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Season- 2

Strategic spatial planning based on Ecosystem services (ES) - A case of Cauvery basin region

Project Title : Strategic spatial planning based on Ecosystem services (ES) - A case of Cauvery basin region

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SUMMARY

Administrative borders are an inevitable component of India's decentralized spatial planning. They seldom correlate with ecological limits and hence serve little ecological purpose on their own. By fragmenting ownership, governance, and management, they impose high costs on biodiversity and ecosystem protection. Though administrative boundaries separate the ecosystem or eco-regions, which are intended to be a single entity for government convenience, they can never be considered independently. This thesis aims to develop a workable spatial planning strategy for a watershed region using ecosystem services as a central focus. Ecosystem services (ES) are the advantages that humans receive from ecosystems. These include provisional services (e.g., food, water supply, energy, and raw materials), regulatory services (e.g., air quality, water regulation, and climate stability), cultural services (aesthetics, recreation/tourism, spiritual), and support services. The process is centered on developing a list of appropriate ecological indicators and corresponding reference values and mapping selected ecosystem services. An exploratory research methodology is used, which includes literature reviews and case studies—remote research-based investigations devise a step-by-step technique for identifying ecosystem service indicators. The list of identified indicators is then reviewed, and the final list is prepared for the watershed region. The study additionally uses the InVEST model and the advanced spatial analysis function of the geographic information system (GIS) for ES spatial mapping. The study supports the necessity for a comprehensive approach to watershed-based planning that considers challenges due to urbanization and climate change while also safeguarding natural ecosystems. The paper finishes with a proposal for a via-media approach to spatial planning that integrates ecological and administrative boundaries and points the way forward with an emphasis on ecologically conscious planning.

Key words: Watershed Planning, Ecological Planning, River basin plan

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CHAPTER 1. INTRODUCTION

1.1. Introduction

When it comes to deciding where to live, people are drawn to water. Throughout human history, rivers have always been the lifeblood of any civilization. Humans have chosen to live near rivers for domestic and agricultural water supply and navigation. The trend is still going on today. However, due to modern socio-economic development, rivers face increasing threats from various sources, including unsustainable withdrawals, pollution, and biodiversity loss. Anthropogenic activities are to blame for much of the current unfavourable state of rivers. The ever-increasing pressures placed on river water by these demands in recent times necessitate better river basin management strategies if the basin is to continue to meet the demands adequately. River restoration and its success rates are frequently dependent on how well it is integrated into the built and natural environments through urban spatial planning. Spatial planning at ecological boundaries, such as watersheds, is required for successful adaptation. A watershed is an area where water from multiple sources drains into a single river or ridge. Watersheds are recognized as a critical spatial unit for planning because they serve as a link between strategic and site-specific plans. A river basin plan is a strategic planning and collaborate plan for achieving water resource goals, which includes assessment and management data for a defined geographical watershed. Over the last two decades, watershed strategies are designed have grown dramatically. It is becoming increasingly popular in countries such as the United States, China, and Europe. The Integrated Watershed Management Programme (IWMP) in India aims to restore ecological balance by utilizing, conserving, and developing degraded natural resources such as soil, vegetative cover, and water. Watershed assessments are being conducted, but no spatial plans in India are based on them. One of the primary reasons for this is India's old planning hierarchy, which adheres to administrative boundaries. Indians must concentrate on basin-level plans to restore deteriorating rivers and the ecological value of basins. Redressing the urban planning framework to include basin-level plans is an urgent need.

"Urban planning is a goal-oriented process that seeks to balance social, cultural, environmental, technical, and economic considerations within a particular legislative framework". The current model of urban development profoundly alters the natural environment, often reducing biodiversity and ultimately threatening human well-being. The socio-ecological approach to urban planning tries to adopt a framework of balancing social attributes and ecological attributes. Many socio-ecological approaches are being adopted for spatial planning, such as the Landscape approach, Green Infrastructure approach, placemaking, and the Ecosystem approach. According to (Jake Rice and Anthony D, 2017) "The Ecosystem Approach is a strategy for the integrated management of land, water, and living resources that promotes conservation and sustainable use in an equitable way". This approach fits perfectly for ecological boundaries-based planning. The ecosystem approach is again subdivided into indicator-based planning, ecosystem assessment based and ecosystem Valuation based planning. Ecosystem indicators and simple measures provide and clear understanding of ecosystem conditions. Hence, the ecosystem approach has been studied to understand its potential in spatial planning.

The Ecosystem Approach to Spatial Planning is not a new concept, but till today it is rarely at the centre of spatial planning. Since the Millennium Ecosystem Assessment (MEA) publication, many researchers and planners have delved into this concept and set examples of better spatial planning. An ecosystem-based spatial development strategy, when used wisely, can result in sustainable development and the reconciliation of anthropogenic sources by addressing the drivers that lead to significant lulc changes. Ecosystem-based approaches and modelling can help analyze and forecast ecosystem changes over time and space. However, modelling is dependent on geo-referenced data, which is often costly and time-consuming to collect and raises concerns about data accuracy. The development and refinement of analytical tools can significantly contribute to spatial planning and conflict resolution.

This thesis attempts to use an ecosystem approach for strategic river basin planning. Using the Cauvery River Basin as an example, the thesis looks beyond administrative boundaries to consider ecosystems, landscapes, and biodiversity value. This thesis would contribute to the holistic visualization of the river basin and adopt an ecosystem approach in future urban planning.

1.2.Problem statement

Administrative boundaries are an unavoidable part of India's decentralized planning. They rarely coincide with ecological boundaries and thus serve no ecological purpose on their own. By fragmenting ownership, governance, and management, they impose high costs on biodiversity and ecosystem conservation. Existing decentralized planning frequently ignores the impact of urbanization on the environment, resulting in master plans failing. Though administrative boundaries separate the ecosystem or eco-regions, which are intended to be a single entity for ease of governance, they can never be considered separately.

Rivers and river basins are continuously pursued in developed countries, despite modernization, urbanization, and industrialization, due to the current persistent consciousness for ecological balance. During the period of scientific inactivity, river basin conservation practices in India deteriorated. Forests are destroyed, lands are eroded, water is mismanaged, and natural resources are mismanaged as a result of the belated basin approach, resulting in environmental degradation and ecosystem service loss.

Hence, it is high time to prioritize eco-regions for resource revitalization, sustainability, and biodiversity conservation. Raising awareness of the benefits provided by ecosystems would aid in site management, equitable resource use, benefit-sharing, and ecosystem management. The ecosystem approach also helps achieve the 2030 Agenda for Sustainable Development goals. India is still in the early stages of valuing ecosystem services, and only a few studies have considered incorporating an ecosystem approach into spatial planning. Mapping ecosystem services is critical for understanding how ecosystems contribute to human well-being and supporting policies that affect natural resources.

1.3.Conceptualization of the project

This project is envisioned as a via-media solution that integrates administrative and ecological borders. Existing decentralised administrative boundary-based planning aids in governance and collecting socioeconomic data. However, they fail to solve environmental challenges caused by development, making the region more vulnerable to disaster. Ecological boundary-based planning, on the other hand, aids in catastrophe resilience, biodiversity protection, and fair resource sharing. The suggested three-tiered research framework aids in comprehending the eco-region as a whole and then superimposing it on administrative borders to produce macro and micro recommendations. Tier 1 analysis is performed at the eco-region boundary (river basin) to gain a comprehensive understanding of the region and to make recommendations that can be implemented when preparing master plans at tier 2 and tier 3 levels. Tier 2 is defined by superimposing district boundaries, while Tier 3 is defined by superimposing LSG boundaries. For proposal implementation, detailed assessments are required at the tier-2 and tier-3 levels. This multilevel framework is a pilot experiment carried out for academic purposes to prioritise eco-regions in spatial planning.

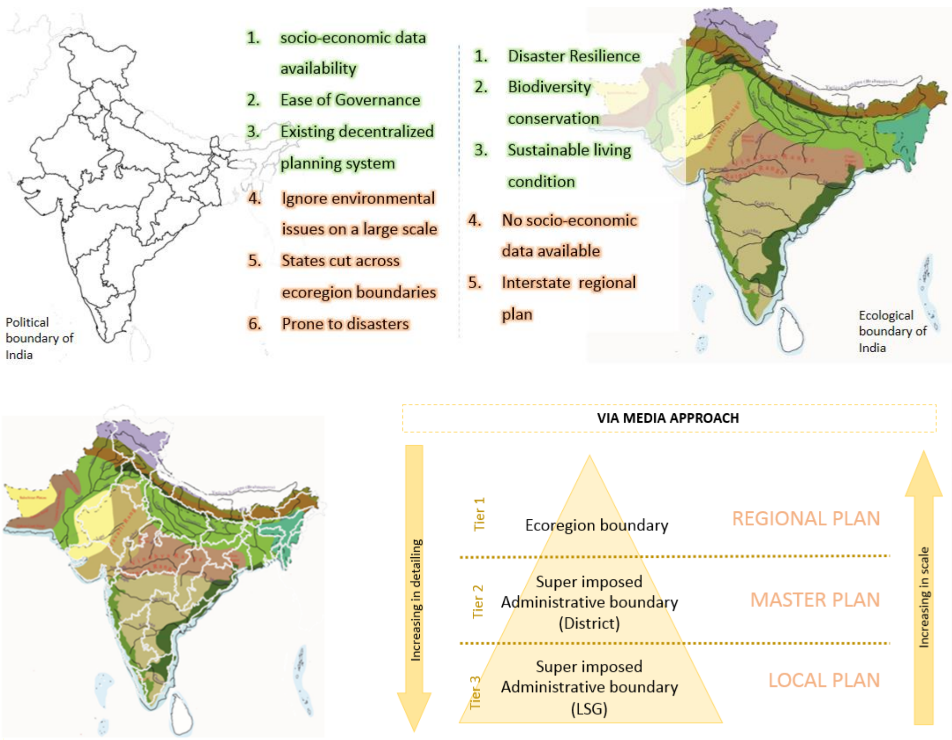


Figure 1.1.1: Via-media solution for integrating administrative and ecological boundaries (Source: Author generated)

1.4.Aim and objective

Aim of the project

Aim of the project is to resuscitate Cauvery River basin, based on ecosystem approach as a case example for river management policy framework and planning.

Objectives of the project

Following four objectives was formulated for achieving the aim of the project. Each objective were then subdivide into task and sub-tasks.

2 To explore ecological boundaries and ecosystem approach in spatial planning through Literature Study

3 To analysis ecosystem services of Cauvery basin region with the best suited indicators and identify priority regions and clusters.

4 To study the Impact of land use land cover changes on ecosystem service and identify key pressures on each ecosystem services

5 To propose strategies, policies and smart innovations for reviving ecosystem services and develop a framework to encourage coherent river management research, policy and planning

1.5.Scope and limitations

This study focuses on the ecological approach in spatial planning, a recent field of interest among researchers. It aims to examine, evaluate and map the ecosystem service of the Cauvery basin and also cover strategies, policies and frameworks for coherent river management in India. The present study is a tier-1 analysis on the ecological boundary, tier-2 can be district level, and tier-3 can be taluk level. Project methodology can be adopted similarly or with the additional variable at tier-2 and tier-3 levels.

The study has been conducted at a regional scale, and on-field Primary and other data collection have been hampered because of Covid. Study Limits to computer-based ES Assessment tools and technologies. The study is also limited to tier-1 assessment and perspective level proposals; detailed tier-2 and tier-3 assessments would be required for spatial implementation

1.6.Data collection: Sources

The study relied solely on secondary data and remote research. Since the study was conducted at the regional level, open-source satellite data such as USGS Earth Explorer, NASA Worldview, Copernicus Open Access Hub, Bhuvan, and Google Earth were used. Before being used for spatial analysis, all satellite data was cleaned and processed with the help of software like SAGA and ARCGIS. Some government reports and documents consulted for the study included the Census 2011, District Statistics Report, District Fact Books, and State Economic Statistics. National and international reports published by think tanks such as NIUA, NMCG, WRI, WWF, World Bank, and Asian Development Bank are also used in the study.

1.7.Structure of the report

The report is divided into eight chapters, followed by references and appendices. The thesis context is introduced and contextualised in the first chapter. The problem statement, goal and objectives, scope and limitations, and data sources are included. The second chapter discusses literature reviews and case studies. The literature in this chapter covers concepts and paradigms, methodology formulation, variables and indicators, and proposal-related studies. The detailed methodology is then described in the third chapter. The fourth chapter describes the study area, including its boundaries and profile. The variable mapping used in the study is discussed in this section. The fifth chapter focuses on LULC and driver modifications. The sixth chapter includes a cluster analysis, SWOT analysis, and a priority list. The seventh chapter focuses on proposals, policy measures, and the framework for implementation. The concluding chapter summarises the findings and discusses the study's contribution and future research directions.

CHAPTER 2. LITERATURE REVIEW

2.1.Introduction

The formwork of this thesis was built using literature studies and case studies. Journals and publications were chosen from open peer-reviewed databases such as Scopus, Google Scholar, and Web of Science. This deck study was also divided into four sections: literature on concepts, theories, and paradigms, literature on methodology, literature on variable selection and screening, and literature on proposals. This chapter will walk one through the knowledge gained from all four literature review sections.

2.2.Concepts, theories and paradigms

Biodiversity and ecoregion

"Biodiversity is the variation among living organisms from different sources including terrestrial, marine and desert ecosystems, and the ecological complexes of which they are a part." - (UN-CBD). Biodiversity is not distributed evenly across the Earth but follows complex patterns determined by climate, geology, and the planet's evolutionary history. These patterns are referred to as "ecoregions." The WWF defines an *ecoregion* as a "large unit of land or water containing a geographically distinct assemblage of species, natural communities, and environmental conditions." The WWF divides ecoregions into terrestrial, freshwater, and marine categories. The terrestrial scheme divides the Earth'sEarth's land surface into eight biogeographic realms and 867 smaller ecoregions. Each ecoregion is subdivided into 14 significant habitats.

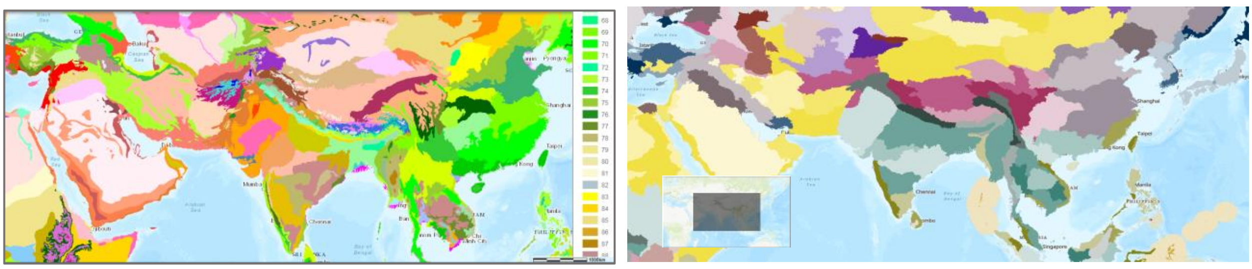


Figure 2.2.1: Terrestrial and freshwater Ecoregions of the World (Source: WWF)

Freshwater systems include rivers, streams, lakes, and wetlands. Freshwater ecoregions differ from terrestrial ecosystems, which define biotic communities on land, and marine ecosystems, which define biotic communities in the oceans. Freshwater ecoregions are based on the distributions and compositions of freshwater fish species and incorporate major ecological and evolutionary patterns. They harbor a significant fraction of biodiversity and suffer from additional classes of threats; freshwater biodiversity has historically been overlooked, and very few studies were done in the freshwater region. At the basin scale, ecoregions can help introduce biodiversity information into water-resource or integrated-basin management activities. River-basin studies can also be used as stratification units to ensure adequate representation of distinct biotas. A counterintuitive planning unit can be introduced to incorporate biogeographic patterns, and regional mandates may choose to compare biodiversity values across ecoregions in the process of setting continental priorities.

Ecosystem services

Ecosystem services (ES) refer to benefits people obtain from ecosystems. These can include provisioning (e.g., food, water supply, energy, and raw materials), regulation (e.g., air quality, water regulation, and climate stability), soil formation/nutrient cycling, cultural services (aesthetics, recreation/tourism, spiritual). Such services value human communities, but this value is not always captured or monetized. Following the increased awareness and acknowledgement of nature's role in supporting human well-being, many tools for measuring, modelling, and valuing ES have been developed in recent years. Detailed information about ES can be helpful for many reasons, including increasing awareness of the benefits provided by these sites, supporting site management decisions, and helping ensure equity in resource use and benefits sharing among stakeholder groups. Information about ES can guide decision-making and support the protection and management of natural ecosystems to ensure an ongoing sustainable flow of benefits for current and future generations. Lastly, this information can inform how these sites contribute to achieving the 2030 Agenda for Sustainability goals. However, if ecosystems are overused and destroyed, they often cease to provide essential services to humankind. Ecosystem services can be perceived as an interface between people and nature, which is illustrated by the 'cascade model' This model describes the pathway of causal interrelations between the ecosystem at one end and the human well-being at another(figure 1.2). The ecosystem's capacity to supply services for human well-being directly depends on the ecosystem's condition. While increasing the pressure on the ecosystem or changing the land use type, people influence the ecosystem service supply or trade-offs between different services. For example, by draining a wetland, people can gain arable land and thus valuable food products, but at the same time lose such services as flood protection, natural habitats and species diversity as well as possibilities for nature tourism. `Biodiversity has an essential role in the supply of ecosystem services, and studies demonstrated a direct linear relationship between species diversity and ecosystem productivity, biomass production, nutrient cycling etc. (Haines-Young and Potschin, 2010). Hence, knowledge of ecosystem service supply and their links to biodiversity and limits of ecological functioning is crucial when making decisions on land use or development projects which are impacting ecosystem conditions.

The millennium Assessment classification system divides ecosystem services into four main categories: Provisioning services include food, materials, and energy, which people directly use; Regulating services are those that cover the way ecosystems regulate other environmental media or processes; Cultural services are those related to the cultural or spiritual needs of people, and the last category is supporting services are ecosystem processes and functions that underpin the other three types of services.

The ecosystem approach considers the environment as a system and recognizing the services that nature provides. The approach guides how we plan and manage the environment for the benefit of society, for now and for future generations. It promotes equitable sharing of the benefits we get from nature and encourages participation from all in decision-making.

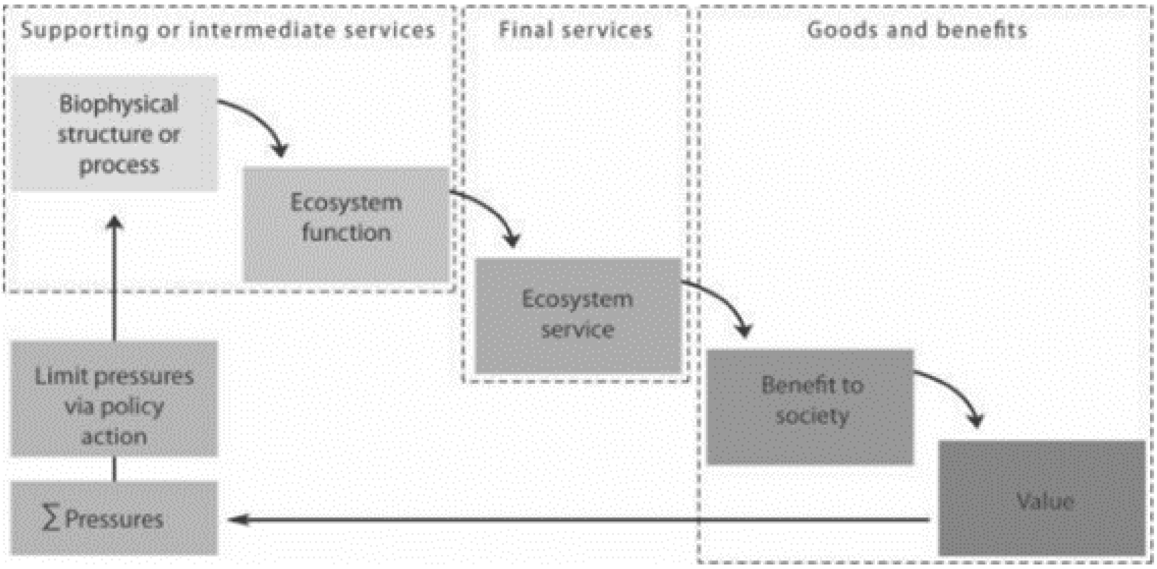


Figure 2.2The Cascade model , (Source: Potschin and Haines-Young, 2016)

Table 2.1: Ecosystem service (source: MEA 2005)

Provisioning Services	Regulating Services	Cultural Services	Supporting Services
Food and fiber.	Air quality maintenance	Cultural diversity	Soil Formation
Fresh Water	Climate regulation.	Spiritual and religious values	Photosynthesis
Fuel	Water regulation.	Knowledge systems	Primary production
Genetic resources.	Erosion control.	Educational values	Nutrient cycling
Biochemical & natural medicines	Water purification and waste treatment	Inspiration	Water cycling
Ornamental resources.	Diseases regulation	Aesthetic values	
	Biological control	Social relations	
	Pollination	Sense of place	
	Natural hazard regulation	Cultural heritage values	
		Recreation and ecotourism	

Following are the twelve principles to be followed while incorporating *Ecosystem Approach* in spatial planning according to Convention on biodiversity guidelines (CBD Guidelines)

1	The objectives of management of land, water and living resources are a matter of societal choices.
2	Management should be decentralized to the lowest appropriate level.
3	Ecosystem managers should consider the effects (actual or potential) of their activities on adjacent and other ecosystems
4	Recognizing potential gains from management, there is usually a need to understand and manage the ecosystem in an economic context
5	Conservation of ecosystem structure and functioning, in order to maintain ecosystem services, should be a priority target of the ecosystem approach.
6	Ecosystems must be managed within the limits of their functioning
7	The ecosystem approach should be undertaken at the appropriate spatial and temporal scales.
8	Recognizing the varying temporal scales and lag-effects that characterize ecosystem processes, objectives for ecosystem management should be set for the long term.
9	Management must recognize that change is inevitable.
10	The ecosystem approach should seek the appropriate balance between, and integration of, conservation and use of biological diversity.
11	The ecosystem approach should consider all forms of relevant information, including scientific and indigenous and local knowledge, innovations and practices
12	The ecosystem approach should involve all relevant sectors of society and scientific disciplines.

Some of challenges involved in applying ecosystem approach are issue of defining and classifying ecosystem services approaches to quantify and value ecosystem services. How to analyze trade-offs involved in land cover and land use change, Lack of spatial analysis and dynamic modelling tools and How to determine the total economic value of different management states

Watershed regions in India

Following the 4 stage delineation, WRIS delineates and codifies the catchment areas into smaller Hydrologic units, i.e. sub watersheds. The user agencies have always felt the need for a national level framework of watersheds, which has been served by the methodology developed. The current bulletin on India's Watershed Atlas is an attempt in that direction, with the entire country divided into -6 Major Water Resources Regions -35 River Basins -112 Catchments -500 Sub-catchments -3237 Watersheds.

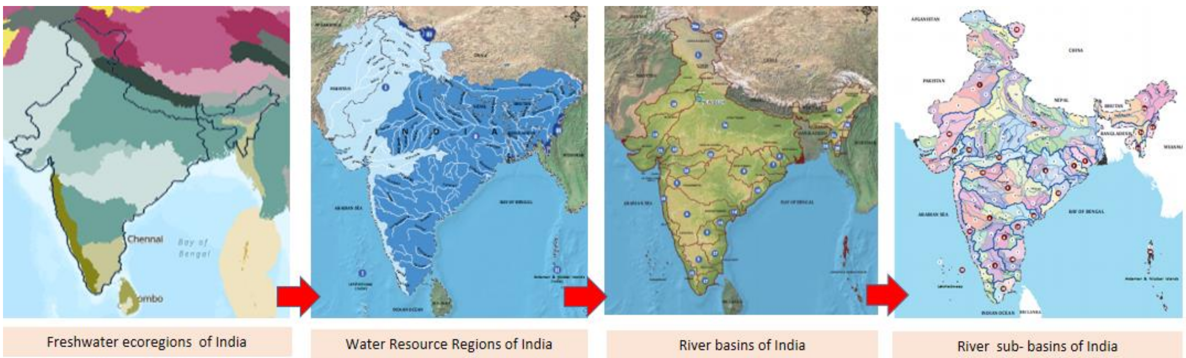


Figure 2.3: Watershed delineation in India (Sources: WRIS, WWF)

2.3.Methodology and methods

Reference 1

TiTle: Integrating ecosystem services into sustainable landscape management: A collaborative approach

Citation: Terêncio, D. P. S., Varandas, S. G. P., Fonseca, A. R., Cortes, R. M. V., Fernandes, L. F., Pacheco, F. A. L., Monteiro, S. M., Martinho, J., Cabral, J., Santos, J., & Cabecinha, E. (2021). Integrating ecosystem services into sustainable landscape management: A collaborative approach. Science of the Total Environment, 794. https://doi.org/10.1016/j.scitotenv.2021.148538.

Inferences: The document focused to analysing ecosystem services with The Driver-Pressure-State-Impact-Response (DPSIR) framework. It used Multi-Criteria Decision Analysis and GIS. Spatial problems are frequently characterized by a large number of viable alternatives as well as multiple, conflicting, and wholly incompatible evaluation criteria. A GIS-MCDA can be used to solve complex problem by transforming and combining geospatial information and value judgments. A GIS-MCDA is a more robust criteria-based technique than a pretty standard binary or 'coincidence' analysis. As a result, it can allow additional values of multicriteria at the same time. This enables more in-depth decision making.

Reference 2

Title: Ecosystem services assessment and sensitivity analysis based on ANN model and spatial data: A case study in Miaodao Archipelago

Citation : Yin, L., Zheng, W., Shi, H., & Ding, D. (2022). Ecosystem services assessment and sensitivity analysis based on ANN model and spatial data: A case study in Miaodao Archipelago. Ecological Indicators, 135, 108511. https://doi.org/10.1016/j.ecolind.2021.108511

Inferences: the study took advantages of InVEST model and the powerful spatial analysis function of the geographic information system (GIS) to map five ecosystem services and Artifcial neural network (ANN) for ESs assessment. Artificial neural networks are widely used computational models in geographic data for classification process, change detection, clustering, linear regression, and predicting the future or forecasting. The study also standardised the data and performed sensitivity analysis. The as a whole ESs contrast and their co - relation were thoroughly investigated.Computer based modelling tools for ecosystem service assessment were also reviewed to identify the most suitable tool for this study. INVEST and water-world was selected among more than 10 tools considering the input and output data format and GIS expertise.

2.4.Indicator selection and screening

The selection of Indicators was a critical process because the study's results would be dependent on it; thus, many national and international reports and studies were consulted before the final selection of Indicators. A comprehensive list of variables was tabulated from EnviStats (38) + global ecosystem indicators (59) + case study indicator (31).

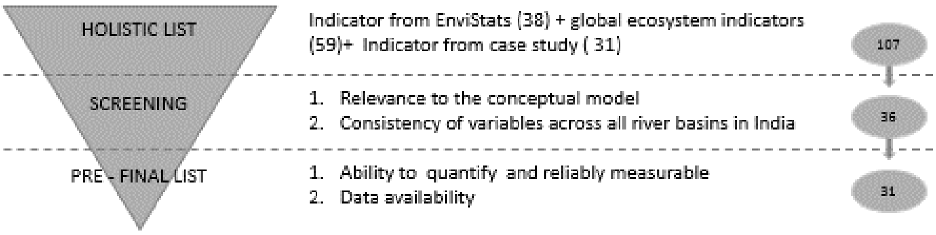


Figure 2.4: Indicator screening

These indicators were chosen based on a concept model that emphasised water availability and people's well-being, river shed tourism potential and economic opportunities, primary economic sustainability, water regulation and vegetation cover, and disaster mitigation. Indicators were further screened based on variable consistency across all river basins in India.

The pre-financial screening focused on removing indicators that could not be quantified or reliably measured and were not available. The pre=final list have 31 indicators which can be used for similar studies in different river basins in India. The final list of indicators were again screened based on the context of Cauvery basin and tier-1 indicators were formulated. The first screening was done based on data type where primary data were omitted. Detailed study with primary data can be done at local self-government level. Second screening was done to understand which all data fit in the ecoregion scale. Data within the scale of District level and ecoregion level where taken forward. Last and the final screening was to omit similar indicators or indicators with high correlation. For example indicators like forest cover and NDVI has high correlation ,hence only forest cover was taken forward in the screening process. The study focuses on 11 indicators out of the shortlisted 13 indicators. Section 3.4 of Chapter 3 will detail out the process of calculating each indicator and section 4.4 of Charter 4 contains the detailed mapping of the below mentioned indicators.

Table 2.2: table of indicators for Cauvery basin

slno	INDICATORS	Data type (P/S)	Scale of data (Eco/dist/lsg)	Similitude	Indicators focused for this study
1	Water yield per person per year	S	Eco/dist/lsg	»	●
2	Water stress index (WSI)	P			
3	Distance between the nearest water access point and each household	P			
4	% Of sewage treated before discharge into surface water body	P			
5	Human activity based contamination	S	Eco	»	●
6	Per capita storage of water	S	dist		
7	Annual renewable freshwater supply by surface water	P			
8	Annual freshwater consumption per sector	P			
9	Tourist footfall	S	dist	»	
10	Recreational potential accessibility	P			
11	Attractive biodiversity	S	Eco/dist/lsg	»	●
12	Economy from tourism	S	dist		
13	Total employment in the tourism sector	S	dist	»	●
14	Access to green spaces for city inhabitants	P			
15	Economy from agriculture	S	dist	»	●
16	Income per capita related to agricultural food production	S	dist		
17	Market price for extracted agricultural goods	S	dist		
18	Economy from fisheries	S	dist	»	●
19	Economic dependency on river basin	S	dist	»	●
20	Tree species diversity	P			
21	Soil infiltration capacity	P			
22	Nitrogen retention	S	Eco/dist/lsg	»	
23	Carbon storage	S	Eco/dist/lsg	»	●
24	NDVI	S	Eco/dist/lsg		
25	% Of forest cover	S	Eco/dist/lsg	»	●
26	Exposure to disaster	S	dist	»	●
27	Total area of coastal wetlands	S	Eco/dist/lsg		
28	Total population protected	P			
29	% Change in area under wetlands	P			
30	Total net erosion	S	Eco/dist/lsg		
31	Habitat treat	s	Eco/dist/lsg	»	●

The indicators were not classified according to the type of ecosystem service, but rather provided a holistic view of the entire basin. The indicator selection is based on the author's research interests and can be modified for use on other sites. It is a pilot study with very few indicators. Following are the indicators and table details out the screening process followed.

2.5. Case studies for proposal

Reference 1

Title : River Basin Planning Principles, Procedures and Approaches for Strategic Basin Planning at ADB

Inferences: The report provided an excellent overview of the characteristics of strategic basin planning and the ten golden rules of basin. Those golden rules are as follows:

Rule 1	Develop a comprehensive understanding of the entire system
Rule 2	Plan and act, even without full knowledge
Rule 3	Prioritize issues for current attention, and adopt a phased and iterative approach to the achievement of long-term goals
Rule 4	Enable adaptation to changing circumstances
Rule 5	Accept that basin planning is an inherently iterative and chaotic process
Rule 7	Address issues at the appropriate scale by nesting local plans under the basin plan
Rule 8	Engage stakeholders with a view to strengthening institutional relationships
Rule 9	Focus on implementation of the basin plan throughout
Rule 10	Select the planning approach and methods to suit the basin needs

The report also helped in understanding the basin planning process and structure of strategic river basin plan.

Reference 2

Case study 1: Mekong River basin management

Inference: The case was studied toughly to understand how the Mekong River Commission manage resources and The MRC supports a basin-wide planning process based on principles of Integrated Water Resources Management (IWRM). Rising in south-eastern Qinghai province, China, Mekong flows through the eastern part of the Tibet Autonomous Region and Yunnan province, after which it forms part of the international border between Myanmar (Burma) and Laos, as well as between Laos and Thailand. The transboundary planning and management of basin and governance framework were studied. MRC Strategic Plan 2021–2025 was also studied in detail to understand the vision, proposals and how they are aligned with sustainability goal.

Reference 3

Inferences: **Yamuna Biodiversity Park** is a pilot project for the development of Biodiversity parks across City. Objective of the project was to bring back original ecological state is to sustain the ecological services and goods that it was rendering to the region. Major Learnings from the project were A biodiversity park is only successful if it can attain complete self-sustenance, hence need large area, Stick to native species.(Ecological Restoration principle), A typical Biodiversity Park should have two basic components: A Nature Conservation Zone and a Visitor Zone and The criteria for judging that an ecosystem has been restored are to check if it is generating Ecological Services and Goods.

2.6.Conclusion

The chapter discussed the literature reviews and case studies that served as the thesis's foundation. The papers and case studies were extremely helpful in developing the methodology for this thesis. The literature studies aided in deciding on the best suitable indicator for study and mapping it. Journal papers were also used to learn about INVEST software and other spatial techniques for analysis.

CHAPTER 3. METHODOLOGY

3.1. Introduction

This chapter details out the methodology formulated for the thesis. The methodology is formulated based on the literature review and case studies.

3.2. Objectives and tasks

Each objectives where divided into tasks and classified under literature study, computer based assessment and knowledge application. Computer based assessment included data analysis with the help of Tools and GIS frameworks. Various software like ARCIS, QGIS, SPSS and excel were used for the same.

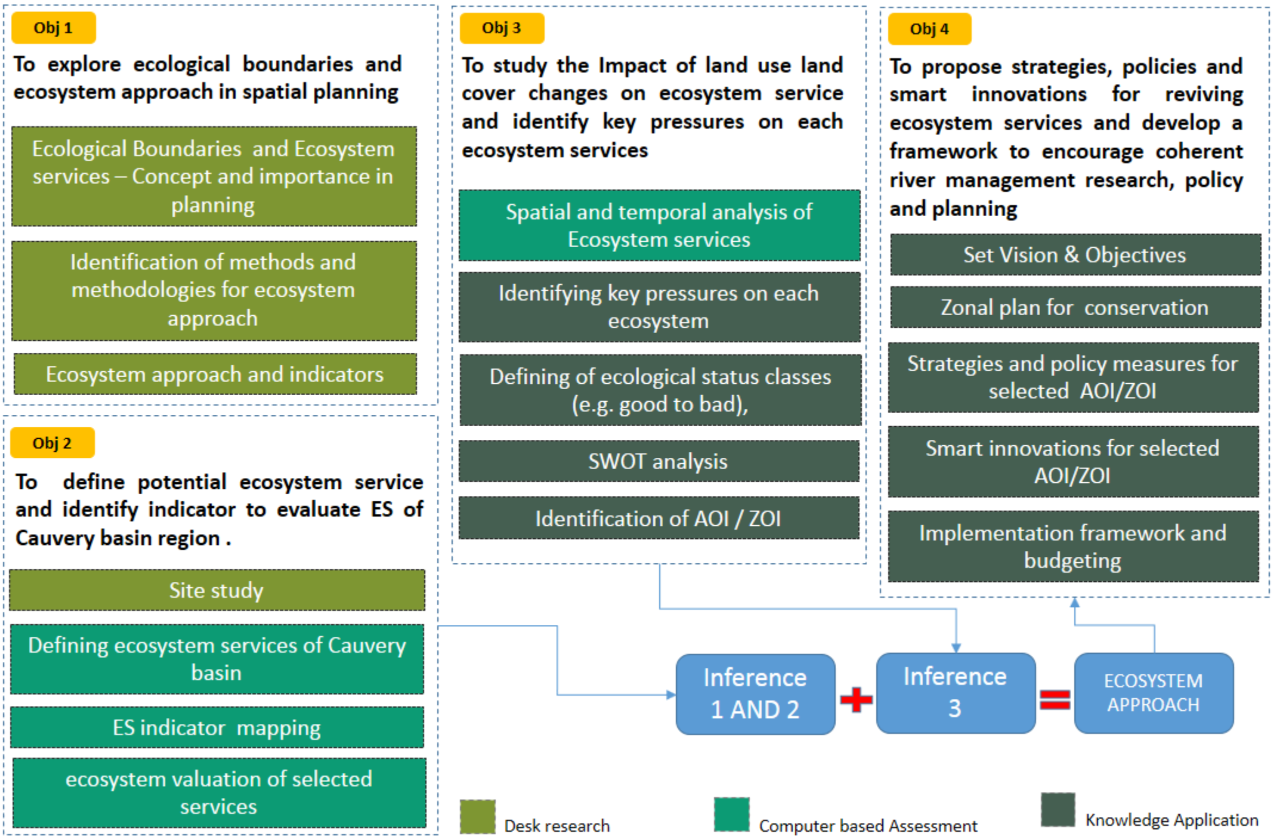


Figure 3.1: Objectives and tasks (Source: Author generated)

3.3. Methodology: Objective 1

The objective one was to explore the concept and possible ways to incorporate ecological approach in basin level. The tasks included remote research and case studies .The research was divided into 4 section namely concepts, methodology, indicator screening and proposals.

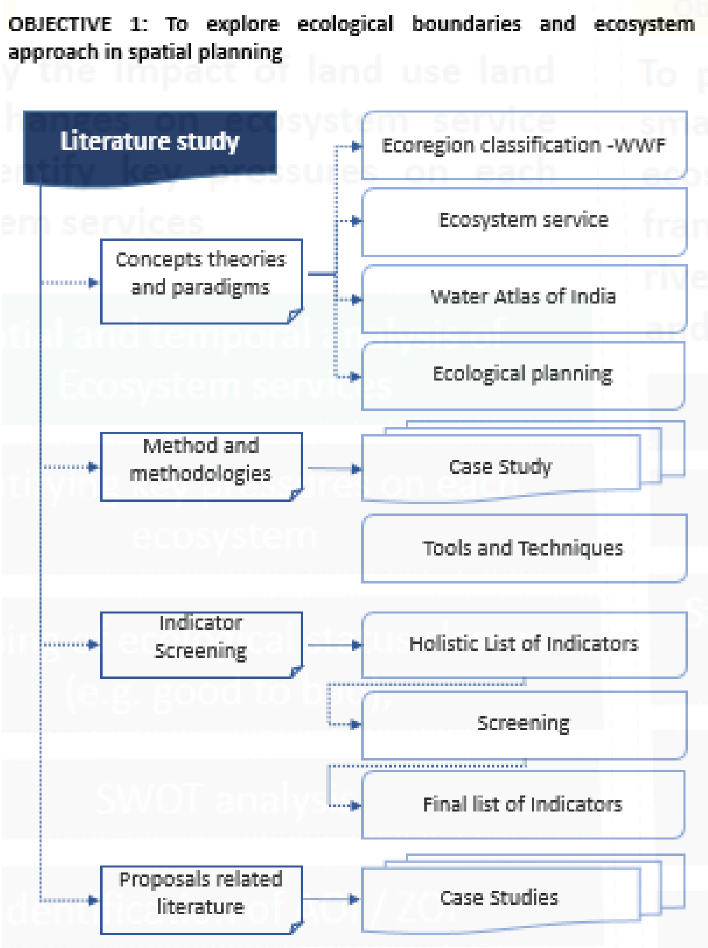


Figure 3.2: Detailed methodology of objective -1

3.4. Methodology: Objective 2

Objective focuses on area study and delineation along with indicator mapping for assessment of ecosystem services. The objective had both remote research and commuter based assessment to be carried out. Indicator selected are analysed based on computer based tools like INVEST, WaterWorld and Arcgis. All data procurement sources are mentioned below.

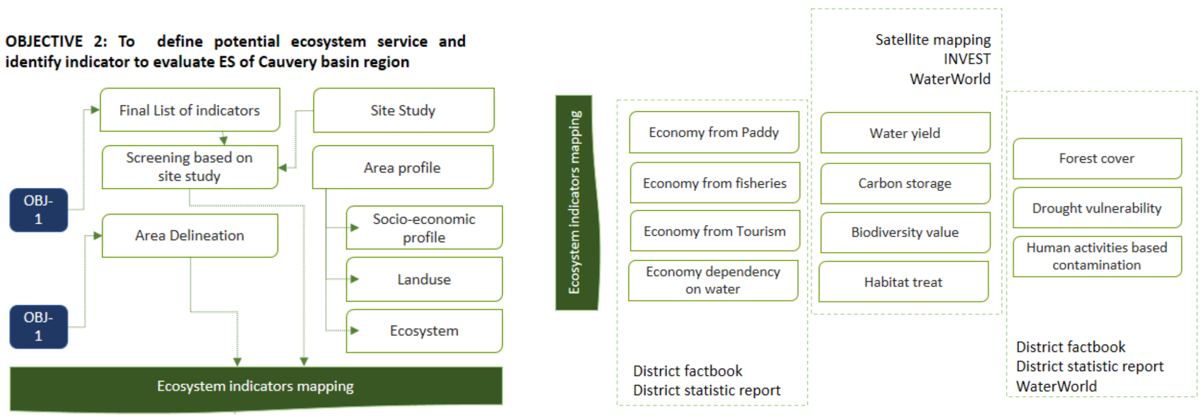


Figure 3.3: Methodology: objective-2

Indicator mapping – methodology

1. Economy from Paddy

The economy generated by paddy was calculated by tabulating paddy production in each district and multiplying it by the current Quintal price. Data on paddy production in each district was obtained from each district's Agriculture Statistics. The data is also available in economic statistics published by each state's statistical division.

2. Economy from Inland Fisheries

Inland fisheries are the extraction of aquatic organisms from inland bodies of water. It is an important ecosystem service that helps with food production and living conditions. Data on inland fish revenues were collected by district from reports published by each state's fisheries department.

3. Economy from tourism

After agriculture, tourism is one of the most important economic drivers in the Cauvery basin. Data on the generated economy by district was gathered from each state's tourism statistics.

4. Economic dependency on basin

The total economy from paddy, inland fisheries, and tourism was divided by the total GDP of each district to determine the district's reliance on the basin's ecosystem services. GDP by district was obtained from each state's statistics division.

5. Water yield

Water yield calculate with the help of INVEST MODEL. It calculate the contribution of water from different parts of the basin. It is based on an expression of the Budyko curve proposed by Fu (1981) and Zhang et al. (2004). The detailed process of water yield in explained in the user-guide published available at "https://invest-userguide.readthedocs.io/en/latest/annual_water_yield.html"

$$y(x) = \left(1 - \frac{AET(x)}{p(x)}\right) . p(x$$

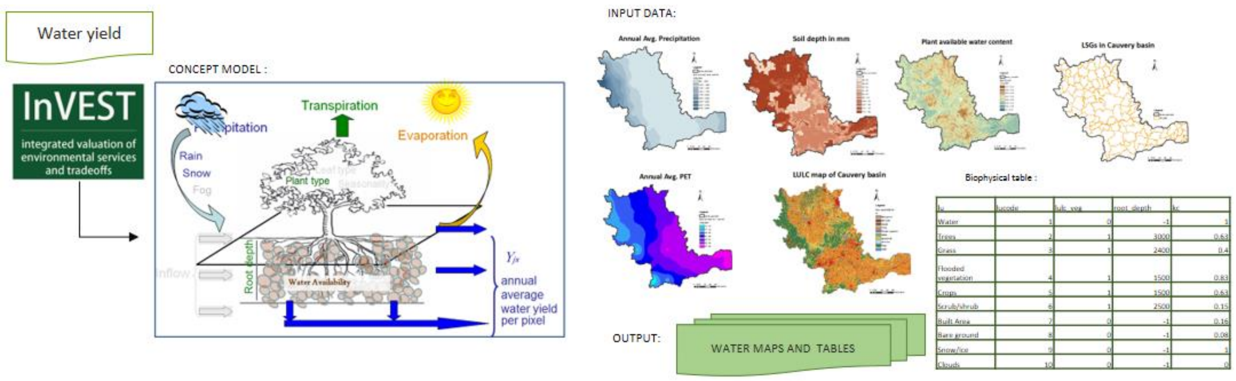


Figure 3.4 : INVEST water yield model –process

6. Exposure to disaster (Drought events)

According to the CEEW Report titled "Preparing India for Extreme Climate Events Mapping Hotspots and Response Mechanisms" published in December 2020, the Cauvery basin suffers from drought more than any other disaster, so drought events are prioritized for this study. Drought event data is collected from CEEW report.

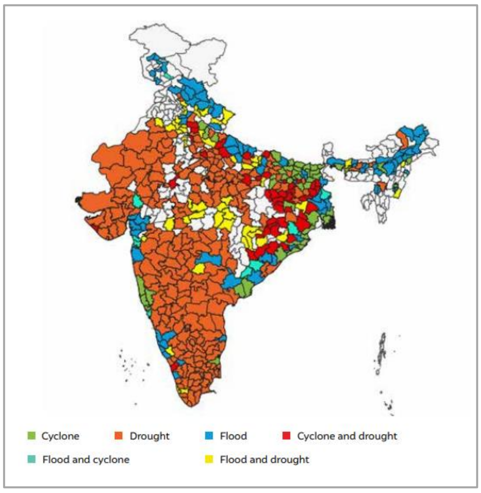


Figure 3.5: Extreme climate hotspots in India (source: CEEW)

7. Forest cover

Forest is an important source of ecosystem services. The district wise forest area in % is collected from District facts books published by Datanet India Pvt.Ltd. It was established as an IT-enabled private limited company in February 2000 to render its services in the socio-economic information domain.

8. Carbon Storage

Carbon storage is one of the most discussed ecosystem services. The INVEST carbon storage model is used in the study to determine the amount of carbon stored in the study region. It uses the ipcc inventory approach to assign cabon storage based on LULC.

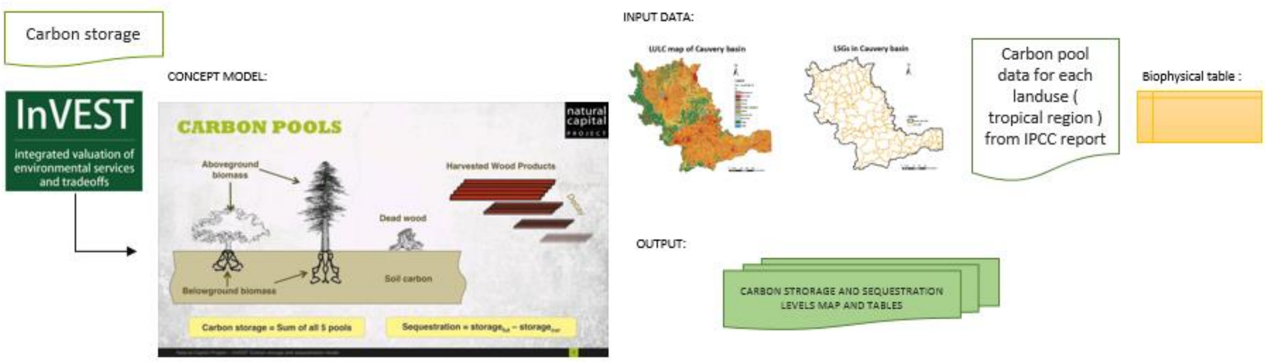


Figure 3.6: INVEST carbon storage model

9. Biodiversity value

Biodiversity value is calculated based on Species richness of IUCN sampled Red List. Biodiversity index combines relative species richness of threatened mammals, amphibians and reptiles and relative range size rarity using the C-value. Richness and rarity values are corrected according to intensity of land-use type.

10. Habitat threat

Habitat threat is worked out with respect to intensive agriculture, urban expansion and a risk to protected areas near urban conurbations. Threat is calculated according to accessibility, proximity to recent deforestation, change in population, climate change and night lights. The data is processed in computer based assessment tool named *water world . It's a part of* Part of policysupport.org suite of tools

11. Human activity based contamination

Mean percentage of water that may be polluted (%) with respect to human activities is calculated with help of water world

3.5. Methodology – Objective 3

Objective three focuses on LULC analysis and identifying drivers on change. LULC change of 3 decades are analysed to understand the drivers in details. Decades selected are 1985, 1995, 2005, and 2015. QGis platform was utilised for analysis and tabulation of the data.

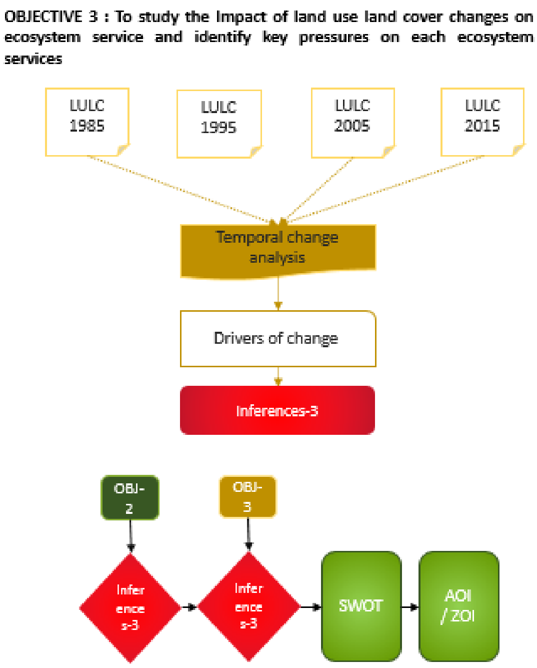


Figure 3.7: Detailed methodology- Objective- 3

Area of interest/Zone of interest

1. Priority map

The overlay tool in ArcGIS is used to perform priority mapping. All indicators are converted to raster files and reclassified on a 1-5 scale. 1 represents the most important area, and 5 represents the least important area. The raster calculator was used to perform fizzy overlay analysis after reclassification. The Cauvery basin is divided into five zones, numbered one to five in order of priority.

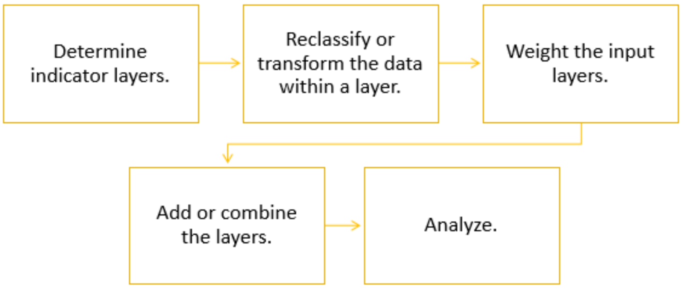


Figure 3.8: General steps to perform overlay analysis

2. Cluster map

Fuzzy membership and fuzzy overlay tools were used to create clusters. The fuzzification, or fuzzy membership process, and fuzzy overlay analysis are the two key stages in fuzzy logic for overlay analysis. In the overall overlay process, these basic processes correspond to the reclassify/transform and add/combine steps, respectively. Based on a specified fuzzification algorithm, fuzzy membership converts the input raster into the 0 to 1 scale, implying the strength of a membership in a set. A value of 1 means full membership with in fuzzy set, while a value of 0 indicates it was not a participant of the fuzzy set. Every cell in a study region is assigned a class or category using the fuzzy method. Using fuzzy method and actual knowledge of the study area, one can identify representative areas of each class.

Figure 3.9: Detailed methodology - Objective 4

3.6. Methodology –Objective 4

Work that requires knowledge application is considered objective four. It entails defining priority zones and conservative hotspots. A more comprehensive approach to governance and a more effective implementation framework have been investigated.

3.7. Conclusion

The methodology developed for this thesis was detailed in this chapter. Mapping ecosystem services made excellent use of computer-based assessment tools. The entirety of the analysis was GIS-based and was completed in ArcGis and QGis. This thesis envisioned a pilot study for incorporating an ecological approach within a watershed boundary, so further refinement can be done by including variables and indicators. The current study employed the most reliable open source, computer-based assessment tool, which assessed ES using global data obtained from satellite images. The study will be limited in terms of data quality because it will be based on secondary and satellite data. The maximum raster resolution is 30 m.

CHAPTER 4. CAUVERY RIVER BASIN

This chapter details out the studies conducted under objective 2

To define potential ecosystem service and identify indicator to evaluate ES of Cauvery basin region.

4.1. Introduction

This chapter will examine the selected site – the Cauvery River Basin – as well as the delineation process and indicator-based mapping. The chapter also explains why Cauvery was chosen as a case study and provides an area profile of the site. The remote research is entirely dependent on statistical data gathered at the district and state levels.

4.2. Study area- Cauvery river basin

Born in the green mountains to quench the thirst downstream, the River Cauvery is home to many and mother to all.

The river begins in the Coorg district of Karnataka at a place called Talakaveri and flows into the Bay of Bengal at Kaveripoompattinam. It has a length of 800 kilometres and is known as the Ganges of the South. The basin encompasses three states and one union territory.

Table 4.1: State-wise distribution of drainage area (source:CWC)

State	Drainage area (sq. km.)
Tamil Nadu	48,730
Karnataka	36,240
Kerala	2,930
Total	87,900

The river basin has approximately 19% forest cover, and major crops grown include paddy, sugarcane, ragi, jwar, and others. Ecotourism is increasingly becoming a significant economic source in the basin. The river's tributaries are divided into left bank and right bank tributaries. Hemavathi, Shimsha, and Arkavathi are major left bank tributaries. The largest tributary, Hemavathi, flows through Hassan city. Bangalore is located on the banks of the Arkavathi River. Kabini, Bhavani, Noyyal, and Amaravati are major right bank tributaries. Kabani tributaries are well-known for the dam and bhavani is popular as it flows through silent valley National Park .

Table 4.2: List of tributaries of cauvery basin

Left Bank	***Right Bank***
The Harangi	The Lakshmantirtha
The Hemavati	The Kabini
The Shimsha	The Suvarnavati, The Bhavani
The Arkavati	The Amaravati and The Noyil

Srirangapatnam, Mysuru, Mandya, Mettur, Erode, Karur, Trichy, Tanjore, Kumbakonam, and Puhar are among the major cities on the Cauvery's banks. Srirangapatam is a historic city with the nearby Ranganthittu bird sanctuary. Every year, a large number of migratory birds visit the sanctuary, which is known as pakshikashi in Karnataka. Mysuru is Karnataka's cultural capital, Erode is a turmeric city, and Karur is known for its home textile and paper mills. Srirangam is a riverine island famous for its Ranganatha Swami temples. Thanjavur is Tamil Nadu's rice bowl. It was historically known for agriculture with three yields per year; however, it is now completely degraded due to extensive cropping and water loss. Tanjavur is also famous for its tanjore dolls, tanjore paintings, and the production of brown statues. Pichavaram, near Kumbakonam, has one of the world's largest mangrove forests. Because of the preserved mangrove area, this location was spared the devastation caused by the tsunami that struck south-east India a few years ago. The following are the major dams and reservoirs on the Cauvery River.

Table 4.3: Major dams of Cauvery basin

RIVER	DAM
Kabini	Kabini Dam
Hemavathi	Gorur Dam
Bhavani	Bhavani Sagar Dam
Amaravati	Amaravati Dam
Cauvery	Krishnaraja sagar Dam Mettur Dam

One of the major waterfall in the basin is Shivanasamudra Waterfalls, it is the 2nd largest falls in India and has Asia's first hydroelectric plant was installed over this fall in 1902.Another major fall in Hogenakkal Falls, this is were Cauvery enters Tamilnadu . Major national parks in the basin include Nagarhole National Park, Silent valley national park, Indra Gandhi National Park , Satyamangalam Tiger reserve and Anaimalai Tiger reserve.Satyamagalam Tiger reserve is known for Tiger, Elephants and critically endangered IndianVulture.

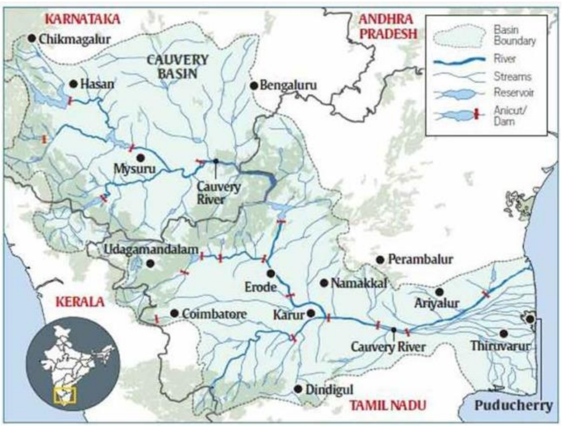


Figure 4.1: Major dams of Cauvery basin (Source: DJS Chanchal, 2018)

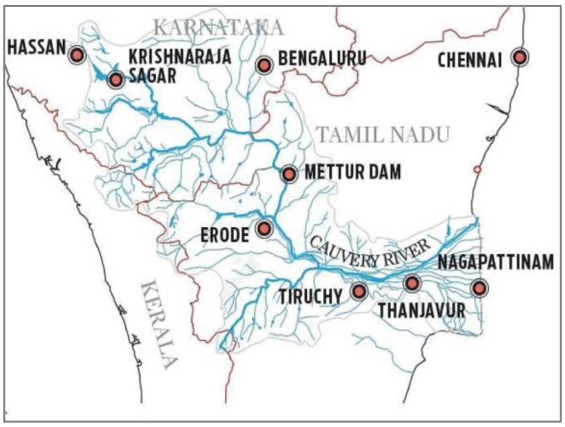


Figure 4.2 : Cauvery river basin and prominent cities

The basin in Karnataka receives rainfall mainly from the S-W Monsoon and partially from N-E Monsoon. The basin in Tamil Nadu receives good flows from the North-East Monsoon.Its upper catchment area receives rainfall during summer by the south-west monsoon and the lower catchment area during the winter season by the retreating north-east monsoon.It is, therefore almost a perennial river with comparatively fewer fluctuations in flow and is very useful for irrigation and hydroelectric power generation.. Cauvery is one of the best-regulated rivers and 90 to 95 percent of its irrigation and power production potential already stands harnessed. The major part of the basin is covered with agricultural land accounting to 66.21% of the total area .

The Cauvery basin is fan shaped in Karnataka and leaf shaped in Tamil Nadu. The run-off does not drain off quickly because of its shape and therefore no fast raising floods occur in the basin. The city of Bangalore is situated just outside this basin.Important industries in the basin include the cotton textile industry in Coimbatore and Mysore, cement factories in Coimbatore and Trichinapally, and industries based on minerals and metals.The Salem steel plant and many engineering industries in Coimbatore and Trichinapally are also situated in this basin.

Cauvery river in south India has been at the centre of a long running water sharing dispute between two states Karnataka and Tamil Nadu. The Cauvery originates in Karnataka and flows through Tamil Nadu before joining the Bay of Bengal. But water levels in Cauvery have been falling due to insufficient rainfall and this has aggravated the farm crisis in both the states. Cauvery has been depleted by over 40% in the last few decades, and 87 percent of the basin's original tree cover has been lost. During the summer, Cauvery cannot reach the ocean, and 70 percent of the Cauvery basin's soil erodes. With the loss of ecosystem services increasing, it is past time to consider a comprehensive approach to river basin management.

4.3. Area delineation

Area delineation is carried out by superimposing ecoregion boundary that is cauvery river basin over existing administrative boundaries. 29 districts and more hundred LSGs comes under Cauvery river basin.

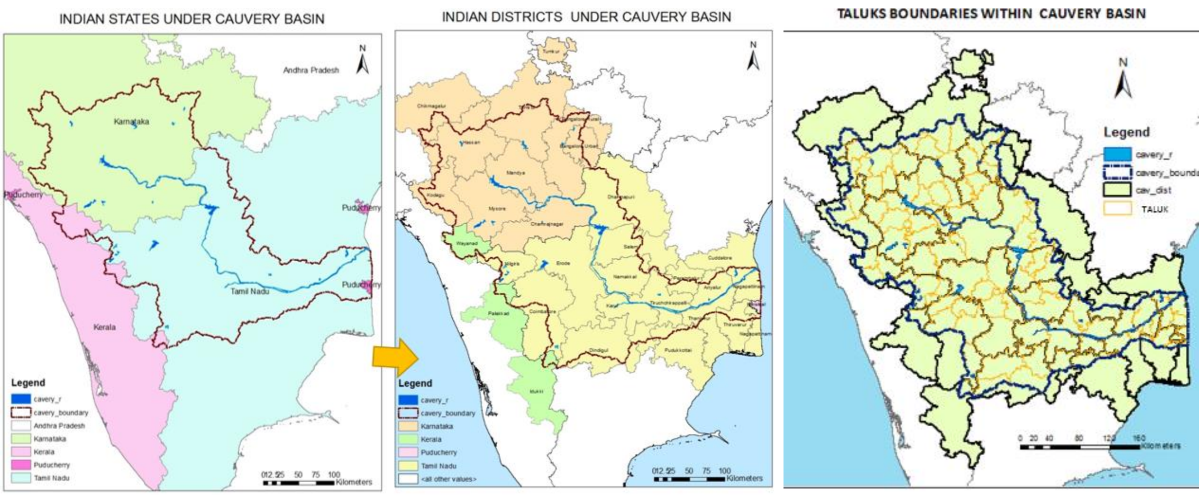


Figure 4.3: Area Delineation (Source: Author generated)

4.4. Ecosystem service indicators

"An ecosystem service indicator is information which communicates the characteristics and trends of ecosystem services, making it possible for policy-makers to understand the condition, trends and rate of change in ecosystem services" (Layke et al. 2012). Indicators are visual representations of system qualities, quantities, or states that are not directly visible to the observer. Ecological indicators aggregate data on phenomena in human-environmental systems in order to characterise environmental management options. They provide signals that relay complex messages in a simple and effective manner, thereby providing communication tools in environmental management (Dale and Beyeler 2001, Wiggering and Müller 2003, Turnhout et al. 2007, Niemeijer and de Groot 2008, ten Brink et al. 2011, Müller and Burkhard 2012).

Economy from Agriculture

A strong agrarian economy advances society by productivity improvement, employment, as well as income. Agriculture is the major driver of economic development in the majority of rural areas. Agricultural practises, on the other hand, have environmental consequences that affect a variety of ecosystem services, such as quality of water, pollination, carbon cycling, soil retainment, carbon capture, and nature conservation. The indicator evaluates the connection between agriculture and the environment.(fig 4.4). lower cauvery sub-basin region is the most dependent region on agriculture and also the rice bowl of Tamilnadu.

Economy from Fisheries

People are living organisms that rely on resources, food, and services for survival.Fish co nsumption is an important part of the South Indian diet.Fish populations generate ecosystem serv ices based on publicised ecological functions and human needs for fish. Districts like Thanjavur, Palakkad and Nagapattinam are high depended on inland fishing (fig 4.5).

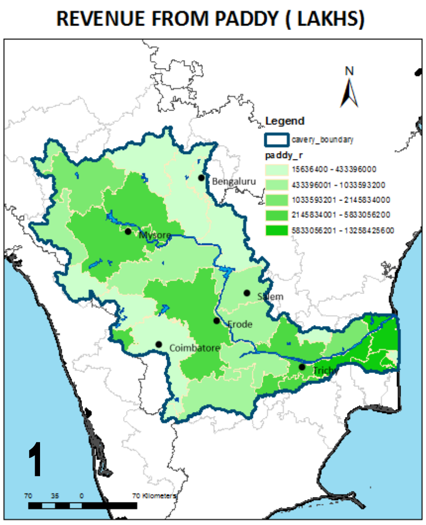


Figure 4.4: INDICATOR-1: Economy from agriculture

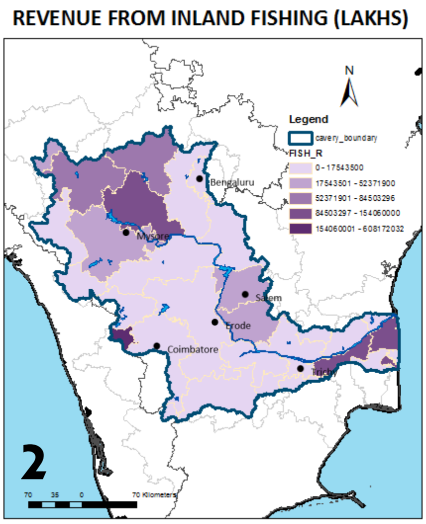


Figure 4.5: INDICATOR-2: Economy from Inland Fisheries

Economy from Tourism

Tourism is directly based on the cultural serices provided by the ecosystem.the recreational value offered by ecosystem is utilized for economy generation and tap in tourism. District like Nilgiri, Hassan, Bengaluru rural, Thanjavur Tiruchirappalli etc are highly dependent on tourism. Ecotourism projects are being developed in Western ghat region (fig 4.6)

REVENUE FROM TOURISM (LAKHS)

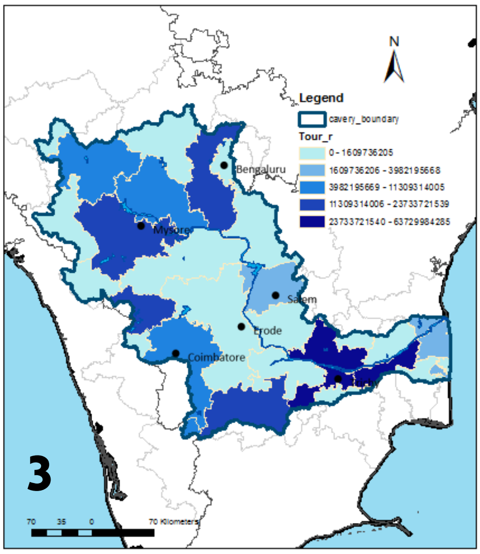


Figure 4.6: INDICATOR-3: Economy from tourism

ECONOMY DEPENDENCY ON WATER

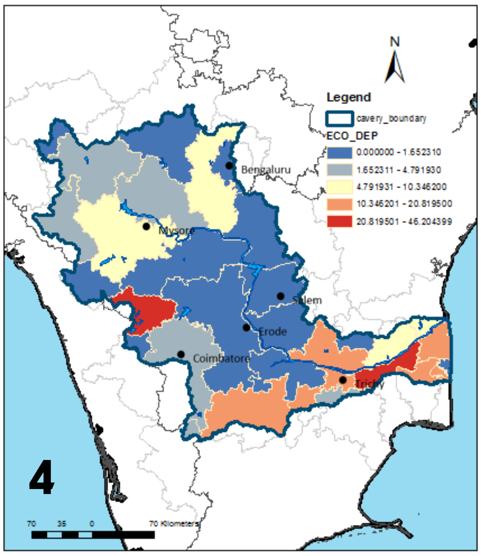


Figure 4.7: INDICATOR -4: Economic dependency on water

Economy dependency on water

Water is a major requirement for all types of economic activities from agriculture to industries. Here the economic dependency is calculated by considering agriculture, inland fisheries and tourism. Lower cauvery basin is highly dependent on water with major shares in districts like Thanjavur, Nilgiri, Nagapattinum, Thiruvavur and, Dindigul

Water yield per person per year

Water yield per person is calculated by dividing the total water yield in the basin by basin population . This show clear regional dispersion in terms of water availability. Lower cavery sub-basin has the least water yield. (fig 4.8)

Exposure to Disaster

Scientific evidence are there to prove that disasters impact on ecosystems similarly losses of ecosystem services only make the disasters worst. Districts in upper Cauvery basin are more prone to drought (fig4.9)

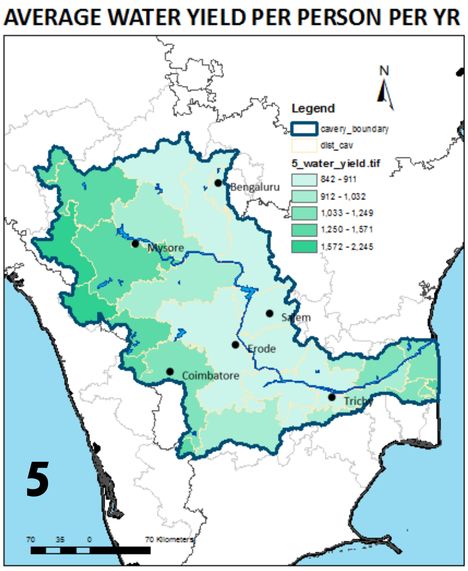


Figure 4.8: INDICATOR-5: Water yield per person

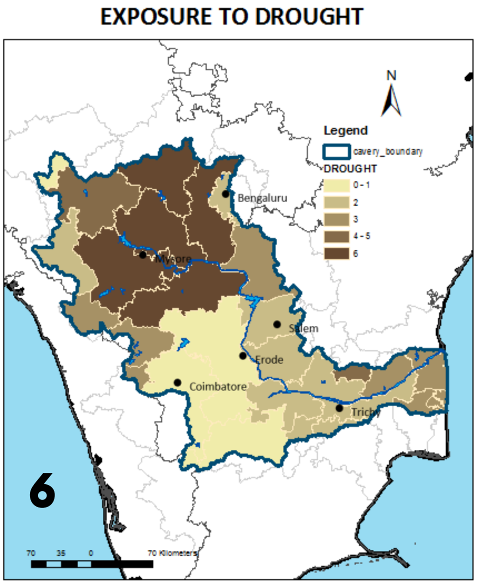


Figure 4.9 : INDICATOR-6: Exposure to disaster

Forest cover

Percentage of forest cover indicate the share of preserved ecosystem in each district. Western ghat region and the middle Cauvery basin has high forest cover compared to other regions. (fig 4.7)

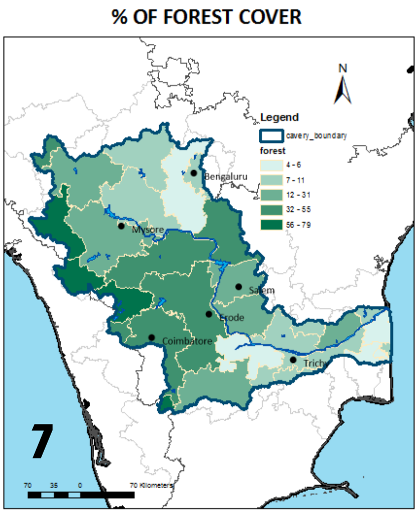


Figure 4.10: INDICATOR-7: Forest cover

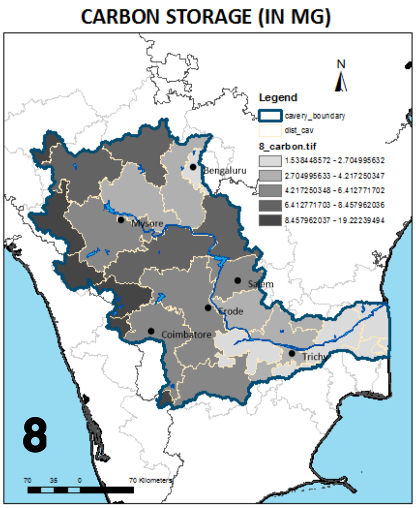


Figure 4.11: INDICATOR-8: carbon storage

Carbon storage

Ecosystems regulate the global climate by storing greenhouse gases. Carbon storage is among major ecosystem service and is given due consideration in wake of global warning. Regions with high forest cover has high carbon storage. (fig 4.11)

Biodiversity value

High biodiversity value indicate good and healthy ecosystem. This indicator helped in identifying areas for conservation and conversion into national and regional parks and sanctuaries (fig 4.12)

BIODIVERSITY VALUE

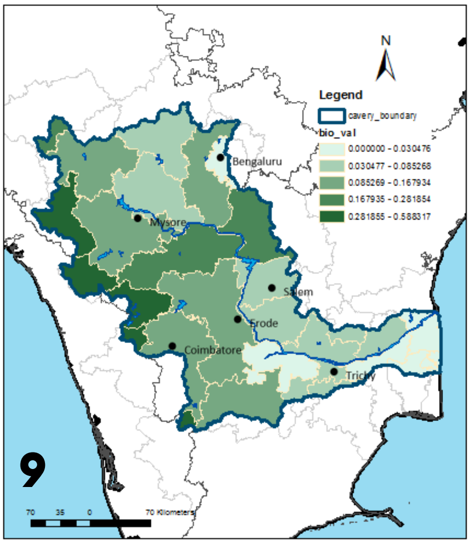


Figure 4.12: INDICATOR -9: Biodiversity value

RELATIVE TREAT TO BIODIVERSITY

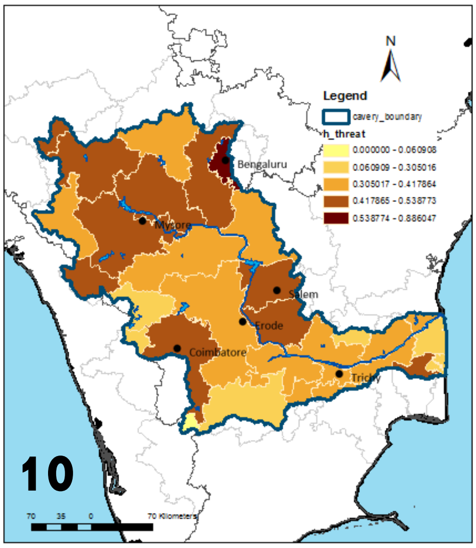


Figure 4.13: INDICATOR-10: Habitat threat

Habitat threat

Habitat threat is majorly due to LULC change followed by over-exploitation of resources. The indicator help in identify regions of risk. Districts like Bangalore urban, Mysuru Mandya are growing urban center with high habitat threat.(fig 4.13)

Human activity based contamination

Water quality depends on the usage of water. This indicator studies how human population and activities are effecting water bodies.

POPULATION IMPACT ON WATER QUALITY

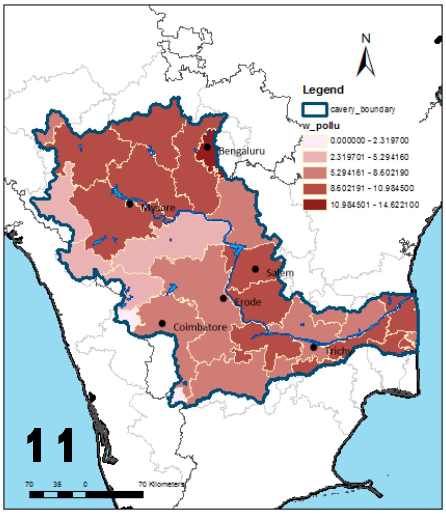


Figure 4.14: Human activity based water pollution

4.5. Clusterinzation and priority setting

Cluster analysis could be a powerful data-mining method for finding discrete cluster groups. Clusters are formed as a result of variable correlation. Clustering assists us in identifying sub-regions with similar strengths and weaknesses. This can then be applied to proposals and policy measures. Priority analysis, on the other hand, assists in identifying sub-regions that require immediate attention. This would aid in more efficiently phasing the proposals.

4.6. Clusterization

Similar sub-regions, a cluster analysis based on fuzzy overlay analysis. Based on it, the Cauvery basin is zoned into five clusters. The five clusters are listed below, along with their names and colour codes.

Table 4.4: District Clustering based ES value

ECOSYSTEM SERVICE VALUE		
CLASS-1	HIGH	Kodagu, Chikmagalur,Wayanad, Palakkad,Idukki
CLASS-2		Coimbatore,Erode,Nilgiri,Chamrajnagar,Dhamapuri, kariakkal
CLASS-3		Hassan,Salem,Namakkal,Karur,Perambalur,Ariyalur
CLASS-4		Tumkur,Bangaloreurban, Mysore, Dindigul,Pudukkottai,Cuddalore,Thiruvarur
CLASS-5	LOW	Mandya,Bangallore rural,Thirichirappalli,Thanjavur,Nagapattinum

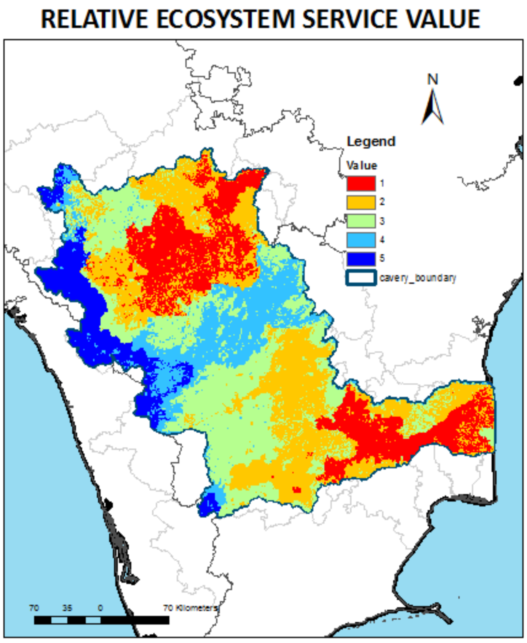


Figure 4.15: clustering based on fuzzy overlay

4.7. Priority setting

The district is prioritised based on the ecosystem service value calculated using fuzzy overlay. Districts such as Thanjavur, Mandya, and Hassan are at the top of the priority list.

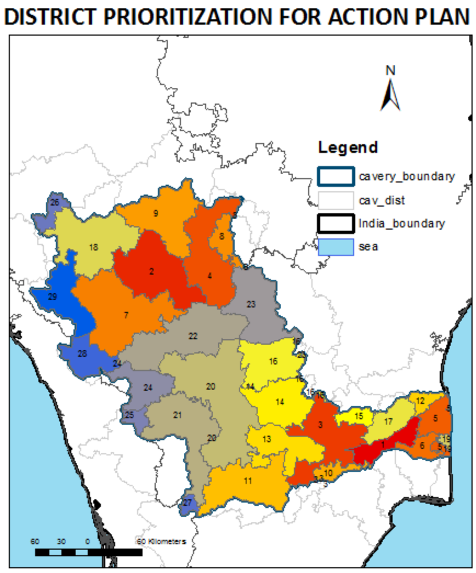


Figure 4.16: District wise Prioritization

4.8. Ecological Status of Surface water bodies

The ecological status of water bodies was determined using zonal statistics. This would aid in the prioritisation of waterbodies for conservation. It demonstrates that the waterbodies in the lower Cauvery subbasin have the lowest ecological value. Waterbodies in Thanjavur and Thirichirapalli are deteriorating. Smaller bodies of water are more vulnerable to urbanisation, deforestation, and climate change.

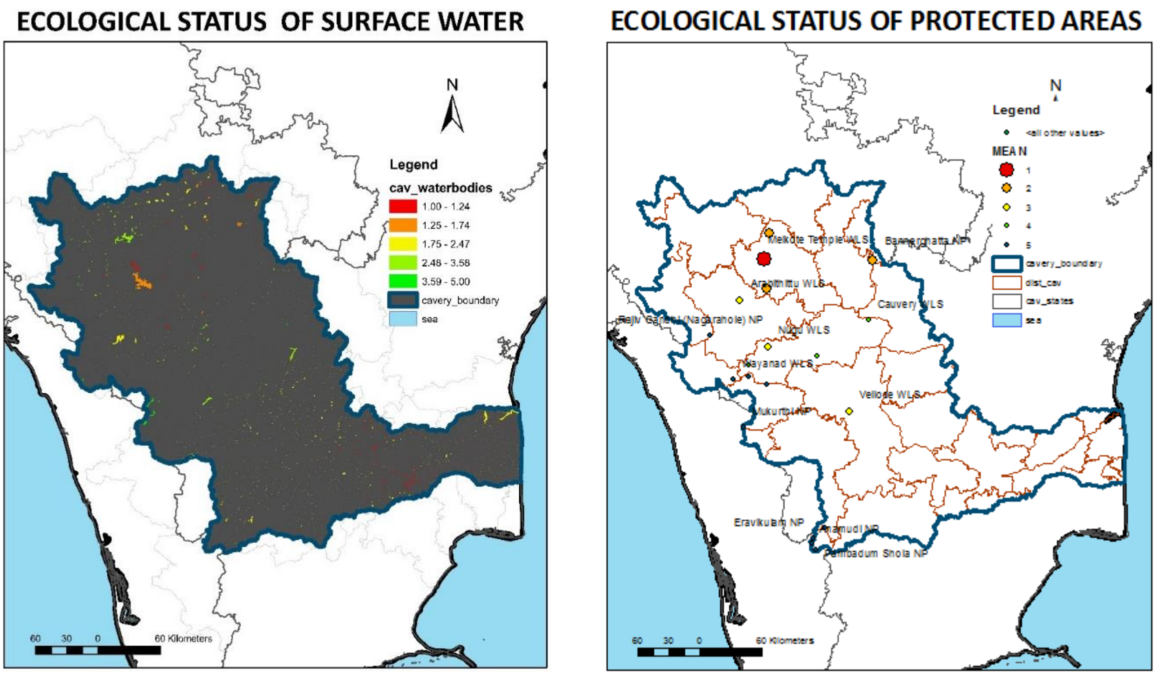


Figure 4.17: ecological status of surface water and protected areas

4.9. Ecological status of protected areas

There are over a dozen protected areas in the basin, including national parks and wildlife refuges. Each protected area's ecological status was assessed in order to prioritise it for conservation. The analysis was carried out using the ArcGIS spatial analysis toolset. Protected areas like Melkote temple WLS , Arabithittu WLS and Bennarghatta NP are to be prioritized for conservation. Melkote WLS is known for exotic foura and fauna which is under treat due to human activities and upcoming tourism in the region.

4.10. Conclusion

Climate-related hazards will be high in districts with high economic dependency, low levels of social welfare, and severe drought sensitivity. These districts are largely situated in the Cauvery lowlands (Cauvery delta region).In districts with poor social welfare, governance capacity to handle food and drought risk is also likely to be low. In these districts, it is necessary to identify governance requirements and build capacity. To protect socioeconomic well-being, management becomes even more critical. If a river covers a substantial section of a district's land, it's more probable that the district will have a high percentage of economic fraction, and the district's water resources will become increasingly important in maintaining industrial and agricultural operations. Physical water shortage is a major stressor for water stress, followed by excessive water demand. Hence, effective dam management and sustainable water usage within the area can relieve stress. Higher and quicker runoff is caused by deforestation and urbanization. Land-use changes, on the other hand, are predicted to have a little influence on freshwater supplies when compared to climate change, dam management, and water usage.

CHAPTER 5. LAND USE LAND COVER CHANGE ANALYSIS

This chapter details out the studies conducted under objective 3

To study the Impact of land use land cover changes on ecosystem service and identify key pressures on each ecosystem services

5.1. Introduction

Land Use / Land Cover (LULC) is the categorization or classification of human activities and natural elements on the landscape over time using established scientific and statistical methods of analysis of appropriate source materials. Land Use Land Cover (LULC) change detection assists policymakers in understanding the dynamics of environmental change in order to ensure sustainable development. To understand the relationships and interactions between human and natural phenomena, timely and accurate land cover maps are required. Regularly updated land cover maps are also required for assessing and monitoring ecological resources, as well as developing appropriate policies.

5.2. Data acquisition and processing

From 1985 to 2015, a three-decade LULC change analysis was performed. Data for the years 1985 to 2005 were obtained from https://daac.ornl.gov/. Landsat satellite imagery, IRS 1C–LISS III (1994–1995) and Resourcesat 1 (2004–2005) imagery, and multi-temporal Landsat 2005 MSS,TM, and ETM+ data were projected to WGS84 datum (UTM 44N projection) at the sub-pixel level were used in this study. This data set contains land use and land cover (LULC) classification products for India at 100-m resolution for the years 1985, 1995, and 2005. Landsat 4 and 5 Thematic Mapper (TM), Enhanced Thematic Mapper Plus (ETM+), and Multispectral (MSS) data, India Remote Sensing satellites (IRS) Resourcesat Linear Imaging Self-Scanning Sensor-1 or III (LISS-I, LISS-III) data, ground truth surveys, and visual interpretation were used to generate the data. The data were classified according to the International Geosphere-Biosphere Programme (IGBP) classification scheme. For LULC map of 2015, the satellite data was collected from Earth explorer and processed to match with the class and attributes of previous years data. Data curing and processing were carried out in ARCGIS .

5.3. Lulc change analysis

LULC change analysis was carried out in QGIS with the help of semi-automatic classification plugin. This plugin allows for the supervised classification of remote sensing images, providing tools for downloading, pre-processing and post processing. A tabulated LULC change metrics helped in identifying the course of change. Major changes were noticed in cropland and plantation. The Changing Structure of Indian Diets was one of the major reason. Increase in demand for other foods, including fruits, vegetables, fats, and livestock products. The consumption of fruits, on the other hand, increased by 553 percent, of vegetables by 167 percent, of milk and milk products by 105 percent, and of meat, eggs, and fish by 85 percent in rural areas over 1977 TO 1999.

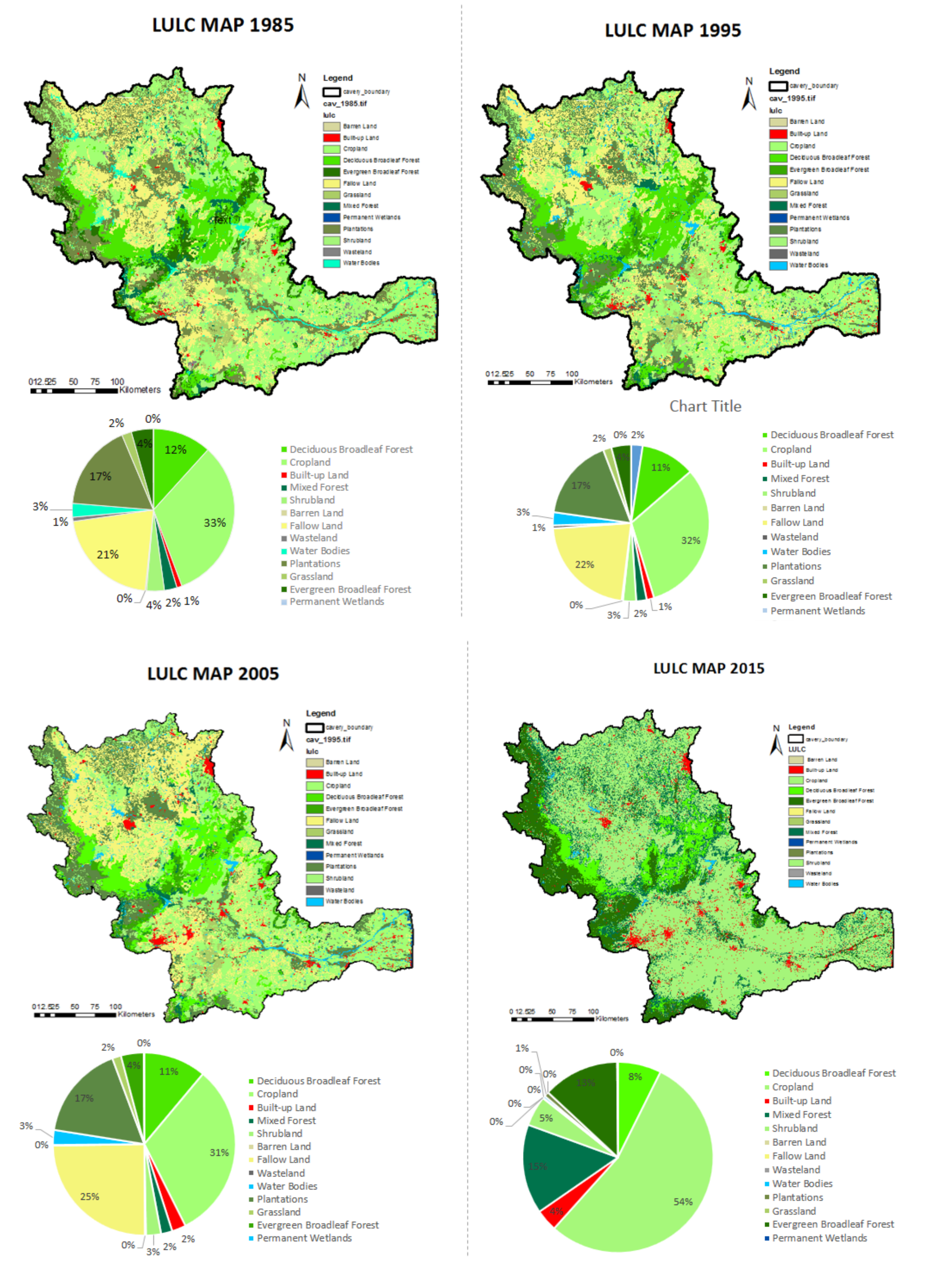


Figure 5.1: LULC map 1985, 1995, 2005 and 2015

Table 5.1: LULC change metrics 1985-1995

LULC % Change Metrics 1985-1995 in Cauvery Basin

1985 ↓ 1995→		1 Deciduous Broadleaf Forest	2 Cropland	3 Built-up Land	4 Mixed Forest	5 Shrubland	6 Barren Land	7 Fallow Land	8 Wasteland	9 Water Bodies	10 Plantations	14 Grassland	15 Evergreen Broadleaf Forest	17 Permanent Wetlands
1	Deciduous Broadleaf Forest	90.4	0.3	0.0	4.6	0.2	0.0	0.7	0.0	0.1	0.6	0.0	3.1	0.0
2	Cropland	0.1	69.7	0.7	0.0	0.0	0.0	21.9	0.1	0.4	6.9	0.1	0.0	0.0
3	Built-up Land	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	Mixed Forest	26.1	0.4	0.0	64.2	0.0	0.0	0.9	0.0	0.2	0.0	0.0	8.1	0.0
5	Shrubland	0.5	5.0	0.1	0.0	77.6	0.0	5.5	1.9	0.1	8.9	0.3	0.1	0.0
6	Barren Land	0.0	1.3	0.7	0.0	0.1	94.9	2.0	0.0	0.0	0.9	0.0	0.1	0.0
7	Fallow Land	0.1	30.5	1.0	0.0	0.0	0.0	61.9	0.0	0.1	5.8	0.4	0.0	0.0
8	Wasteland	0.1	9.6	0.3	0.1	0.0	0.0	19.8	65.0	0.0	4.5	0.5	0.0	0.0
9	Water Bodies	0.2	2.3	0.0	0.0	0.0	0.0	2.5	0.0	93.4	1.5	0.0	0.0	0.0
10	Plantations	0.0	15.3	0.6	0.0	0.0	0.0	9.4	0.0	0.3	74.2	0.0	0.0	0.0
14	Grassland	0.0	11.9	0.4	0.0	0.0	0.0	1.3	0.0	0.1	1.0	85.1	0.2	0.0
15	Evergreen Broadleaf Forest	4.1	0.3	0.0	0.5	0.0	0.0	1.1	0.0	0.0	11.7	0.0	82.1	0.0
17	Permanent Wetlands	0.0	59.4	0.0	0.0	0.0	0.0	10.0	0.0	0.1	13.3	0.0	0.0	17.1
% Change		21.7	106.1	3.8	-30.4	-21.9	-5.0	37.1	-32.9	-5.2	29.4	-13.6	-6.3	-82.8

Table 5.2: LULC change metrics 1995-2005

LULC % Change Metrics 1995-2005 in Cauvery Basin

1995 ↓ 2005→		1 Deciduous Broadleaf Forest	2 Cropland	3 Built-up Land	4 Mixed Forest	5 Shrubland	6 Barren Land	7 Fallow Land	8 Wasteland	9 Water Bodies	10 Plantations	14 Grassland	15 Evergreen Broadleaf Forest	17 Permanent Wetlands
1	Deciduous Broadleaf Forest	87.7	0.5	0.0	3.9	0.9	0.0	0.6	0.0	0.2	2.9	0.0	3.1	0.0
2	Cropland	0.2	61.1	1.4	0.1	0.8	0.0	26.2	0.0	0.6	8.6	0.8	0.1	0.1
3	Built-up Land	0.0	2.0	96.4	0.0	0.0	0.0	0.4	0.0	0.3	0.7	0.0	0.0	0.0
4	Mixed Forest	21.1	0.8	0.1	64.7	1.1	0.0	1.3	0.0	0.2	8.8	0.1	1.9	0.0
5	Shrubland	0.8	14.8	0.5	0.6	57.9	0.1	18.8	0.0	0.2	5.5	0.0	0.8	0.0
6	Barren Land	1.0	6.5	0.3	0.0	15.3	60.5	13.6	0.0	0.0	2.6	0.1	0.2	0.0
7	Fallow Land	0.2	29.7	0.9	0.1	1.5	0.0	56.0	0.1	0.4	10.6	0.3	0.0	0.0
8	Wasteland	0.1	27.3	1.1	0.1	21.1	0.0	33.1	13.5	0.3	2.7	0.9	0.0	0.0
9	Water Bodies	0.8	9.7	0.5	0.3	0.3	0.0	4.6	0.0	79.3	3.8	0.1	0.2	0.4
10	Plantations	0.1	20.7	1.5	0.0	0.7	0.0	14.7	0.0	0.6	61.3	0.1	0.1	0.2
14	Grassland	0.0	21.9	1.0	0.0	0.2	0.0	7.8	0.0	0.1	1.4	67.0	0.5	0.0
15	Evergreen Broadleaf Forest	8.3	0.4	0.0	1.5	0.4	0.0	0.3	0.0	0.1	3.7	0.2	84.9	0.0
17	Permanent Wetlands	0.0	33.4	0.0	0.0	0.0	0.0	1.4	0.0	1.3	2.0	0.0	0.0	61.9
% change		20.3	128.8	3.6	-28.7	0.2	-39.3	78.8	-86.3	-16.3	14.7	-30.3	-8.2	-37.3

Table 5.3: LULC change metrics 2005-2015

LULC % Change Metrics 2005-2015 in Cauvery Basin

2005 ↓ 2015→		1 Deciduous Broadleaf Forest	2 Cropland	3 Built-up Land	4 Mixed Forest	5 Shrubland	6 Barren Land	7 Fallow Land	8 Wasteland	9 Water Bodies	10 Plantations	14 Grassland	15 Evergreen Broadleaf Forest	17 Permanent Wetlands
1	Deciduous Broadleaf Forest	48.2	5.1	0.0	27.7	2.5	0.0	0.0	0.0	0.0	0.5	0.0	15.9	0.0
2	Cropland	0.2	77.9	3.3	11.0	3.4	0.0	0.0	0.0	0.0	0.4	0.0	3.8	0.0
3	Built-up Land	0.1	27.0	60.6	6.3	3.0	0.2	0.0	0.0	0.0	0.5	0.0	2.2	0.1
4	Mixed Forest	16.8	17.8	0.2	36.3	9.6	0.0	0.1	0.0	0.1	3.6	0.0	15.4	0.0
5	Shrubland	7.6	27.8	0.8	30.8	20.9	0.0	0.0	0.0	0.0	2.5	0.0	9.5	0.0
6	Barren Land	3.9	22.6	2.2	21.8	37.6	0.0	0.0	0.0	0.0	6.4	0.0	5.5	0.0
7	Fallow Land	0.3	72.9	2.8	11.7	9.6	0.0	0.0	0.0	0.0	0.5	0.0	2.2	0.1
8	Wasteland	0.0	85.9	1.3	0.4	10.7	0.3	0.0	0.0	0.0	1.3	0.0	0.1	0.0
9	Water Bodies	1.3	50.4	1.6	12.5	5.1	1.2	0.0	0.0	12.9	6.6	0.0	4.8	3.6
10	Plantations	1.5	38.6	2.2	17.3	1.5	0.0	0.0	0.0	0.0	0.5	0.0	38.4	0.0
14	Grassland	0.2	80.9	2.2	3.8	1.5	0.0	0.0	0.1	0.0	4.5	0.0	6.9	0.1
15	Evergreen Broadleaf Forest	25.8	2.6	0.0	17.6	0.2	0.0	0.0	0.1	0.0	0.7	0.0	52.9	0.0
17	Permanent Wetlands	0.3	58.7	8.4	2.3	1.4	5.4	0.0	0.0	3.2	18.6	0.0	0.2	1.6
% change		6.3	468.2	14.4	99.3	7.1	-92.8	-99.9	-99.8	-83.7	-53.4	-100	57.5	-94.4

Changing Exports and the Production Basket of High Value Agriculture was another reason .Indian exports during the 1990s grew at an annual rate of 10.1 percent, compared to 7.4 percent during the 1980s.Unlike the "Green Revolution" of the late 1960s, the 1990s was a decade of "golden revolution," with a major breakthrough in the production of fruits, and "blue revolution," with the dramatic growth of inland fisheries..

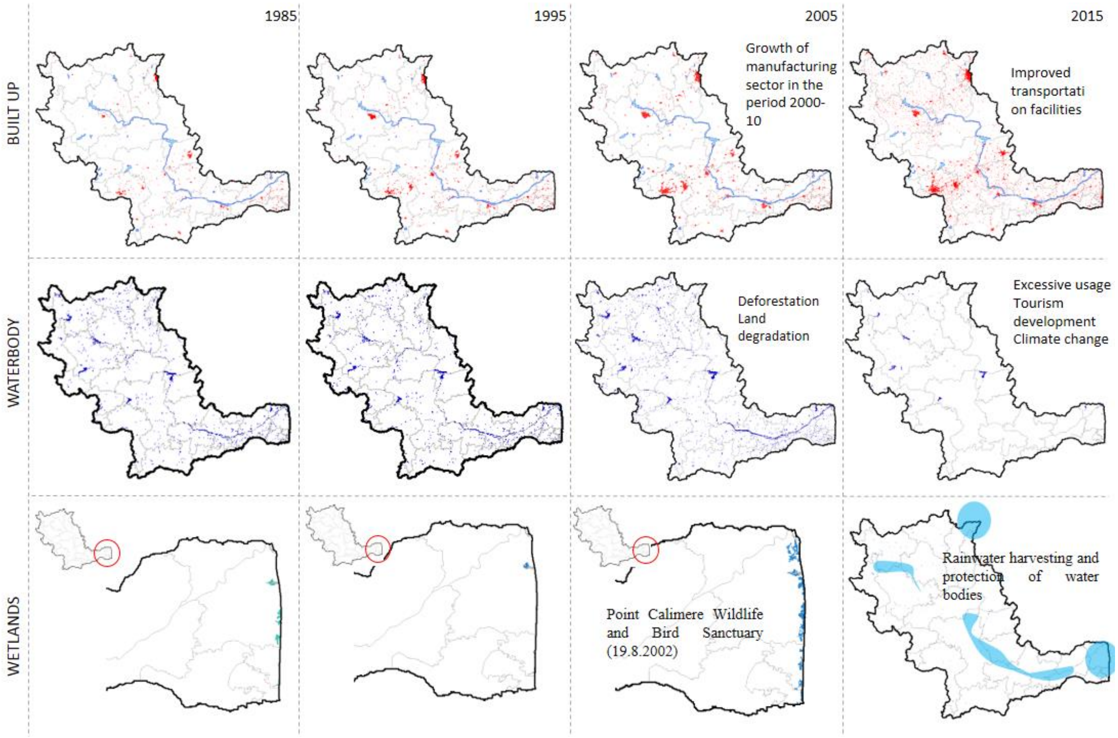


Figure 5.2: decadal change in built up, waterbodies and wetlands

Adding to this was the High value agriculture and the rise of supermarkets. Vertical integration between the farm, the firm, and the fork mutually beneficial to small scale producers, wholesale and processing firms, retailers and consumers. Fragmentation of cropland with 81 percent of farm holdings are of less than five acres (two hectares). Innovative institutions such as cooperatives, producers' associations, and contract farming reduced transactions costs by vertically integrating production, marketing, and processing

5.4. Conclusion

At a holistic level Intensification of cultivation was greatly visible. Basin is dominated by cropland and plantations. Accelerated developmental activities implemented resulted in a drastic and complicated LULC transition. Rapid growth of Tire-I and Tire-II cities, primarily because of enhanced transportation facilities and waterbodies, leading to habitat fragmentation. During 1980-2000, massive afforestation program has been undertaken in the form of the social forestry program in the basin.

CHAPTER 6. PROPOSALS AND IMPLEMENTATION FRAMEWORK

6.1. Introduction

The chapter look into strategic frameworks, incorporating basin plan to conventional spatial planning hierarchy, institutional framework for cauvery and device proposals for better management of river basin.

6.2. Vision and Goal

The vision for the Cauvery river basin's strategic planning is a holy and healthy river with a flourishing basin. Healthy soil, revitalization of waterbodies, planned development, sustainable agriculture, and collaboration are the priorities set for reclaiming ecosystems.

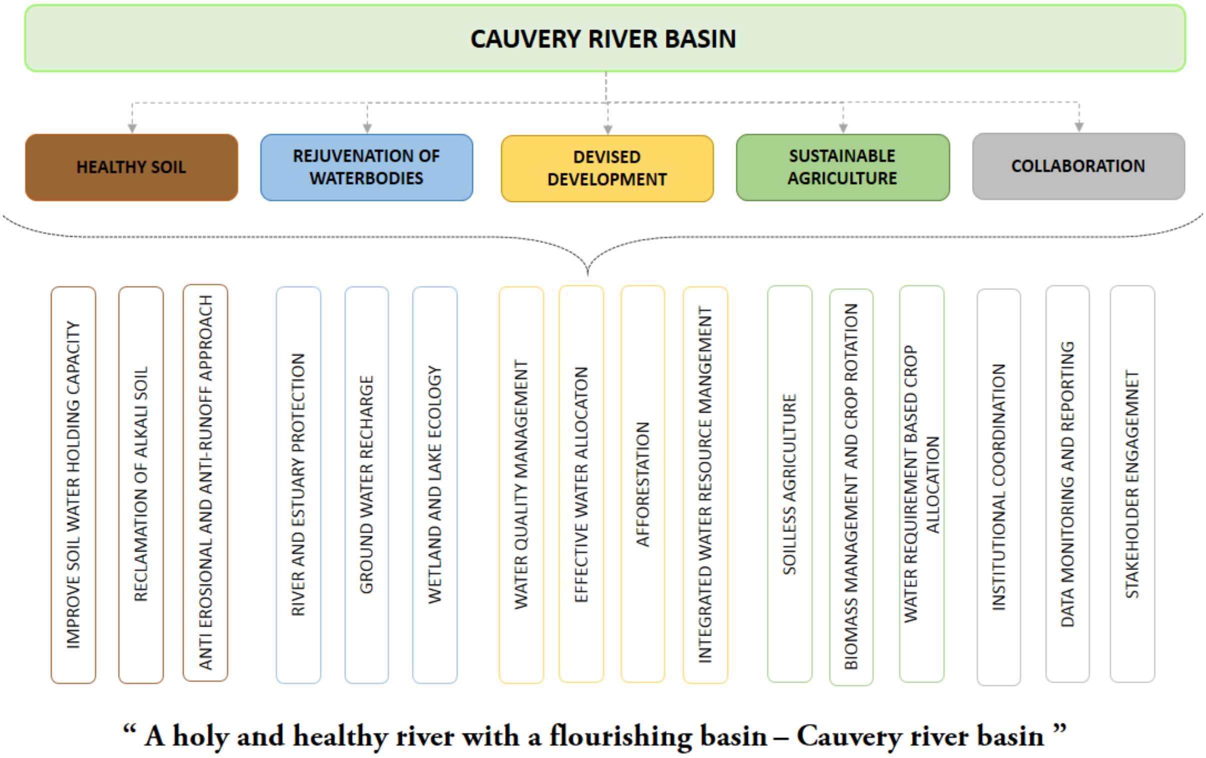


Figure 6.1: Vision for Cauvery basin

6.3. Implementation framework

In India, the existing conventional planning framework excludes river basin/watershed planning. As a result, watershed-level studies are not being converted into spatial plans. This thesis proposes a new framework for spatial planning that includes basin plans as a type of regional plan that will be enhanced during the development of master plans and local area plans.

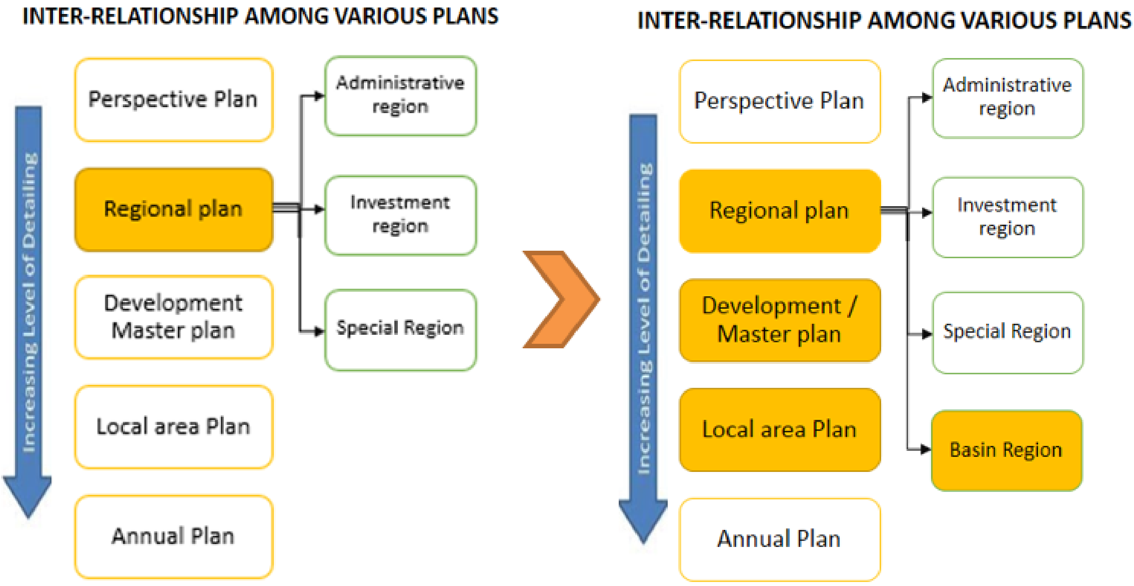


Figure 6.2 : Incorporating basin plans to conventional planning framework

The basin plan can be developed using a top-down approach in which each stakeholder collaborates effectively. The study would be carried out at the ecoregional level using indicators. Following that, the site's requirements and vulnerabilities will be discussed. After stakeholder analysis, the need, priority areas, and conservation zones will be finalised.

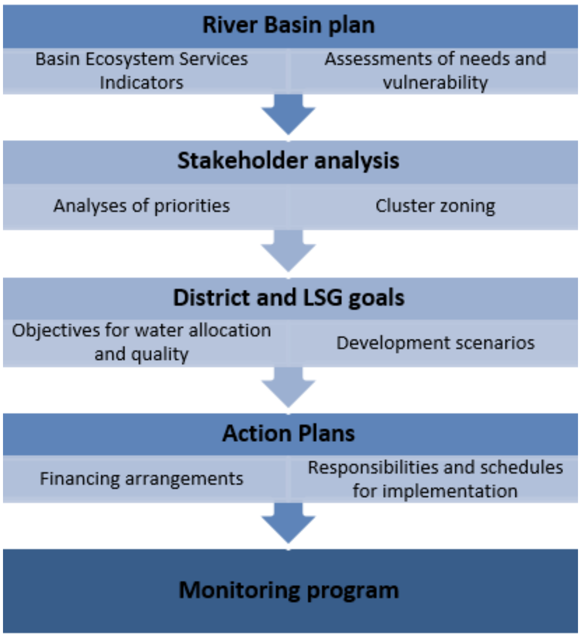


Figure 6.3: Flowchart for implementing basin plan

District goals and action plans must be in sync with the basin plan. Water allocation objectives and development scenarios will be constantly checked in a hierarchical manner. The river basin authority will also be in charge of implementing action plans, as well as financial arrangements and monitoring programmes.

6.4. Governance framework for Cauvery basin

The Central Government notified the Cauvery Water Management Scheme on 1st June, 2018, inter alia, constituting the 'Cauvery Water Management Authority' (CWMA) and the 'Cauvery Water Regulation Committee' under the Inter-State River Water Disputes Act, 1956. (CWRC). Since then, the cauvery basin has been managed by these two separate authorities. Their job responsibilities include carrying out the decision of the Cauvery Water Disputes Tribunal, effective monitoring of the hydro-meteorological situation in the Cauvery Basin, and annual and seasonal water account reports. Currently There is no single, or overall, institution directly responsible for management the Basin

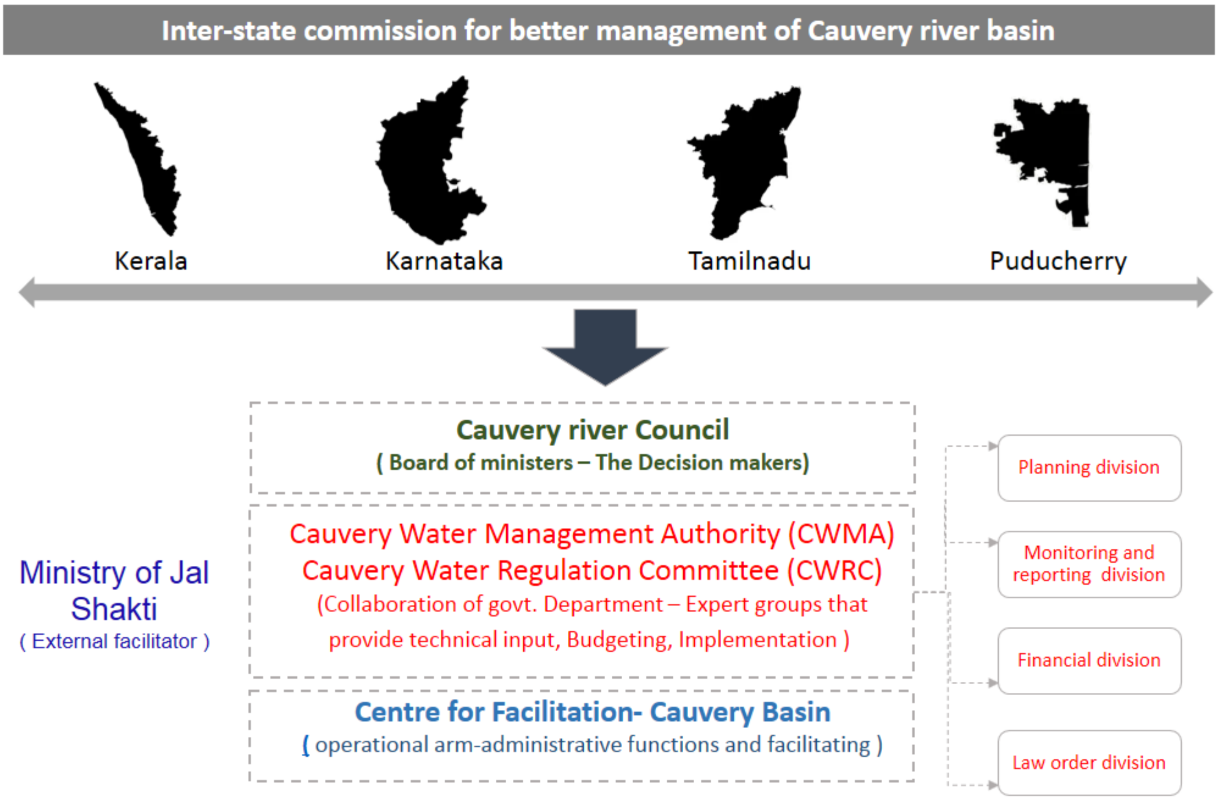


Figure 6.4: Cauvery basin- governance mechanism

The thesis also focus on proposing a suitable governance mechanism for Cauvery river basin and the same is attached above. (Fig 6.4). An interstate commission for basin management is proposed with 3 major institutional sub-division.

Cauvery River Council is made up of ministers from all three states of Kerala, Karnataka, and Tamil Nadu, as well as a representative from the union territory of Puducherry. The river basin strategic plans will be approved by the council. The river basin commission's functional wing is comprised of the Cauvery Water Management Authority and the Cauvery Water Regulation Committee. Their job portfolio is further expanded with departments such as planning, monitoring and reporting, financial, and law and order. The Cauvery Basin Facilitation Center is the commission's administrative arm, connecting the basin commission to all stakeholders in the basin.

6.5. Proposals

Innovative and natural based solutions are focused for river management in this thesis. Some of the tools of proposals are the listed below.

Table 6.1: Tools of proposal: Healthy Soil

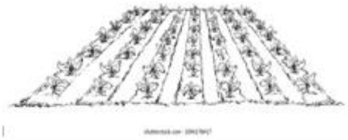
THEME	TOOLS	REPRESENTATION
HEALTHY SOIL	Improve soil water holding capacity	
	Reclamation of alkali soil	
	Phytoremediation as green infrastructure	
	Anti erosional and anti-runoff approach	

Table 6.2:: Tools of proposal: Rejuvenation of waterbodies

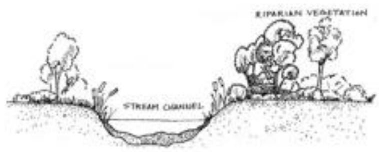
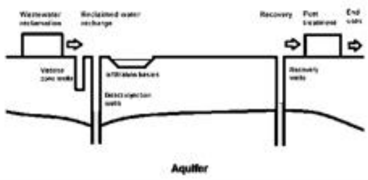
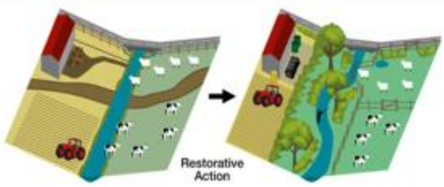
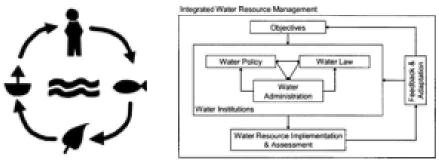
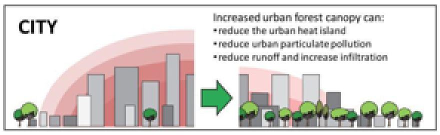
THEME	TOOLS	REPRESENTATION
REJUVENATION OF WATERBODIES	River and estuary protection	
	Ground water recharge	
	Wetland and lake ecology	

Table 6.3 : Tools of proposals: Devised development

THEME	TOOLS	REPRESENTATION
DEVISED DEVELOPMENT	Water quality management	
	Integrated water resource management	
	Afforestation	

Process of implementation these tool are also work out at eco-regional level with interstate water commission as the governing body. The following sessions details out the implementation process for proposals formulated.

P1-Mainstreaming sustainable agriculture (saps)

The basin commission can use this proposal to focus on leveraging central government schemes and policies to mainstream sustainable agriculture. The implementation procedure is discussed further below. The commission will serve as an agricultural sustainability and support system, identifying sites for pilot projects and coordinating with Krishi vigyan kendras for implementation through capacity building and technical assistance. The commission will also focus on implementing the agricultural contingency plan prepared for all districts by ICAR.

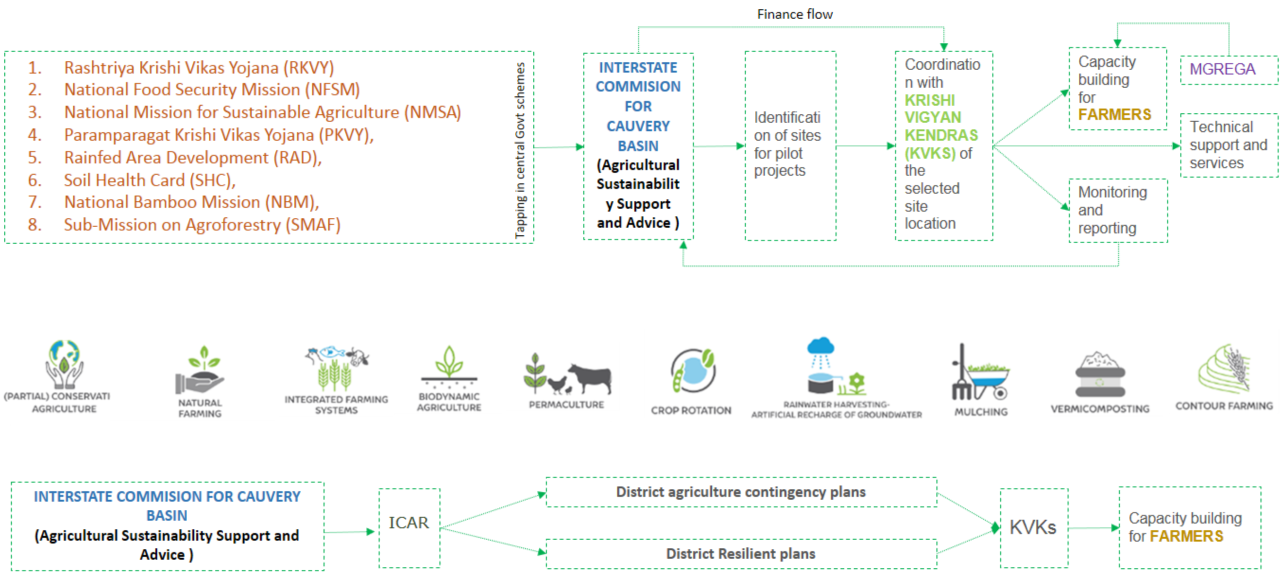


Figure 6.5: Mainstreaming Sustainable agriculture- implementation process

P2- Waterbody rejuvenation - priority areas for action

This project prioritizes areas for revitalization. The water bodies are prioritized based on the ecological value calculated from the analysis part; a case study of Thanjavur water bodies is used to explain the process. Thanjavur's water bodies are being studied to better understand the ground problems and possible solutions.

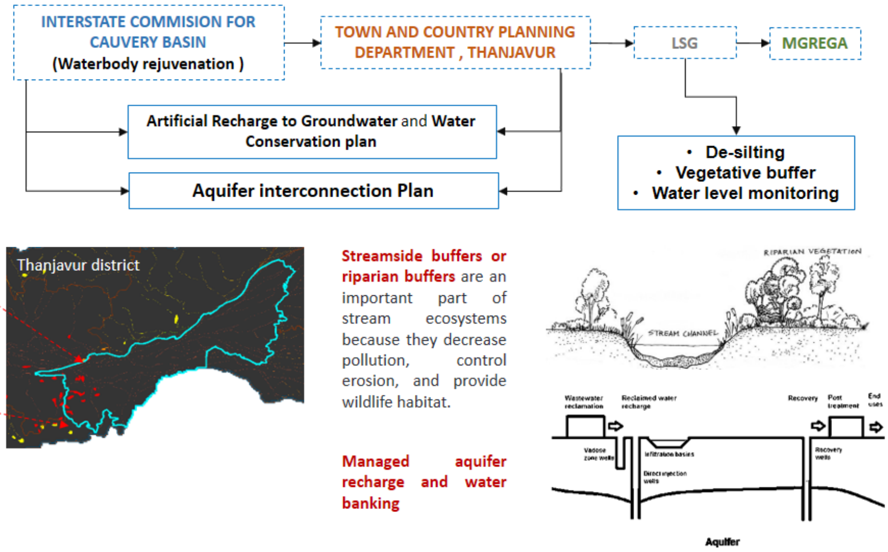


Figure 6.6: Water body rejuvenation- implementation process

P3- Devised development – safeguarding protected areas

This project focuses on identifying protected areas that are losing ecosystem services and attempting to restore them through strategic measures. The implementation process is explained below using melkote WLS as an example.

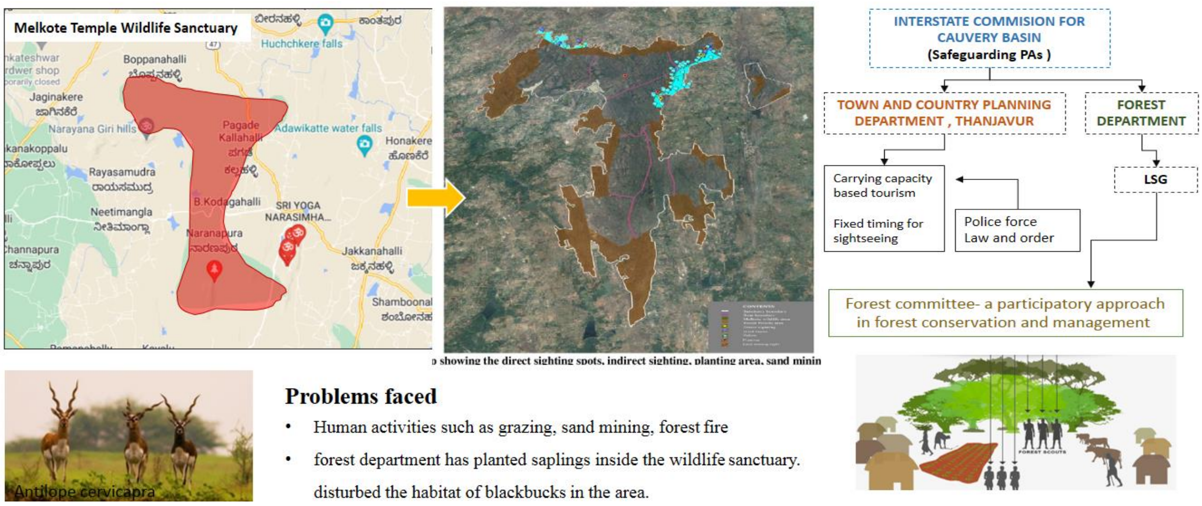


Figure 6.7: Devised development - Implementation process

CHAPTER 7. CONCLUSION

River basins have been regarded as among the most important ecosystems, playing an essential part in providing unique ecosystems for a diverse range of plant and animal life. Furthermore, these ecosystems provide a variety of goods and services that contribute to public welfare and poverty reduction. River basins, on the other hand, suffer permanent losses as a result of intense use as well as pressures. As a result, effective and sustainable river basin management has emerged as a critical issue around the world.

The neglect of natural capital planning approaches is a major flaw in India's spatial planning structure. This flaw is eliminated by using a river basin planning approach.Data availability at the ecoregional level would make spatial planning easier. Every ten years, a consensus on major basin problems and needs must be considered.Basin plans only work when stakeholders coordinate properly; thus, general agreement among downstream and upstream actors should be encouraged.Water resources should be highlighted as a critical structuring concept for spatial planning at all levels. The river basin management approach necessitates not just working to improve water quality but also integrating the region's environmental, socioeconomic, and land use factors.

The main thrust of the present study was to look into holistic river basin planning over administrative boundary bounded spatial planning. The research's principal goal of integrating ecological approach in river basin boundary was accomplished. As a result, priority regions for ecological restoration were determined. These findings will aid future research on ecological approach in Spatial planning, particularly in terms of strengthening the region's resilience and capacity to adapt to climate change. Case specific and broad planning recommendations based on the developed model can be formulated as an extended arm of the study.

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CERTIFICATE OF COMPLETION

This is to certify that this thesis project titled "**Strategic spatial planning based on Ecosystem Services (ES) - A case of Cauvery basin region**" was carried out by Smt. **Arunima KT**, a student of **M.Plan (Urban Planning),** at the **National Institute of Technology, Calicut**. The research for this project was undertaken under the guidance of the afore-mentioned institute and completed during the period of **27th December 2022** to **30th July 2022**.

This project was shortlisted under the *Sponsored Thesis Project Competition on "RE-IMAGINING URBAN RIVERS" (Season- 2)* hosted by the National Institute of Urban Affairs (NIUA) and the National Mission for Clean Ganga (NMCG).

This report has been submitted by the student as a final deliverable under the competition. All parts of this research can used by any of the undersigning parties.

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