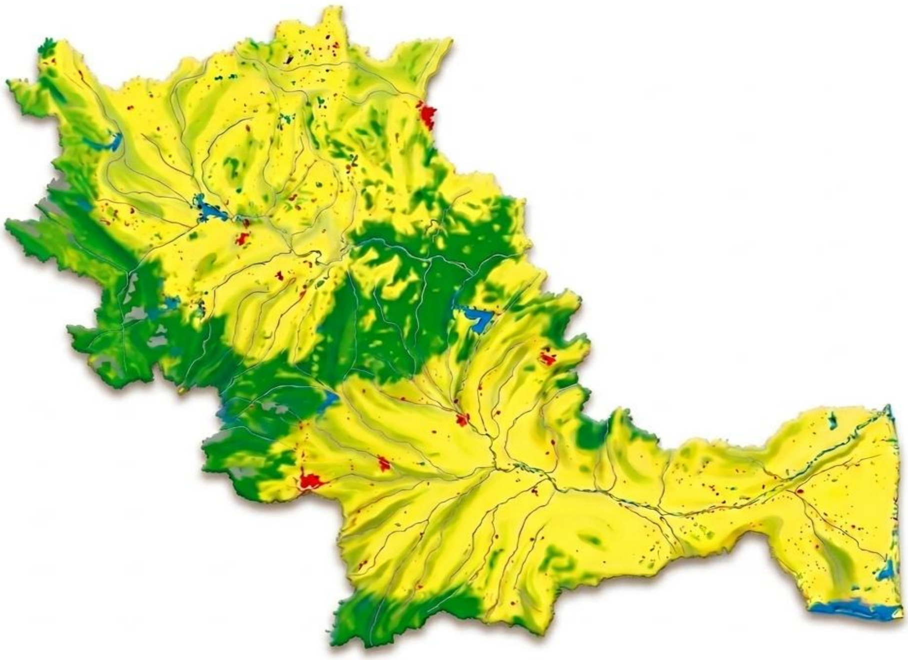
National River Conservation Directorate
Ministry of Jal Shakti,
Department of Water Resources,
River Development and Ganga Rejuvenation
Government of India

Land Use/Land Cover Cauvery River Basin



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Land Use/ Land Cover

Cauvery River Basin

National River Conservation Directorate (NRCD)

The National River Conservation Directorate, functioning under the Department of Water Resources, River Development and Ganga Rejuvenation, and Ministry of Jal Shakti providing financial assistance to the State Government for conservation of rivers under the Centrally Sponsored Schemes of 'National River Conservation Plan (NRCP)'. National River Conservation Plan to the State Governments/ local bodies to set up infrastructure for pollution abatement of rivers in identified polluted river stretches based on proposals received from the State Governments/ local bodies.

www.nrcd.nic.in

Centres for Cauvery River Basin Management Studies (cCauvery)

The Centre for Cauvery River Basin Management Studies (cCauvery) is a Brain Trust dedicated to River Science and River Basin Management. Established in 2024 by IISc Bengaluru and NIT Tiruchirappalli, under the supervision of cGanga at IIT Kanpur, the centre serves as a knowledge wing of the National River Conservation Directorate (NRCD). cCauvery is committed to restoring and conserving the Cauvery River Basin (CRB) and its resources through the collation of information and knowledge, research and development, planning, monitoring, education, advocacy, and stakeholder engagement.

www.ccauvery.org

Centre for Ganga River Basin Management and Studies (cGanga)

cGanga is a think tank formed under the aegis of NMCG, and one of its stated objectives is to make India a world leader in river and water science. The Centre is headquartered at IIT Kanpur and has representation from most leading science and technological institutes of the country. cGanga's mandate is to serve as think-tank in implementation and dynamic evolution of Ganga River Basin Management Plan (GRBMP) prepared by the Consortium of 7 IITs. In addition to this, it is also responsible for introducing new technologies, innovations, and solutions into India.

www.cganga.org

Acknowledgment

This report is a comprehensive outcome of the project jointly executed by IISc Bengaluru (Lead Institute) and NIT Tiruchirappalli (Fellow Institute) under the supervision of cGanga at IIT Kanpur. It was submitted to the National River Conservation Directorate (NRCD) in 2024. We gratefully acknowledge the individuals who provided information and photographs for this report.

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Preface

In an era of unprecedented environmental change, understanding our rivers and their ecosystems has never been more critical. This report aims to provide a comprehensive overview of our rivers, highlighting their importance, current health, and the challenges they face. As we explore the various facets of river systems, we aim to equip readers with the knowledge necessary to appreciate and protect these vital waterways.

Throughout the following pages, you will find an in-depth analysis of the principles and practices that support healthy river ecosystems. Our team of experts has meticulously compiled data, case studies, and testimonials to illustrate the significant impact of rivers on both natural environments and human communities. By sharing these insights, we hope to inspire and empower our readers to engage in river conservation efforts.

This report is not merely a collection of statistics and theories; it is a call to action. We urge all stakeholders to recognize the value of our rivers and to take proactive steps to ensure their preservation. Whether you are an environmental professional, a policy maker, or simply someone who cares about our planet, this guide is designed to support you in your efforts to protect our rivers.

We extend our heartfelt gratitude to the numerous contributors who have generously shared their stories and expertise. Their invaluable input has enriched this report, making it a beacon of knowledge and a practical resource for all who read it. It is our hope that this report will serve as a catalyst for positive environmental action, fostering a culture of stewardship that benefits both current and future generations.

As you delve into this overview of our rivers, we invite you to embrace the opportunities and challenges that lie ahead. Together, we can ensure that our rivers continue to thrive and sustain life for generations to come.

Centres for Cauvery River Basin
Management Studies (cCauvery)
IISc Bengaluru (Lead Institute), NIT Tiruchirappalli (Fellow Institute)

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Abbreviations and Acronyms

%	Percentage
&	And
′	Minute
°	Degree
NRCD	National River Conservation Directorate
MoJS	Ministry of Jal Shakti
LULC	Land Use and Land Cover
CRB	Cauvery River Basin
GIS	Geographic Information System
GEE	Google Earth Engine
ESA	European Space Agency
LCC	Land Cover (ESA dataset)
SoI	Survey of India
UAV	Unmanned Aerial Vehicle
LiDAR	Light Detection and Ranging
CWC	Central Water Commission
IWRIS	India Water Resources Information System

Continuation of Abbreviations and Acronyms

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1. Introduction

Land use and land cover (LULC) play a fundamental role in understanding the environmental, ecological, and socio-economic dynamics of a river basin. Land use refers to the manner in which land resources are utilized for human activities such as agriculture, urban development, industrial expansion, and infrastructure, whereas land cover represents the physical characteristics of the Earth's surface, including forests, croplands, water bodies, wetlands, built-up areas, and barren lands. Together, land use and land cover patterns influence hydrological processes, groundwater recharge, soil erosion, sediment transport, and ecosystem health within a river basin.

In the Cauvery River Basin (CRB), changes in land use and land cover have occurred over several decades due to population growth, urbanization, agricultural intensification, industrial development, and infrastructure expansion. These transformations directly affect water availability, river flow regimes, biodiversity, and watershed stability. Understanding the spatial and temporal dynamics of LULC is therefore essential for sustainable river basin management, environmental conservation, and long-term planning of water resources.

Advancements in geospatial technologies, including remote sensing, Geographic Information Systems (GIS), and high-resolution satellite imagery, have significantly improved the capability to monitor and analyse land use and land cover patterns at regional and basin scales. Satellite datasets such as Cartosat, Sentinel, and other high-resolution Earth observation imagery provide detailed information on current land use and land cover conditions. These datasets are complemented by Survey of India (SoI) toposheets, government surveys, and field-based observations, including information collected through Smart Cities programmes and other initiatives of central, state, and local governments. In recent years, emerging technologies such as Unmanned Aerial Vehicles (UAVs), drone surveys, and LiDAR-based mapping have further enhanced the spatial resolution and accuracy of land cover assessments.

For comprehensive basin analysis, it is also important to examine historical or reference conditions of land use and land cover. Historical patterns can be reconstructed using archival satellite imagery such as CORONA, historical SoI toposheets, and documented anecdotal or archival information. These datasets provide insights into the natural landscape conditions and land utilization patterns before the onset of rapid urban and agricultural expansion.

In addition to analysing historical and present conditions, defining the target condition of land use and land cover is crucial for guiding sustainable development within the basin. Target conditions represent the desired future state of land resources that balances ecological conservation, agricultural productivity, urban growth, and water resource sustainability. Such targets support informed decision-making for river basin management, watershed restoration, biodiversity conservation, and climate resilience.

Therefore, the assessment of land use and land cover in the CRB is structured into three components: reference conditions (historical baseline), present conditions (current land use and land cover distribution), and target conditions (desired future landscape scenarios). This integrated approach provides a comprehensive understanding of landscape dynamics and supports effective planning and management strategies for the long-term sustainability of the basin.

2. Basin Setting and Geomorphology

The Cauvery River originates at Talakaveri in the Western Ghats of Karnataka at an elevation of about 1,341 m above sea level and flows southeast through Tamil Nadu, covering a total length of approximately 800 km before emptying into the Bay of Bengal. The basin covers an area of about 85220.39 sq. km, supporting diverse ecosystems and major cities such as Bengaluru, Mysuru, and Tiruchirappalli. CRB, extending across southern India, features a diverse topography with distinct geographical zones. The upper basin region is characterized by steep gradients, dense forests, and heavy monsoon rainfall, contributing to the river's flow. This area consists of undulating hills and plateaus, several significant tributaries, such as the Hemavati, Shimsha, Arkavathy, Kabini, and Bhavani, join the Cauvery in this region, creating a complex river system. Continuing into the lower basin, predominantly in Tamil Nadu, the terrain gradually flattens into fertile plains with elevations below 100 m. This area is notable for its agricultural productivity, facilitated by the river's water and the fertile alluvial soil. The river eventually fans out into a delta before emptying into the Bay of Bengal near Poompuhar. The basin's diverse topography is integral to its hydrology, with seasonal variations in flow heavily influenced by monsoon rains, leading to high flow during the southwest monsoon and lower flow during the dry season. Key infrastructure such as the Krishna Raja Sagara dam in Karnataka and the Mettur dam in Tamil Nadu play crucial roles in water management for irrigation and supply. The ecological richness of the basin, from the dense forests of the Western Ghats to the agricultural plains and fertile delta, supports a wide range of wildlife and human activities, making the Cauvery River a vital lifeline for the regions it traverses.

Major tributaries of the Cauvery include the Hemavati, Kabini, Bhavani, Noyyal, and Amaravati rivers. These tributaries significantly contribute to the river’s flow and the overall water resources of the basin. The basin is a crucial water resource for the states it traverses, providing water for domestic, agricultural, and industrial purposes. The basin supports extensive irrigation systems, which are vital for the region’s agriculture. The construction of numerous dams and anicuts (weirs) facilitates the distribution of water for irrigation. Major irrigation projects include the Krishnaraja Sagar Dam, the Mettur Dam, and the Grand Anicut. The river's flow is highly seasonal, with most of the annual discharge occurring during the monsoon season (June to September). The river and its tributaries are harnessed for hydroelectric power generation. Key hydroelectric projects include the Shivanasamudra Falls Hydroelectric Project, one of the oldest in Asia, and the Mettur Dam Hydroelectric Project. The basin plays a critical role in recharging groundwater aquifers. The interaction between surface water and groundwater systems ensures the availability of water during dry periods. Effective management of surface water is crucial for maintaining groundwater levels, especially in the lower reaches of the basin.

The river's flow is regulated by a series of dams and reservoirs, which help mitigate the impacts of flooding during the monsoon season. These structures also store water for use during dry periods, ensuring a reliable water supply throughout the year. The river transports significant amounts of sediment, which is crucial for maintaining the fertility of the delta region. The annual flooding deposits nutrient-rich silt on agricultural lands, enhancing soil fertility and supporting agriculture. The basin's forests and wetlands contribute to climate regulation by sequestering carbon dioxide and moderating local temperatures. They also play a role in maintaining regional rainfall patterns. The salient features of the basin are shown in Table 2.

The geomorphology of CRB encompasses the study of its physical features, landforms, and the processes shaping them. The Cauvery River traverse diverse terrains, leading to a variety of geomorphological characteristics. The upper reaches of the Cauvery River originate in the Western Ghats, a major mountain range characterized by rugged terrain, high rainfall, and dense forest cover. The geomorphology of this region includes steep slopes, narrow valleys, and deep gorges. The river's headwaters, near Talakaveri in Karnataka, initially flows through a series of cascades and waterfalls. These features are a result of tectonic uplift and volcanic activity in the geological past, which have created a landscape marked by intense weathering and erosion. The Western Ghats serve as a crucial watershed, with numerous tributaries joining the Cauvery in this stretch, contributing to its perennial flow.

As the Cauvery River descends from the Western Ghats into the Mysore Plateau, the river flows through more gently undulating terrain. The middle basin is characterized by broad valleys, alluvial plains, and intermontane depressions. Here, the river meanders through a landscape influenced by both fluvial and tectonic processes. The region features extensive floodplains, sediment deposits, and river terraces formed by historical changes in river flow and sediment load. Important geomorphological features in this section include the Krishnaraja

Sagara dam and reservoir, which has significantly altered the river's natural flow and sediment transport dynamics. Additionally, this stretch includes the deltaic plains where the river branches into distributaries, contributing to the formation of fertile agricultural land.

In the lower reaches, particularly as the river enters Tamil Nadu, the Cauvery flows through a predominantly flat and expansive landscape characterized by the formation of a large delta. This delta, known as the Cauvery Delta, is one of the most fertile and intensively cultivated regions in India. The geomorphology here is dominated by depositional processes, with extensive alluvial deposits forming a network of distributaries and canals. The delta is crisscrossed by numerous irrigation channels, reflecting the region's dependence on the river for agriculture. The lower basin's geomorphology also includes levees, backwaters, and floodplain lakes, which are crucial for managing flood risks and sustaining local ecosystems.

As the Cauvery River approaches its confluence with the Bay of Bengal, the river's geomorphology is influenced by coastal processes, including tidal actions and sea level changes. The interaction between fluvial and marine processes leads to the formation of estuaries, tidal flats, and mangrove swamps, which are important for maintaining coastal biodiversity and protecting against coastal erosion. The river's mouth, where it empties into the sea, is characterized by a dynamic interplay of sediment deposition and erosion, contributing to the continual reshaping of the coastal geomorphology.

Climatic variations

Climate is defined as the long-term average of variations in temperature, humidity, atmospheric pressure, wind, precipitation, and other meteorological variables specific to a region. CRB, encompassing multiple states in India, exhibits a variety of climatic zones due to its extensive geographical spread. Notably, approximately 54% of the CRB lies within Tamil Nadu, particularly the middle and lower regions of the basin (India WRIS, 2014). The climate of these regions primarily depends on monsoon rainfall, making them susceptible to drought during monsoon failures. Consequently, the basin's climate ranges from dry sub-humid to semi-arid. In CRB, four distinct seasons occur, i.e., winter, summer, south-west monsoon, and north-east monsoon.

Historical Land Use of the CRB

Understanding the historical land use patterns of a river basin is essential for evaluating long-term environmental changes and their impacts on hydrological processes, ecological stability, and socio-economic development. Historical land use provides a baseline against which present and future transformations in land utilization can be assessed. In the CRB, land use patterns have evolved under the combined influence of climatic variability, agricultural development, population growth, and infrastructural expansion. The basin historically supported extensive agricultural systems, forest ecosystems, and traditional water management practices that shaped the regional landscape over centuries.

The CRB is one of the major river systems of peninsular India, extending across Karnataka, Tamil Nadu, Kerala, and the Union Territory of Puducherry. The basin exhibits diverse physiographic, climatic, and geological characteristics that have historically influenced land use distribution across different regions. The western part of the basin, particularly the Western Ghats, historically supported dense forest ecosystems, whereas the central plateau regions were largely dominated by agricultural land use. The eastern part of the basin, especially the Cauvery delta in Tamil Nadu, has historically been characterized by irrigated agriculture supported by fertile alluvial soils and canal irrigation systems.

Historically, agriculture has been the dominant land use activity within the CRB. Studies indicate that a substantial proportion of the basin area has been under cultivation due to favorable soil conditions and the availability of water resources from the Cauvery River and its tributaries. Approximately two-thirds of the basin area has historically been used for agricultural purposes, while forest cover accounts for a significant portion of the upper catchment regions. Water bodies, built-up areas, and wastelands constitute comparatively smaller proportions of the basin landscape. These land use patterns reflect the long-standing dependence of the basin population on agriculture and irrigation systems supported by the Cauvery River (Sreelash et al., 2020).

The upper catchment regions of the basin, located within the Western Ghats, historically supported dense evergreen and semi-evergreen forests. These forest ecosystems played a crucial role in maintaining the hydrological balance of the basin by regulating rainfall infiltration, groundwater recharge, and surface runoff processes. The forested landscapes of the Western Ghats contributed significantly to sustaining river flows and maintaining ecological stability within the basin. Over time, however, portions of these forest areas have been converted into plantation crops, agricultural lands, and settlements due to expanding human activities and economic development.

Traditional irrigation systems have played an important role in shaping the historical land use patterns of the CRB. The basin has a long history of water management practices dating back several centuries. Numerous tanks, reservoirs, canals, and diversion structures were constructed to store and distribute river water for agricultural use. These irrigation systems enabled extensive cultivation of crops such as paddy, sugarcane, millets, pulses, and oilseeds across various parts of the basin. The Cauvery delta region, often referred to as the “rice bowl” of South India, historically supported intensive paddy cultivation through canal irrigation networks that have developed over centuries.

The spatial distribution of land use in the basin has also been influenced by variations in rainfall and topography. The western highland regions receive higher rainfall and historically supported dense vegetation cover, including forests and plantation crops. In contrast, the central plateau regions are largely characterized by dryland agriculture and rain-fed farming systems due to relatively lower rainfall and semi-arid climatic conditions. The eastern plains and deltaic regions historically supported irrigated agriculture due to fertile soils and well-developed irrigation infrastructure derived from the Cauvery River.

Changes in land surface characteristics, including land use and land cover transformations driven by human activities, have significant impacts on hydrological processes within river basins. Alterations in land use can influence runoff generation, evapotranspiration, groundwater recharge, and infiltration processes, ultimately affecting the hydrological regime of a basin. Studies examining the hydrological characteristics of the CRB have demonstrated that changes in rainfall patterns and land surface conditions can significantly influence streamflow patterns and water availability across different parts of the basin (Sreelash et al., 2020).

Long-term analyses of land use and land cover dynamics indicate that significant transformations have occurred within the CRB during recent decades. Rapid urbanization, agricultural expansion, and infrastructural development have progressively altered the traditional land use mosaic of the basin. Studies evaluating decadal land use and land cover changes reveal that urban areas have increased substantially over time, while natural vegetation cover has declined in several regions. Such changes have important implications for basin-scale hydrological processes, including increased surface runoff and modifications in watershed hydrology (Dixit et al., 2024).

Historical land use patterns also reflect the socio-economic dependence of communities within the Cauvery Basin on agriculture and water resources. A significant proportion of the basin population resides in rural areas and relies heavily on agriculture as the primary livelihood. Groundwater resources have increasingly been utilized to supplement surface water irrigation, particularly in semi-arid regions where rainfall variability is high. Consequently, land use practices have gradually evolved in response to changing water availability, technological advancements in irrigation, and socio-economic development.

1. Methodology

The land use and land cover (LULC) analysis of the CRB was carried out using the European Space Agency Climate Change Initiative Land Cover (ESA CCI-LC) dataset for the years 1992, 1995, 2000, 2005, 2010, 2015, 2020, and 2022. The ESA CCI-LC product provides annual global land cover maps at 300 m spatial resolution and is specifically designed for long-term climate and environmental studies. The dataset is generated through a supervised classification approach using multi-source satellite observations. The classification methodology combines machine learning algorithms and training datasets, followed by spatial and temporal consistency checks to improve classification reliability (ESA, 2017)

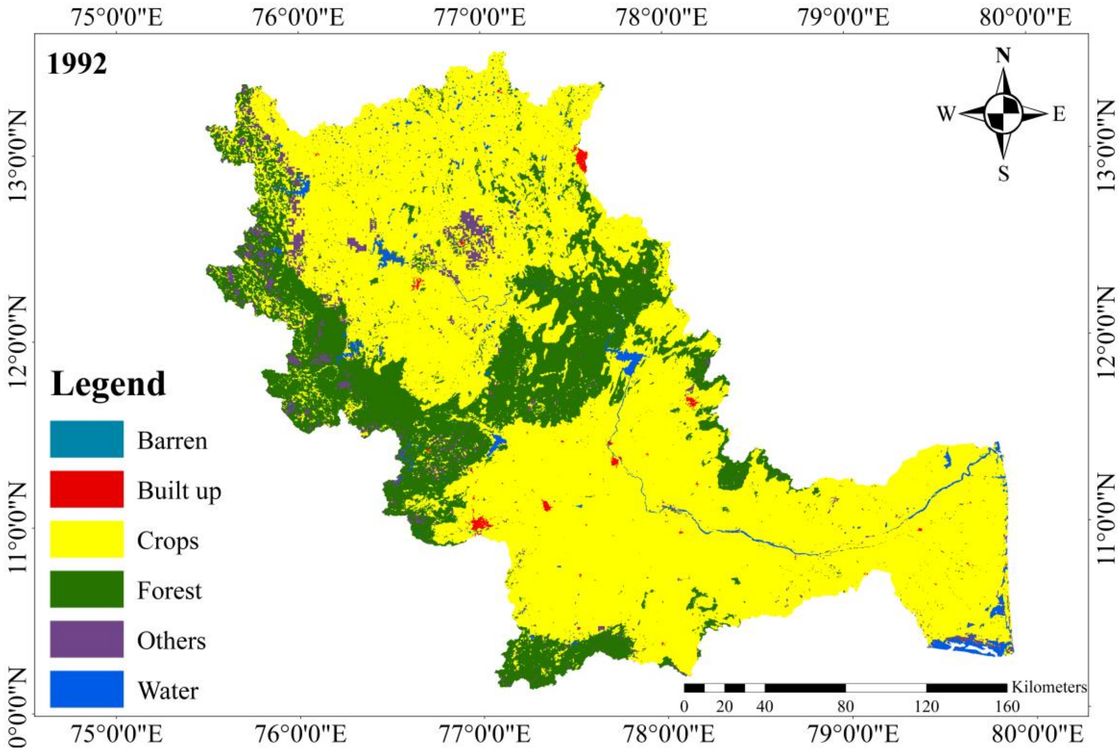
The ESA CCI-LC maps are produced through automated classification rather than manual digitization. The classification process incorporates spectral, temporal, and ancillary environmental information to assign land cover classes according to the United Nations Land Cover Classification System (LCCS). The product has undergone extensive validation using independent reference datasets and global ground-truth observations.

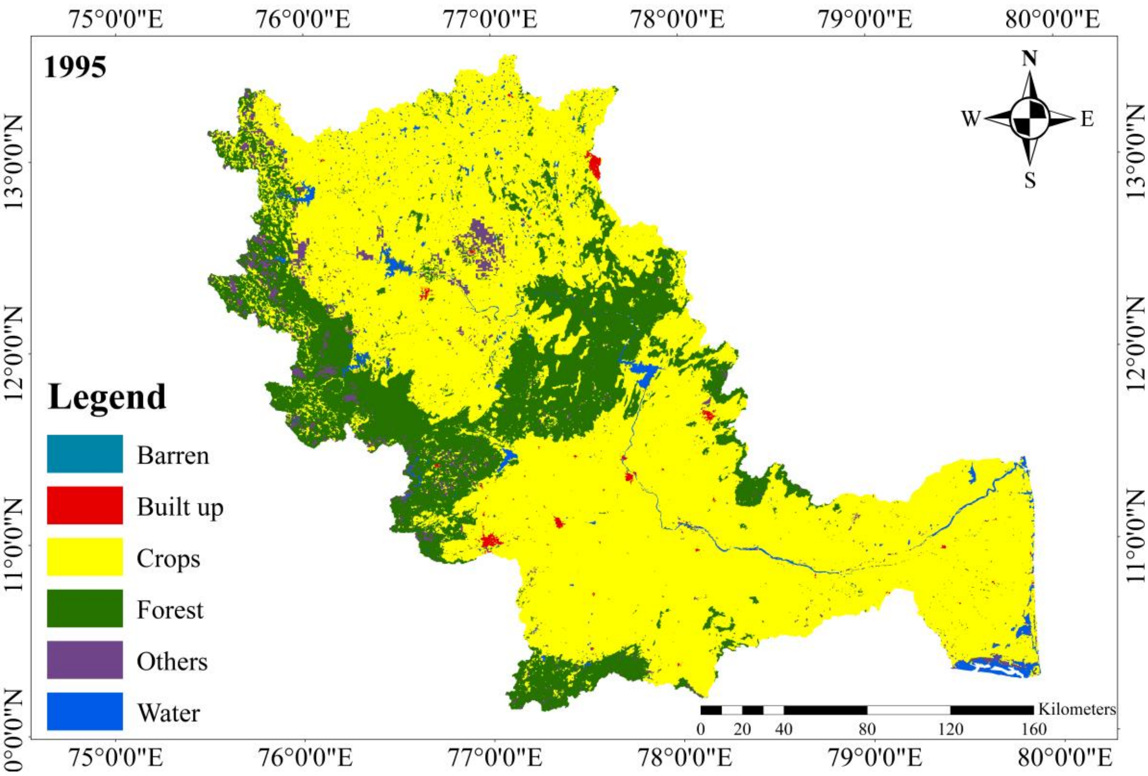
The reclassified land cover categories used in this study are:

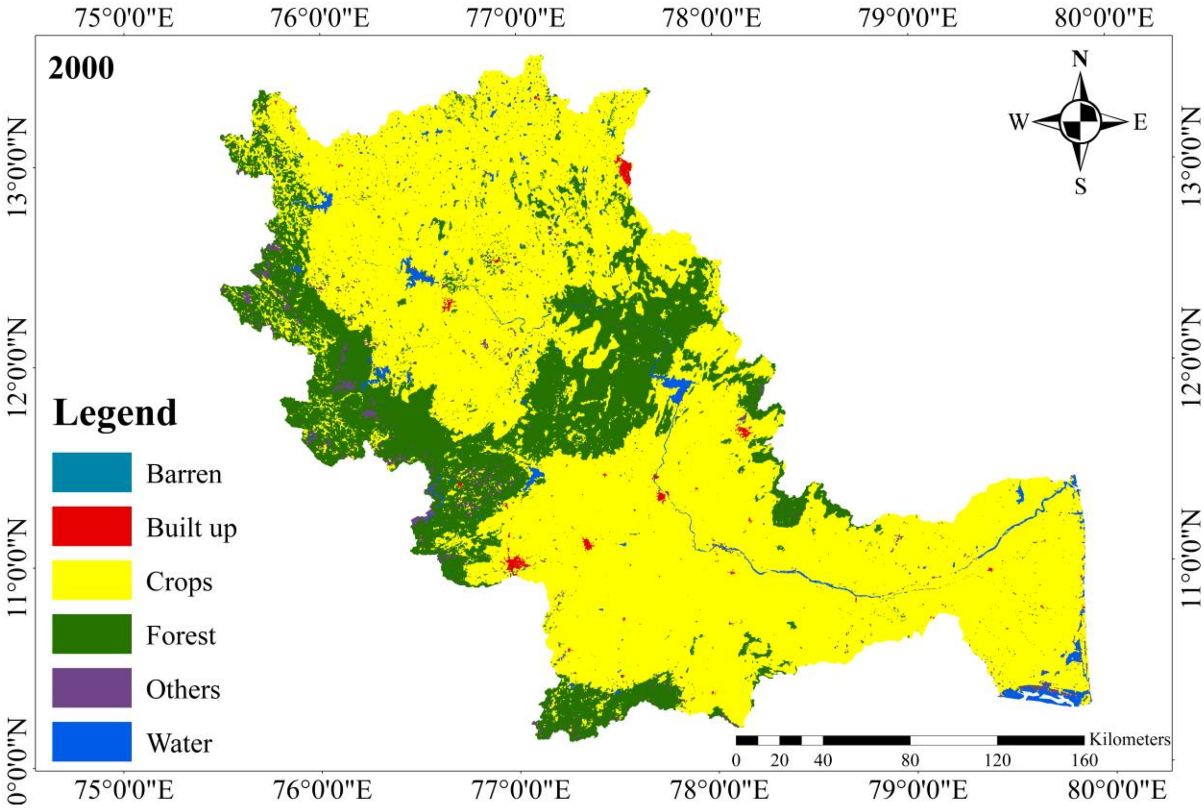
- Cropland: Areas under agricultural use, including irrigated and rainfed croplands.
- Forest: Natural forests, plantation forests, and dense vegetation cover.
- Water Bodies: Rivers, lakes, reservoirs, canals, and other surface water features.
- Built-up Area: Urban areas, settlements, infrastructure, and impervious surfaces.
- Others: Scrubland, grassland, fallow land, and mixed or transitional land cover.
- Barren Land: Exposed rock, sandy areas, and non-vegetated surfaces.

2. Basin Characteristics

Present LULC Map & Statistics



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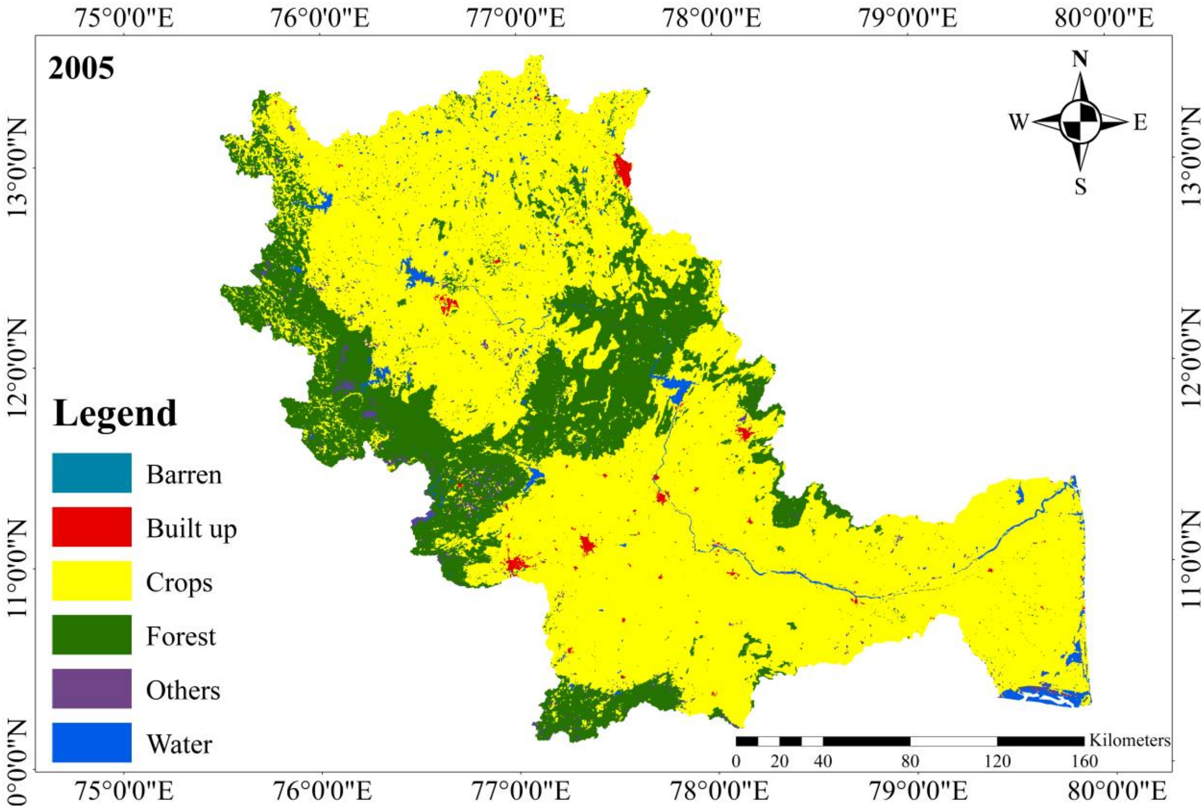
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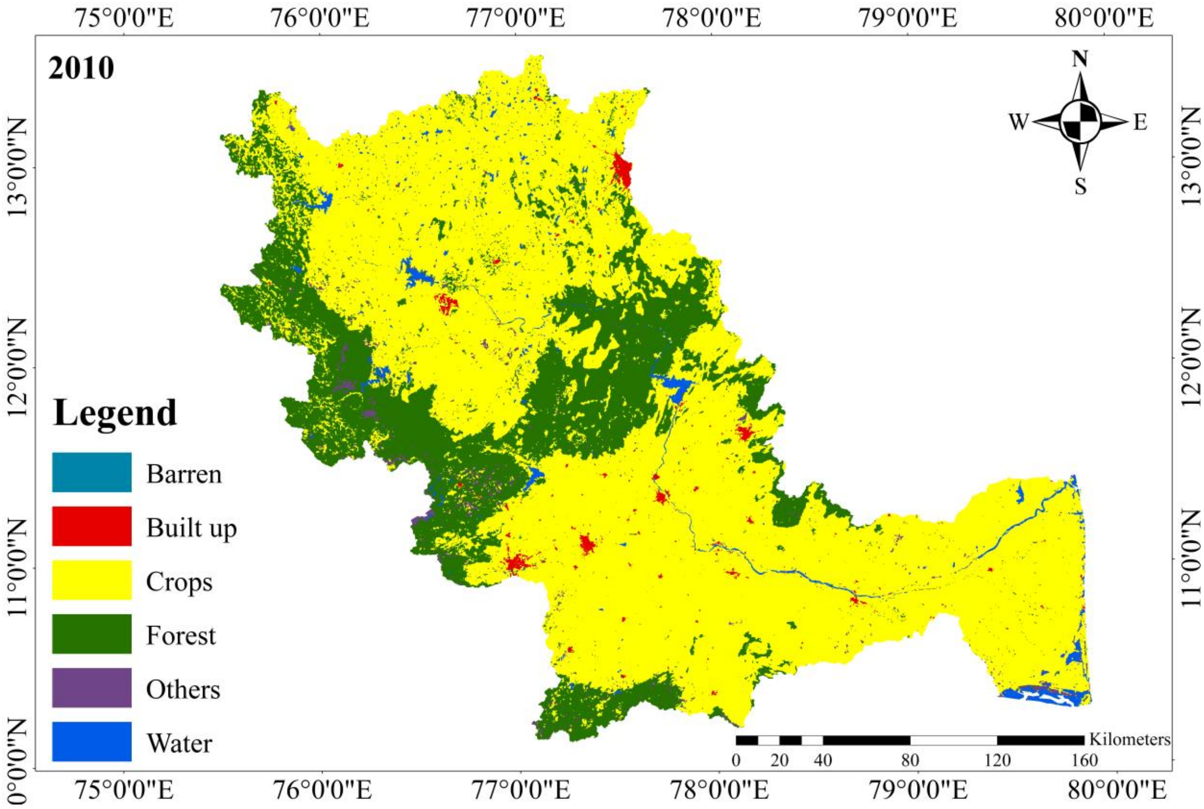
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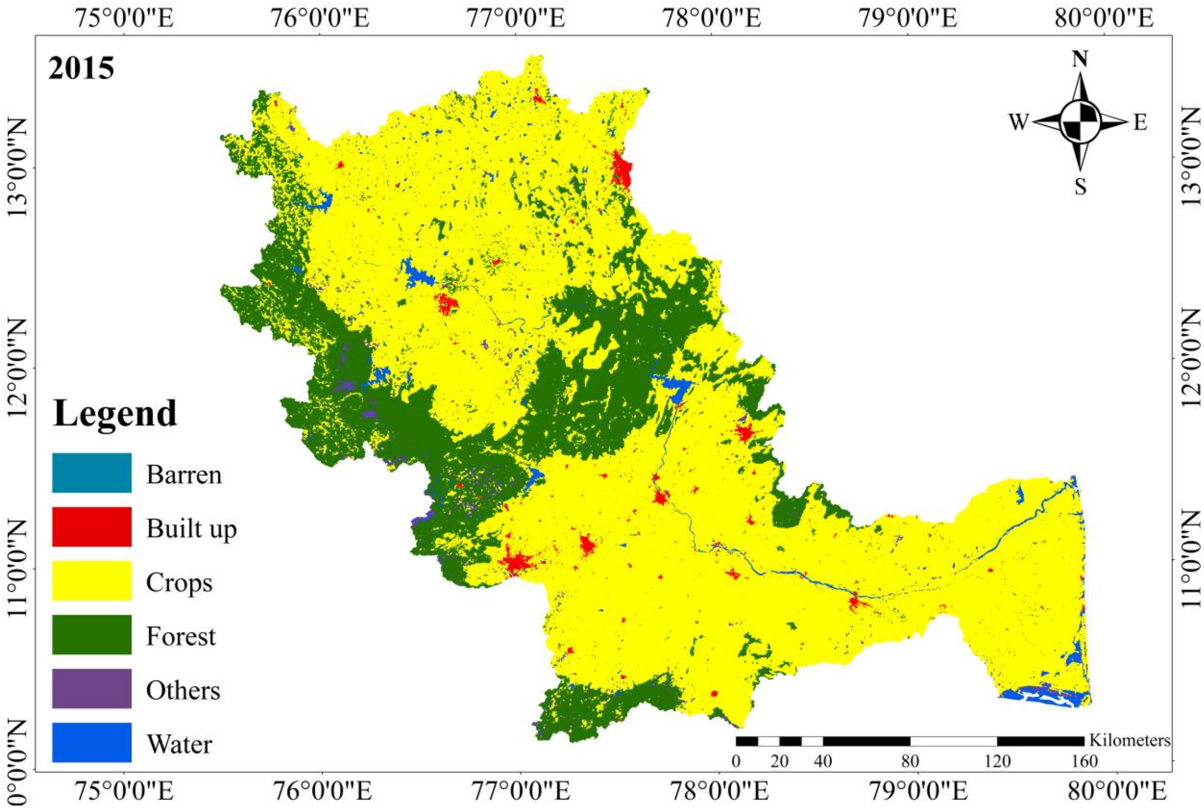
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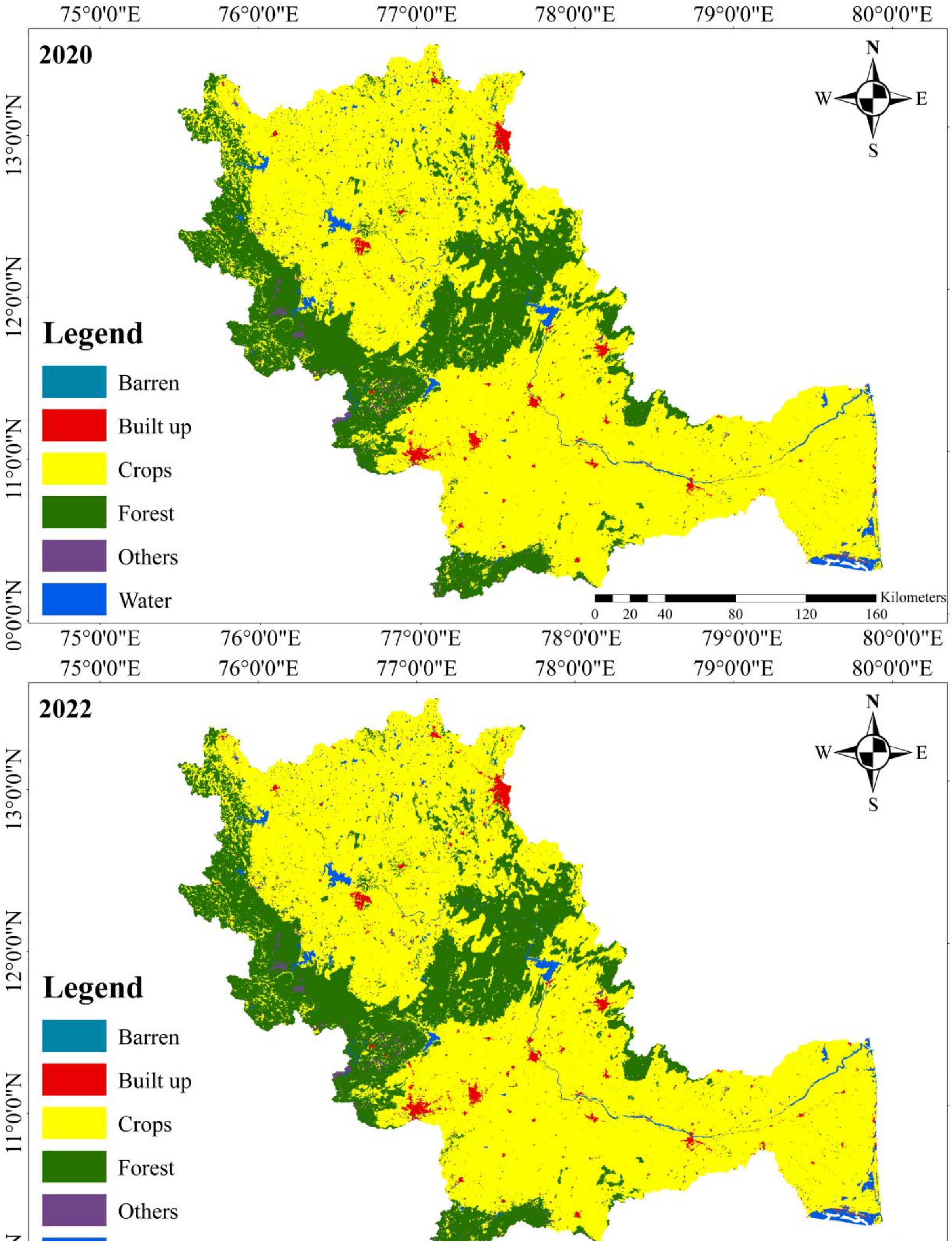

Fig. 2 Multi-temporal Land Use/Land Cover Maps of the Cauvery River Basin (1990-2022)

The present LULC dynamics of the Cauvery River Basin have been assessed using ESA Land Cover (LCC) datasets for multiple time periods spanning from 1990 to 2022. The analysis provides insights into long-term spatial and temporal changes in land use patterns within the basin. The LULC classes considered in this study include cropland, forest, water bodies, built-up area, others (including scrubland and mixed classes), and barren land. The area of each class is expressed in square kilometres (km^2), enabling a quantitative comparison of changes over time.

Land Use/Land Cover Distribution in 1990

In 1990, the CRB was predominantly characterized by agricultural land use, with cropland covering approximately 61,638.6 km^2, making it the dominant land cover class in the basin. Forest areas occupied around 19,430.5 km^2, representing a significant portion of the upper catchment regions, particularly in the Western Ghats. Water bodies accounted for approximately 1,559.06 km^2, reflecting the presence of reservoirs, rivers, and irrigation networks within the basin.

The built-up area was relatively limited during this period, covering only 304.31 km^2, indicating low levels of urbanization. The category classified as "others," which includes scrubland, fallow land, and mixed vegetation, occupied around 2,270.29 km^2, suggesting the presence of transitional and less intensively utilized landscapes. Barren land constituted a negligible area of approximately 2.04 km^2, indicating minimal exposure of bare surfaces within the basin.

Land Use/Land Cover Distribution in 1995

By 1995, slight changes in land use patterns were observed. Cropland increased marginally to 61,887.9 km^2, indicating continued agricultural expansion. Forest cover showed a slight decline to 19,397.2 km^2, suggesting gradual conversion of forested areas for agricultural or developmental purposes.

Water bodies remained relatively stable at 1,557.19 km^2, reflecting consistent hydrological conditions during this period. The built-up area increased to 319.18 km^2, indicating early stages of urban growth within the basin. A significant change was observed in the "others" category, which decreased to 2,041.51 km^2, suggesting conversion of these lands into agricultural or other land use classes. Barren land remained unchanged and negligible in extent.

Land Use/Land Cover Distribution in 2000

In 2000, cropland further expanded to approximately 62,587.6 km^2, reinforcing the dominance of agriculture in the basin. Forest cover declined to 19,562.5 km^2, continuing the trend of gradual forest reduction. Water bodies remained stable at around 1,561.88 km^2.

The built-up area increased significantly to 347.70 km^2, reflecting growing urbanization and infrastructural development. The “others” category showed a marked decrease to 1,144.27 km^2, indicating substantial land conversion towards agriculture or settlements. This period reflects increasing anthropogenic pressure on land resources within the basin.

Land Use/Land Cover Distribution in 2005

By 2005, cropland reached approximately 62,409.4 km^2, maintaining its dominant share in the basin. Forest cover showed a slight increase to 19,724.2 km^2, possibly due to improved forest management practices or classification variations.

Water bodies remained nearly constant at 1,560.28 km^2. The built-up area increased further to 564.21 km^2, indicating accelerated urban expansion during this period. The “others” category declined to 945.70 km^2, suggesting continued transformation of transitional lands into agriculture or urban uses. Barren land remained negligible.

Land Use/Land Cover Distribution in 2010

In 2010, cropland reached its peak at approximately 62,268.8 km^2, highlighting the sustained agricultural intensity of the basin. Forest cover remained relatively stable at 19,772.6 km^2. Water bodies decreased slightly to 1,559.8 km^2, indicating minor variations in surface water availability.

The built-up area showed a notable increase to 707.60 km^2, reflecting rapid urbanization and expansion of settlements. The “others” category increased slightly to 894.52 km^2, possibly due to land degradation or classification shifts.

Land Use/Land Cover Distribution in 2015

In 2015, cropland slightly decreased to 61,971.5 km^2, indicating stabilization of agricultural expansion. Forest cover remained stable at 19,782 km^2, suggesting minimal change in forest extent.

Water bodies increased marginally to 1,594.28 km^2, possibly reflecting improved water storage or climatic variability. Built-up areas expanded significantly to approximately 1,000-1,033 km^2, indicating a rapid rise in urbanization across the basin. The “others” category remained around 800-850 km^2, showing continued reduction of transitional land classes.

Land Use/Land Cover Distribution in 2020

By 2020, cropland showed a slight reduction to 61,573.2 km^2, indicating possible diversification or land conversion. Forest cover increased slightly to 20,215.1 km^2, suggesting marginal recovery or improved classification accuracy.

Water bodies remained stable at 1,585.06 km^2. Although built-up data is not explicitly provided, trends from previous years indicate continued urban expansion.

Land Use/Land Cover Distribution in 2022

The most recent assessment for 2022 shows cropland covering approximately 61,065.81 km^2, which indicates a gradual decline in agricultural land compared to earlier decades. Forest cover increased to 20,435.13 km^2, suggesting a positive trend in forest area.

Water bodies accounted for 1,594.99 km^2, showing stability in hydrological features. Built-up areas increased significantly to 1,324.49 km^2, reflecting rapid urban growth and infrastructure development across the basin. The "others" category reduced to 783.36 km^2, indicating continued conversion of transitional land classes. Barren land remained negligible at around 2.04 km^2.

Overall Trends (1990-2022)

The long-term analysis of LULC dynamics in the CRB reveals several important trends:

- Agriculture (cropland) has consistently remained the dominant land use, though showing a slight decline in recent years.
- Forest cover has remained relatively stable with a slight increasing trend in recent years.
- Built-up areas have shown a significant and continuous increase, which highlights rapid urbanization.
- Water bodies have remained relatively stable over time.
- The "others" category has steadily decreased, which indicates conversion to agriculture and urban land uses.

3. Land Use and Land Cover Change Analysis (1990-2022)

The analysis of land use and land cover (LULC) dynamics in the Cauvery River Basin over the period 1990-2022 reveals significant transformations driven by anthropogenic activities, population growth, and developmental pressures. The multi-temporal assessment using ESA Land Cover datasets highlights both gradual and rapid changes across different land use categories, particularly in cropland, forest, built-up areas, and transitional land classes.

Cropland has remained the dominant land use throughout the study period, with its area fluctuating between 61,000 km^2 and 62,500 km^2. In 1990, cropland covered approximately 61,638.6 km^2, which increased to a peak of 62,587.6 km^2 in 2000, followed by a gradual decline to 61,065.81 km^2 in 2022. This slight reduction in cropland area in recent years may be attributed to urban expansion, land conversion for infrastructure, and changes in agricultural practices. Despite this decline, agriculture continues to dominate the basin, reflecting its socio-economic importance.

Forest cover in the basin has remained relatively stable with a marginal increasing trend over the study period. The forest area increased from 19,430.5 km^2 in 1990 to 20,435.13 km^2 in 2022, indicating a net gain of approximately 1,000 km^2. This increase may be attributed to afforestation programs, conservation initiatives, and improved forest management practices. However, localized deforestation and land conversion may still exist in certain parts of the basin.

The most significant change observed during the study period is the rapid expansion of built-up areas. The built-up area increased dramatically from 304.31 km^2 in 1990 to 1,324.49 km^2 in 2022, representing more than a fourfold increase. This rapid urban growth is primarily driven by the expansion of major urban centres such as Bengaluru, Mysuru, Coimbatore, and other emerging towns within the basin. The increase in built-up areas reflects intensified economic development, infrastructure growth, and population pressure.

Water bodies have remained relatively stable over time, with minor fluctuations between 1,550 km^2 and 1,595 km^2. This stability indicates that large reservoirs, rivers, and major water systems in the basin have not undergone significant areal changes, although seasonal and interannual variability may still influence water availability.

The “others” category, which includes scrubland, fallow land, and mixed vegetation, has shown a consistent declining trend. The area under this category decreased significantly from 2,270.29 km^2 in 1990 to 783.36 km^2 in 2022, indicating a substantial conversion of transitional and less productive lands into agriculture or built-up areas. This decline reflects increasing land-use intensification and reduced availability of marginal or unused lands.

Barren land has remained negligible throughout the study period, indicating limited exposure of bare surfaces within the basin.

Present Land Use/Land Cover -Sentinel-Based LULC (2017-2025)

The present land cover of the CRB for the year 2017 and 2025 has been analysed using Sentinel-based satellite imagery, providing a more detailed and accurate representation of surface characteristics compared to medium-resolution datasets. The classification includes major land cover classes such as cropland, forest, rangeland, built-up areas, water bodies, flooded vegetation, bare ground, and cloud cover. The use of high-resolution imagery enables better delineation of urban areas, river networks, and heterogeneous landscapes within the basin.

The analysis indicates that cropland remains the dominant land cover, occupying approximately 41,808.12 km^2, reflecting the continued agricultural dependence of the basin. Forest cover accounts for about 17,924.34 km^2, primarily concentrated in the Western Ghats and upper catchment regions, highlighting their ecological significance. Rangeland covers approximately 12,813.02 km^2, representing transitional and semi-natural landscapes.

A significant expansion of built-up areas is observed, covering around 11,083.77 km^2, indicating rapid urbanization and infrastructure development, particularly around major cities such as Bengaluru, Mysuru, and Coimbatore. Water bodies, including rivers, reservoirs, and lakes, occupy approximately 1,416.54 km^2, showing relative stability in surface water extent. Minor classes such as flooded vegetation (57.38 km^2) and bare ground (116.91 km^2) represent localized features within the basin, while cloud cover is negligible.

The high-resolution Sentinel-based LULC map provides improved spatial detail and accuracy, making it highly suitable for urban planning, hydrological modelling, and resource management. When compared with long-term ESA-based analysis, the 2025 dataset clearly highlights ongoing trends of urban expansion, stabilization of forest cover, and dominance of agriculture, thereby offering a more refined understanding of present land cover conditions in the CRB.

A comparison between ESA CCI (2022) and Sentinel-based (2025) LULC shows differences due to variations in spatial resolution and classification schemes. The ESA dataset generalizes land cover, while Sentinel data captures finer details, especially for built-up and heterogeneous landscapes. Cropland differences arise because ESA includes mixed classes, whereas Sentinel separates cropland and rangeland. Therefore, the variations are not inconsistencies but reflect improved accuracy and detail in high-resolution Sentinel data.

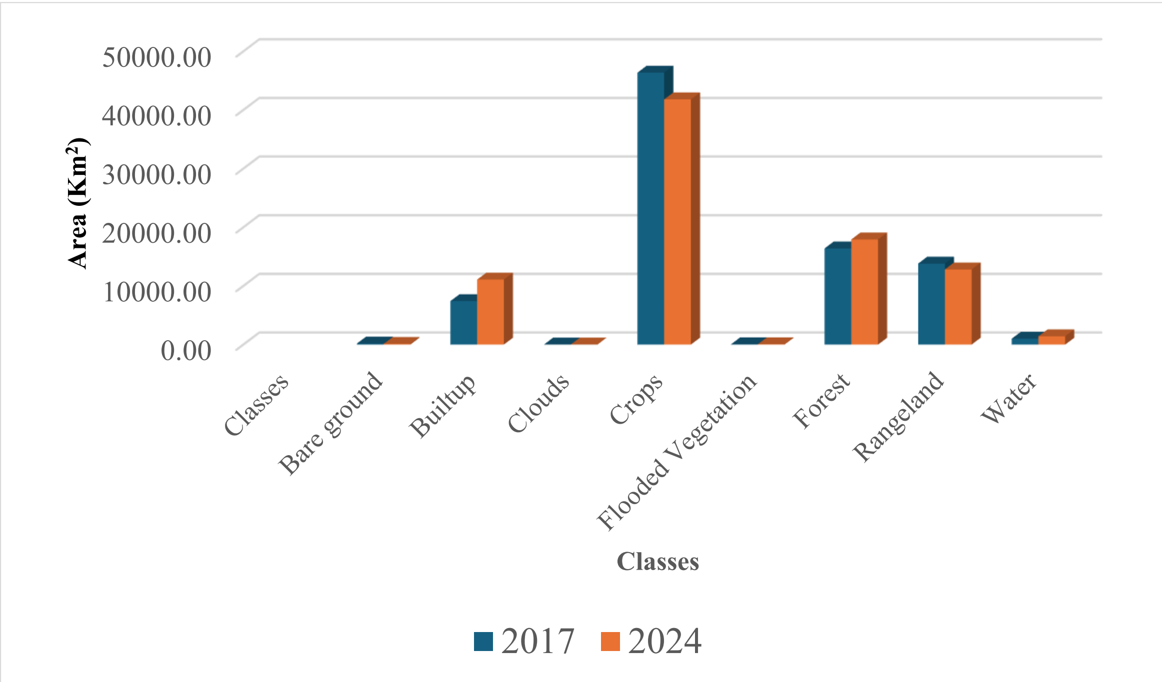

Fig. 3 Comparative LULC area distribution of the CRB for 2017 and 2024, showing changes across major classes.

4. Temporal Analysis

The temporal analysis of LULC in CRB shows significant transformations over the past three decades, driven primarily by anthropogenic pressures, urbanization, and land-use intensification. The multi-temporal assessment based on ESA Land Cover datasets (1990-2022) and high-resolution Sentinel-based observations (2017-2025) provides a comprehensive understanding of both long-term trends and recent changes in land cover dynamics.

The long-term analysis (1990-2022) indicates that cropland has consistently remained the dominant land use, with its area fluctuating between approximately 61,000 km^2 and 62,500 km^2. However, a gradual decline is observed after 2000, suggesting increasing conversion of agricultural land to urban and infrastructural uses. In contrast, forest cover has remained relatively stable, with a slight increasing trend of nearly 1,000 km^2 over the study period, reflecting the influence of afforestation and conservation initiatives.

The most prominent change is the rapid expansion of built-up areas, which increased more than fourfold from about 304 km^2 in 1990 to 1,324 km^2 in 2022. This growth is primarily associated with the expansion of major urban centres such as Bengaluru, Mysuru, and Coimbatore, indicating intensified economic development and population pressure within the basin. Meanwhile, water bodies have remained relatively stable, showing only minor fluctuations, suggesting that major hydrological features have not undergone significant areal changes.

A notable declining trend is observed in the “others” category, which includes scrubland, fallow land, and mixed vegetation. This class decreased substantially from approximately 2,270 km^2 in 1990 to 783 km^2 in 2022, indicating large-scale conversion of transitional landscapes into agriculture and built-up areas. Barren land has remained negligible throughout the study period.

The high-resolution Sentinel-based LULC analysis (2017–2025) further refines these observations by capturing finer spatial details. The results indicate that cropland (41,808 km^2) and rangeland (12,813 km^2) together dominate the landscape, aligning with ESA-derived agricultural extent when combined. Built-up areas show a substantial increase (~11,083 km^2), highlighting the extent of urban sprawl that is not fully captured in medium-resolution datasets. Forest cover (~17,924 km^2) remains concentrated in the Western Ghats and upper catchment regions, maintaining ecological stability.

A comparison between ESA (2022) and Sentinel-based (2025) datasets reveals variations in area estimates due to differences in spatial resolution and classification schemes. The ESA dataset (300 m resolution) generalizes land cover classes, whereas Sentinel imagery (10 m resolution) captures finer spatial heterogeneity, particularly in urban and mixed land use areas. Therefore, the observed differences are not inconsistencies but reflect improved detection and classification accuracy in high-resolution data.

Hydrological Implications of LULC Change

Changes in land use and land cover significantly influence the hydrological behaviour of river basins by altering key processes such as surface runoff, infiltration, evapotranspiration, and groundwater recharge. In the CRB, the observed LULC changes over the period 1990-2022 have important implications for the basin's hydrological regime.

The rapid increase in built-up areas has led to the expansion of impervious surfaces, which reduce infiltration and increase surface runoff. This results in higher peak flows during rainfall events, increased risk of urban flooding, and reduced groundwater recharge. Urbanization also alters natural drainage patterns, leading to changes in flow pathways and increased pressure on stormwater management systems.

The slight decline in cropland area and the conversion of transitional lands into urban areas may further reduce soil permeability and infiltration capacity. Agricultural lands generally facilitate moderate infiltration and evapotranspiration; however, their conversion to built-up areas disrupts these processes, leading to enhanced runoff generation.

The relatively stable or slightly increasing forest cover has a positive influence on hydrological processes. Forest ecosystems enhance infiltration, regulate surface runoff, reduce soil erosion, and improve groundwater recharge. The increase in forest cover observed in the basin may contribute to localized improvements in watershed stability and hydrological balance.

The reduction in the "others" category, which includes scrublands and fallow lands, indicates a loss of transitional landscapes that often act as buffer zones between natural and developed areas. These areas play an important role in regulating runoff and preventing soil erosion. Their decline may lead to increased land degradation and sediment transport in certain regions.

Water bodies in the basin have remained relatively stable in terms of area; however, hydrological processes such as storage, flow variability, and seasonal availability may still be affected by upstream land use changes. Increased runoff due to urbanization can lead to higher sediment loads in reservoirs, affecting their storage capacity and operational efficiency.

Target Condition of Land Use and Land Cover

The target condition of land use and land cover for the CRB aims to achieve a balanced and sustainable landscape that supports ecological integrity, water resource sustainability, and socio-economic development. Given the observed trends of urban expansion and land-use transformation, it is essential to adopt a strategic approach to land management within the basin.

One of the primary objectives is the conservation and enhancement of forest cover, particularly in the upper catchment areas of the Western Ghats. Forest ecosystems play a critical role in maintaining hydrological stability, reducing soil erosion, and preserving biodiversity. Afforestation and reforestation programs should be strengthened to restore degraded forest lands.

Sustainable agricultural practices should be promoted to ensure long-term productivity while minimizing environmental impacts. This includes efficient irrigation techniques, crop diversification, soil conservation measures, and the adoption of climate-resilient agricultural systems. Protection of prime agricultural land from unplanned urban expansion is also essential.

Urban growth within the basin should be planned and regulated to minimize its environmental impact. Compact urban development, improved land-use planning, and the incorporation of green infrastructure can help reduce the negative effects of urbanization on hydrological processes. Preservation of open spaces and urban green areas is important for maintaining ecological balance.

The restoration and protection of wetlands, tanks, and water bodies should be prioritized to enhance groundwater recharge, improve water availability, and support aquatic ecosystems. Traditional tank irrigation systems, which have historically played a significant role in the basin, should be revitalized and integrated into modern water management strategies.

Degraded lands and transitional areas should be rehabilitated through appropriate land management practices such as afforestation, soil stabilization, and watershed development programs. These measures will help improve land productivity and reduce environmental degradation.

Infrastructure and Urban Development in the Cauvery Basin

Rapid urbanization and infrastructure development within the CRB have significantly influenced land use patterns and water resource dynamics. Major urban centres such as Bengaluru, Mysuru, and Coimbatore have experienced substantial expansion, leading to increased demand for water supply, sanitation, and drainage infrastructure. Government initiatives such as AMRUT, Jal Shakti Abhiyan, and various state-level development programs have been implemented to improve water resource management and urban infrastructure. The basin is characterized by extensive water supply networks, treatment plants, sewerage systems, and stormwater drainage systems designed to meet the growing needs of urban populations. However, challenges such as inadequate infrastructure, inefficient resource utilization, and misalignment with rapid urban growth continue to affect sustainable development within the basin. Effective planning and integrated infrastructure management are therefore essential to ensure long-term sustainability

Demographic and Socio-Economic Characteristics

The demographic profile of the CRB plays a critical role in shaping land use patterns, water demand, and environmental pressures. The basin supports a large and diverse population distributed across urban and rural regions. Population growth, increasing density, and migration trends have contributed to expanding urban areas and intensification of land use. A significant proportion of the population is engaged in agriculture, while urban areas are characterized by diversified economic activities including industry and services. Socio-economic indicators such as education, employment, and income levels influence resource utilization patterns and development trajectories within the basin. The increasing population pressure has direct implications for water demand, land use change, and environmental sustainability, highlighting the need for integrated planning and resource management strategies.

5. Impact assessment of LULC Change

The changes in LULC within CRB have significant implications for the basin's environmental, hydrological, and socio-economic systems. The multi-temporal analysis (1990-2022) combined with high-resolution Sentinel-based observations highlights the increasing influence of anthropogenic activities, particularly urbanization and land-use intensification, on basin dynamics.

One of the most critical impacts is observed in the hydrological regime of the basin. The rapid expansion of built-up areas has led to an increase in impervious surfaces, which significantly reduces infiltration and enhances surface runoff. This results in higher peak discharge during rainfall events, increased flood susceptibility in urban regions, and reduced groundwater recharge. The alteration of natural drainage patterns due to urban expansion further exacerbates hydrological imbalances within the CRB.

The gradual decline in cropland and transitional land categories (such as scrubland and fallow land) indicates increasing land-use conversion towards urban and infrastructural development. While agricultural lands support moderate infiltration and evapotranspiration, their conversion into built-up areas reduces soil permeability and increases runoff generation, thereby impacting soil moisture dynamics and local hydrological processes.

The relatively stable or slightly increasing forest cover has a positive influence on basin hydrology and ecology. Forest ecosystems enhance infiltration, regulate runoff, reduce soil erosion, and contribute to groundwater recharge. However, localized fragmentation and land conversion in certain areas may still affect ecosystem connectivity and biodiversity.

The reduction in transitional land classes, including rangelands and scrublands, is another important concern. These areas act as ecological buffers, regulating runoff, preventing soil erosion, and supporting biodiversity. Their decline may lead to increased land degradation, sediment transport, and reduced resilience of the landscape.

Although the areal extent of water bodies appears relatively stable, changes in upstream land use can influence their functional characteristics, including storage capacity, sedimentation rates, and seasonal variability. Increased runoff due to urbanization can contribute to higher sediment loads in reservoirs, affecting their efficiency and long-term sustainability.

From a socio-economic perspective, the expansion of urban areas reflects population growth, economic development, and infrastructure expansion within the basin. However, this growth also increases pressure on water resources, land availability, and environmental sustainability. The interaction between demographic changes and land use transformation highlights the need for integrated basin management approaches.

The impact assessment indicates a shift towards a more urbanized and intensively utilized landscape, with significant implications for hydrological processes, ecological stability, and resource management. These findings emphasize the importance of adopting sustainable land use planning strategies to balance development with environmental conservation in the CRB.

6. Conclusion

The land use and land cover analysis of the CRB over the period 1992-2022 reveals significant spatial and temporal transformations driven by anthropogenic and natural factors. The basin is predominantly characterized by agricultural land use, which has remained the dominant land cover throughout the study period, although a slight decline is observed in recent years. Forest cover has remained relatively stable, with a marginal increasing trend, indicating the influence of conservation efforts and afforestation initiatives. The most notable change observed is the rapid expansion of built-up areas, which have increased more than fourfold over the study period. This reflects accelerated urbanization and infrastructure development across the basin, particularly around major cities. The decline in transitional land categories such as scrubland and fallow land further indicates increasing land-use intensification.

These changes have important implications for the hydrological regime of the basin, including increased surface runoff, reduced infiltration, and altered groundwater recharge patterns. The stability of water bodies suggests that major hydrological features remain intact; however, their functional dynamics may be influenced by upstream land use changes.

7. Recommendations and Role of Stakeholders

The observed changes in land use and land cover within the CRB highlight the need for integrated and sustainable management strategies. The following recommendations are proposed to ensure balanced development and environmental sustainability:

Land Use Planning and Management

Regulate unplanned urban expansion through effective land-use zoning and planning

Protect prime agricultural lands from conversion into built-up areas

Promote sustainable agricultural practices, including efficient irrigation and soil conservation

Forest and Ecosystem Conservation

Strengthen afforestation and reforestation programs in degraded areas

Protect existing forest cover, particularly in the Western Ghats

Restore scrublands and transitional ecosystems that act as ecological buffers

Water Resource Management

Conserve and restore traditional water bodies such as tanks, lakes, and wetlands

Promote rainwater harvesting and groundwater recharge initiatives

Integrate surface and groundwater management strategies

Urban Planning and Infrastructure

Encourage compact urban development to minimize land consumption

Incorporate green infrastructure to reduce runoff and improve infiltration

Improve stormwater drainage systems to manage urban flooding

Role of Stakeholders

Effective implementation of these strategies requires coordinated efforts from multiple stakeholders:

Government Agencies: Formulate policies, enforce land-use regulations, and implement conservation programs

Research Institutions: Conduct continuous monitoring, modelling, and impact assessment studies

Local Communities: Participate in sustainable land management and conservation practices

Urban Planners and Engineers: Develop environmentally sustainable infrastructure

Non-Governmental Organizations (NGOs): Promote awareness and community engagement

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