Strategic Spatial Planning Based on Ecosystem Services (ES): A Case of Cauvery Basin

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Abstract

India's decentralized spatial planning includes administrative borders, which often do not align with ecological boundaries and thus fail to effectively serve the ecological purposes. These borders fragment ownership, governance, and management, thereby posing significant challenges for protection of biodiversity and ecosystems. Despite being intended for administrative convenience, ecosystems or eco-regions cannot be independently managed. This paper proposes a spatial planning strategy for the watershed regions, emphasizing Ecosystem Services (ES) as the central focus. ES are the benefits that humans receive from ecosystems which include provisioning (food, water, energy, raw materials), regulating (air quality, water regulation, climate stability), cultural (aesthetics, recreation, spiritual), and support services. The research employs an exploratory methodology that comprises literature reviews and case studies, which help to identify and map ecosystem service indicators. This involves developing a list of ecological indicators with reference values and mapping selected services using the InVEST model and GIS spatial analysis. The identified indicators will be reviewed and finalized for the watershed region. The study advocates a watershed-based planning approach that will address urbanization and climate change challenges while protecting the natural ecosystems. It concludes with a proposal for integrating ecological and administrative boundaries, thus promoting an ecologically conscious spatial planning approach.

Keywords: Watershed Planning, Ecological Planning, River Basin Plan

Introduction

When it comes to deciding where to live, people are drawn towards water. Throughout human history, rivers have been the lifeblood of any civilization. Humans have chosen to live near rivers for domestic needs, agricultural water supply, and navigation. This trend is continuing till today. However, due to modern socio-economic development, rivers face increasing threats from various sources that include unsustainable withdrawals, pollution, and loss of biodiversity. Anthropogenic activities are to blame for much of the current unfavourable state of our rivers. The ever-increasing pressures placed on river water by these demands in recent times necessitate better river basin management strategies if the basin has to continue to adequately meet these demands.

River restoration and its success rates are dependent on how well it has been integrated into the built and natural environments through urban spatial planning. For successful adaptation, spatial planning is required at ecological boundaries such as watersheds. A watershed is an area where water from multiple sources drains into a single river or ridge. Watersheds are recognized as critical spatial units for planning because they are a link between strategic and site-specific plans. A river basin plan is strategic planning that collaborates for achieving water resource goals, which includes assessment and management of data for a defined geographical watershed.

Over the last two decades, designed watershed strategies have grown dramatically all around the globe. 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. Even though a lot of research and assessment have been conducted at the watershed or basin level, the adaptation of the same to spatial planning is lacking in India. One of the primary reasons for this is India's conventional planning hierarchy which adheres to administrative boundaries. The fact is that in India, administrative boundaries rarely align along the eco-regions, and often divide eco-regions into pieces that threaten its holistic conservation. Indians must concentrate on basin-level planning to restore the deteriorating rivers and the ecological value of basins. Key steps towards this should be redressing the urban planning framework to include basin-level plans which 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" (Angela Heymans, 2019). The current model of urban development profoundly alters the natural environment, thus reducing biodiversity and ultimately threatening the well-being of humans. The socio-ecological approach to urban planning adopts a framework of balancing social 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 Rice and Smith, 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, ecosystem assessment-based, and ecosystem valuation-based planning. Ecosystem indicators are simple measures that provide clear understanding of the ecosystem conditions. Hence, this paper studies the ecosystem approach to understand its potential in spatial planning.

The Ecosystem Approach to Spatial Planning is not a new concept, but till today, it has rarely been at the centre of spatial planning. Since the Millennium Ecosystem Assessment (MEA) publication 2005, 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, results in sustainable development and the reconciliation of anthropogenic sources by addressing the drivers that lead to significant Land Use Land Cover (LULC) changes. Ecosystem-based approaches and modelling help in analyzing and forecasting the 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.

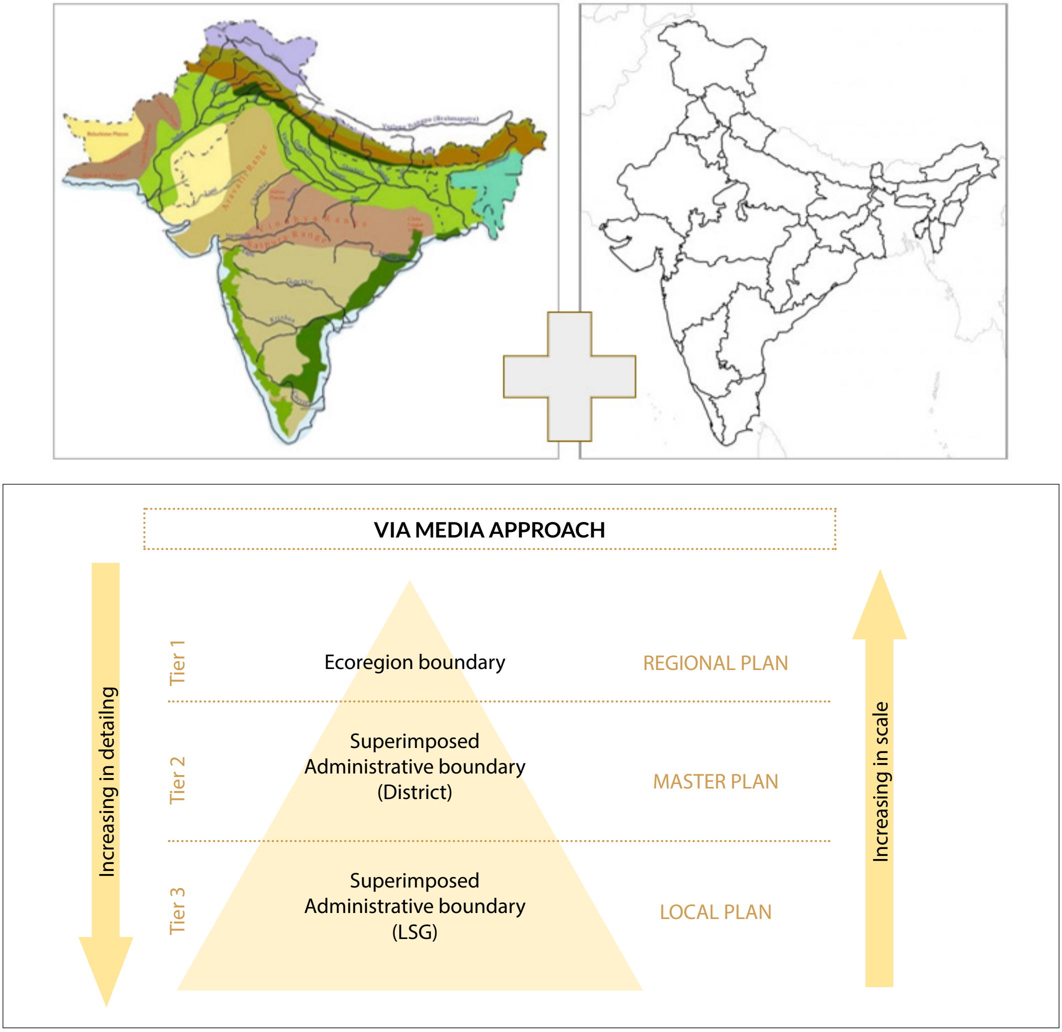
This paper attempts to use an ecosystem approach for strategic river basin planning. Using the Cauvery River Basin as an example, the study looks beyond the administrative boundaries to consider the value of ecosystems, landscapes, and biodiversity. This paper would contribute to the holistic visualization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

Conceptualization of the Project

This project is envisioned as a via-media solution[1] that integrates the administrative and ecological borders. Existing decentralised administrative boundary-based planning aids in governance and collecting socio-economic data. However, they fail to solve the environmental challenges that have been caused by development, thus making the region more vulnerable to disaster. On the other hand, ecological boundary-based planning aids in catastrophe resilience, biodiversity protection, and fair resource sharing. The suggested three-tiered research framework will aid in comprehending the eco-region as a whole and then superimposing it on the administrative borders to produce macro and micro recommendations.

[1] *A compromise or middle path between two extreme positions. It seeks a balanced approach that incorporates elements from both sides, aiming to find a practical and acceptable resolution that avoids the disadvantages of the extremes*

Figure 1: Via-Media Solutions for Integrating Administrative and Ecological Boundaries



Source: Prepared by Author

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 the master plans at Tier-2 and Tier-3 levels. Tier-2 is defined by superimposing the 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 that has been carried out for academic purposes to prioritise the eco-regions in spatial planning.

Objectives and Methodology

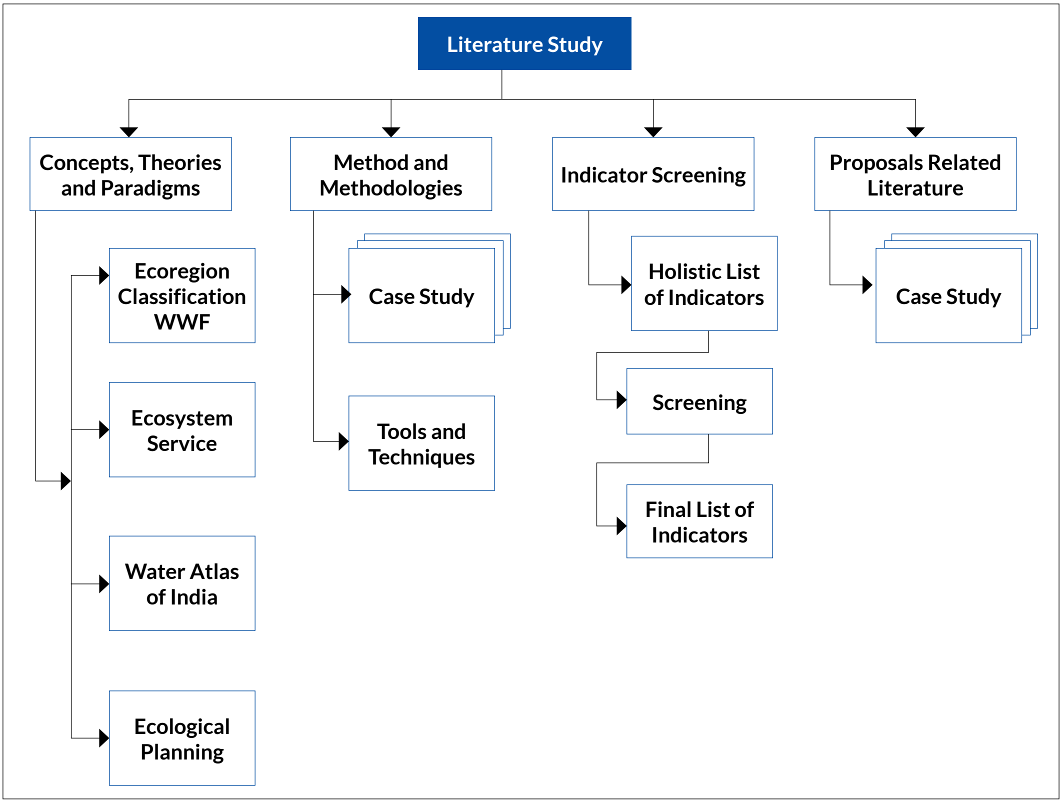
The study aimed to propose a strategic planning process to resuscitate the Cauvery River basin, based on the ecosystem approach as a case study for river management policy framework and planning. The following four objectives were formulated to achieve the aim of the study. Each objective was then sub-divided into tasks and sub-tasks:

- To explore the ecological boundaries and ecosystem approach in spatial planning through literature review.
- To create an indicator system to analyze the ecosystem services of the Cauvery River basin and identify the priority regions and clusters.
- To develop a governance framework that encourages coherent river management research, policy, and planning.

Objective-1: Literature Review

Objective-1 was to explore the concept and the possible ways of incorporating the ecological approach at the basin level. The tasks included remote research and case studies. The research was divided into four sections namely concepts, methodology, indicator screening, and proposals.

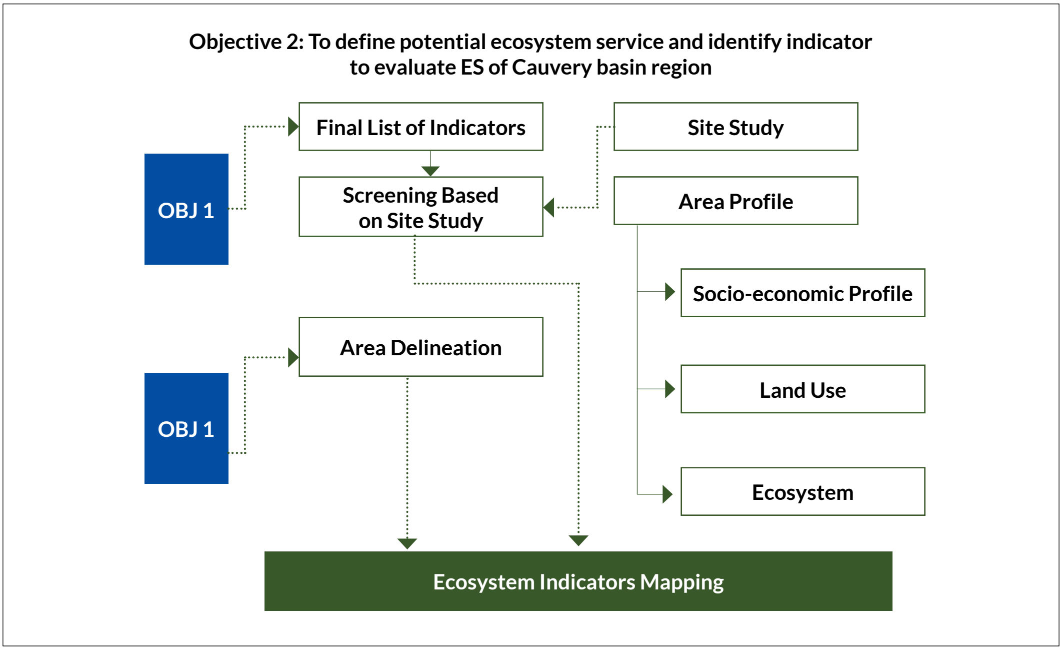
Figure 2: Detailed Methodology of Objective-1



Objective-2: Ecosystem Service Assessment

Objective-2 focused on the study area and delineation along with indicator mapping for assessment of the ecosystem services. The selected Indicators were analysed based on computer-based tools like INVEST, WaterWorld, and ArcGIS. Further, Fuzzy membership and Fuzzy overlay tools were used to create clusters and identify the priority regions. All indicators were converted to raster files and reclassified on a scale of 1-5, where 1 represented the most important area, and 5 represented the least important area. The whole Cauvery basin was divided into five zones, numbered one to five, in order of priority.

Figure 3: Objective-2 - Methodology



Objective-3: Governance Mechanism and Implementation Framework

Objective-3 was focused on redressing the conventional spatial planning in India and proposing a governance framework for better management of the Cauvery basin. The tasks included understanding the lacunas of the existing planning hierarchy and remote research on successful governance frameworks and institutional structures.

Cauvery River Basin

The River Cauvery begins in the Coorg district of Karnataka from 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.

Figure 4: View of Cauvery River from Rock Fort of Trichy

Source: Flanet, P. (n.d.). La rivière Cauvery à sec. Flickr. Retrieved from https://www.flickr.com/photos/bridelice/9193038978/ on June 1, 2023.

Table 1: State-Wise Distribution of Drainage Area of Cauvery basin

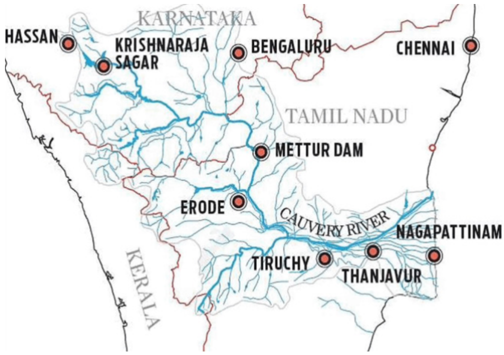
State	Drainage area (sq. km.)
Tamil Nadu	48,730
Karnataka	36,240
Kerala	2,930
Total	87,900

Source: Central Water Commission, 2012

The river basin has approximately 19% forest cover, and the 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 the left bank and the right bank tributaries. Hemavathi, Shimsha, and Arkavathi are the major left bank tributaries. The largest tributary, Hemavathi, flows through Hassan city. Bengaluru is located on the banks of the Arkavathi River. Kabini, Bhavani, Noyyal, and Amaravati are the major right bank tributaries. The Kabani tributaries are well-known for their dam while the Bhavani tributary is popular as it flows through the Silent Valley National Park. Srirangapatnam, Mysuru, Mandya, Mettur, Erode, Karur, Trichy, Tanjore, Kumbakonam, and Puhar are among the major cities on the banks of River Cauvery.

The basin in Karnataka receives rainfall mainly from the South-West monsoon and partially from the North-East monsoon. The basin in Tamil Nadu receives good flows from the North-East monsoon. Its upper catchment areas receive rainfall during summer by the South-West monsoon and the lower catchment areas during the winter season from the retreating North-East monsoon. Therefore, it is almost a perennial river with comparatively fewer fluctuations in flow and is very useful for irrigation and generation of hydroelectric power. River Cauvery is one of the best-regulated rivers and 90 to 95 percent of its irrigation and power production potential has already been harnessed. A major part of the basin is covered with agricultural land which accounts to 66.21 percent of the total area.

Figure 5: Cauvery River Basin and Prominent Cities



Source: InsightsIAS, 2022, Retrieved form https://www.insightsonindia.com/wp-content/uploads/2022/03/river.png as on June 1, 2023.

Cauvery River in South India has been at the centre of a long running water sharing dispute between the states of Karnataka and Tamil Nadu. River Cauvery originates in Karnataka and flows through Tamil Nadu before joining the Bay of Bengal. But water levels in the river have been falling due to insufficient rainfall and this has aggravated the farm crisis in both the states. The water in River 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 (Kaibara, 2021). During summer, the river cannot reach the ocean, and 70 percent of the Cauvery basin's soil gets eroded. With the increasing loss of ecosystem services, it is time to consider a comprehensive approach to river basin management.

Result and Discussions

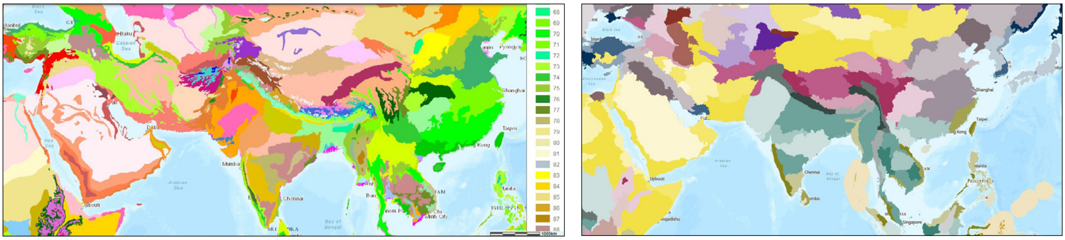
This section explains in depth the study's major conclusions and their implications. As per the three main goals of the study, sub-sections have been separated accordingly. The knowledge obtained from peer-reviewed publications and case studies has been covered in the literature review, which is then followed by the conclusions that have been drawn from the analysis of the ecosystem services, and finally, suggestions have been provided for the improved governance of the Cauvery Basin.

Literature Review

Biodiversity and Eco-region

According to the UN-CBD (United Nations-Convention on Biological Diversity, 2006), "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". Biodiversity is not evenly distributed across the Earth but follows complex patterns that are determined by climate, geology, and the planet's evolutionary history. These patterns are referred as "eco-regions." The World Wide Fund (WWF) defines an *eco-region* as a "large unit of land or water containing a geographically distinct assemblage of species, natural communities, and environmental conditions" (David M. Olson, 2001). The WWF divides eco-regions into terrestrial, freshwater, and marine categories. The terrestrial scheme divides the Earth's land surface into eight biogeographic realms and 867 smaller eco-regions. Each eco-region is subdivided into 14 significant habitats.

Figure 6: Terrestrial and Freshwater Eco-regions of the World



Source: WWF, Retrieved from https://www.worldwildlife.org/ on June 1, 2023.

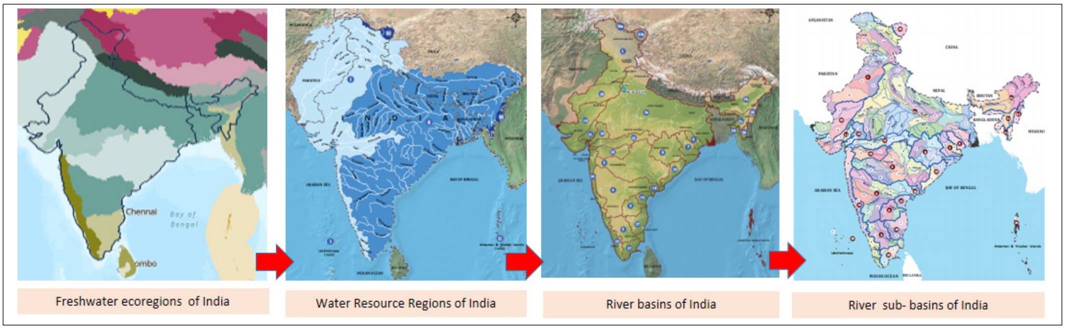
Freshwater systems include rivers, streams, lakes, and wetlands. Freshwater eco-regions differ from terrestrial ecosystems, which define the biotic communities on land, and marine ecosystems, which include biotic communities in the oceans. Freshwater eco-regions are based on the distributions and compositions of freshwater fish species and incorporate major ecological and evolutionary patterns. They harbor a significant fraction of biodiversity and suffer additional classes of threats. Historically, freshwater biodiversity has been overlooked, and very few studies have been done in the freshwater region.

At the basin scale, eco-regions help in introducing information about biodiversity into water-resources or integrated-basin management activities. River-basin studies can also be used as stratification units to ensure adequate representation of the distinct biotas. A counterintuitive planning unit can be introduced to incorporate biogeographic patterns, and in the process of setting continental priorities regional mandates may choose to compare the biodiversity values across eco-regions.

Watershed Regions in India

Water Resources Information System (WRIS), India delineates and codifies the catchment areas into smaller Hydrologic units, i.e. sub-watersheds. User agencies have always felt the need for a national level framework of watersheds, which has been served by the methodology that was 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 Catchment areas, 500 Sub-catchment areas, and 3237 Watershed regions.

Figure 7: Watershed Delineation in India



Sources: India-WRIS (n.d.). Retrieved from https://indiawris.gov.in/wris/ on June 1, 2023.

Journal Reviews and Case Studies

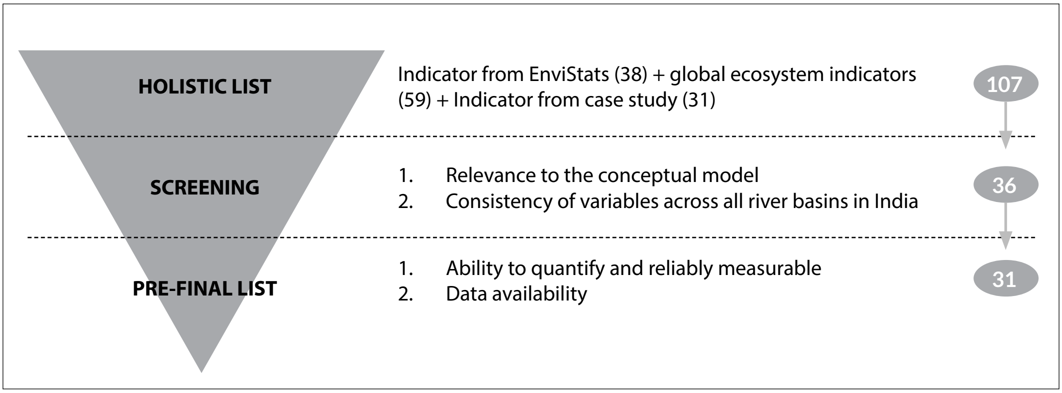
S No.	Title	Inference
1	Integrating ecosystem services into sustainable landscape management: A collaborative approach (Terêncio et al., 2021)	The document focuses on analyzing ecosystem services with the Driver-Pressure-State-Impact-Response (DPSIR) framework. It used Multi-Criteria Decision Analysis (MCDA) and GIS. Spatial problems are characterized by many viable alternatives as well as multiple, conflicting, and wholly incompatible evaluation criteria. A GIS-MCDA can be used to solve complex problems by transforming and combining the geospatial information and value judgments. A GIS-MCDA is a more robust criteria-based technique than a standard binary or 'coincidence' analysis. As a result, it allows additional values of multi-criteria at the same time. This enables more in-depth decision making.
2	Assessment of ecosystem services and sensitivity analysis based on the ANN model and spatial data: A case study in Miaodao Archipelago (Yin et al., 2022)	The study took advantage of the InVEST model and the powerful spatial analysis function of the Geographic Information System (GIS) to map five ecosystem services and Artificial Neural Network (ANN) for ES 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 standardized the data and performed sensitivity analysis. As a whole, the ES 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 WaterWorld were selected among more than 10 tools by considering the input and output data format and GIS expertise.
3	River Basin Planning Principles, Procedures, and Approaches for Strategic Basin Planning at ADB (Pegram, 2020)	The report provides an overview of the characteristics of strategic basin planning and the ten golden rules of basins. The report also helped in understanding the basin planning process and the structure of strategic river basin plans.

S No.	Title	Inference
4	Case study 1: Mekong River Basin Management	The case was studied thoroughly to understand how the Mekong River Commission managed resources and the MRC supports a basin-wide planning process that is based on the principles of Integrated Water Resources Management (IWRM). Rising in the South-eastern Qinghai province, China, River Mekong flows through the eastern part of the Tibet Autonomous Region and Yunnan province, after which it forms a part of the international border between Myanmar (Burma) and Laos, as well as between Laos and Thailand. The trans-boundary planning and management of the basin and governance framework were studied. The MRC Strategic Plan 2021–2025 was also studied in detail to understand the vision, proposals, and how they aligned with the sustainability goals.
5	Case study 2: Yamuna Biodiversity Park	The Yamuna Biodiversity Park is a pilot project for the development of biodiversity parks across the city. The objective of the project was to bring back the original ecological state 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 it needs a large area, and it should stick to the native species (Ecological Restoration principle). A typical Biodiversity Park should have two basic components: A Nature Conservation Zone and a Visitor Zone. The criteria for judging if an ecosystem has been restored are to check if it is generating Ecological Services and Goods.

Indicator Selection and Screening

The selection of Indicators was a critical process because the results of the study would be dependent on it. Thus, many national and international reports and studies were consulted before the final selection of Indicators. A thorough set of variables was tallied using case study indicators, global ecosystem indicators, and the EnviStats.

Figure 8: Indicator Screening



These indicators were chosen based on the concept model that emphasised the availability of water 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 those indicators that could not be quantified or reliably measured and were not available. The pre-final list had 31 indicators which could be used for similar studies in different river basins of India (Figure 7). The final list of indicators was again screened based on the context of the Cauvery basin and Tier-1 indicators were formulated. The first screening was done based on the data type where primary data were omitted. Detailed study with primary data could be done at the local self-government level.

The second screening was done to understand which data fit the eco-region scale. Data within the scale of district and eco-region levels were 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 had 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 selected from the pre-final list of 31 indicators.

The indicators were not classified according to the type of ecosystem service, but rather they provided a holistic view of the entire basin. The selection of indicators is based on the author's research interests and thus can be modified for use on other sites. It is a pilot study with very few indicators. Following are the selected indicators (Table 2):

Table 2: Table of Indicators for Cauvery Basin

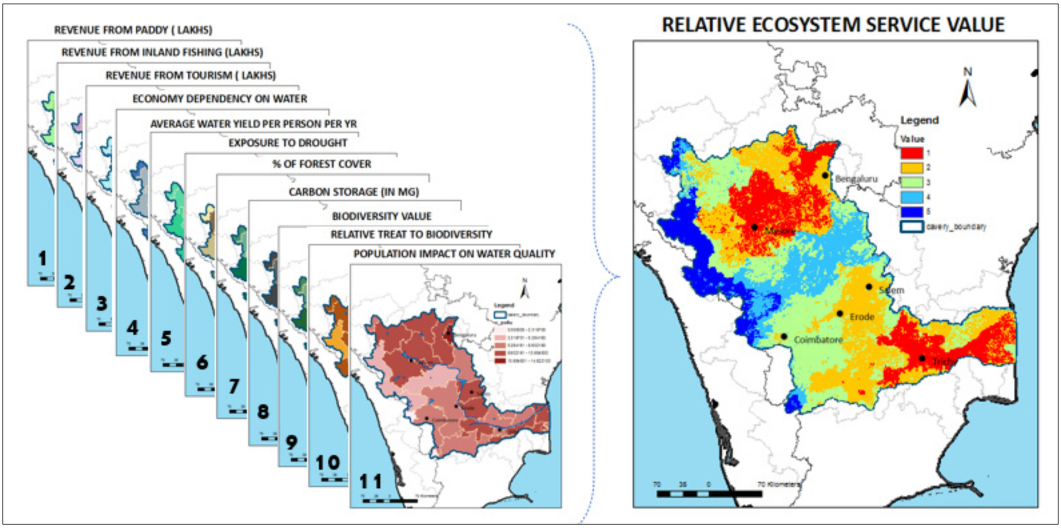
S. No.	Indicator
1	Economy from paddy
2	Economy from fisheries
3	Economy from tourism
4	Economic dependency on water
5	Water yield per person
6	Exposure to drought
7	Forest cover
8	Carbon storage
9	Biodiversity value
10	Habitat threat
11	Human activity-based contamination

Ecosystem Service Assessment

The use of computer-based evaluation methods for mapping ecosystem services was effective. The analysis was entirely GIS-based and performed in ArcGIS and QGIS (Quantum Geographic Information System). The study used the most trustworthy open source, computer-based assessment method, which evaluated ES using global data that was gathered from the satellite images. Each indicator was mapped out and evaluated both alone and collectively. The study demonstrated that regions having significant economic dependency, poor levels of social welfare, and acute drought sensitivity will be most affected by climate-related hazards. Most of these districts are in the Cauvery plains (Cauvery delta region).

The risk of food shortages and drought is more likely to occur in areas that have low ecosystem service levels. It is essential to pinpoint governance needs in these districts and increase capacity. Management is crucial to safeguard the socio-economic well-being. A district is more likely to have a high water related economic fraction if a significant portion of its territory is covered by a river. Its water resources will also play a bigger role in supporting the industrial and agricultural operations. Water stress is mostly caused by physical water shortage, which is followed by excessive water demand. Therefore, water stress can be reduced through efficient dam management and the responsible use of water in the region. Urbanization and deforestation lead to more and faster run offs. In contrast to climate change, dam management, and water use, land-use changes are anticipated to have little impact on freshwater supply.

Figure 9: Ecosystem Service Assessment to Identify Priority Clusters



Source: Prepared by Author

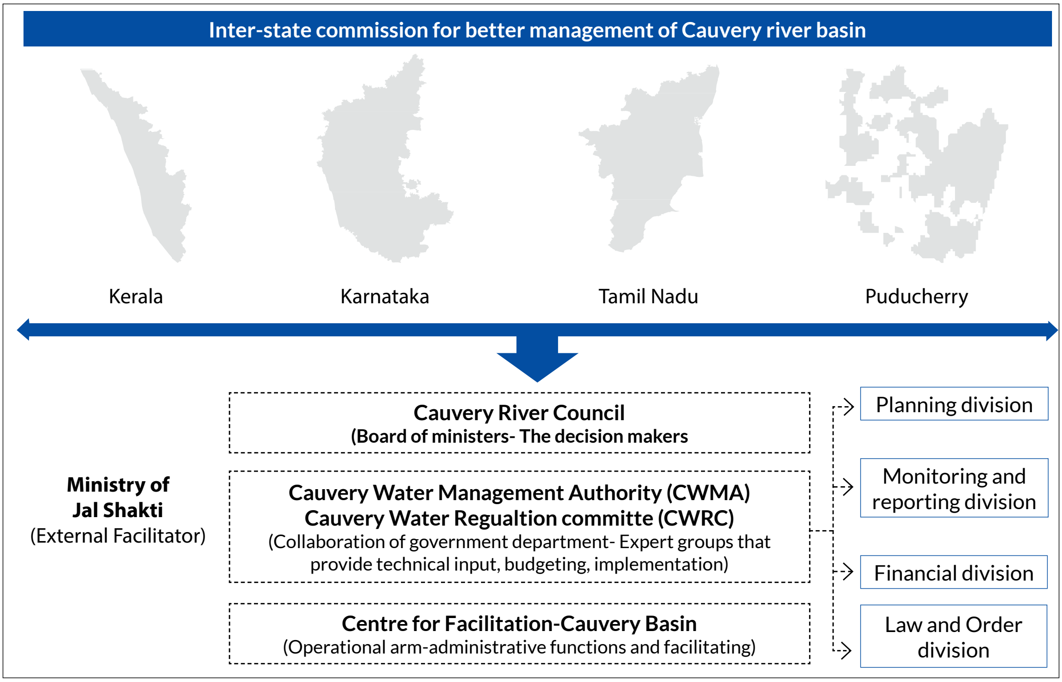
Overlay analysis is a data-mining method for finding discrete cluster groups. The study identified five clusters ranked from low to high relative ecosystem service values. According to the study, rapid ecological restoration is required in areas like Mandya, Bangalore Rural, Thirichirappalli, Thanjavur, and Nagapattinam (High priority cluster) to revive ES. After the green revolution, Cauvery basin's delta region saw a surge in development. The extensive agricultural activities in this region and high demand for water supply led to the deterioration of shallow aquifers in the delta region. River Cauvery being a seasonal river was also drying up due to low rainfall. Thirty percent of the basin region has moderate ES value and is scattered over the districts of Tumkur, Bangalore Urban, Mysore, Dindigul, Pudukkottai, Cuddalore, and Thiruvarur (Yellow coloured region). Almost 8 percent of the territory around the Western Ghats has high ES values, while 50 percent of the region has acceptable ES values. High ES districts include Kodagu, Chikmagalur, Wayanad, Palakkad, and Idukki (Figure 9).

Governance Mechanism and Implementation Framework

The Central Government notified the Cauvery Water Management Scheme on 01 June 2018, inter alia, constituting the 'Cauvery Water Management Authority' (CWMA) and the 'Cauvery Water Regulation Committee' (CWRC) under the Inter-State River Water Disputes Act, 1956. Since then, the Cauvery basin has been managed by these two separate authorities. Their job responsibilities include carrying out the decisions 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 that is directly responsible for management of the Basin.

The study focuses on proposing a suitable governance mechanism for the Cauvery River basin and the same is attached. (Figure 10). An interstate commission for basin management is proposed with three major institutional sub-divisions. 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's strategic plans are approved by the council. The river basin commission's functional wing comprises 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 Centre is the commission's administrative arm which connects the commission to all stakeholders in the basin.

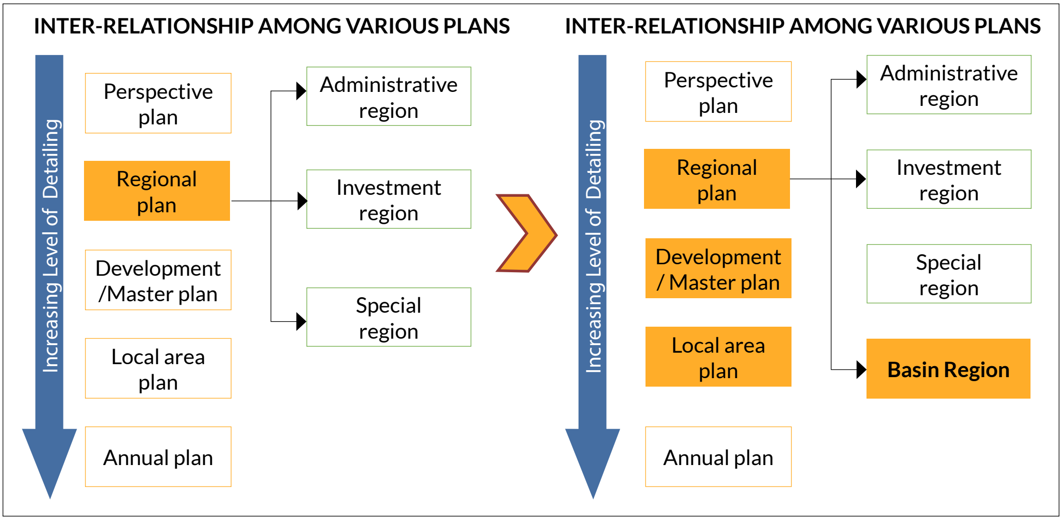
Figure 10: Cauvery Basin Governance Mechanism



Source: Prepared by Author

In India, the existing conventional planning framework excludes river basin/watershed planning. As a result, watershed-level/basin studies are not 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 the master plans and the local area plans.

Figure 11: Incorporating Basin Plans to Conventional Planning Framework



Conclusion

River basins have been regarded among the most important ecosystems since they play an essential part in providing unique ecosystems for a diverse range of plant and animal lives. Furthermore, these ecosystems provide a variety of goods and services that contribute to public welfare and in poverty reduction. On the other hand, river basins suffer permanent losses because of intense use as well as anthropogenic pressures. As a result, effective and sustainable river basin management has emerged as a critical issue globally. The neglect of natural capital planning is a major flaw in India's spatial planning structure. The study proposed strategic basin planning as a way forward to eliminate this flaw.

Data availability at the eco-regional level makes basin planning easier, hence every ten years, accumulation of the 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 critical structuring concepts for spatial planning at all levels. The river basin management approach necessitates not just working to improve the water quality but also integrating the region's environmental, socio-economic, and land use factors.

The main thrust of the present study was to investigate holistic river basin planning over administrative boundaries that bound spatial planning. The principal goal of the research to integrate ecological approach in river basin boundaries 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 changes. Case specific and broad planning recommendations based on the developed model were formulated as an extended arm of the study.

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Conflict of Interest

Authors have no conflict of interest to declare.

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