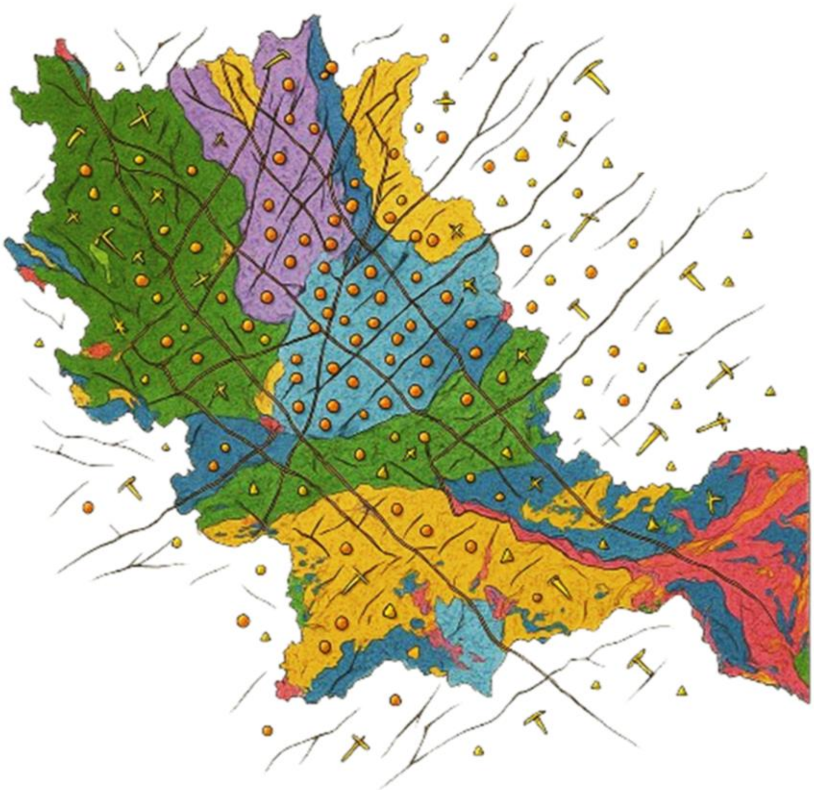
National River Conservation Directorate
Ministry of Jal Shakti,
Department of Water Resources,
River Development and Ganga Rejuvenation
Government of India

Geological Profile of Cauvery River Basin



March 2025

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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 CRB Management and Studies (cCauvery)

The Centre for CRB Management and 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

Centres 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 and Studies (cCauvery)
IISc Bengaluru (Lead Institute), NIT Tiruchirappalli (Fellow Institute)

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Abbreviations and Acronyms

%	Percentage
&	And
′	Minute
°	Degree
g	Gram
L	Litre
m	Metre
Ma	Mega Annum
sq. km	Square Kilometre
AMDER	Atomic Minerals Directorate for Exploration and Research
BHUKOSH	GSI National Geoscience Portal
CGWB	Central Ground Water Board
CRB	Cauvery River Basin
CUTN	Central University of Tamil Nadu
CWC	Central Water Commission
DEM	Digital Elevation Model
DGH	Directorate General of Hydrocarbons
DGM	Department of Geology and Mining
DSF	Discovered Small Fields
ECMI	Eastern Continental Margin of India
EIA	Energy Information Administration
ENE–WSW	East Northeast to West Southwest
EW	East West
GEE	Google Earth Engine
GOI	Government of India
GSI	Geological Survey of India
HELP	Hydrocarbon Exploration and Licensing Policy
KG	Krishna Godavari
LKM	Line Kilometre
LULC	Land Use/Land Cover
MBGL	Meters Below Ground Level
MCDR	Mineral Conservation and Development Rules
MMTOE	Million Metric Tonnes of Oil Equivalent
MODIS	Moderate Resolution Imaging Spectroradiometer
MoES	Ministry of Earth Sciences
MoPNG	Ministry of Petroleum and Natural Gas
Mb	Body Wave Magnitude
Ms	Surface Wave Magnitude
Mw	Moment Magnitude
M?	Magnitude Type Unknown
NDVI	Normalized Difference Vegetation Index
NELP	New Exploration Licensing Policy
NDR	National Data Repository
NNE–SSW	North Northeast to South Southwest – North South
NOC	National Oil Company
NW–SE	Northwest to Southeast

OALP	Open Acreage Licensing Policy
ONGC	Oil and Natural Gas Corporation Limited
PEL	Petroleum Exploration Licence
PGM	Precious Group Metals
PML	Petroleum Mining Lease
PSM	Petroleum System Modelling
SRTM	Shuttle Radar Topography Mission
TAMIN	Tamil Nadu Minerals Limited
TCF	Trillion Cubic Feet
USGS	United States Geological Survey
WNW–ESE	West Northwest to East Southeast
WRIS	Water Resources Information System

1. Introduction

The Cauvery River basin (CRB) is one of the major rivers of the peninsular India. It rises at an elevation of 1,341 m at Talakaveri on the Brahmagiri range near Cherangala village of Kodagu district of Karnataka and drains into the Bay of Bengal. The total length of the river from origin to outfall is around 800 km. In size, it is smaller than the Godavari, the Mahanadi and the Krishna. Its important tributaries joining from left are the Harangi, the Hemavati, the Shimsha and the Arkavati whereas the Lakshmantirtha, the Kabbani, the Suvarnavati, the Bhavani, the Noyyal and the Amaravati join from right (India WRIS, 2014).

A detailed geological profile of the CRB is essential for understanding its complex subsurface structure, stratigraphy, and resource potential. The basin's evolution through multiple tectonic phases from Gondwana rifting to post-collision sedimentation has resulted in a diverse assemblage of lithologies, including fossil-rich limestones, fluvial sandstones, and deltaic clays. Understanding these geological layers helps in assessing groundwater availability, mineral and hydrocarbon resources, and soil characteristics crucial for agriculture. The geological profile aids in identifying zones vulnerable to natural hazards such as subsidence or landslides and informs sustainable planning for infrastructure development, water management, and environmental conservation across the basin.

The CRB is witnessing significant anthropogenic and natural geological disturbances. Activities such as mining, tunnelling, fracking, and riverbed extraction have altered the basin's geomorphology. These interventions, along with deforestation and hill slope changes, have increased the risk of hazards like landslides, earthquakes, and sinkholes. Monitoring and managing these changes are crucial for sustainable development and disaster resilience in the region.

In August 2018, the southern state of Kerala 83 was hit by the most intense rainstorm in decades, causing severe flooding and triggering thousands 84 of landslides that resulted in 483 deaths across the state. In the Western Ghats, local daily rainfall 85 exceeded the long-term average by more than 36%, causing numerous slopes to fail in a short time; 86 in total, this event triggered an estimated 4728 landslides (Martha et al., 2019). The Wayanad landslide serves as a stark reminder of the ever-growing challenges posed by climate change and the necessity of adaptive, forward-looking disaster management. It is also important to study the forest dynamics, especially in global biodiversity hotspots for their ecological and climate significance. The Western Ghats Biodiversity Hotspot (WGBH), recognised as a UNESCO World Heritage site is a key testament to the ecological diversity in India (UNESCO; Bhagwat et al., 2005; Reddy et al., 2016).

Recent studies emphasize the importance of integrating geospatial tools and satellite-based monitoring to detect and analyse environmental changes in the CRB. Remote sensing techniques have proven instrumental in mapping deforestation, land use transitions, and surface deformation linked to human interventions and natural disasters. The interplay between geological processes and anthropogenic pressures has underscored the urgency for watershed-level planning and ecosystem restoration. Strengthening community-based disaster preparedness and implementing data-driven land management strategies are critical for ensuring long-term sustainability in the basin.

2. Basin Configuration

CRB is a peri-cratonic rift basin covering an area of over 50,000 sq. km, encompassing both onshore and offshore regions with water depths reaching up to 2,000 m. Situated in the southern segment of the Eastern Continental Margin of India (ECMI), it is recognized as a Category I petroliferous basin, indicating proven hydrocarbon reserves and active production (Mukherjee et al., 2025).

The basin hosts a sedimentary succession over 6,000 meters thick, spanning from the Permian to the present, and has been the focus of intensive hydrocarbon exploration through drilling (Raju & Reddy, 2016; Reddy et al., 2013). Along the western margin in Tamil Nadu's Ariyalur district, Aptian to Palaeocene strata marked by prominent major and minor unconformities are prominently exposed (Nagendra & Reddy, 2017).

The basement geology of the CRB is primarily composed of Archean to Late Proterozoic crystalline rocks, accounting for nearly 80% of the region. The remaining area features Phanerozoic sedimentary rocks, predominantly found along the coastal zones and inland river valleys. The hard rock landscape is largely made up of Charnockite and Khondalite groups along with their migmatitic variants, in addition to supracrustal formations from the Sathyamangalam and Kolar Groups and the Peninsular Gneiss Complex. These units have been intruded by ultramafic bodies, basaltic dykes, granites, and syenites (CUTN, 2022).

The major structural elements of the CRB include (DGH India):

- Ariyalur-Pondicherry Depression
- Kumbakonam-Madnam-Portonovo High
- Tranquebar Depression
- Karaikal High
- Nagapattinam Depression
- Vedaranyam High
- Thanjavur Depression
- Pattukottai-Manargudi Ridge
- Mandapam Ridge
- Mannar Depression
- Vedaranyam-Tiruchirapalli Fault

2.1. Geological Overview

The CRB is largely underlain by Archean-aged (>2500 Ma) gneissic, charnockitic, and granitic rocks. Geologically, the basin is divided into two main terranes: the Dharwar Craton in the north and the southern granulite terrane. These are separated by a transitional zone in the north, where granitic bodies and supracrustal belts (schist belts) have undergone metamorphism, typically reaching amphibolite facies or lower grades (Fathima et al., 2023). South of this transition, the granitic and supracrustal units exhibit high-grade metamorphism, forming granulite-facies rocks such as charnockites, pyroxene granulites, and high-grade amphibolites. The gneissic and charnockitic rocks in this transitional zone have been radiometrically dated to between 3000 and 2500 Ma (Friend and Nutman, 1991). A major fault and thrust zone mark the boundary between the Dharwar Craton and the granulite belt, where charnockite terrains have been uplifted and thrust over the cratonic rocks (Radhakrishna, 1968).

2.2. Tectonic Dynamics

The CRB exhibits evolutionary trends, stratigraphic sequences, and sea-level fluctuation patterns comparable to those observed in several central European basins, such as the Danish Basin, North Sea Basin, North German Basin, and the Northern Gulf of Mexico Basin (Nagendra et al., 2011a, 2011b). During the Archean and Proterozoic eras, the basin's crystalline foundation underwent a complex geological evolution involving multiple deformation phases, anatexis (partial melting of existing rocks), magmatic intrusions, and successive metamorphic events. In the northern and central parts of the basin, the Precambrian terrain of Tamil Nadu is characterized by intense fracturing and deep faulting. In contrast, the overlying Phanerozoic sedimentary formations have largely retained their primary structural features, with bedding planes that range from nearly horizontal to inclinations of up to 100°. The underlying crystalline basement displays strong evidence of polyphase deformation and metamorphism, marked by well-developed foliation patterns that follow lithological boundaries. Later tectonic activity introduced additional S-fabrics, adding further complexity to the basin's structural architecture.

The regional structural trends of the CRB vary across different sectors. The predominant trend follows an NNE-SSW orientation, characterized by long, linear, canoe-shaped folds. In the northwest, the structural trend shifts closer to NS, displaying evidence of multiphase folding, though distinct regional structures remain undefined. The central region exhibits a diverse structural pattern, with trends varying from EW to ENE-WSW and WNW-ESE. South of the Tambaraparani River, a pronounced NW-SE structural grain is observed, reflecting the influence of tectonic forces that have shaped the basin's evolution over geological time.

Several Precambrian shear zones have been identified, including:

- Moyyar Shear Zone
- Bhavani Shear Zone
- Salem Shear Zone
- Attur Shear Zone
- Cauvery Shear Zone
- Dharmapuri Shear Zone
- Gangavalli Shear Zone
- Achankovil Shear Zone

These shear zones played a crucial role in shaping the basin's structural complexity and controlling its hydrocarbon potential (CUTN, 2022).

2.3. Stratigraphic Overview

The stratigraphic framework of the CRB has been established through a synthesis of surface geological mapping and subsurface datasets obtained from seismic interpretations and drilling records. The basin rests on a Precambrian basement composed predominantly of granites and gneisses, prominently exposed along its western margin. Overlying this crystalline foundation are sedimentary successions from the Late Jurassic to Early Cretaceous, including Gondwana units such as the Shivganga Beds and the fossiliferous Therani Formation, which contains index fossils like Ptilophyllum acutifolium.

The Early Cretaceous sequence, referred to as the Uttatur Group, comprises surface formations like Kalakundi, Karai Shale, and Maruvathur Clay, with their subsurface counterparts represented by the Andimadam, Sattapadi, and Bhuvanagiri Formations. The Andimadam Formation extending across structural depressions such as the Ramnad, Tanjore, Tranquebar, and Ariyalur-Pondicherry grabens consists primarily of micaceous sandstones and silty shales. The marine-derived Sattapadi Shale functions as a key hydrocarbon source rock, while the Bhuvanagiri Formation, dominated by sandstones, reflects deposition in environments ranging from the middle shelf to upper bathyal settings. The Palk Bay Formation, unique to the Palk Bay region, is composed of calcareous sandstones and sandy claystones deposited in a fan-delta environment. The Late Cretaceous interval includes the Trichinopoly and Ariyalur Groups, which feature prominent lithological units such as Kudavasal Shale, Nannilam Formation, Porto-Novo Shale, and Komarakshi Shale, deposited in a variety of marine and fine-grained sedimentary settings.

The Tertiary succession, well-preserved both at the surface and in the subsurface, includes the Niniyur Formation (Paleocene) and the Cuddalore Sandstone (Mio–Pliocene). In the subsurface, these are grouped into the Nagore and Narimanam Groups, demarcated by regional unconformities. The Nagore Group, spanning the Paleocene to Eocene, includes formations such as Kamalapuram, Karaikal Shale, Pandanallur, and Tiruppundi. The overlying Narimanam Group encompasses younger formations including Niravi, Kovilkalappal, Shiyali Claystone, Vanjiyur Sandstone, Tirutaraipundi Sandstone, Madanam Limestone, Vedaranniyam Limestone, and the Tittacheri Formation, deposited in settings ranging from shallow marine to deltaic environments. The Tittacheri Formation, which grades into the Cuddalore Sandstone, marks the stratigraphic transition from the Miocene to Pliocene (DGH, India).

3. Source of Datasets

The assessment of the CRB integrates diverse datasets to understand its geological and geomorphic processes. BHUKOSH, the official portal of the Geological Survey of India (GSI), provides authoritative data on lineaments and landslide inventories, which are critical for hazard zonation and structural mapping. Seismic and geological references are supplemented by the United States Geological Survey (USGS), while petroleum exploration and resource data are provided by the Directorate General of Hydrocarbons (DGH), Ministry of Petroleum and Natural Gas (MoPNG), and the National Data Repository (NDR). Mineral inventory statistics are obtained from the Ministry of Mines, and broader oil and gas trends are referenced from the U.S. Energy Information Administration (EIA). Remote sensing and satellite imagery support assessments of tectonic activity, landform changes, and coastal morphology. In addition, peer-reviewed scientific journals and official government reports offer valuable insights into specific events such as tsunamis, earthquakes, and erosion patterns in the basin.

For analysing hill slope changes, satellite-derived elevation models such as the SRTM DEM (USGS) and NASA DEM are accessed via Google Earth Engine (GEE). These datasets facilitate terrain analysis and slope classification. Sentinel-2 imagery support land use/land cover (LULC) and deforestation studies, Additional inputs such as OpenLandMap soil layers and MODIS land cover products further enhance the spatial understanding required for sustainable basin management and disaster mitigation.

4. Excavations, explosions and mining activities in the basin

Human interaction with the Earth's surface and subsurface is driven by numerous objectives ranging from construction and infrastructure development to mineral resource extraction and scientific exploration. Three foundational components of such geotechnical and geoscientific operations are excavations, explosions, and mining activities. Each of these processes influences the physical environment and is associated with specific techniques, hazards, and applications. Table 1 provides a consolidated overview of excavation-related activities across the CRB to understand the scale and diversity of excavation practices in the region.

Table 1. Overview of various excavation-related activities in the CRB

Type	Government Agency	Region / Purpose	Presence of Explosion
Archaeological Excavations	Tamil Nadu Dept. of Archaeology, ASI	Kodumanal (Erode), Karur, Keeladi	No
Quarrying & Mining Operations	Tamil Nadu Minerals Ltd (TAMIN)	Granite, vermiculite, limestone, industrial minerals	Yes
Irrigation/Infrastructure Works	Govt Public Works / Irrigation Departments	Dam-related excavations, rock cutting	Possibly minor controlled blasting
State Mining Departments	Karnataka Dept. of Mines & Geology	Iron ore, granite, limestone quarries in CRB	Yes

The depth of quarrying in the Charnockite rocks for excavating Rough Stone in the villages of Erode district varies from 10m to more than 45m. As the Charnockite rock is predominantly massive and without joints in nature, the water table has not encountered up to the known depth of 45m. Hence, the depth of quarrying of Rough Stones may be allowed 2m above the ground water table level. The thickness of the weathered part which occurs over the

Charnockite varies from 2m to 5m and it varies from place to place. The weathered part is used as earth fill (locally called as gravel). Photographs of a granite quarry and a stone quarry are presented in Figs. 1 and 2.

Fig. 1. Granite quarry in Kinathukadavu

(Source: DGM, Tamil Nadu)

Fig. 2. Field photograph of Stone quarry located in Perode village, Erode Taluk of Erode district (Source: DGM, Tamil Nadu)

4.1. Karnataka

As per the National Mineral Inventory (2020), Karnataka is one of India's most resource-rich states, hosting 79% of the country's vanadium ore, 69% of iron ore (magnetite), 41% of tungsten ore, 36% of asbestos, 25% of limestone, 25% of manganese ore, 19% of primary gold ore, 12% of kyanite, and 7% of platinum group metal (PGM) resources. Major mineral occurrences include bauxite in Belagavi, Chikkamagaluru, Uttara & Dakshina Kannada, and Udupi districts; chromite in Chikkamagaluru, Hassan & Mysuru; gold in Chitradurga, Dharwad, Kalaburagi, Hassan, Haveri, Kolar, Raichur & Tumakuru; hematite iron ore in Bagalkot, Bellary, Chikkamagaluru, Chitradurga, Dharwad, Davangere, Gadag, Uttara Kannada, Shivamogga & Tumakuru; magnetite iron ore in Chikkamagaluru, Hassan, Uttara & Dakshina Kannada and Shivamogga; kyanite in Chikkamagaluru, Chitradurga, Coorg, Mandya, Mysuru, Shivamogga & Dakshina Kannada; and limestone widely distributed across Bagalkot, Belagavi, Bellary, Chikkamagaluru, Chitradurga, Davangere, Gadag, Kalaburagi, Hassan, Mysuru, Uttara & Dakshina Kannada, Shivamogga, Tumakuru & Udupi districts. Additionally, magnesite occurs in Coorg, Mandya & Mysuru; manganese ore in Belagavi, Bellary, Chikkamagaluru, Chitradurga, Davangere, Uttara Kannada, Shivamogga & Tumakuru; and other minerals like asbestos, pyrite, copper, graphite, molybdenum, nickel, PGM, sillimanite, silver, titanium minerals, tungsten, vanadium, and vermiculite are also present in various districts.

Karnataka remains a leading producer of several key minerals. The state contributes 94% of India's gold ore and 93% of primary gold production, continuing its dominance in the gold sector. Iron ore output recorded a 3% increase in quantity and 21% in value, while limestone production grew by 5%. Magnesite and manganese ore output showed moderate growth, whereas limeshell production surged by an impressive 256%, accompanied by a significant rise in value. During 2023–24, a total of 177 mines in Karnataka reported production under the Mineral Conservation and Development Rules (MCDR) framework, reflecting active mining operations across the state (Ministry of Mines, INDIA).

4.2. Tamil Nadu

As per National Mineral Inventory (2020), Tamil Nadu is the leading holder of country's resources of vermiculite, molybdenum, rutile, garnet, and ilmenite. The State accounts for the country's 79% vermiculite, 46% garnet, 66% molybdenum, 34% magnesite, 27% titanium minerals, 24% sillimanite, 8% PGM and 5% each graphite & iron (magnetite) resources. Important minerals that are found to occur in the State are: bauxite in Dindigul, Namakkal, Nilgiris & Salem districts; garnet in Ramanathapuram, Tiruchirapalli, Tiruvarur, Kanyakumari, Thanjavur & Tirunelveli districts; graphite in Madurai, Ramnathapuram, Sivaganga & Vellore districts; Similarly, occurrences of minerals, such as, limestone in Ariyalur, Coimbatore, Cuddalore, Dindigul, Kanchipuram, Karur, Madurai, Nagapattinam, Namakkal, Perambalur, Ramnathapuram, Salem, Thiruvallur, Tiruchirapalli, Tirunelveli, Vellore, Villupuram & Virudhunagar districts; magnesite in Coimbatore, Dharmapuri, Karur, Namakkal, Nilgiri, Salem, Tiruchirapalli, Tirunelveli & Vellore districts; titanium minerals in Kanyakumari, Nagapattinam, Ramanathapuram, Thiruvallur, Tirunelveli & Thoothukudi districts; vermiculite in Dharmapuri, Tiruchirapalli & Vellore districts; and zircon in Kanyakumari district have been established.

Other minerals that occur in the state are apatite in Dharmapuri & Vellore districts; chromite in Coimbatore & Salem districts; copper, lead-zinc & silver in Villupuram district; gold in Dharmapuri district; iron ore (magnetite) in Dharmapuri, Erode, Nilgiris, Salem, Thiruvannamalai, Tiruchirapalli & Villupuram districts; kyanite in Kanyakumari & Tirunelveli districts; molybdenum in Dharmapuri, Dindigul & Vellore districts; pyrite in vellore district;

sillimanite in Kanyakumari, Karur & Tirunelveli districts; tungsten in Madurai districts and wollastonite in Dharmapuri & Tirunelveli districts.

The principal minerals produced in the state are Graphite, Limestone, Magnesite, Marl, Minor Mineraland Vermiculite. Tamil Nadu saw mixed results across its minerals. Limestone production increased by 9%, contributing 6% to the national total. Graphite production grew by 46%, while vermiculite production experienced a 100% increase from the previous year. On the other hand, marl production fell by 11%, and the state's magnesite production, despite a 26% rise in quantity, showed only modest growth in value. The number of mines in Tamil Nadu that submitted MCDR returns during 2023-24 is 222.

4.3. Kerala

Kerala is well-known for its deposits of excellent quality china clay and beach sands containing valuable minerals like ilmenite, rutile, sillimanite, zircon, garnet, leucoxene and monazite. The State is the principal producer of limeshell and sillimanite. The State also accounts for 23% china clay and 10% sillimanite of the country's resources. As per AMDER of the Department of Atomic Energy, Kerala state accounts for 144.02 million tonnes of ilmenite, 7.83 million tonnes of rutile and 7.96 million tonnes of zircon resources. Important mineral occurrences in the State are: bauxite in Kannur, Kasaragod, Kollam & Thiruvananthapuram districts; china clay in Alappuzha, Ernakulam, Kannur, Kasaragod, Kollam, Kottayam, Palakkad, Thiruvananthapuram & Thrissur districts; limestone in Alappuzha, Ernakulam, Kannur, Kollam, Kottayam, Kozhikode, Malappuram, Palakkad & Thrissur districts; quartz/silica sand in Alappuzha, Kasargod, Thiruvananthapuram & Wayanad districts; sillimanite in Kollam & Thiruvananthapuram districts; and titanium minerals in Kasaragod, Kollam, Pathanamthitta & Thiruvananthapuram districts. Other minerals that occur in the State are fire clay in Alappuzha, Ernakulam, Kannur & Kollam districts; garnet in Kollam & Thiruvananthapuram districts; gold in Malappuram & Palakkad districts; granite in Palakkad & Thiruvananthapuram districts; graphite in Ernakulam, Idukki, Kollam, Kottayam & Thiruvananthapuram districts; iron ore (magnetite) in Kozhikode & Malappuram districts; kyanite in Kollam & Thiruvanantha-puram districts; lignite in Kannur districts; magnesite in Palakkad district; and steatite in Kannur & Wayanad districts (Ministry of Mines, GOI) (Fig. 3).

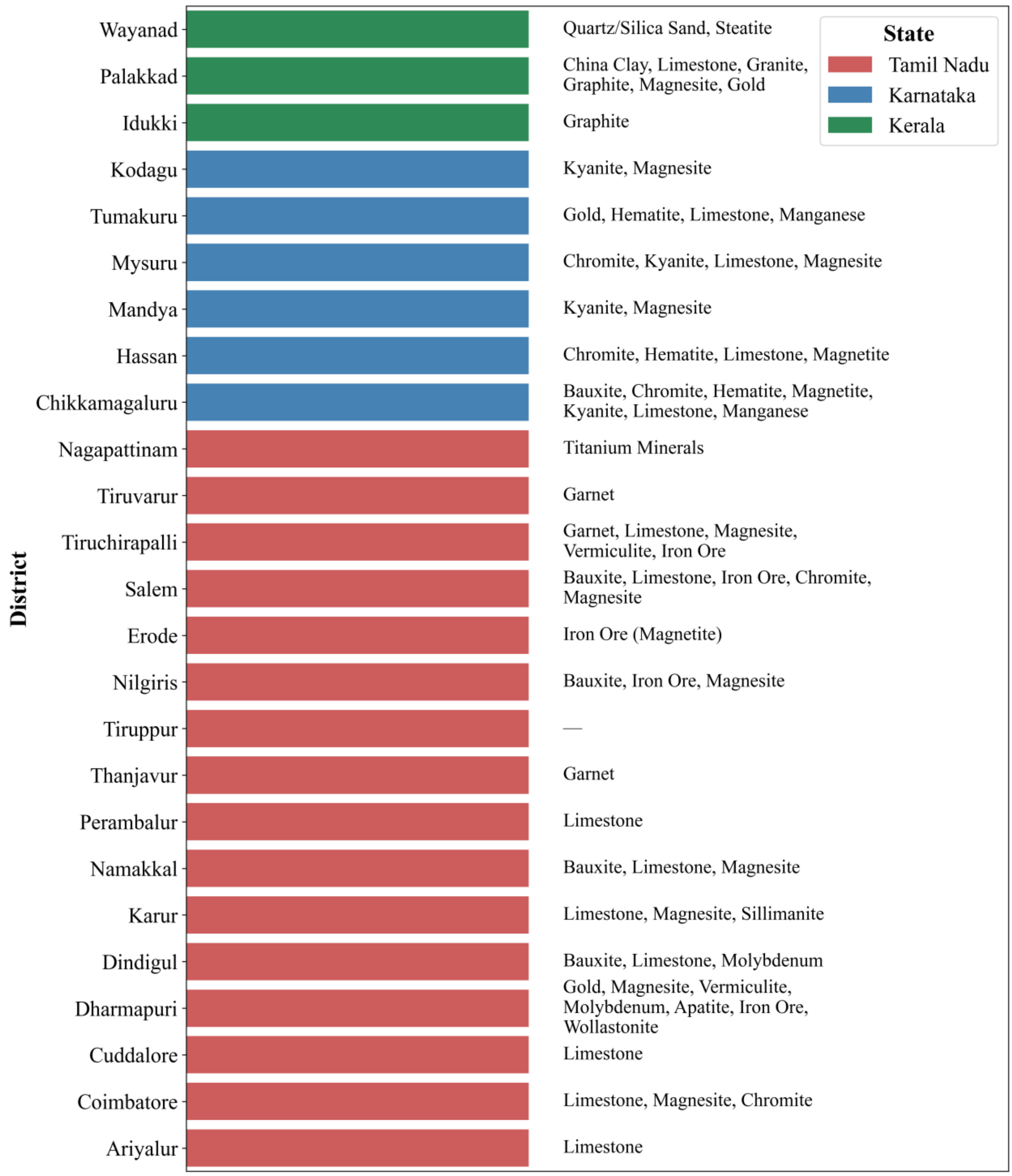


Fig. 3. District-wise distribution of major mineral occurrences across the CRB

(Source: Indian Minerals Yearbook 2023, Ministry of Mines, GOI)

The CRB hosts a wide range of economically significant mineral resources. In Kerala, the districts of Idukki, Palakkad, and Wayanad feature key deposits such as graphite (Idukki), a combination of china clay, limestone, granite, gold, graphite, and magnesite (Palakkad), and quartz/silica sand and steatite (Wayanad). Karnataka's basin districts, Chikkamagaluru, Hassan, Mandya, Mysuru, Tumakuru, and Kodagu-contain diverse minerals including bauxite, chromite, hematite and magnetite iron ores, kyanite, limestone, manganese ore, magnesite, and gold. Tamil Nadu's portion of the basin, encompassing sixteen districts, shows even greater mineral diversity. Notable occurrences include limestone (widespread across most districts), magnesite and iron ore (magnetite) in several locations, and specific minerals like bauxite (Dindigul, Namakkal, Salem, Nilgiris), gold (Dharmapuri), vermiculite, molybdenum, apatite, chromite, wollastonite, sillimanite, garnet, and titanium minerals in select districts such as Dharmapuri, Karur, Tiruchirapalli, and Nagapattinam. This mineral richness underscores the geological complexity and resource potential of the CRB across the three southern Indian states. Fig. 4 shows the spatial distribution of different categories of degraded and problematic lands, overlaid with the CRB.

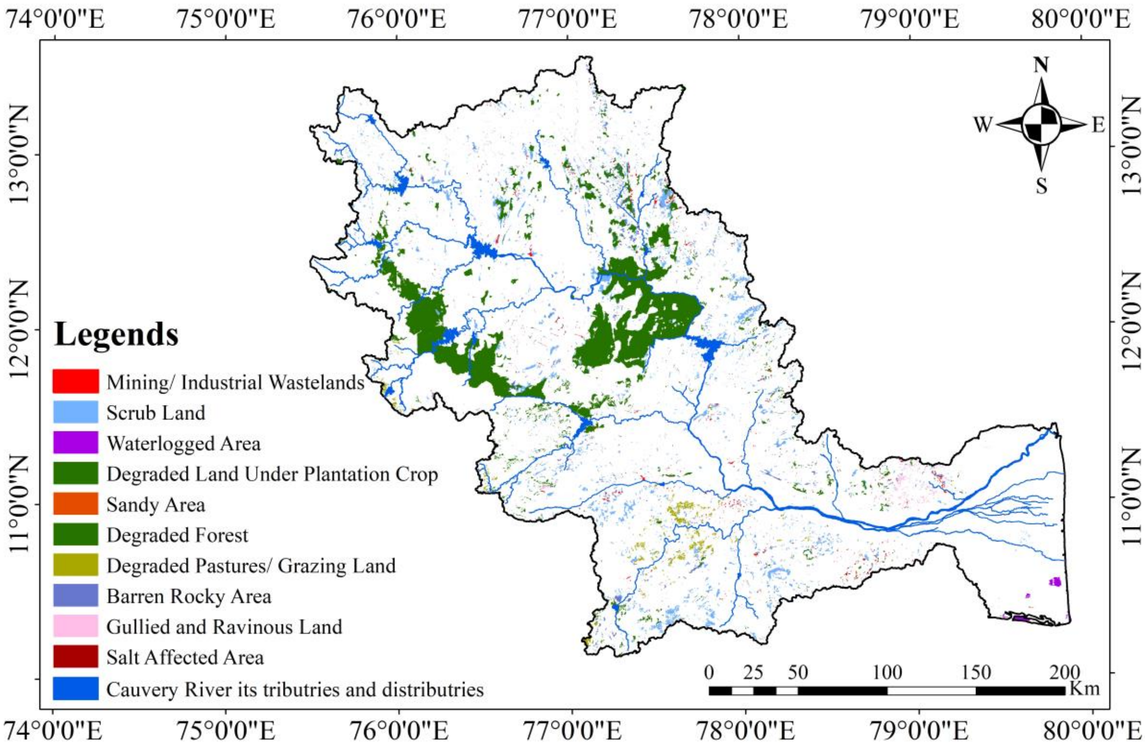


Fig. 4. Spatial distribution of various categories of wastelands in the CRB (2015-16)

(Source: India WRIS)

5. Tunnelling Data

Tunnelling in CRB presents a fascinating interplay of ancient terrains, sedimentary basins, and rapidly evolving infrastructure demands. In Karnataka, the iconic Bagur–Navile Water Tunnel with its 9.7 km of excavation at depths between 23m and 60 m under the terrain of Channarayapatna was driven through basaltic and crystalline formations in a project that spanned 1979 to 1990. Engineering geological records from this and similar irrigation tunnels reveal a range of challenges: faulted crystalline basement, jointed rock-mass, and variable groundwater inflow, requiring detailed borehole logging and hydrological assessment.

The tunnelling data landscape for Karnataka, Kerala, Tamil Nadu and Puducherry emphasizes geotechnical richness, successful execution hinges on thorough geological-engineering investigations, detailed borehole and rock-mass characterization, pre-alignment hazard assessment, and real-time monitoring systems for deformation, water ingress, and vibrations. Furthermore, the interplay of natural hazards-landslides in West Coast Ghat terrain, saprolite instabilities in the Deccan plateau and granite-gneiss domains, and ecological sensitivities-demands an integrated risk-informed design and adaptive construction strategy. Although exact counts may vary (main vs. subsidiary tunnels), the core infrastructure within the CRB is described in Table 2.

Table 2. Major Tunnels within the CRB

State/Region	Tunnel Name	Type	Length	Year Completed	Purpose	Source
Karnataka (Hassan)	Bagur–Navile Tunnel	Water-conveyance	~9,700 (m)	1979–1990	Hemavati Shimsha inter-basin irrigation	https://en.wikipedia.org/wiki/Bagur_Navile_Tunnel
Karnataka (Ramanagaram)	Sathegala–Ramanagaram Tunnel	Water-conveyance	~11,200 (m)	Under construction	Drinking water project for Bangalore	(Project X India) https://projectxindia.com/2022/08/27/11-2-km-tunnel-to-transport-river-cauvery-water-from-sathegala-weir-to-ramanagara/?utm_source=chatgpt.com
Kerala (Thrissur–Palakkad)	Kuthiran Tunnel	NH-544	1.6 km, twin tube	Completed	Highway Tunnel	https://blognhai.wordpress.com/2021/12/22/kuthiran-tunnel-keralas-first-ever-road-tunnel/

6. Hill Slope Change

Hill slope change refers to the alteration in the gradient, shape, or stability of slopes over time due to natural processes or human interventions. In river basins like CRB, especially along the Western Ghats and highland regions, slope changes play a crucial role in influencing soil erosion, runoff patterns, landslide susceptibility, and sediment transport to downstream systems. Hill slope change is essential for effective watershed management, disaster risk reduction, and sustainable land use planning.

To assess the temporal variation in terrain steepness within the CRB, a slope change analysis was performed using multi-temporal Digital Elevation Model (DEM) available in Google Earth Engine (GEE). The study utilized the Shuttle Radar Topography Mission (SRTM) DEM, representing conditions around the year 2000, and the NASADEM dataset, which reflects surface elevations circa 2020. Both datasets have a spatial resolution of 30m and were clipped to a predefined basin. Using GEE, slope layers were generated for each DEM, representing surface inclination in degrees. The slope change was calculated by subtracting the SRTM-derived slope from the NASADEM-derived slope, resulting in a raster that quantifies changes in slope over a two-decade period. This allowed identification of areas that have experienced significant geomorphological transformations, potentially due to erosion, deforestation, infrastructure development, or other anthropogenic activities.

The map illustrates the spatial distribution of slope changes across the CRB, based on a comparative analysis of DEM over time (Fig. 5). This type of analysis is a valuable tool for understanding surface processes, geomorphic transformations, and potential anthropogenic impacts within a watershed.

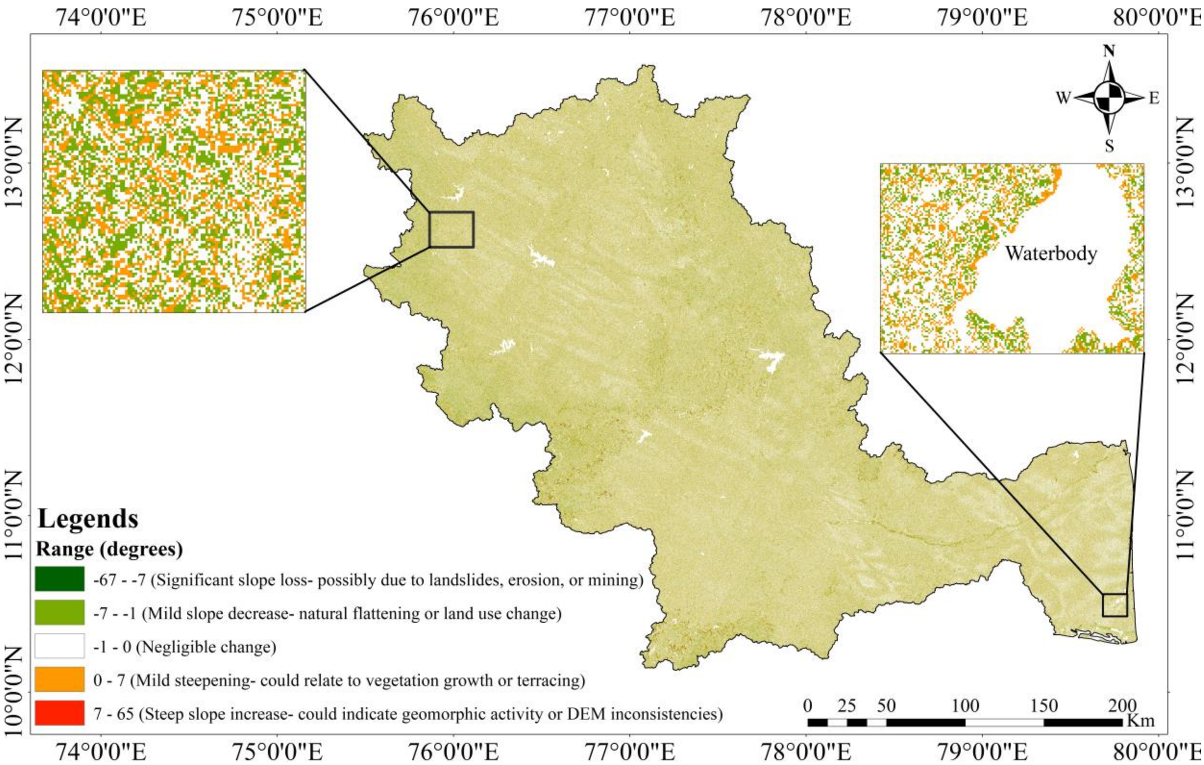


Fig. 5. Slope change detection across the CRB

Fig. 5 categorizes slope changes into five classes, ranging from significant slope loss (depicted in dark green) to steep slope increase (in red). Areas that exhibit a significant decrease in slope (ranging from -67° to -7°) may be indicative of geomorphic disturbances such as landslides, riverbank erosion, deforestation, mining activities, or construction projects such as roads and dams. These regions are crucial for hazard monitoring, especially in hilly terrains or areas prone to instability.

Moderate slope decreases (-7° to -1°) are interpreted as signs of natural flattening, possibly due to sediment deposition or minor land-use changes such as agricultural expansion. Meanwhile, negligible changes (-1° to 0°) dominate the landscape, indicating areas with relatively stable topography over the observed time span.

On the other end of the spectrum, mild steepening (0° to 7°) may be linked to vegetation growth or terracing activities, which alter surface roughness without significantly reshaping the terrain. Steep slope increases (7° to 65°, shown in red) may suggest more dynamic geomorphic changes or errors associated with DEM inconsistencies, such as resolution differences, sensor noise, or misregistration between datasets. These areas warrant further ground-based or remote sensing investigation.

This map demonstrates the spatial heterogeneity of geomorphic activity in the CRB and helps identify zones that are undergoing active transformation, either due to natural processes or human intervention. Such analyses are vital for watershed management, hazard mitigation planning, and sustainable land-use policy formulation.

7. Natural Geological Hazards in the CRB

The CRB and its adjoining areas, spanning Tamil Nadu, Karnataka, and Kerala, have experienced a range of natural geological hazards including tectonic movements, earthquakes, landslides, and coastal transformations driven by tsunamis. These hazards have shaped the geomorphology of the region and pose critical challenges to infrastructure, agriculture, and human settlements. A detailed understanding of these events, drawn from remote sensing data, seismic records, and sedimentological studies, is essential for regional planning and disaster risk reduction.

7.1. Tectonic and Geomorphic Hazards in the Cauvery Delta

Remote sensing investigations in the Cauvery Delta have identified significant geomorphic anomalies such as uplifted coastal ridges, offset drainages, warped palaeochannels, and sudden river course changes (Ramasamy & Saravanavel, 2020). These features point toward recent crustal activity, particularly vertical uplift and tilting, indicating that the region is still tectonically active. The detection of prominent NE–SW and NW–SE trending lineaments has further reinforced the hypothesis of active fault systems. Such movements could trigger secondary hazards like land subsidence, floodplain deformation, and instability in river dynamics.

7.2. Tsunami Impacts on Coastal Morphology

The Sumatra tsunami (26 December 2004) had a devastating impact along the Tamil Nadu coast. In Kalpakkam, the tsunami inundated up to 530 meters inland, depositing extensive sand sheets (Anandan & Sasidhar, 2011). Coastal vegetation such as Casuarina trees and sand dunes withstood the force and minimized inland damage in some zones. In contrast, Vellar estuary witnessed flattening of dunes and reconfiguration of the estuarine mouth (Pari et al., 2008). Additionally, fishing infrastructure was destroyed, with boats displaced over 1.5 km inland and more than 200 deaths reported.

Along the South Kerala coast, the tsunami induced severe beach erosion, destruction of berms and backshores, and formation of tidal flats (Rasheed et al., 2006). Similarly, the East Coast of Tamil Nadu experienced widespread geomorphic and sedimentological changes including erosion of estuaries, breaching of coastal ridges, and deposition of marine sediments forming new sandbars and spits (Singarasubramanian et al., 2005).

7.3. Earthquake Activity in the CRB Region

Though considered part of the relatively stable Peninsular Shield, the CRB and its surrounding regions in Tamil Nadu, Karnataka, Kerala, and Puducherry have experienced several notable earthquakes over the past century, underlining the latent tectonic stress in the area. One of the earliest and most significant events was the Coimbatore earthquake of 8 February 1900, widely felt across southern India, and remains the largest historical seismic event in this region. Subsequent tremors, including the 1938 (M~5.8) and 1993 (M~5.2) earthquakes in the Gulf of Mannar, further revealed offshore seismic vulnerabilities along the southeastern coastline. On 29 July 1972, a moderate Mb 5.0 earthquake occurred again in Coimbatore, showing recurrence of seismic activity in that zone.

A particularly impactful event was the 26 September 2001 earthquake (Mw 5.5) off the coast of Puducherry in the Bay of Bengal, resulting in three fatalities and structural damage along the Tamil Nadu–Puducherry coastline. Around the same region, the catastrophic 2004 Indian Ocean earthquake and tsunami, with a moment magnitude of Mw 9.1–9.3, caused devastating human loss in Tamil Nadu, particularly in Nagapattinam district, and remains one of the deadliest seismic events in history. More localized seismic occurrences include the 7 June 2008 (M~3.8) tremor in the Palar Valley, and the 12 August 2011 (M~3.5) earthquake near Ariyalur in the CRB, which led to one reported death and minor damages across Perambalur, Tiruchirappalli, and Villupuram districts.

Karnataka, while not frequently affected, experienced a strong Mw 6.5 earthquake on 11 December 1967, underscoring the importance of monitoring deep-seated faults even in low-seismicity zones. More recently, on 3 March 2020, twin earthquakes of Mw 4.6 occurred, one north of Thiruvananthapuram (Kerala) and the other near Tirunelveli (Tamil Nadu), highlighting continuing tectonic adjustments in the southern tip of the Indian peninsula.

7.4. Landslides in the Western Ghats and Basin Highlands

Between 2015 and 2022, the states falling within the CRB i.e., Kerala, Tamil Nadu, Karnataka and Puducherry witnessed a considerable number of landslide events, as documented by the Geological Survey of India (GSI) and presented in an official Lok Sabha reply by the Ministry of Mines. Kerala, owing to its rugged terrain and intense monsoonal rainfall, recorded the highest number of landslides, totalling 2,239 incidents particularly concentrated in the Western Ghats region. Tamil Nadu reported 196 landslides, with many occurring in the Nilgiri and Kodagu hills, areas characterized by steep slopes and increasing anthropogenic pressure such as deforestation and infrastructure development. Karnataka, another state with significant hill terrains in the Western Ghats, reported 194 landslide events during the same period (Table 3). These figures underline the geomorphological vulnerability of the CRB, especially where land use changes, quarrying, and heavy rainfall converge to destabilize slopes, emphasizing the need for proactive landslide risk mapping and mitigation strategies.

Table 3. Major Geological and Coastal Hazards in the CRB and Adjacent Coastal Regions

Hazard	Description	Study Area	Key Findings	Source
Tectonic/ Geomorphic	Land surface deformation caused by crustal movement, faulting, or seismic uplift	Cauvery Delta, Tamil Nadu	1. Several geomorphic anomalies (e.g., uplifted coastal ridges, warped palaeochannels, offset drainages) suggest recent tectonic activity. 2. Detected vertical uplifts and tilting of landforms, especially in the delta front and interdistributary areas. 3. Remote sensing revealed changes in river course alignments, 4. attributed to fault-induced tilting or vertical displacement. 5. Identified major NE–SW and NW–SE trending lineaments interpreted as active faults.	Remote sensing revealed geomorphic anomalies and recent earth movements in Cauvery delta, Tamil Nadu, India (Ramasamy & Saravanavel, 2020)
Tsunami (Dec. 2004)	Changes in coastal morphology	Kalpakkam, East Coast Tamil Nadu	1. Inundation ranged from 95 to 530 meters inland. 2. Total area affected: 4.0 km^2. 3. Extensive sand deposition along the shore (some with monazite traces). 4. Shift in shoreline due to transgression and regression of the sea.	Changes in coastal morphology at kalpakkam, east coast, India due to 26 december 2004 sumatra tsunami (Anandan & Sasidhar 2011)

			5. Coastal vegetation such as scrubs, grasses, conifers, small trees uprooted or washed away. 6. Casuarina trees and sand dunes with vegetation acted as natural tsunami barriers, reducing inland impact.	
Tsunami Dec. 2004)	Morphological changes at Vellar estuary	Vellar estuary	1. The Vellar estuary on India's southeast coast underwent extensive erosion, sand dune flattening, formation of tidal flats, and reconfiguration of the estuarine mouth. 2. The tsunami eroded coastal sand dunes, forming a tidal flat of 31 ha, and washed away natural protective features like barrier islands. 3. Fishing villages were inundated, with boats thrown 1.5 km inland and over 200 casualties reported. 4. Sediment deposition created shallow zones in the estuary's inlet, hindering navigation for fishing vessels.	Morphological changes at vellar estuary, India- impact of the December 2004 tsunami (Y. Pari et al. 2008)

Tsunami (Dec. 2004)	impacts on morphology of beaches	South Kerala Coast	1. Severe erosion of beach berms and backshores. 2. Creation of tidal flats, breach of beach ridges. 3. Sediment was eroded from the seaward side and deposited inland. 4. Vegetation reduced erosion, but most of it was destroyed during wave run-up. 5. Some existing seawalls were destroyed by the tsunami.	Tsunami impacts on morphology of beaches along South Kerala coast, west coast of India (Rasheed et al., 2006)
Tsunami (Dec. 2004)	Geomorphic and Sedimentological Changes in the East Coast of Tamil Nadu	East Coast of Tamil Nadu	1. Coastal dunes, estuaries, and sand ridges were eroded or breached. 2. Formation of new erosional channels, deposition of shelf sediments, and coastal flattening observed. 3. Sand bars developed perpendicular to the coast near M.G.R. Tittu. 4. Spits, tombolos, tidal flats, and barrier dunes along the coast were disrupted. 5. Coastal morphology changed significantly due to differential erosion and deposition. 6. Heavy mineral layers with erosion structures identified in deposits.	Geomorphic and sedimentological changes in the east coast of Tamil Nadu by Indian ocean tsunami-2004. (Singarasubramanian et al., 2011)

Earthquake (26 September 2001)		Tamil Nadu & Puducherry	A moderate earthquake occurred in the Bay of Bengal, off the coast of the union territory of Puducherry, on 25 September 2001 at 20:26 PM local time resulting in three deaths and minor damage to property in Puducherry and coastal Tamil Nadu. It had a magnitude of Mw=5.5.	https://asc-india.org/seismi/seis-tamil-nadu.htm
Earthquake (08 February 1900)		Coimbatore area, Tamil Nadu	Known as the Coimbatore earthquake, it was felt over a large section of south India and is the largest event during the historical period.	https://asc-india.org/seismi/seis-tamil-nadu.htm
Earthquake (10 September 1938)		Gulf of Mannar	Gulf of Mannar (M? 5.8 (3)	https://asc-india.org/seismi/seis-tamil-nadu.htm
Earthquake (29 July 1972)		Coimbatore area, Tamil Nadu	Maximum observed intensity VI (3). This event was centred in the eastern section of the city of Coimbatore. Mb 5.0 (2).	https://asc-india.org/seismi/seis-tamil-nadu.htm
Earthquake (06 December 1993)		Gulf of Mannar	Felt in Colombo, Sri Lanka. Mb 5.2, Ms 4.7 (5)	https://asc-india.org/seismi/seis-tamil-nadu.htm
Earthquake (26 September 2001)		Off the coast of Puducherry, Mw 5.5	A "very great" earthquake struck the North Indian Ocean & the Bay of Bengal at 00:58 UTC on 26 December 2004. 2,30,210 people were estimated to have been killed in the Indian Ocean-wide tsunami	https://asc-india.org/seismi/seis-tamil-nadu.htm

			generated by this earthquake, including at least 8,010 in Tamil Nadu and 599 in Puducherry. Most deaths in Tamil Nadu occurred in the district of Nagapattinam.	
Earthquake (7 June 2008)		Palar Valley region, M=3.8	A mild earthquake occurred in the Palar Valley region in Tamil Nadu, on 7 June 2008 at 23:35 PM local time. It had a magnitude of M?=3.8 and was felt in many parts of Vellore district.	https://asc-india.org/seismi/seis-tamil-nadu.htm
Earthquake (12 August 2011)		Ariyalur area, Tamil Nadu, M=3.5	A mild earthquake occurred in the Kaveri basin in Ariyalur district, Tamil Nadu on 12 August 2011 at 11:36 AM local time in India. It had a magnitude of M?=3.5 and was felt in several districts in southern Tamil Nadu. It was blamed for one death and minor damage in the districts of Kudalur, Perambalur, Tiruchirapalli and Villupuram.	https://asc-india.org/seismi/seis-tamil-nadu.htm
Earthquake (3 Mar 2020)		Kerala (north of Thiruvananthapuram)	Mw 4.6	https://asc-india.org/seismi/seis-tamil-nadu.htm
Earthquake (3 Mar 2020)		Tamil Nadu (near Thirunelveli)	Mw 4.6	https://asc-india.org/seismi/seis-tamil-nadu.htm

Earthquake (11 Dec 1967)		Karnataka	Mw 6.5	https://asc-india.org/seismi/seis-tamil-nadu.htm
Landslide (2015–2022)		Kerala	2,239 Landslides	https://www.hindustantimes.com/india-news/kerala-recorded-highest-number-of-landslides-in-india-in-past-7-yearscentre-101658917106327.html?utm_source=chatgpt.com
Landslide (2015–2022)		Tamil Nadu	196	https://timesofindia.indiatimes.com/india/india-faces-3782-major-landslides-in-past-seven-years-disaster-linked-to-loss-of-forest-cover/articleshow/93200283.cms?utm_source=chatgpt.com

Landslide (2015–2022)		Karnataka	194	https://timesofindia.indiatimes.com/india/india-faces-3782-major-landslides-in-past-seven-years-disaster-linked-to-loss-of-forest-cover/articleshow/93200283.cms?utm_source=chatgpt.com

Fig. 6 shows the spatial distribution of landslide points in the CRB. The map highlights landslide occurrences (marked as red dots) alongside the Cauvery River and its tributaries/distributaries (depicted in blue). A clear clustering of landslide points is observed along the Western Ghats region, particularly in the districts of Coorg (Kodagu), Chikmagalur, Hassan, Wayanad, Nilgiris, and Coimbatore, where steep slopes, heavy rainfall, and geological conditions contribute to slope instability. Additional landslide points are also visible in the southern part of the basin, especially around Dindigul. The distribution indicates that landslides are concentrated in the hilly and high-relief western portions of the basin, while the eastern plains show negligible occurrences. Overall, the map emphasizes the geomorphic and climatic control on landslide susceptibility within the CRB.

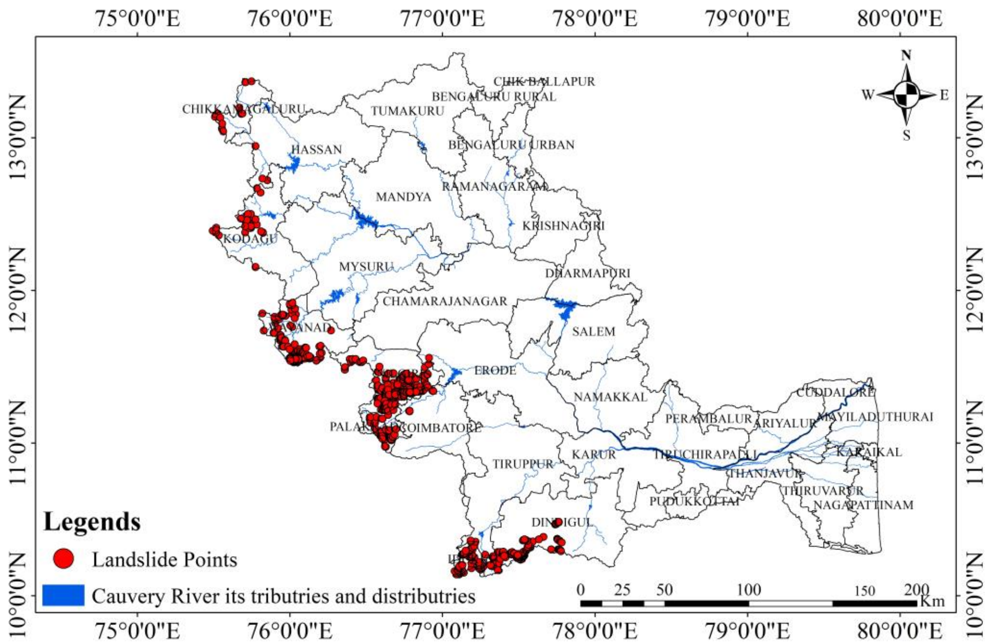


Fig. 6. Spatial Distribution of Landslide Points in the CRB (Source: Bhukosh, GSI)

The map illustrates the spatial concentration of landslide incidents (red points) across the CRB, with a notable density along the Western Ghats region in Kerala, Karnataka, and Tamil Nadu. The landslide-prone zones align with high-relief, tectonically active, and monsoon-influenced terrains. The Fig. 7 illustrates the spatial distribution of recorded earthquake events within the CRB. The map emphasizes the region's tectonic sensitivity despite its location in a traditionally low seismicity zone.

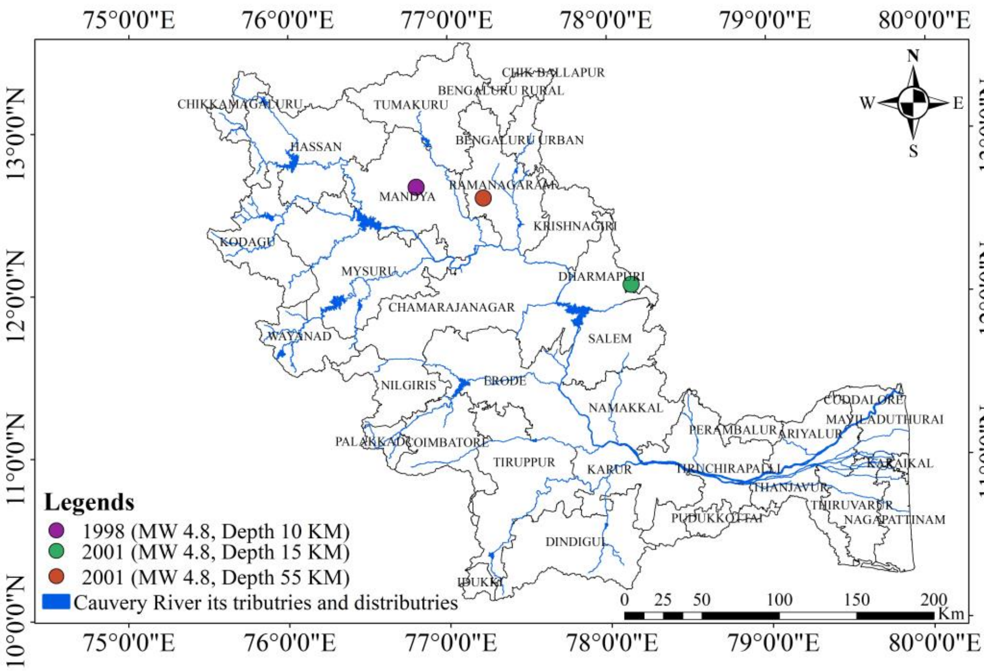


Fig. 7. Historical Earthquake Events in the CRB

(Source: India WRIS, USGS)

The Fig. 8 illustrates the historical record of earthquakes across different districts of the CRB. The map marks epicentres of past seismic events with coloured dots representing various districts, alongside the Cauvery River and its tributaries. The legend lists earthquake occurrences with corresponding years, such as Salem (1859, 1860, 1861, 1959), Tiruchirappalli (1864), Mysore (1865), Coimbatore (1865, 1972), Nilgiri (1882, 1897), Bengaluru Urban (1916), and multiple events in Mandya (1970–1973).

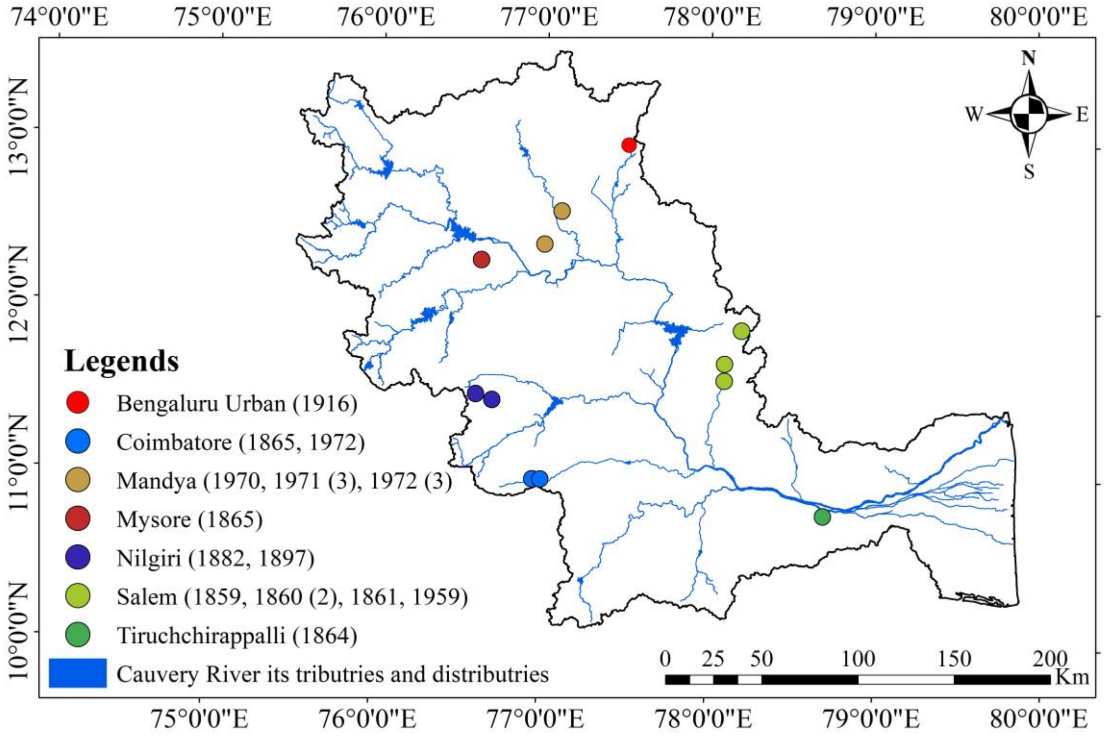


Fig. 8. Locations of the epicentre Earthquake occurred

(Source: Bhukosh)

8. Fracking Zone

According to Directorate General of Hydrocarbons (DGH), the CRB, classified as a Category I basin due to its significant commercial hydrocarbon discoveries, spans a vast area of 240,000 sq. km across onland and offshore domains. It hosts nine hydrocarbon plays ranging from the Archean Basement through the Jurassic, Cretaceous, and up to the Miocene. With a sedimentary thickness of up to 8,000 meters, the basin features varied depositional settings and structural complexities including rift grabens and passive margin sequences. The total hydrocarbon inplace is estimated at 1,427 MMTOE, of which only 292 MMTOE has been discovered, indicating over 80% of resources remain untapped. Extensive exploration datasets, including over 235,000 LKM of 2D seismic data and 849 well logs-support its high prospectivity. Current focus areas include the underexplored ultra-deepwater zones, particularly in the Gulf of Mannar, with resource-rich plays in the Cretaceous and Jurassic sequences. This basin represents a key strategic frontier for India’s energy security, with upcoming acreage releases planned under OALP Round IX.

8.1. Shale Oil and Gas Potential in the CRB

The CRB has been identified as one of the promising sedimentary basins in India with potential for shale oil and gas exploration. Shale hydrocarbons are unconventional sources trapped within fine-grained sedimentary rocks and require specialized extraction techniques such as horizontal drilling and hydraulic fracturing. Unlike conventional hydrocarbons, shale formations act as both source and reservoir, making them critical in meeting future energy demands.

According to DGH, India, the CRB is among six major Indian basins considered prospective for shale gas and oil resources. Other basins include Cambay, Gondwana, Krishna-Godavari (KG), Indo-Gangetic, and Assam & Assam-Arakan. The Energy Information Administration (EIA) of the USA estimated in 2013 that four basins including the Cauvery, hold about 584 trillion cubic feet (TCF) of shale gas and 87 billion barrels of shale oil collectively. Further, the US Geological Survey (USGS) estimated that the Cauvery, KG, and Cambay basins hold a combined technically recoverable shale gas volume of 6.1 TCF.

The Government of India, under the policy introduced on 14 October 2013, permitted National Oil Companies (NOCs) such as ONGC and OIL to initiate shale exploration in onland nomination blocks. ONGC has undertaken shale exploration in 50 blocks under Phase I, including nine in the CRB. These blocks include Kuthalam, Greater Bhuvanagiri, Greater Narimanam, Ramanathapuram, and others. Exploration activities in these blocks include geological and geophysical studies, pilot drilling, hydro-fracturing, and geochemical assessments. The aim is to assess resource potential and determine commercial viability.

This initiative reflects the strategic importance of the CRB in India's energy portfolio. While commercial production has not yet been established, preliminary assessments show promise for the basin's shale hydrocarbon reserves. The identification and exploitation of these resources are crucial for enhancing national energy security and reducing dependency on imports (Ministry of Petroleum and Natural Gas, Government of India (2025), Energy Information Administration (2013), Directorate General of Hydrocarbons (2025), USGS (2014).

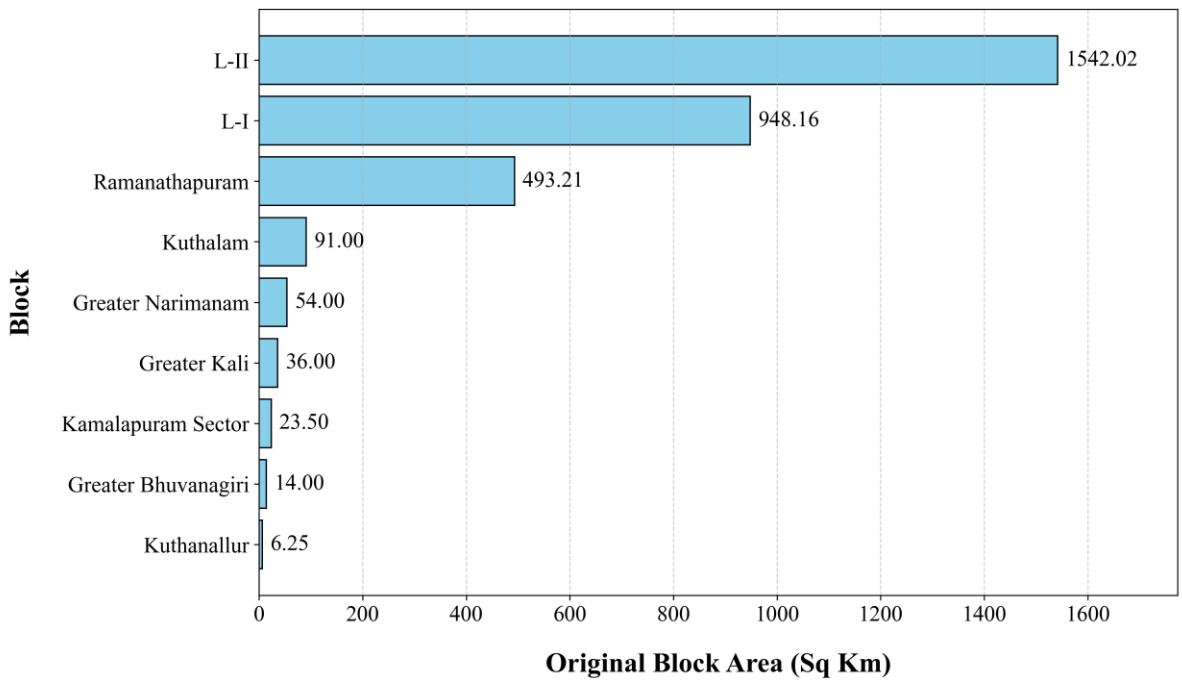
The current dataset on shale resource exploration within the CRB is geographically constrained, with available data largely restricted to the Tamil Nadu segment. Other portions of the basin, especially those extending into Karnataka, Kerala, and Puducherry, or either unsurveyed or lack publicly accessible or formally reported exploration records, highlighting a critical data gap for comprehensive basin-scale analysis. Table 4 outlines the shale gas exploration blocks within the CRB, detailing the licensed areas and the current status of the nine identified blocks.

Table 2. Shale Gas Exploration Blocks in the CRB (License Area and Status in the CRB 09 Blocks)
(Source: DGH, India)

S. No.	Block	Original Block Area (sq. km)	Validity of License Up to	Current Status
1	Kuthalam	91	2021	Phase-I
2	L-I	948.16	2019	Phase-I
3	Greater Bhuvanagiri	14	2027	Phase-I
4	Greater Kali	36	2030	Phase-I
5	Greater Narimanam	54	2026	Phase-I
6	Ramanathapuram	493.21	2019	Phase-I
7	Kuthanallur	6.25	2024	Phase-I
8	Kamalapuram Sector	23.5	2019	Phase-I
9	L-II	1542.02	2019	Phase-I

Both L-I (also written LI) and L-II (LII) are onland blocks situated in the central part of the CRB, within Tamil Nadu. L-II PML Block covers approximately 1,524 sq. km, overlapping three sub-basins in the central Cauvery region-considered the most prospective block due to the presence of several existing fields and favourable geology.

The original block area (in sq. km) across different blocks, highlighting significant variations in spatial extent is shown in Fig. 9. Among the blocks, L-II (1542.02 sq. km) and L-



I (948.16 sq. km) occupy the largest areas, together accounting for the majority of the total extent. Ramanathapuram is the third largest block with 493.21 sq. km, while other blocks such as Kuthalam (91.00 sq. km), Greater Narimanam (54.00 sq. km), Greater Kali (36.00 sq. km), and Kamalapuram Sector (23.50 sq. km) are considerably smaller. The smallest blocks are Greater Bhuvanagiri (14.00 sq. km) and Kuthanallur (6.25 sq. km) (Table 4). Overall, the chart emphasizes the dominance of L-II and L-I in block size compared to the much smaller extents of the remaining blocks.

Fig. 9. Area distribution of shale gas exploration blocks in the Tamil Nadu part of the CRB under Phase-I. The L-I and L-II blocks represent the largest allocations, highlighting a major focus of unconventional hydrocarbon resource development in this region

Fig. 10 provides an overview of the CRB setup, linking the river basin with its offshore geological extension. Fig. 10 (a) shows the CRB within the states of Karnataka, Kerala, and Tamil Nadu, highlighting its drainage extent up to Puducherry. Moreover, Fig. 10 (b) depicts the Cauvery sedimentary basin, covering both onshore and offshore areas. Different colours indicate basin divisions such as onland, shallow water, and deepwater zones, while symbols mark oil and gas wells, producing fields, and seismic survey blocks (2D/3D). The overlay of petroleum exploration blocks (NELP, HELP, DSF, PML) demonstrates the basin's hydrocarbon exploration and production.

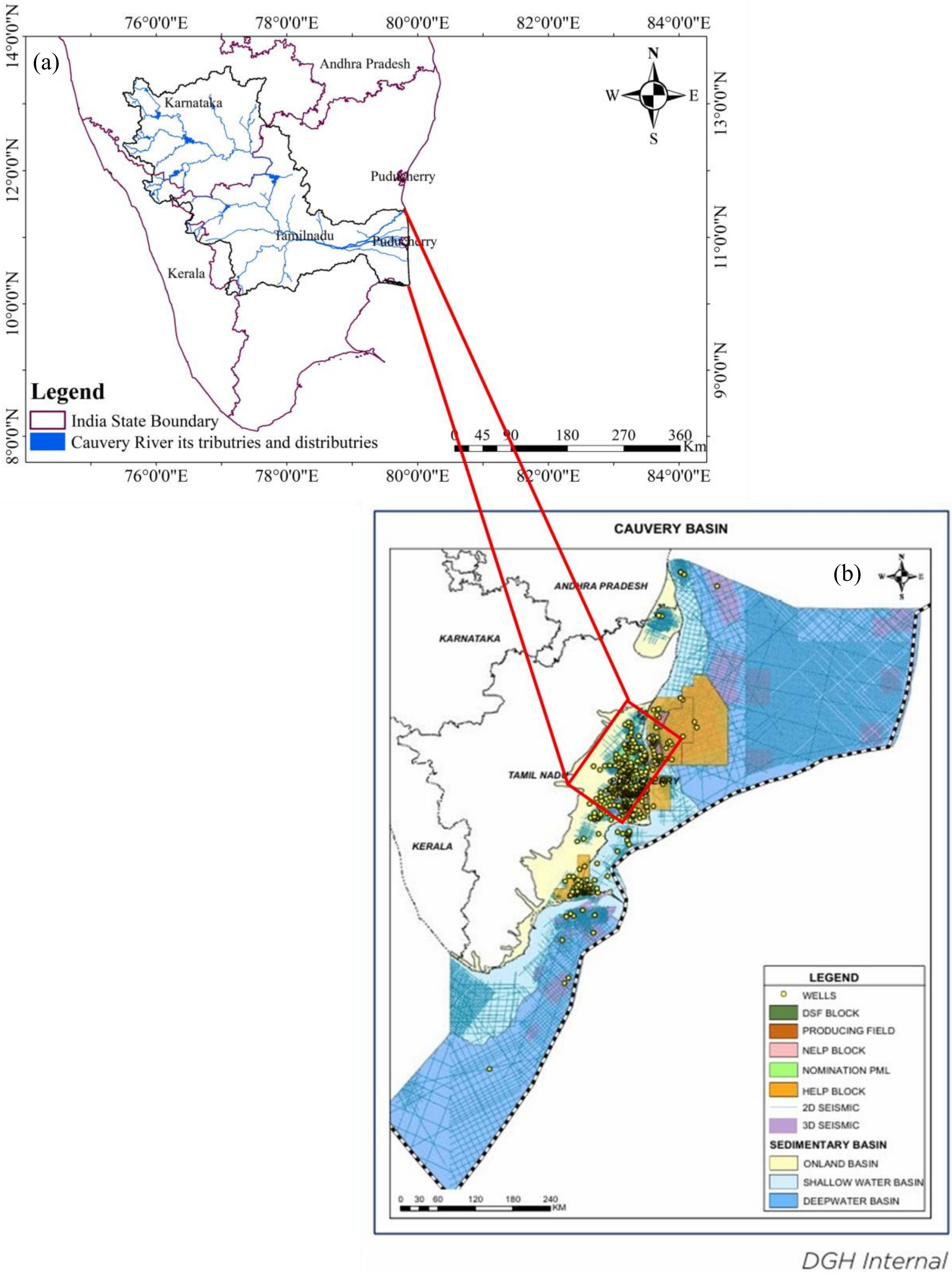


Fig. 10. Hydrocarbon exploration blocks and well distribution in the CRB, highlighting active oil and gas activities across Tamil Nadu's onland, shallow water, and deepwater zones. (Source: DGH, India)

The Fig. 11 highlights the locations of four notable shale gas exploration blocks-Great Bhuvanagiri (Red), Kuthalam (Green), Greater Narimanam (Purple), and Kuthanallur (Blue) within the eastern deltaic region of the CRB. The CRB and its tributaries are shown in blue, providing context for the hydro-geological setting. These blocks fall in close proximity to the river's coastal stretch in Tamil Nadu, indicating their potential strategic importance for hydrocarbon development and energy security in southern India.

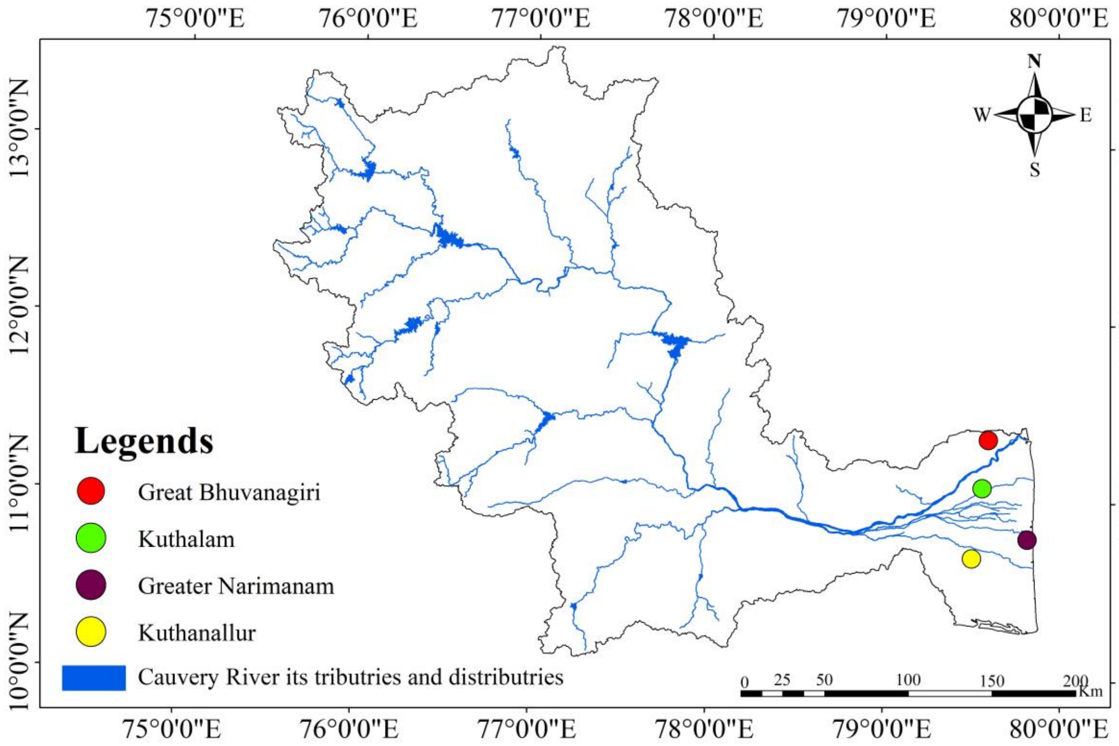


Fig. 11. Spatial Distribution of Selected Shale Gas Blocks in Tamil Nadu Segment of the CRB

(Source: DGH, India)

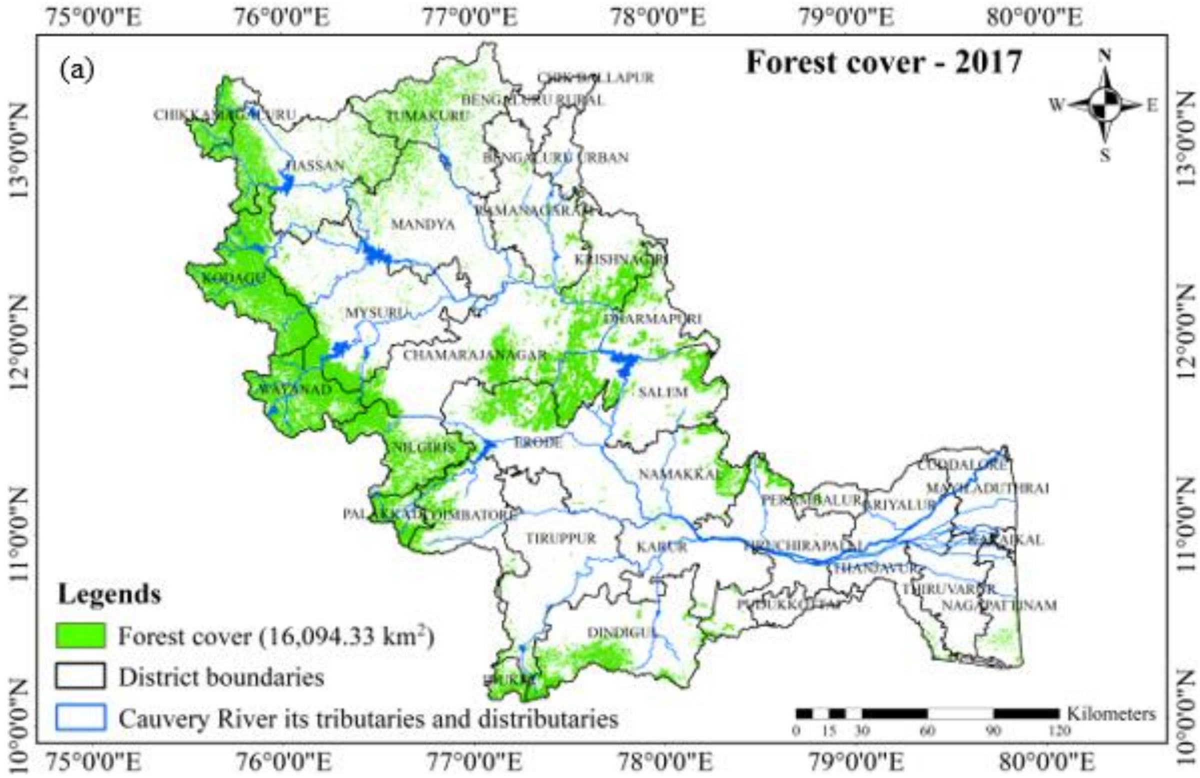
9. Deforestation

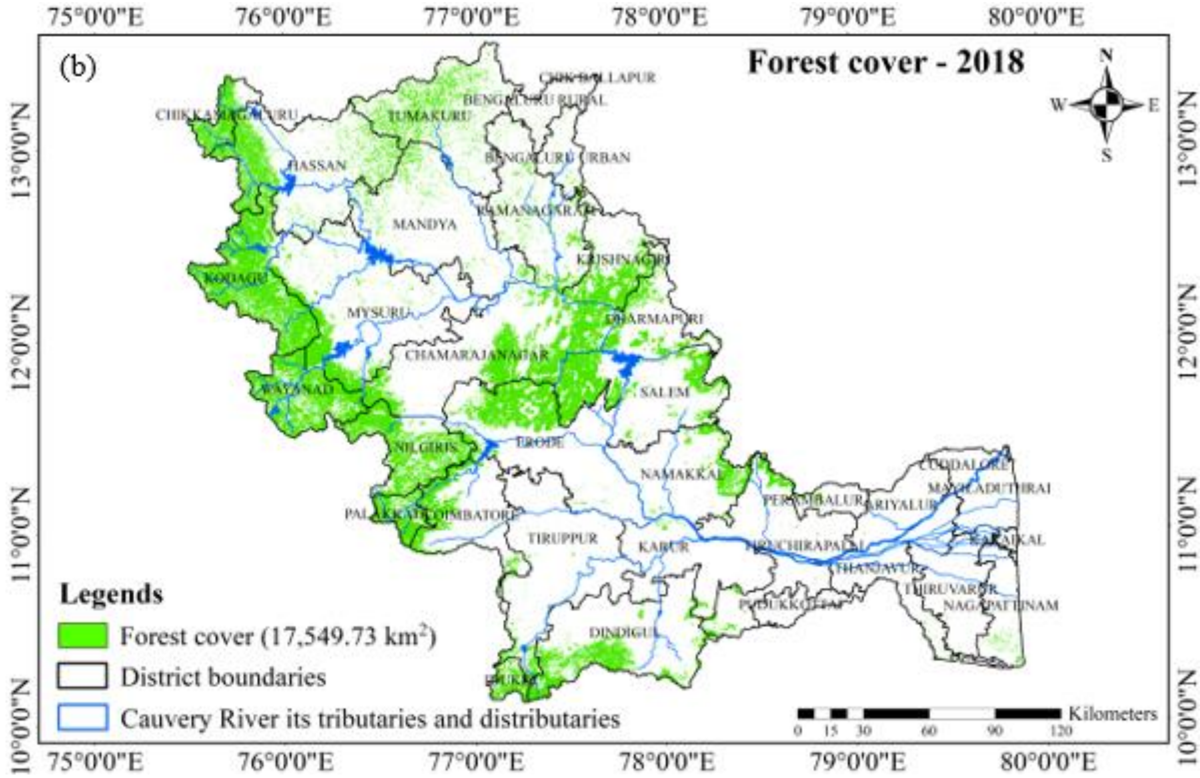
According to the Food and Agriculture Organization (FAO), the world lost about 420 million hectares of forest between 1990 and 2020. While afforestation and reforestation programs have slowed net forest loss, the rate of primary forest destruction remains high, especially in countries like Brazil, Indonesia, and parts of Africa.

In India, forest cover has seen marginal improvements through plantation schemes, but dense natural forests are declining due to developmental pressures. Regions like the Western Ghats, Northeast India, and parts of the Deccan Plateau are especially vulnerable. The CRB, stretching across Karnataka, Tamil Nadu, Kerala and Puducherry, faces threats from deforestation due to agricultural encroachment, sand mining, and infrastructure development, which in turn exacerbate landslides and water scarcity.

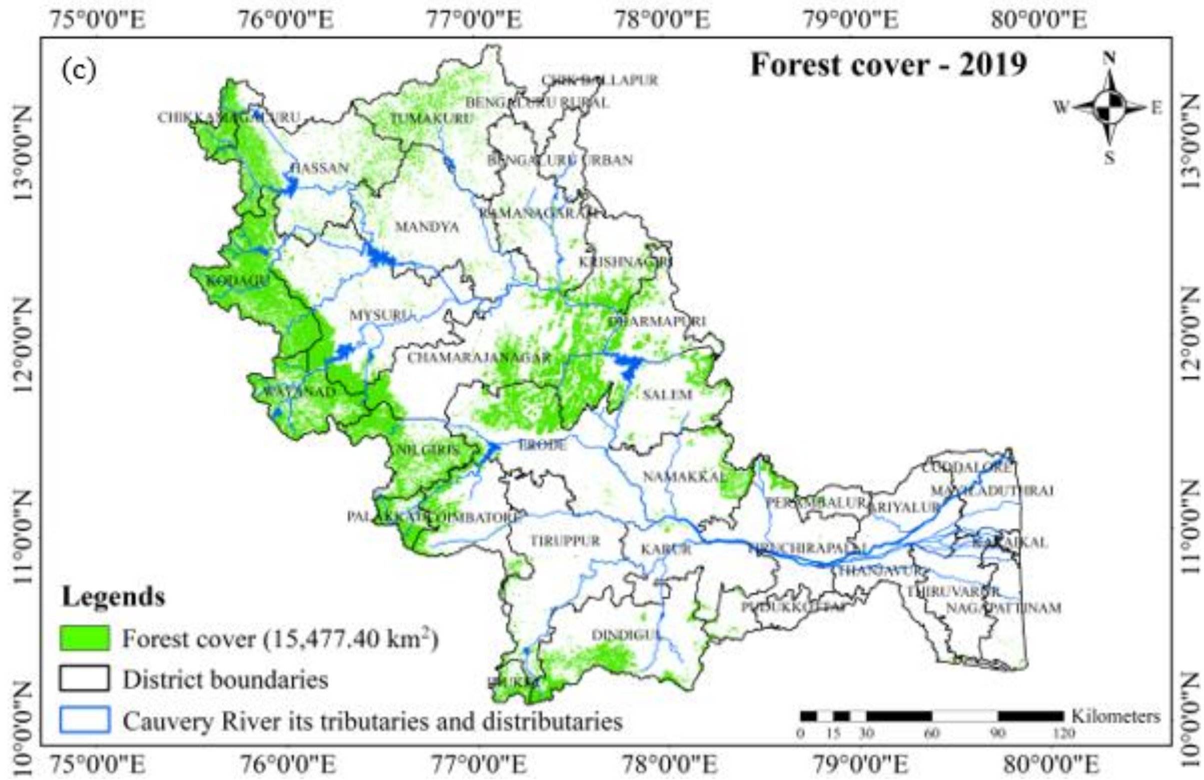
Estimating deforestation in the CRB is crucial for understanding the long-term sustainability of its water resources, ecological balance, and land stability. The basin supports millions of people across Karnataka, Tamil Nadu, Kerala, and Puducherry, and its forests play a vital role in maintaining the hydrological cycle, preventing soil erosion, and sustaining biodiversity. Rapid deforestation in the upper catchment areas can lead to reduced groundwater recharge, increased sedimentation in rivers, higher flood risks, and greater vulnerability to landslides and droughts. Accurate assessment of forest loss helps policymakers implement targeted conservation strategies, regulate land use, and promote reforestation efforts to secure the basin's environmental health and ensure water security for future generations.

The forest cover in the CRB region has exhibited noticeable interannual fluctuations between 2017 and 2024, reflecting both gains and losses likely influenced by anthropogenic activities, climatic variability, and policy interventions. Starting from 16,094.33 sq. km in 2017, forest area increased to 17,549.73 sq. km in 2018 but declined sharply in 2019 to 15,477.4 sq. km. A significant recovery occurred in 2020 and 2021, reaching 19,135.99 sq. km, followed by a peak in 2022 at 21,985.63 sq. km. However, the trend reversed again, with a decrease to 20,426.4 sq. km in 2023 and further to 17,607.37 sq. km in 2024 (Figs. 12 and 13). This erratic pattern suggests episodic deforestation and afforestation activities, possibly due to land-use change, plantation drives, forest degradation, or remote sensing classification inconsistencies. Overall, while some years show promising gains in forest cover, the declining trend in the most recent years raises concerns about forest sustainability and highlights the need for consistent, science-based forest management and conservation efforts in the basin.

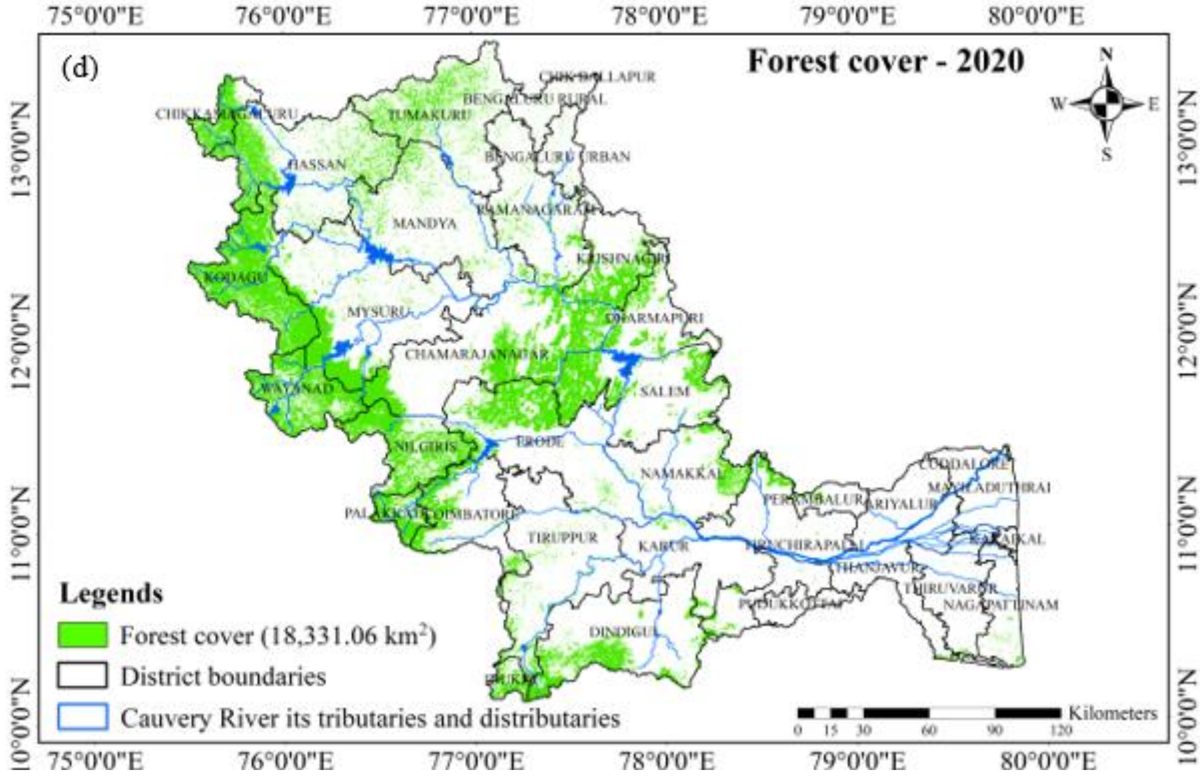




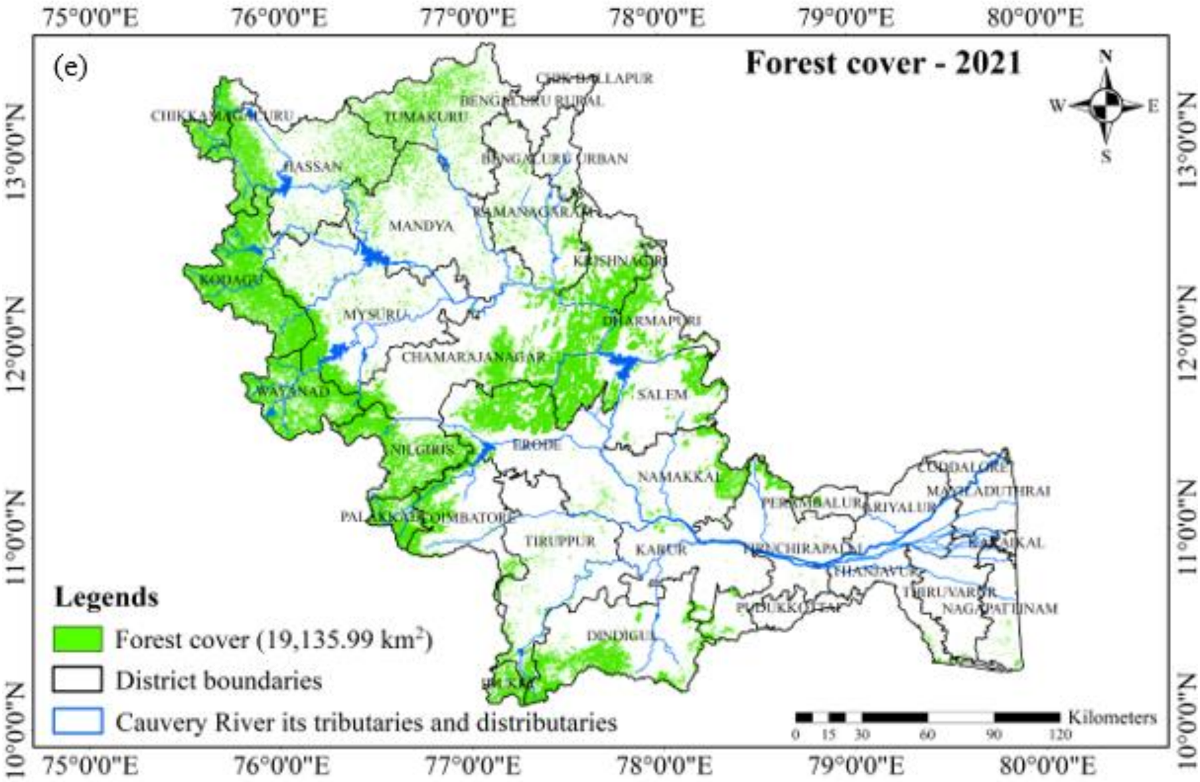
(b)
Forest cover - 2018
Legends
Forest cover (17,549.73 km²)
District boundaries
Cauvery River its tributaries and distributaries
Kilometers



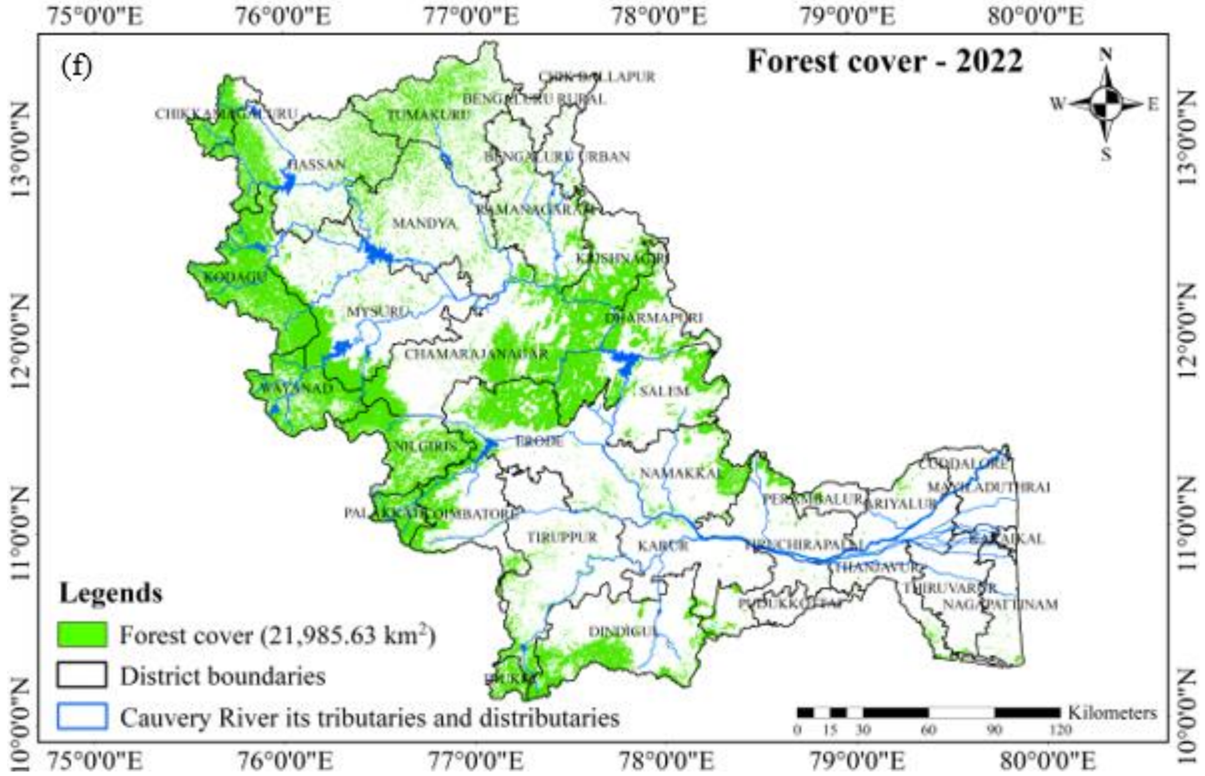
(c)
Forest cover - 2019
Legends
Forest cover (15,477.40 km²)
District boundaries
Cauvery River its tributaries and distributaries
Kilometers

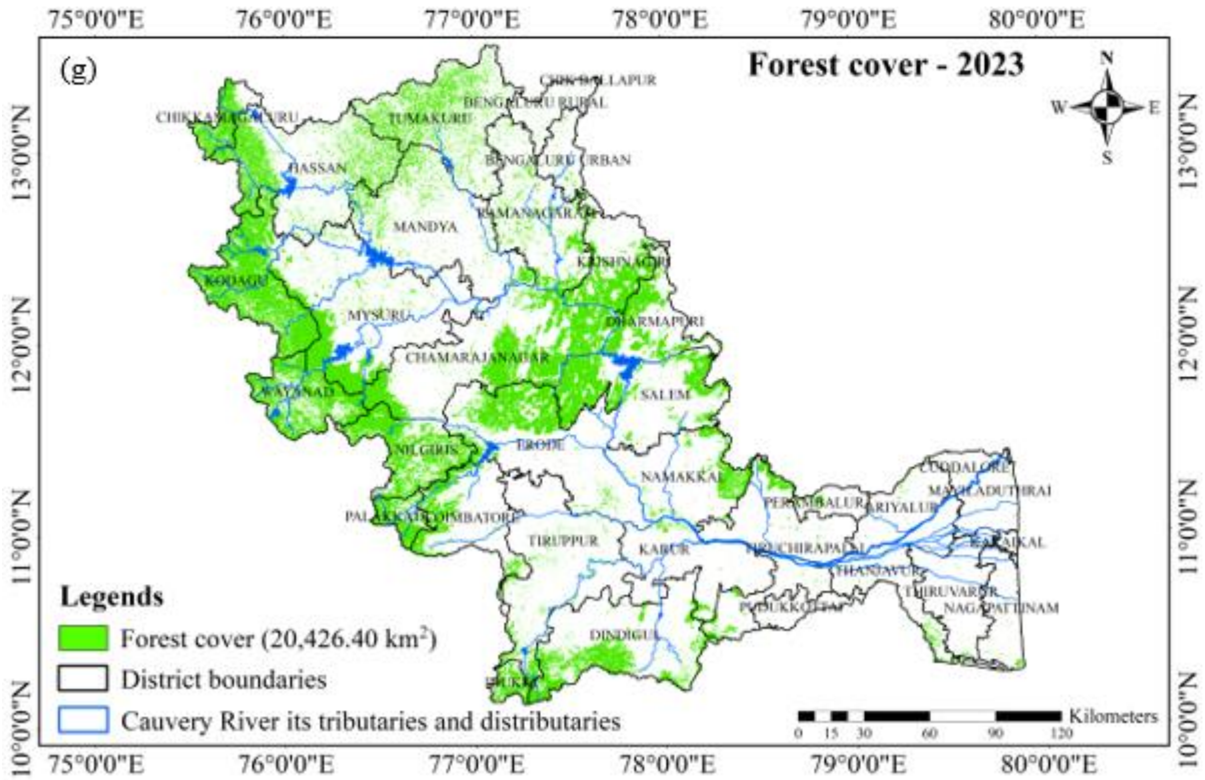


Forest cover - 2020
(d)
Legends
Forest cover (18,331.06 km²)
District boundaries
Cauvery River its tributaries and distributaries
Kilometers



Forest cover - 2021
(e)
Legends
Forest cover (19,135.99 km²)
District boundaries
Cauvery River its tributaries and distributaries
Kilometers


(f)
Forest cover - 2022
Legends
Forest cover (21,985.63 km²)
District boundaries
Cauvery River its tributaries and distributaries
Kilometers
MANDYA
MYSURU
CHAMARAJANAGAR
SALEM
NAMAKKAL
TIRUPPUR
KARUR
DINDIGUL
75°0'0"E
76°0'0"E
77°0'0"E
78°0'0"E
79°0'0"E
80°0'0"E
10°0'0"N
11°0'0"N
12°0'0"N
13°0'0"N


(g)
Forest cover - 2023
Legends
Forest cover (20,426.40 km²)
District boundaries
Cauvery River its tributaries and distributaries
Kilometers
MANDYA
MYSURU
CHAMARAJANAGAR
SALEM
NAMAKKAL
TIRUPPUR
KARUR
DINDIGUL
75°0'0"E
76°0'0"E
77°0'0"E
78°0'0"E
79°0'0"E
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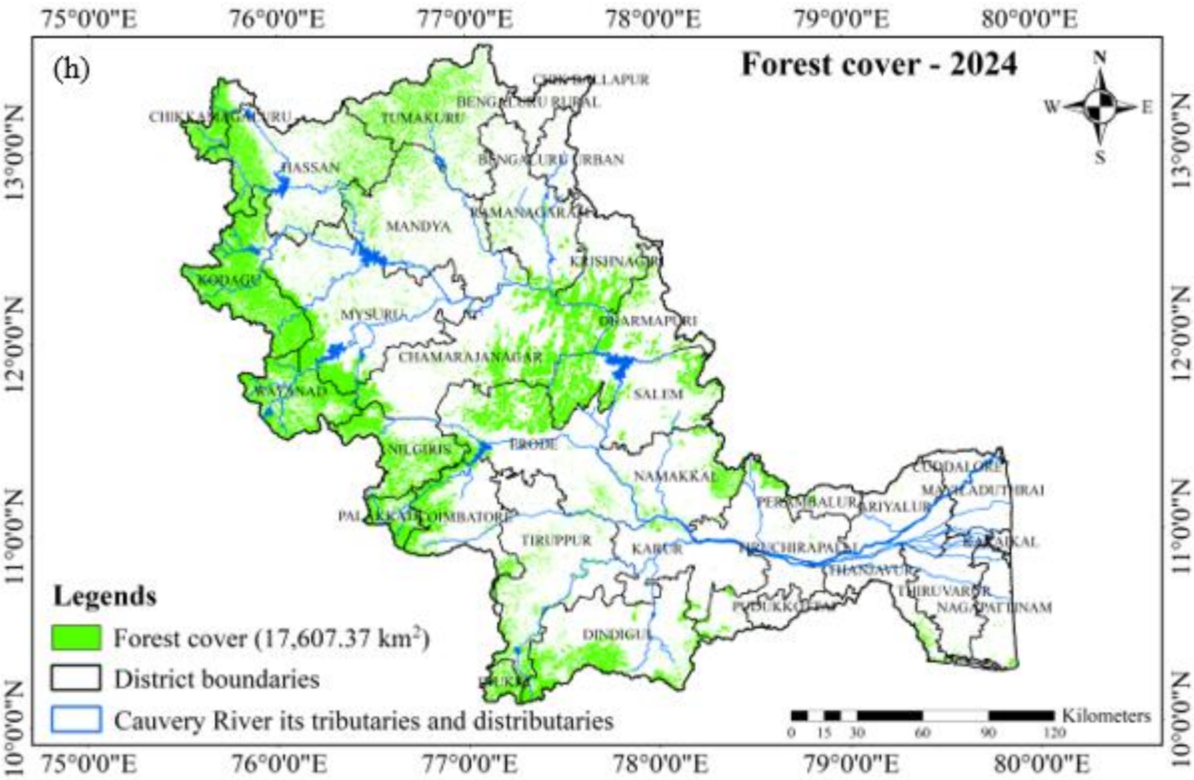

Fig. 12. Forest cover maps of the CRB for the years (2017-2024) using Sentinel-2 10 m resolution data from Esri's Land Cover Explorer.

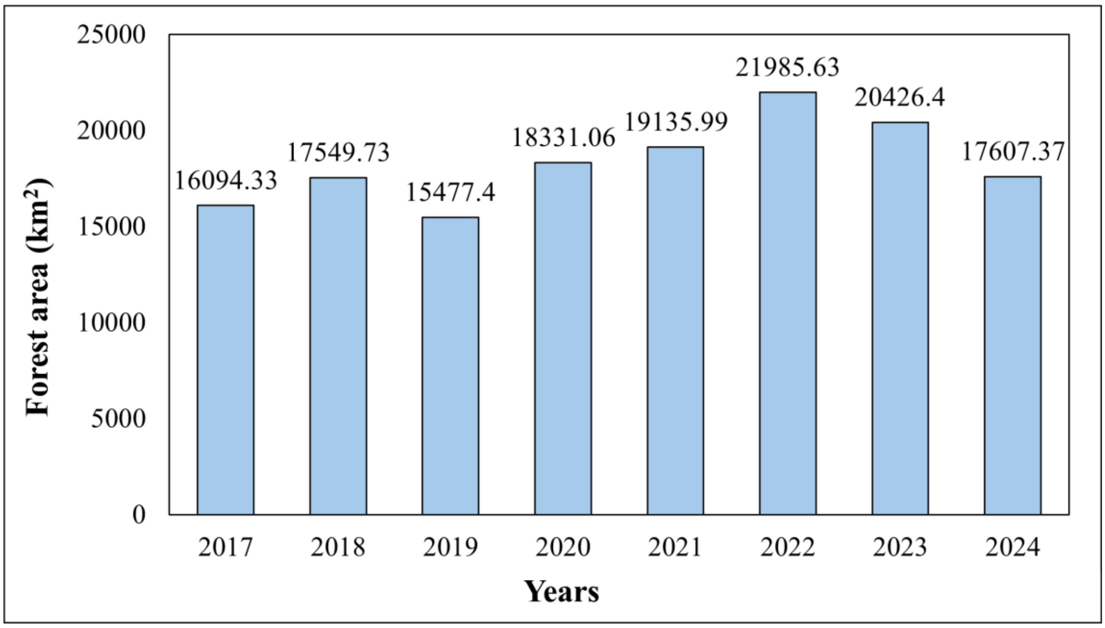

Fig. 13. Annual Forest cover variation in the CRB from 2017 to 2024, highlighting fluctuating trends in forest area

10. Riverbed Mining

Riverbed mining refers to the extraction of natural aggregates such as sand, gravel, pebbles, and minor minerals from the beds and banks of rivers. These materials are vital for construction industries, concrete production, and infrastructure development. While riverbed mining is an important economic activity, its unregulated and excessive execution has emerged as a serious environmental concern worldwide, particularly in developing nations like India, where rapid urbanization has significantly increased the demand for construction materials.

The CRB and its tributaries, flowing through Karnataka, Tamil Nadu, Kerala, and Puducherry, have been extensively mined for these resources. However, unregulated and illegal riverbed mining in the basin has raised significant environmental and socio-economic concerns. This basin carries sand from different locations and deposits largely in the basin. Sand mining in the riverbed leads to several impacts i.e. erosion of riverbed, increase in river gradient and alteration in river morphology. Further it also effects on upstream of the river, varies in the river flow velocity and further leads in changes downstream environment. Rapid urbanization is the major cause for sand demand and is responsible for unsustainable extraction of sand from dried river paths. Due to increasing demand for sand, it is being over extracted at different depth varying from three to forty feet, from different streams and basins. These effects directly the riverine habitats such as, the riverbed lose its ability to hold water and affects groundwater recharge threat to riverbanks and nearby structures and premature failure of irrigation wells associated in farming causes erosion or degradation of the rivers or nearby environment. Sand mining is a direct and obvious cause of erosion and also impacts the local wildlife. Since the extraction of sand is a simple process, the people carry out sand mining in huge quantity without considering its adverse effect on environment (EMPRI). During their study the sand mining was found in Maralagala (Doddapalya), Mahadevapura, Somnathpura, Purgali, Harale (Fig. 14) and Dhanagere villages in the Middle Cauvery sub-basin.

Fig. 14. Sand transportation in Harale village

(Source: EMPRI)

Recent data reveals the alarming prevalence of illegal mining activities across the southern states of India, particularly in Karnataka, Kerala, and Tamil Nadu (data.gov.in). These activities predominantly involve unauthorized sand extraction from riverbeds, stone quarrying, and minor mineral mining, posing significant challenges to environmental sustainability and governance.

In the financial year 2022–23, Tamil Nadu recorded the highest number of illegal mining cases among the three states, with 4,495 cases, followed by Kerala with 3,671 cases and Karnataka with 2,960 cases (Table 5). Despite such high numbers, there is a stark contrast in the enforcement measures across these states. For instance, Karnataka lodged 384 FIRs, filed 150 court cases, and seized 340 vehicles engaged in illegal mining operations. This indicates a comparatively stronger enforcement framework. On the other hand, Kerala and Tamil Nadu, despite reporting the highest illegal mining cases, did not lodge any FIRs or initiate court cases during the same period, highlighting significant gaps in enforcement mechanisms and legal actions.

The financial penalties realized by state governments also vary widely. Kerala collected the highest fine amounting to ₹6,840.16 lakh, indicating either larger scale illegal operations or higher penalty impositions per case. Karnataka, in comparison, realized ₹1,546.18 lakh, whereas Tamil Nadu, despite reporting the highest cases, collected only ₹743.12 lakh, which raises questions on the efficacy of penalty systems and deterrence measures.

This data underscores the critical need for uniform enforcement policies, real-time monitoring using drones and remote sensing technologies, and stringent legal actions to curb illegal mining practices. These activities not only degrade river ecosystems and alter hydrological cycles but also result in loss of state revenue and create socio-economic conflicts in mining-prone regions.

Table 3. Illegal Sand Mining Cases in Karnataka, Kerala and Tamil Nadu (2022–23)

(Source: https://www.data.gov.in/search?title=mining&type=resources&sortby=_score)

Sl. No.	State	Illegal Mining Cases 2022-23	FIR Lodged (No.)	Court Cases Filed (No.)	Vehicle Seized (No.)	Fine Realized by State Govt. (Rs. Lakh)
1	Karnataka	2960	384	150	340	1546.18
2	Kerala	3671	0	0	0	6840.16
3	Tamil Nadu	4495	0	0	0	743.12

11. Summary and Recommendations

The geological profile outlines the diverse lithological, structural, and geomorphological characteristics of the study area, highlighting its complex geological history and resource potential. The region's lithology comprises a varied mix of igneous, metamorphic, and sedimentary formations, each representing different geologic periods and tectonic environments. Structural analysis reveals faulting, folding, and jointing patterns that have influenced the present-day topography and drainage system. Geomorphological features such as river terraces, alluvial plains, and erosional landforms reflect the interplay between tectonics and surface processes over time. The mineral resource inventory indicates the occurrence of economically significant minerals, with spatial distribution closely linked to lithological units and tectonic settings. Additionally, the document notes human impacts such as mining, construction, and land use changes that are reshaping the geological landscape. The study area's geology is the product of a dynamic interplay of tectonic forces, sedimentation, magmatism, and erosional processes spanning millions of years. Its rich lithological diversity supports varied mineral resources, offering significant economic opportunities, though also posing environmental and sustainability challenges. Understanding the structural framework is crucial for hazard assessment, groundwater management, and infrastructure planning. Geomorphological mapping reinforces the importance of river systems in shaping the landscape and influencing sediment transport. Sustainable resource management, guided by detailed geological mapping and monitoring, is essential to balance economic benefits with environmental protection. The geological profile thus serves as a baseline for further research, policy-making, and informed decision-making in resource utilization, hazard mitigation, and regional development.

12. Significance of the Geological Profile Data

Geological profile data is a vital resource that provides detailed insights into a region's lithology, structural features, geomorphology, and mineral distribution, serving as a foundation for sustainable resource management, hazard assessment, groundwater studies, and infrastructure planning. By revealing the type, quality, and spatial distribution of rocks and minerals, it enables informed decision-making for mining, agriculture, and urban development while aiding in the prediction and mitigation of natural hazards such as landslides and earthquakes. Additionally, it supports environmental conservation, facilitates groundwater exploration, and serves as an essential reference for scientific research and education, thereby bridging the gap between geoscience knowledge, policy-making, and sustainable development.

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