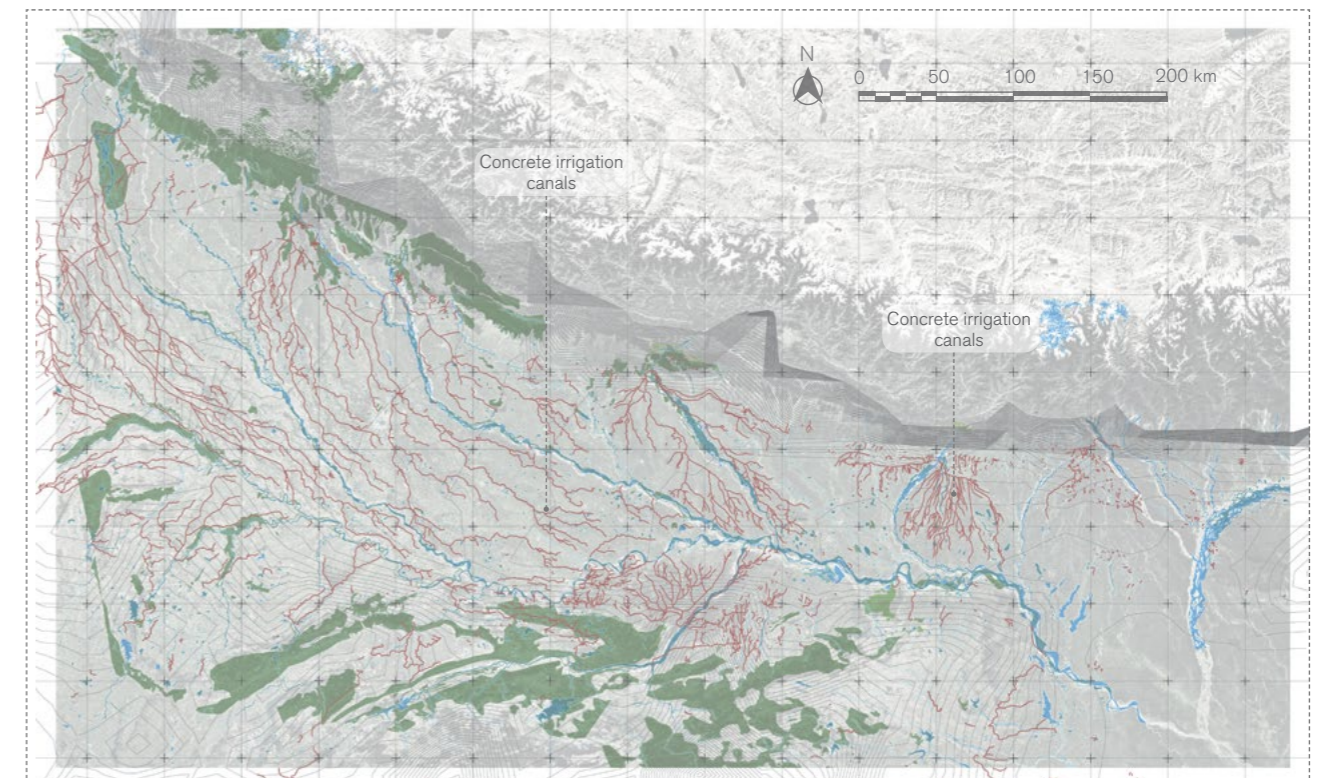


Fig. 73. Spatial Plan for Action 3 (Regional Strategy 1)



## Spatial Actions and Design Interventions

### 4. Design for buffer zone

Designing for buffer zones as a mitigating action to flooding is highly recommended. The design of the buffer zone creates layers (rings) of flood defense mechanism. The initial low floods can be mitigated with the first buffer line of vegetation. While more serious floods can be defended with embankments.

The design for the buffer zone also helps in gaining more time to prepare for worst-case scenarios.

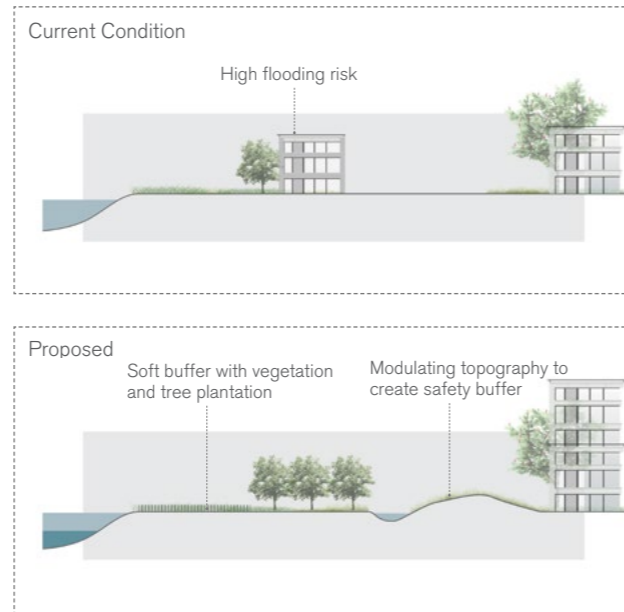


Fig. 74. Current -Proposed section for Action 4 (Regional Strategy 1)

### What it means at Metropolitan Scale?

- Declaring no-construction zone fro 200m from river.
- Adding necessary measures for cities close to the river and currently built on the river edge.

### What it means at Local Scale?

- Plan for different grades or lines of safety measures as per the flooding and drainage pattern locally. (eg: bushes, trees, flood-able landscape, embankments)

## Stakeholder Engagement

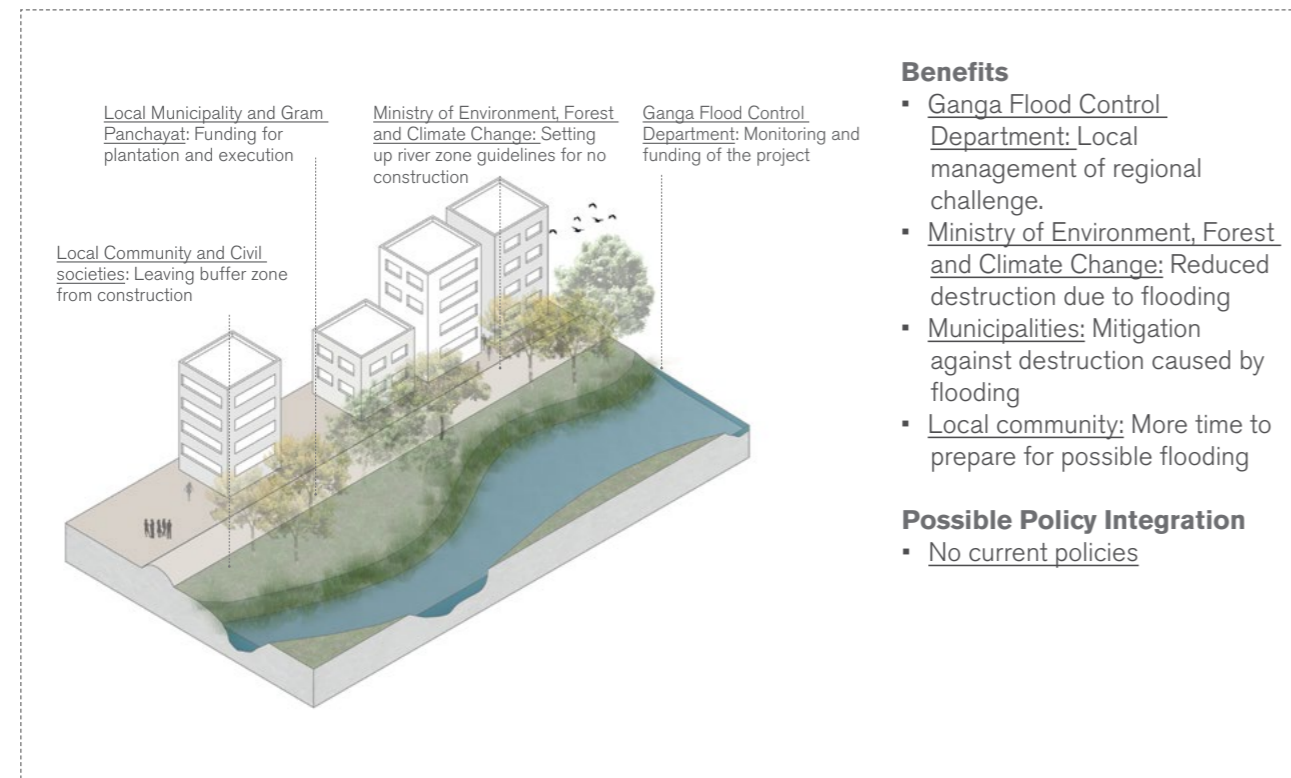


Fig. 75. Stakeholder Engagement for Action 4 (Regional Strategy 1)

## Regional Plan for Action

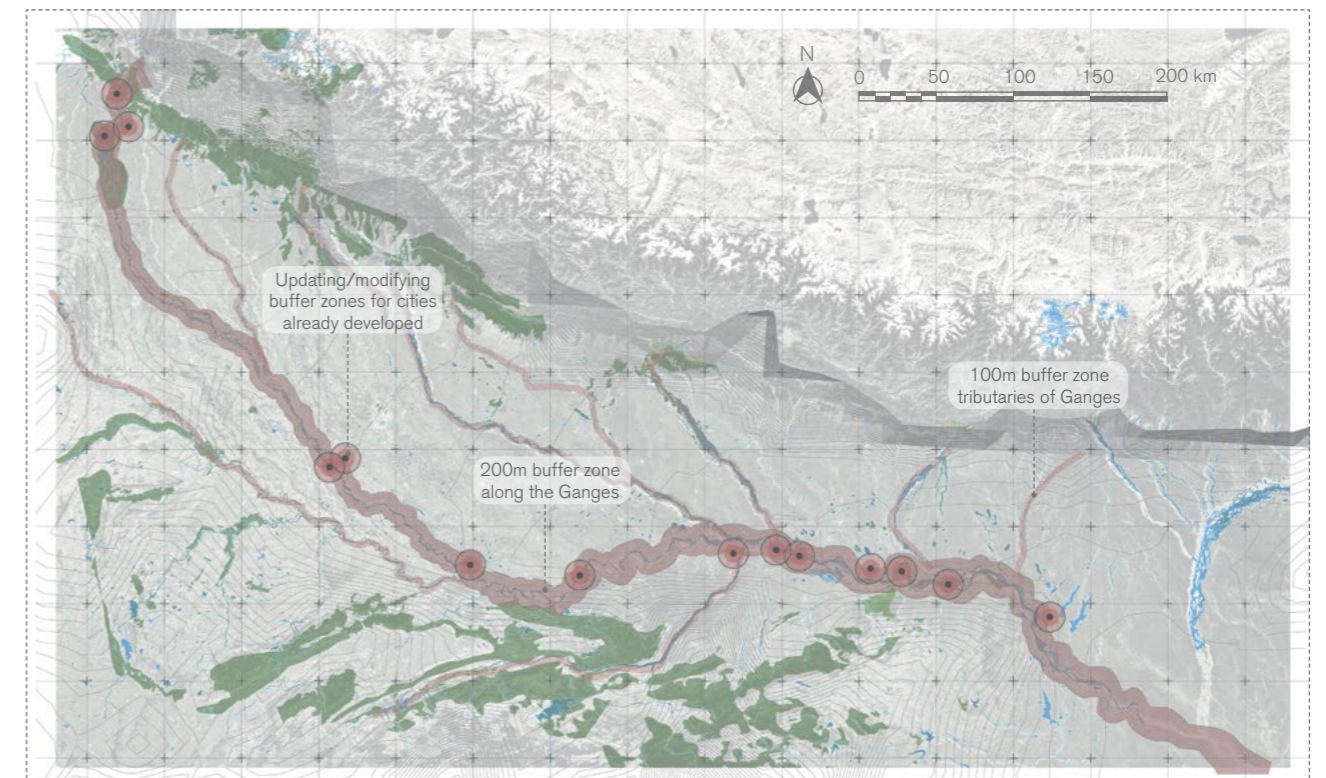
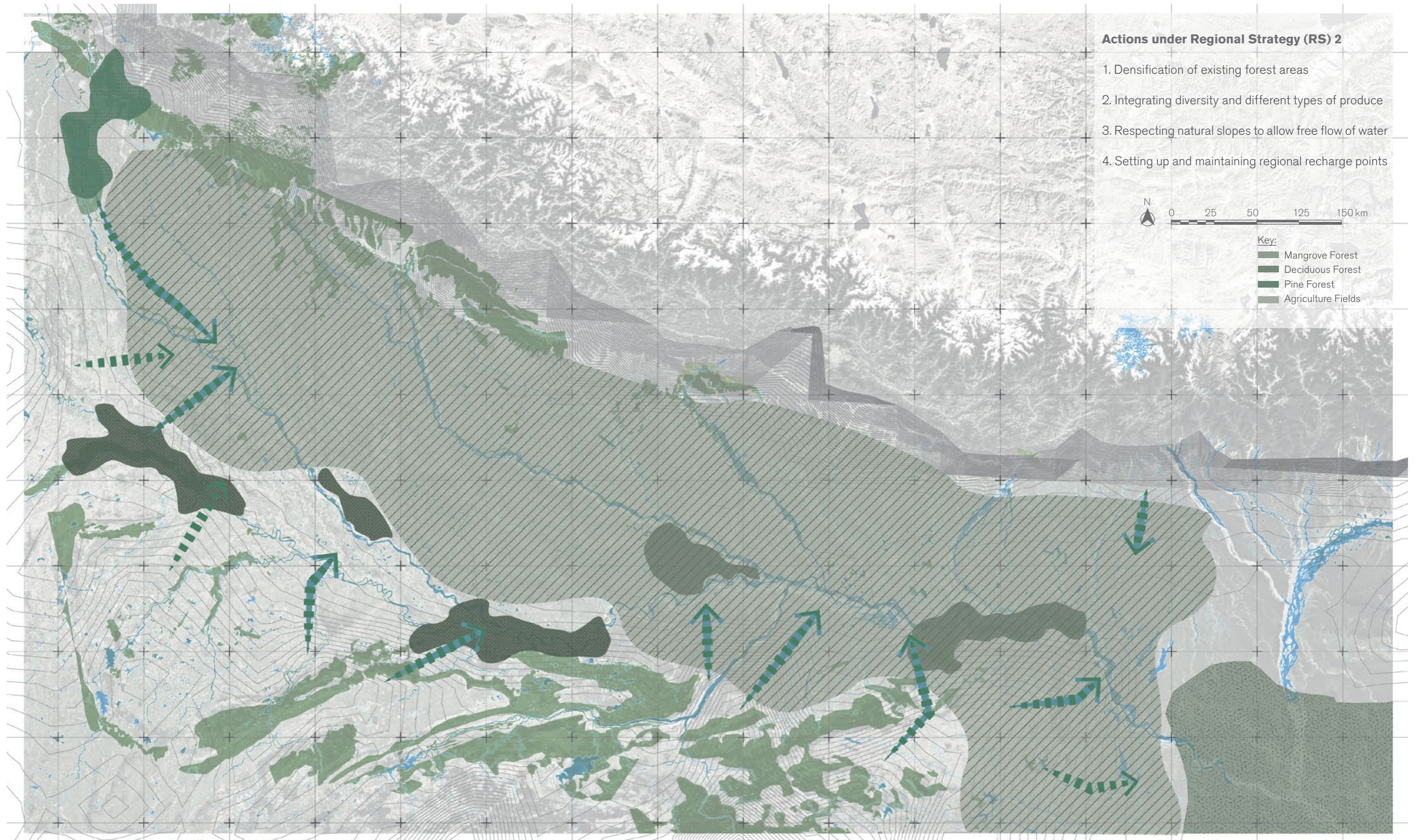


Fig. 76. Spatial Plan for Action 4 (Regional Strategy 1)



7.2.2. Strategy 2: Performative landscape strategy for water cycle management





## Spatial Actions and Design Interventions

### 1. Densification of existing forest areas

Deforestation activities in the river basin have increased to satisfy demands for agricultural lands and urban expansions. These activities are causing an imbalance in the evaporation and groundwater absorption. Thus it important to density the existing forest areas, and further declare them protected to avoid clearing of forest lands.

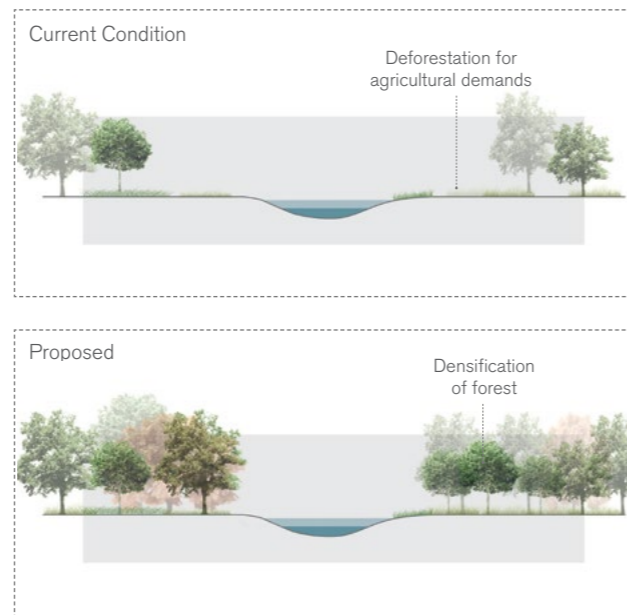


Fig. 77. Current -Proposed section for Action 1 (Regional Strategy 2)

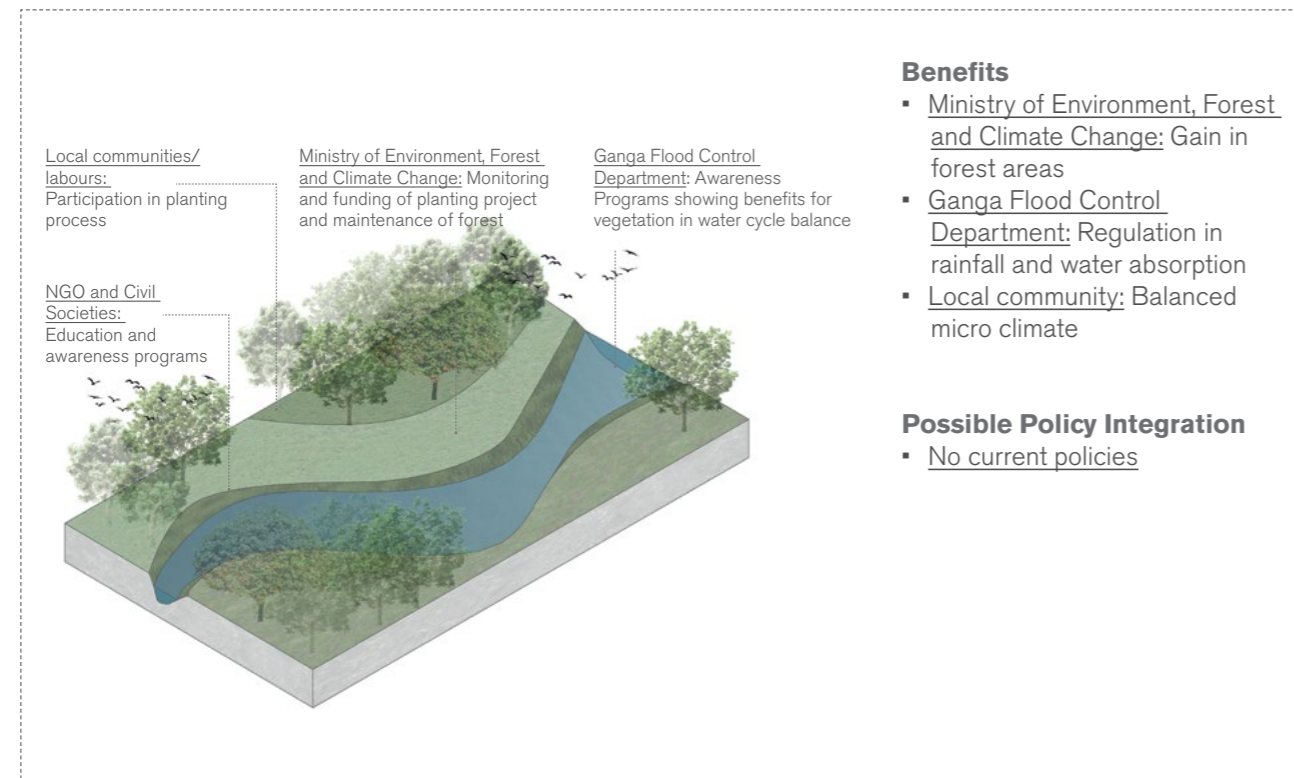
### What it means at Metropolitan Scale?

- Identifying local species favourable for plantation and densification of the existing forest. (eg: Pine trees, Deciduous trees, Mangrove)

### What it means at Local Scale?

- Collaborating with local NGOs, schools, Forest Departments and communities to encourage and conduct plantation programs.

## Stakeholder Engagement



### Benefits

- **Ministry of Environment, Forest and Climate Change:** Gain in forest areas
- **Ganga Flood Control Department:** Regulation in rainfall and water absorption
- **Local community:** Balanced micro climate

### Possible Policy Integration

- No current policies

Fig. 78. Stakeholder Engagement for Action 1 (Regional Strategy 2)

## Regional Plan for Action

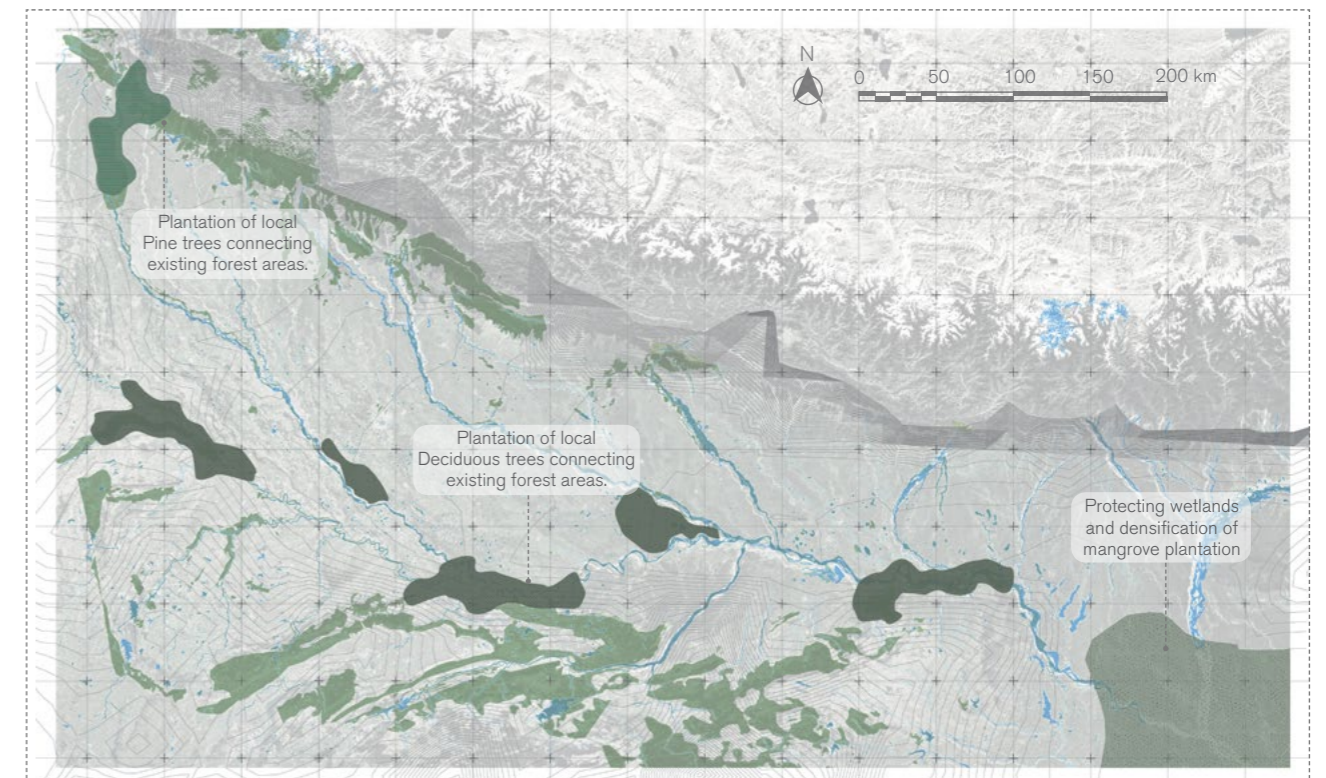


Fig. 79. Spatial Plan for Action 1 (Regional Strategy 2)



## Spatial Actions and Design Interventions

### 2. Integrating diversity and different types of produce

Each local species of vegetation plays a unique role in maintaining the hydrology and ecosystem of the basin. With more and more greed for the cultivation of cash crops, the nutrient contents of the soil and the water levels are being disturbed. With combinations of tree plantation in farming, these disturbances can be balanced, without losing on profits and income.

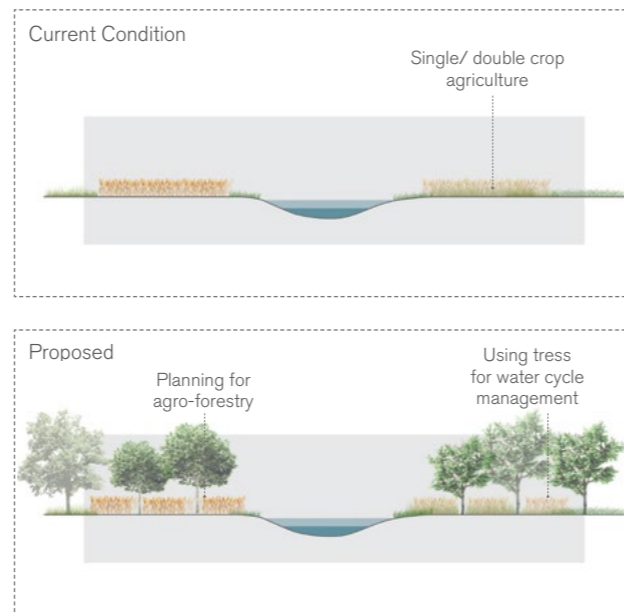


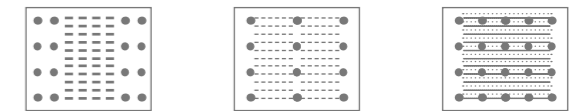
Fig. 80. Current -Proposed section for Action 2 (Regional Strategy 2)

### What it means at Metropolitan Scale?

- Developing policies and awareness programs to promote Agro-Forestry to add tree plantation within agricultural fields.
- Listing possible species and combinations of crops and trees for the region to facilitate farmers.

### What it means at Local Scale?

- Collaborating with local NGOs, agricultural universities and interact with farmers to share knowledge about patterns of farming.



## Stakeholder Engagement

**Benefits**

- **Ministry of Environment, Forest and Climate Change:** Gain in forest areas
- **Namami Gange - NMCG:** Opportunity to become largest river basin producer
- **Ministry of Agriculture & Farmers' Welfare:** Possibility and set-up for further research in agro-forestry, its benefits and implementations techniques
- **Ganga Flood Control Department:** Regulation in rainfall and water absorption
- **Farmers:** Increased productivity due to timber and other goods

**Possible Policy Integration**

- No current policies

Fig. 81. Stakeholder Engagement for Action 2 (Regional Strategy 2)

## Regional Plan for Action

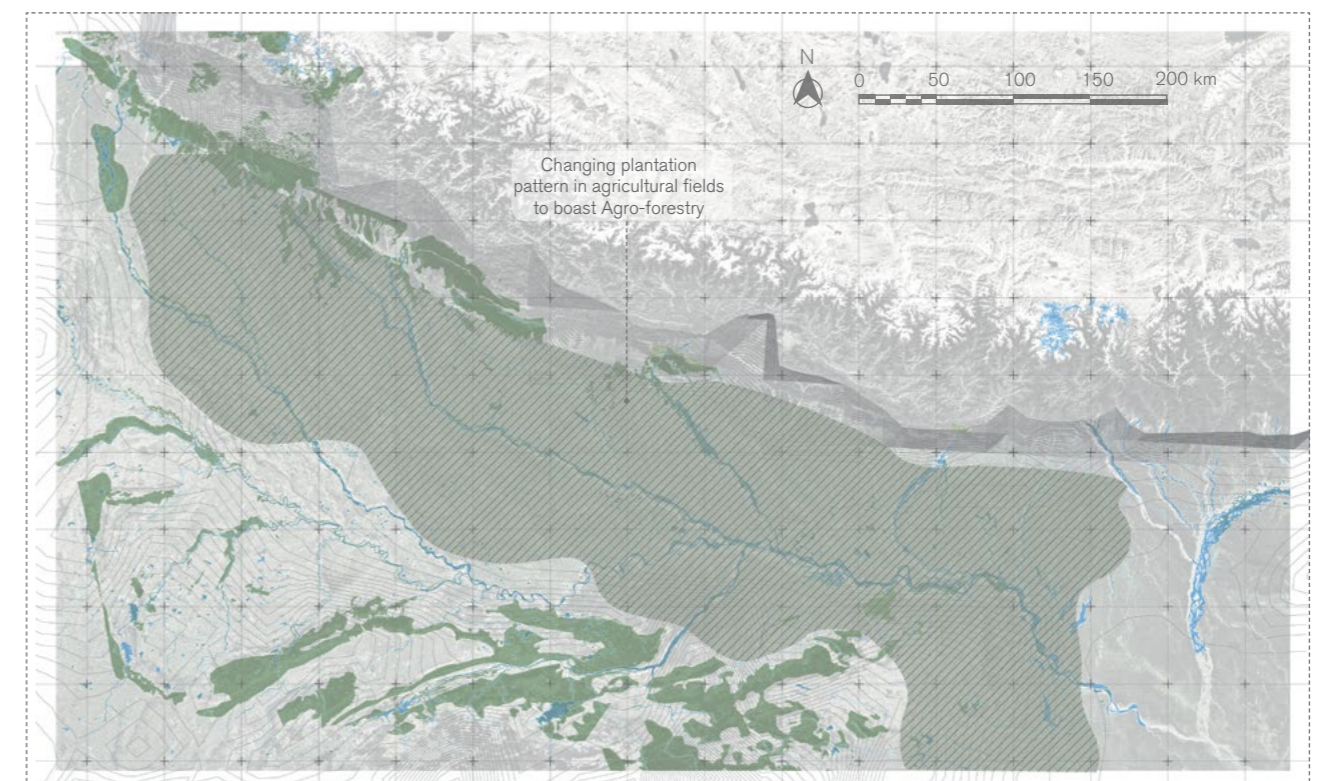


Fig. 82. Spatial Plan for Action 2 (Regional Strategy 2)



## Spatial Actions and Design Interventions

### 3. Respecting natural slopes to allow free flow of water

Modeling of topography to make maximum land available for development is being carried out in the basin. Which means constructions are being carried out in high as well as low lands, without considering the existing natural layers of the system. This causes hindrance in the process of the natural flow of water and drainage leading to flooding conditions. Hence, respecting the existing topography allows mitigation towards flooding.

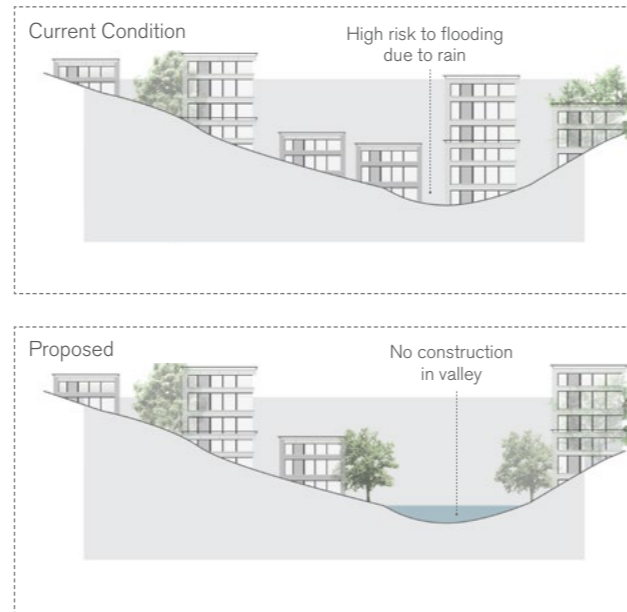


Fig. 83. Current -Proposed section for Action 3 (Regional Strategy 2)

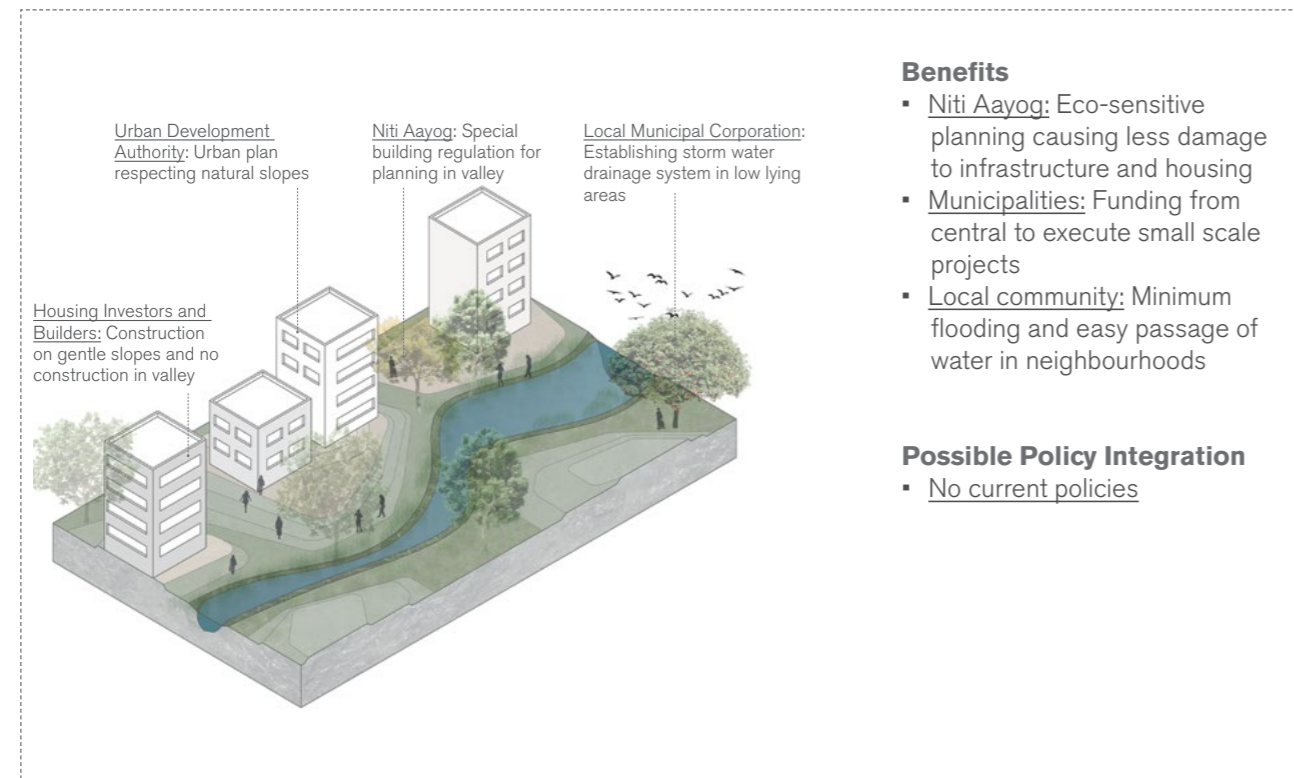
### What it means at Metropolitan Scale?

- Mapping local slopes within the regional slopes, to identify possible construction and no-construction zone.

### What it means at Local Scale?

- Negotiating and compensating with landowners to avoid construction within the valley where it is extremely necessary to leave the area vacant.  
- Special building guidelines for building in the valley (eg: construction on stilts) to allow free flow of water.

## Stakeholder Engagement



### Benefits

- **Niti Aayog:** Eco-sensitive planning causing less damage to infrastructure and housing
- **Municipalities:** Funding from central to execute small scale projects
- **Local community:** Minimum flooding and easy passage of water in neighbourhoods

### Possible Policy Integration

- No current policies

Fig. 84. Stakeholder Engagement for Action 3 (Regional Strategy 2)

## Regional Plan for Action

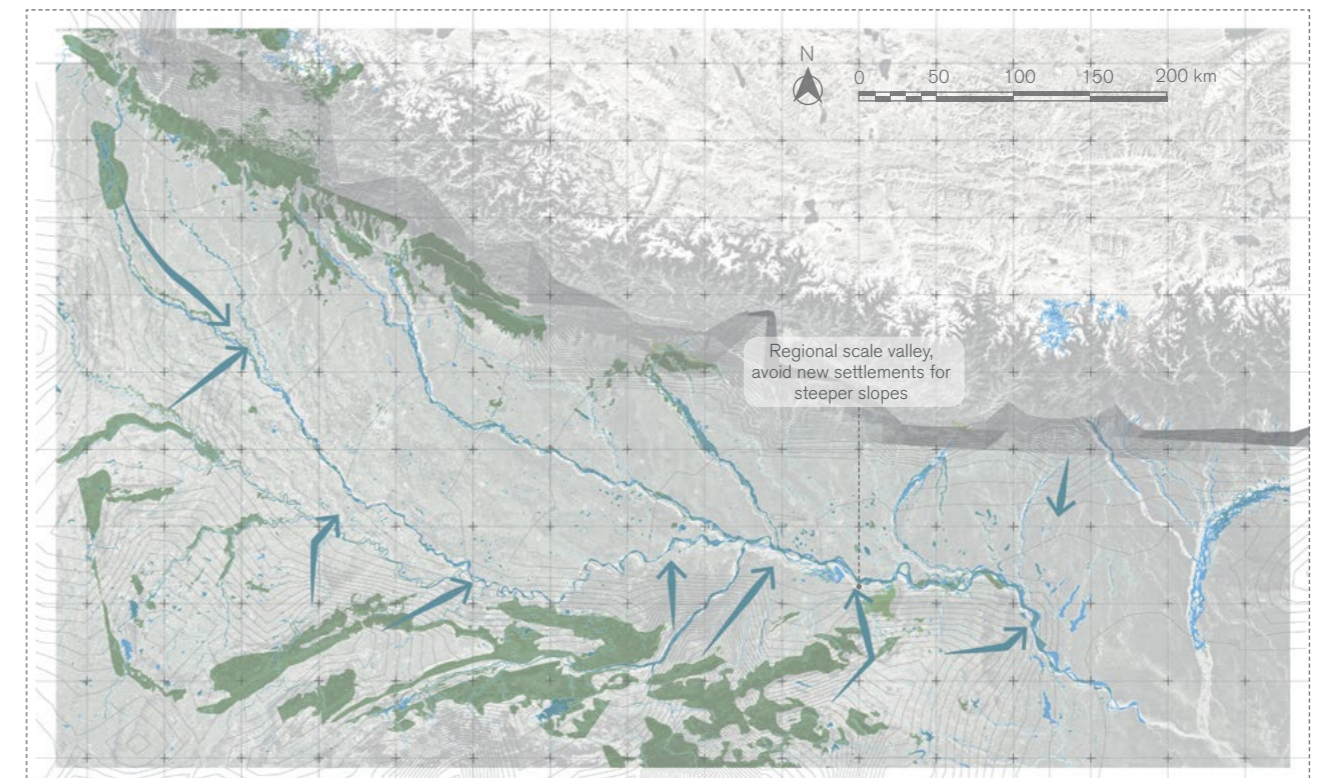


Fig. 85. Spatial Plan for Action 3 (Regional Strategy 2)



## Spatial Actions and Design Interventions

### 4. Setting up and maintaining regional recharge points

It has been analysed the more than 0.5 billion m<sup>3</sup> of water per km<sup>2</sup> is lost to every season to surface runoff due to lost opportunities for groundwater recharge. Remodeling of topography, to add more recharge points, in terms of small lakes, and increased vegetation would reduce water loss in terms of surface run-off and will help in maintaining and increasing the groundwater table.

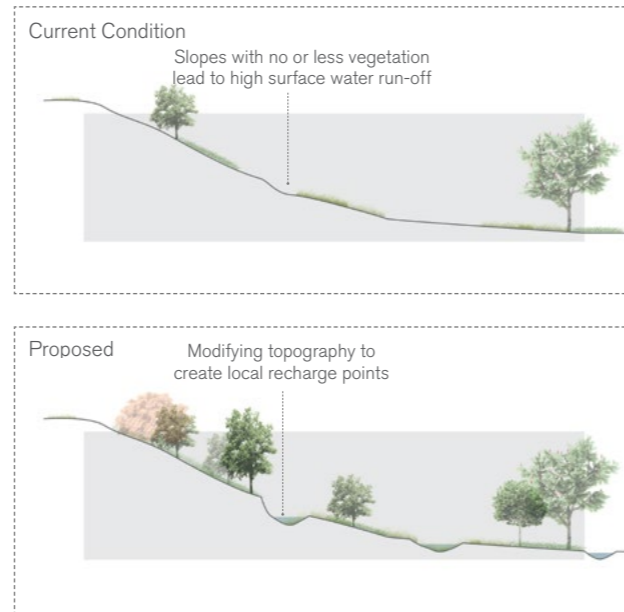


Fig. 86. Current -Proposed section for Action 4 (Regional Strategy 2)

### What it means at Metropolitan Scale?

- Mapping local slopes within the regional slopes and mapping flow of water during monsoon seasons.

### What it means at Local Scale?

- Add programs like parks and lakes for water catchment, storage and slow seepage to groundwater.  
- Direct water through narrow trenches to local catchments

## Stakeholder Engagement

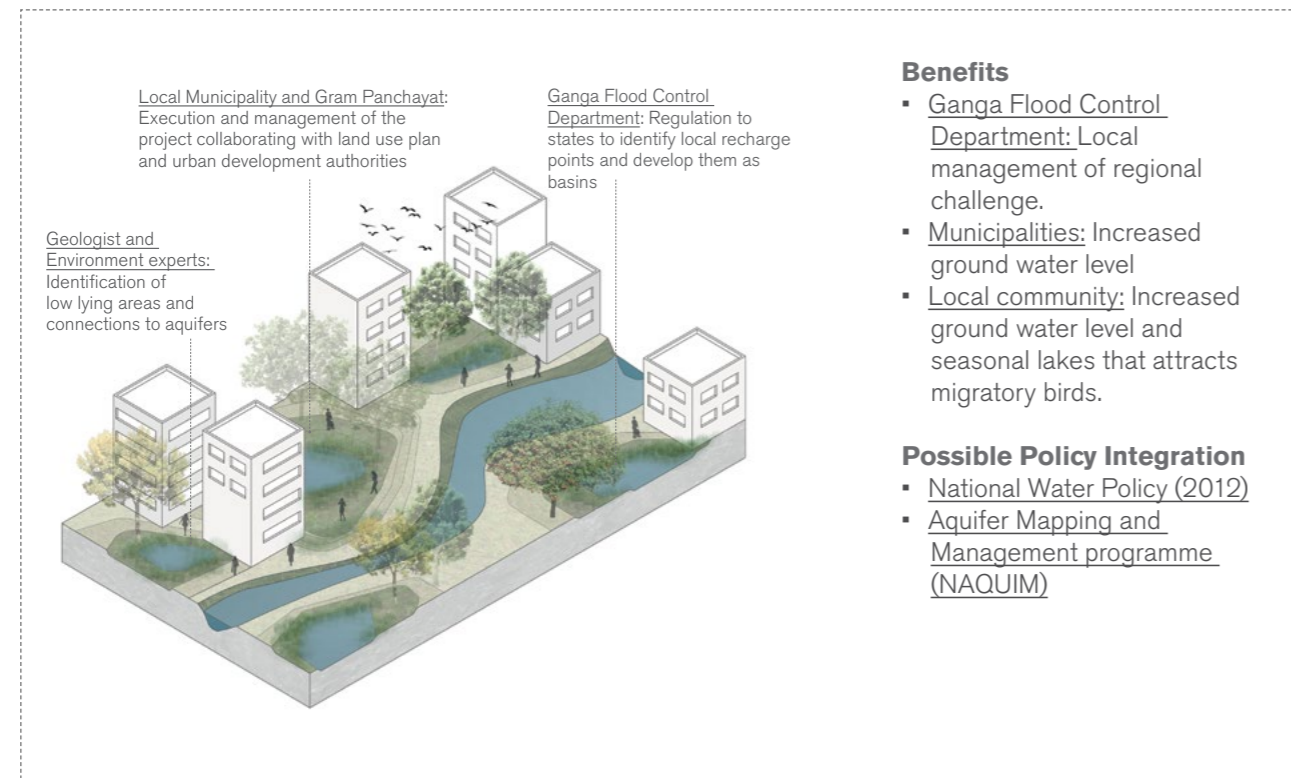


Fig. 87. Stakeholder Engagement for Action 4 (Regional Strategy 2)

## Regional Plan for Action

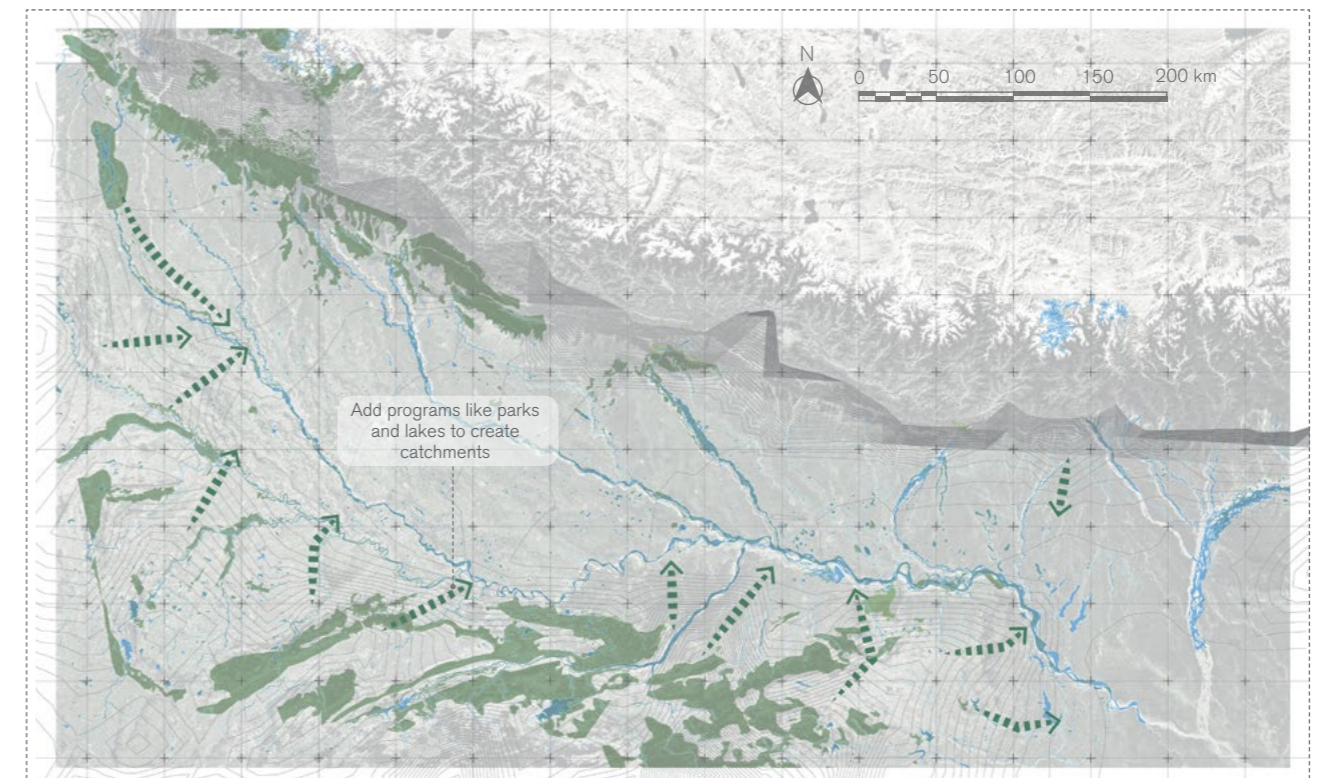
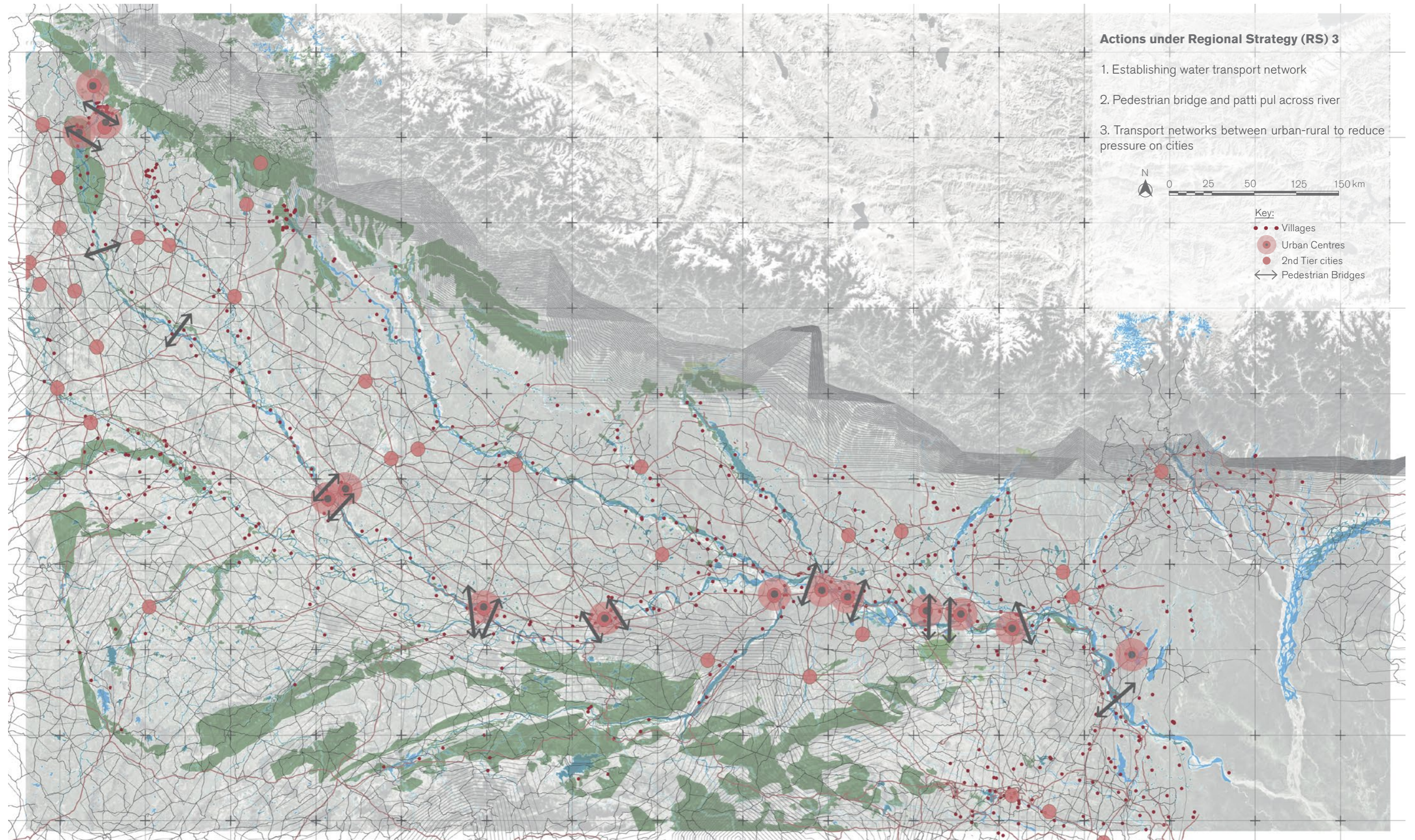


Fig. 88. Spatial Plan for Action 4 (Regional Strategy 2)



### 7.2.3. Strategy 3: Comprehensive connectivity across the basin





## Spatial Actions and Design Interventions

### 1. Establishing water transport network

The river Ganges was once a major route for transportation for goods. Goods like bamboo and jute were mostly transported from the deltas to the other cities. With the reduced flow of water and increased sediments, this water transport system has collapsed. By lowering of flood plains and maintaining a continuous flow of water, boat transportation could be revived, to establish easy connections from villages to cities.

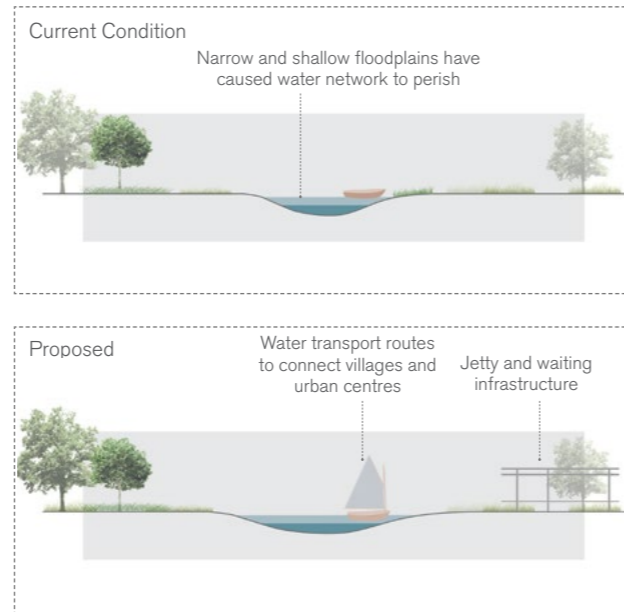


Fig. 89. Current -Proposed section for Action 1 (Regional Strategy 3)

### What it means at Metropolitan Scale?

- Identifying local routes of travel used often by commuters
- Set-up a boating association (Public /PPP) to organize and regulate safety and rates for water transport routes

### What it means at Local Scale?

- Construction of Jetties and platforms for boats and passengers.

## Stakeholder Engagement

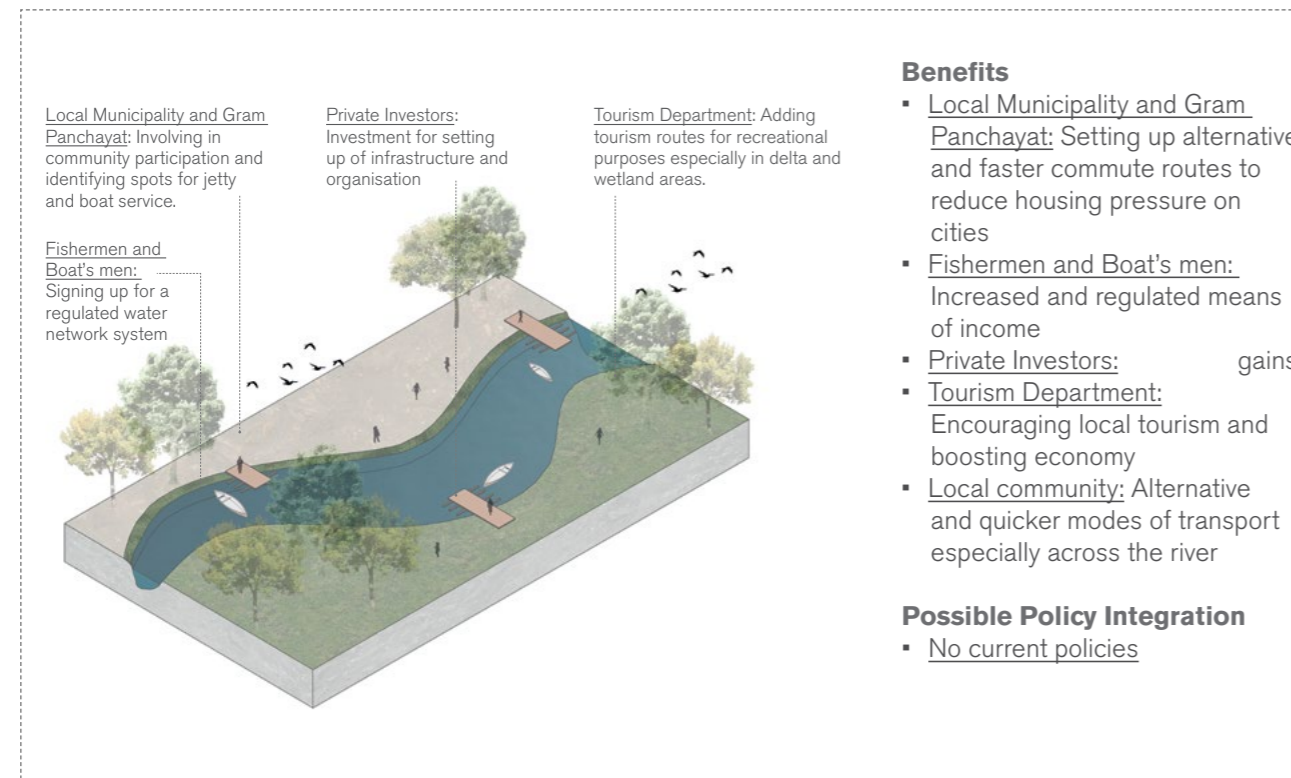


Fig. 90. Stakeholder Engagement for Action 1 (Regional Strategy 3)

### Benefits

- **Local Municipality and Gram Panchayat:** Setting up alternative and faster commute routes to reduce housing pressure on cities
- **Fishermen and Boat's men:** Increased and regulated means of income
- **Private Investors:** gains
- **Tourism Department:** Encouraging local tourism and boosting economy
- **Local community:** Alternative and quicker modes of transport especially across the river

### Possible Policy Integration

- No current policies

## Regional Plan for Action

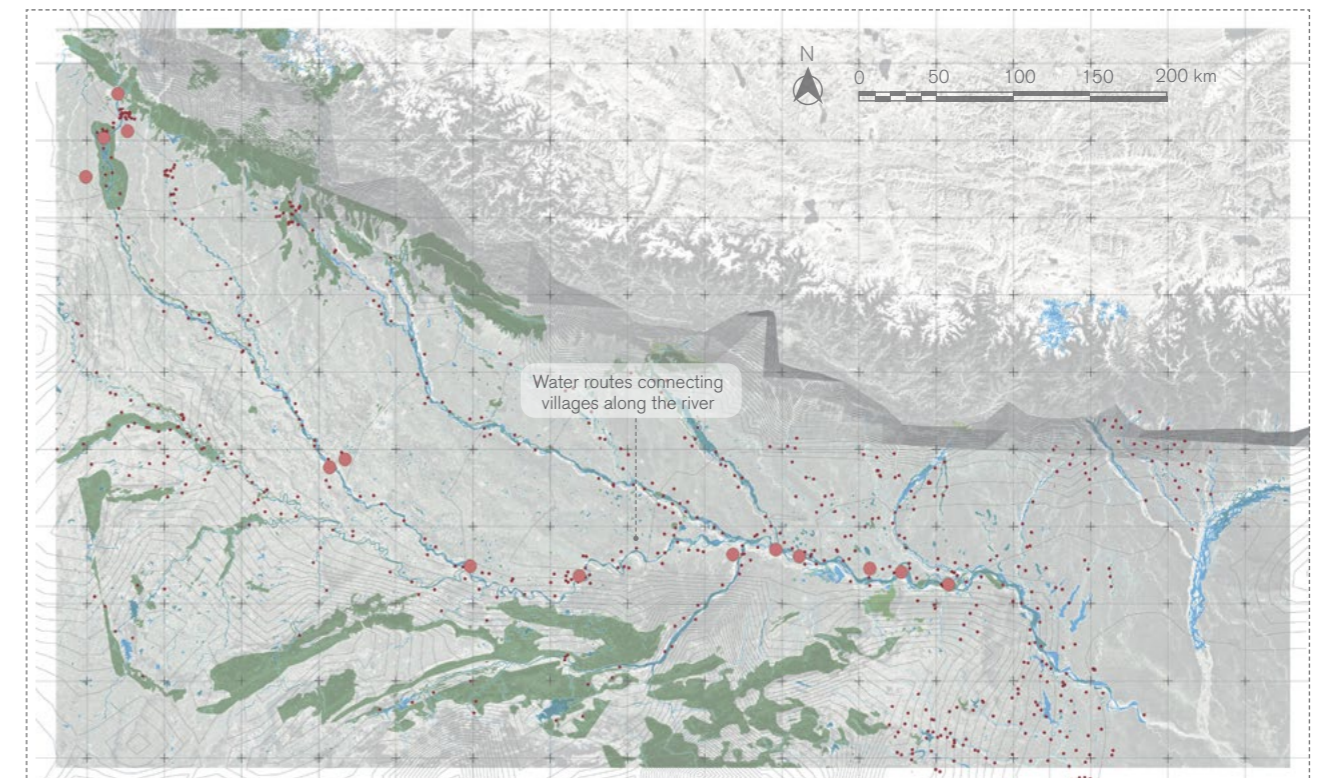


Fig. 91. Spatial Plan for Action 1 (Regional Strategy 3)



## Spatial Actions and Design Interventions

### 2. Pedestrian bridge and *patti pul* across river

Often within the basin, a city is developed on one side of the river bank. Labours and farmers travel on daily basis from villages across the river to make income. With one couple of large bridges connecting both ends, they are forced to take longer routes. Introducing bridges connecting important nodes, easy and robust transportation network can be established, and pressure on existing infrastructure can be reduced.

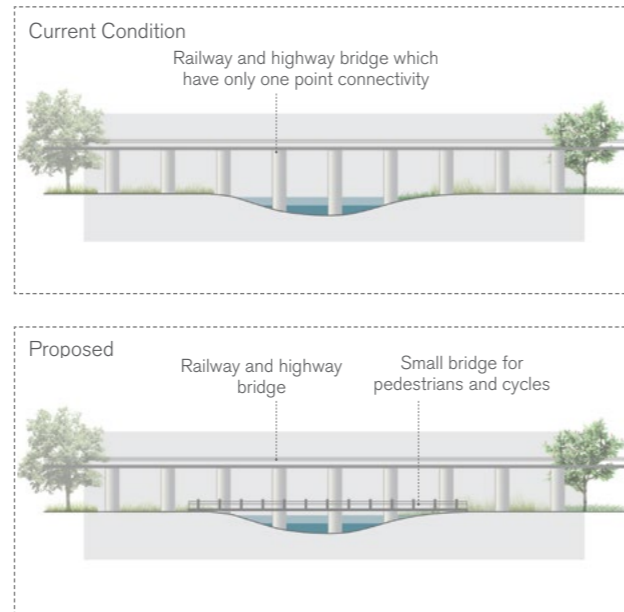


Fig. 92. Current -Proposed section for Action 2 (Regional Strategy 3)

### What it means at Metropolitan Scale?

- Identifying local routes of travel used often by commuters

### What it means at Local Scale?

- Planning for approach roads to pedestrian and small scale bridges

## Stakeholder Engagement



Fig. 93. Stakeholder Engagement for Action 2 (Regional Strategy 3)

## Regional Plan for Action

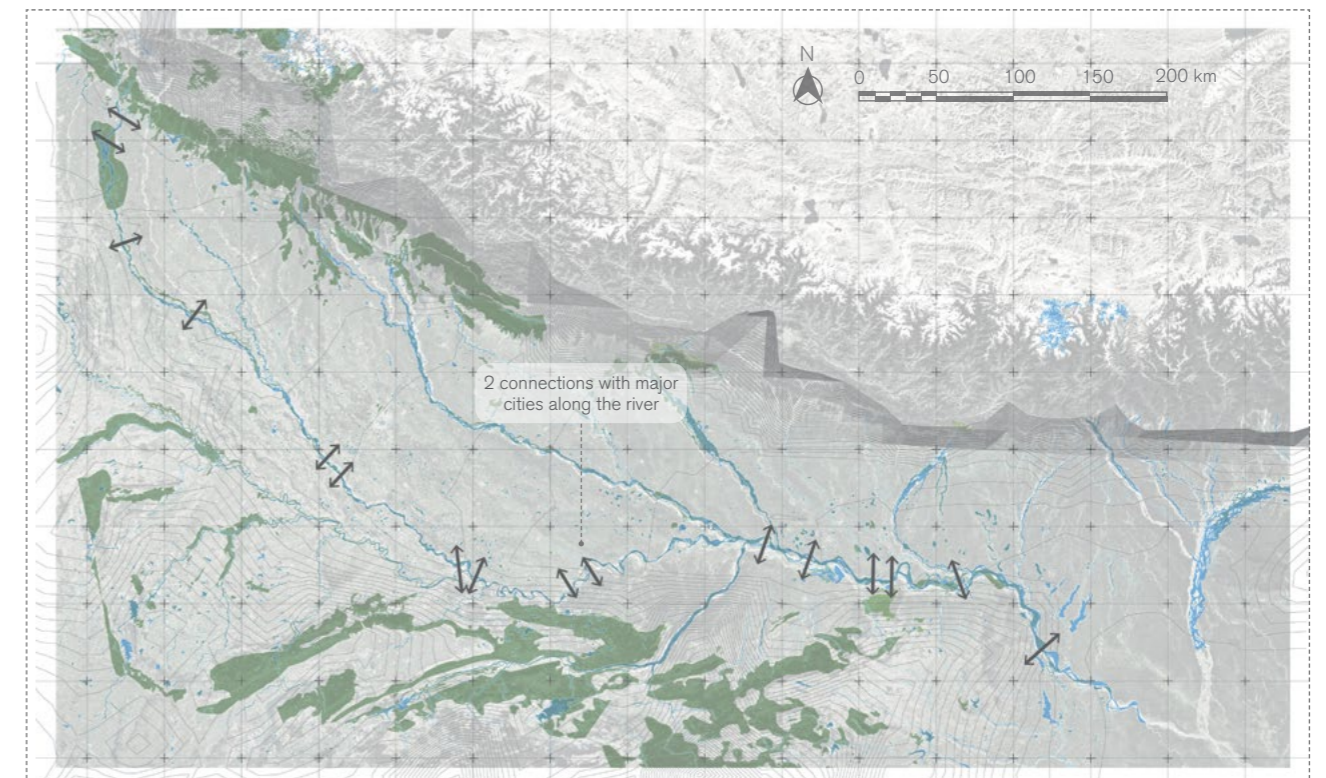


Fig. 94. Spatial Plan for Action 2 (Regional Strategy 3)



## Spatial Actions and Design Interventions

### 3. Transport networks between urban-rural to reduce pressure on cities

Weak transport network force developments to concentrate in urban centres. Furthermore, labourers from nearby villages are forced to migrate to cities, instead of traveling daily. Hence, establishing stronger links between major urban cities, 2nd tier cities and villages can help distribution of function and reduce pressure on cities.

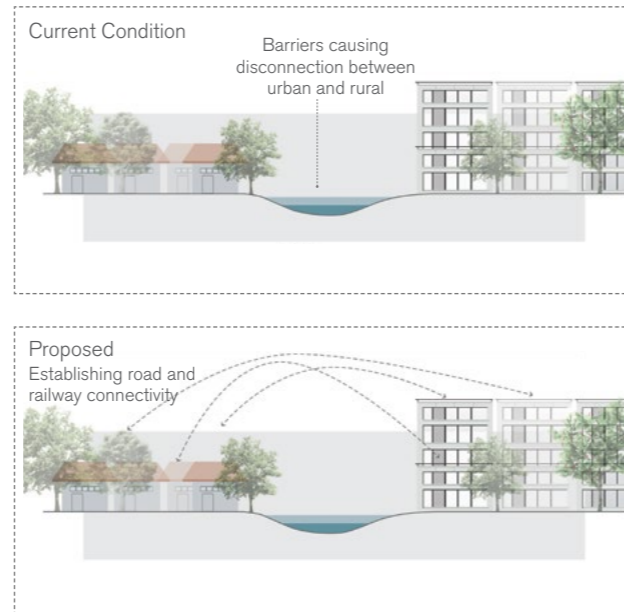


Fig. 95. Current -Proposed section for Action 3 (Regional Strategy 3)

### What it means at Metropolitan Scale?

- Updating Land Use Plan to accommodate the distribution of functions to nearby cities.
- Strengthen road and railway links (public transport) with an intercity network.

### What it means at Local Scale?

- No specific action planned for the local scale.

## Stakeholder Engagement

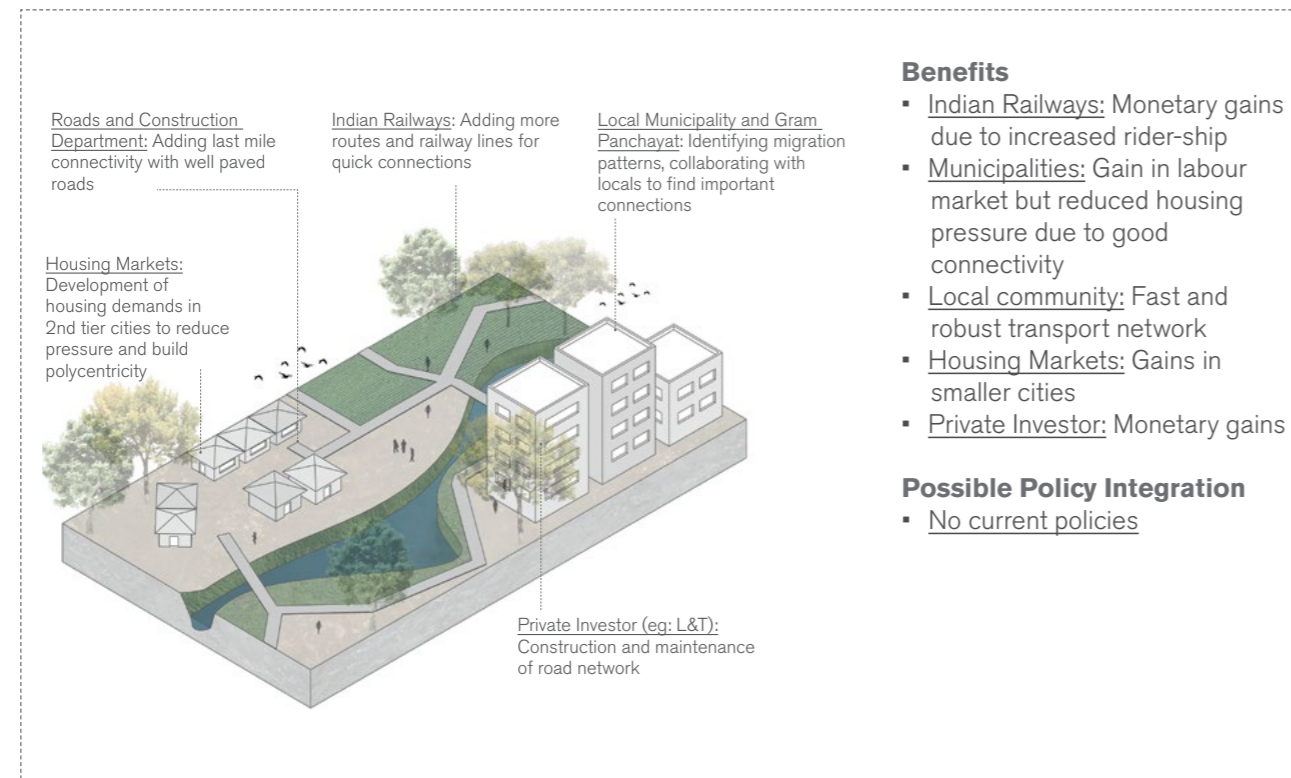


Fig. 96. Stakeholder Engagement for Action 3 (Regional Strategy 3)

## Regional Plan for Action

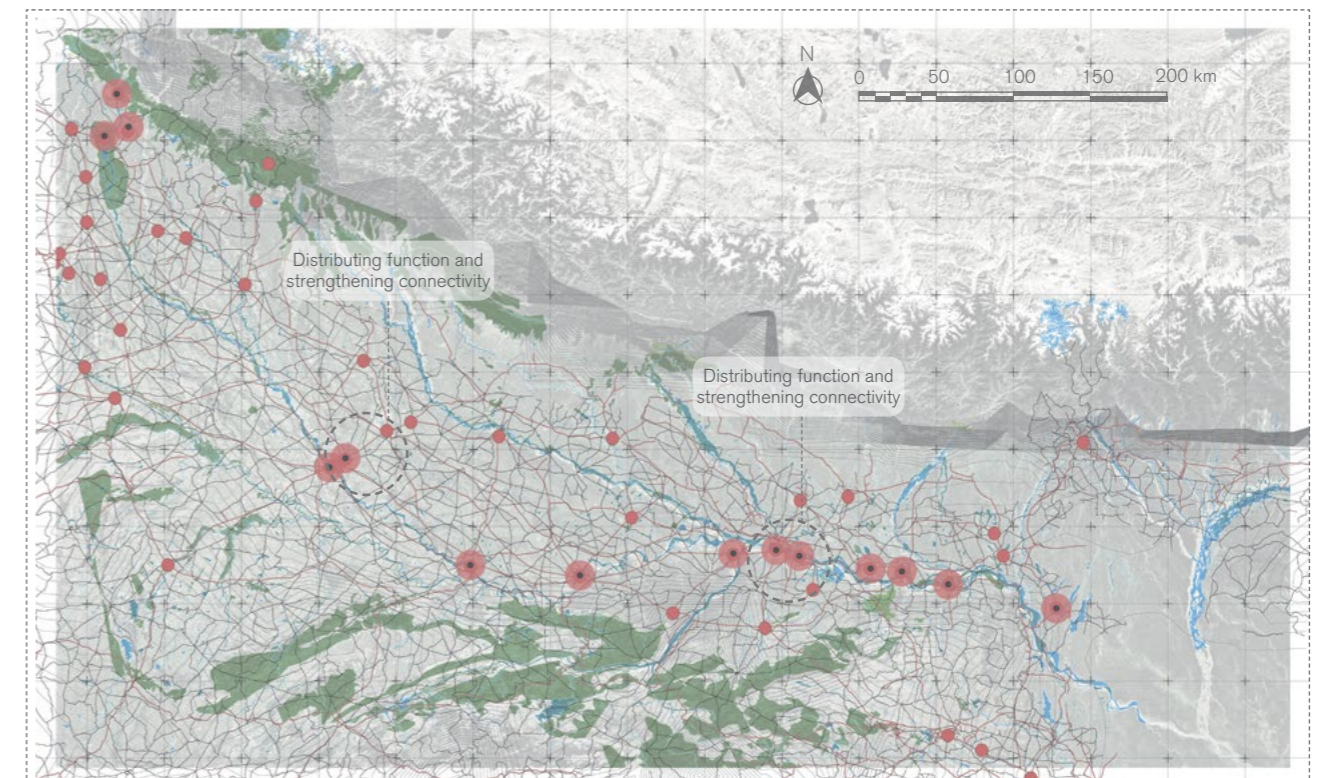
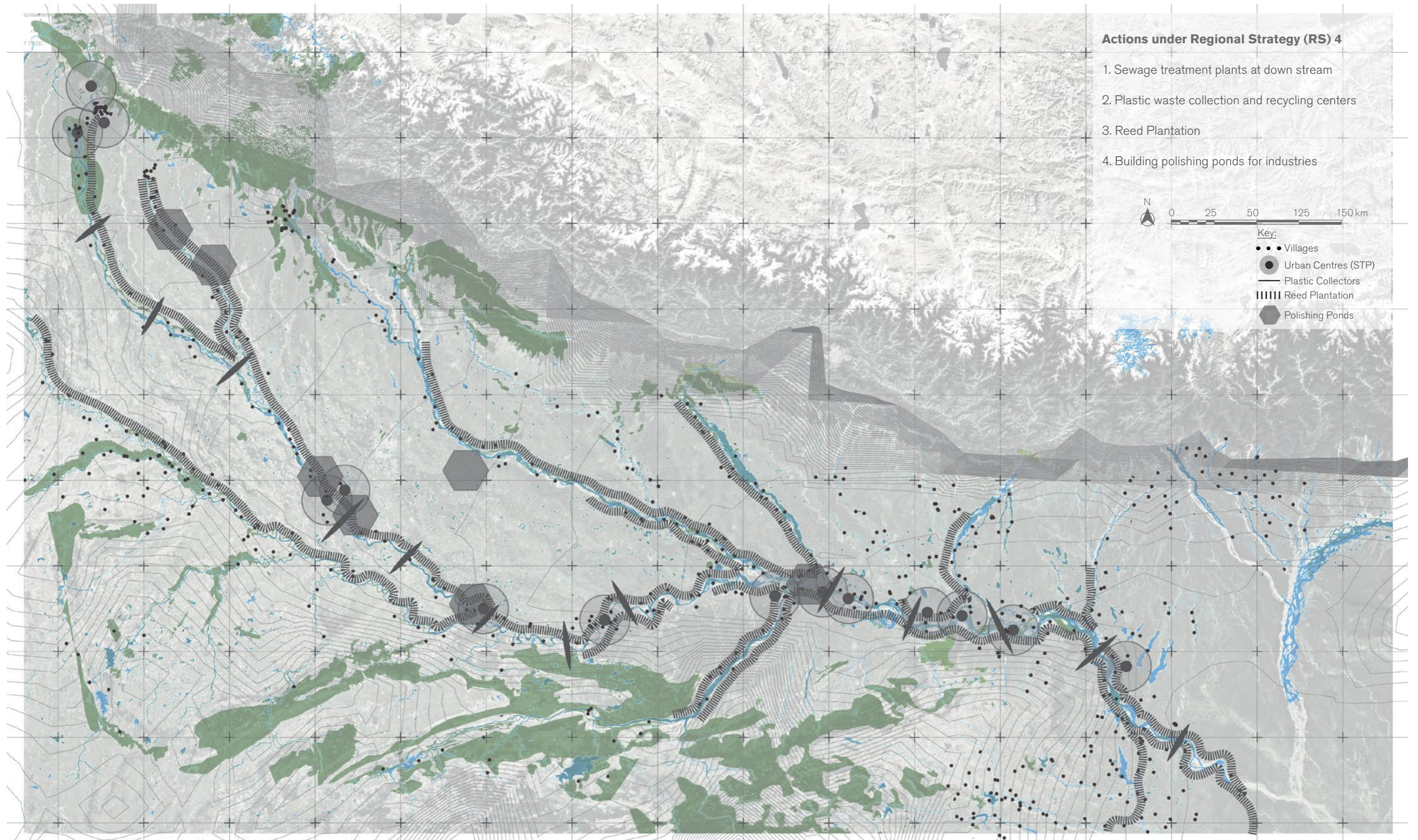


Fig. 97. Spatial Plan for Action 3 (Regional Strategy 3)

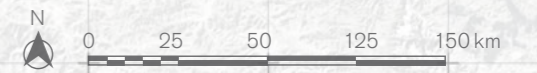


### 7.2.4. Strategy 4: Pollution management



#### Actions under Regional Strategy (RS) 4

1. Sewage treatment plants at down stream
2. Plastic waste collection and recycling centers
3. Reed Plantation
4. Building polishing ponds for industries



- Key:
- Villages
  - Urban Centres (STP)
  - Plastic Collectors
  - ▨ Reed Plantation
  - Polishing Ponds



## Spatial Actions and Design Interventions

### 1. Sewage treatment plants at down stream

Cities and villages along the river, discard untreated sewage and wastewater directly into the Ganges. As per the latest available data, approximately 6.04 billion liters (The race to save the river Ganges, 2020) of waste is flowing into the river. Construction of sewage treatment plants and monitoring stations should be carried out downstream of every settlement along the river.

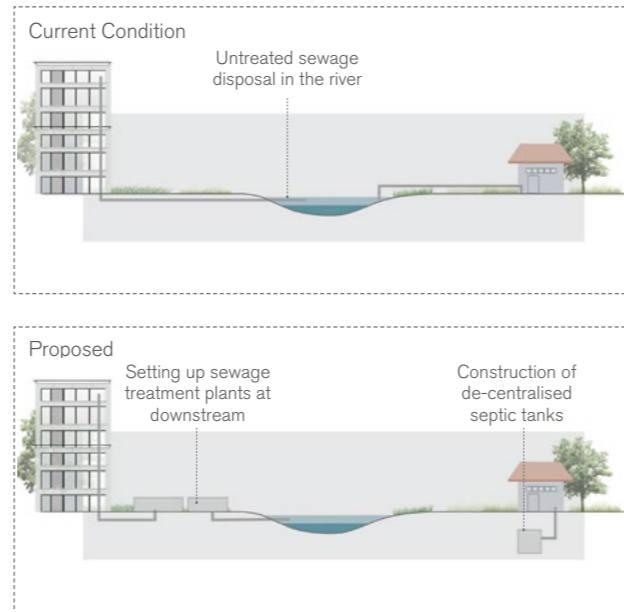


Fig. 98. Current -Proposed section for Action 1 (Regional Strategy 4)

### What it means at Metropolitan Scale?

- Establishing a sewer network plan, calculating capacities and construction of STPs

### What it means at Local Scale?

- Making sure each house/building is connected to the network.
- Compulsory toilet schemes for each house.

## Stakeholder Engagement

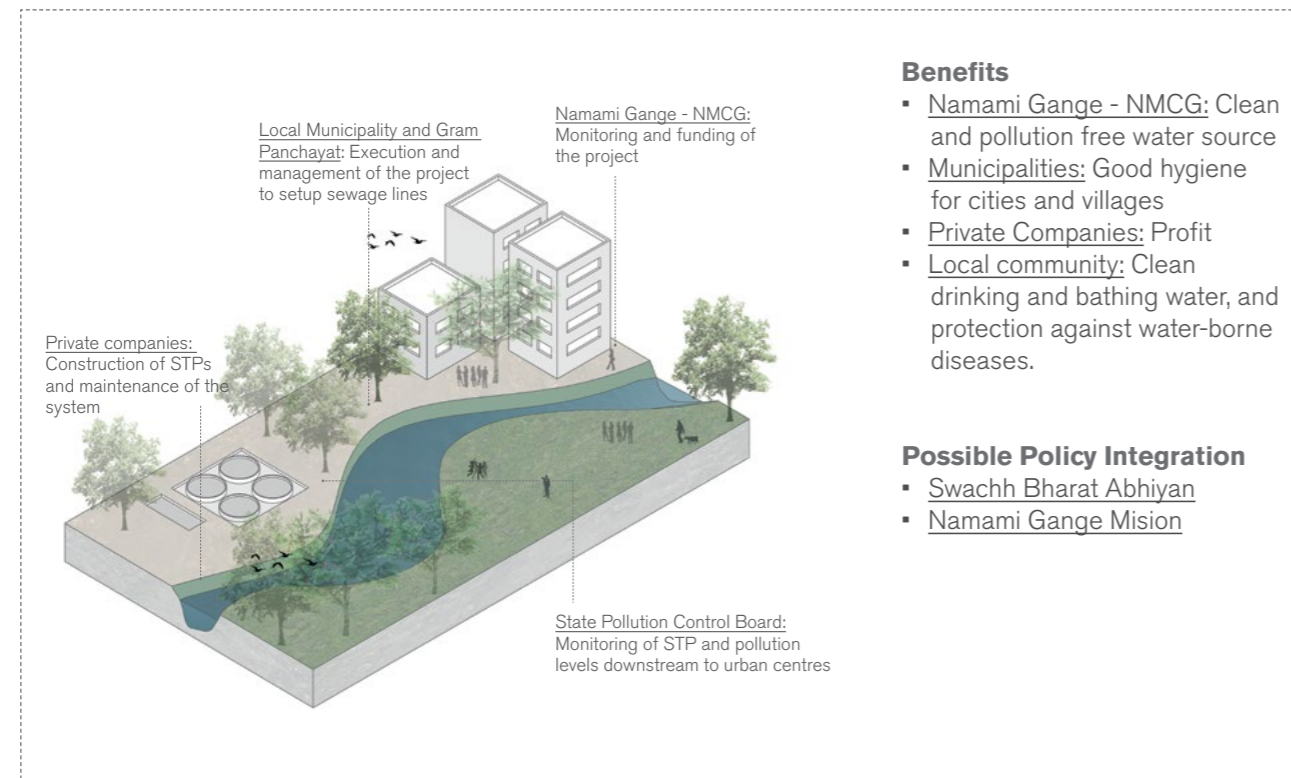


Fig. 99. Stakeholder Engagement for Action 1 (Regional Strategy 4)

### Benefits

- Namami Gange - NMCG: Clean and pollution free water source
- Municipalities: Good hygiene for cities and villages
- Private Companies: Profit
- Local community: Clean drinking and bathing water, and protection against water-borne diseases.

### Possible Policy Integration

- Swachh Bharat Abhiyan
- Namami Gange Mision

## Regional Plan for Action

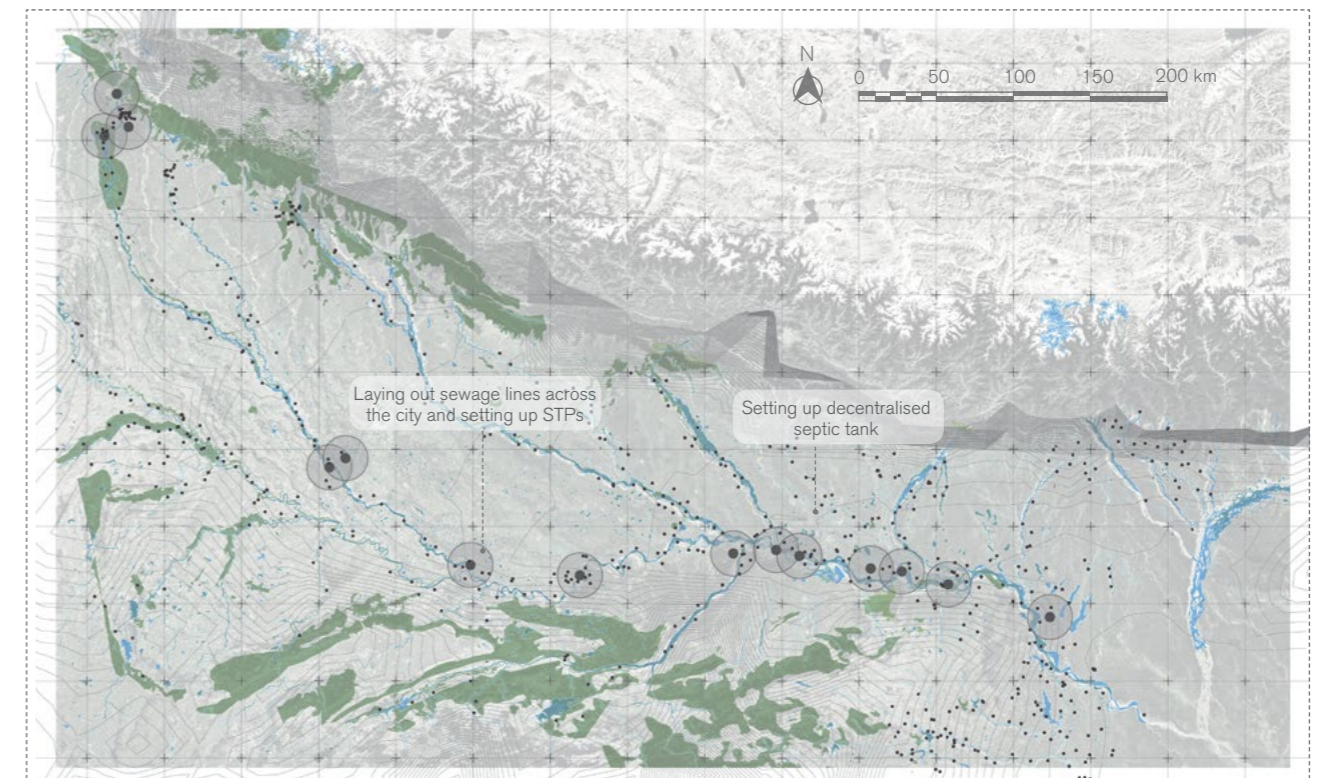


Fig. 100. Spatial Plan for Action 1 (Regional Strategy 4)



## Spatial Actions and Design Interventions

### 2. Plastic waste collection and recycling centers

Plastic is one of the most prominent pollutants in the river. With a daily increase in plastic waste flowing in the water, the aquatic animals and plants are under threat. Booms made of wire mesh and pipes can be suspended into the river at several intervals to collect plastic (Make A Change - 100 Trash Barriers To Be Installed in Bali Rivers To Reduce Plastic Pollution, 2020). Furthermore, recycling units are set up to collect and recycle plastic to create types of furniture like seatings for the river-edge.

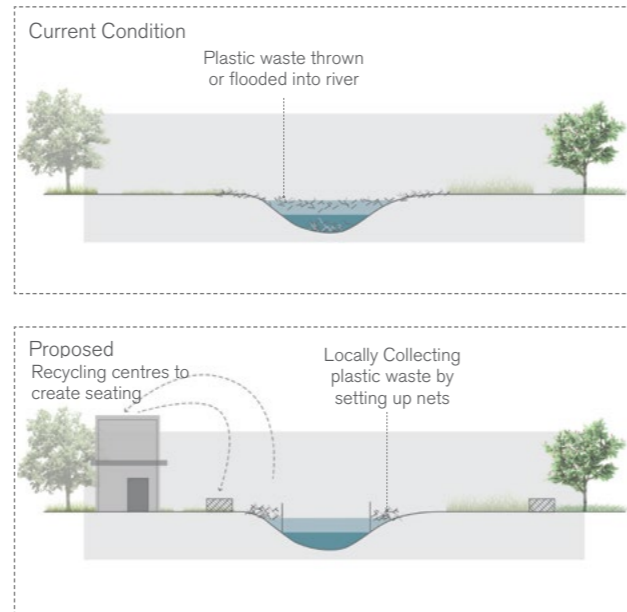


Fig. 101. Current -Proposed section for Action 2 (Regional Strategy 4)

### What it means at Metropolitan Scale?

- Sorting of waste before dumping on grounds near the river.
- Identifying hot spots for possible waste entry in the river and setting up bars to filter plastic (often before and after the water passes close to the city)

### What it means at Local Scale?

- Setting up booms to filter water in the river from plastic waste.
- Promoting recycle factories for each city to collect and recycle waste locally.

## Stakeholder Engagement

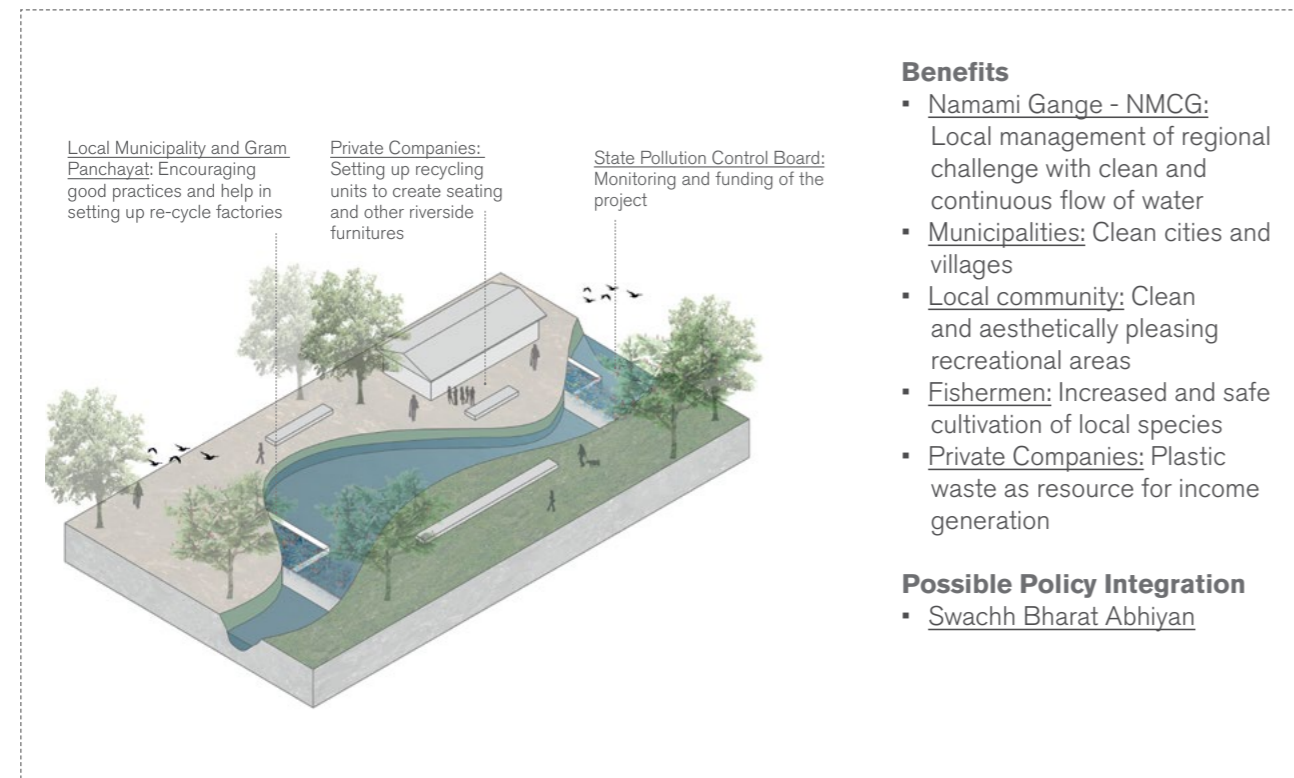


Fig. 102. Stakeholder Engagement for Action 2 (Regional Strategy 4)

### Benefits

- **Namami Gange - NMCG:** Local management of regional challenge with clean and continuous flow of water
- **Municipalities:** Clean cities and villages
- **Local community:** Clean and aesthetically pleasing recreational areas
- **Fishermen:** Increased and safe cultivation of local species
- **Private Companies:** Plastic waste as resource for income generation

### Possible Policy Integration

- **Swachh Bharat Abhiyan**

## Regional Plan for Action

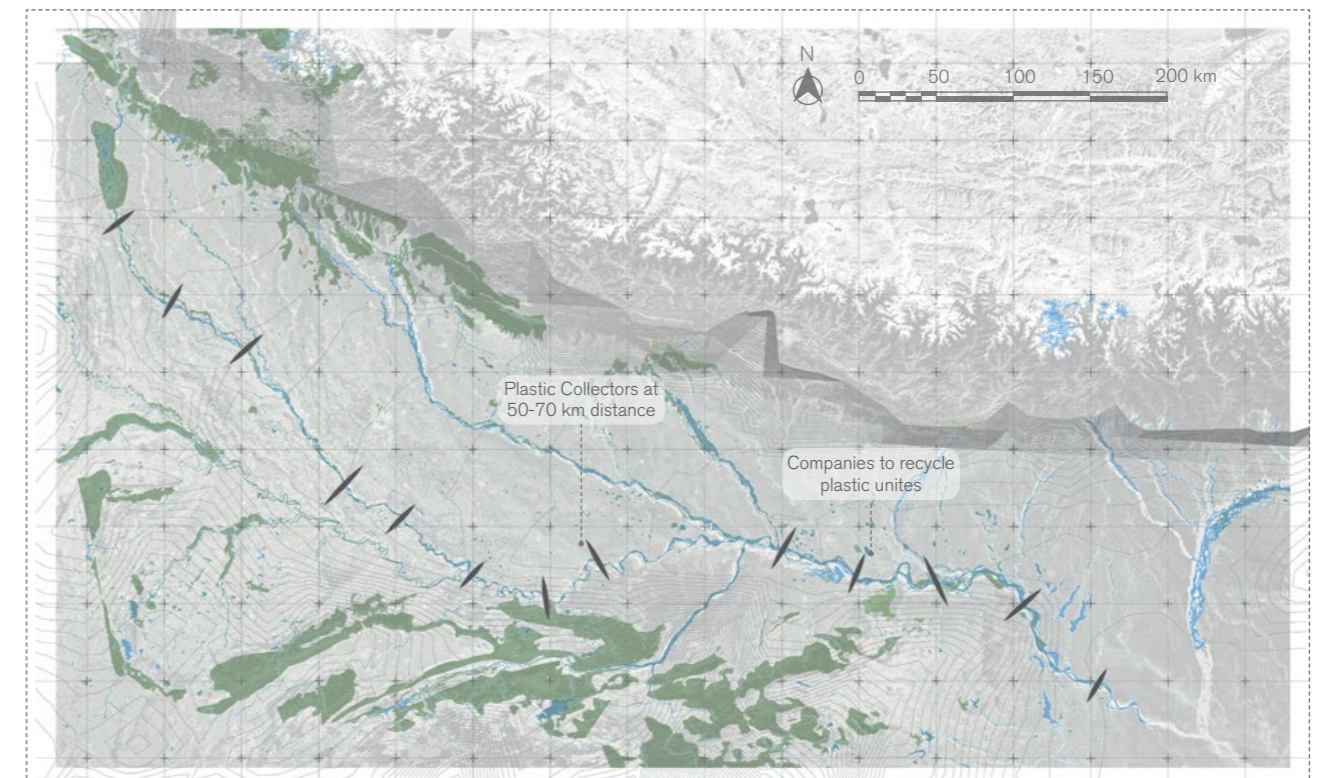


Fig. 103. Spatial Plan for Action 2 (Regional Strategy 4)



## Spatial Actions and Design Interventions

### 3. Reed Plantation

A high amount of agricultural run-off is flown into the river. With the increased use of insecticides and pesticides, the run-off water causes danger to aquatic life. This pollution is non-point source pollution and enters the river through unaccountable paths. Thus to protect the river from the risk of chemicals, reed plantation shall be carried out on the edges. These plantation helps to reduce the pollution levels and oxygenate water before entering the river.

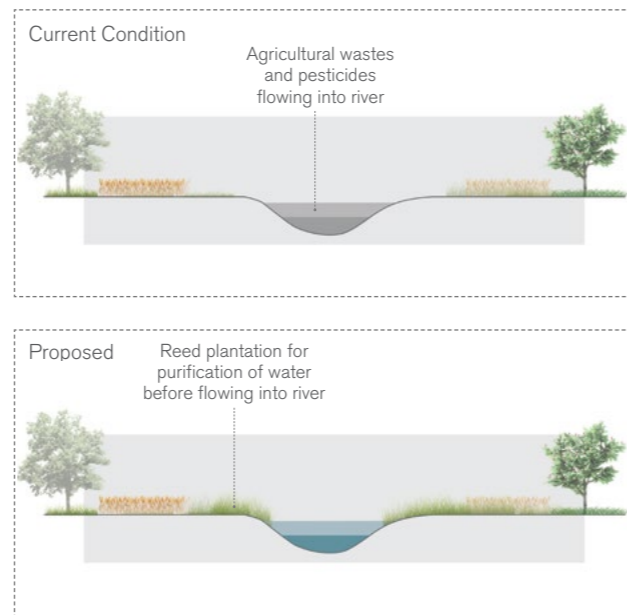


Fig. 104. Current -Proposed section for Action 3 (Regional Strategy 4)

### What it means at Metropolitan Scale?

- Marking flow directions and identifying immediate impact zones.

### What it means at Local Scale?

- Collaborating with farmers for plantation and maintenance of reed along streams and rivers from the basin.

## Stakeholder Engagement

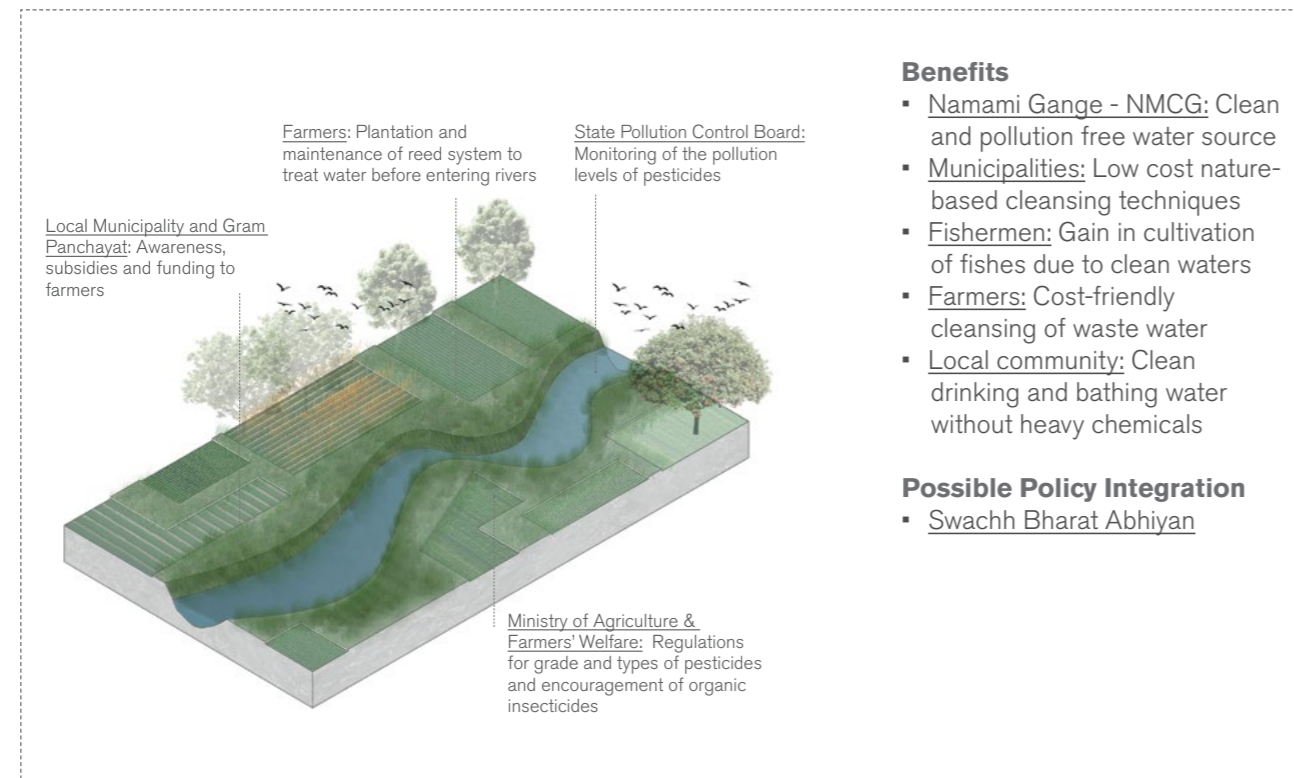


Fig. 105. Stakeholder Engagement for Action 3 (Regional Strategy 4)

## Regional Plan for Action

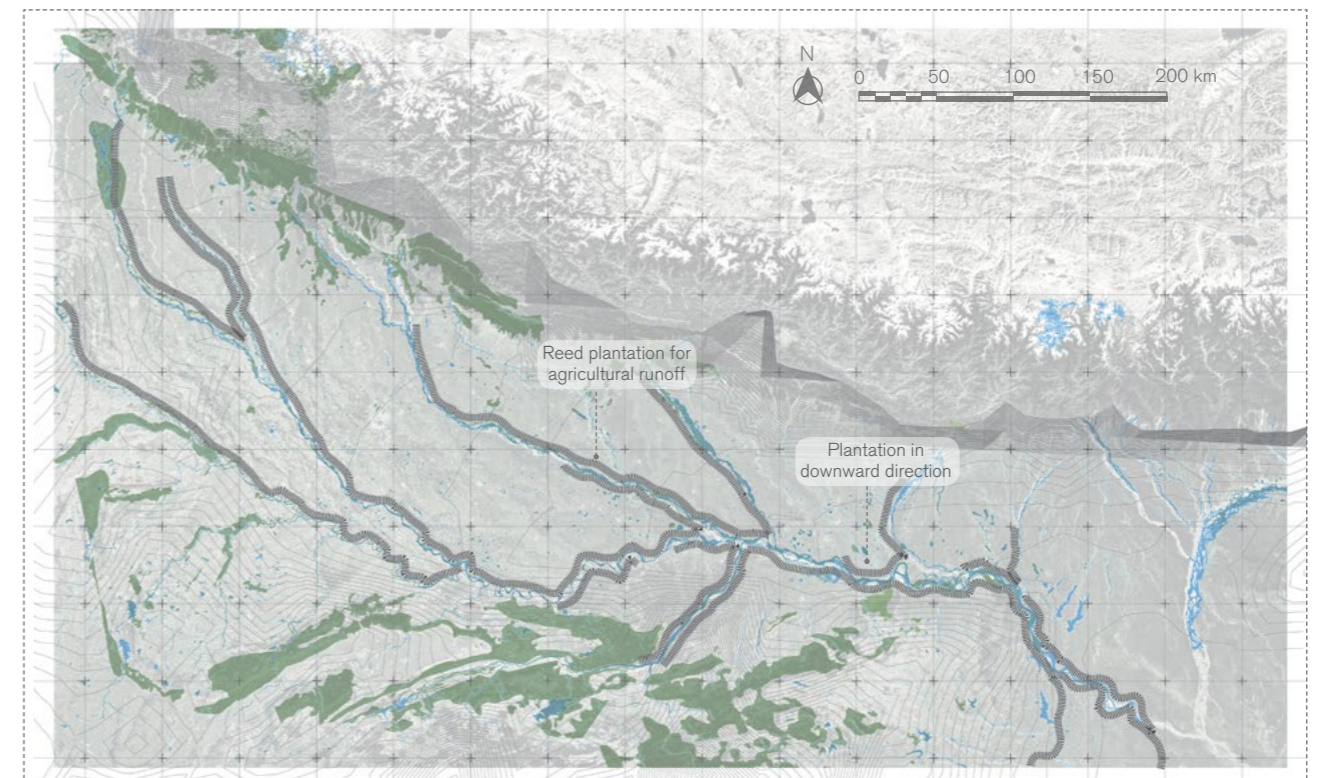


Fig. 106. Spatial Plan for Action 3 (Regional Strategy 4)



## Spatial Actions and Design Interventions

### 4. Building polishing ponds for industries

Tannery and Paper Pulp industries two of the most common industries located on the banks of river Ganges. With no proper regulations and required infrastructures, these industries dump waste directly into the river. This has led to a high amount of arsenic and fluoride in the water. Setting up in-house treatment plants and building polishing ponds can help in reducing chemical contents in wastewater before releasing it in the river.

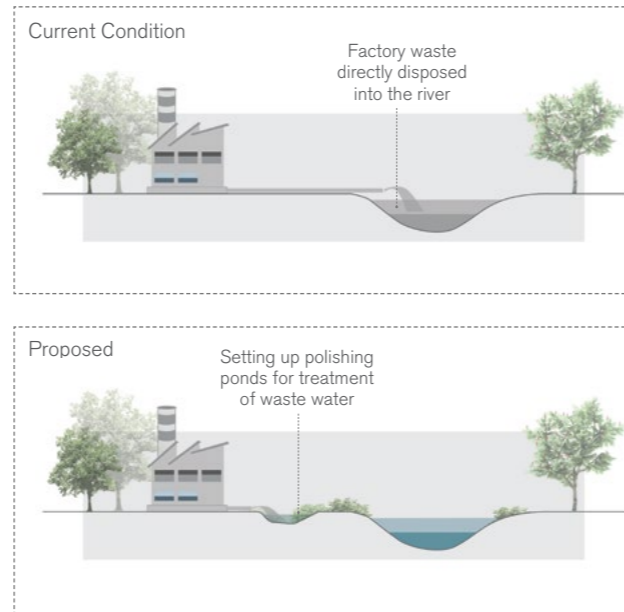


Fig. 107. Current -Proposed section for Action 4 (Regional Strategy 4)

### What it means at Metropolitan Scale?

- Regulating industries and monitoring the pollutant levels before it enters the river.

### What it means at Local Scale?

- Each industry to construct a polishing pond and check water pollution levels before it enters the river system.

## Stakeholder Engagement

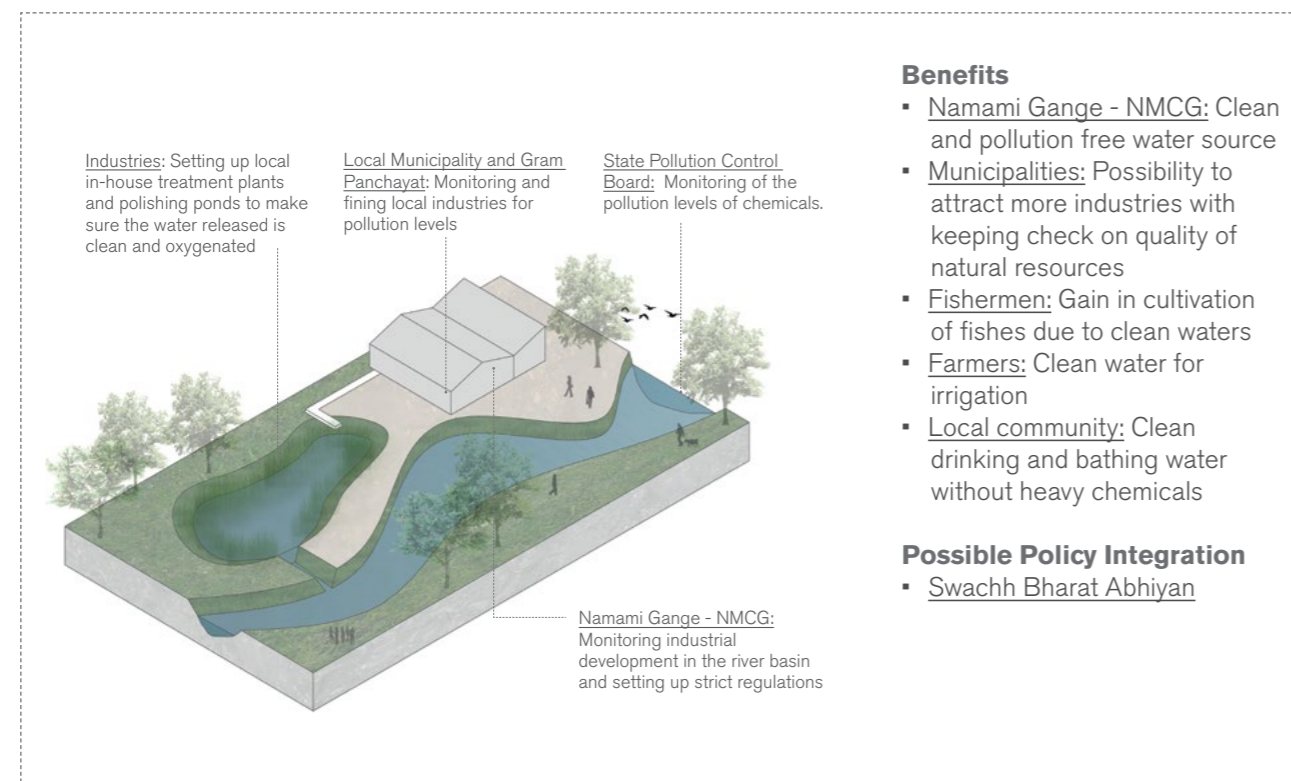


Fig. 108. Stakeholder Engagement for Action 4 (Regional Strategy 4)

## Regional Plan for Action

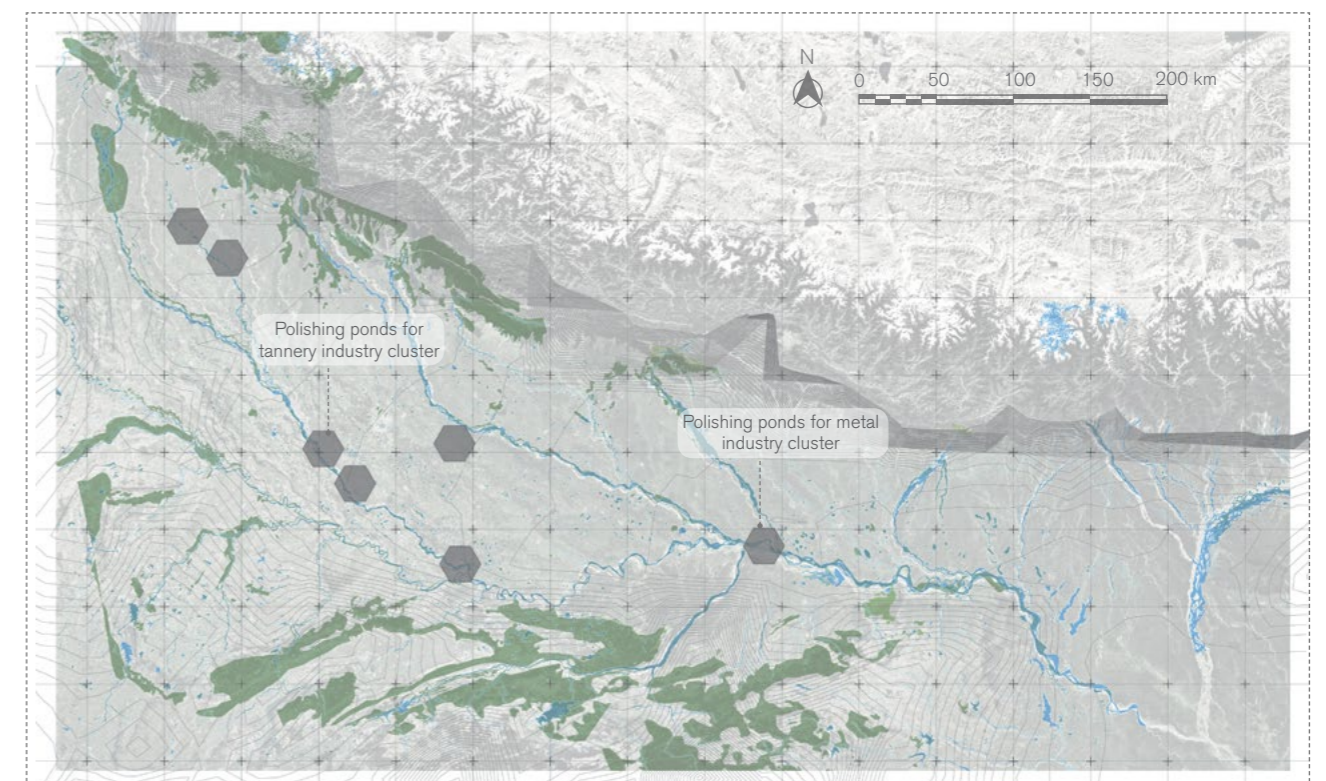
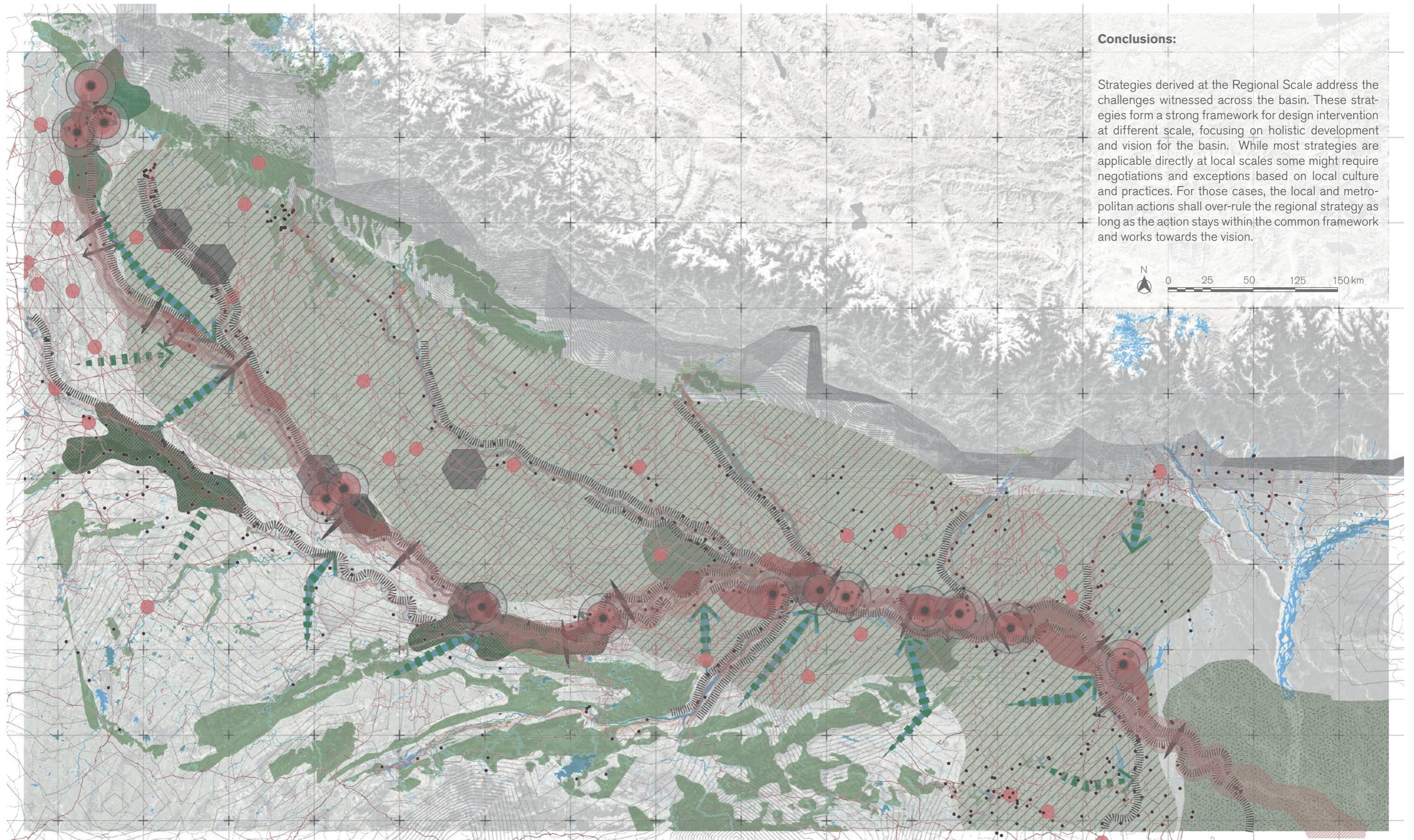


Fig. 109. Spatial Plan for Action 4 (Regional Strategy 4)

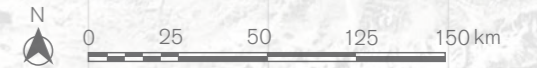


### 7.3. STRATEGIC PLAN FOR THE GANGES RIVER BASIN



#### Conclusions:

Strategies derived at the Regional Scale address the challenges witnessed across the basin. These strategies form a strong framework for design intervention at different scale, focusing on holistic development and vision for the basin. While most strategies are applicable directly at local scales some might require negotiations and exceptions based on local culture and practices. For those cases, the local and metropolitan actions shall over-rule the regional strategy as long as the action stays within the common framework and works towards the vision.







# 8 Metropolitan Scale Strategies and Design

This chapter further lays down a more detailed framework of strategies at a metropolitan scale based on the its context, activities carried out in the cities and actors involved. There strategies fall under the larger framework of Regional Strategies but are more specific. The strategies at this scale will differ for each metropolitan area based on its location and requirements as per cultural practices prevailing in the region within the basin. In this chapter metropolitan scale strategies for Patna metropolitan area is formulated as it is one of the most vulnerable metropolitan in the river basin.



Understanding Problem Field

Chapter 2

- Current Challenges in Ganges River Basin
- Drivers of Change
- Governance Challenges for Ganges River Basin

Introduction

Chapter 1

- Context
- Relationship between human systems and ecological systems

Chapter 3

- Socio-ecological vulnerability analysis across scales
- Problem Statement (Spatial Justice)
- Line of Inquiry:
  1. Dual Nature of Externalities
  2. Capital

Chapter 4

- Theories:
  1. Urbanization
  2. Vulnerability
  3. Resilience Thinking
  4. Social Capital and Governance
- Notions:
  1. Interdependence - Integration
  2. Infrastructure Ecology
  3. Evolutionary Resilience

Research Methodology

Chapter 5

- Conceptual Framework: Adaptive Spatial Planning Model

Vision

Chapter 6

- Principles
  1. Robustness
  2. Adaptivity
  3. Connectedness
  4. Diversity
- Frame of Reference
  1. Knowledge of System Behaviour
  2. Dynamic Adaptive Planning Pathways
  3. Stakeholder Collaboration
- Systemic Goals

Design

Chapter 7

Regional Strategies

Mitigation Strategies that are derived for challenges across the basin

Evaluation

Chapter 10

Scenarios

- Case 1
- Case 2
- Case 3

Chapter 8

Metropolitan Scale Strategies

Mitigation Strategies that are derived for challenges for metropolitan scale

Chapter 9

Local Adaptation

Adaptation of multiple strategies to achieve resilience

1. Urban
2. Peri-Urban
3. Rural

Adaptive Planning Pathways



## 8.1. CHALLENGES AT METROPOLITAN SCALE OF PATNA



Image (an): Sewage flowing into river at Patna  
Source: Author

### 1. Lack of Infrastructure (Sewage and Water Supply)

The Patna Metropolitan Region lacks basic infrastructure for water supply and sanitation. There are no proper water supply lines across the city and the majority of the population depends on private bore pumps for water supply. Setting up of pumps is expensive and it also reduces groundwater levels to a great extent, making accessibility to safe drinking water more difficult. On the other, infrastructure for drainage of rainwater and sewage is also not adequate. Open drainage lines run through the city, directly entering the river, creating unhygienic conditions for living.



Image (ap): Dense Urban Centers  
Source: Author

### 3. Relationship of the city with the river

Currently the city of Patna is facing away from the river, losing on the opportunity on gaining benefits from the river context. The access routes to the river are not well constructed, and lack activities to attract public. With lack of interaction, the city tends to neglect its importance and potential in alleviating social and ecological vulnerabilities.



Image (ao): Building over natural streams  
Source: Author

### 2. Dense Urban Fabrics and Loss of green-blue networks

The need to expand the city and fulfill demands for housing has led to cover natural streams canals. Covering streams leads to fragmentation of small scale water networks and hampers the easy flow of water especially drainage of rainwater during monsoon. Moreover, to extend urban growth parks and water bodies encroach. These actions not only lead to a high probability for flooding but also cause loss of local species of plants and animals and disturbances in the local ecology.



Image (aq): Water Pollution at Kanpur discharged in the river  
Source: Author

### 4. Lack of Industries (Agro)

The Ganges River basin is highly cultivated, yet the region of Bihar especially the Patna Metropolitan lacks the presence of industries. With no industries or processing units, raw produce is exported out. With this opportunity for economic development and employment, creation is also lost. Thus developing agro-industries can help in reducing social vulnerabilities while also positively impacting agricultural production.



## 8.2. STRATEGIES FOR SOCIO-ECOLOGICAL RESILIENCE AT METROPOLITAN SCALE



Image (ar): Rain-water harvesting streetscape  
Source: greywateraction, edited by author

### 1. Using Infrastructure networks for integrated socio-ecological development



**MS1**

The Patna Metropolitan Region is currently undergoing development in terms of newly added infrastructure networks. Several roads within the city are under construction. This opens up the opportunity to integrate rainwater harvesting, planter beds and multi-utility tunnels with separate sewage and stormwater drains. Thus, making the new infrastructure more resilient to current and future needs.



Image (as): Living with wetlands  
Source: L. Ulrich, 2030palette.org, edited by author

### 2. Designing of performative landscape for ecological and socio-economic benefits



**MS2**

Even small interventions within the landscape can create a huge impact on achieving mitigation against the changing climate. Currently, this aspect of planning within the Patna Metropolitan has not been given enough attention, leading to unplanned development and encroachment of lakes, streams and green patches. Therefore, focusing on the benefits of the performative landscape within the city could help achieve resilience.



Image (at): Waterfront promenade on Kungsholmen  
Source: Suneet Mohindru. Pintrest, edited by author

### 3. Activating River Edge



**MS3**

With an active water edge, more awareness and actions can be carried out to establish a relationship with the river. Programs like retail and restaurants can earn from the benefits of increased activities along the river. With activating river edge the amount of space available for recreation increasing greatly, making the city more liveable and potential to attract tourists, boosting its economy.



Image (au): Agro Industries  
Source: MYSILO, edited by author

### 4. Establishing Agro industries and small scale industries



**MS4**

The development of industries plays a crucial role in the economic and social growth of the city. Agriculture remains the primary occupation for the state of Bihar. Thus, with the establishment of agro-industries, within the vicinity of farms, the agriculture and process can increase. This would help in providing farmers with better rates for their products and increase job opportunities for locals.



### 8.2.1. Strategy 1: Using Infrastructure networks for integrated socio-ecological development





## Spatial Actions and Design Interventions

### 1. Multi-utility underground tunnels

With the Namami Gange initiative, the construction of sewage systems is being carried out in major areas of the city. This opens the opportunity to build a multi-utility tunnel catering to all necessary services, like water supply and drainage. Designing for a single tunnel makes maintenance and services easy during crises like flooding. Moreover, the system can also incorporate rainwater harvesting systems and storm-water drains.

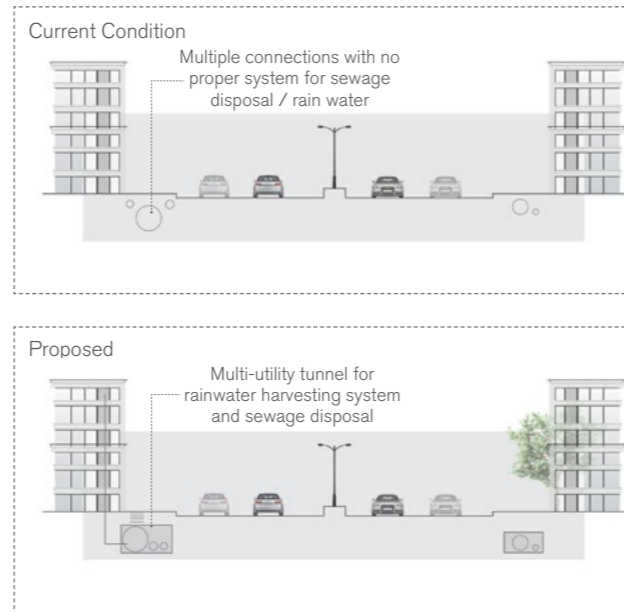


Fig. 110. Current -Proposed section for Action 1 (Metropolitan Strategy 1)

### What it means at Regional Scale?

- Guidelines to include services in a single multi-utility tunnel. (Which services can be paired together and how to locate them within the tunnel)

### What it means at Local Scale?

- Connecting every plot with the multi-utility tunnel. (Sewage, Rain-water)

## Stakeholder Engagement

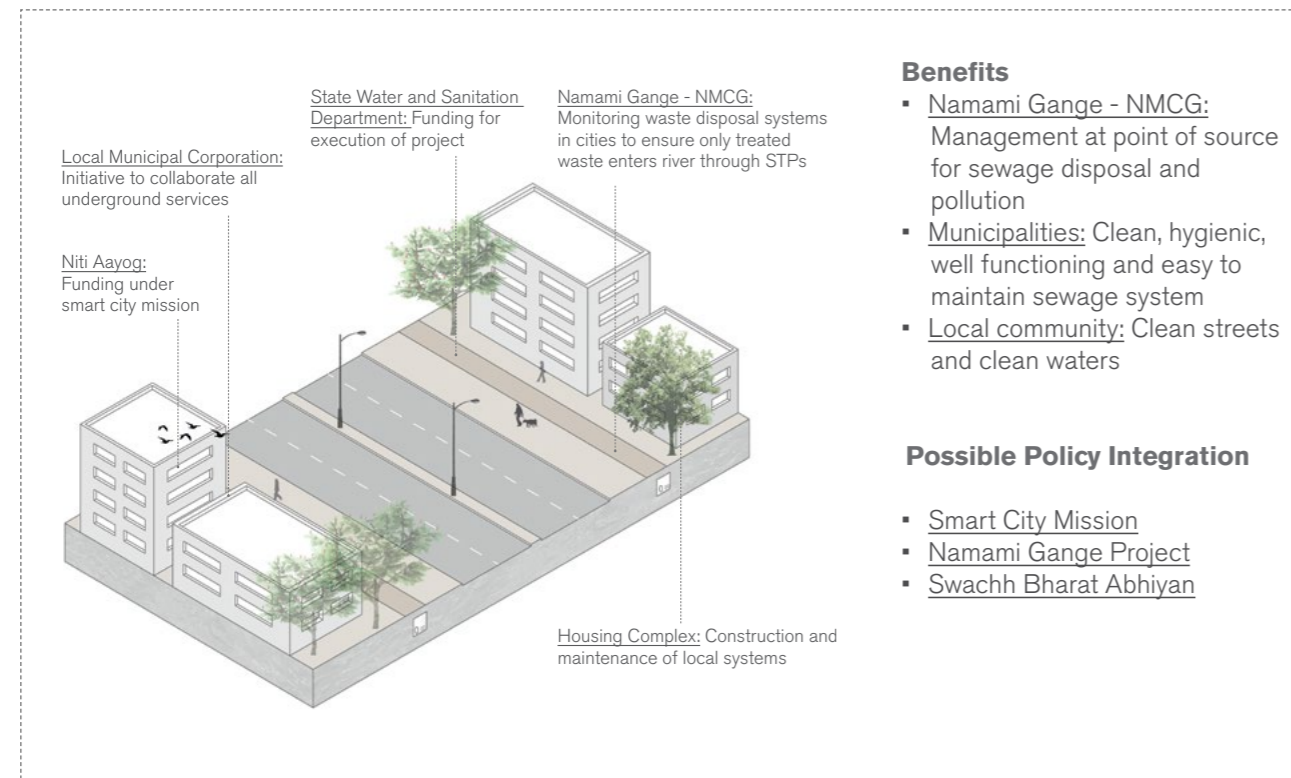


Fig. 111. Stakeholder Engagement for Action 1 (Metropolitan Strategy 1)

## Strategic Plan for Action



Fig. 112. Spatial Plan for Action 1 (Metropolitan Strategy 1)



## Spatial Actions and Design Interventions

### 2. Setting up storm-water harvesting network

Open rainwater drains running through the city create serious threats to the hygiene conditions. Instead designing for planter beds along the street can not only help in harvesting rainwater but also cater plantation for added value to the streets and shaded footpaths.

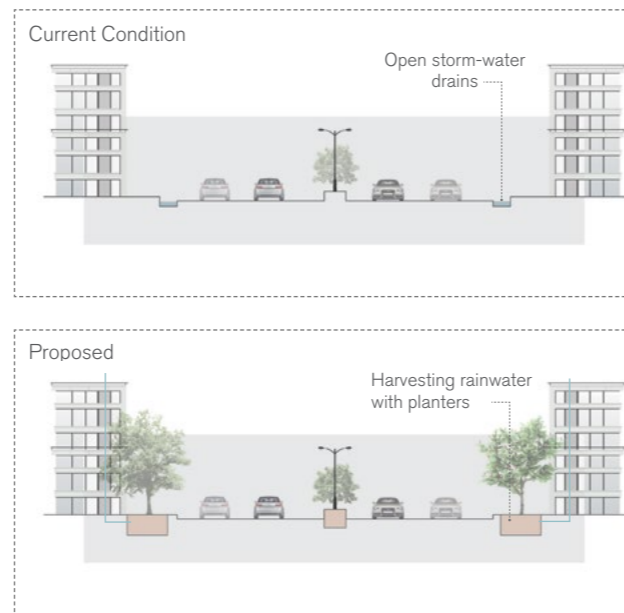


Fig. 113. Current -Proposed section for Action 2 (Metropolitan Strategy 1)

### What it means at Regional Scale?

- Guidelines and regulations on rainwater harvest to include in disaster management and water resource policies.

### What it means at Local Scale?

- Connecting every building and terraces with planter bed (and stormwater network)

## Stakeholder Engagement

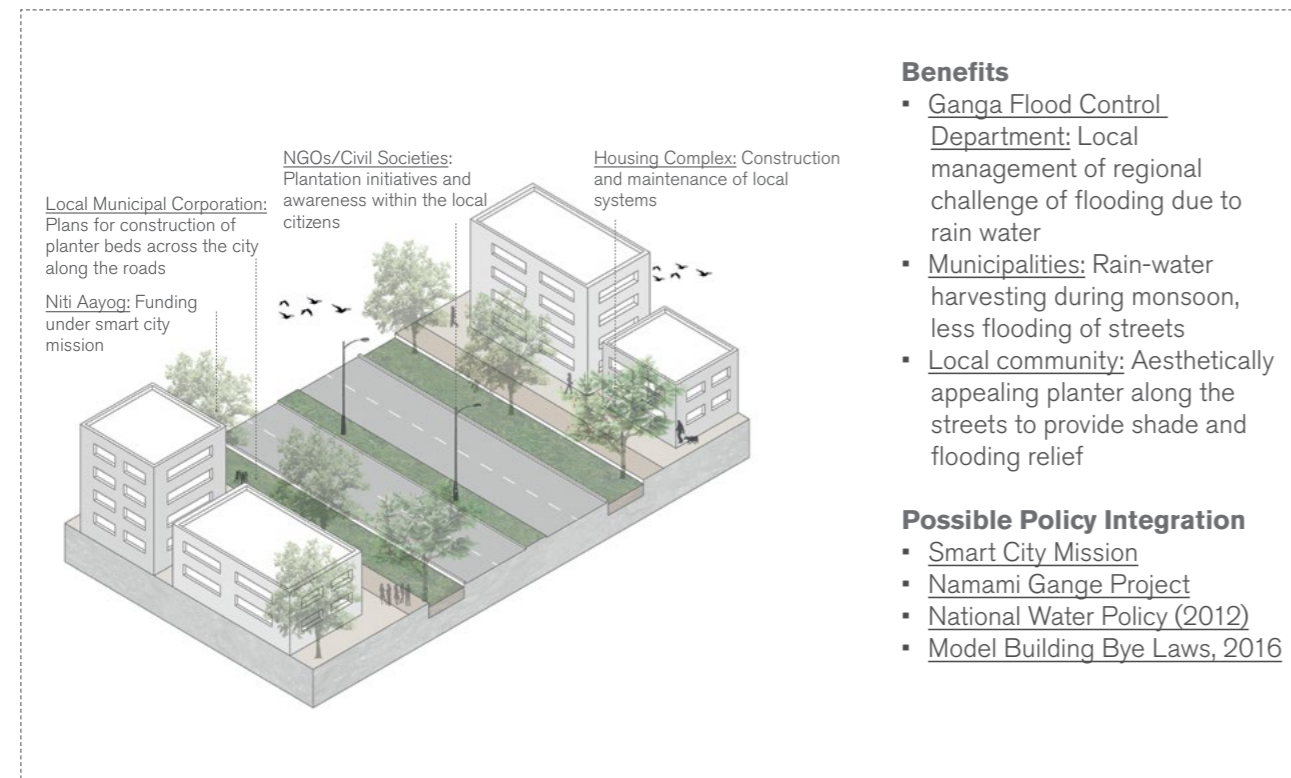


Fig. 114. Stakeholder Engagement for Action 2 (Metropolitan Strategy 1)

## Strategic Plan for Action



Fig. 115. Spatial Plan for Action 2 (Metropolitan Strategy 1)



## Spatial Actions and Design Interventions

### 3. Planter-beds and pocket parks along streets.

Planter beds and pocket parks can help in local absorption of rainwater as well as create public spaces that are easily accessible to all. Thus with narrowing of wider streets or creating wider footpaths while developing new areas can facilitate the integration of pocket parks into planning.

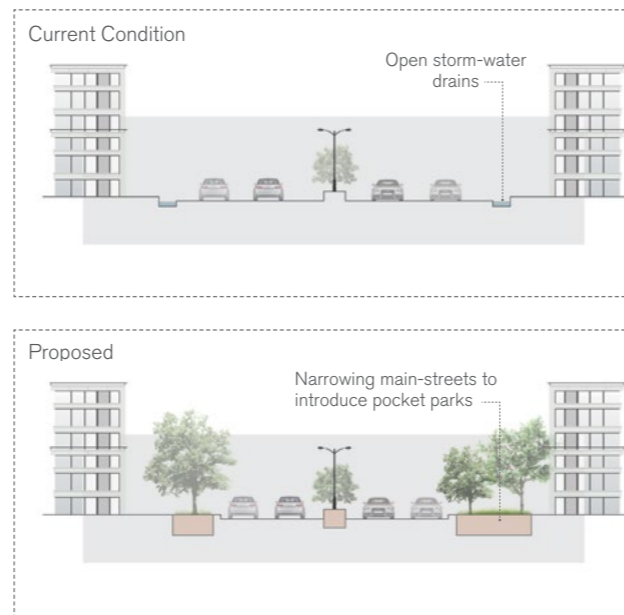


Fig. 116. Current -Proposed section for Action 3 (Metropolitan Strategy 1)

### What it means at Regional Scale?

- Plan highways and rail routes with sufficient buffer for water absorption.

### What it means at Local Scale?

- Reducing road widths and offsetting plots to create wider footpaths and pocket parks where possible. (Especially on main streets)

## Stakeholder Engagement

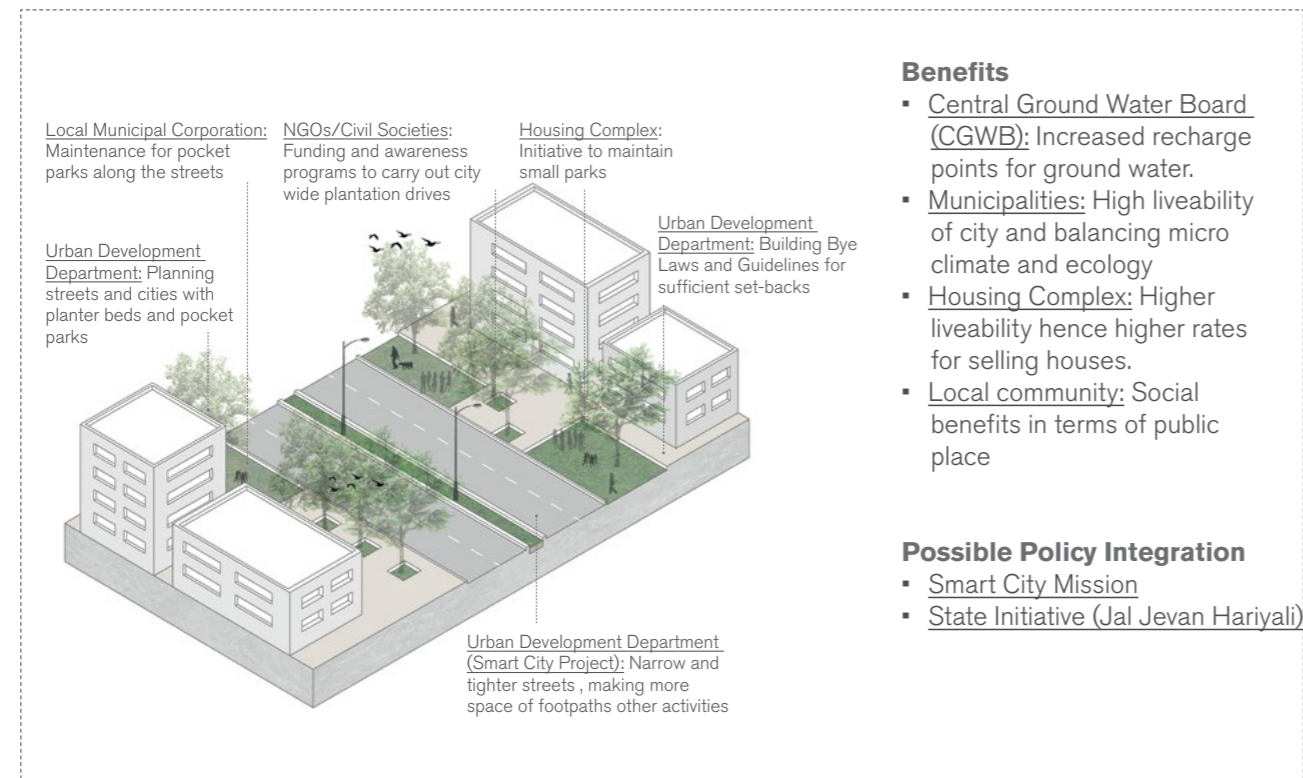


Fig. 117. Stakeholder Engagement for Action 3 (Metropolitan Strategy 1)

## Strategic Plan for Action



Fig. 118. Spatial Plan for Action 3 (Metropolitan Strategy 1)



## Spatial Actions and Design Interventions

### 4. Adopting pervious material palette.

Approximately 70% of the ground is covered with impervious paving like concrete or tar. This causing increase in surface water run-off with an extremely low recharge of groundwater. With more and more extraction of groundwater in the city, it is important to recharge groundwater during monsoons. Hence, adopting previous material will allow the absorption of water. This will also reduce the heat island effect caused due to the heating of hard surfaces.

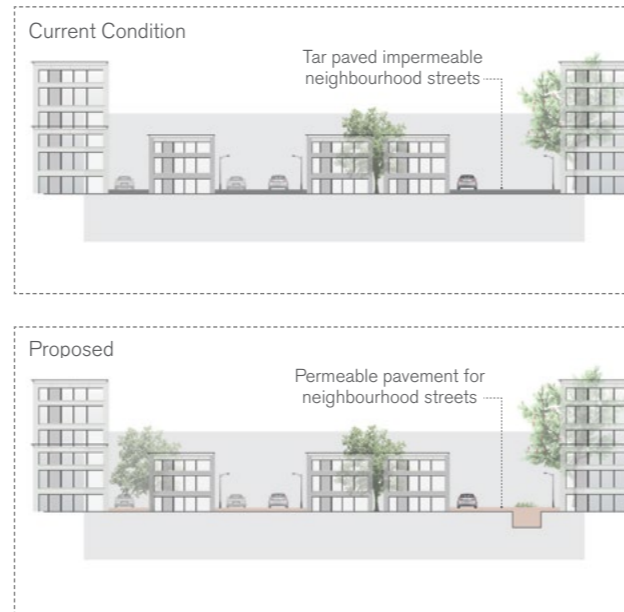


Fig. 119. Current -Proposed section for Action 4 (Metropolitan Strategy 1)

### What it means at Regional Scale?

- Restriction on the construction of cement and tar roads for neighbourhoods. National policies to adopt paver blocks for paving in small neighbourhoods

### What it means at Local Scale?

- Collaborating with societies and setting up PPP (40-60% cost benefits) to pave roads with paver blocks.

## Stakeholder Engagement

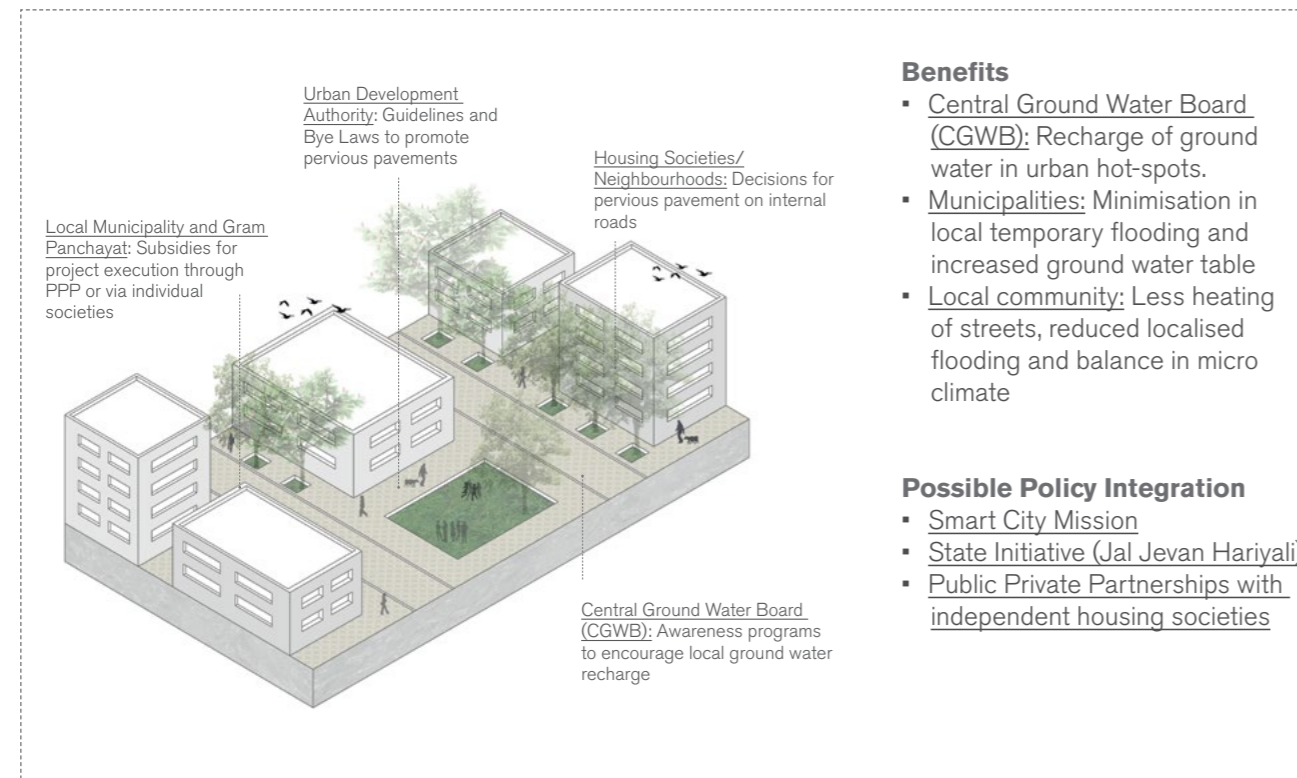


Fig. 120. Stakeholder Engagement for Action 4 (Metropolitan Strategy 1)

## Strategic Plan for Action



Fig. 121. Spatial Plan for Action 4 (Metropolitan Strategy 1)



8.2.2. Strategy 2: Designing of performative landscape for ecological and socio-economic benefits





## Spatial Actions and Design Interventions

### 1. Connecting green patches

While independent landscape patches are important for the maintenance of micro temperature and water absorption, a connected network of patches helps in the building of the ecosystem. These connections can be either connection on the ground through planter beds or connections of tree canopies to allow the flow of the ecosystem. Planting trees on streets can help in achieving this continuous network.

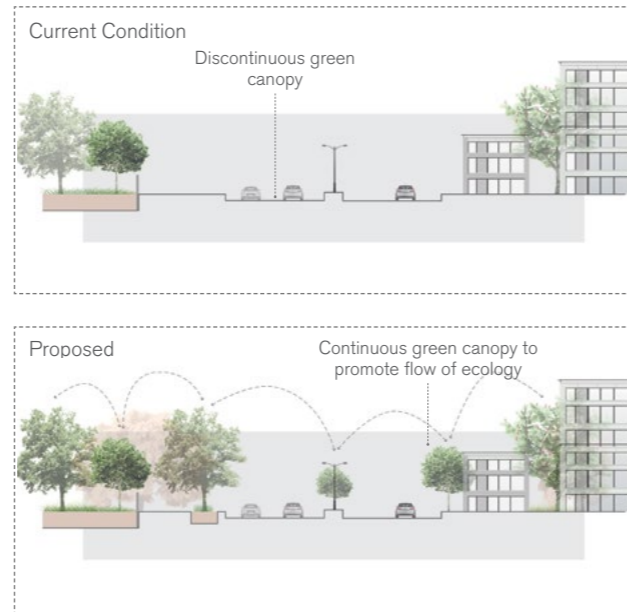


Fig. 122. Current -Proposed section for Action 1 (Metropolitan Strategy 2)

### What it means at Regional Scale?

- Awareness and importance of connected green spaces and green fingers

### What it means at Local Scale?

- Tree plantation, adding small patches of planters, parks within the network

## Stakeholder Engagement

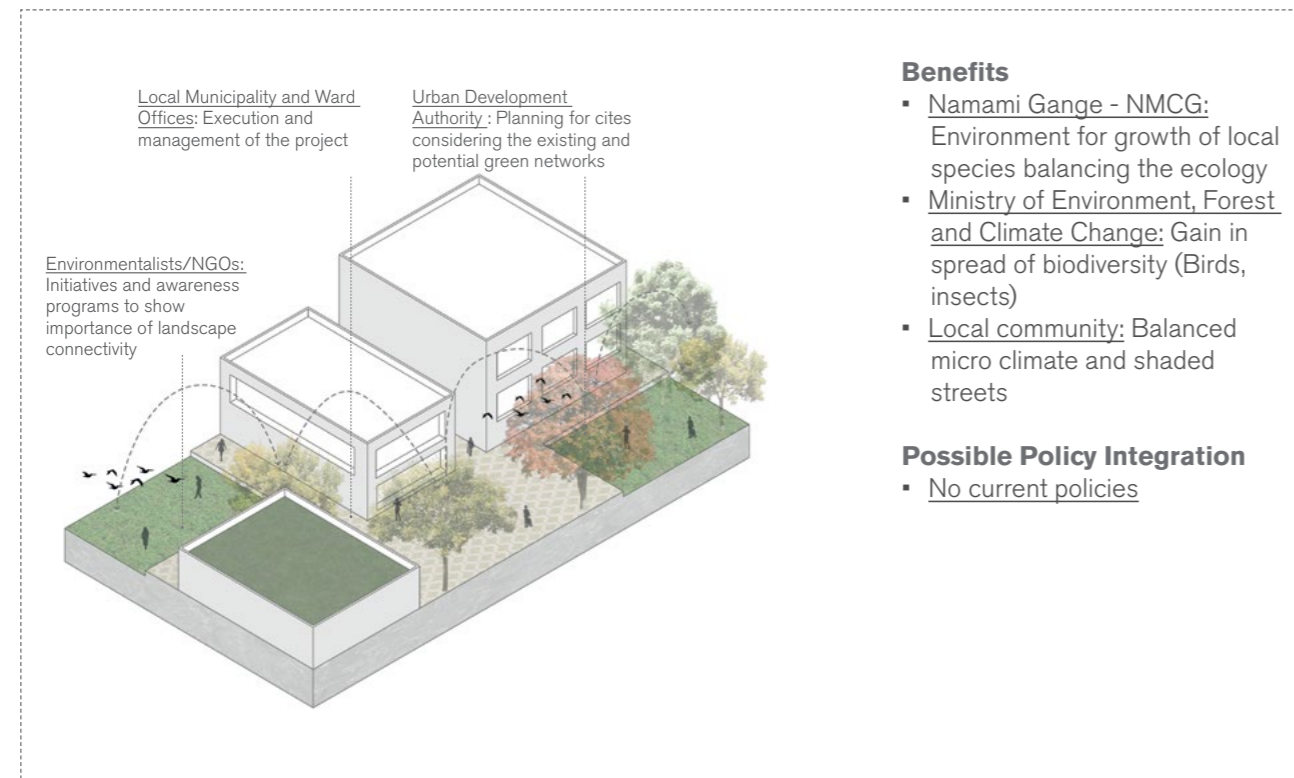


Fig. 123. Stakeholder Engagement for Action 1 (Metropolitan Strategy 2)

## Strategic Plan for Action



Fig. 124. Spatial Plan for Action 1 (Metropolitan Strategy 2)



## Spatial Actions and Design Interventions

### 2. Daylighting water canals and natural streams

Several irrigation canals, drainage canals and natural streams run through the city. Constantly increasing land prices and pressure has forced towards covering of these canals in certain sections for development. This has caused in broken network off water drainage as well as led to degradation of water quality due to lack of exposure to oxygen and light. Daylighting of canals will help in re-establishing the drainage network and also revive the ecosystem.

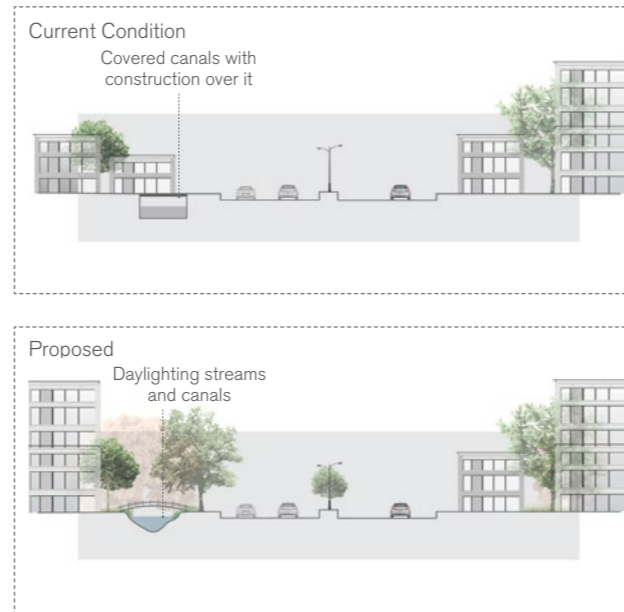


Fig. 125. Current -Proposed section for Action 2 (Metropolitan Strategy 2)

### Stakeholder Engagement

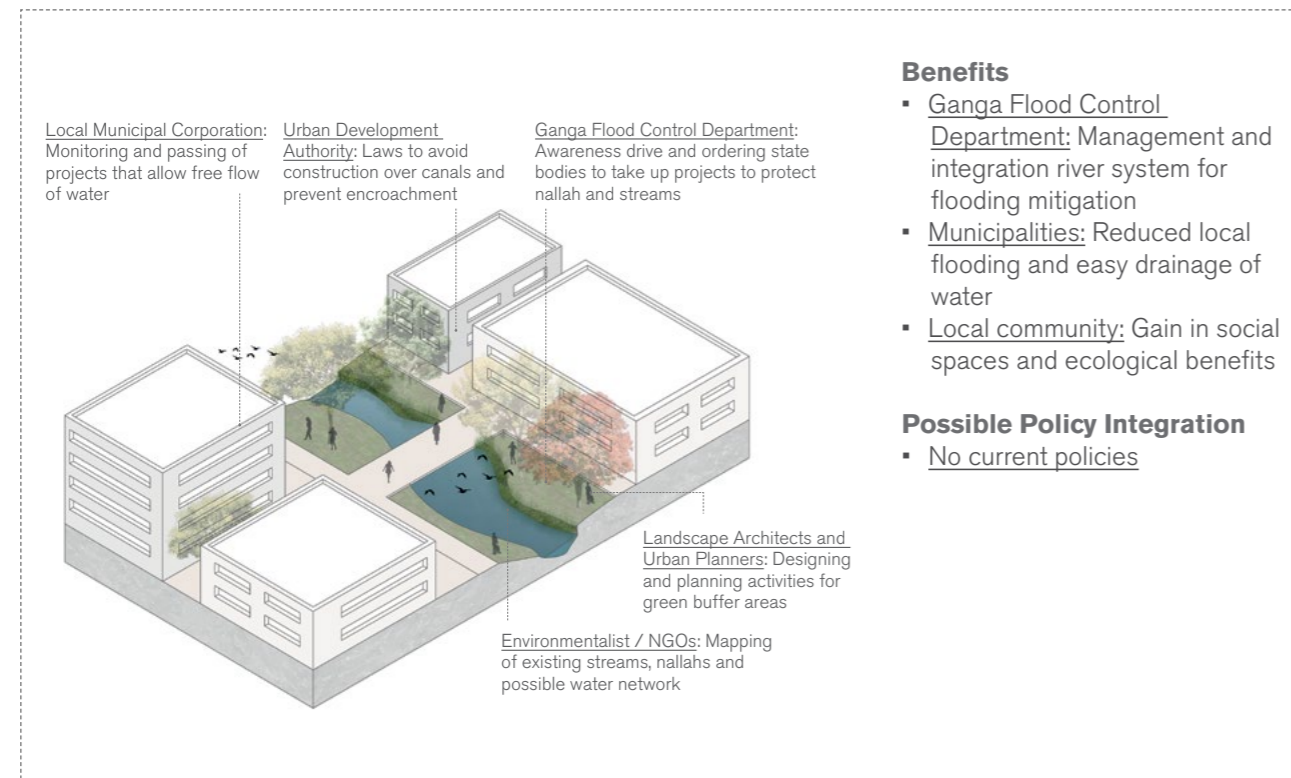


Fig. 126. Stakeholder Engagement for Action 2 (Metropolitan Strategy 2)

### What it means at Regional Scale?

- Regulations and policies to maintain natural streams and canals during the development of cities

### What it means at Local Scale?

- Moving away constructions on the stream, designing for canals and streams to become public places and parks.

- Special by-laws for buildings near/on canals and streams. (eg: using stilts to allow a flow of water.)

### Strategic Plan for Action



Fig. 127. Spatial Plan for Action 2 (Metropolitan Strategy 2)



## Spatial Actions and Design Interventions

### 3. Promoting urban farming

Small independent actions like terrace farming also help in achieving resilience. The actions make the community prepared with alternative sources during a crisis, as well as helps in reducing micro temperature due to the increased vegetation.

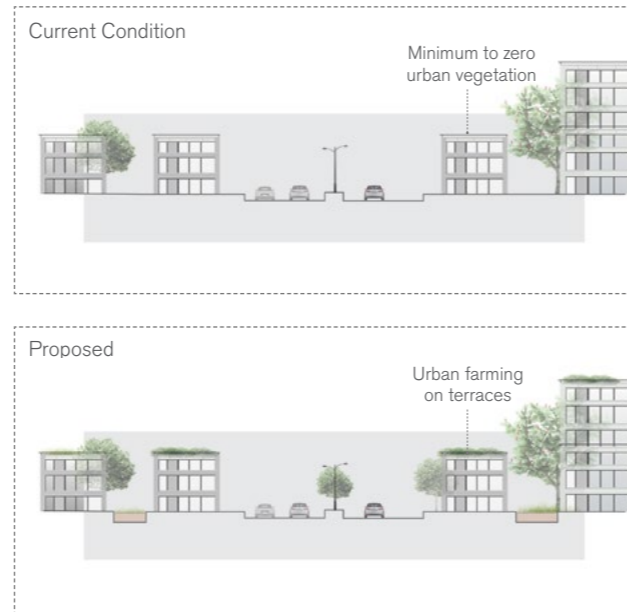


Fig. 128. Current -Proposed section for Action 3 (Metropolitan Strategy 2)

### What it means at Regional Scale?

- Policies to encourage urban farming, subsidies under state schemes.

### What it means at Local Scale?

- Designing buildings to accommodate possibilities for urban farming on terraces, balconies and facades.

## Stakeholder Engagement

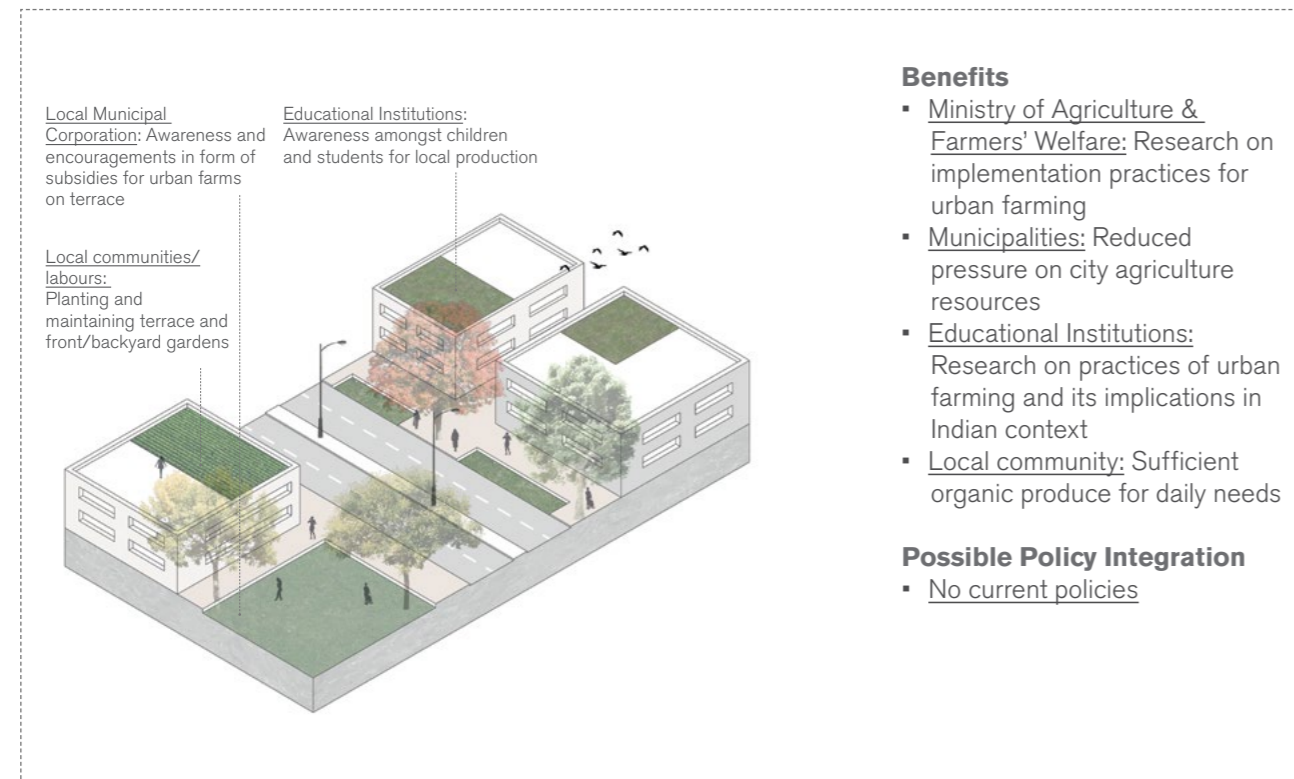


Fig. 129. Stakeholder Engagement for Action 3 (Metropolitan Strategy 2)

## Strategic Plan for Action



Fig. 130. Spatial Plan for Action 3 (Metropolitan Strategy 2)



## Spatial Actions and Design Interventions

### 4. Reclaiming green areas and wetlands

Increasing land demands has led to unplanned development, encroaching wetlands and ponds. By reclaiming the wetlands and green patches, the temporary water storage and biodiversity can be revived, since many migratory birds fly to these wetlands. The challenge of land demand can be addressed with an increasing vertical density of the development which is currently single or double-story.

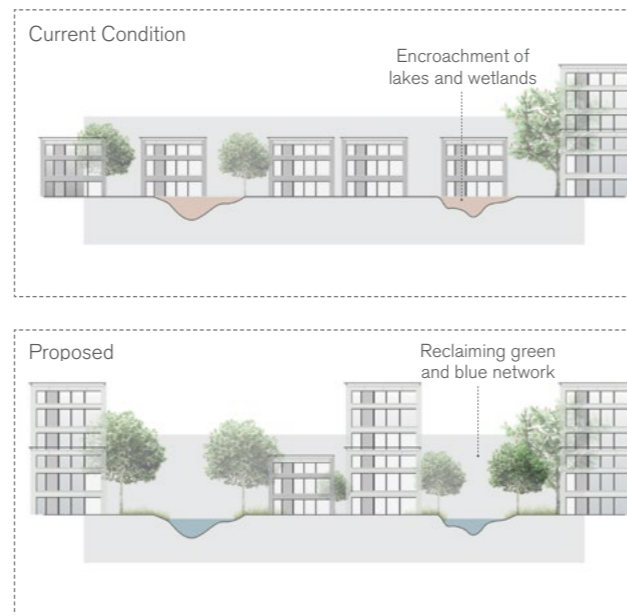


Fig. 131. Current -Proposed section for Action 4 (Metropolitan Strategy 2)

### What it means at Regional Scale?

- Strict regulation and declaration of no development zones to protect wetlands, ponds and lakes.

### What it means at Local Scale?

- Densification around wetlands and ponds to achieve housing capacity, making spaces more ecologically thriving and liveable.

## Stakeholder Engagement

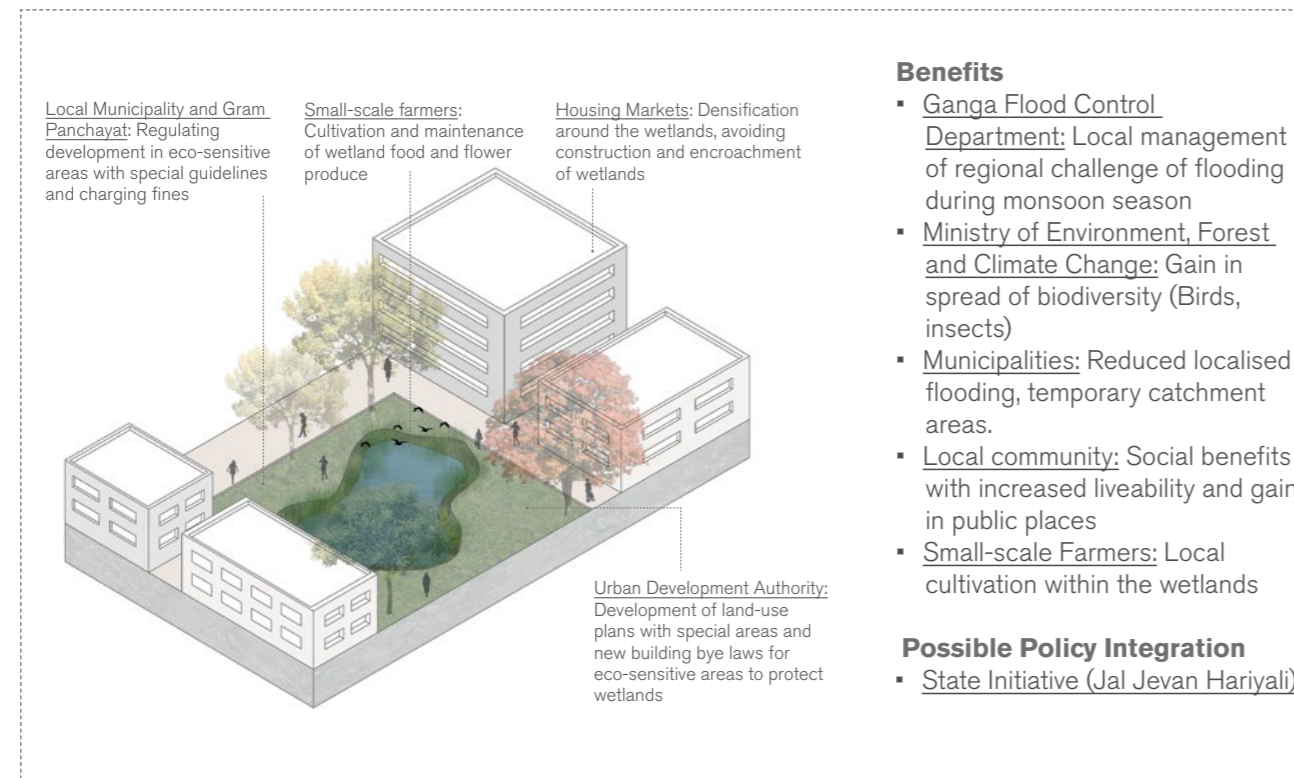


Fig. 132. Stakeholder Engagement for Action 4 (Metropolitan Strategy 2)

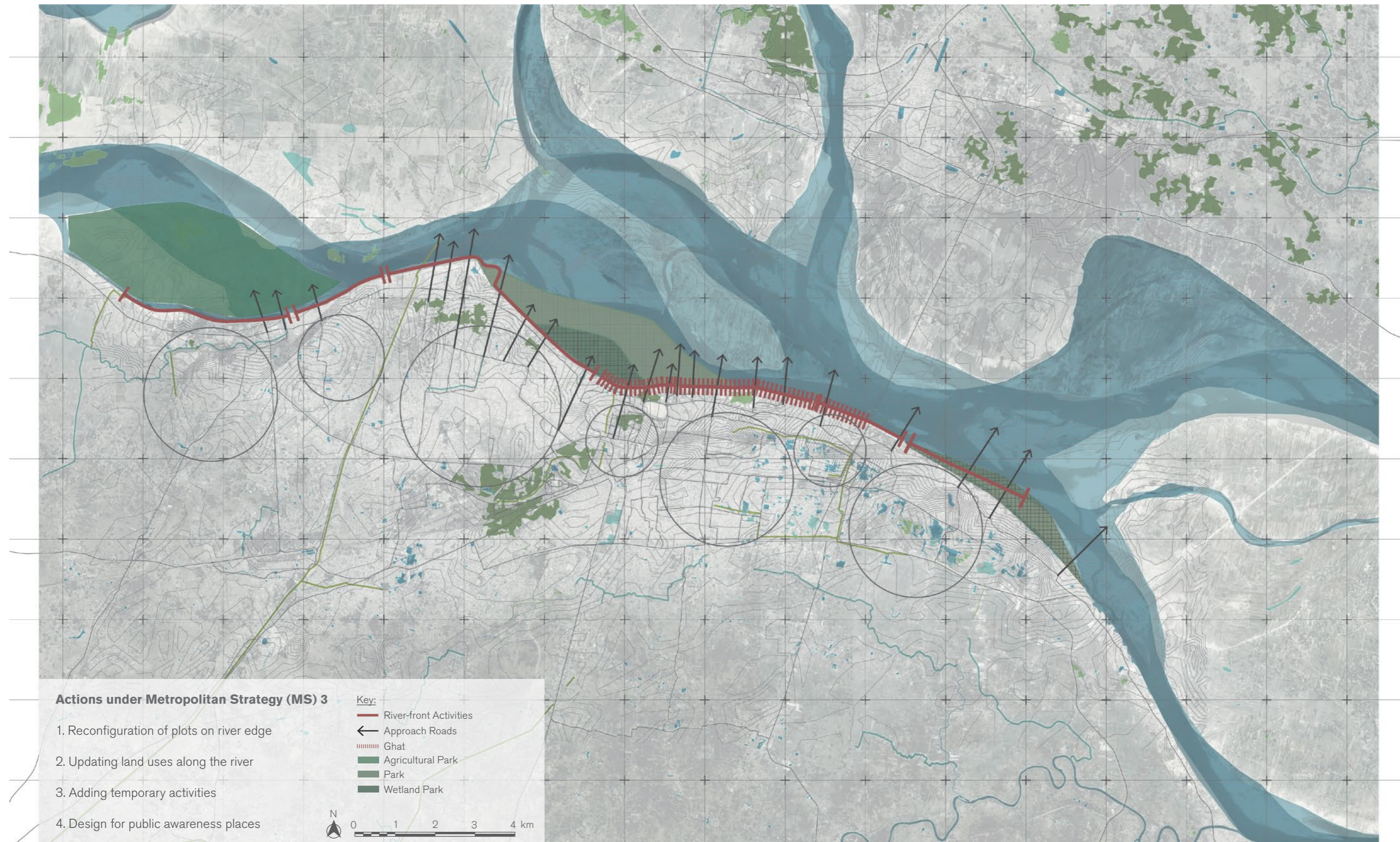
## Strategic Plan for Action



Fig. 133. Spatial Plan for Action 4 (Metropolitan Strategy 2)



8.2.3. Strategy 3: Activating river edge





## Spatial Actions and Design Interventions

### 1. Reconfiguration of plots on river edge

The current layout of the plots along the riverside allows very minimum access to the river-front through narrow unpaved roads. With difficulty in finding easy and safe access, people tend to avoid using riverfront as a public place. Thus, reconfiguration of plots and granting special development rights to immediate plots can increase accessibility to the river.

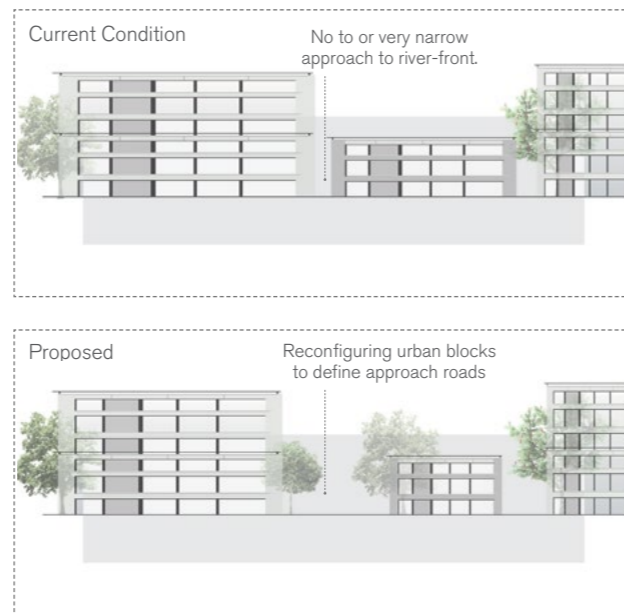


Fig. 134. Current -Proposed section for Action 1 (Metropolitan Strategy 3)

## Stakeholder Engagement

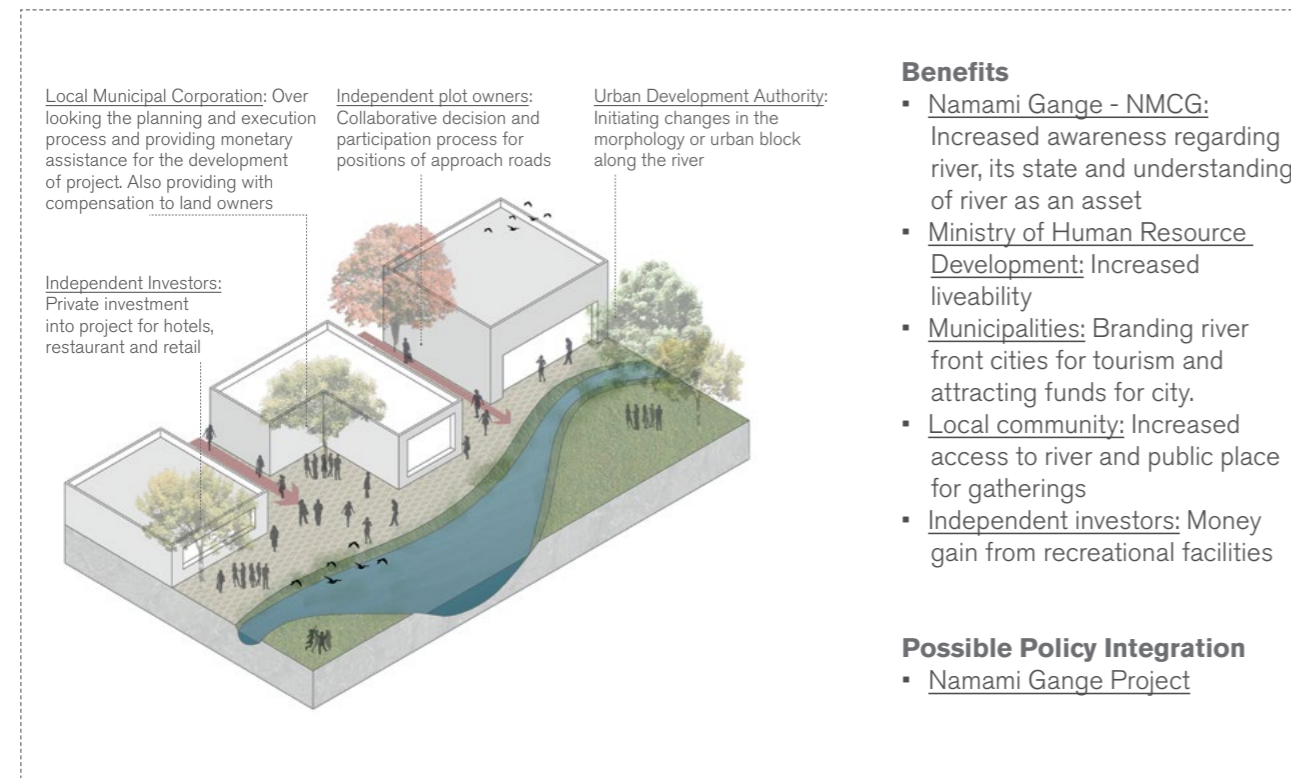


Fig. 135. Stakeholder Engagement for Action 1 (Metropolitan Strategy 3)

## What it means at Regional Scale?

- Schemes and programs for the development of riverfronts for cities along the Ganges River.

## What it means at Local Scale?

- Analysing existing road network to find connection that can be extended to the river.

- Negotiating with landowners to give up land for the development of roads.

## Strategic Plan for Action



Fig. 136. Spatial Plan for Action 1 (Metropolitan Strategy 3)



## Spatial Actions and Design Interventions

### 2. Updating land uses along the river

With mostly only private building located along the river edge, activation of public space becomes more difficult. Updating the land uses to more public functions like restaurant and retail would attract more crowd and help in activating the edge. With active edge function, a healthy relationship between the river and the city can be established.

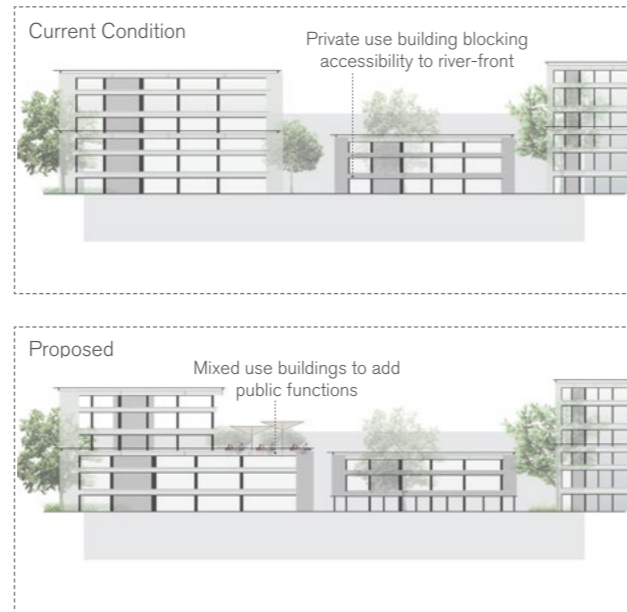


Fig. 137. Current -Proposed section for Action 2 (Metropolitan Strategy 3)

### What it means at Regional Scale?

- Schemes and projects for the development of riverfronts for cities along the Ganges River.

### What it means at Local Scale?

- Collaborating with local stakeholders to build infrastructure to accommodate new activities and program

## Stakeholder Engagement

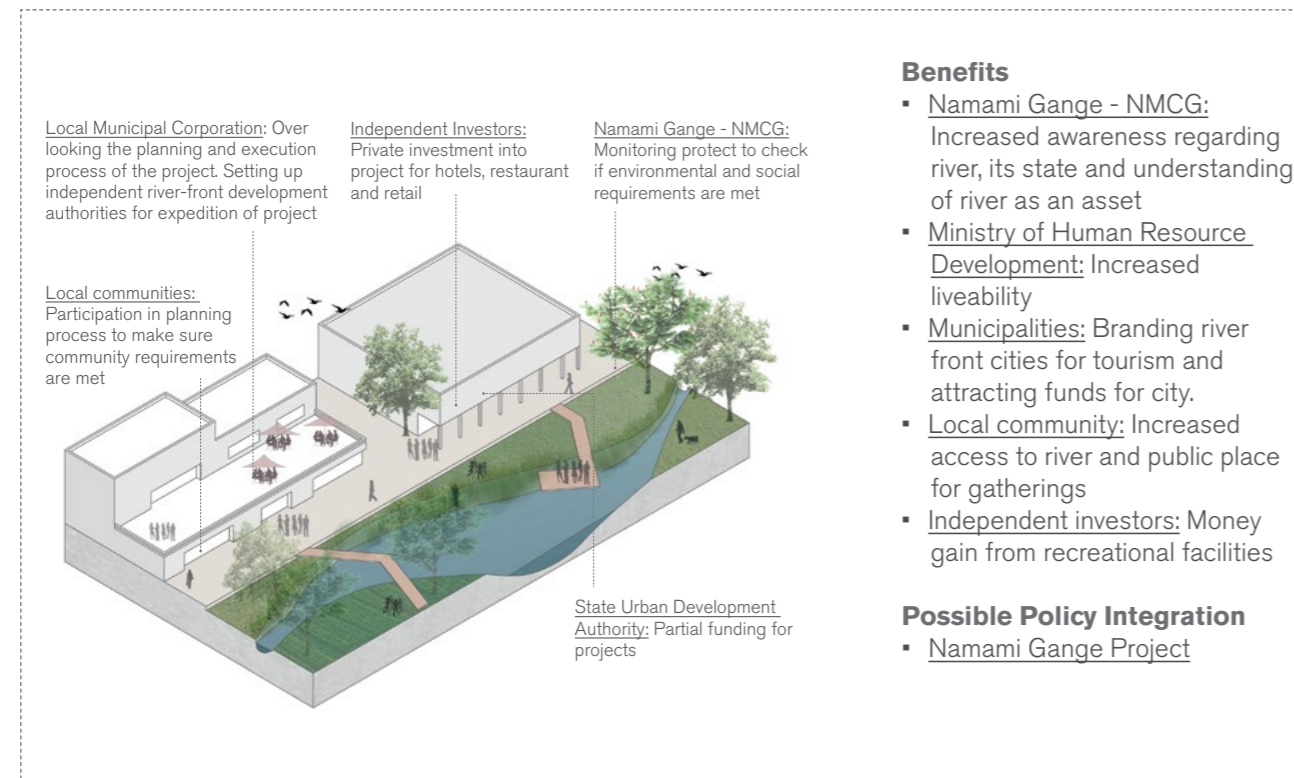


Fig. 138. Stakeholder Engagement for Action 2 (Metropolitan Strategy 3)

## Strategic Plan for Action

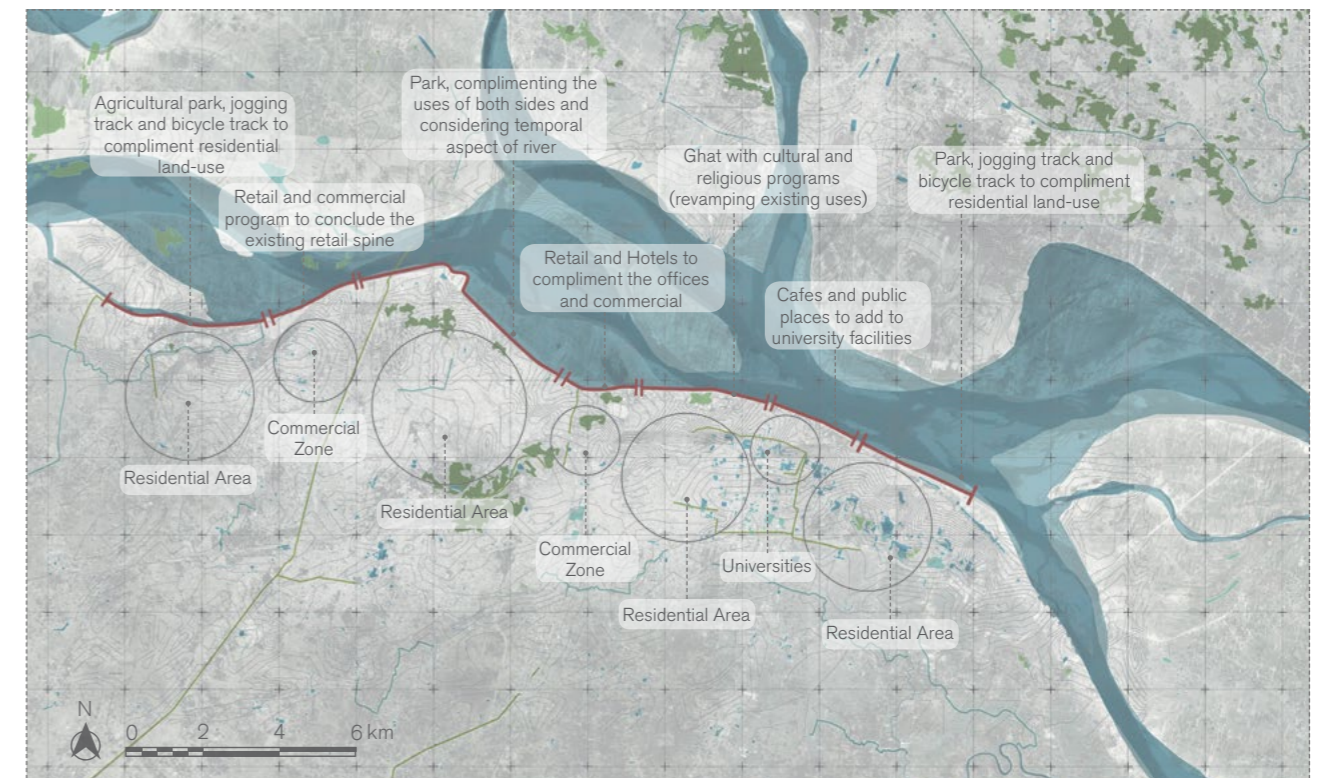


Fig. 139. Spatial Plan for Action 2 (Metropolitan Strategy 3)



## Spatial Actions and Design Interventions

### 3. Adding temporary activities

Temporary functions such as food kiosks, canopies and seating would attract crowd towards utilization of space. Moreover, with temporary facilities, the types of equipment could be moved away during the harsh monsoon flooding and activities could be carried out for another dry month without any interruptions or infra-structural loss.

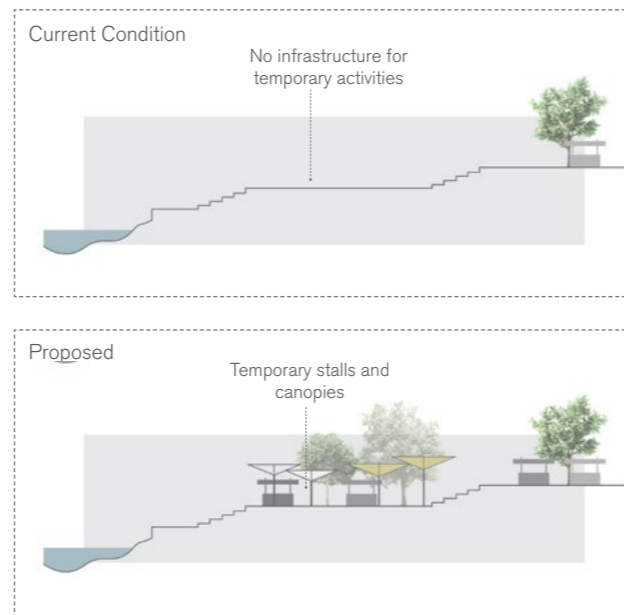


Fig. 140. Current -Proposed section for Action 3 (Metropolitan Strategy 3)

### What it means at Regional Scale?

- No specific action required at the regional scale

### What it means at Local Scale?

- Participation with locals and users to inquire about needs like canopies, tables, chairs.

## Stakeholder Engagement

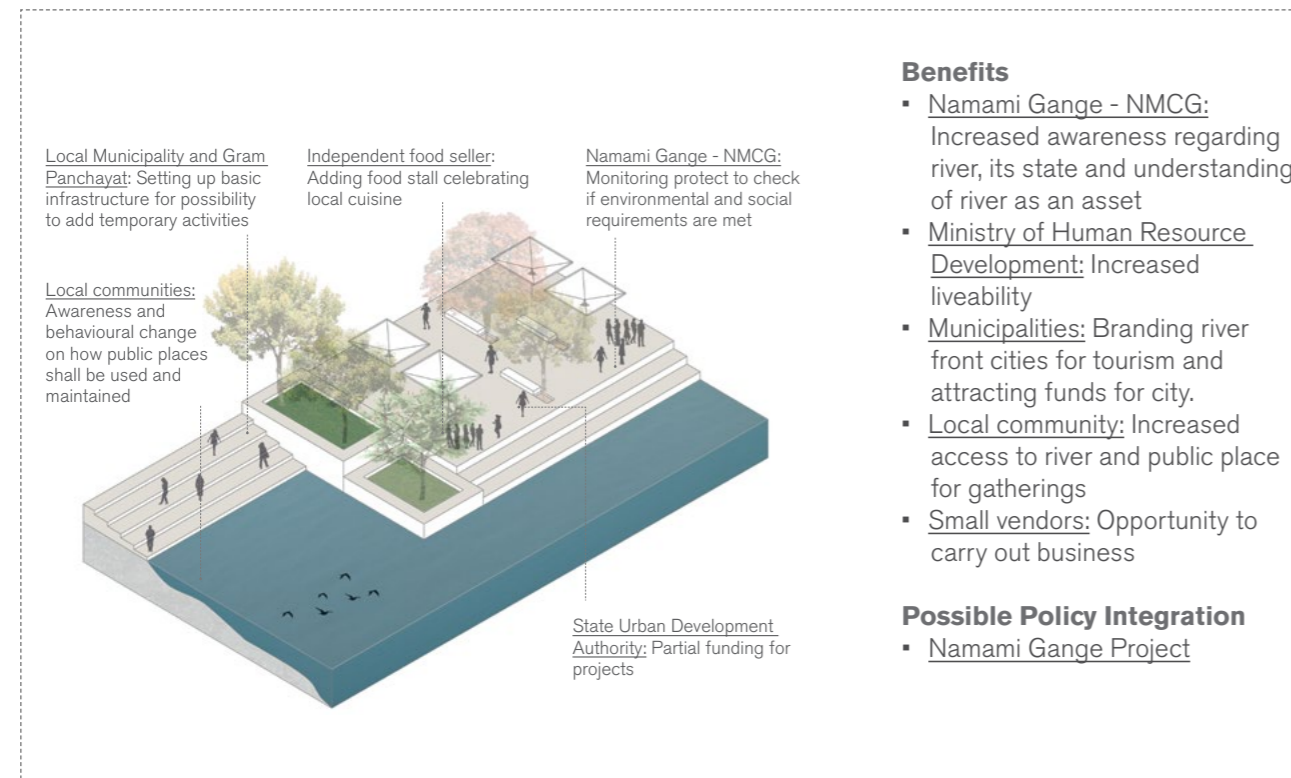


Fig. 141. Stakeholder Engagement for Action 3 (Metropolitan Strategy 3)

## Strategic Plan for Action

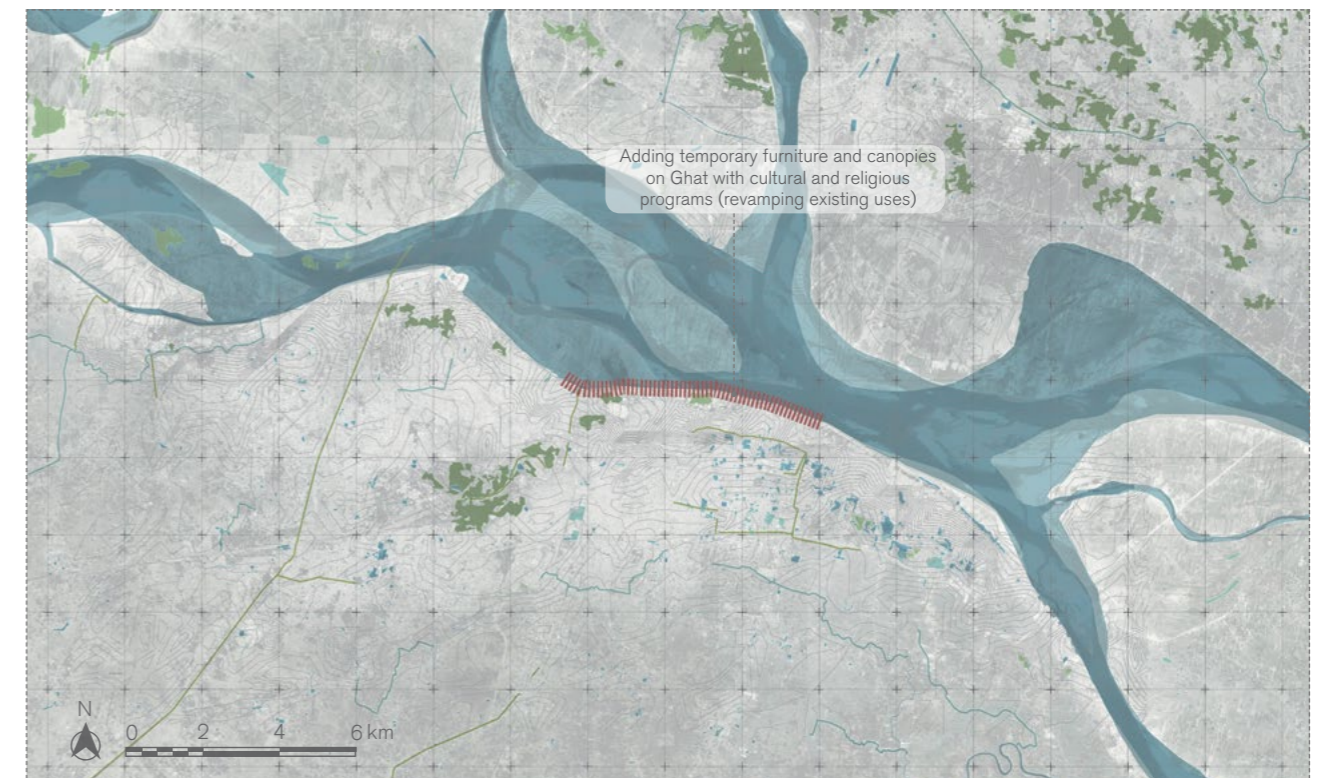


Fig. 142. Spatial Plan for Action 3 (Metropolitan Strategy 3)



## Spatial Actions and Design Interventions

### 4. Design for public awareness places

One of the most critical actions while activating river edges is to add awareness. With low literacy rates and awareness about the importance of the river, people tend to exploit the resources for their benefits. Thus, adding awareness centers along the river edge for the public will help in rebuilding a healthy relationship with the river.

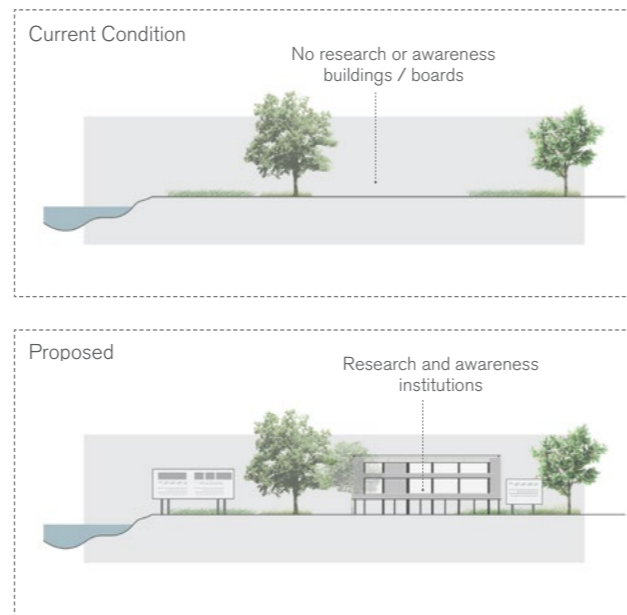


Fig. 143. Current -Proposed section for Action 4 (Metropolitan Strategy 3)

### What it means at Regional Scale?

- Funding research institutes to set up public awareness programs and infrastructure, collaborating with local governments and NGOs

### What it means at Local Scale?

- Collaboration between research institutes and local government, landowners and NGOs
- Design for Parks and information panels

## Stakeholder Engagement

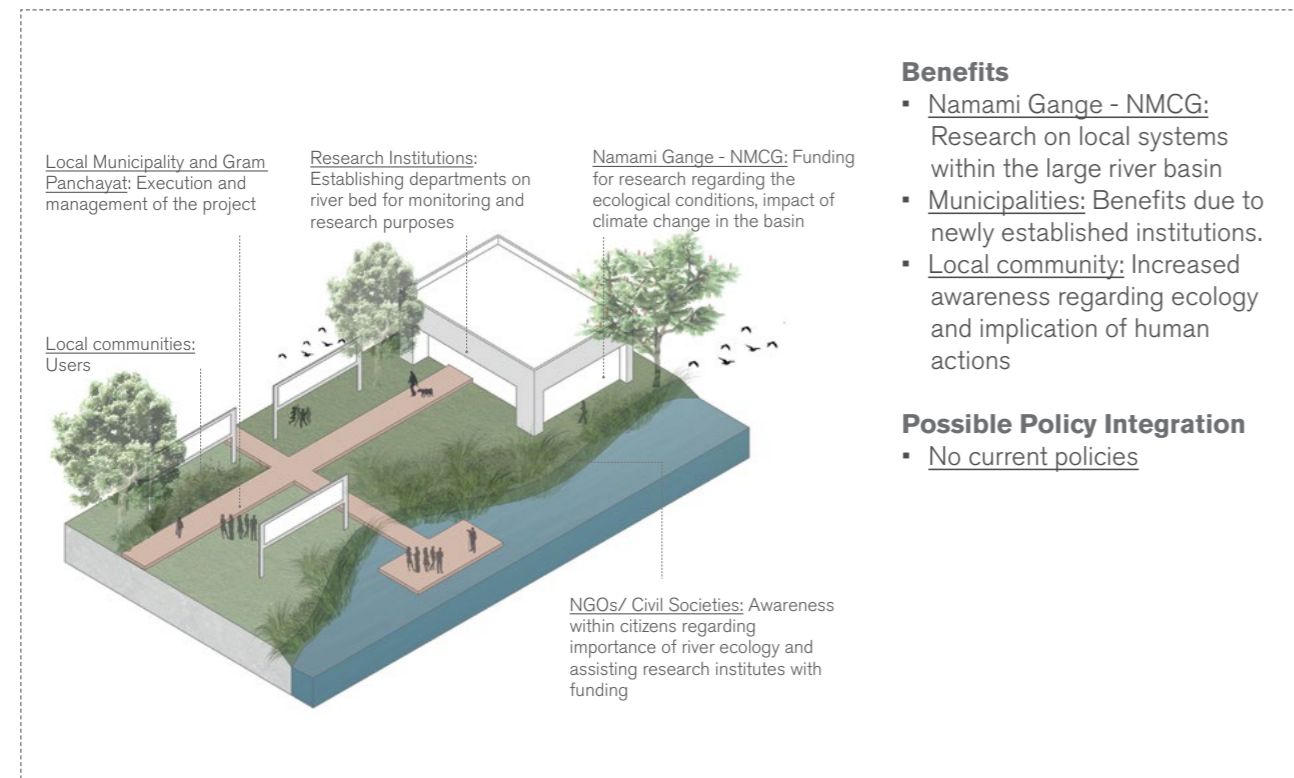


Fig. 144. Stakeholder Engagement for Action 4 (Metropolitan Strategy 3)

## Strategic Plan for Action

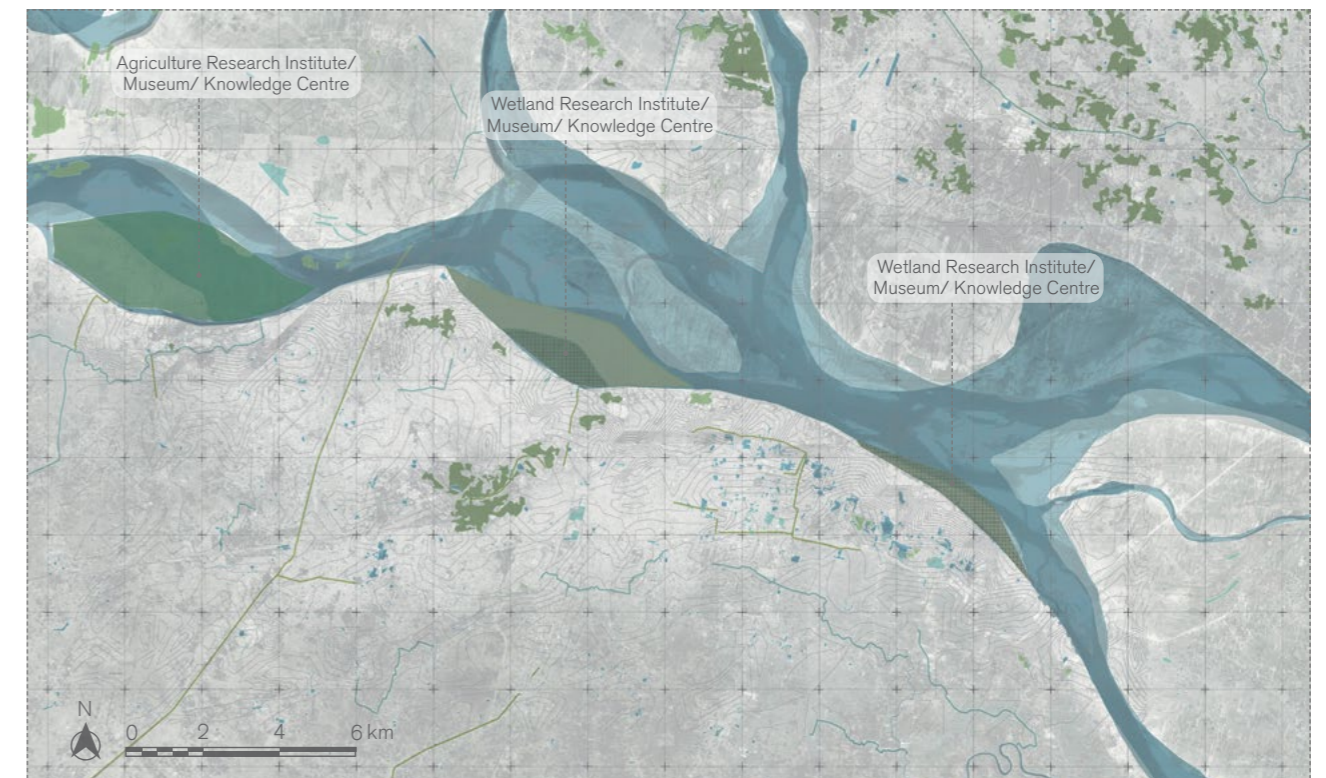


Fig. 145. Spatial Plan for Action 4 (Metropolitan Strategy 3)



8.2.4. Strategy 4: Establishing Agro-industries and small scale industries





## Spatial Actions and Design Interventions

### 1. Using peri-urban areas to establish Agro-industries

Industrial development in the Patna Metropolitan Region is extremely low. Since agriculture is one of the primary sources of income generation in the region, establishing agro-industries and processing units would help in boosting the economy of the city. Peri-urban areas make the best suitable areas for such development since they have the potential to act as a connector between rural agricultural production and urban consumption.

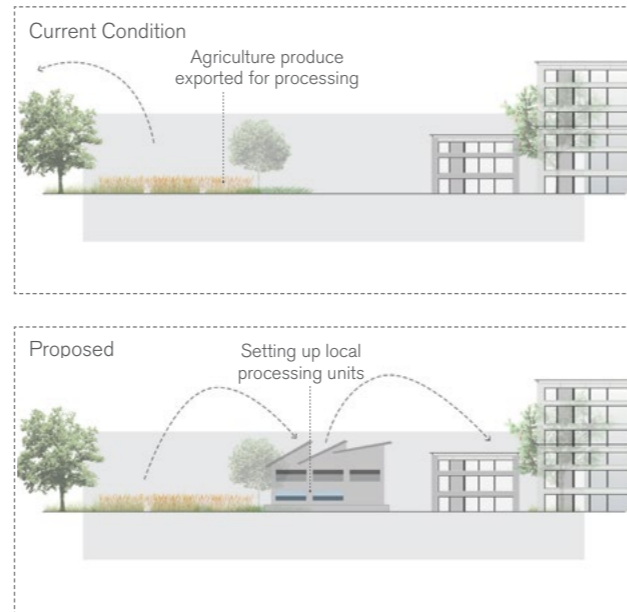


Fig. 146. Current -Proposed section for Action 1 (Metropolitan Strategy 4)

### What it means at Regional Scale?

- Policies to set-up local food processing units.
- Relaxations and subsidies for factories
- Adding special development zones within rural areas to allow setting up of factories.

### What it means at Local Scale?

- Collaboration with farmers to acquire land and production of local crops

## Stakeholder Engagement

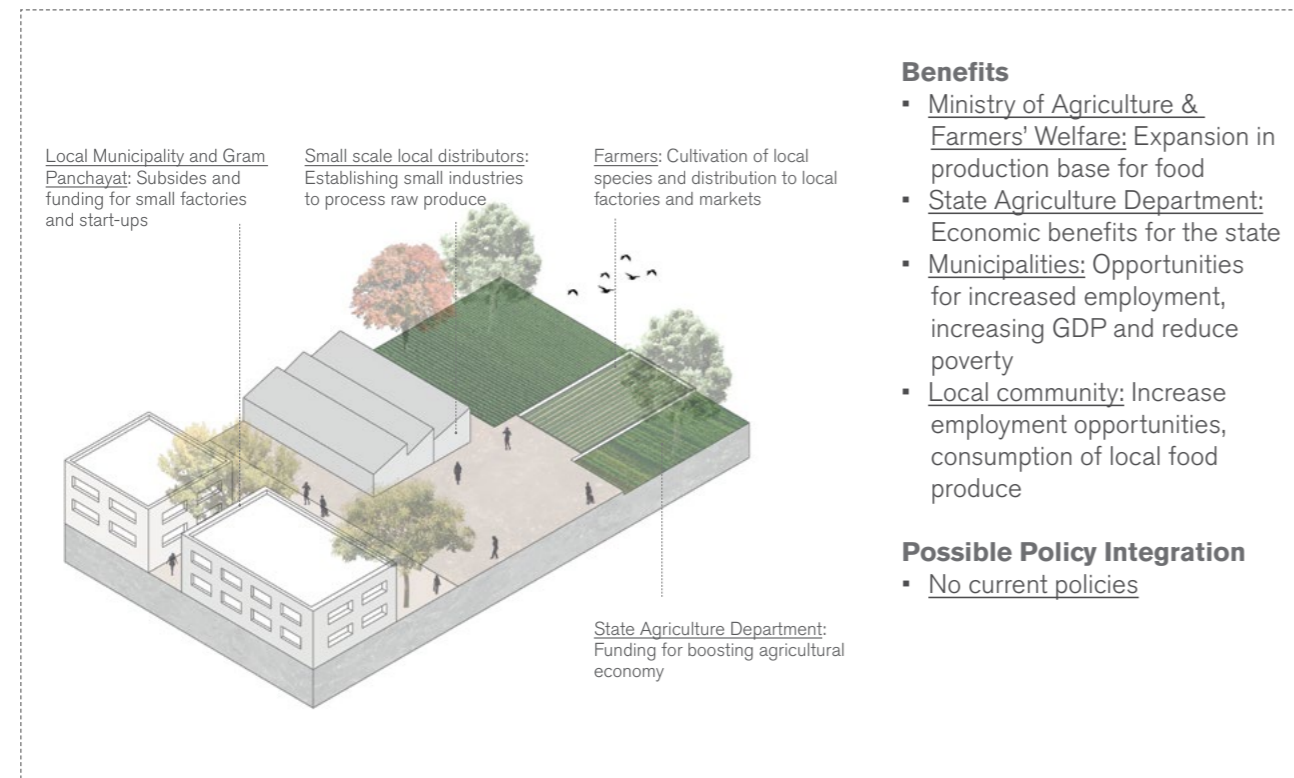


Fig. 147. Stakeholder Engagement for Action 1 (Metropolitan Strategy 4)

## Strategic Plan for Action



Fig. 148. Spatial Plan for Action 1 (Metropolitan Strategy 4)



## Spatial Actions and Design Interventions

### 2. Encouraging and facilitating production of local species

Cultivation of cash crops to gain quick and easy income is gaining more popularity within the farmers. Exotic species are overtaking the local species causing an imbalance in the food chains and ecosystem. Therefore, boosting the production of local crops and farming with a double/triple cropping method can help in re-establishing the balance.

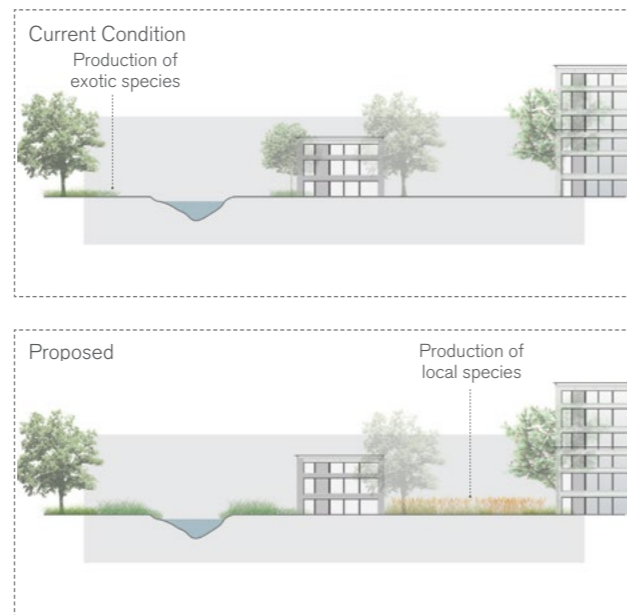


Fig. 149. Current -Proposed section for Action 2 (Metropolitan Strategy 4)

### What it means at Regional Scale?

- Listing local crops as top priority crops for cultivation
- Regulating rates of exotic crops

### What it means at Local Scale?

- Working with NGOs to create awareness about crops and their impact of ecosystem
- Encouraging communities to set-up small scale cottage industries fro bamboos (local grass)

## Stakeholder Engagement

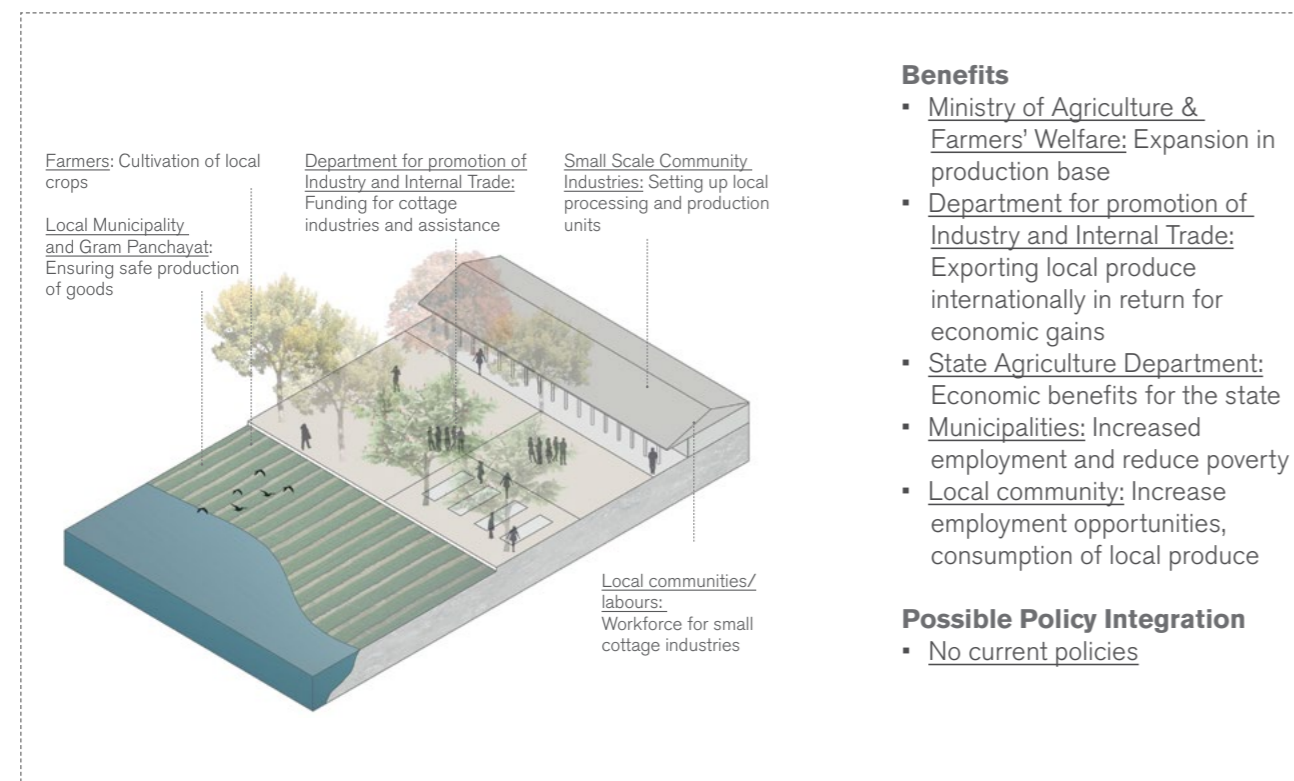


Fig. 150. Stakeholder Engagement for Action 2 (Metropolitan Strategy 4)

## Strategic Plan for Action



Fig. 151. Spatial Plan for Action 2 (Metropolitan Strategy 4)



## Spatial Actions and Design Interventions

### 3. Setting up test farms for research and educational purposes

Research on healthy methods to increase food production is necessary to boost the agricultural sector. With smart farming and vertical farming being adopted in different parts of the world, research on how new techniques and technologies can be implemented would facilitate higher production in the region.

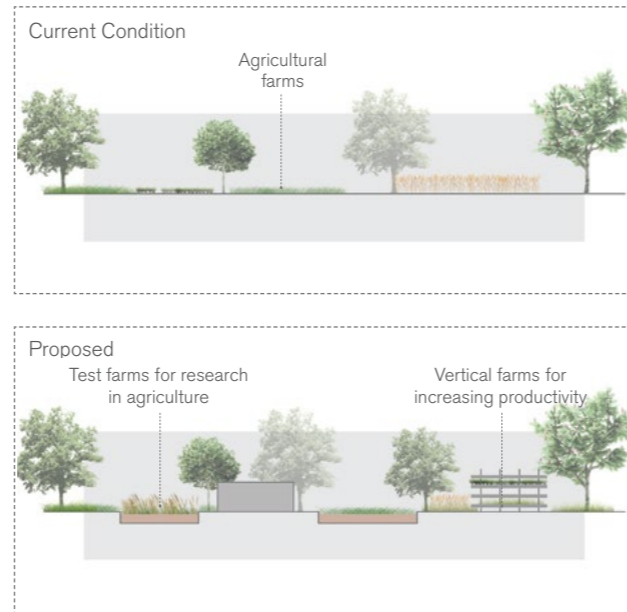


Fig. 152. Current -Proposed section for Action 3 (Metropolitan Strategy 4)

### What it means at Regional Scale?

- Encouraging new knowledge and research in food production.
- Funding schemes for research institutions

### What it means at Local Scale?

- Setting up facilities depending on local climate, suitable crop and cultivation
- Collaborating with villages in vicinity to set up common facilities

## Stakeholder Engagement

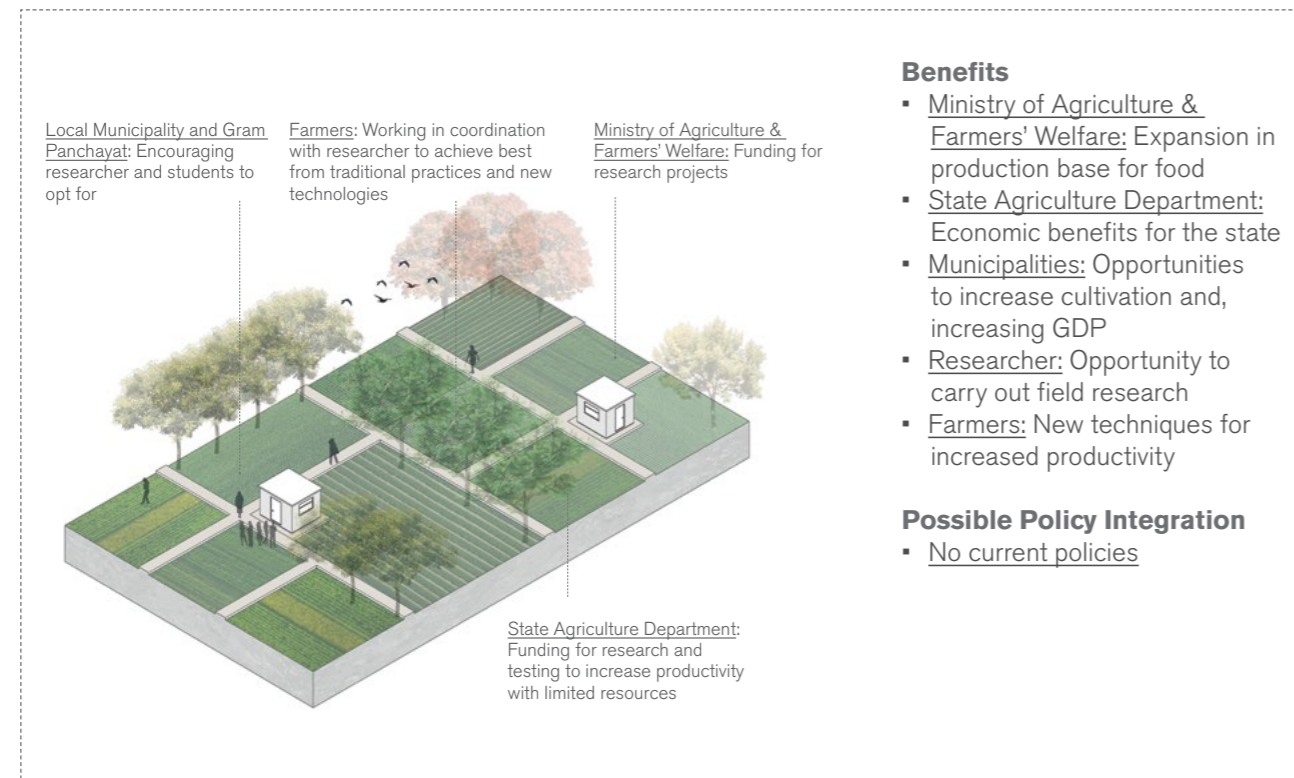


Fig. 153. Stakeholder Engagement for Action 3 (Metropolitan Strategy 4)

## Strategic Plan for Action

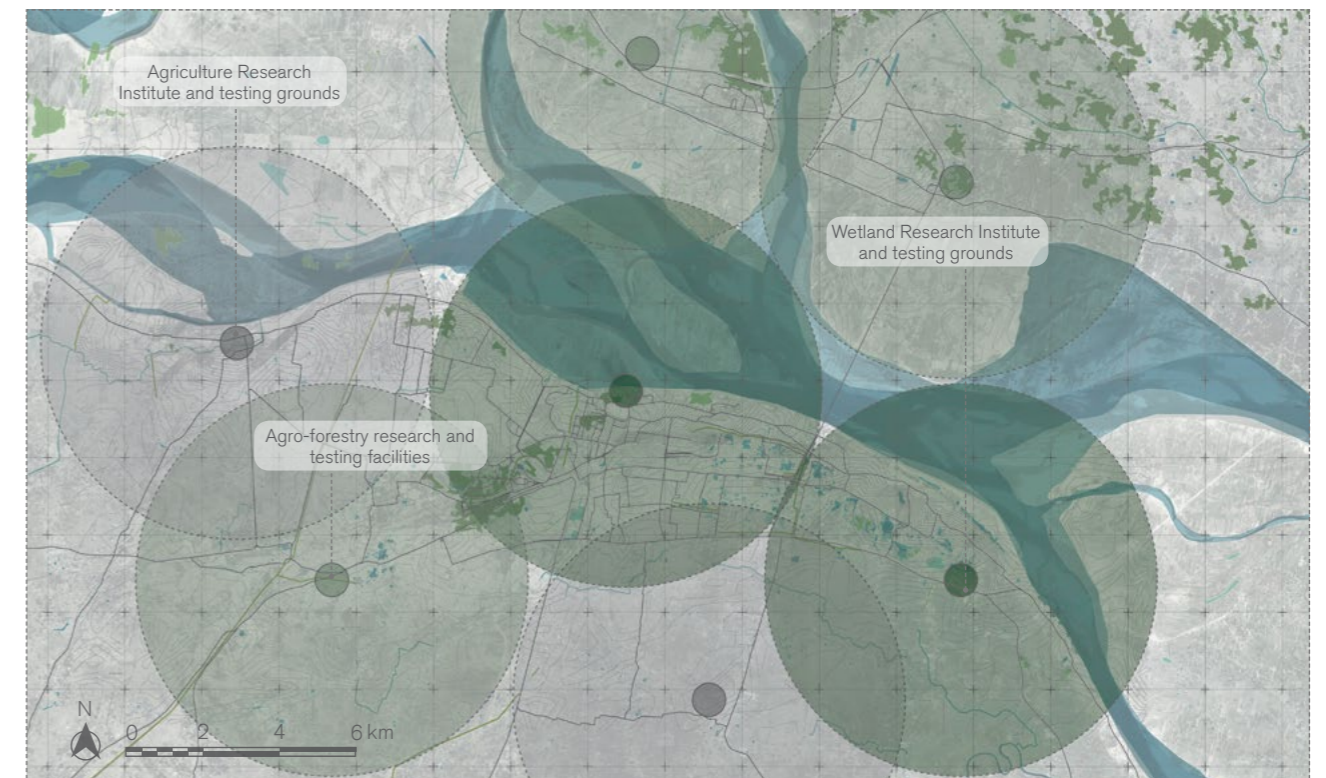


Fig. 154. Spatial Plan for Action 3 (Metropolitan Strategy 4)



## Spatial Actions and Design Interventions

### 4. Reviving wetland food production

Special wetland plants such as lotus and makhana grow in the wetlands of Bihar. The inability to understand its importance in food production has left the options of using them as production grounds unexplored. Hence exploring the possibilities of cultivating wetlands, would not only benefit the production but would also help in reviving the lost ecosystems of wetlands.

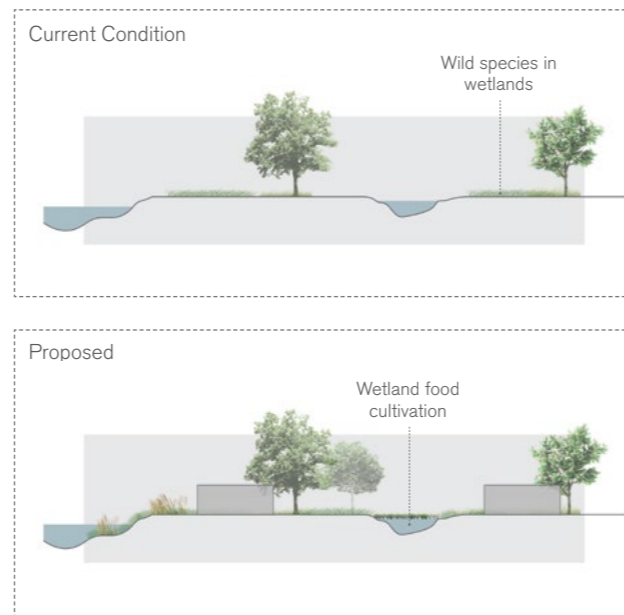


Fig. 155. Current -Proposed section for Action 4 (Metropolitan Strategy 4)

### What it means at Regional Scale?

- Focusing on food production in wetlands.

### What it means at Local Scale?

- Plantation of plants for harvesting like lotus, makhana

## Stakeholder Engagement

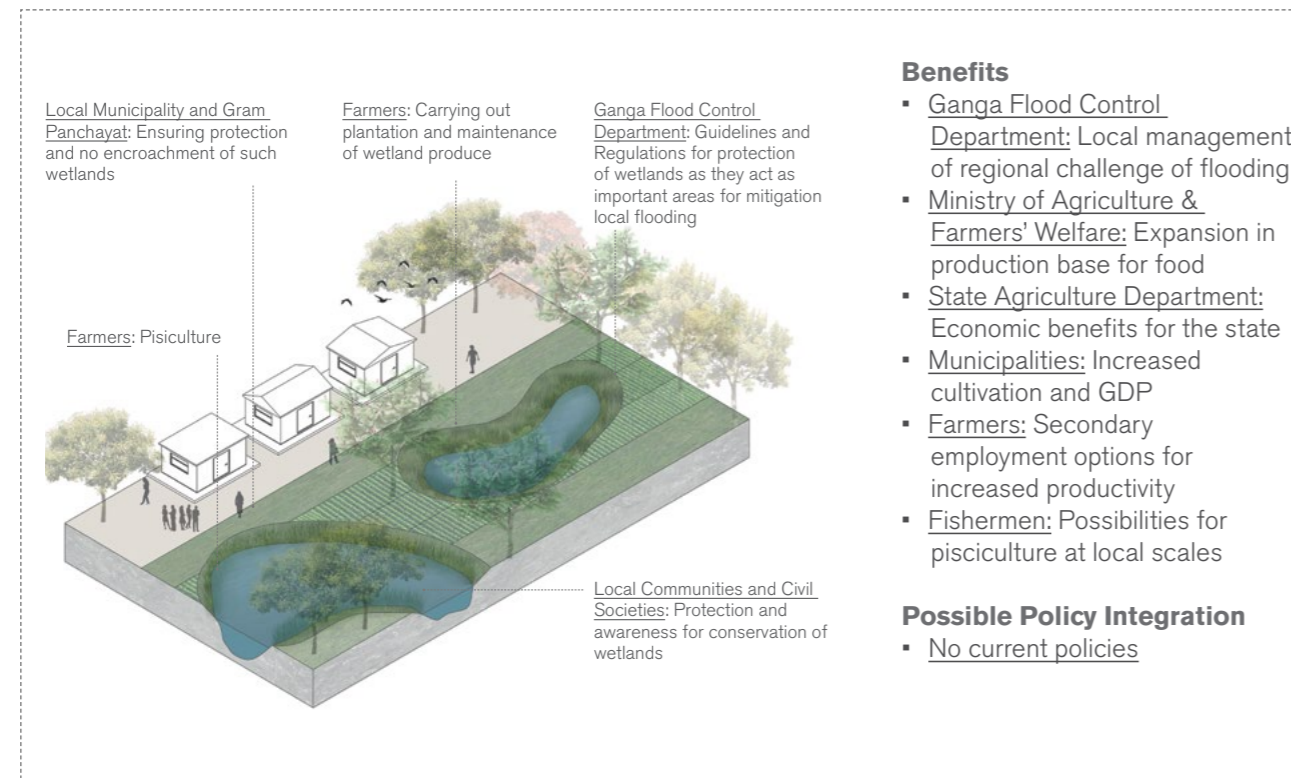


Fig. 156. Stakeholder Engagement for Action 4 (Metropolitan Strategy 4)

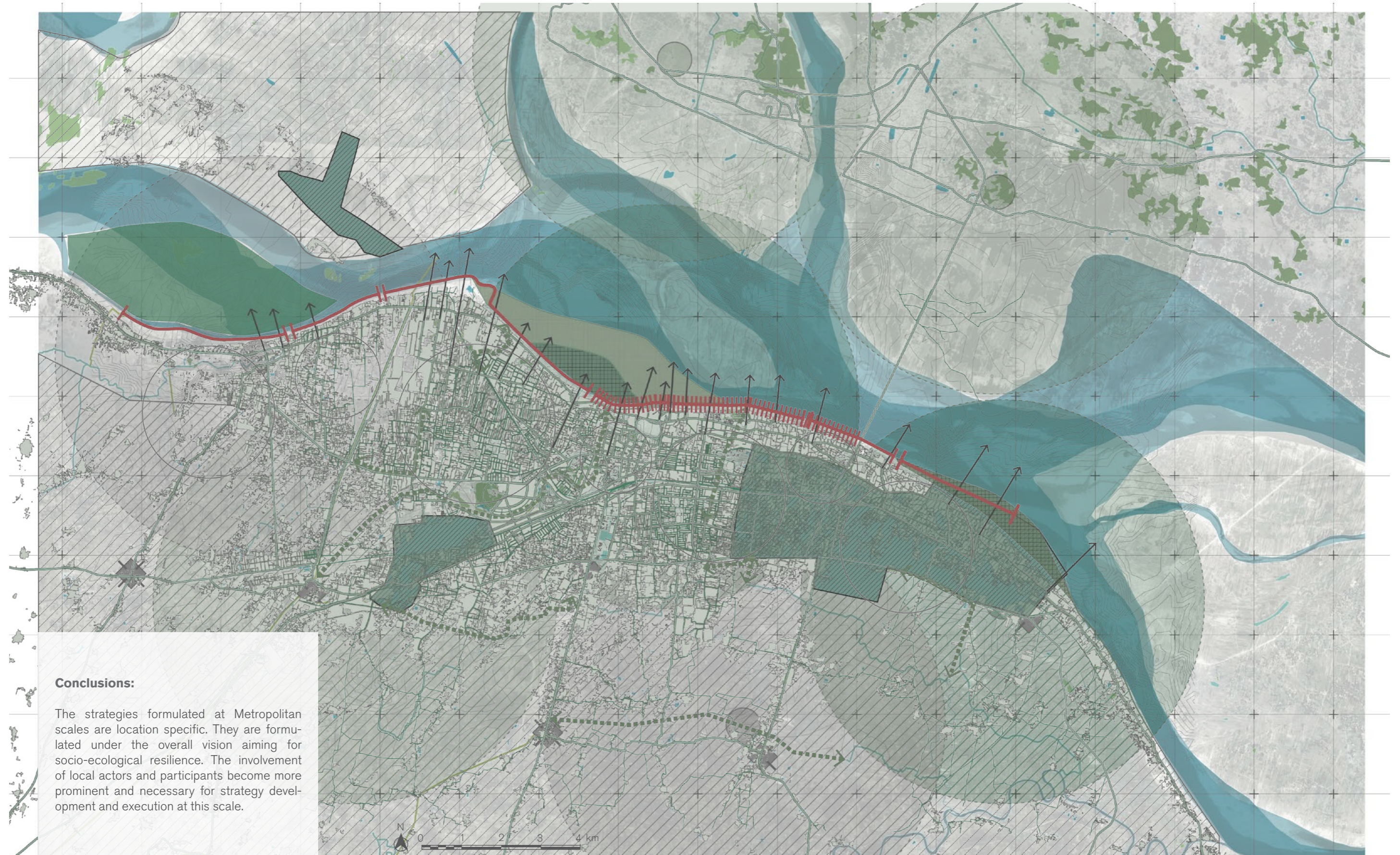
## Strategic Plan for Action



Fig. 157. Spatial Plan for Action 4 (Metropolitan Strategy 4)



### 8.3. STRATEGIC PLAN FOR THE PATNA METROPOLITAN REGION



#### Conclusions:

The strategies formulated at Metropolitan scales are location specific. They are formulated under the overall vision aiming for socio-ecological resilience. The involvement of local actors and participants become more prominent and necessary for strategy development and execution at this scale.





## 9 Application of Strategies at Micro Scale and Local Adaptation

This section of the report shows the implementation of Regional and Metropolitan strategies at local scales. The strategies are tested at three different locations, in rural, peri-urban and rural areas. The chapter details out how the combination of different mitigation strategies from larger scales works to achieve adaptation to climate change at the local scale. The implementation is further elaborated with required stakeholder analysis and integration. Thus, the following chapter concludes how local adaptation within the larger framework of mitigation strategies and policies can help to achieve resilience.



Understanding Problem Field

Chapter 2

- Current Challenges in Ganges River Basin
- Drivers of Change
- Governance Challenges for Ganges River Basin

Introduction

Chapter 1

- Context
- Relationship between human systems and ecological systems

Chapter 3

- Socio-ecological vulnerability analysis across scales
- Problem Statement (Spatial Justice)
- Line of Inquiry:
  1. Dual Nature of Externalities
  2. Capital

Chapter 4

- Theories:
  1. Urbanization
  2. Vulnerability
  3. Resilience Thinking
  4. Social Capital and Governance
- Notions:
  1. Interdependence - Integration
  2. Infrastructure Ecology
  3. Evolutionary Resilience

Research Methodology

Chapter 5

- Conceptual Framework: Adaptive Spatial Planning Model

Vision

Chapter 6

- Principles
  1. Robustness
  2. Adaptivity
  3. Connectedness
  4. Diversity
- Frame of Reference
  1. Knowledge of System Behaviour
  2. Dynamic Adaptive Planning Pathways
  3. Stakeholder Collaboration
- Systemic Goals

Design

Chapter 7

Regional Strategies

Mitigation Strategies that are derived for challenges across the basin



Chapter 8

Metropolitan Scale Strategies

Mitigation Strategies that are derived for challenges for metropolitan scale



Chapter 9

Local Adaptation

Adaptation of multiple strategies to achieve resilience

1. Urban
2. Peri-Urban
3. Rural

Adaptive Planning Pathways

Evaluation

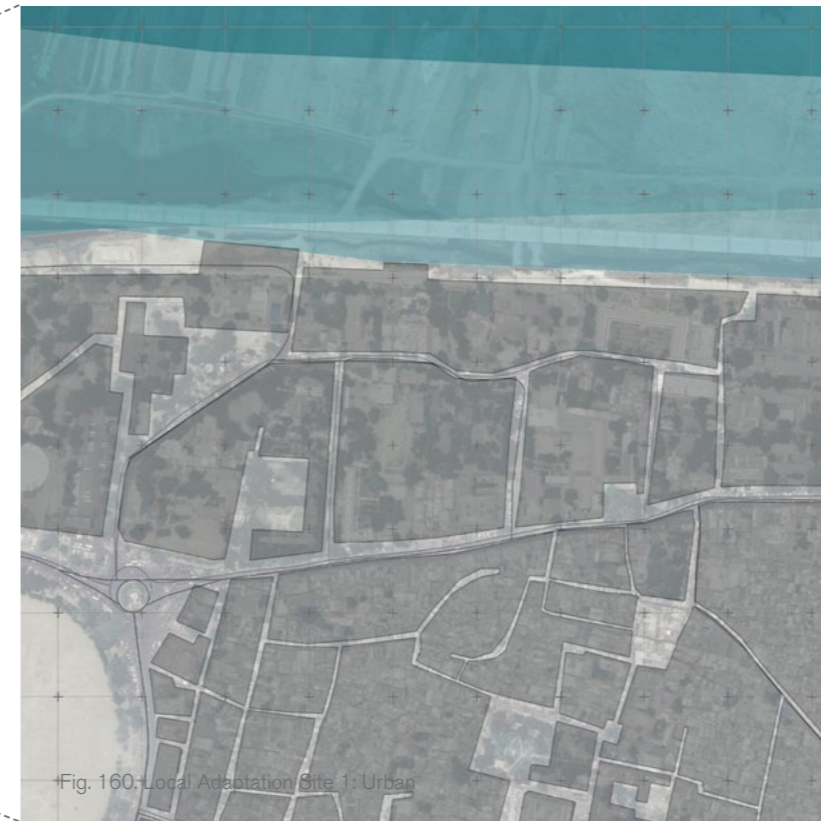
Chapter 10

Scenarios

- Case 1
- Case 2
- Case 3



## 9.1. STRATEGIC ZOOM INS



### 1. Urban

The selected zoom-in within the urban boundaries of Patna is one of the oldest areas in the city. The area is located in the most prominent part of the city and is also a place for the central vegetable market. Several farmers and vegetable vendors from across the river come to this point either in boats/private vehicles to sell their daily produce.

With most plots and buildings in this location being either private or government offices the accessibility to the river is blocked for locals.



### 3. Rural

The third zoom-in selected to check the local adaptation of regional strategies is located in the rural areas of Patna district. The site is mostly agriculture fields along small river Punpun, a tributary of Ganges river system running next to the fields. The fields are located in medium to high flooding zones. Yet, during summers the farmers are now experiencing low water availability. Hence, using strategies for adaptation and mitigation towards water crisis has become necessary.



### 2. Peri-Urban

This zoom-in is located within the fringes of the Patna City. The area once open land, with small ponds and wetlands, is now developing at a tremendous rate. Encroachment of wetlands, ponds and green areas is carried out to acquire land. Even within the newly proposed Land Use Plan, the area has been given rights for residential development. Thus it is necessary for the new development to respond to the current conditions of the site and respect the ecology of the area, and the river system.



### 9.1.1. Manifestation 1: Urban Area

The first zoom-in to test the local adaptation of strategies is located in the urban centre of the Patna city. The area is one of the most prominent parts of the city, with an exhibition ground and large vegetable market. Several farmers and vegetable vendors from the other side cross the river bed with no defined roads to sell their vegetables on this end of the river. The market places an important node in the distribution of vegetables on this side of the river.

Secondly, The access to the river from this part is through unpaved approach roads, with open drains for wastewater. This condition makes the river less accessible to the locals. As part of the river-front project, ghats are also built in this part. Though the ghats are currently built, the steps are leading to nowhere as the river moved back due to lack of continuous and sufficient water. Hence, it is necessary to intervene in the area, by adding more access routes to the river, activating the edge with changed land-use and more public buildings.

Moreover, since the riverbed is currently dry for almost 9 months during the year, it has a potential to be designed for temporal activities that can create awareness within the locals about the river, its behaviour and the ecological systems. The strategies used for the challenges are derived at regional as well as metropolitan scale.

#### Strategies Used

##### Regional Scale



RS1:  
Room for the River



RS3:  
Comprehensive Connectivity

##### Metropolitan Scale



MS2:  
Landscape Interventions



MS3:  
Activating River-edge

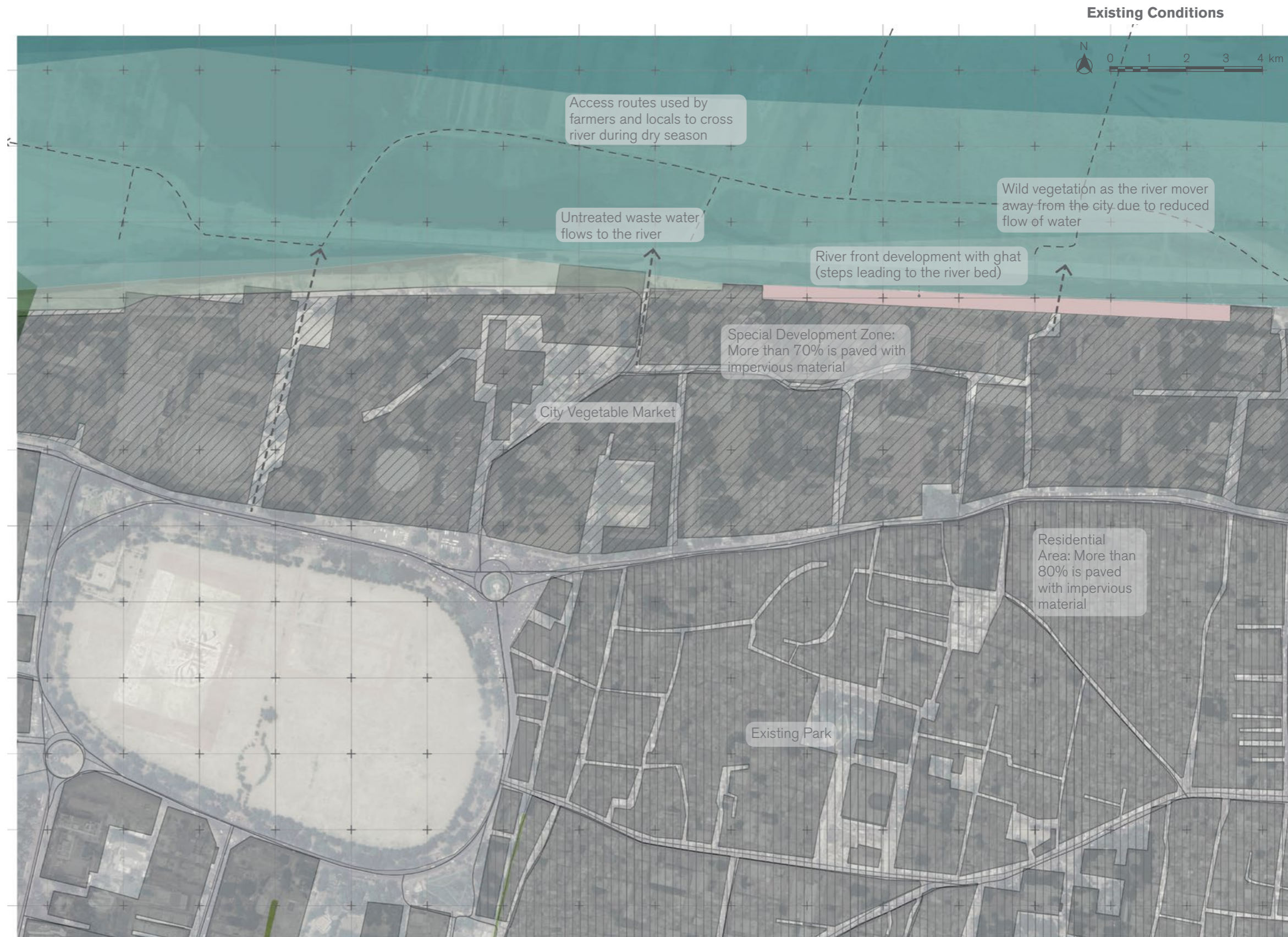


Fig. 162. Site1 (Urban) : Existing conditions and challenges



**Layers of System**

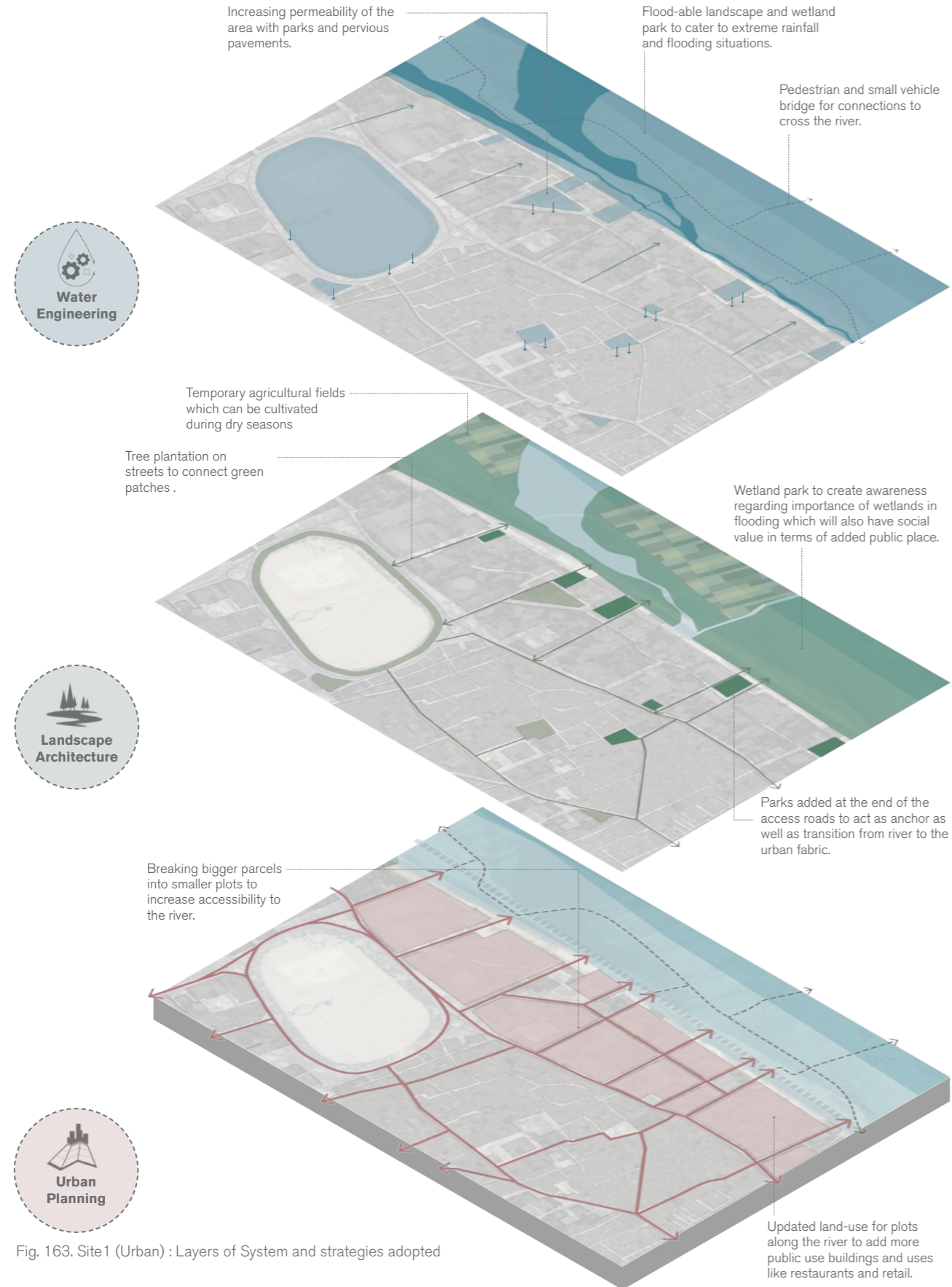


Fig. 163. Site1 (Urban) : Layers of System and strategies adopted

**Strategies Used**





## Stakeholders and Local Engagement

Stakeholder	Sector	Type of Involvement	Level	Type of Engagement	Action/Interest
▪ Namami Gange (NMCG)	Public	- Regulatory - Funding	- Primary	- Power: High - Interest: High	- Resolving challenges faced by the river
▪ Ganga Flood Control Department (GFCD)	Public	- Regulatory - Funding	- Primary	- Power: High - Interest: High	- Regulating with state bodies for flood warnings and mitigation
▪ Ministry of Human Resource Development	Public	- Monitoring	- Tertiary	- Power: High - Interest: Low	- Working to reduce social vulnerability and for social justice
▪ Ministry of Environment, Forest and Climate Change (Central) (EFCC)	Public	- Regulatory - Monitoring	- Secondary	- Power: Low - Interest: High	- Policies and programs for climate change
▪ Bihar State Government (BSGov)	Public	- Regulatory - Administrative - Funding	- Primary	- Power: High - Interest: High	- Water distribution and management
▪ Bihar: Urban Development Department (BUDD)	Public	- Planning - Administrative	- Primary	- Power: High - Interest: High	- Planning and Development of Urban Areas
▪ Developers (Dev)	Private	- Investment - Execution	- Primary	- Power: High - Interest: High	- Monetary gains from the development
▪ Independent investors (Retail/ Restaurants) (I Inv)	Private	- Investment	- Secondary	- Power: Low - Interest: High	- Monetary gains from the development
▪ Landowners (Lo)	Public Private Civil Societies	- Participatory - Investment	- Primary	- Power: Low - Interest: High	- Monetary gains from the development
▪ Farmers (Fm)	Private	- Users	- Tertiary	- Power: Low - Interest: Medium	- Added and regularised farming opportunities
▪ Research Institutions (RI)	Civil Societies Private	- Educational / Advisory	- Secondary	- Power: Low - Interest: High	- Awareness regarding on going climate crisis and mitigation
▪ Patna Municipal Corporation (PMC)	Public	- Regulatory - Implementing	- Primary	- Power: Medium - Interest: High	- Adding public place and development for city
▪ Urban Planners (UP) / Landscape Architects (LA)	Private	- Planning	- Primary	- Power: Low - Interest: High	- Designing for active river edge and river ecology
▪ Ward Office/ Ward Committee (WO)	Public	- Collaborative - Execution	- Primary	- Power: Low - Interest: High	- Collaboration and Participation with citizens and gov.
▪ NGOs	Civil Societies	- Users	- Tertiary	- Power: Medium - Interest: High	- Awareness and protection of environment
▪ Local Communities / Citizens (Cit)	Civil Societies	- Users	- Primary	- Power: Low - Interest: High	- Added public places and protection to flooding

Table: Site1 (Urban) : Stakeholder Engagement

## Networks and Relationships

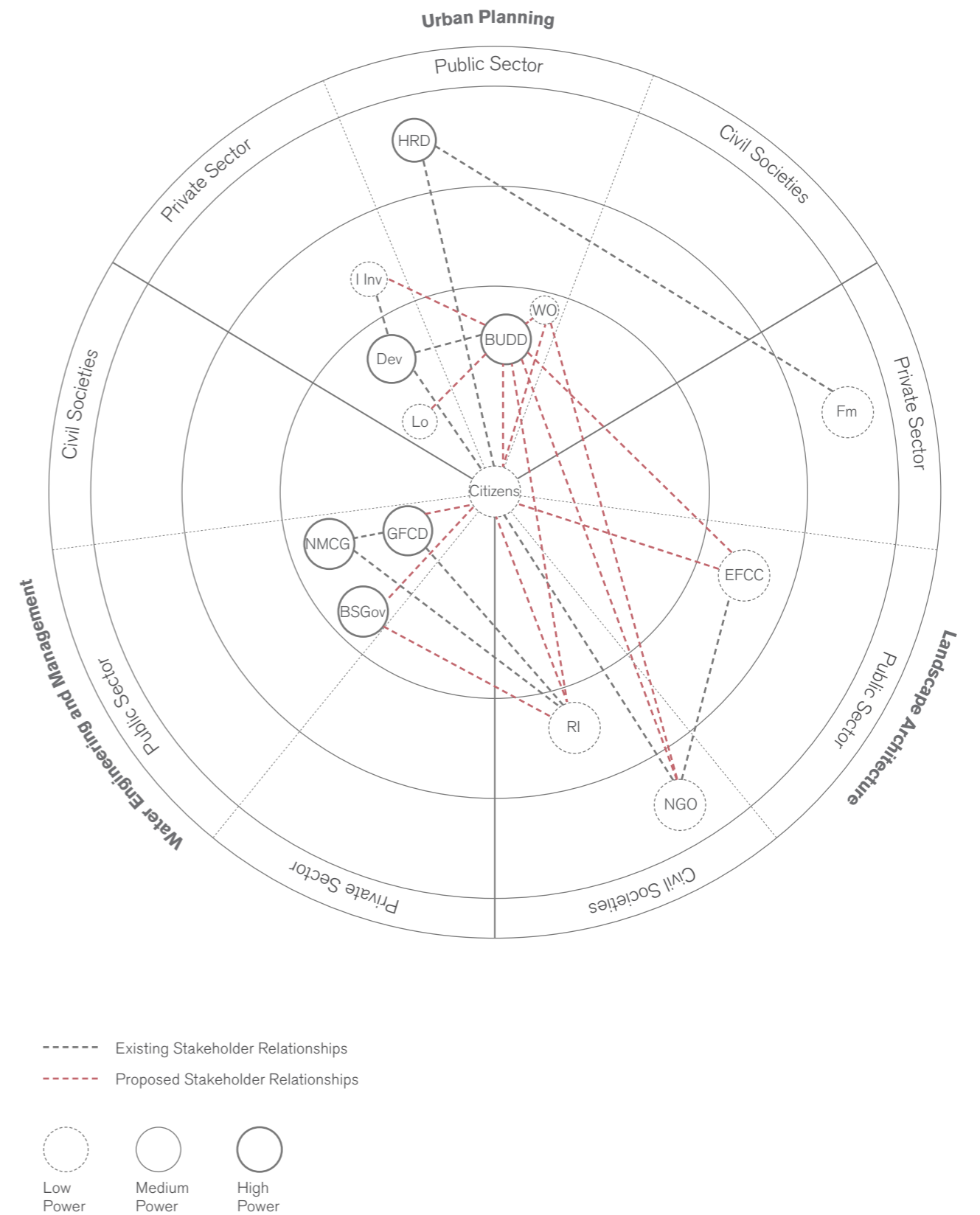
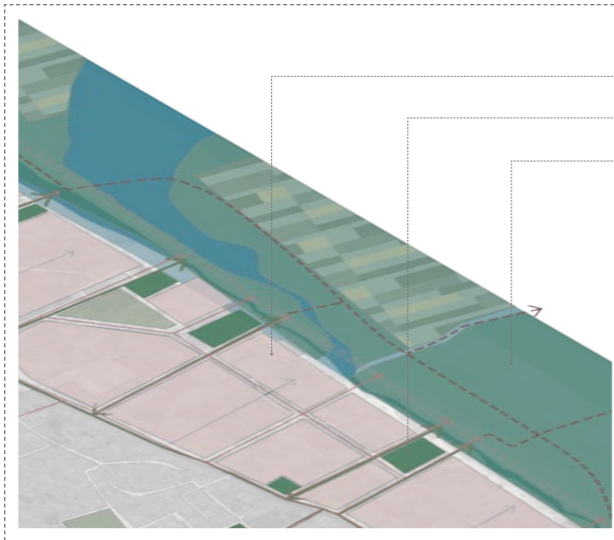


Fig. 164. Site1 (Urban) : Stakeholder Networks

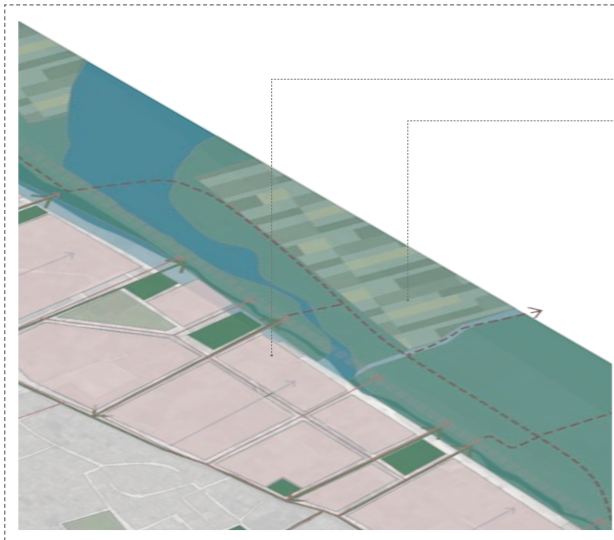


## Benefits and Impact



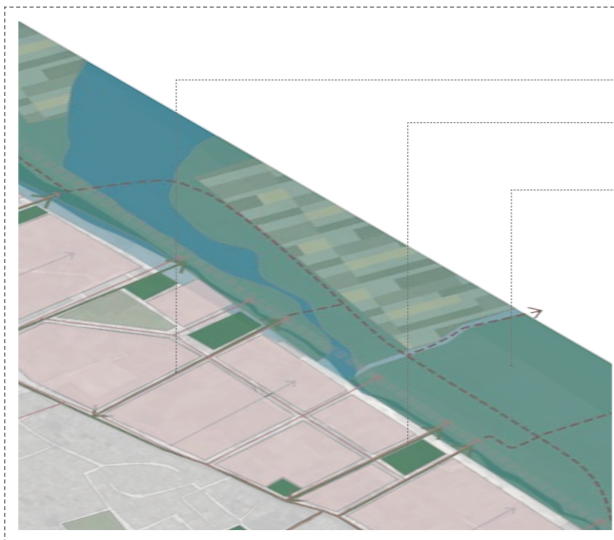
### 1. Social

- Increased public accessibility
- Parks and public places
- Awareness and knowledge centres



### 2. Economic

- Increased land value
- Higher agriculture produce



### 3. Ecological

- Connected tree canopies
- Constructed wetlands to revive ecology and act as flooding buffer
- Increased permeability for local ground water recharge

Fig. 165. Site1 (Urban): Social, Economic and Ecological benefits of adopted strategies

## Before and After

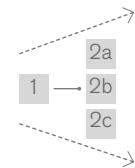


Fig. 166. Site1 (Urban): Before and After visualization of strategies at location



## Operability: Adaptive Pathway Planning for Urban Area

### 1: Sewage Network



**2a:** Activating riverfront, adding temporary structures to existing Ghats

#### Actors:

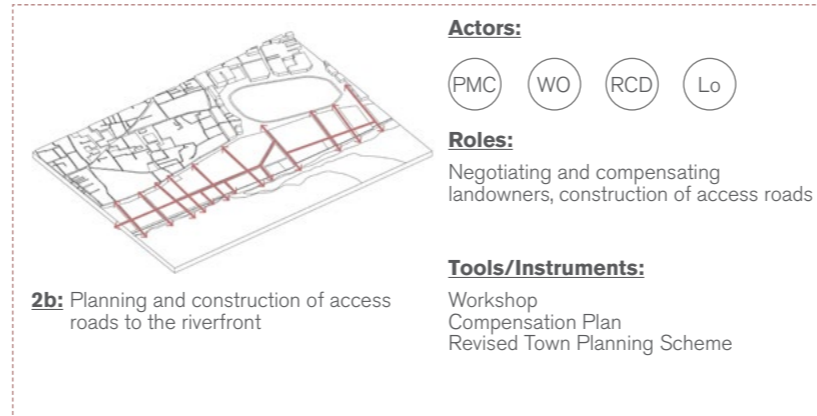


#### Roles:

Funding and execution for temporary infrastructure like benches, street lights, canopies etc.

#### Tools/Instruments:

Survey of requirements  
Design Plan



**2b:** Planning and construction of access roads to the riverfront

#### Actors:

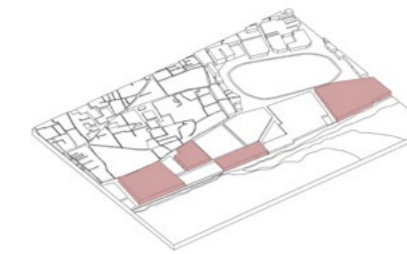


#### Roles:

Negotiating and compensating landowners, construction of access roads

#### Tools/Instruments:

Workshop  
Compensation Plan  
Revised Town Planning Scheme



**2c:** Changing land use for a few buildings along the riverfront

#### Actors:

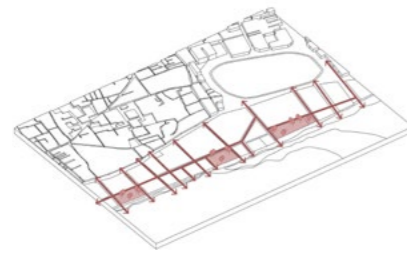
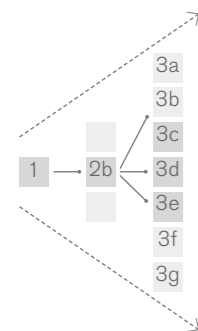


#### Roles:

Re-development and Re-programming of existing development

#### Tools/Instruments:

Incentive Schemes



**2b+3c:** Constructing parks along the riverfront

#### Actors:

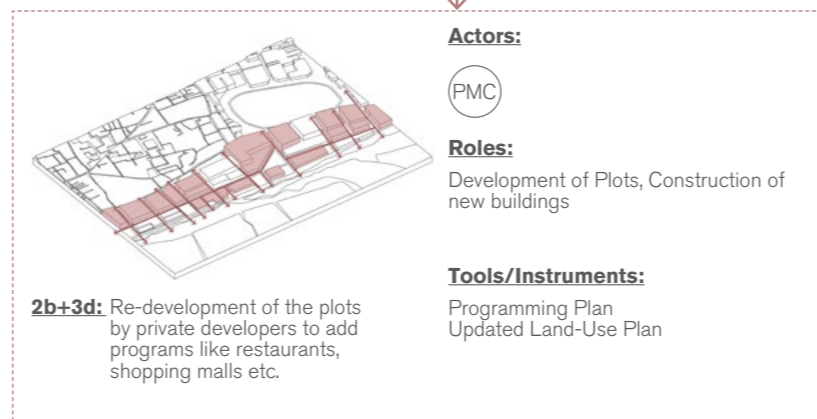


#### Roles:

Designing, Execution and Maintenance of Public Parks

#### Tools/Instruments:

Planting Plan  
Incentives



**2b+3d:** Re-development of the plots by private developers to add programs like restaurants, shopping malls etc.

#### Actors:

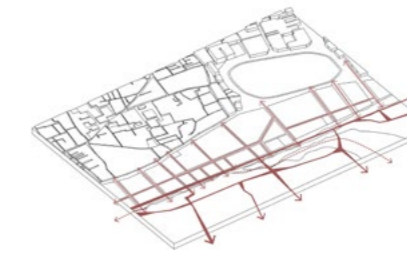


#### Roles:

Development of Plots, Construction of new buildings

#### Tools/Instruments:

Programming Plan  
Updated Land-Use Plan



**2b+3e:** Establishing water connectivity with boat routes and pathways.

#### Actors:



#### Roles:

Conduct surveys and map most used routes, design and execute board-walks and boat routes

#### Tools/Instruments:

Survey - Mapping  
Data Collection  
Water Transport Network Plan

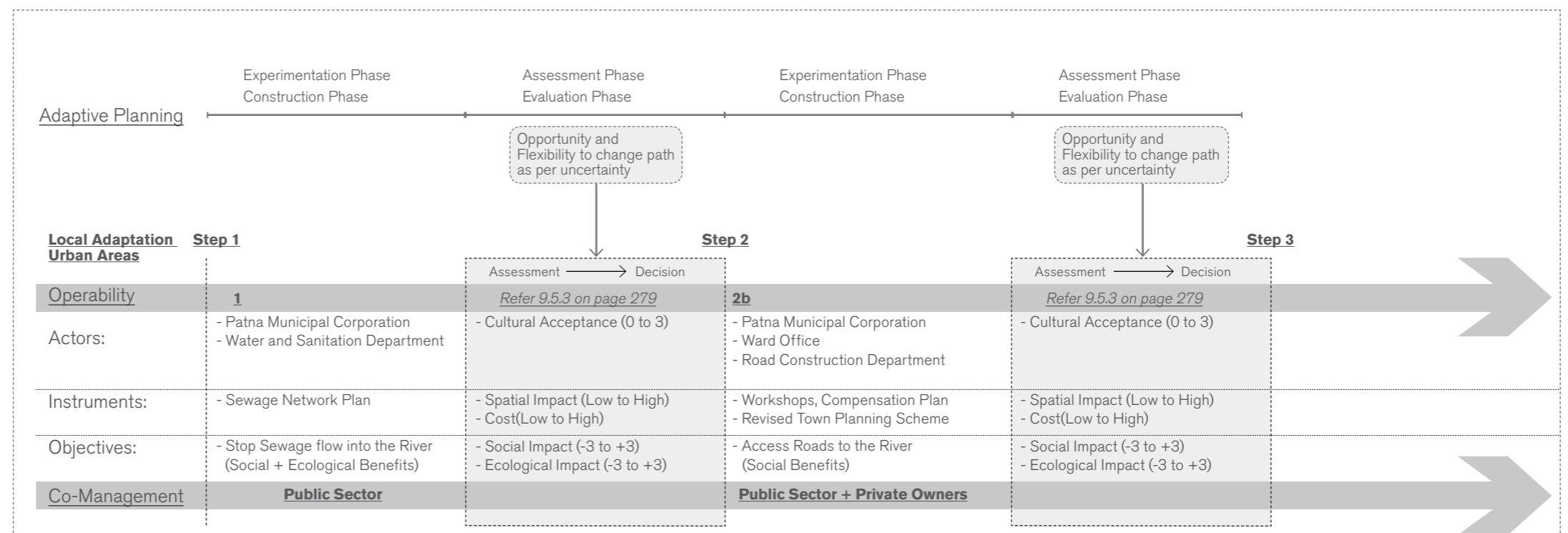
Fig. 167. Dynamic Planning Pathway for Urban Area in PMC

The model of Adaptive Spatial Planning is based on the values of Co-Management of resources, Dynamic Planning Pathways and Adaptive Governance. Thus, local adaptation of regional and metropolitan scale strategies for the urban area should follow these principles. Here, one of the possible pathways for local adaptation in the urban area is elaborated.

The pathway begins with an assumed step 1 of sewage network line. Based on the detailed sequencing of action pathways detailed in [section 9.5.2 on page 278](#), multiple possible pathways are explored. After each step is accomplished, there lies a possibility of assessment and flexibility for potential next steps.

For example, in this case, the result is a sequence outcome of 4 different actions.

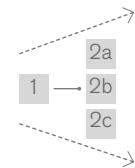
- 1: Sewage Network
- 2b: Establishing access to the river
- 3d: Re-development of Plots
- 4f: Constructing Wetlands and Farms





## Operability: Adaptive Pathway Planning for Urban Area

### 1: Sewage Network



**2a:** Activating riverfront, adding temporary structures to existing Ghats

#### Actors:

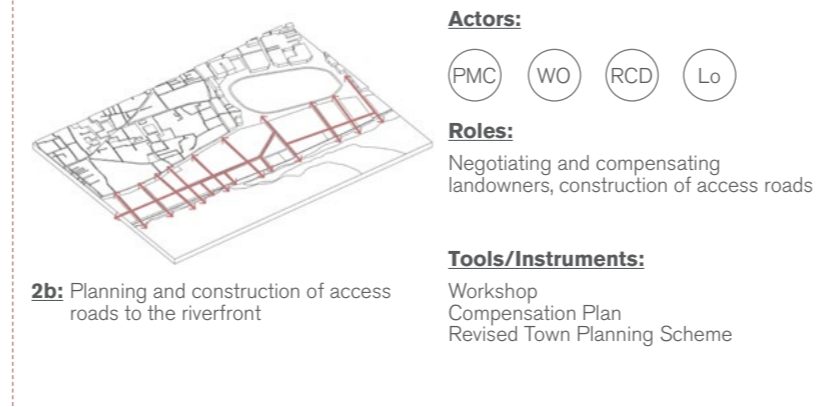


#### Roles:

Funding and execution for temporary infrastructure like benches, street lights, canopies etc.

#### Tools/Instruments:

Survey of requirements  
Design Plan



**2b:** Planning and construction of access roads to the riverfront

#### Actors:

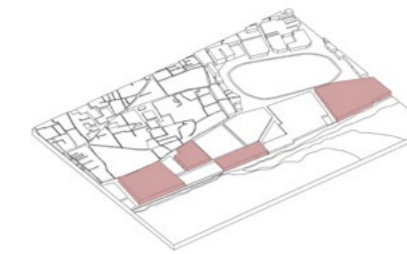


#### Roles:

Negotiating and compensating landowners, construction of access roads

#### Tools/Instruments:

Workshop  
Compensation Plan  
Revised Town Planning Scheme



**2c:** Changing land use for a few buildings along the riverfront

#### Actors:

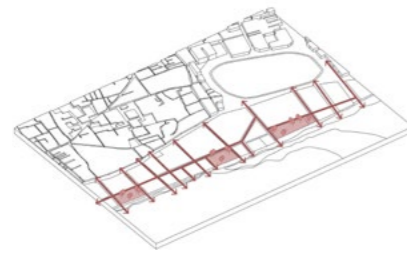
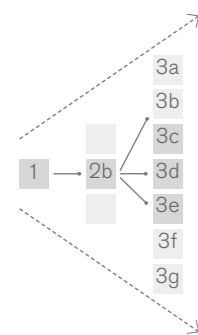


#### Roles:

Re-development and Re-programming of existing development

#### Tools/Instruments:

Incentive Schemes



**2b+3c:** Constructing parks along the riverfront

#### Actors:

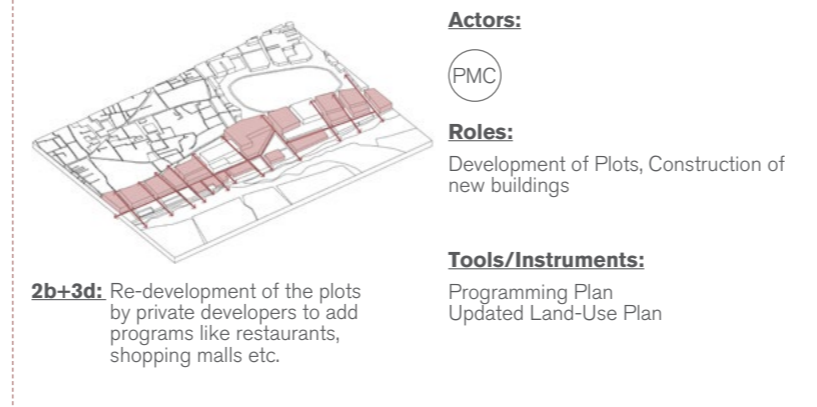


#### Roles:

Designing, Execution and Maintenance of Public Parks

#### Tools/Instruments:

Planting Plan  
Incentives



**2b+3d:** Re-development of the plots by private developers to add programs like restaurants, shopping malls etc.

#### Actors:

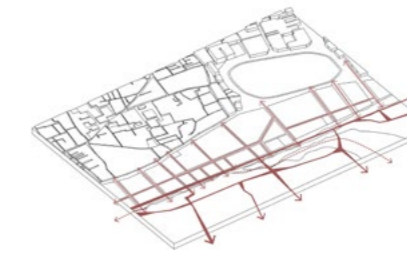


#### Roles:

Development of Plots, Construction of new buildings

#### Tools/Instruments:

Programming Plan  
Updated Land-Use Plan



**2b+3e:** Establishing water connectivity with boat routes and pathways.

#### Actors:

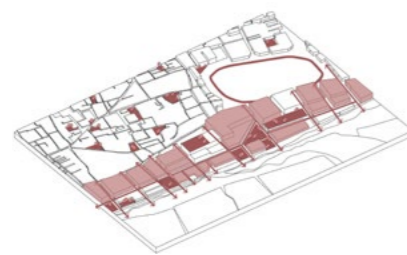
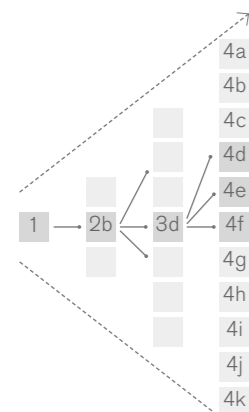


#### Roles:

Conduct surveys and map most used routes, design and execute board-walks and boat routes

#### Tools/Instruments:

Survey - Mapping  
Data Collection  
Water Transport Network Plan



**2b+3d+4d:** Connecting green patches, taking greens along the river into the city

#### Actors:



#### Roles:

Planning and Maintaining Terrace and Backyard Gardens

#### Tools/Instruments:

Subsidies



**2b+3d+4e:** Increasing permeability by promoting permeable paver blocks, maintaining slopes to river

#### Actors:

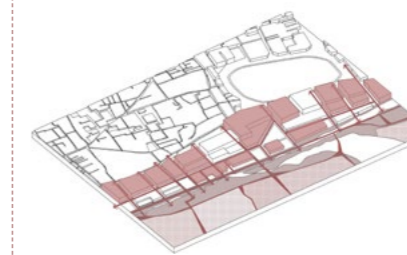


#### Roles:

Re-paving private plots and roads with paver blocks

#### Tools/Instruments:

Subsidies



**2b+3d+4f:** Constructing wetland parks and regulating temporary agricultural fields for dry seasons on the river bed

#### Actors:

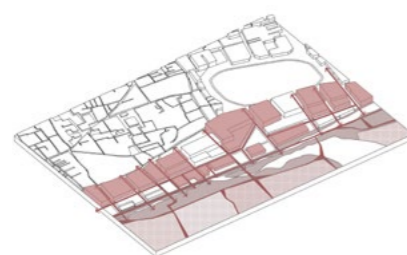


#### Roles:

Construction of Wetland Parks and Temporary Plantation of Crops.

#### Tools/Instruments:

Design Plan  
Planting Plan



**1+2b+3d+4f:**

Fig. 168. Dynamic Planning Pathway for Urban Area in PMC

Local Adaptation Urban Areas	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8
		Assessment: Decision	Assessment: Decision	Assessment: Decision	Assessment:			
<b>Operability</b>	<b>1</b>	<b>2b</b>	<b>3d</b>	<b>4f</b>				
<b>Actors:</b>	- Patna Municipal Corporation - Water and Sanitation Department	- Patna Municipal Corporation - Ward Office - Road Construction Department	- Patna Municipal Corporation	- Independent Investors + NGOs - Landscape Architects - Farmers				
<b>Instruments:</b>	- Sewage Network Plan	- Workshops, Compensation Plan - Revised Town Planning Scheme	- Programming Plan - Updated Land Use Plan	- Design Plan - Planting Plan				
<b>Objectives:</b>	- Stop Sewage flow into the River (Social + Ecological Benefits)	- Access Roads to the River (Social Benefits)	- Creating Activities along the River (Social + Economic Benefits)	- Buffer with temporary landscapes (Social + Ecological Benefits)				
<b>Co-Management</b>	<b>Public Sector</b>	<b>Public Sector + Private Owners</b>	<b>Public Sector</b>	<b>Citizens + Civil Societies</b>				



### 9.1.2. Manifestation 2: Peri-Urban (Fast developing areas)

The second site selected for testing the local adaptation of regional and metropolitan scale strategies is located within the peri-urban area of the Patna City. The area is a mix of residential buildings and agricultural farms. Also, the topographically the area is a low lying land, which forms a combination of ponds and large swampy patches. These patches also referred to as 'Tal' are a huge expanse of land with depression often filled with water during monsoons. These areas become home to migratory birds during the winters and often turn dry during the summers.

With constant unplanned encroachment of Tals and wetlands, the water holding and drainage within the area have become a challenge. As per the new development plan rights for residential development in the area have been granted. With no existing infrastructure for sewage disposal and water supply, it becomes extremely important to plan infrastructure development considering future scenarios and integrated approach.

#### Strategies Used

##### Regional Scale



**RS2:**  
Landscape  
Interventions

##### Metropolitan Scale



**MS1:**  
Infrastructure  
Interventions



**MS2:**  
Landscape  
Interventions



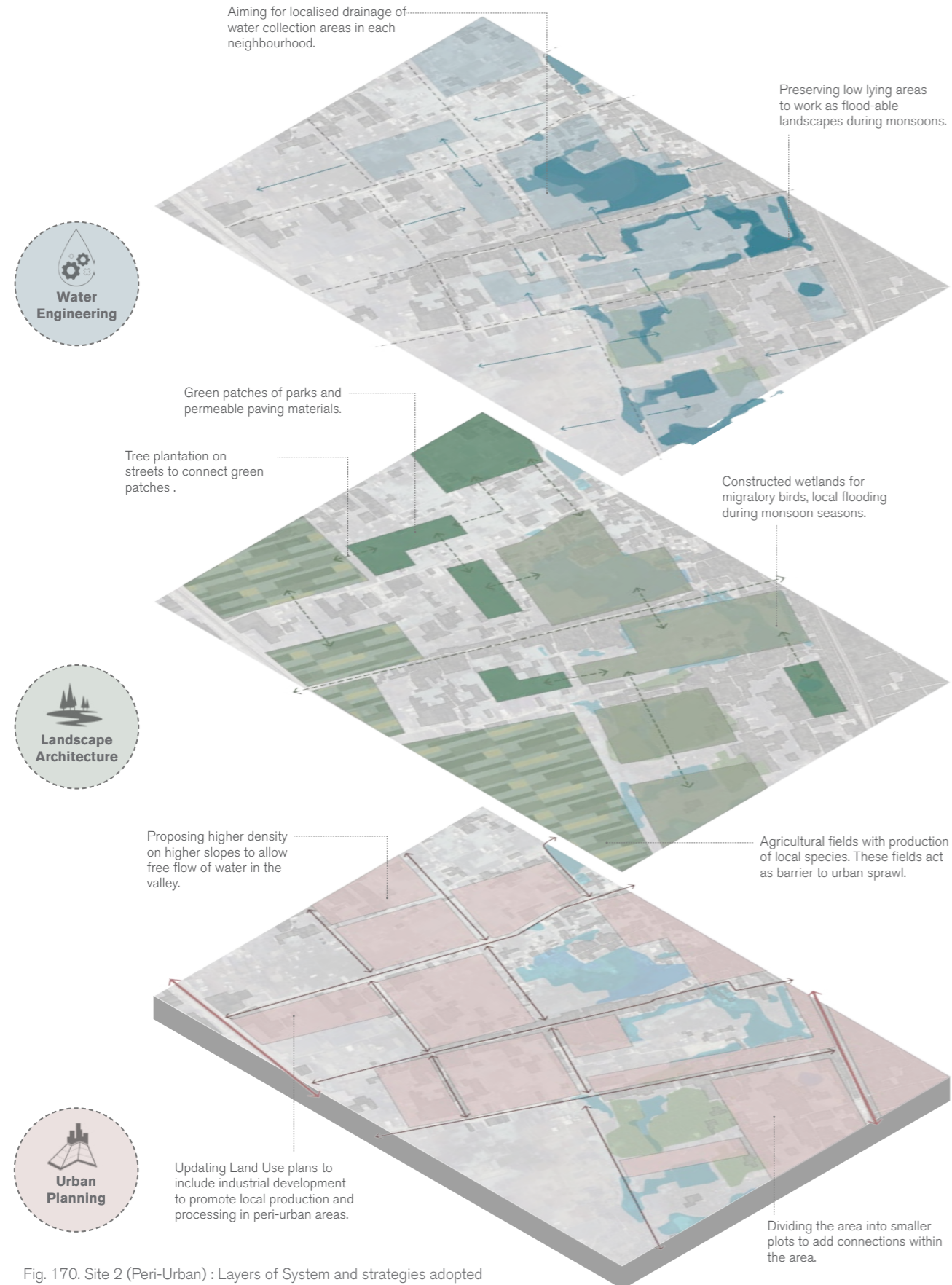
**MS4:**  
Industrial  
Development



Fig. 169. Site1 (Urban) : Existing conditions and challenges



**Layers of System**



**Strategies Used**

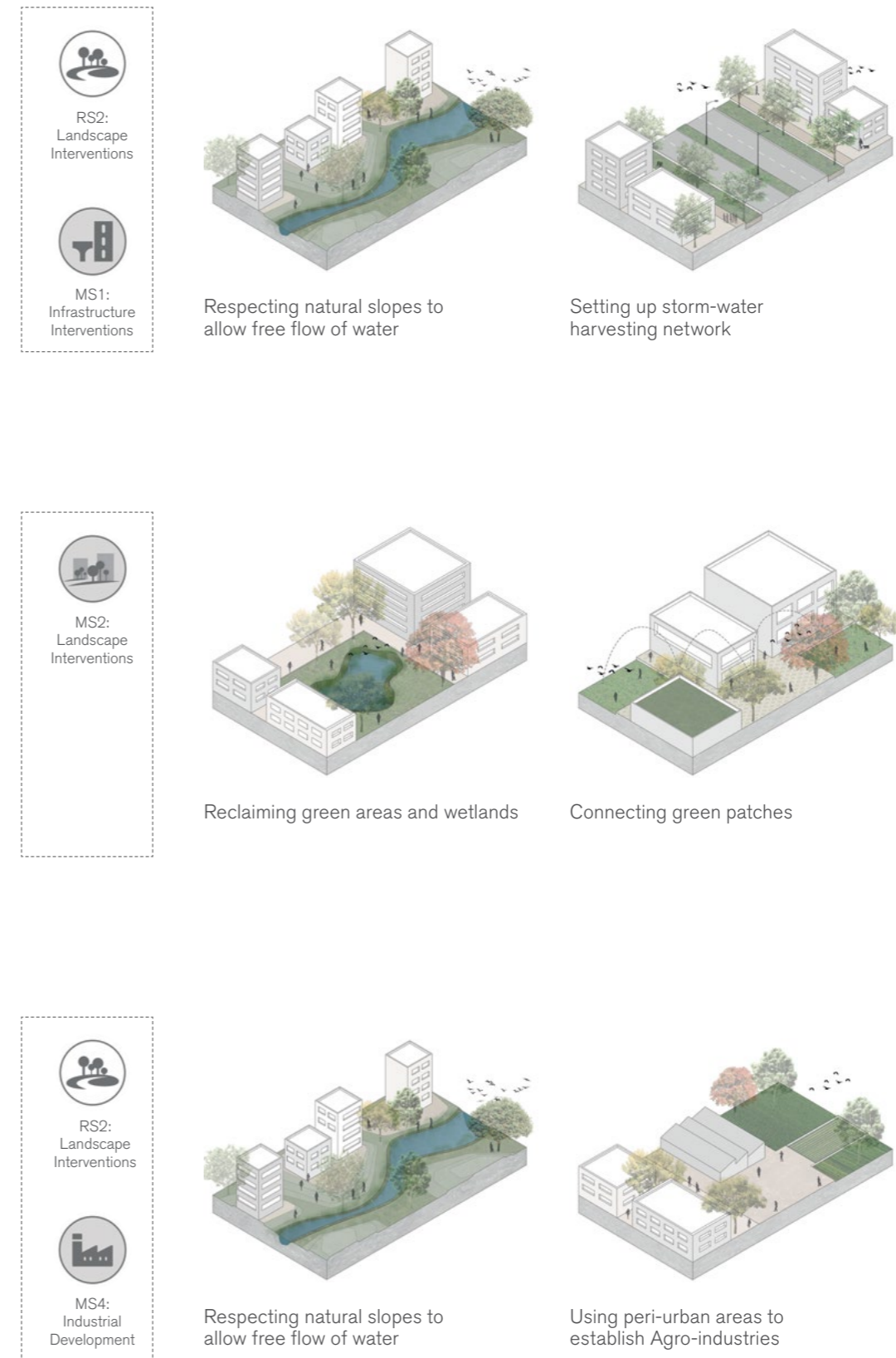


Fig. 170. Site 2 (Peri-Urban) : Layers of System and strategies adopted



## Stakeholders and Local Engagement

Stakeholder	Sector	Type of Involvement	Level	Type of Engagement	Action/Interest
• Namami Gange (NMCG)	Public	- Regulatory - Funding	- Tertiary	- Power: Medium - Interest: High	- Resolving challenges faced by the river
• Ganga Flood Control Department (GFCD)	Public	- Regulatory - Funding	- Tertiary	- Power: Medium - Interest: Medium	- Regulating with state bodies for flood warnings and mitigation
• Central Ground Water Board (CGWB)	Public	- Regulatory	- Tertiary	- Power: Medium - Interest: High	- Increased ground-water recharge
• Ministry of Environment, Forest and Climate Change (Central) (EFCC)	Public	- Regulatory - Monitoring	- Secondary	- Power: Low - Interest: High	- Policies and programs for climate change
• Bihar: Water Resources (BWR)	Public	- Regulatory - Administrative	- Primary	- Power: High - Interest: High	- Water distribution and management
• Bihar: Environment and Forest Department (BEFD)	Public	- Regulatory	- Primary	- Power: High - Interest: High	- Maintenance and regulations of ponds and wetlands
• Bihar: Urban Development Department (BUDD)	Public	- Planning - Administrative - Funding	- Primary	- Power: High - Interest: High	- Planning and Development of Urban Areas
• Developers (Dev)	Private	- Investment - Execution	- Primary	- Power: High - Interest: High	- Monetary gains from the development
• Housing Associations and Market (HA)	Private	- Investment - Execution	- Primary	- Power: High - Interest: High	- Monetary gains from the development
• Landowners (Lo)	Private Civil Societies	- Participatory - Investment	- Primary	- Power: Low - Interest: High	- Monetary gains from the development
• Farmers (Fm) / Fishermen (FsM)	Private	- Users	- Primary	- Power: Low - Interest: Medium	- Added and regularised farming opportunities
• Factories and Industries (Indus)	Private	- Investment	- Primary	- Power: Medium - Interest: High	- Investment and profit from factories
• Patna Municipal Corporation (PMC)	Public	- Regulatory - Implementing	- Primary	- Power: Medium - Interest: High	- City development, Housing and public place
• Urban Planners (UP) / Landscape Architects (LA)	Private	- Planning	- Primary	- Power: Low - Interest: High	- Neighbourhood development and Constructed wetland parks
• Tourism Department (TD)	Public Private	- Users	- Secondary	- Power: Low - Interest: Medium	- Monetary gains from Wetland parks
• Patna Regional Development Authority (PRDA)	Public	- Execution	- Primary	- Power: Medium - Interest: Medium	- Infrastructure Development
• Ward Office	Public	- Collaborative - Execution	- Primary	- Power: Medium - Interest: Medium	- Collaboration and Participation with citizens and gov.
• NGOs	Civil Societies	- Awareness / Advisory	- Tertiary	- Power: Medium - Interest: High	- Awareness and protection of environment
• Local Communities / Citizens (Cit)	Civil Societies	- Users	- Primary	- Power: Low - Interest: High	- Liveable housing development

Table: Site 2 (Peri-Urban) : Stakeholder Engagement

## Networks and Relationships

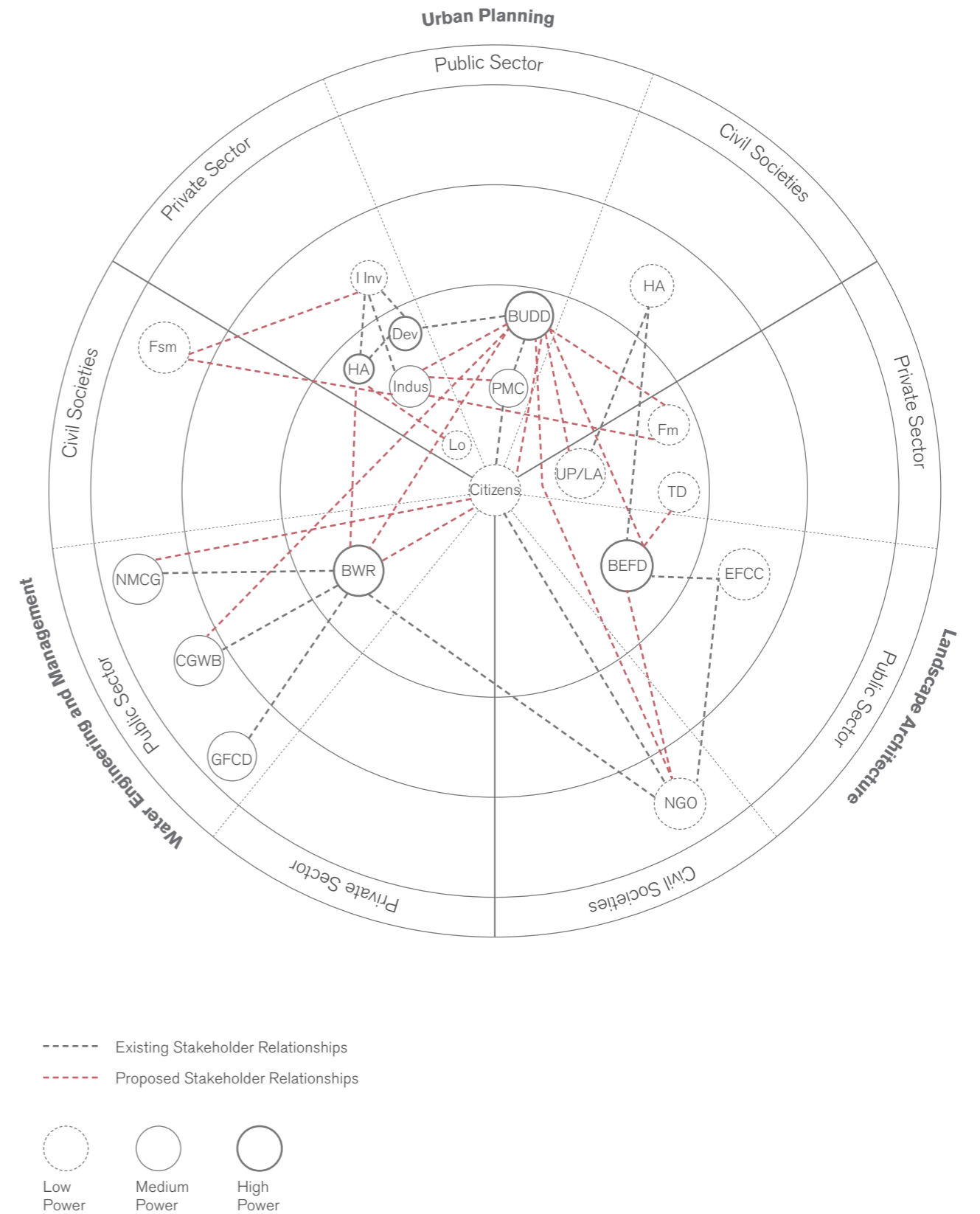
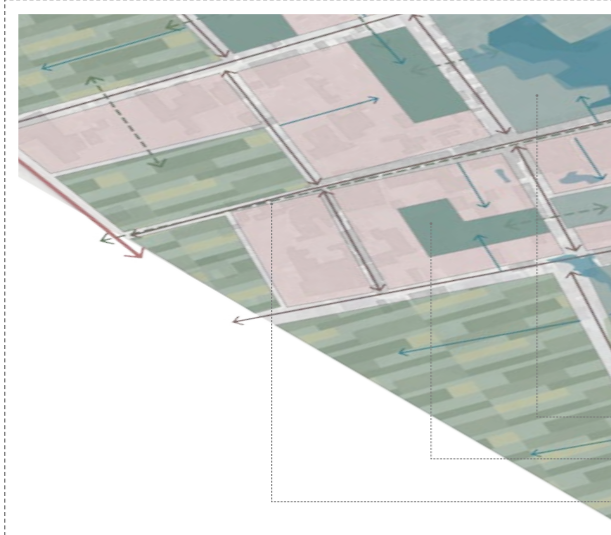


Fig. 171. Site 2 (Peri-Urban) : Stakeholder Networks

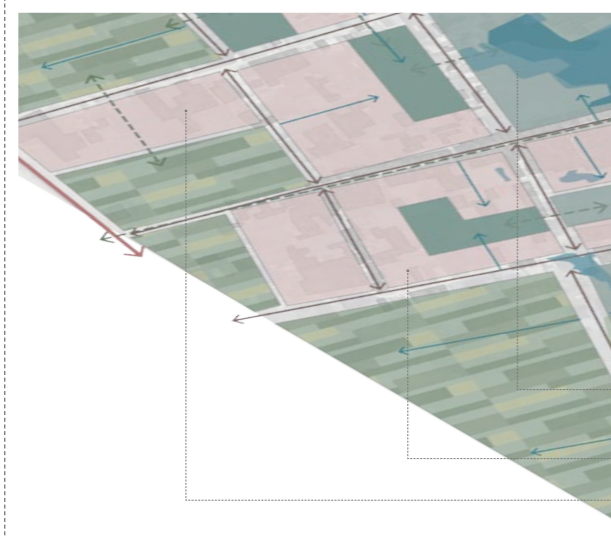


## Benefits and Impact



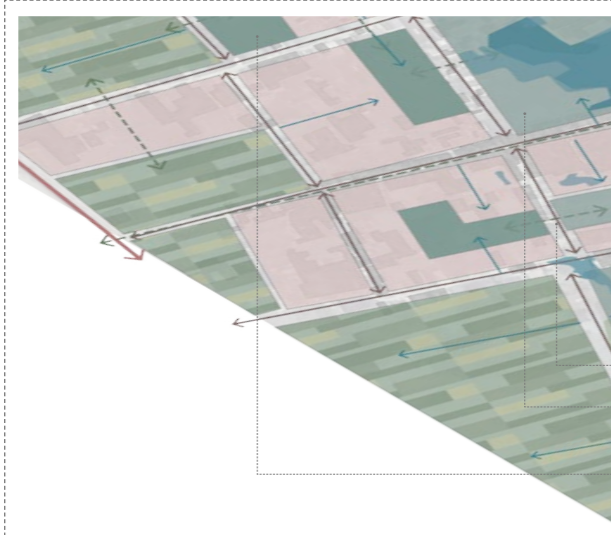
### 1. Social

- Increased liveability (Living in wetlands)
- Parks and public places
- Increased accessibility



### 2. Economic

- Opportunity to promote tourism for wetlands
- Increased land value
- Industries: employment opportunities



### 3. Ecological

- Connected tree canopies
- Constructed wetlands to revive ecology and act as flooding buffer
- Localised water drainage and ground water recharge

Fig. 172. Site 2 (Peri-Urban): Social, Economic and Ecological benefits of adopted strategies

## Before and After



Fig. 173. Site2 (Peri-Urban): Before and After visualization of strategies at location



## Operability: Pathway Planning for Peri-Urban Area

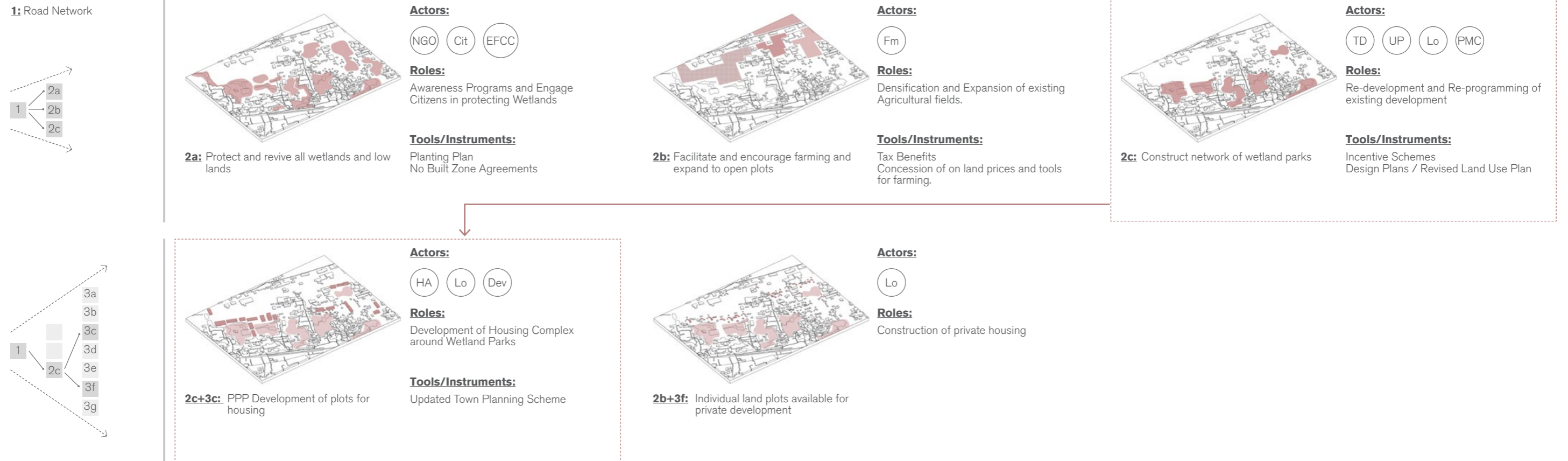


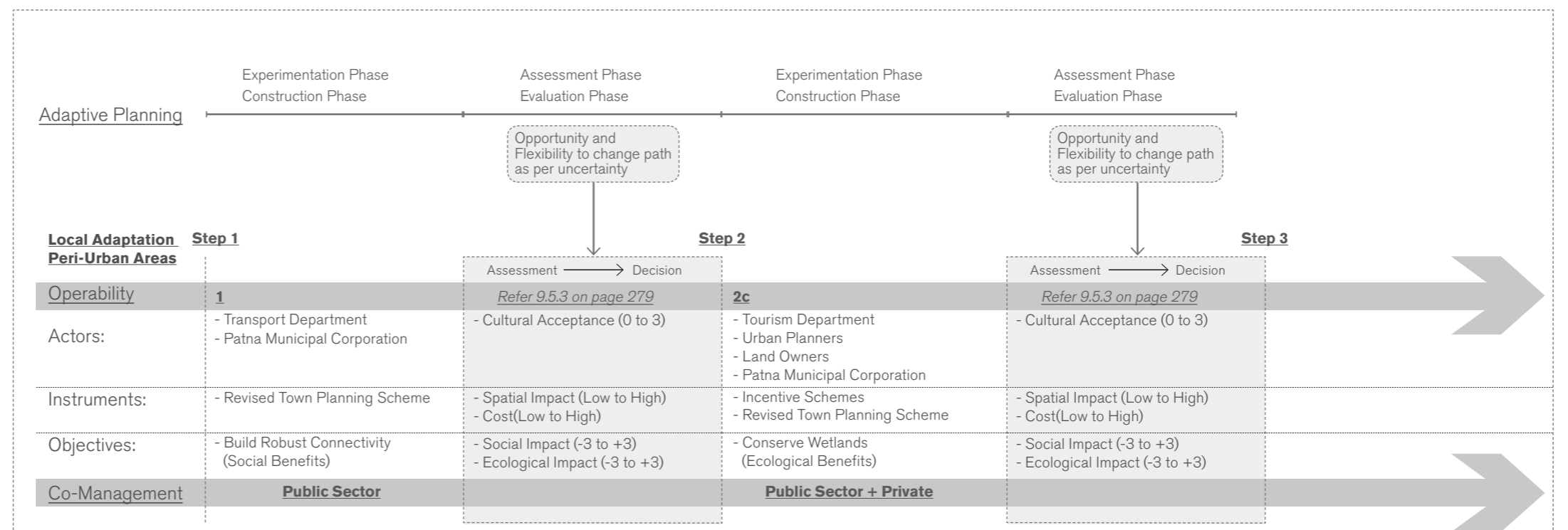
Fig. 174. Dynamic Planning Pathway for Peri-Urban Area in PMC

Dynamic Pathway Planning is explored for the operability of local adaptation of Peri-Urban areas within the Patna Metropolitan Region. The aim for this region is to curtail the further expansion of urban boundaries and stop the encroachment of wetlands and farms. Thus, actions selected here aim at the revival of wetlands and densification of existing built areas.

The process of Adaptive Spatial Planning allows flexibility of selection of paths, based on assessment and discussions within the stakeholders after every step. Thus this approach allows flexible planning that can adapt with current and possible future uncertainties.

The pathway selected here is based on aimed objectives and healthy co-management of resources.

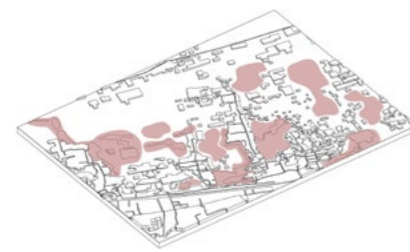
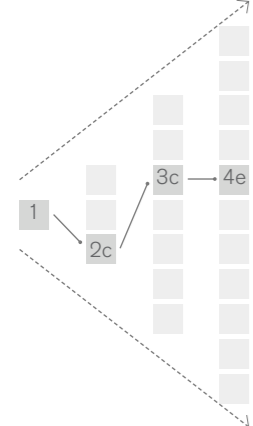
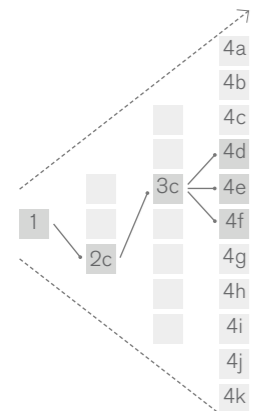
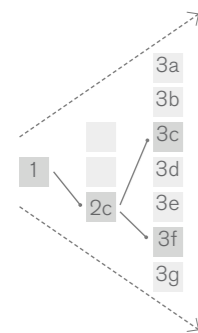
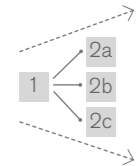
- 1: Transport Network
- 2b: Establishing access to the river
- 3d: Re-development of Plots
- 4f: Constructing Wetlands and Farms





## Operability: Pathway Planning for Peri-Urban Area

1: Road Network



**2a:** Protect and revive all wetlands and low lands

**Actors:**



**Roles:**

Awareness Programs and Engage Citizens in protecting Wetlands

**Tools/Instruments:**

Planting Plan  
No Built Zone Agreements



**2b:** Facilitate and encourage farming and expand to open plots

**Actors:**

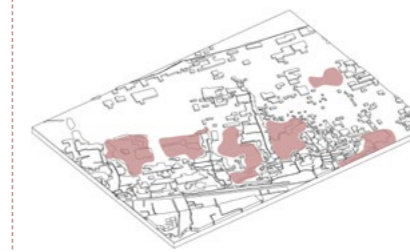


**Roles:**

Densification and Expansion of existing Agricultural fields.

**Tools/Instruments:**

Tax Benefits  
Concession of on land prices and tools for farming.



**2c:** Construct network of wetland parks

**Actors:**

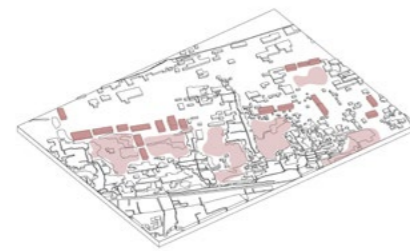


**Roles:**

Re-development and Re-programming of existing development

**Tools/Instruments:**

Incentive Schemes  
Design Plans / Revised Land Use Plan



**2c+3c:** PPP Development of plots for housing

**Actors:**

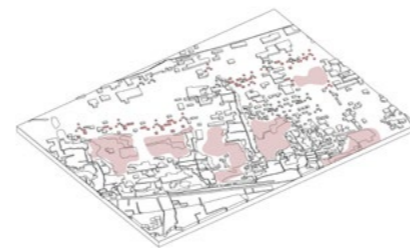


**Roles:**

Development of Housing Complex around Wetland Parks

**Tools/Instruments:**

Updated Town Planning Scheme



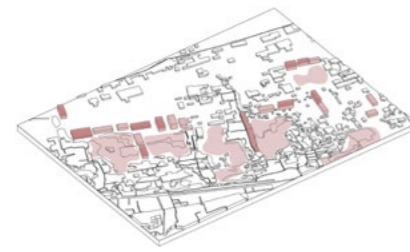
**2b+3f:** Individual land plots available for private development

**Actors:**



**Roles:**

Construction of private housing



**2c+3c+4d:** Densification of existing and new development

**Actors:**

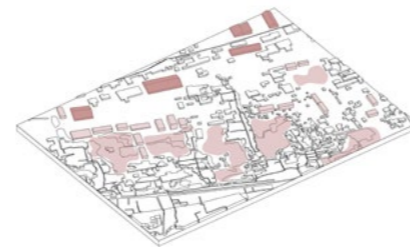


**Roles:**

Densification of Existing and New Housing Development

**Tools/Instruments:**

Increased FSI  
Transfer of Development Rights



**2c+3c+4e:** Establishing small scale industrial and commercial hubs connecting rural agricultural fields to urban areas

**Actors:**

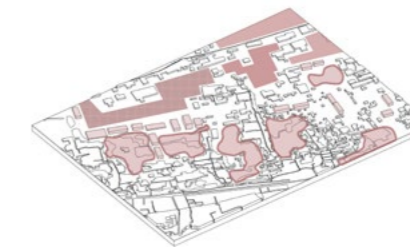


**Roles:**

Establish Food Process and other Agricultural Product Manufacturing Industries

**Tools/Instruments:**

Subsidies for Industrial Development  
Tax Benefits



**2c+3c+4f:** Promoting urban farming on terraces, open plots and in wetlands

**Actors:**

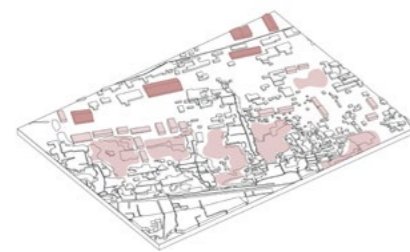


**Roles:**

Cultivation of Crops and Urban Farms

**Tools/Instruments:**

Subsidies



**1+2c+3c+4e:**

Fig. 175. Dynamic Planning Pathway for Peri-Urban area in PMC

Local Adaptation Peri-Urban Areas	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8
		Assessment: Decision	Assessment: Decision	Assessment: Decision	Assessment			
<b>Operability</b>	<b>1</b>	<b>2c</b>	<b>3c</b>	<b>4e</b>				
<b>Actors:</b>	- Transport Department - Patna Municipal Corporation	- Tourism Department - Urban Planners - Land Owners - Patna Municipal Corporation	- Housing Association - Developers - Land Owners	- Factories and Industries - Patna Municipal Corporation				
<b>Instruments:</b>	- Town Planning Scheme	- Incentive Schemes - Revised Town Planning Scheme	- Revised Town Planning Scheme	- Subsidies for Industrial Development - Tax Benefits				
<b>Objectives:</b>	- Establish well connected network (Social Benefits)	- Conserve Wetlands (Ecological Benefits)	- Protecting Wetlands + Housing (Social + Economic Benefits)	- Income Generation (Social Benefits)				
<b>Co-Management</b>	<b>Public Sector</b>	<b>Public Sector + Private</b>	<b>Public Sector</b>	<b>Citizens + Civil Societies</b>				



### 9.1.3. Manifestation 3: Rural Area

The rural areas of Patna Metropolitan is composed of 1395 villages and 332 Panchayats (Government of Bihar). Agriculture fields of rice, wheat and sugar-cane are prominent in this region. The selected zoom-in to test the local adaptation of regional and metropolitan strategies is an area located on the banks of Punpun River, one of the tributaries of Ganges River in Patna.

The existing conditions show cultivation of single crops in the agricultural fields. Moreover, the run-off from the fields, with high chemical contents due to insecticides and pesticides flow directly into Punpun river. Punpun River being one of the tributaries of the Ganges river carries these pollutants to the Ganges River. Hence, it is important to not only derive and test strategies for the Ganges river but the entire river system, within the basin.

Secondly, the site falls within medium to high flooding zone. Recently even in 2019, the area experienced devastating floods with loss of crops and life. Thus, adopting strategies to create more room for the river and to the management of pollution entering the river system is extremely necessary.

#### Strategies Used

##### Regional Scale



RS1:  
Room for the River



RS2:  
Landscape Interventions



RS3:  
Comprehensive Connectivity



RS4:  
Pollution Management

##### Metropolitan Scale



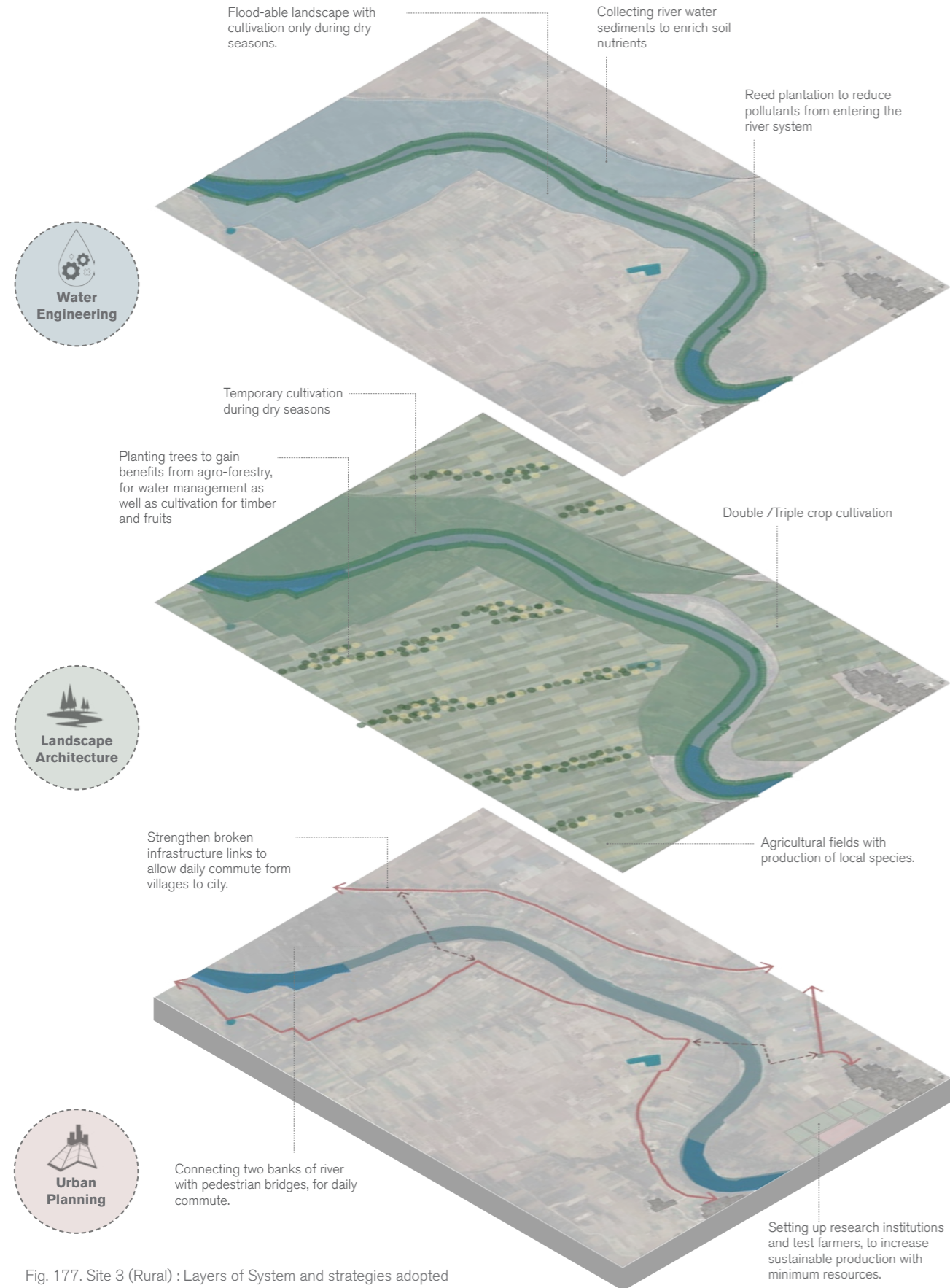
MS4:  
Industrial Development



Fig. 176. Site1 (Rural) : Existing conditions and challenges



**Layers of System**



**Strategies Used**



Fig. 177. Site 3 (Rural) : Layers of System and strategies adopted



## Stakeholders and Local Engagement

Stakeholder	Sector	Type of Involvement	Level	Type of Engagement	Action/Interest
• Namami Gange (NMCG)	Public	- Regulatory	- Tertiary	- Power: Medium - Interest: High	- Resolving challenges faced by the river
• Ganga Flood Control Department (GFCD)	Public	- Regulatory - Funding	- Secondary	- Power: Medium - Interest: Medium	- Regulating with state bodies for flood warnings and mitigation
• Ministry of Agriculture & Farmers' Welfare (AFW)	Public	- Regulatory - Funding	- Primary	- Power: Medium - Interest: High	- Boosting Agro-forestry and industries
• Bihar: Agriculture Department (BAD)	Public	- Regulatory - Monitoring - Funding	- Primary	- Power: High - Interest: High	- Advice and programs to boost agricultural production
• Bihar: Water Resources (BWR)	Public	- Regulatory - Administrative	- Primary	- Power: High - Interest: High	- Water distribution and management for agriculture
• Bihar: Environment and Forest Department (BEFD)	Public	- Regulatory	- Secondary	- Power: Medium - Interest: High	- Maintenance and regulations of ponds and wetlands
• Bihar: Rural Development Department (BRDD)	Public	- Planning - Administrative - Funding	- Primary	- Power: Low - Interest: High	- Planning and Development of Rural Areas
• Bihar: Road Construction Department (BRCD)	Public	- Planning - Execution	- Secondary	- Power: Medium - Interest: Medium	- Establishing stronger road network between urban and rural areas
• Bihar: Industry Department (BID)	Public	- Funding - Administrative	- Primary	- Power: Medium - Interest: High	- Establishing agro industries
• Farmers (Fm) / Fishermen (Fsm)	Private	- Users	- Primary	- Power: Low - Interest: Medium	- Regularised farming and fishing opportunities
• Factories and Industries (Indus)	Private	- Investment	- Primary	- Power: Medium - Interest: High	- Investment and profit from factories
• Patna Regional Development Authority (PRDA)	Public	- Execution	- Primary	- Power: Medium - Interest: Medium	- Infrastructure Development (Roads, irrigation canals)
• Gram Panchayat (GMP)	Public Civil Societies	- Users	- Secondary	- Power: Low - Interest: Medium	- Development, safety against flooding and job opportunities within the village
• Research Institutions (RI)	Civil Societies	- Exploratory - Research	- Secondary	- Power: Low - Interest: High	- Research and testing to improve and increase production
• Independent Investors (I Inv)	Private	- Investment - Trading	- Primary	- Power: Medium - Interest: High	- Establishing agro industries
• NGOs	Civil Societies	- Awareness / Advisory	- Tertiary	- Power: Medium - Interest: High	- Awareness and safety to climate change - Demand for rights
• Local Communities / Citizens (Cit)	Civil Societies	- Users	- Primary	- Power: Low - Interest: High	- Quality, low cost food produce, safety, job opportunities

Table: Site 3 (Rural): Stakeholder Engagement

## Networks and Relationships

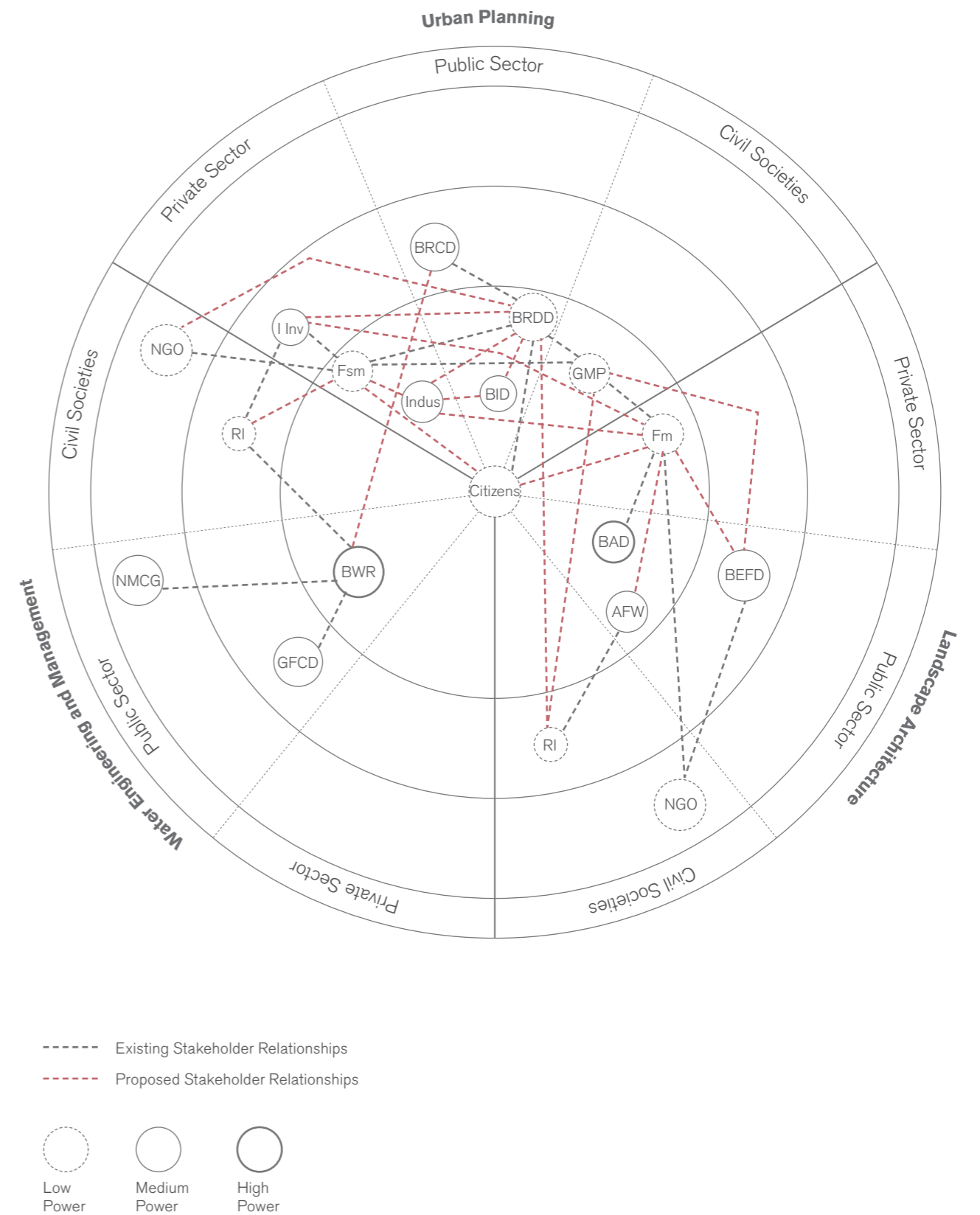


Fig. 178. Site 3 (Rural): Stakeholder Networks



## Benefits and Impact



### 1. Social

- Robust connectivity to cities and across the river



### 2. Economic

- Increased productivity due to local research and testing
- Production of agricultural crops as well as timber and fruits



### 3. Ecological

- Improved water quality
- Room for river to expand during monsoon
- More ground-water recharge and water management due to tree plantation

Fig. 179. Site 3 (Rural): Social, Economic and Ecological benefits of adopted strategies

## Before and After



Fig. 180. Site3 (Rural): Before and After visualization of strategies at location



## Operability: Pathway Planning for Rural Area

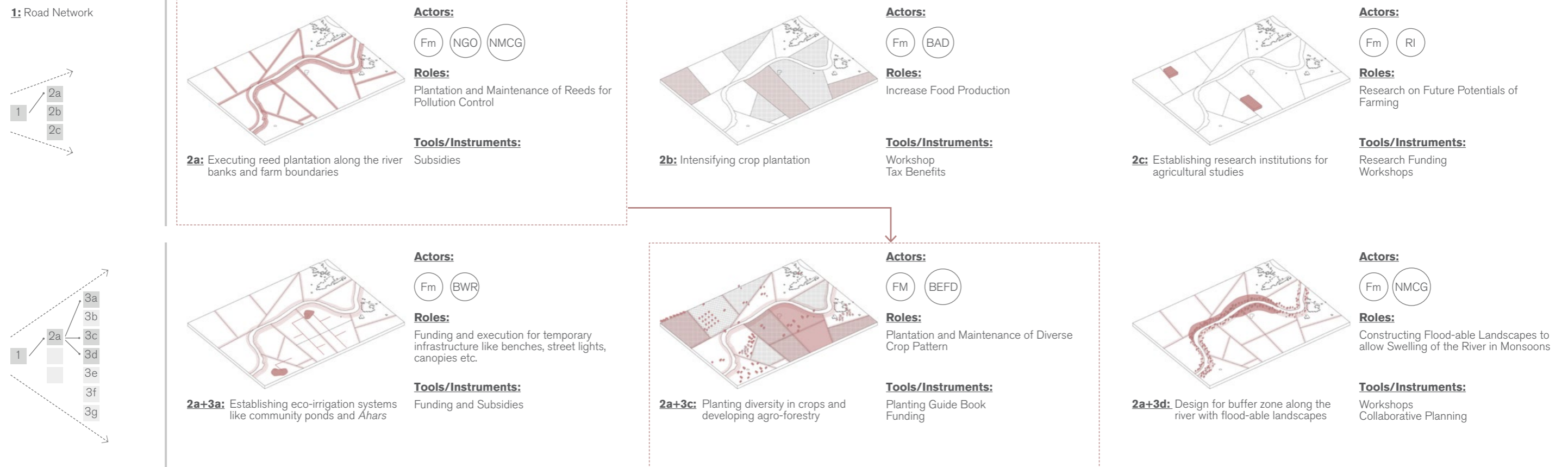


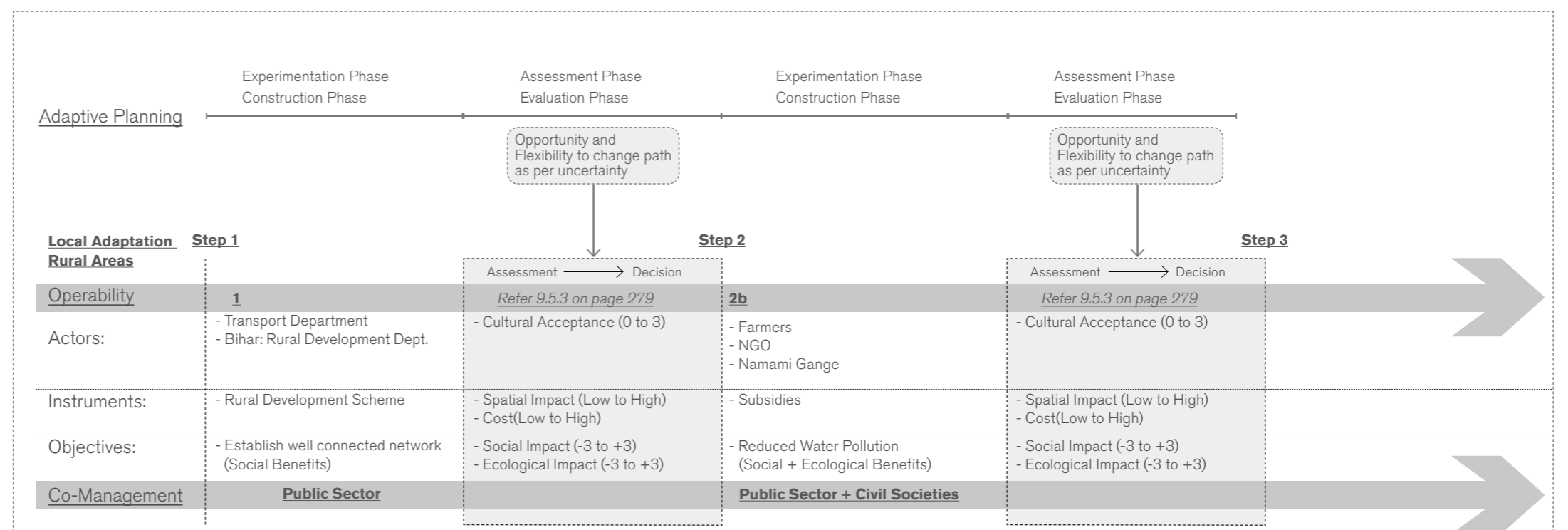
Fig. 181. Dynamic Planning Pathway for Rural Area in PMC

The operability of local adaptation of Adaptive Spatial Planning Model in rural areas of Patna Metropolitan Region is carried out by sequencing actions to protect farms from flooding, create opportunities for increased production and income generation.

The sequencing of actions starts with a very important and urgent step of building strong transport links between rural areas and urban areas. The pathway further explores, assessing each step with proposed assessment criteria (9.5.3 on page 279) and adapting pathway based on new generate requirements due to changing climate. As the framework allows experimenting and testing of implemented actions, the pathways can further be implemented at other similar location for the same results.

The sequencing of action for Rural areas is as followed:

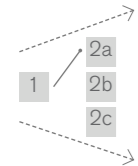
- 1: Transport Network
- 2b: Reed Plantation
- 3d: Diversity Integration
- 4f: Establishing Industries





## Operability: Pathway Planning for Rural Area

### 1: Road Network



**2a:** Executing reed plantation along the river banks and farm boundaries

**Actors:** Fm, NGO, NMCG

**Roles:** Plantation and Maintenance of Reeds for Pollution Control

**Tools/Instruments:** Subsidies

**2b:** Intensifying crop plantation

**Actors:** Fm, BAD

**Roles:** Increase Food Production

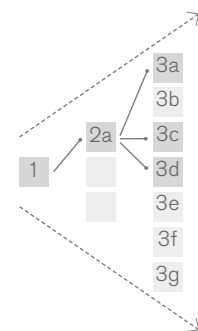
**Tools/Instruments:** Workshop, Tax Benefits

**2c:** Establishing research institutions for agricultural studies

**Actors:** Fm, RI

**Roles:** Research on Future Potentials of Farming

**Tools/Instruments:** Research Funding, Workshops



**2a+3a:** Establishing eco-irrigation systems like community ponds and Ahars

**Actors:** Fm, BWR

**Roles:** Funding and execution for temporary infrastructure like benches, street lights, canopies etc.

**Tools/Instruments:** Funding and Subsidies

**2a+3c:** Planting diversity in crops and developing agro-forestry

**Actors:** FM, BEFD

**Roles:** Plantation and Maintenance of Diverse Crop Pattern

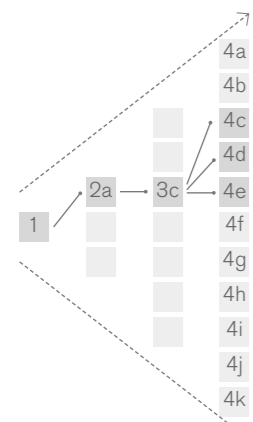
**Tools/Instruments:** Planting Guide Book, Funding

**2a+3d:** Design for buffer zone along the river with flood-able landscapes

**Actors:** Fm, NMCG

**Roles:** Constructing Flood-able Landscapes to allow Swelling of the River in Monsoons

**Tools/Instruments:** Workshops, Collaborative Planning



**2c+3c+4c:** Construction of local fishing ponds to promote pisciculture

**Actors:** Fm, Fsm

**Roles:** Construction of Fish Ponds and Development of Pisciculture

**Tools/Instruments:** Pisciculture Funding

**2c+3c+4d:** Developing vertical farming along with animal husbandry to increase economic gains

**Actors:** Fm, BAD

**Roles:** Construct Vertical Farms and Increase Food Production

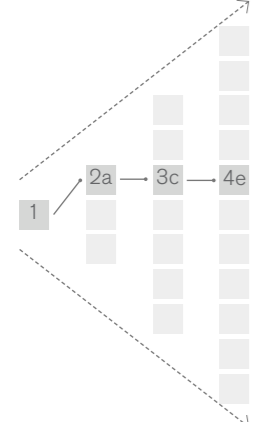
**Tools/Instruments:** Construction Manual and Tool-kits, Funding

**2c+3c+4e:** Setting up local food processing industries to create jobs and income gains locally

**Actors:** Fm, Indus, BID

**Roles:** Construction and Establishment of Industries for Food Processing

**Tools/Instruments:** Tax Benefits, Business Plans, Funding



**1+2a+3c+4e:**

Local Adaptation Rural Areas	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8
		Assessment: Decision	Assessment: Decision	Assessment: Decision	Assessment:			
<b>Operability</b>	<b>1</b>	<b>2a</b>	<b>3c</b>	<b>4e</b>				
<b>Actors:</b>	- Transport Department - Bihar: Rural Development Dept.	- Farmers - NGO - Namami Gange	- Farmers - Bihar: Environment and Forest Dept	- Farmers - Industries - Bihar: Industry Department				
<b>Instruments:</b>	- Rural Development Scheme	- Subsidies	- Planting Guide Book - Funding	- Design Plan - Planting Plan				
<b>Objectives:</b>	- Establish well connected network (Social Benefits)	- Reduced Water Pollution (Social + Ecological Benefits)	- Balance Water and Ecology (Economic + Ecological Benefits)	- Buffer with temporary landscapes (Social + Ecological Benefits)				
<b>Co-Management</b>	<b>Public Sector</b>	<b>Public Sector + Civil Societies</b>	<b>Public + Private Sector</b>	<b>Public + Private Sector</b>				

Fig. 182. Dynamic Planning Pathway for Rural Area in PMC



## 9.2. COMMUNITY PARTICIPATION

Community participation is a key aspect of local adaptation. With the lack of a formal framework for participation, planning for local interventions lack perspectives from the communities regarding the problems faced and expectation from planning.

To establish an Adaptive Spatial Planning Model for the Ganges River Basin it is also necessary to formulate a framework to include views and actions from locals. With the below proposed system, locals and civil societies can participate in the planning process in a more regulatory manner. Moreover, with a standardised list of actions derived based on systemic goals, regional strategies and metropolitan strategies, the individual actions can play a greater role in the systemic change and resilience across the river basin.

### Step 1: Create / Recognize



Do a Local Deed towards Climate Change Adaptation

The first step for community participation towards climate adaptation is to do a local deed. These deeds can be selected from a catalogue prepared by the local municipal corporation and ward offices following the regional and metropolitan strategies.

### Step 3: Formalize



Inform Local Government

The next step would be to formalize these actions. With the help and power of local ward offices, actions under this project can be formalised to inform policies and planning documents.

### Step 2: Collaborate



Spread Awareness and Engage Community

The second step would be to create community awareness and encourage participation. Several local NGOs can help in conducting meetings and informal session to engage the community. Benefits from traditional knowledge of farmers and fishermen with exchange and innovation from research organization can happen at this platform.

### Step 4: Gain



Gain Benefits in form of subsidies / rewards

And the final step of the process would be to gain subsidies and rewards from the local bodies in return of the actions carried out. This method would encourage locals to strengthen their bonds and work towards a common vision.

Source: SOCC, Asia Initiative, adapted by author

## 9.3. RE-DISTRIBUTION OF ROLES FOR SPATIAL PLANNING

(Current Capacities vs Proposed Roles)

<u>Level of Governance</u>	<u>Current Roles</u>	<u>Redefined Roles</u>
<b>Level 0: Ward Offices</b>	<p>Locally elected member to represent ideas from the community to municipal corporation</p> <p>Zero decision power in terms of budget and project proposal for the area (ward)</p>	<p>Capacity to conduct participatory meetings monthly/ quarterly to identify and needs and desires of the community</p> <p>Power to formulate projects and overlook execution for small scale urban development projects (eg: pervious paving, rain water harvesting ) planned within metropolitan strategic framework</p>
<b>Level 1: Local Municipalities</b>	<p>Develop Land Use Plan and local urban development projects for the city</p> <p>Execution of State planned water infrastructure projects within the city.</p>	<p>Capacity to carry out participatory planning and conduct meetings with locals and ward office to design a Land Use Plan</p> <p>Inform State departments of local challenges and need to formulate state vision</p> <p>Design for local infrastructure projects within the border framework of state strategies</p>
<b>Level 2: State Government</b>	<p>Planning of Infrastructure Projects</p> <p>Deciding/Approving funds for Spatial Planning Projects of Cities and Rural Areas</p>	<p>Bridge between Local Planning and National Policies</p> <p>Developing strategies under National vision considering local challenges</p>
<b>Level 3: Central Government</b>	<p>Independently setting up Policies</p> <p>Allocation of funds to States for development projects</p>	<p>Work as Mediator between different States for cross state projects</p> <p>Allocation of funds based on inputs from State and Local Governments</p> <p>Development of Policies with Inputs from several sectors and levels of governance.</p>

Table: Current and Proposed Roles of Governenig Bodieas at different scales



#### 9.4. TEMPORAL ASPECT OF PROPOSED PLANNING FRAMEWORK

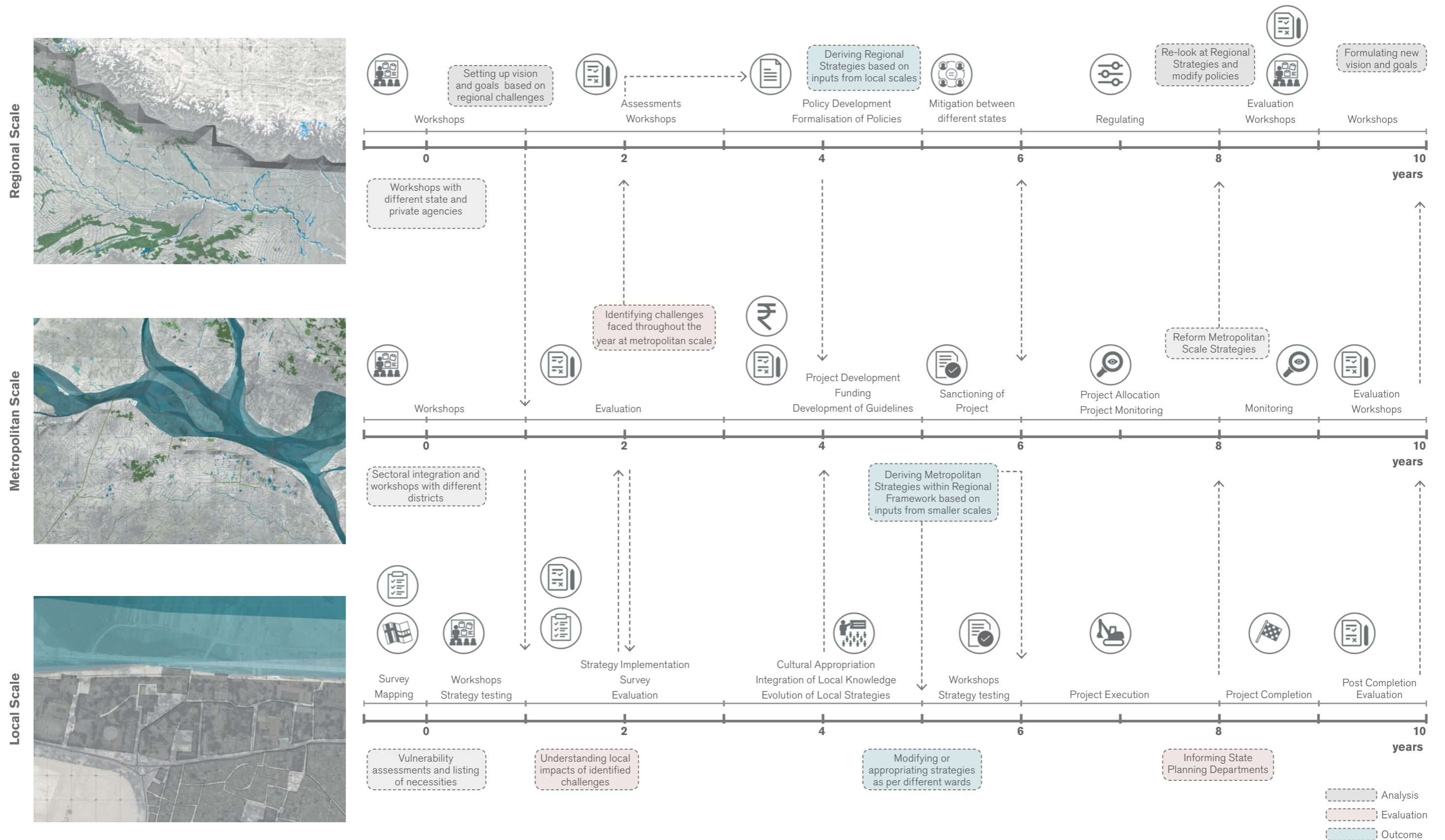


Fig. 183. Temporal understanding of local adaptation and actions required across scales.



## 9.5. DEVELOPING DYNAMIC PATHWAYS

### 9.5.1. Tipping Points

Tipping points within the system are the points when the magnitude of external change is such that some actions and policies are no longer applicable in the same manner and need modifications (Dynamic Adaptive Policy Pathways, Deltares, 2020). The tipping points for the project are speculated in water management (flooding and drought), urban planning and landscape aspects.

The first tipping point is a point in the near future where there lies a high possibility of floods and drought while the second tipping point occurs when the frequency of these activities are high. Thus, the magnitude of external pressure increases from tipping point 1 to tipping point 2, and the system could witness failure if adequate actions are not incorporated.

#### Tipping point 1

**Water Management:** (a) Increased temperatures and possible drought  
(b) High rainfall and flooding probability.

**Urban Planning:** Increased population within the urban centres

**Landscape:** Reduced local species

#### Tipping point 2:

**Water Management:** (a) Higher temperature and droughts  
(b) Increased flooding frequency

**Urban Planning:** Land crisis within urban centres

**Landscape:** Loss of local species

### 9.5.2. Sequencing Actions

Based on the understanding of the existing crisis in the Ganges River Basin and especially within the Bihar and Patna Metropolitan Area, the strategies were derived to address these challenges. The sequencing of actions depend on the requirements of challenges, possible prerequisite required for certain actions and most importantly based on approaching tipping points.

For example, lowering of flood plains would work as a viable action for a certain capacity of increased flooding, but when flooding conditions become more severe, actions like building flood-able landscapes will become more relevant.

Similarly, actions like laying permeable pavements would work to a certain capacity, but for a higher amount of recharge for groundwater, setting up of regional recharge points would be required.

Thus sequencing of actions was based on its co-relation with different actions and its importance within the tipping point scenarios.

### 9.5.3. Assessment Criteria

		Actions	Social Impact	Ecological Impact	Spatial Impact	Cost	Cultural Acceptance
Flooding	Reducing Causes	▪ Lower flood plains	++	--	medium	medium	▲▲▲
		▪ Naturalizing river edge	+++	++	high	low	▲▲▲
		▪ Respecting natural slopes	+	++	high	medium	▲
	Reducing Impacts	▪ Adding flood-able landscapes	++	++	medium	low	▲
		▪ Daylighting canals and streams	0	++	high	high	▲▲
		▪ Design for buffer zone	+++	0	medium	medium	▲▲
Drought	Reducing Causes	▪ Pervious paving materials	0	+	low	high	▲▲▲
		▪ Setting up regional recharge points	--	++	medium	medium	▲
		▪ Respecting natural slopes	+	++	high	medium	▲
Landscape	Reducing Causes	▪ Densification of existing forests	0	+++	low	low	▲▲▲
		▪ Reclaiming green areas	-	+++	high	high	▲
		▪ Connecting green patches	+	++	low	low	▲▲
	Reducing Impacts	▪ Integrating diversity	0	++	low	low	▲▲
		▪ Planter beds and pocket parks	+++	+	low	medium	▲▲▲
		▪ Promoting local planting	-	++	low	low	▲▲
Urban Planning	Reducing Causes	▪ Transport networks	++	-	high	medium	▲▲▲
		▪ Sewage treatment / Pollution	+++	+	medium	high	▲▲
	Reducing Impacts	▪ Activating river edge	+++	-	high	high	▲▲▲
		▪ Establishing agro-industries	+++	-	high	medium	▲▲▲
		▪ Promoting urban farming	++	+	low	low	▲▲▲

#### Key:

Low Positive Impact	+	Low Negative Impact	-	Low Acceptance	▲
Moderate Positive Impact	++	Moderate Negative Impact	--	Moderate Acceptance	▲▲
High Positive Impact	+++	High Negative Impact	---	High Acceptance	▲▲▲

Table: Assessment Criteria for actions within Dynamic Adaptive Pathway  
Source: Dynamic Adaptive Policy Pathways, Deltares, 2020, Adapted by Author

### 9.5.4. Selection of preferred path

#### Method 1: Paths for different locations (Strategic Projects)

Multiple site locations and possible pathways can be laid out within the adaptive pathway planning framework to determine which sites have a possibility to attain desired results and create more impact on the ecological and social needs. This approach can be used to determine strategic projects for the region, that could further boost the development for socio-ecological resilience.

#### Method 2: Path variations based on actors initiating/collaborating

The second method to use the dynamic pathways is understanding variations in the output based on the actors initiating the projects or collaborating. Several pathways can be formed based on permutations of actors involved. This can further be evaluated based on the assessment criteria so that high social and ecological impacts can be achieved.



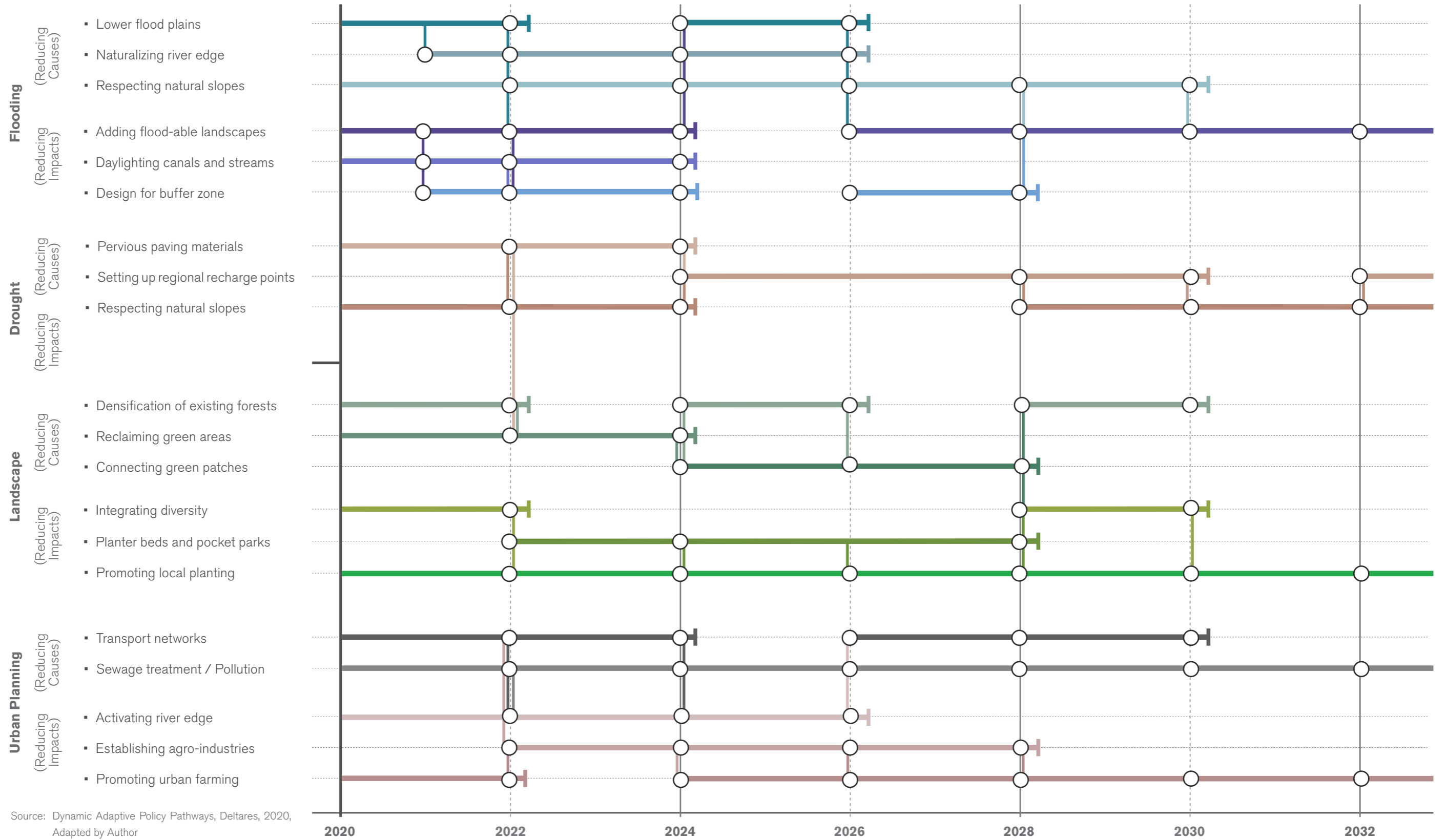
**Adaptive Pathway Framework**  
Sequencing Actions

Water Management: (a) Increased temperatures and possible drought  
(b) High rainfall and flooding probability.  
Urban Planning: Increased population within the urban centres  
Landscape: Reduced local species

Water Management: (a) Higher temperature and droughts  
(b) Increased flooding frequency  
Urban Planning: Land crisis within urban centres  
Landscape: Loss of local species

**Tipping point 1**

**Tipping point 2**



Source: Dynamic Adaptive Policy Pathways, Deltares, 2020, Adapted by Author



### Adaptive Pathway Framework

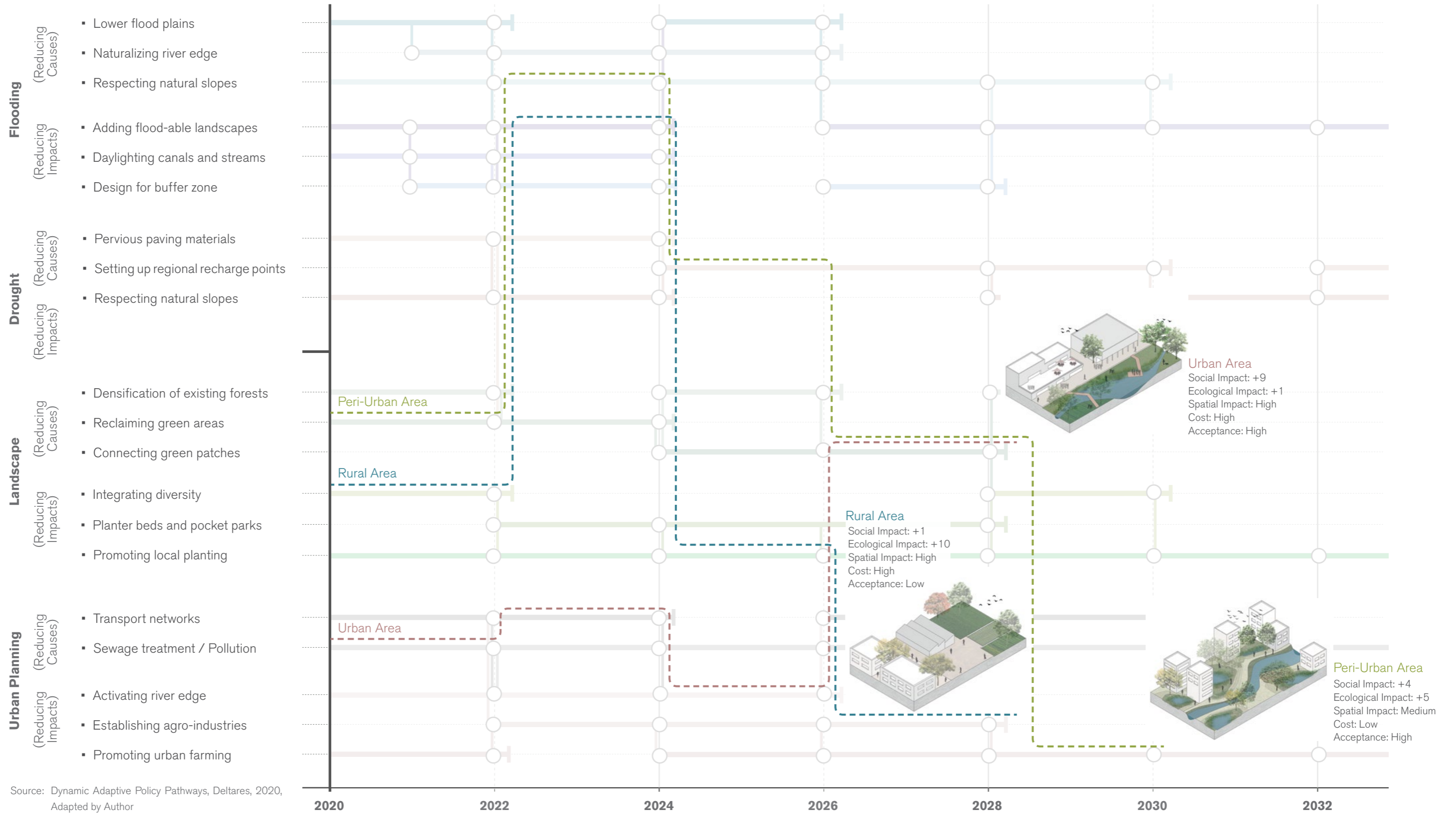
Method 1: Paths for different locations (Strategic Projects)

**Water Management:** (a) Increased temperatures and possible drought  
(b) High rainfall and flooding probability.  
**Urban Planning:** Increased population within the urban centres  
**Landscape:** Reduced local species

**Water Management:** (a) Higher temperature and droughts  
(b) Increased flooding frequency  
**Urban Planning:** Land crisis within urban centres  
**Landscape:** Loss of local species

**Tipping point 1**

**Tipping point 2**



Source: Dynamic Adaptive Policy Pathways, Deltares, 2020, Adapted by Author



### Adaptive Pathway Framework

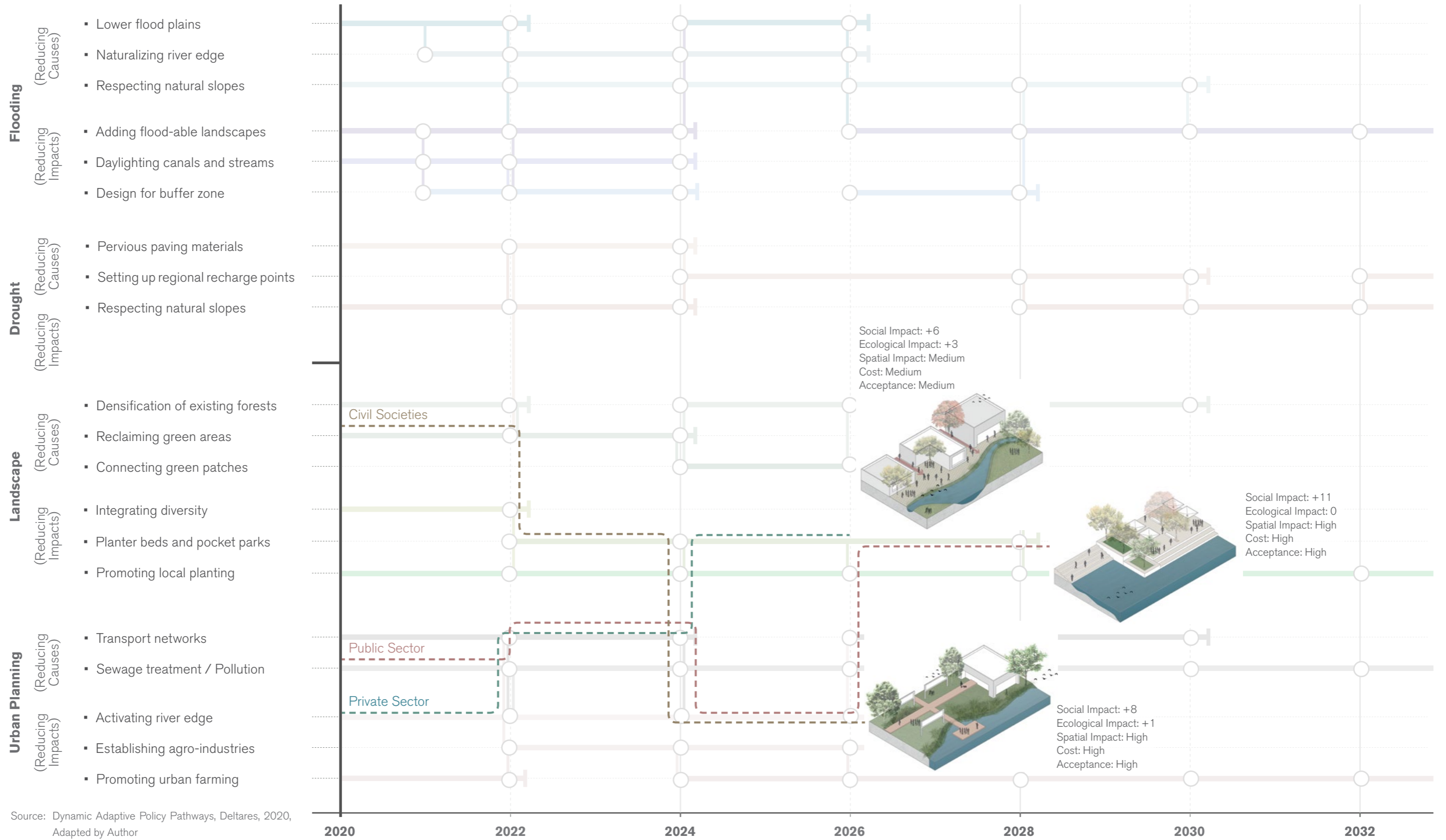
Method 2: Path variations based on actors initiating/collaborating

**Water Management:** (a) Increased temperatures and possible drought  
(b) High rainfall and flooding probability.  
**Urban Planning:** Increased population within the urban centres  
**Landscape:** Reduced local species

**Water Management:** (a) Higher temperature and droughts  
(b) Increased flooding frequency  
**Urban Planning:** Land crisis within urban centres  
**Landscape:** Loss of local species

**Tipping point 1**

**Tipping point 2**



Source: Dynamic Adaptive Policy Pathways, Deltares, 2020, Adapted by Author



## 9.6. FROM LOCAL TO REGIONAL

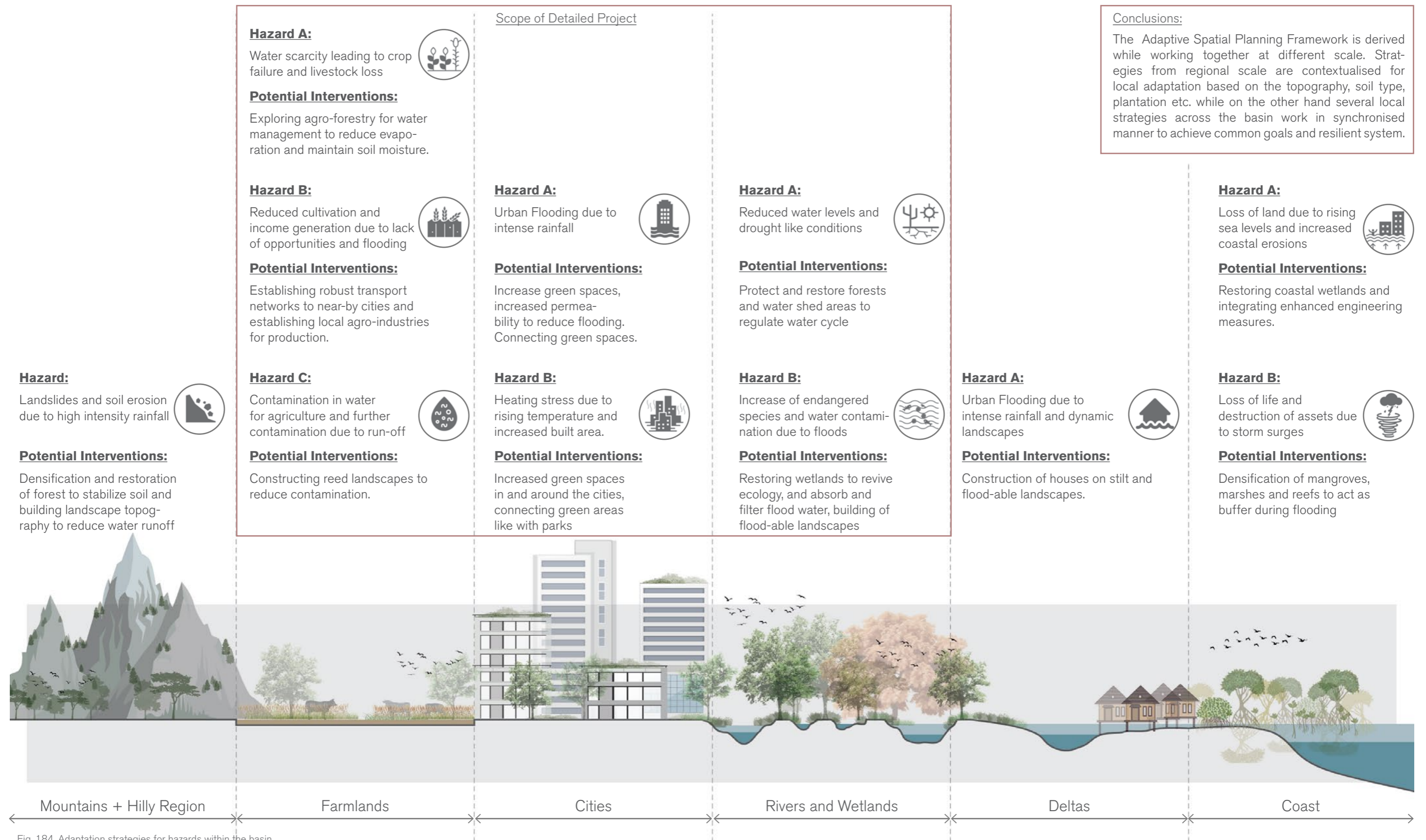
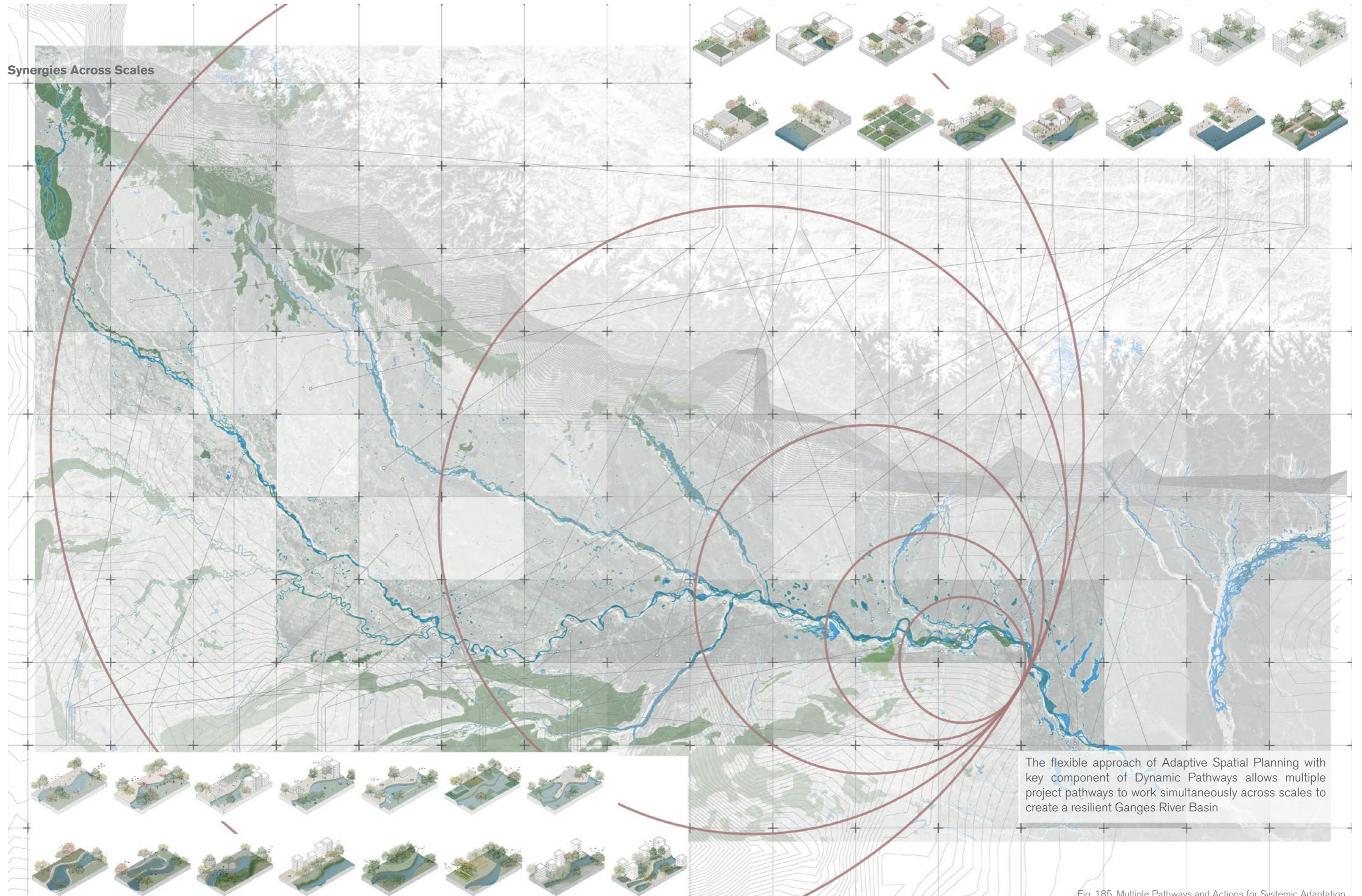


Fig. 184. Adaptation strategies for hazards within the basin  
Source: Global Commission on Adaptation, Adapt Now report, 2019, Adapted by Author



Synergies Across Scales



The flexible approach of Adaptive Spatial Planning with key component of Dynamic Pathways allows multiple project pathways to work simultaneously across scales to create a resilient Ganges River Basin



# 10. Evaluation

This section of the report tests the approach of adaptive planning pathway and strategies at different scales in different scenarios. The 3 scenarios are based on the level of integration within the planning sectors and connected links between local adaptation and regulatory policies.





Understanding Problem Field

Chapter 2

- Current Challenges in Ganges River Basin
- Drivers of Change
- Governance Challenges for Ganges River Basin

Introduction

Chapter 1

- Context
- Relationship between human systems and ecological systems

Chapter 3

- Socio-ecological vulnerability analysis across scales
- Problem Statement (Spatial Justice)
- Line of Inquiry:
  1. Dual Nature of Externalities
  2. Capital

Chapter 4

- Theories:
  1. Urbanization
  2. Vulnerability
  3. Resilience Thinking
  4. Social Capital and Governance
- Notions:
  1. Interdependence - Integration
  2. Infrastructure Ecology
  3. Evolutionary Resilience

Research Methodology

Chapter 5

- Conceptual Framework: Adaptive Spatial Planning Model

Vision

Chapter 6

- Principles
  1. Robustness
  2. Adaptivity
  3. Connectedness
  4. Diversity
- Frame of Reference
  1. Knowledge of System Behaviour
  2. Dynamic Adaptive Planning Pathways
  3. Stakeholder Collaboration
- Systemic Goals

Design

Chapter 7

Regional Strategies

Mitigation Strategies that are derived for challenges across the basin

Chapter 8

Metropolitan Scale Strategies

Mitigation Strategies that are derived for challenges for metropolitan scale

Chapter 9

Local Adaptation

Adaptation of multiple strategies to achieve resilience

1. Urban
2. Peri-Urban
3. Rural

Adaptive Planning Pathways

Evaluation

Chapter 10

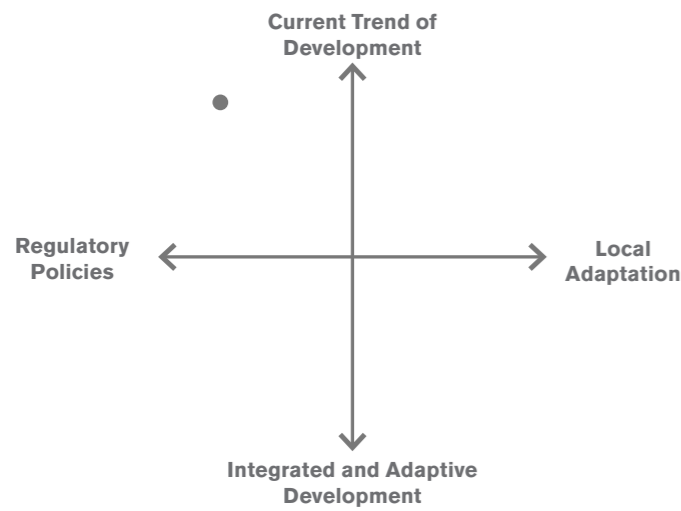
Scenarios

- Case 1
- Case 2
- Case 3



## 10.1. SCENARIOS

### 10.1.1. Case 1: Proposing strategies within the current trend of development (Speculative)



The first scenario is a speculative scenario that shows how planning pathways would perform under national regulatory policies without on-going / concurrent local adaptation. With rapid urbanisation and no sectoral or multilevel integration, the process of planning would not respond to challenges at multiple scales.

#### Tipping point 1:

**Water Management:**  
-Increased temperatures and possible drought  
-High rainfall and flooding probability.

**Urban Planning:**  
-Increased population within the urban centres

**Landscape:**  
-Reduced local species

No Local Adaptation + No Vertical Integration → System Failure before Disaster

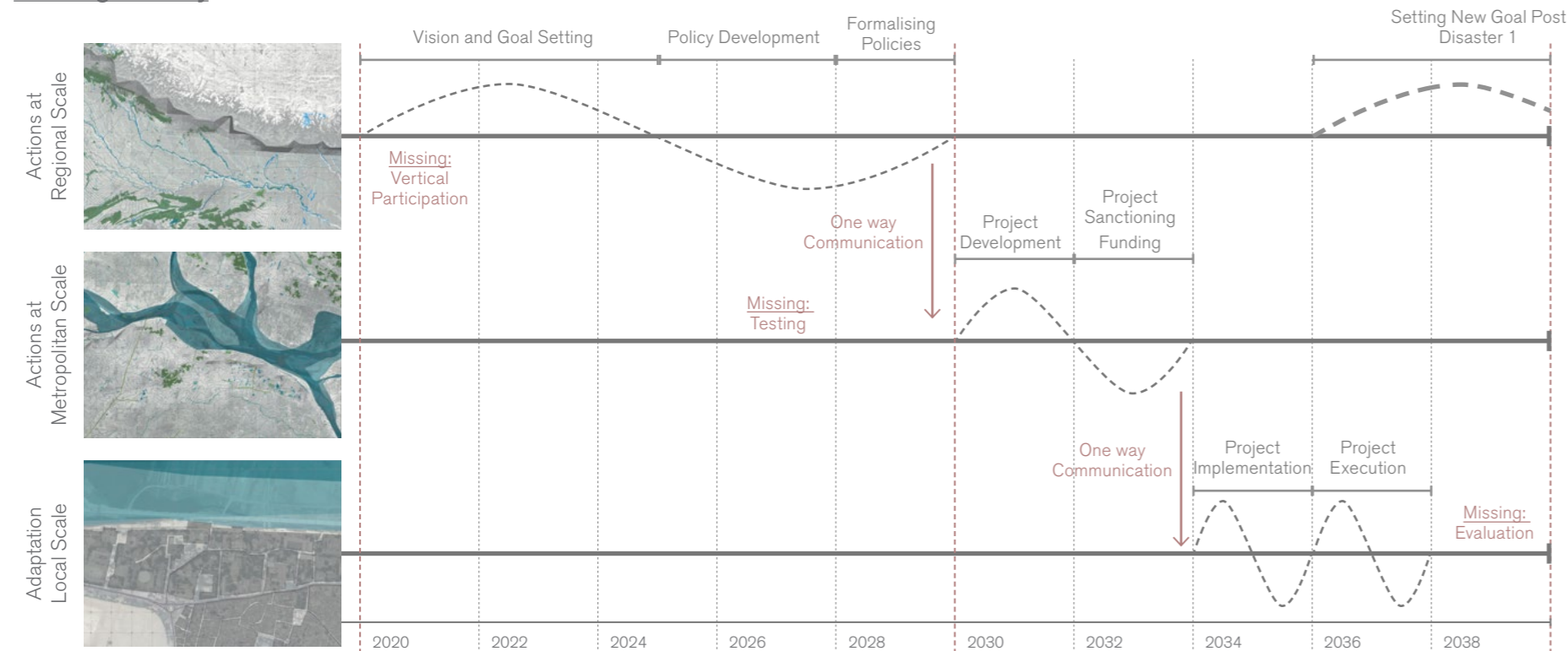
#### Tipping point 2:

**Water Management:**  
-Higher temperature and droughts  
-Increased flooding frequency

**Urban Planning:**  
-Land crisis within urban centres

**Landscape:**  
-Loss of local species

### Planning Pathway



### Results

In this scenario, there is a lack of multi-level integration and connection between local adaptation and national policies. With this scenario, the first tipping point is reached by the time the vision, strategies and policies are developed at the regional scale. Since the strategies are not tested, at the local scale, the understanding and conclusion of failure are not obtained.

Later, when the strategies are implemented at local scales they fail to achieve required output since the system is now under different and more intense challenges. In reality, this extreme case scenario does not exist as there are several local strategies independently adopted by communities.

### Impact Assessment

This speculative scenario highlights the extreme situation of top-down planning approach. With this approach, the system is not prepared for impacts from extreme weather conditions. With the only local implementation and zero adaptation, the system is unable to pass the tipping points and experiences failure.

Due to lack of local adaptation of strategies, the maximum adaptive capacity of the system is lower than the impact of the disaster. However, the collapse of the ecological system is gradual compared to the human system, since ecological system is comparatively adaptive than human systems.

### Impact

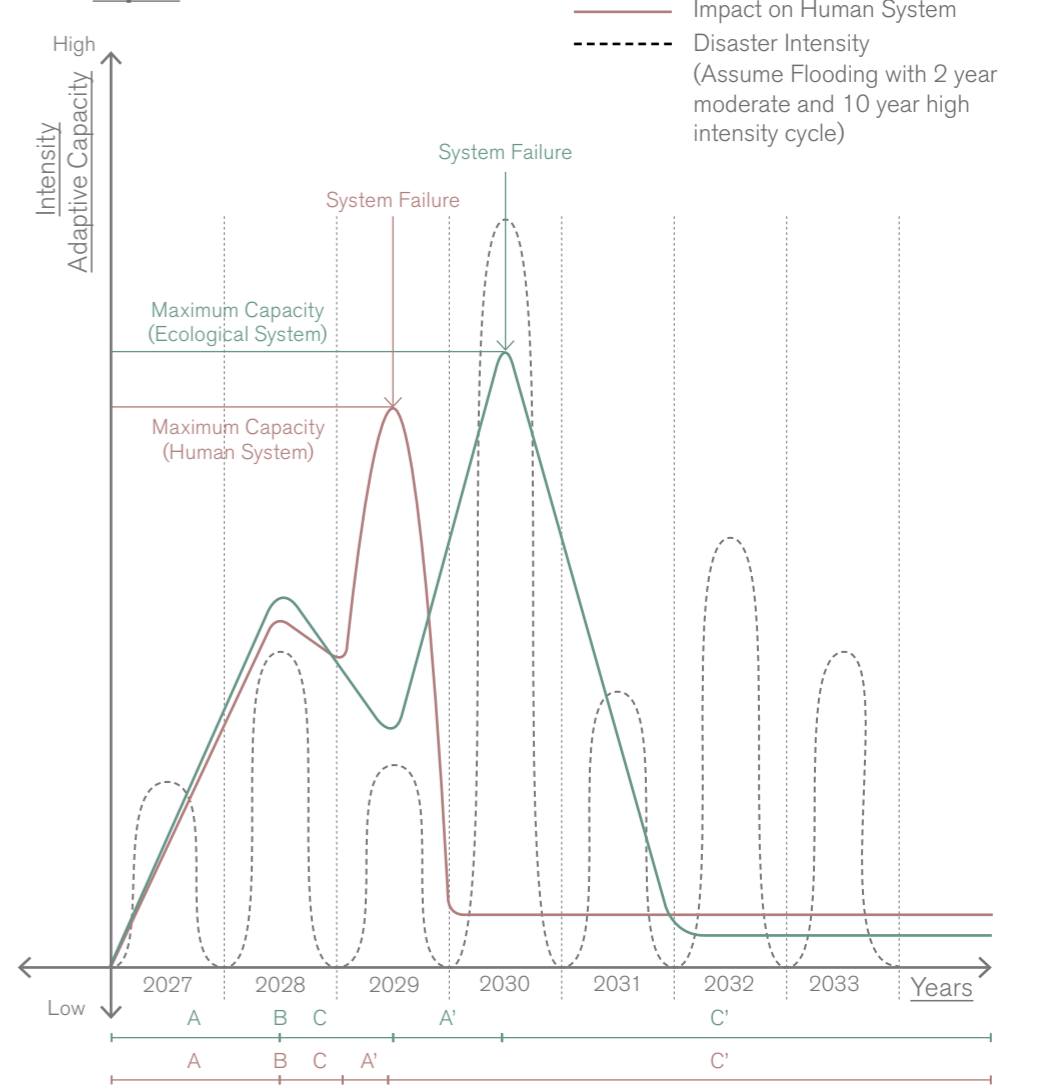
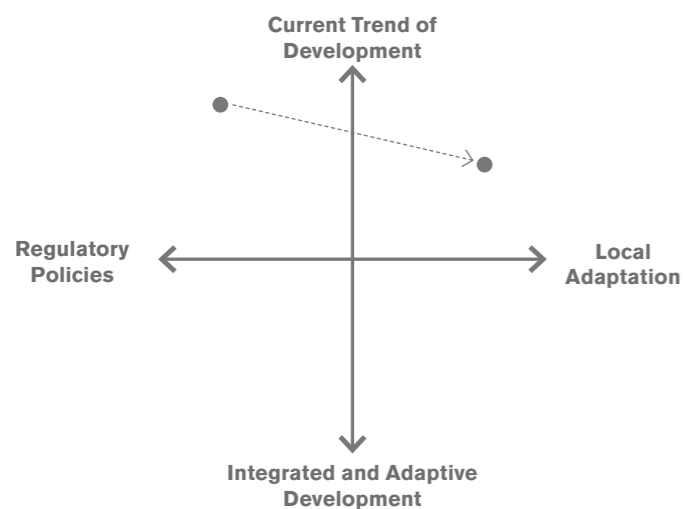


Fig. 186. (Above) Planning process and project cycles across scales for scenario case 1

Fig. 187. (Right) Impact Assessment for SES system under disaster  
Source: Bases on understanding of SES system by Holing 1986



**10.1.2. Case 2: Local adaptation of strategies within the current planning framework (Current condition)**



The second scenario describes the current situation where there are local scale intervention, though they act independently. This scenario, still lacks multilevel and sectoral integration.

$$\text{Local Adaptation} + \text{Min. Vertical Integration} \rightarrow \text{System Failure after Disaster}$$

**Tipping point 1:**  
Water Management:  
 -Increased temperatures and possible drought  
 -High rainfall and flooding probability.  
Urban Planning:  
 -Increased population within the urban centres  
Landscape:  
 -Reduced local species

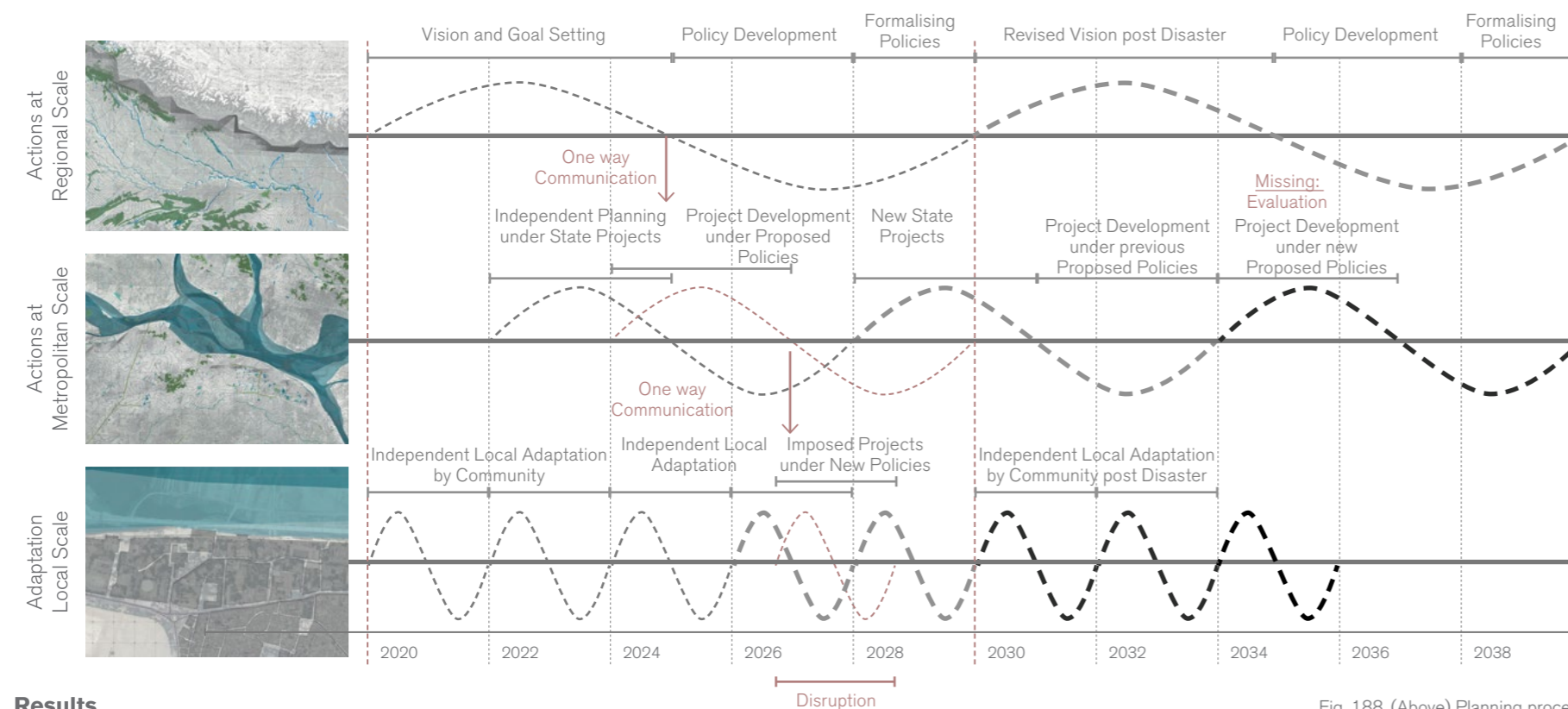
**Tipping point 2:**  
Water Management:  
 -Higher temperature and droughts  
 -Increased flooding frequency  
Urban Planning:  
 -Land crisis within urban centres  
Landscape:  
 -Loss of local species

**Impact Assessment**

This case scenario focuses on the lack of vertical integration within the planning system. Within this scenario, several local adaptations take place, yet they are not linked with the national planning policies and visions. Due to the presence of local adaptation, a decrease in disaster impact and increase in adaptive capacity is noticed.

With this increased adaptive capacity and moderate climate mitigation, the system is able to face extreme disaster. However, with the lack of resilient and integrated approach, the system experiences failure post-disaster.

**Planning Pathway**



**Results**

The planning results in this case, work on 2 different scales, regional and local. Though the 2 scales lack integration. Thus the inputs from local scale do not reach for the regional policy recommendations.

As there are already actions simultaneously being carried out at different scales the policies do work in the preferred time frame, but they are not prepared for tipping points, and are only updated when an extreme tipping point is reached, which is late for adaptation to climate change.

**Impact**

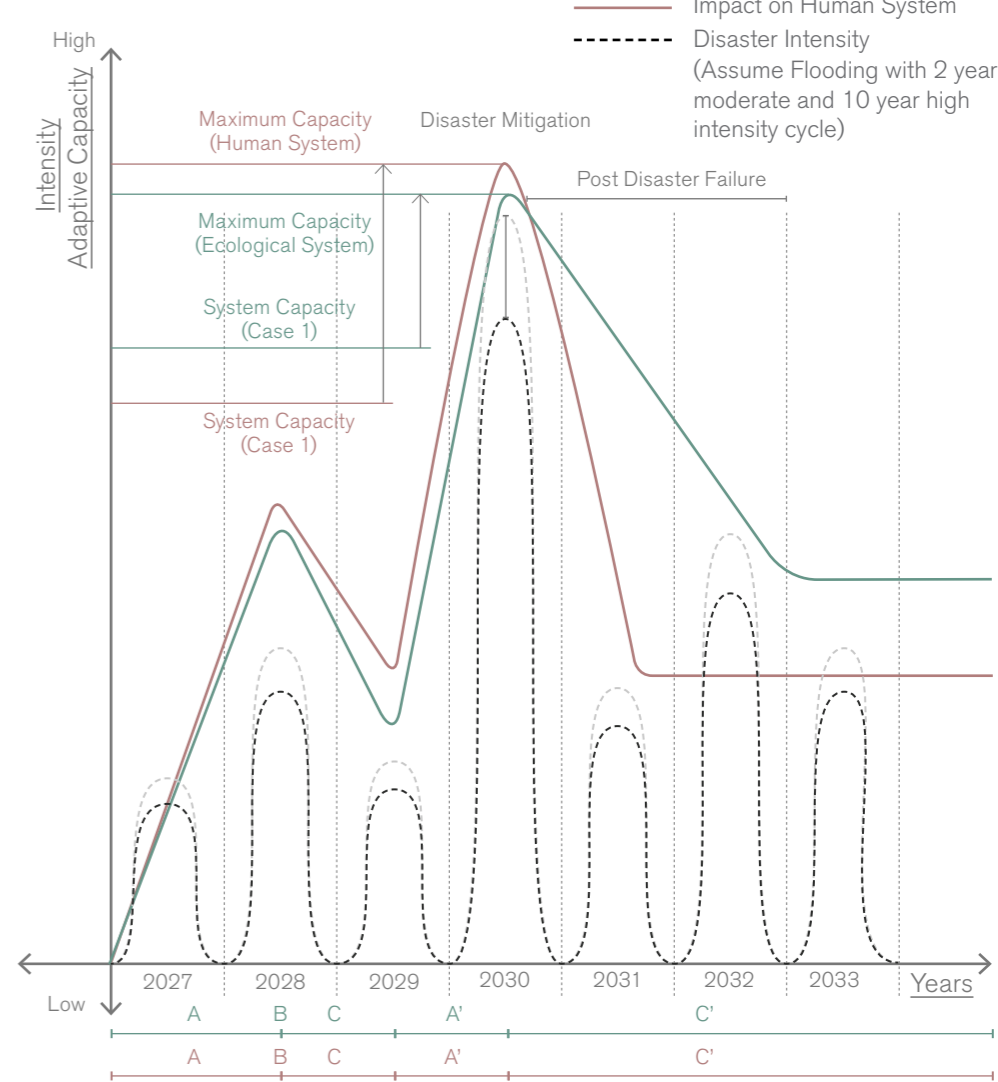
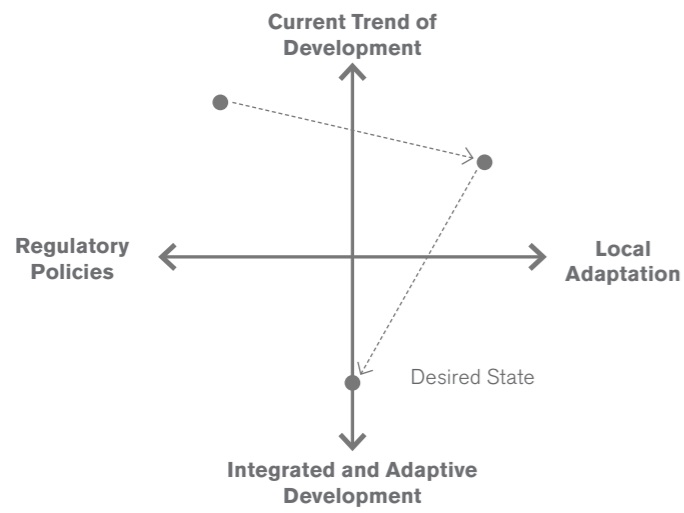


Fig. 188. (Above) Planning process and project cycles across scales for scenario case 2

Fig. 189. (Right) Impact Assessment for SES system under disaster  
 Source: Based on understanding of SES system by Holing 1986



**10.1.3. Case 3: Local adaptation of strategies within the adaptive planning framework (Desired)**



The third case scenario is the desired scenario. In this case, the local adaptation meets regulatory policies at regional scales. The scenario also witnesses an integrated and adaptive development across sectors. This is the desired scenario to achieve resilience to climate change.

Local Adaptation + Max. Vertical Integration → Resilient System

**Tipping point 1:**

Water Management:

- Increased temperatures and possible drought
- High rainfall and flooding probability.

Urban Planning:

- Increased population within the urban centres

Landscape:

- Reduced local species

**Tipping point 2:**

Water Management:

- Higher temperature and droughts
- Increased flooding frequency

Urban Planning:

- Land crisis within urban centres

Landscape:

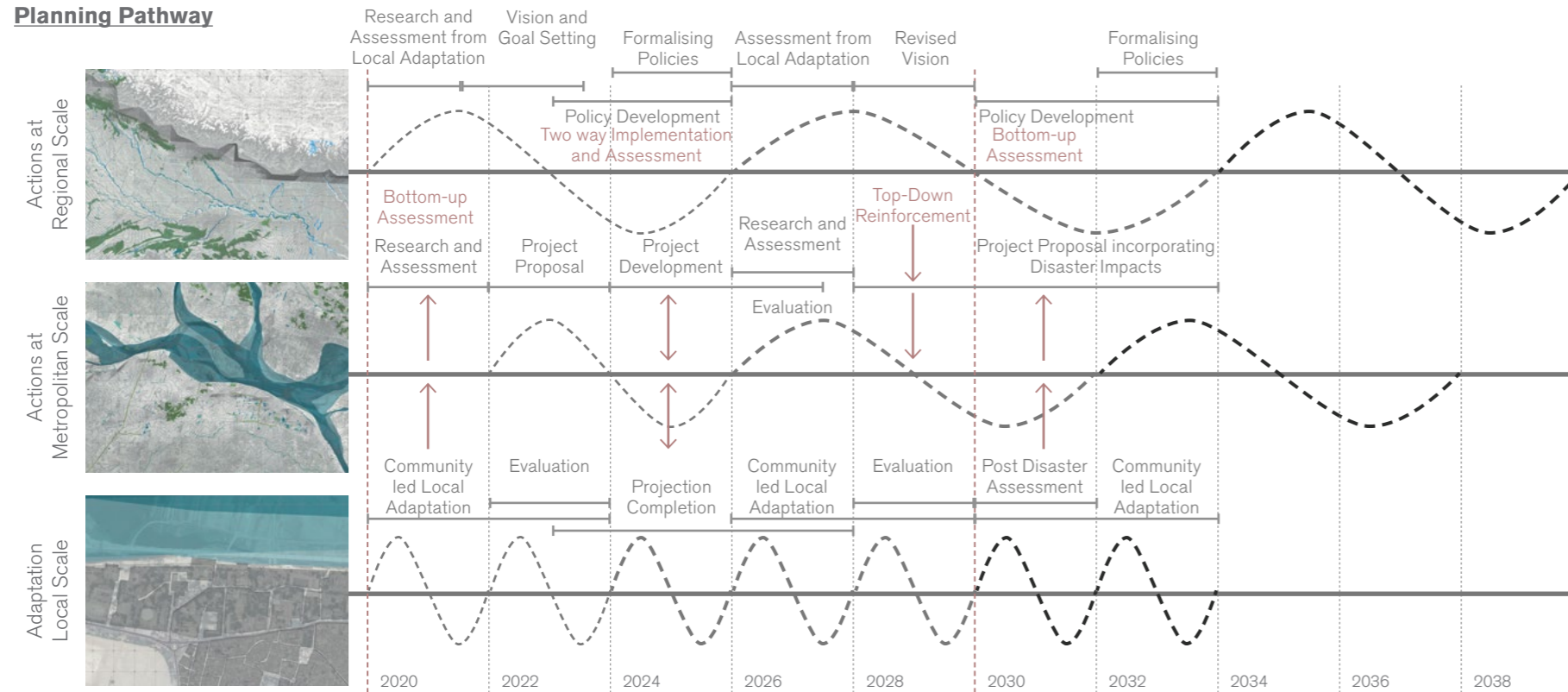
- Loss of local species

**Impact Assessment**

The desired case scenario focuses on achieving both climate mitigation and adaptation. With systemic planning across scales and successful adaptation at the local scale, both human and ecological systems become resilient.

In the graph below it can be noted how systemic action help reducing disaster impact and create the possibility for adaptation, increasing the system's capacity to combat the disaster.

**Planning Pathway**



**Results**

Under this scenario, it can be observed that the local and regional scale work together to achieve resilience. Herewith input and testing of regional strategies from the local, can help in reducing the time frame for preparedness. This also enables to foresee possible challenges of tipping point and be prepared with possible alternatives for new pathways before the point is reached.

**Impact**

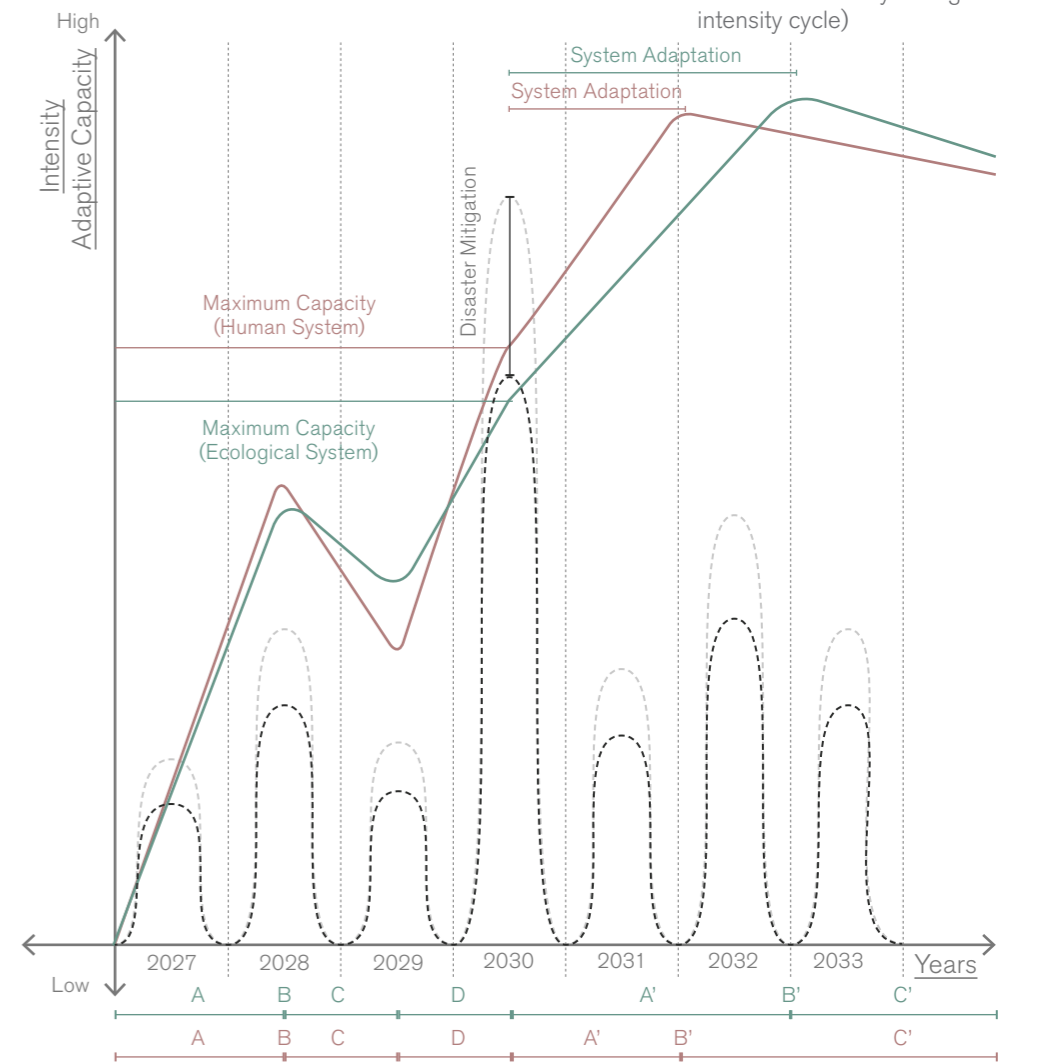
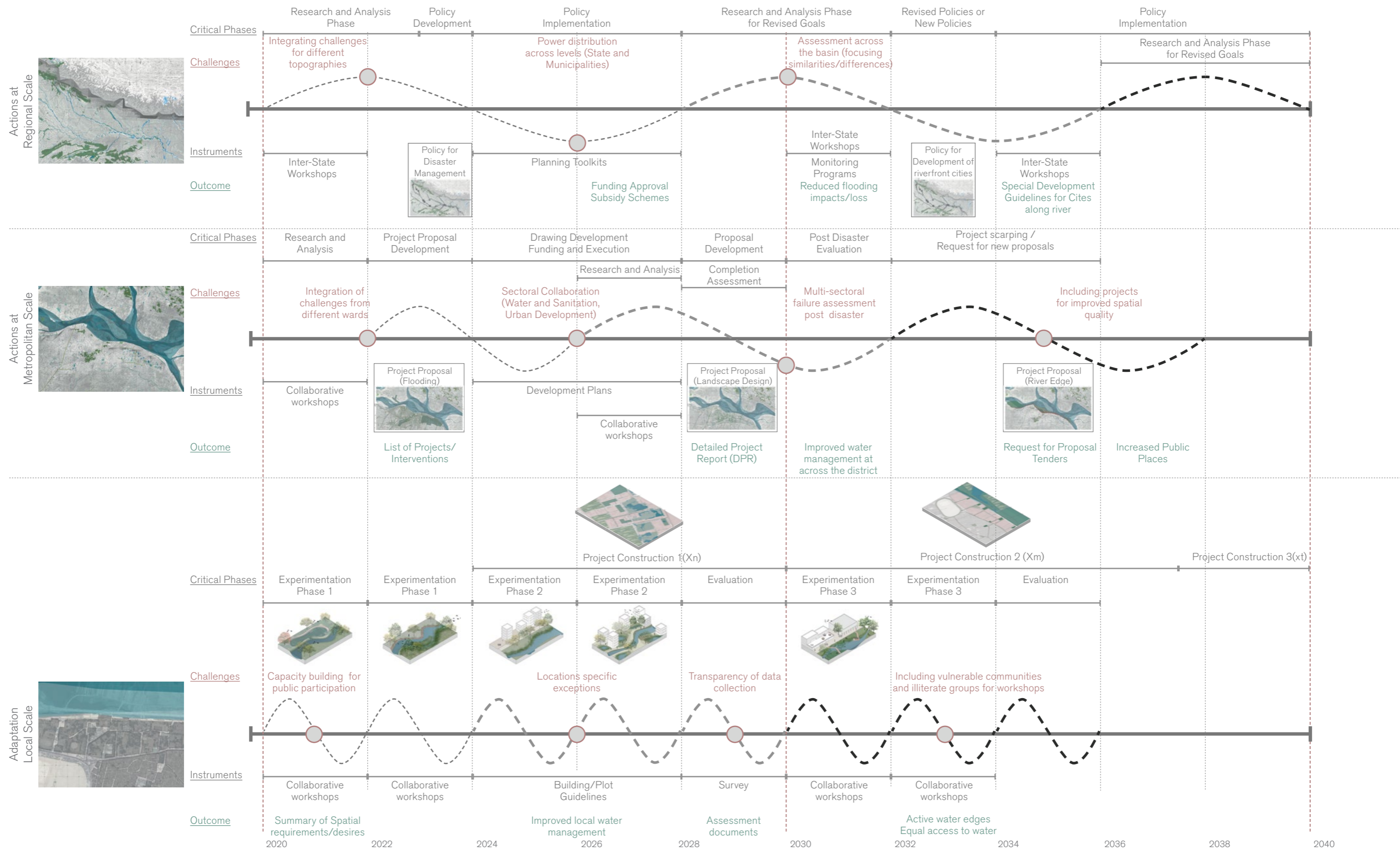


Fig. 190. (Above) Planning process and project cycles across scales for scenario case 3

Fig. 191. (Right) Impact Assessment for SES system under disaster  
Source: Based on understanding of SES system by Holing 1986



### Detailed Proposed Planning Pathway and Challenges within the Current Capacities







# 11 • Conclusions

The following section concludes the findings of the project. The project emphasises on bridging the gaps between the regional mitigation policies to local adaptation to achieve resilience. The project illustrates how design and interventions at a certain scale impact the Socio-ecological System. With systemic goals and transcalar planning approach and adaptive spatial planning framework, resilience for the system can be achieved.



## CONCLUSION

### Socio-Ecological System

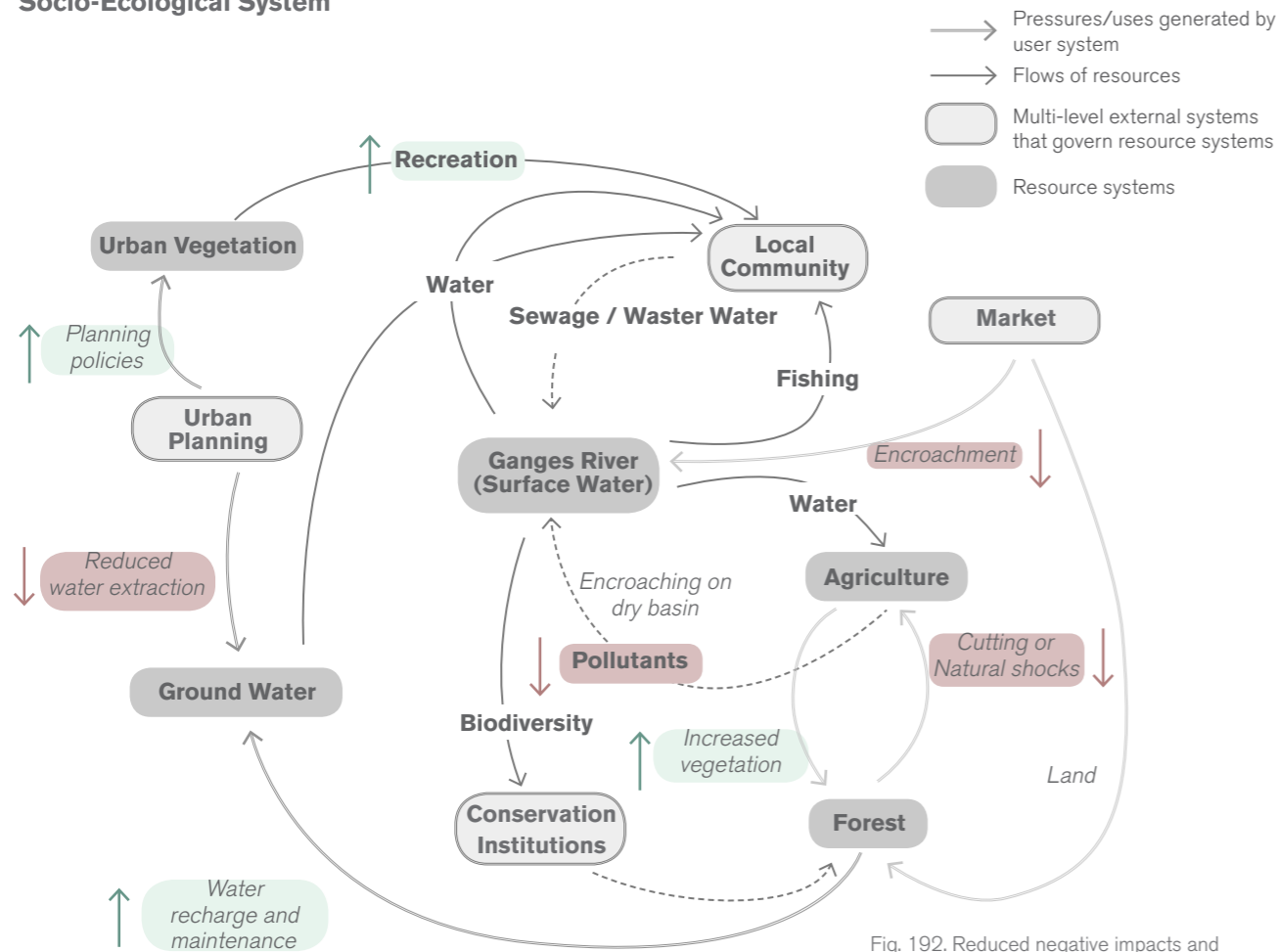


Fig. 192. Reduced negative impacts and increased Eco-system services

It is necessary to understand the current functioning of socio-ecological system of the Ganges River Basin, and intervening with strategies at different scales to address the negative impacts of anthropogenic and climate change activities to achieve a more resilient system could be achieved.

The chart above depicts how with interventions of strategies at both regional and metropolitan scale has helped achieve local adaptation to reduce *Pollution*, *Encroachment* and increase *Water Recharge*, and *Vegetation* to achieve resilience in sub-systems and hence the Ganges River System

### Line of Inquiry

#### 1. Dual Nature of Externalities:

Externalities of development would cause both negative and positive impacts. With adaptive spatial planning and integrated ecosystem-based adaptation, the negative externalities could be turned to positive impacts. Moreover, the adaptation strategies used for climate mitigation can result not only in just risk protection but also help gain benefits and achieve resilience.

#### 2. Capital:

Performative landscape interventions can be planned to also work as ecosystem services, not just for climate adaptation but also for food production - supply and for social and recreational benefits. Thus planning for diverse and flexible use of performative landscape would help in reducing ecological vulnerability (water management: flooding and crisis), social vulnerability (public parks and recreation) and economic vulnerability (food and supplies).

### Resilience

Resilience to climate change is proposed to be achieved through several strategies for mitigation and adaptation at different scales. The functional diversity (addressing different issues leading to high climate change risk) and response diversity (addressing issues of flooding, drainage and storage) enables to build a resilient system against current and future risks.

As observed from local adaptation for strategies, a win-win situation for climate change adaptation, socio-economic development and environmental protection can be achieved through ecosystem-based adaptation (Munang et al., 2013).

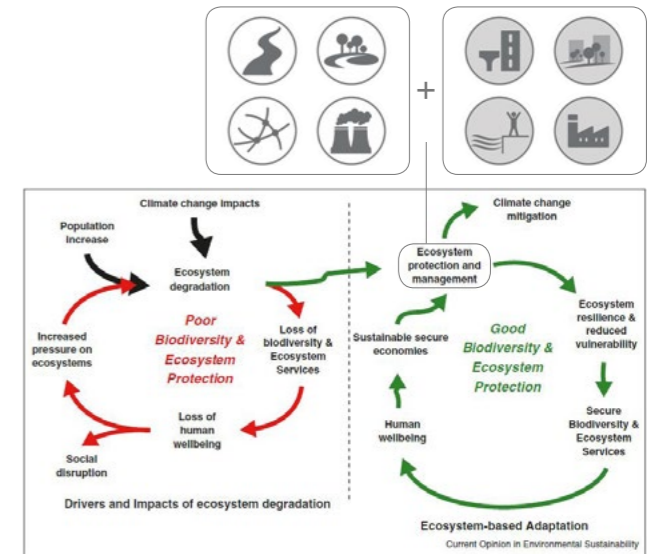


Fig. 193. Impact of strategies and interventions  
Source: Munang et al., 2013

### Adaptive Spatial Planning

The framework of adaptive spatial planning enables a flexible approach to plan for uncertainty, integrating local communities in the planning process. Local adaptation allows early testing of strategies and informing policies simultaneously with results and local knowledge, reducing the time-line compared to traditional planning where policies are derived at a central level without an in-depth understanding of local context. Furthermore, adaptive spatial planning allows shifting pathways, when desired outputs are not met or when the system is hit with an unexpected challenge. Thus, adaptive spatial planning model is the new model of planning that needs to be explored and utilised for climate change adaptation.

### Spatial Justice

Within the adaptive spatial planning model, the strategies are developed at different scales, emphasising on the benefits of stakeholders within each action. This ensures that the accessibility and distribution of resources are equitable. Thus fulfilling the requirement of distributive spatial justice.

Secondly, the planning approach includes local communities and governing bodies in deriving strategies and inform policies at the national level. This approach secures that the procedural aspect of spatial justice is achieved.





# 12. Reflection

This section reflects on the research aim, methodology, the social and scientific relevance of the project, limitations and ethical considerations observed during the process.



## 12.1. REFLECTION

### Project Introduction and Motivation

The capitalistic and economy-driven approach towards urbanization in India has led to a great disparity between different socio-cultural groups as well as a huge pressure on the ecological systems. Further, with the changing climate, these groups are increasingly vulnerable to hazards. This can be observed even in the Ganges River Basin where unplanned urbanization has caused a fragmented river system that puts several local settlements at increasing risk.

The approach to planning water-centric projects has not been a holistic approach in past, and with uncertainties of changing times, the planning approach needs to be more adaptive. The project aims to re-look at the current development trend within the existing system and derive a possible adaptive spatial planning model for design, that would include local communities and governing bodies into the planning process. The focus lies in emphasising the importance of a holistic approach to planning for the Ganges River Basin and bridging the gap between the national mitigation policies and local adaptation to climate change, to alleviate social, economic and ecological vulnerabilities

### Relation between the topic and the master programme

The Ganges River Basin is highly engineered and is ecologically deteriorating. The approach to deal with urgency and risk in the country remains top-down, excluding the local communities, causing issues of spatial justice. The policies developed for climate adaptation and mitigation are drawn at a higher level, lacking sectoral integration and local participation. Thus, there is a requirement to re-structure and formulate new planning model for the river basin, that focuses on the integration of different stakeholder, and aims to achieve a holistic development at all scales.

My graduation research, under the Urbanism track, aims at deriving an Adaptive Spatial Planning Model for the Ganges River Basin, that includes participation from stakeholders, communities and governing bodies to achieve socio-ecological resilience. Moreover, the aspect of procedural and distributive spatial justice is further explored by establishing co-management of resources with the society and the government. The concepts of [Spatial Justice](#) and [Adaptive Spatial Planning Model](#) explored during the graduation project are in line with the current master's track of urbanism.

Further, the guidance of Transitional Territories studio helped in formulating the methodology and approach for the thesis. The Transitional Territories studio deals with the dynamic relationship between the natural processes and societal practices within urbanized areas, which is similar to the case in the Ganges River Basin.

The river basin is currently struggling to find a balance between societal practices and ecological processes. My topic of graduation builds on notions of panarchy of the socio-ecological system by Holling (1986). Though the studio focuses on research and design within the North Sea, the line of inquiries established within the studio help in the alignment of this project in the context of India. The following line of inquiries are further explored and elaborated in the thesis.

Capital: Using resources within the Ganges River Basin to help alleviate the socio and economic vulnerabilities and further balance the ecological disturbances.

Dual Nature of Externalities: The externalities in the SES (Socio-ecological systems) are identified and intervened to achieve resilience.

Thus, under the framework of Transitional Territories studio, focusing on climate change, water risks and planning within the constantly changing territories has helped to develop the project on pillars of urban planning, landscape architecture, water management, governance and society.

### Relationship between Research and Design

Design for performative landscapes and cities within a sensitive ecological basin like the Ganges River Basin requires understanding the relationship between the human systems and the ecological systems. With the uncertainty of future risks, due to climate change and unplanned development, it is necessary to adopt adaptive methods of planning. The existing research from Adger (2003-2009) on SES and the panarchy of adaptive cycles from Holling (1986) are used to derive the process of designing infrastructure and interventions within the river basin. Thus, in the initial process of the project, the research helps in the deriving design of a system of relations within the SES of the basin.

Later in the process, strategies are designed for the regional as well as the metropolitan scale. These strategies are then tested at the local scale to establish the links between regional mitigation and local adaptation. Also, the process of planning is evaluated through the adaptive planning model, thus following the path of research by design.



## Research Approach and Methodology

The methods used for the evolution of this project is a mix of deductive and well as inductive research methods. At the beginning of the project, a deductive approach was adopted to understand the notions of socio-ecological resilience, adaptation, climate change mitigation and vulnerability. This was carried out with an intensive literature review. This helped in establishing the line of research and development of the conceptual framework for the project. Further on, quantitative and well as qualitative research methods of transcalar mapping and interviews were carried out to comprehend the information of resource systems and user systems for establishing the understanding of complex systems involved at regional, city and local scales. Case studies and fieldwork informed the qualitative understanding of space.

Later, in the design process of the project, the approach of Frame of Reference (Van Koningsveld, 2003) is used to derive the strategic and operational objectives of the project. With design and stakeholder analysis at different scales, the understanding and development of Adaptive Spatial Planning model are derived. This approach is an inductive research approach used to establish my understanding of Adaptive Spatial Planning Model for socially, economically and environmentally vulnerable area of the Ganges River Basin. This understanding is tested at different scales and in different conditions through design development and impact assessment.

### Limitations:

The census data collection in India happens every 10 years, hence the last data available for research dates to 2011. Also, there is the unavailability of certain data due to security policies and lack of mapping. This lack of availability of recent data has hampered certain aspects of research. These data were either extrapolated or assumed for the scope of the project.

Secondly, the transparency and reliability of data sources is also a question when data are not published in open source. Comparison of data from several sources and interviews with locals and experts were used to establish an understanding of the current scenario within the project.

The thesis also aims at integrating local institutions both formal and informal institutions into the adaptation. The initial intention was to focus on informal institutions for local adaptation, but during the fieldwork process, the understanding about informal institutions became clearer. These Informal intuitions often can get dissolved or emerge in the time of crises. It will be important to understand the dynamic conditions of these institutions for successful integration into adaptive planning, and therefore more focus was laid on formal local institutions like wards. Also, the local involvement of local communities is based on the benefits that individuals see in the project, hence it is essential to show individual benefits. Yet these decisions are subjective and difficult to quantify. Thus, local ward offices were considered for the formal local scale institutions that could facilitate the adaptation process.

With the massive scale of the Ganges River Basin and the time constrain the graduation project, metropolitan strategies are derived only for a specific area within the basin. These strategies are contextual and would differ at different sections of the river, especially like mountains and deltas.

## Scientific Relevance:

The project builds on the understanding of Socio-Ecological Systems and concepts of resilience. Intensive research has been carried out to understand the working of SES, but very little has been translated into practical design solutions. The project aims to bridge the missing link between the theoretical understanding of SES and practical implementation of design interventions within the system. Furthermore, the project builds on the new approach of planning, Adaptive Spatial Planning Model, to achieve a coherent development across the river basin. With the design for interventions and actions that have consequences at different scales, it is necessary to exploit the potential of adaptive planning that has the capacity to evolve with the crisis. Thus, the thesis explores and evaluates the ideas and notions of SES, Resilience and Adaptive Planning for the Ganges River Base, in the developing country of India.

## Societal Value:

The vulnerable settlements in The Ganges are most affected by climate risks leading to loss of economy and life. The current patterns of urbanization and planning is leading towards increased vulnerability especially of marginalised groups. Additionally, the project focuses on the issues of incomplete and outdated infrastructure system, also questioning the pattern and impacts of existing big scale infrastructure and urban developments along the river. It aims to provide water justice to the neglected group whose lives and livelihoods are dependent on the river. The project also seeks to answer the environmental problems caused by infrastructure projects and water challenges due to constant urban growth and development of industries along the river to achieve environmental justice. These problems will be even more critical in the future, as pressure for water, resources and land will only be increasing. Secondly, community participation in the planning process will help in delivering spatial justice to the marginalized group. It is important to address these issues today, to promise prosperity tomorrow.



### **Ethical Considerations:**

1. Ganga plays an important role in the cultural history of the place. The river is associated with various customs and these customs and celebrations are further aggravating the challenges the environmental challenges on the river, cause further water scarcity, poverty and health issues. While the project focuses on the economic and environmental issues of the water, the societal aspect also needs to be looked upon. The solutions shall focus on solving issues without hurting/disrespecting the cultural feelings of the community using the river and rather including their participation in the approach.

2. Engineered solutions mostly disturb the ecology of the existing landscape, but are still necessary for certain problems like sewage treatment/hydro power generation (renewable energy) and thus a conscious decision needs to be made as to what extent (infrastructure) development shall be carried out weighing their pros and cons.

3. Few cities along the river have been one of the oldest settlements in India. The communities do have few methods of coping against risk and planning for resilience. Though these methods have been almost eradicated with new planning policies and development models. It would be interesting to study these models, if exist, to understand the aspect of social capital.

### **Transferability:**

The nature of current planning models adopted by India, and many countries around the world focusing on the economy, has been causing challenges on the ecology. The project focuses on the understanding of complex systems by identifying sub-systems and points of interventions within the systems. Furthermore, it also focuses on identifying actors and stakeholder involved in the project, balancing out the power interest graph by making communities more involved and distributing power at local scales. These concepts of design, and framework of planning can be adopted by complex socio-ecological projects/challenges after acknowledging the unique characteristics of that project site, location and actors involved.

Secondly, while designing for areas with river basin context, it is necessary to understand how interventions at the one-point impact the system. Laying out systemic goals and regional strategies, help in aligning the values for design across the basin. This methodology and design framework are transferable to other river systems that are aiming for holistic development.

### **Dilemmas:**

The river Ganges since ages holds an important place in the Hindu religion. The current challenges of pollution to an extent is also caused due to religious activities carried out on the banks of the river. Although the river is an important aspect for a certain group, all communities hold equal rights to space and water. Moreover, the greater challenge in the basin is the uncertainty caused by rapid climate change and unplanned development. Thus, my focus in this thesis, has been to consider the environment as a public good, open and accessible to all and hence the opinions, concerns and participation for the design of the new adaptive planning shall remain exclusive of the religious aspect of the river.

### **Impacts of the COVID 19 pandemic:**

The current pandemic has shed light on several shortcomings of the way cities are planned. It is understood that the importance of public-places and its accessibility cannot be neglected. With India being in strict lock-down for more than a month and lack of sufficient public places and its accessibility, mental health challenges are emerging at a rapid rate.

Moreover, the emphasis of access to safe water cannot be emphasised enough. With a lack of infrastructure and poor condition of water, more communities become vulnerable to the pandemic. The question of water justice needs to be answered.

Secondly, with industries along the Ganges river being shut, the pollution levels in the river are low, and with river water being cleaner and fit to touch (BBC, 2020). This shows how much human systems impact ecological systems and vice-versa. It emphasises more on why planning should focus on SES and its functioning to achieve greater benefits and results.

### **Conclusions:**

During my graduation project, I have developed my skills in understanding the multifaceted aspects of complex planning projects. The process has helped me develop my analytical as well as theoretical reasoning skills. It has helped me develop the skill of breaking down a complex project into several smaller challenges yet retaining the connections and importance of the parts in the whole. While there have been developments with a capitalist approach to gain maximum social and economic benefits, the pressure on resources is what needs focus now. It is important that we relook at the patterns and establish a new paradigm for balanced development.



## 12.2. TIME-LINE





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**Adaptive Planning integrating Self-Organised Informal Institutions**  
Identifying Challenges to Climate Change and Achieving Resilience: Case of Ganges River Basin, India

Theories of Urban Planning and Design

MSc. of Architecture, Urbanism and Building Sciences,  
Technische Universiteit Delft

Jahnavi Bhatt

4794516  
jahnavi.bhatt17@gmail.com

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Course Co-ordinator: Dr.ir. G. Bracken

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**Abstract**

Pressure on natural resources has intensified in recent decades, stressing communities worldwide. With problems of climate change, there has been a constant risk, especially on the vulnerable groups. Planning in fast-developing countries, especially in India is focused on economic development. This constant urge towards economic gain has led to over-exploitation of natural resources. Achieving resilience in both social and ecological aspects has become an urgent need. While most planning documents fail to address resilience, few confuse it with disaster management and mitigation. The essence of resilience as a continuous “adaptive cycle” (Holling, 1986) has been explored within its theoretical domain, yet it requires exploration for its application. These adaptive cycles of transformation, demand innovation in thinking and planning for unpredictable scenarios. The current planning in India for climate change is centralized with national policies, failing to achieve resilience. The concept of resilience should be explored by understanding the benefit of social capital within self-organized informal institutions and their management. The paper aims to identify the role of self-organized informal institutes and how their strong social bonds and cultural values can help in bridging the gap between national policies and local adaptations, to achieve climate-resilient design solutions based on strategic planning.

**Key Words:** climate change, vulnerability, resilience, adaptive planning, self-organized informal institutions,

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**1. Introduction**

The Ganges River has held a high ecological, social and environmental significance for the country and its people. With the rapid growth and development of urban centers along the river, the pressure on the river basin and the water demands are constantly increasing. The unregulated development of various sectors along the river bank has led to extreme degradation of the river. The current state of the river is impacting the societies dependent on the river. Section 2 of the paper informs about the general context of the Ganges and the impacts in the region. Section 3 of the paper explores the concept of vulnerability and resilience. The application of the resilience concept to climate adaptation is further elaborated in section 4. Understanding further how adaptive planning is key to achieve resilience, section 5 details out the current planning processes in India and the need for Actor-Relational planning for successful climate adaptation. Climate adaptation is a local action, understanding the role of institutions, their positive and negative impacts, and especially the role of self-organized institutions and their cultural values is elaborated in section 6. Further, it is important to identify the characteristics of institutions that are important for adaptive capacity and (re)designing of the institutions. These characteristics are investigated in section 7 of the paper. Finally, section 8 draws important steps to build further on the role of the local institution to a national scale for adaptation.

**2. Ganges: Context**

The Ganges basin covers an area of 1,016,124 km<sup>2</sup> and is the most populated river basin in the world with a density of about 400 persons/km<sup>2</sup> (Acciavatti, Bierig, Corrigall & Mehrotra, 2015). More than half of the population in the region directly rely on the agriculture sector or secondary occupation like fishing, boating and animal husbandry for employment. The ongoing rapid urbanization and industrialization along the river banks pose a serious threat to the environment, impacting the food production and employment in the river basin. The delta region in the eastern part of the basin faces constant erosion hazard due to the morphological changes of the river, while the plains in the western part suffer from water scarcity and fluctuating rainfall. Over the years there has been a major shift in the hydrology and the quality of river water due to several human activities. The river is also facing water challenges because of construction of huge barrages and dams for hydroelectricity and irrigation, unmonitored industrial use of water and intensive unplanned development of the cities and towns on its bank.

**2.1. Climate Change Impacts**

The Ganges river basin has experienced a rise in mean temperature. The glacier origins of Ganges have been melting rapidly impacting the microclimate of the region. Due to the reduction in forest cover, the region is experiencing impacts of flooding and unregulated river flow (Hofer, 2019). With increasing temperature, the precipitation in certain regions has increased tremendously and is experienced in short periods of heavy rainfall. The climate change is affecting the biophysical characteristics of the basin, leading to shifts in the monsoon regimes, which results in increasing cycles of flood and drought, causing massive human destruction (Irengbam et al., 2019). The rising sea levels and the morphological changes in the river water flow have also imposed threats in the delta regions of Sundarbans, causing loss of income source and houses (Moors et al., 2011).

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## 2.2. Anthropogenic Impacts

Huge infrastructure projects are planned and executed along the river to achieve economic gains. 24 dams are already planned and executed on the northern tributaries that form the river Ganges to achieve hydro-power energy (Acciavatti, Bierig, Corrigan & Mehrotra, 2015). In the central belt of the river, an elaborated network of canals was constructed since 1853, for irrigation and water supply purposes. These infrastructure projects are compromising the ecology and hydrology of the river. The infrastructure has led to a fragmented river system. With unregulated industries and unmanaged sewage systems, the water in Ganga is highly polluted and unfit for domestic use or drinking. (Irengbam et al., 2019). The contamination and shortage of water are leading to exploitation of groundwater for irrigation and domestic use. Moreover, the capitalist development approach in India is creating a spatially unjust society (E. Soja, 2009).

## 2.3. Vulnerability in the Ganges

The basin is a complex society, with most of the population still live in rural areas and with low standards of living. These areas experience poor services of infrastructure and government benefits. The socio-economic and the political fabric in the region is still dominated by the caste system, breeding social and economic vulnerabilities (Dulal, 2014). Majority of institutions are polarized by the elites, further limiting economic opportunities to the marginalized population. More than 100 people lost their lives and several others were impacted in 2019 floods in the state of Bihar and Uttar Pradesh (BBC News, 2019). As most of the economically poor people reside in eco-sensitive high-risk zone, their vulnerability to ecological conditions is also high. While the impact of climate change will be felt on all, the poor lose the most. This loss varies across the basin depending upon the coping capacity of the communities and their access to resources (Adger, 2007). Though the total amount of water in the Ganges basin is enough to meet the societal, economic, and environmental requirements of the region, it requires optimum water management strategies (Dulal, 2014).

## 3. Concept of Resilience

### 3.1. Understanding Vulnerability and Hazard

Vulnerability to environmental hazards means potential loss. The loss is specific to the geographical location of the hazard and is also described in the hazard-of-place model of vulnerability developed by Cutter (2003) to understand the social aspect of vulnerability. The model portrays how the hazard potential is either moderated or enhanced by a geographic filter and social fabric of the place. To understand the vulnerability over a region like the Ganges, it is extremely important to develop a system to calculate the Social Vulnerability Index, based on the factor specific to the location of the region and social relations within the communities. Development of such model with the Ganges river basin will help in determining the social and natural hazards indicators, improving the method of hazard assessment and establish areas of high risk and concerns for immediate actions and mitigation.

### 3.2. Evolution of Resilience

The older models of ecosystem dynamics were focused on the 'balance of nature', assuming that the biophysical system tends to reach towards stable equilibrium cycle with a single climax aftershock (Clements, 1936). Later in 1990s resilience was closely related to 'new

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ecology' (Botkin, 1990). This system understood the dynamics of ecosystems as a system revolving around multiple equilibriums. Further, study and research were carried out to understand the interactive dynamics between social and ecological systems. Building on the theories of the co-evolutionary nature of human and biophysical stems the concept of a social-ecological system (SES) was developed. This new concept of evolutionary resilience places an important role in shifting the focus away from the quantitative availability of resources and moves towards the scope of available response options (Cote and Nightingale, 2012). The SES resilience helps to develop a framework to analyse human-environment dynamics. The approach is a dynamic and forward-looking approach to human and environment change. With the approach of focusing on human actions, the aspects of culture, social bonding and indigenous knowledge play an important role within the system to achieve resilience. Hence with stronger human system knowledge, SES can help in analysing feedbacks and in determining which forms of environmental governance is best suited.

### 3.3. Adaptation to Climate Change

The risks associated with the changing climate are uncertain and needs the highest attention priority, in order to prevent and reduce future human and economic losses. Vulnerability is a socially constructed phenomenon and is influenced by institutional and economic dynamics (Adger, 2003). Adaptation strategies highly depend on the technological innovations within the communities and availability of resources. Within the communities living on the banks of Ganges, the risk to climate change is high as most of the communities are directly dependent on resources that are sensitive to climate change. Over the years these communities have developed local techniques to adapt to the changing climate. With the constant increase in climate risks and exclusion for certain groups from planning, the hazards in the region seem to be increasing as the techniques developed in the past are no longer applicable (Dulal, 2014). Therefore, it is important to take steps towards resilience for climate change.

## 4. Resilience: From Theory to Practice

### 4.1. Resilience and Climate Adaptation

Promoting resilience involves planning not only for recovery from shocks but also cultivating preparedness and seeking transformative opportunities which emerge from it. Today, resilience is largely seen as a response to climate change uncertainties and socio-economic insecurities. Resilience for climate change has ignored the socio-ecological aspect of it. India's current climate change and resilience policies are mainly engineered design approach for disaster risk management, focusing on returning to normal (pre-disaster) conditions.

### 4.2. Evolutionary Resilience for the Ganges river basin

With the uncertainty in future water availability trends in the Ganges river basin, decreasing vulnerability by augmenting resilience is the preferred way to adapt to climate change. The evolutionary resilience talks in favour of 'People and Nature' as an interdependent system. It shows the ability of socio-ecological system to change, adapt or transform in response to stress and strains. Within a complex adaptive system (Cites, Regions) there are continuous interactions between small-large, slow-fast subsystems depending on scales. These systems by going through adaptive cycles, self-organise and maintain resilience. Thus, resilience as a conceptual framework can help thinking about process like climate change as a dynamic and

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holistic process (S Davoudi et al., 2013). It is important to talk about this resilience framework in a social context. This gives an opportunity to intervene in the continuous system of persistence, transformability and adaptability with the preparedness of the local communities and institutions (learning/reacting capacity of human systems). Thus, the system of evolutionary resilience helps in moving forward from the old practice of engineered approach, promoting adaptability dynamics with socio-ecological perspective and future forward-looking transformations.

## 5. Adaptive Planning

Adaptive planning policies are necessary for current climate change. These policies can help increase society's capacity to adapt to the anticipated as well as unanticipated risks. The important adaptive policy (re)design and implementation tools include decentralized decision making, multi-stakeholder engagement and integration of institutions, and the continuous learning process.

### 5.1. Planning Process in India

Post-independence, in 1950, the Planning Commission was set up by the Government of India, to develop Five Year Plans that guides development at state and local district levels. As per the Indian Constitution, urban improvement is a state subject (Landmarks & Development of Town Planning process in India, 2019). The local government does not have the power to pass enactment on urbanization, and urban projects. While the National Planning Commission laid out detailed guidelines for development, funds were allocated state-wise to implement projects in the state.

With the 74th amendment bill in 1992, there came a shift in the planning process. Governing bodies were formed at town and city-levels to carry out development (Landmarks & Development of Town Planning process in India, 2019). Though the decisions were still made at the centre, the implementation process was made simpler with smaller governing bodies of gram panchayats and municipalities working at local scales.

With the changing economic patterns and development of neo-liberal policies, new planning commission, called the Niti Aayog, was established in January 2015. The planning commission was aimed to achieve bottom-up approach of planning, though the term bottom-up is vaguely used. The power was now distributed to state governing bodies, to develop plans to achieve sustainable development. The local bodies and most importantly the stakeholders, the people are still excluded from the planning process (Rattani et al., 2019). With the new development strategies, there are now points in the planning process where public meetings are carried out and public opinions are heard to achieve the actual demands of people. Though these formal moments of the public hearing are introduced in the planning process, these processes are not carried out fairly.

The climate change adaptation policies in India are yet to be integrated into the overall national planning framework. The policies lack co-operation of decentralised governance and local planning processes. There is an absence in the framework and mechanism that facilitates a mix of top-down and bottom-up approach by including community-based adaptation (Mehta et al., 2019). Moreover, the top-down engineered approach to pollution and climate control

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on diverse communities that have their own cultural and religious understandings have not delivered positive outcomes (Das and Tamminga, 2012).

### 5.2. India: National Action Plan on Climate Change

India's National Action Plan on Climate Change (NAPCC) was released in 2008 with 8 national priority mission for climate change adaptation and mitigation. The watershed development projects within this plan are unfortunately based on the belief that water is an infinite resource and can be managed simply with water harvesting techniques (Dulal, 2014). For a transboundary river basin, shared with 5 states within India, a need for multi-level co-operation is extremely necessary to reduce basin-level vulnerability to climate change (Moors et al., 2011). Unfortunately, the complex governance system with several actors and inconsistent policies for river development have resulted in severe degradation of the river's water and ecosystem (Irengbam et al., 2019).

The current approach to climate change as seen in the NAPCC is national scale, broad and lacks local specifications. The mission's accomplishments must be carried out at ground level, which requires functional and efficient decentralized structures and institutions. There lies a necessity for a shift in the approach methods for the preparation of action plan integrating ideas from implementing agencies, stakeholders and communities. Moreover, the mission lacks effective monitoring of projects undertaken (Chaudhary & Walker, 2019). As the Ganges basin is highly dependent on natural resources and climate sensitivity, the vulnerability in the region will grow unless people have improved access to user-friendly and reliable climate information and local inclusive institutes for adaptation.

### 5.3. Actor-Relational Approach in Planning

For successful execution of planning processes there is a need of strong institutional framework of national, provisional and local planning bodies. Yet, recent times the planning system started experiences failure in promoting human environment perspective. This is because the current and past planning frameworks have always been developed from within the system, or from a government related perspective. Spatial planning has become a bureaucratic process. This leads to a single-minded approach on land-use regulations to deal multi-actor, multi-scaling network of society (Luuk Boelens, 2010).

With the evolution of Actor-Network Theory (ANT) in planning, this approach of single-minded approach can be changed. ANT is based on the idea that the world is made up of multiple heterogeneous networks of actors. Considering the theory of ANT in planning, governance and spatial planning can become a more collaborative process, with informal partnerships between public, private and civic actors (Luuk Boelens, 2010). The planning process under such framework can become a long process involving bilateral talks round table discussions, yet the process seems to be able to achieve a fruitful outcome for most of the people involved. This planning framework is completely contradictory to the existing framework in India. For India to achieve socio-ecological resilience it is important to consider these aspects in planning.

Secondly, for a robust outcome, it is important to understand the role of social capital in collective actions of planning process and adaptation to climate change. Networking social

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capital with linkages with a “well-functioning” state can help to achieve co-management of resources (Adger, 2003). Hence, co-management of resource with strong networks within social capital can help communities cope with the stress brought by climate change.

## 6. Role of Institutions

Communities living in the Ganges river basin have been using various indigenous techniques to fight the climate change impacts with crop diversification, water management and irrigation systems. Despite this with the continuous growing uncertainties of climate, it can be assumed that these independent indigenous methods and the current low adaptive capacities will not be enough to face future climate change.

The fragmentation and top-down power distribution within authority are problematic when it comes to facilitating climate change adaptation. In this situation, local institutions can certainly influence the way different social groups can gain access to resources. As adaptation to climate change is local, and the role of institutions is important. Institutions can help structure the impacts and vulnerability. These institutions also play a vital role in mediating between individuals and governing bodies (Dulal, 2014). There are 3 types of formal local institutions that play a crucial role in adaptation. These are (a) Public institutions like the municipalities and gram panchayats (b) Private institutions like NGOs and charitable trusts and (c) Civil Societies like co-operations (Agrawal, McSweeney & Perrin, 2019). Apart from these formally organized institutions, several self-organized informal institutions are working in the Ganges river basin and their integration into planning climate-adaptive strategy is crucial.

### 6.1. Self-organized Informal Institution

According to the UNFCCC database, out of 118 cases of climate adaptation in 46 countries show that most civil institutions involved in the adaptation process are informal institutions (Agrawal, McSweeney and Perrin, 2019). These informal institutions are often governed by cultural and societal norms, with shared moral values. They are engaged in activities like labour sharing, information exchanges and indigenous or traditional practices of resource usage. These self-organized institutions often supplement local government capacities and in many instances like disaster management take up tasks that the governmental organizations are unable to perform due to limitations of resources. The responses of these self-organized institutions are often developed to protect their livelihoods and thus have a strong economic character.

Within the Ganges river basin, the organizations are hierarchical and are majorly responsible only for construction of big infrastructural projects. Currently, the institutions in the basin are not capable of fulfilling more demanding and complex functions of water management, with the integration of environmental and social concerns related to resource and their fair and equitable distribution (Dulal, 2014). Some of the most important self-organized informal institutions in the basin are within the fishermen communities, farmers, boat dwellers and communities managing the Ghats.

‘Without local institutions, rural poor groups will find it far costlier to pursue the adoption of effective adaptation practices relevant to

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their local needs, as well as difficult to increase their information knowledge on adaptation options.’

-Agrawal, McSweeney & Perrin, 2019

### 6.2. Positive Effects of Self-organized Local Institutions

The self-organized local institutions shape the ability of the communities to respond to climate change. They create environment and conditions for innovation to happen to sustain the existing livelihoods. Secondly, these institutions also shape the impact of climate change on the communities. The communities that are engaged and involved with these types of informal institutions have access to information and resources, that are user-friendly and can be beneficial during disaster and crisis. The closely-knit social networks within the communities due to such informal institutions can form efficient communal pooling of resources (Adger, 2009). Moreover, these institutions then become the link between the government, NGOs and other formal institutions to the communities, providing them with external support needed during the disaster. Thus, these local self-organized institutions play a key role in shaping vulnerability, the same climate phenomenon will have different impacts on the communities depending on the social and institutional factors within the community. Unfortunately, even though these institutions have a very important role in climate adaptation, they are often ignored by the government (Dulal, 2014).

### 6.3. Negative Effects of Self-organized Institutions

High synchronization and complementarity are important for adaptation in the Ganges river basin. The existing power distribution and caste system prevalence in the region may create exclusion of certain social groups from participation and organization of institutions. This imbalance of power and exclusion can end up reinforcing the existing inequalities. Though there has been a question about the power distribution amongst various stakeholders and fair distribution of resources and decision making since there still lies a possibility of powerful stakeholder overpowering the weaker stakeholders. Also, within informal institutions the rule-making process is less transparent (High, C. et al., 2007). These informal institutions can, however, become obstacles in the implementation of a formal adaptation framework. Thus, it is extremely necessary to study and positively reinforce institutional relationships.

### 6.4. From Coping Capacity to Adapting Capacity

Institutions play a key role in mediating the transformation of coping capacity into adaptive capacity (Agrawal, McSweeney & Perrin, 2019). While coping capacity and strategies are short-term response to climate change event or disaster, adaptive capacity is a long-term change in activities and structure of the system. The current designing and implementation of disaster preparedness plans, that are designed for mitigation of immediate climate impacts can be termed as strengthening the coping capacity of the society, yet it fails to address the long-term strategies in for institutional changes in the socio-economic and political framework of the society. The strategies used by people who live in highly vulnerable areas in the time of disaster can be termed as their coping capacity, and with the strengthening of formal and informal institutions within the communities there lies an opportunity to convert this coping capacity to adaptive capacity (Dulal, 2014).

The on-going policies in the Ganges river basin can be termed as a reactive approach to the changing environmental and increasing climate hazards. With inputs from communities,

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through small scale self-organized informal institutions, and strong link between social capital and governance, this approach can be changed to a proactive approach to climate change hence converting communities' coping capacity to more sustainable long-term adaptive capacity.

### 6.5. Cultural Values of Self-Organized Institutions for Adaptive Planning

Fishing communities along the Ganges river have been facing high impacts of climate change. Fishermen and their communities around the world are already constantly adapting to various forms of change (Coulthard, 2009). Currently, fishing communities in the Ganges river basin lack strong formal institutions that can fight for the community's rights. Although the fishing communities in the state of Bihar have in past held successful protest and agitations for their rights for fishing against the government. The 3 fishing communities in the Bhagalpur district of Bihar now have rivalries amongst different groups that are based on their caste and fishing methods since the resources are depleting with effects of climate change. These current differences are severely limiting their ability to combat climate change. Thus, though they possess strong social bonds within their individual communities, the intra-community bonds within the communities need to be strengthened, taking advantage of their diverse fishing methods and strategies.

Secondly, within the fishing communities in the Ganges have independently and in small clusters have adapted strategies of crop diversification and cultivation of crops that require less water. These strategies and actions show the innovation capacity of the farming community. On the other hand, they have also adopted the strategy of construction of independent borewells for irrigation of crops. This action has led to groundwater depletion and increased water scarcity in the region. Thus, though the community shows skills of robustness and innovation to overcome climate change resilience, the lack of knowledge and foresightedness have led to the creation of practices that are not sustainable in the long term (Kelkar & Dey, 2017).

Apart from this, urban areas show strong bonds of kinship in times of flooding and other climate disasters. Short term self-organized informal institutions are formed on immediate need basis. These institutions work for food relief and resource distribution in small scales until relief and help are arranged by the government and other formal institutions. Conversely, small groups have been independently building embankments along the river and river tributaries to safe-guard from flooding. As much as 3000km of embankments are built by such small informal institutions for self-protection. These embankments are short term solutions and have worsened the flooding situation in the region, blocking the natural flow of rainwater in the river (Dulal, 2014) (Acciavatti, Bierig, Corrigall & Mehrotra, 2015). Other than these there exist several self-organized institutions managing temple precincts, Ghats and other shared public spaces. The boatmen in the river also organize themselves into small groups for better economic opportunities.

These efforts are currently undertaken individually or in small scale self-organized informal institutions. There are several groups who have carried out organized protests for rights. It is important to socially strengthen the groups that are willing to act and on the other hand impart knowledge to the communities that already possess strong social capital. To enhance the adaptive capacity of the communities in the basin it is critical to provide them with

strategies and tools that help them identify risks and opt for adaptation options that are required for reduction of climate risk.

### 7. Institutional Characteristics for Adaptive Capacity

Understanding the importance of the informal institutions in the process of planning and climate adaptations, it is then important to evaluate the characteristics of the institutions that are important to strengthen the adaptive capacity of the society. The Adaptive wheel approach highlight 6 dimensions: Variety, learning capacity, room for autonomous change, leadership, availability of resources and fair governance for adaptive capacity (Gupta et al., 2010). Based on the preliminary data and analysis of the Ganges basin region, the self-organized informal institutions within the fishing and the farming communities possess the character of variety for solutions to their depleting income generation resources. There exists diversity within the groups on the techniques used for these solutions. Based on past experiences, the institutions have developed moderate to high leaning capacity. As these institutions are self-organized, they to promote room for autonomous change and are collaborative in nature. They possess high human resources, but less financial resources and authority.

Contrary to this, within the formal institutions (government), most of the characteristics can be seen to lie in low or low to moderate scale. The formal organizations have high authority and financial resources but low variety, learning capacity and fair governance. The next step would be to understand how collaboration between formal and informal institutions shall be carried out to achieve a high level of adaptative capacity of the society.



(Fig1: Adaptive Capacity Wheel, Source: Gupta et al., 2010)

### 8. How to build further?

The actions that are taken at the lowest scale of watershed level and within small communities will have impacts at the larger drainage basin scale. Thus, for an adaptive Ganges basin, it is important to map small units within the basin and conduct assessment of small actions at all scales. It is important to look beyond hierarchical, top-down one-sided policies and move forward with the integration of self-organized informal institutions to formulate a framework that creates an environment for innovation and adaptation. Involving self-organized informal institutions into adaptation planning framework and easy implementation is beneficial since they are already in a state of constant adaptation.



This process of integration of self-organized informal institutions to formal governing and planning process will empower and facilitate informal institutes to work at the weakest point to then revise guidelines for formal, expanding the city and greater urban regions. The 2 important linkages that need to be strengthened are

- Linkages of communities and household to the institutions: the degree to which different households are linked to various institutions in their locality impacts their access to resources and decision-making, and thereby their capacity to adapt.
- Linkages between different sets of institutions: the effectiveness of an institution in coordinating and responding to climate change is shaped by its connections with other local and external institutions (Agrawal, McSweeney & Perrin, 2019).

The infrastructure projects developed within this framework will not only be based on engineering aspects to reduce short term impacts of climate risk but will also acknowledge the long-term vulnerability to climate change, incorporating the socio-ecological aspects of people who live in the high-risk areas (Dulal, 2014). Thus, adaptive capacity could be enhanced by encouraging partnerships between informal processes and formal interventions (Agrawal, McSweeney & Perrin, 2019).

## 9. Conclusion

Based on the literature review, it can be concluded that process of resilience is not the ability of the society to mitigate climate change and disaster management, but it is the ability of the society to take the risk as an opportunity to grow further and adapt to the change. The vulnerability of the society is highly dependent on the society's ability to adapt. Also, vulnerability is a socio-ecological process which is also dependent of the local factors like the location of the place and learning capacity. Thus, adaptation is a local concept. To achieve higher adaptation, it is important to translate the national governance policies at local scales and include local conditions with cultural values and feedbacks loops for development of national policies. For this, the integration of local, self-organized institutions in adaptive planning is necessary. The integration will help in linking the policies which are formulated within the formal institutions at the national scales translate to strategies and design interventions executed at the local scale. The integration will further help, local designs to become tools for exploration to test the strategies and evaluate the policies. The process of adaptive planning will also help in transferring the rights of the Ganges river to the local communities, making the resource distribution just. While the approach and integration look theoretically feasible and beneficial approach to achieve adaptive planning it requires more data and site-specific analysis to modify the institutional characteristics and achieve optimum benefits. Secondly, most self-organized informal institutions are formed for economic gains and thus if they are empowered without truthful knowledge about climate change risks and need for sustainable adaptation, these institutions can become negative impact and barrier on the current climate change adaptation strategies.

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## Interviews and Field Work

### Locals

#### General

- Lack of awareness
- Do not see individual benefit
- Think the issues are temporary

#### Spatial

- Lack of connectivity across the river
- Lack of public place
- Groundwater is depleting (need deeper pumps)
- Silt Deposition

#### Economic

- Lack of Agro Industries
- Fishermen changing occupation

### Experts

#### General

- Lack of awareness
- Cultural habits
- River is more like existing context

#### Spatial

- Air Pollution due to sand from barren river bed and sand mining
- Encroachment of water bodies

#### Economic

- River no longer plays major role in economy

#### Governance

- Lack of capacity for public engagement
- Majority of power lies at State and District level.



Special Thank you for expert inputs

Dr. Shailendra Kumar Mandal - NIT Patna

Mr. H. K. Mazhari, IAS

Dr. Ashok Kumar Ghosh, Chairman of Bihar State Pollution Control Board

Mr. I N Jha, Institute of Environment and Eco Development

Mr. Prabhakar Kumar, Patna



Questions for community members and civil societies:

**General Information**

Age:

Occupation:

Area of Residence:

Area of Work:

**Challenges**

Do you have access to safe water facility? (Yes/No/Occasionally)

What is the source of water of domestic use? (Municipality tap/ Well/ Ground water Pump/ River/ Streams)

What are the problems faced due to the current conditions of River Ganga? (Clean water/ Lack of Public Space/ Irrigation Challenges/ Flooding/ Pollution)

**Aspirations**

What would you like to change in the River?

How do you want the river to be useful to you?

**Awareness**

Are you aware of the current plans that the government has for the river? If so, what are your thoughts about it?

What do you think you as an individual or small group can do for the Ganges River?

Do you think your actions can play an important role in climate adaptation and how?

Questions for Authorities:

**General Information**

Field/ Section:

**Challenges**

What are the current challenges that you face while designing for water bodies/ Ganges River?

Which department is responsible for making decisions related to the river and other water bodies?

Who takes the final call for a project? (Municipality/State/Central Government)

Have things changed after the New Namami Gange Board? If so How and What?

Which departments should work together to achieve sustainable development?

What is the current focus and what are the current goals regarding river development?

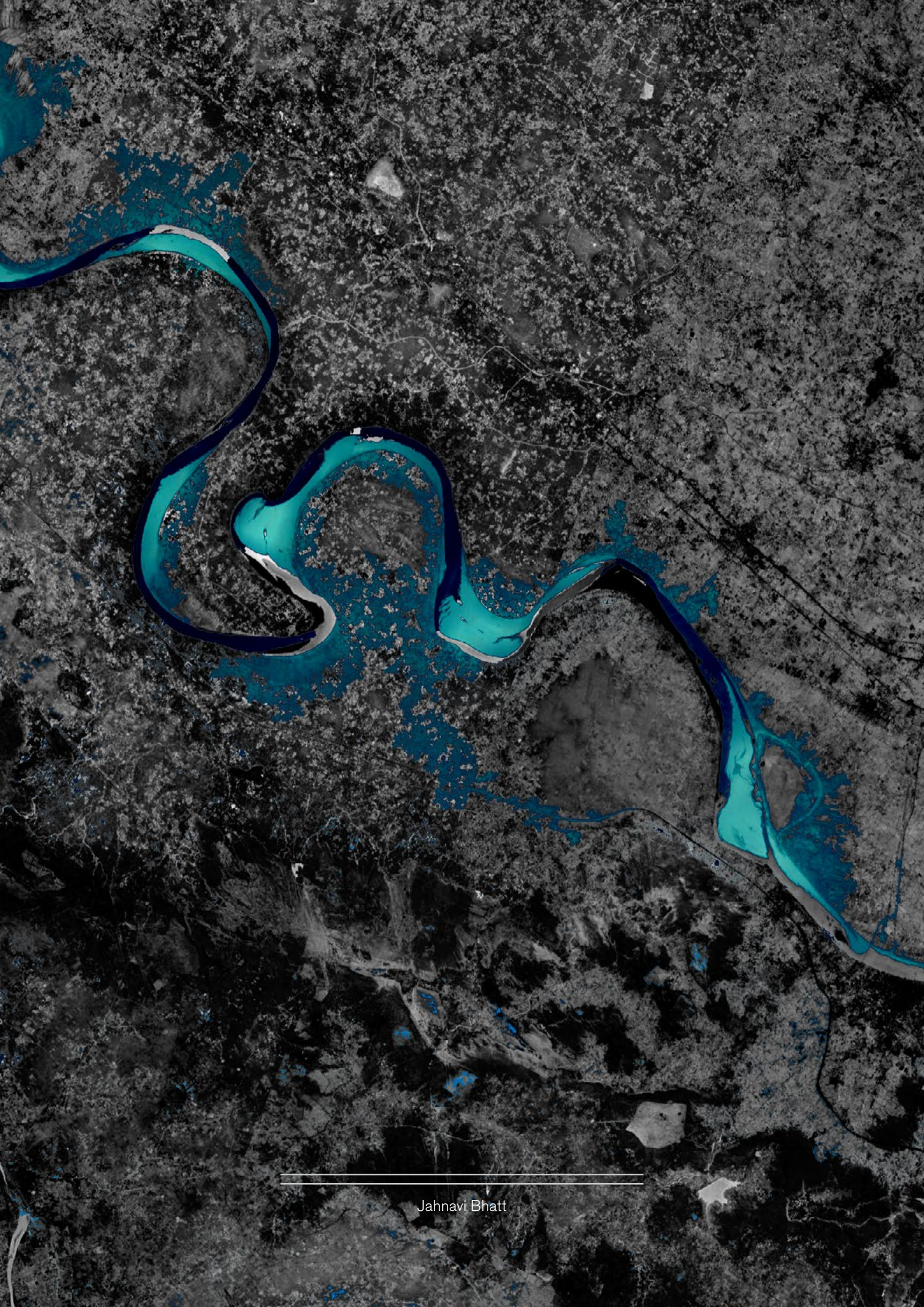
**Participation**

What role do local planning bodies, like municipal co-operation play in management of the river and the activities related to it like industries around it or the fishing activities?

What the aspirations of the communities regarding the river?

What role do you think community can play in climate adaptation regarding the Ganges river?





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Jahnavi Bhatt