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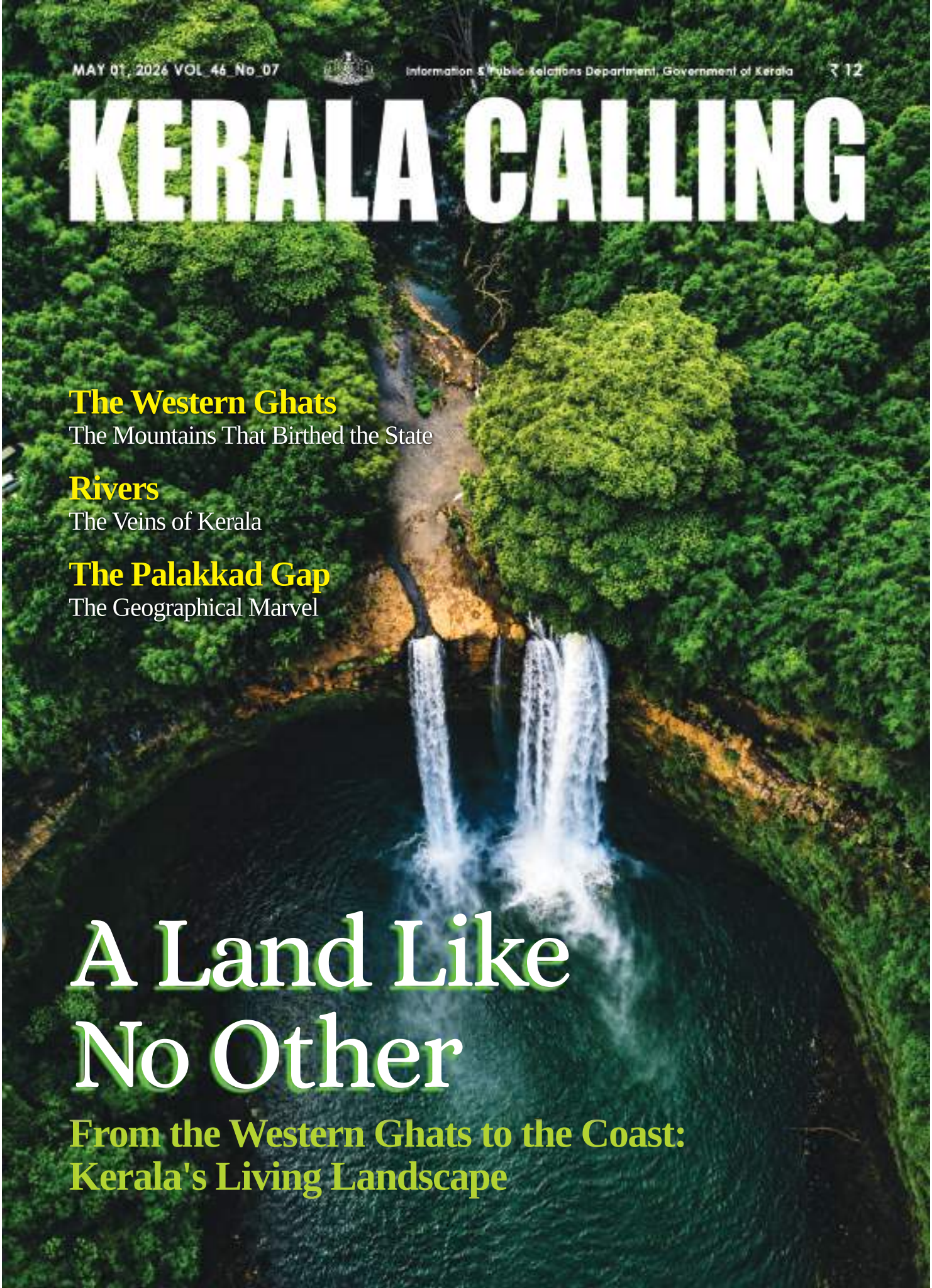


The Western Ghats
The Mountains That Birthed the State

Rivers
The Veins of Kerala

The Palakkad Gap
The Geographical Marvel

A Land Like No Other

From the Western Ghats to the Coast: Kerala's Living Landscape

A Tapestry of Land, Water and Life

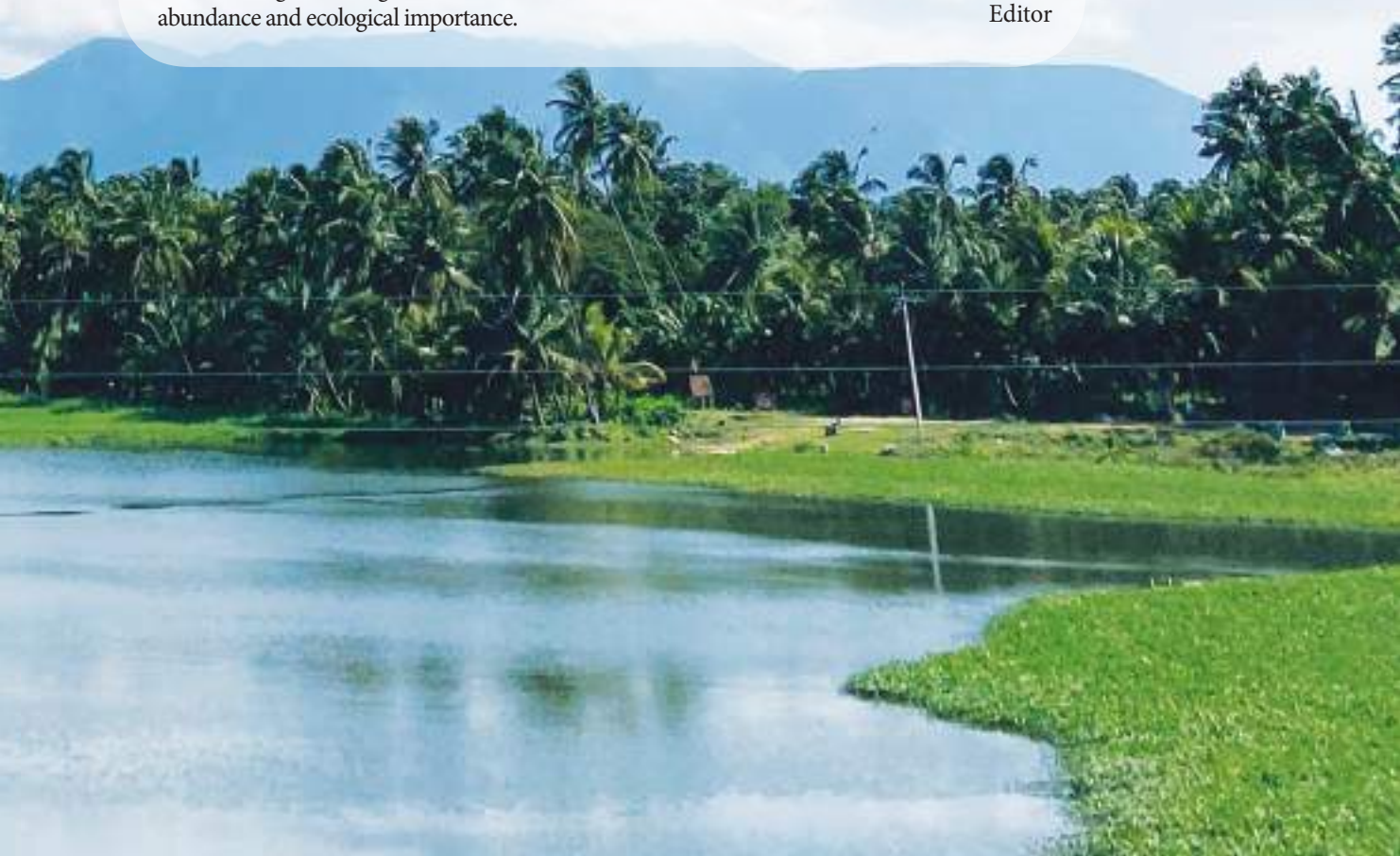
Kerala—aptly celebrated as "God's Own Country"- presents a magnificent spectrum of geological and ecological wonders. Defined by its distinctive triple-tier topography, the state unfolds from the towering Western Ghats to the undulating midlands and onward to the serene coastal plains, all within a remarkably narrow stretch of land.

The Western Ghats—a lush tapestry of life—stand as both a natural barrier and a globally significant biodiversity hotspot. These forested highlands seamlessly connect with the state's famed backwaters and coastal ecosystems, together nurturing an exceptional range of flora and fauna. Kerala's water bodies—its rivers, lakes, and wetlands—serve as vital lifelines that sustain both landscapes and communities, while its monsoon patterns and water resources have earned global recognition for their abundance and ecological importance.

Among its many striking features, the Palakkad Gap stands out as a remarkable geological marvel, carving a natural corridor through the mountainous terrain and influencing both climate and culture across the region.

The May issue of Kerala Calling turns its focus to this unique geographical identity. From wetlands and water bodies to sacred groves and lush green expanses, each element contributes to a landscape of rare richness. Beyond its scenic allure, Kerala offers profound geological insight—it is not merely a region of natural beauty but a landscape endowed with exceptional richness in every dimension. Taken together, these features affirm a simple truth: Kerala is not just distinct—it is a land unlike any other.

T.V. Subhash IAS
Editor



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Navigator

Kerala, A Rare Geological Museum

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Widely known by the epithet 'God's Own Country', Kerala, from a scientific perspective, is truly a geological wonder.

Despite its relatively small geographical area, Kerala exhibits remarkable geology, diverse topography, complex landforms, rich mineral resources, intricate water systems, an extensive network of rivers, and a versatile climate. The state covers an area of approximately 38,863 square kilometers and includes 44 rivers, a coastline of about 570 kilometers, and more than 11,000 square kilometers of forest area. The climate is tropical humid and monsoon-driven, with rainfall primarily from the southwest monsoon (June–September) and the northeast monsoon (October–December), and an average annual rainfall of about 3100 mm.

Unique Geological History

The geological framework and stratigraphic sequence of Kerala can be broadly divided into three major stages:

(1) Precambrian crystalline rocks along with acid to ultrabasic intrusive

(2) Tertiary sedimentary formations

(3) Quaternary/recent deposits

This sequence indicates that Kerala's geological history spans billions of years and includes significant time gaps. A notable feature of the region is the presence of multiple generations of mafic dyke swarms that intrude and cut across the older crystalline basement.

The oldest Precambrian rocks occupy nearly 80% of the state. These include high-grade metamorphic rocks such as charnockite, khondalite, and gneiss, with ages ranging from about 0.5 to 3 billion years. They form part of the Southern Granulite Terrain of peninsular India. In the Kasaragod region, geological studies have identified oldest rocks interpreted as remnants of a micro-continent, representing fragments of Earth's earliest continental crust. These rocks serve as the basement over which all younger formations were deposited. They are also intruded by granites, pegmatites, and basic to ultrabasic igneous bodies.

Overlying the Precambrian basement are Tertiary sedimentary rocks (formed about 66 to 2.6 million years ago), mainly confined to the coastal belt of Kerala. The Quilon Formation (comprising limestone and marl) and the Varkala Formation (comprising sandstone, clay, and lignite layers) are the principal units of this stage. These sediments were deposited in ancient marine and coastal environments, and are often overlain by extensive laterite formations.

The youngest deposits belong to the Quaternary period (formed about 2.6 million years ago to the present). These include fluvial deposits such as the Periyar Formation, marine deposits along the coast, and fluvio-marine deposits seen in areas such as Guruvayur and Viyyam. These sediments are formed through the combined action of rivers and the sea, and are widely distributed across coastal plains, backwaters, and river valleys.

A notable feature of Kerala's stratigraphy is the absence of rocks belonging to the Paleozoic (538–252 million years ago) and Mesozoic (252–66 million years ago) eras, which are present in many other parts of India. This gap is attributed either to intense erosion or to the lack of favourable conditions for deposition during those periods. As a result, Kerala's geological column is considered "incomplete."

In addition, major tectonic features such as the Western Ghats, the Palakkad Gap, and numerous shear zones, together with widespread laterite formation, further enhance the geological diversity of the region.

Distinctive Topography

Kerala's topography is distinctly unique compared to other Indian states. It is essentially a narrow, wedge-shaped strip of land lying between the Western Ghats and the Arabian Sea. The state's physiography is broadly divided into three major units: the Highlands, the Midlands, and the Lowlands.

The eastern part of the state is dominated by the Western Ghats, which rise as a massive mountainous wall. This region is characterised by high peaks, deep valleys, and gorges. The average elevation is around 1,500 meters, with some peaks exceeding 2,500 meters. These highlands form the source region for most of Kerala's rivers.

To the west of the highlands lie the Midlands, a transitional zone consisting of undulating terrain with low hills and valleys. Lateritic hills and extensive agricultural lands are typical features of this region. Further west are the Lowlands, which are generally flat and include coastal plains enriched with backwaters, river mouths, and lagoons. These low-lying areas are water-rich and host Kerala's characteristic backwater systems. Each of these regions shows marked differences in soil type, water availability, and agricultural practices—for instance, sandy and lagoonal environments in the coastal belt, lateritic terrains in the midlands, and rugged mountainous landscapes in the highlands.

Overall, one of the most significant scientific features of Kerala's topography is the sharp variation in elevation over a very short horizontal distance. Most rivers originating in the Western Ghats flow from east to west, while much of the state's developmental activities are aligned along a north–south axis. This creates a kind of mismatch with the natural energy and drainage systems. Consequently, the rapid gradient from the highlands to the coast strongly influences water flow and climate, and is increasingly contributing to environmental and hydrological challenges in Kerala today.

Western Ghats

The Western Ghats is a major mountain chain that runs parallel to the western coast of India for about 1,600 km, extending from Gujarat through Kerala to Tamil Nadu. It is considered one of the most prominent escarpment systems in India and represents a significant geological feature. The Western Ghats are associated with the Reunion hotspot and the volcanic activity of the Deccan Traps volcanism, along with large-scale crustal uplift (epeirogenic uplift) along the continental margin.

In the Kasaragod region, geological studies have identified oldest rocks interpreted as remnants of a micro-continent, representing fragments of Earth's earliest continental crust.

Therefore, the Western Ghats are not merely a mountain range, but a dynamic geological record reflecting deep Earth processes and plate tectonics. They are also recognised as one of the world's major biodiversity hotspots and have been designated as a UNESCO World Heritage Site.

Mineral Resources

Kerala, though a small state, holds considerable significance in terms of mineral resources. The heavy mineral placer deposits found along its coastal belt are globally renowned. In addition, minerals such as china clay, bauxite, graphite, gold, silica sand, and limestone serve as raw materials for industries like ceramics, glass, and cement. Building materials such as granite and laterite are also widely used in construction.

Gold in Kerala occurs mainly in two forms: primary (lode) gold deposited through hydrothermal fluids in quartz veins and shear zones, and secondary (placer) gold accumulated in river sediments and coastal sands. Gold is commonly associated with minerals such as pyrite, arsenopyrite, and chalcopyrite. Among the major gold-bearing areas, the Nilambur–Pandalur region is the most prominent, with

recorded concentrations ranging from 0.5 to 4.5 g/t; small-scale mining was carried out here during the colonial period. Occurrences have also been reported from the Wayanad region, along the Bhavani Shear Zone in Attappadi, and the Punalur–Nellikuthu area, though generally in lower concentrations. Studies by the Geological Survey of India confirm the presence of gold in these areas; however, economically viable large-scale mining is limited. Nevertheless, with modern technology and sustainable approaches, small-scale eco-friendly extraction may be feasible in the future.

Kerala's coastline hosts extensive black sand (heavy mineral placer) deposits at several locations. These sands are rich in minerals such as hornblende, tremolite–actinolite, hypersthene, clinopyroxene, zircon, monazite, garnet, sillimanite, epidote, staurolite, and apatite. Major deposits occur in areas such as Neendakara, Kayamkulam, Thrikkunnapuzha, Varkala, and along the Chavakkad–Ponnani coast. The karimanal (black sand) deposits at Attipra are also well known. Among these, the Chavara deposits—rich in ilmenite, rutile, leucoxene, zircon, and monazite—are considered the most significant.

In addition, the iron-rich laterites and lodestone occurrences in the Kasaragod region present potential for scientific and sustainable mining, which may be explored in the future.

Rich Water Resources

Of the 44 rivers in the state, 41 flow westward into the Arabian Sea, while the remaining three flow eastward and form part of the Cauvery River basin. As most of the rainfall is received during the monsoon, the rivers exhibit strong seasonal flow and variability. The extensive backwater–lagoon system is another distinctive hydrological feature of Kerala.

Kerala's freshwater lakes play a crucial role in water security. The highland lakes of Wayanad—such as Pookode Lake, Karlad Lake, and Kunkichira Lake—function as rain-fed upland reservoirs that support groundwater recharge and local water supply. Sasthamkotta Lake, the largest freshwater lake in Kerala, is a primary source of drinking water for the Kollam region. Vellayani Lake serves both agricultural and drinking water needs in southern Kerala.

Kerala, though a small state, holds considerable significance in terms of mineral resources.

Groundwater conditions in Kerala are complex. In crystalline hard-rock aquifers, water is stored mainly within fractures and weathered zones. Laterite aquifers have good storage capacity during the monsoon but experience rapid depletion in the dry season. Of an annual replenishable groundwater availability of about 5.53 billion cubic meters, only around 2.7 billion cubic meters are utilised—approximately 50% extraction.

Geoheritage

Kerala hosts several unique geological features of high scientific and heritage value, including the Varkala Cliff, the Laterite of Angadipuram, the Cheruvathoor Formation, and the traditional groundwater harvesting system of northern Kerala known as Surangam (Tunnel Wells).

These features provide valuable insights into Earth's evolutionary history, past climatic conditions, and the interactions between soil and water systems. Given their scientific importance and cultural significance, it is essential to recognise and conserve them as designated geoheritage sites.

The convergence of ancient rocks, dynamic landforms, rich mineral resources, and complex water systems transforms the state into a living scientific laboratory. Kerala is not merely a small geographic region; it is a rare window into the long-term history of the Earth.

Building a Resilient Kerala

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The Kerala State Biodiversity Strategy and Action Plan (KSBSAP 2025–2035) sets out a roadmap to make Kerala the most biodiverse-friendly developed state by 2035, aligning with the Kunming–Montreal Global Biodiversity Framework (K-MGBF) and the Sustainable Development Goals.

Kerala's Living Natural Heritage

Kerala, spanning 38,863 sq. km and physiographically divided into Highland (48%), Midland (42%), and Coastal Lowland (10%), is an ecological powerhouse with ecosystems ranging from diverse forest types, laterite hills, mangroves, wetlands, grasslands, and Myristica swamps to unique agro-ecological zones (5 zones/23 units). The state's forests (including green cover), covering nearly 29% of its size, encompass tropical wet evergreen, semi-evergreen, moist and dry deciduous, montane shola-grassland systems, and mangroves, and are home to 16 wildlife sanctuaries and 7 national parks. These forests serve as hydrological lifelines through 44 major rivers. The state's 590+ km coastline, extensive backwaters, estuaries, and agro ecosystems such as Kuttanad, Kole, Kaippad, and Pokkali fields sustain biodiversity and livelihoods while buffering climate extremes.

Kerala, spanning 38,863 sq. km and physiographically divided into Highland (48%), Midland (42%), and Coastal Lowland (10%), is an ecological powerhouse with ecosystems ranging from diverse forest types, laterite hills, mangroves, wetlands, grasslands, and Myristica swamps to unique agro-ecological zones (5 zones/23 units). The state's forests (including green cover), covering nearly 29% of its size, encompass tropical wet evergreen, semi-evergreen, moist and dry deciduous, montane shola-grassland systems, and mangroves, and are home to 16 wildlife sanctuaries and 7 national parks. These forests serve as hydrological lifelines through 44 major rivers. The state's 590+ km coastline, extensive backwaters, estuaries, and agro ecosystems such as Kuttanad, Kole, Kaippad, and Pokkali fields sustain biodiversity and livelihoods while buffering climate extremes.

Encompassing 450 km of the Western Ghats—one of the world's 36 biodiversity hotspots and a UNESCO World Heritage Site—Kerala contributes over 25% of India's plant diversity within just 1.18% of its land area, with forests safeguarding 1,272 endemic plant species, a rich repository of medicinal plants, and flagship fauna such as the lion-tailed macaque and Nilgiri tahr. Its'freshwater fish and amphibian diversity exceed 60% of endemism, while vertebrate wealth includes 1,847 species (905 fish, 151 amphibians, 173 reptiles, 500 birds, 118 mammals), alongside 598 spider species, 328 butterflies, and 181 odonates, totalling around 12,000 taxa. Coastal and marine ecosystems add 468 marine fish species and diverse crustaceans, molluscs, and mammals, further underscoring Kerala's extraordinary biodiversity heritage.

Indicators for Measuring Biodiverse-Friendliness in a Fast-Urbanising State

The Western Ghats, while globally celebrated for their biodiversity and ecosystem services, are also among the most densely human-populated

biodiversity hotspots, creating intense pressure on fragile ecosystems. Kerala, with 72% of its geographical area lying within the Ghats, is the most densely populated state in the region, with 860 persons per sq. km and urbanisation projected to reach 96% by 2036. This convergence of exceptional biodiversity richness and high human density makes safeguarding ecological wealth while pursuing developmental outcomes Kerala's most critical challenge. Achieving a biodiverse-friendly trajectory in Kerala requires a set of measurable indicators that are aligned with the K-MGBF 23 targets.

Kerala's Contrast in Social Development and Biodiversity Friendliness

Kerala consistently ranks at the top of NITI Aayog's SDG India Index, excelling in social development indicators such as poverty reduction (SDG 1), health and well-being (SDG 3), quality education (SDG 4), and gender equality (SDG 5). These achievements reflect the state's strong institutional capacity and inclusive governance, making it one of the most socially advanced states in the country. At the same time, Kerala is endowed with extraordinary biodiversity wealth. Yet, as highlighted in the comparative assessment of SDG performance (see table), Kerala's environmental SDGs, particularly SDG 2 (agrobiodiversity and zero hunger), SDG 13 (climate action), SDG 14 (life below water), and SDG 15 (life on land), remain constrained by weakened habitat restoration, man-animal conflicts, invasive species control, agrobiodiversity incentives, and ecosystem resilience, leaving biodiversity friendliness lagging Kerala's social achievements.

2035 Roadmap: Kerala State Biodiversity Strategy and Action Plan (KSBSAP)

The vision of making Kerala India's most biodiversity-friendly State by 2035 rests on concrete, measurable actions that are aimed at strengthening Local Institutional Architecture for Implementation of the KSBSAP 2025–2035.The KSBSAP 2025–2035 provides a comprehensive roadmap for positioning Kerala as India's most biodiversity-friendly state by 2035. It identifies eight Biodiversity Target Areas (KBTAs) with 80 specific Action Targets (KBATs), aligned to the National Biodiversity Strategy and Action Plan (NBSAP), the Kunming–Montreal Global Biodiversity Framework (KMGBF), and the Sustainable Development Goals (SDGs).

The KSBSAP action framework

Table: Kerala's SDG Performance: Strengths vs Constraints

SDG Goal	Kerala's Performance	Strengths / Achievements	Biodiversity-friendliness Gaps/Improvement Areas
SDG 1–No Poverty	Top performer	Lowest poverty incidence; strong social safety nets	Limited livelihood-linked biodiversity enterprises due to weak financing
SDG 2–Zero Hunger (Agrobiodiversity)	Strong but improvable	Custodian farmers, traditional rice systems (Kuttanad, Pokkali, Kole), crop diversity	Need stronger incentives for agrobiodiversity conservation, underfunded support for genetic diversity programmes
SDG 3–Good Health & Well-being	Leading	High life expectancy, strong healthcare system	Environmental health risks (pollution, biodiversity loss) under-addressed due to fiscal gaps
SDG 4–Quality Education	Leading	Highest literacy, strong enrolment, gender parity	Biodiversity education not mainstreamed into curricula
SDG 5–Gender Equality	Strong	High female literacy, strong participation in local governance	Gender mainstreaming in biodiversity programmes remains weak
SDG 13–Climate Action	Moderate	Disaster preparedness and resilience frameworks	Environmental budget only 0.15–0.20% of State Budget, limiting climate and biodiversity action
SDG 14–Life Below Water	Moderate	Rich marine biodiversity, strong fisheries institutions	Coastal ecosystem restoration and pollution control underfunded
SDG 15–Life on Land	Moderate	Extraordinary biodiversity wealth, strong institutional architecture (KSBB, BMCs, NGOs)	Habitat restoration, invasive species control, and biodiversity financing severely underfunded

is systematically mapped to the Kunming–Montreal Global Biodiversity Framework (KMGBF) and the Sustainable Development Goals, ensuring Kerala's biodiversity governance is benchmarked against global standards. By embedding targets such as halting species extinction, restoring 30% of degraded ecosystems, conserving 30% of land and waters, reducing invasive species, and mobilizing substantial financial resources, the plan positions Kerala within international commitments while addressing local priorities. With 80 targets across eight thematic areas to be achieved by 2035, but as noted the progress will remain constrained if the fragmented financing and poor convergence continue.

2035 Roadmap: 30 'Model BMCs' as Strategic Anchors for K-SBSAP

The K-SBSAP 2035 has rationalized its implementation strategy by short listing 30 Biodiversity Management Committees (BMCs) across all fourteen districts of the state to serve as model institutions in its implementation. Their selection is guided by ecological significance, administrative diversity, and conservation history, ensuring representation across Kerala's three physiographic zones—Highland, Midland, and Coastal Lowland—and across governance levels of Grama Panchayats, Municipalities, and Corporations. Priority has been given to BMCs with strong biodiversity management records, including those that have pioneered People's Biodiversity Registers (PBRs), Access and Benefit Sharing (ABS) mechanisms, and community-led eco-restoration. This strategic short listing ensures that fragile ecosystems such as shola-grasslands, mangroves, wetlands, river basins, and tribal landscapes are represented, while also embedding livelihood opportunities through biodiversity-based enterprises, nurseries, and seed banks.

The rationale for the 2030 timeline of the 30 model BMCs is closely tied to global commitments. The 2030 deadline of the Kunming-Montreal Global Biodiversity Framework (K-MGBF) coincides with the end of the UN Decade on Ecosystem Restoration (2021–2030), the Sustainable Development Goals (SDGs), and the critical 1.5°C climate stabilization target. By aligning with these milestones, Kerala ensures that its biodiversity strategy is globally synchronized. The remaining five years (2030–2035) under K-SBSAP are earmarked for replication and scaling, where the successes of the 30 model BMCs will be extended to the rest of Kerala's 1,036 BMCs.

Turning Biodiversity Wealth into Sustainable Growth

Kerala, home to nearly a quarter of India's plant diversity within just 1.18% of its land area, envisions becoming the most biodiverse-friendly developed state by 2035. This mission is anchored in the KSBSAP 2025–2035 and global K-MGBF commitments, supported by strong biodiversity institutions—1,034 Biodiversity Management Committees, district coordinators, and Technical Support Groups—that provide a decentralized framework for conservation and sustainable use. To bridge the adequate financing gap and to achieve balanced SDG outcomes, Kerala must triple or more its environmental funding, ensuring statutory mandates, local biodiversity funds, and private sector contributions converge into a robust, outcome-oriented system. Only then can Kerala match its social development leadership with ecological leadership, transforming biodiversity wealth into resilience, economic opportunity, and global recognition as India's most biodiverse-friendly developed state by 2035.

The Mountains That Birthed a State

Dr. T.V. Sajeev
Chief Scientist
Kerala Forest Research Institute

Geologically speaking, Kerala is not just bordered by the Western Ghats; the entire state is the washed-down, alluvial child of these ancient mountains.

To understand the geographical anomaly that is Kerala, one must look deep into the Earth's geological past. Roughly 88 million years ago, the supercontinent Gondwana was fracturing. As the Indian tectonic plate violently tore away from Madagascar to begin its long drift toward Eurasia, the monumental continental breakup created a massive fault line. The western edge of the Indian peninsula thrust upward, creating an immense, stepped escarpment known today as the Western Ghats. Unlike the Himalayas, which are folded mountains formed by the collision of tectonic plates, the Western Ghats are a geological edge—a towering wall of basaltic and metamorphic rock rising abruptly from the Arabian Sea.

But these mountains did not merely form a border; they actively manufactured the landmass below them. Over millions of years of intense tropical weathering, the relentless force of rainfall battered these peaks. The water eroded the rock, washing billions of tons of sediment, silt, and minerals down the steep western slopes. This continuous, slow-motion avalanche of geological debris settled at the foothills and along the coast, slowly building the undulating lateritic midlands and the fertile coastal plains.

The Great Rainmakers and the Anomaly of the Gap

This towering geological barricade is the sole reason Kerala experiences its defining meteorological phenomenon: the monsoon. Standing at an average elevation of 1,200 meters—and peaking at 2,695 meters at Anamudi—the Ghats act as a massive physical barrier against the moisture-laden winds blowing in from the Arabian Sea. When the South-West Monsoon hits this wall between June and September, the air is forced upward in a classic display of orographic precipitation. As the air rises, it cools and condenses, dumping tremendous amounts of rain on the windward side. Just as the land begins to dry, the retreating North-East Monsoon rolls in over the mountains between October and December. Because of the Ghats' unique positioning, Kerala is washed with massive volumes of fresh water twice every year, sustaining an intense hydrological cycle that dictates the state's agriculture and culture. However, the mountain wall is not entirely unbroken. The Palakkad Gap, a unique 30-kilometer-wide breach in the otherwise continuous mountain range, dramatically alters the geography of central Kerala.

An Ecological Masterpiece: From Sea to Sky

The relentless rainfall and extreme topographical gradient—dropping from over 2,600 meters to sea level in a horizontal distance of just 35 to 120 kilometers—have created a compressed ecological masterpiece. Imagine taking a walk from the Arabian Sea to the highest peaks. You would begin in the saline, tide-washed mangrove forests of the coast, which act as a vital biological shield against cyclones and coastal erosion. Moving inland into the midlands, you navigate human-dominated

landscapes peppered with ancient sacred groves (Kavus). These are isolated, untouched patches of primal forest preserved for centuries by local communities, acting as vital micro-reservoirs of endemic biodiversity.

As the elevation rises, you cross expansive, sun-baked laterite plateaus. While they appear barren in the summer, the monsoons transform them into vibrant, fleeting micro-habitats filled with carnivorous plants and endemic wildflowers. Entering the lower slopes, you pass through valuable forest plantations before being swallowed by the lush, broad-leaved canopy of the moist deciduous forests, home to towering teak and rosewood. In the deep, perpetually wet valleys here, you will stumble upon Myristica swamps—prehistoric, water-logged ecosystems characterised by wild nutmeg trees with sprawling, stilt-like breathing roots that look like alien architecture.

Ascending further into the mist, the landscape morphs into dark, dense tropical evergreen forests, such as those in Silent Valley. Here, the canopy is so thick the forest floor rarely sees the sun, and the branches echo with the calls of the endangered Lion-tailed Macaque and the Great Hornbill. Crossing over the crest into the rain shadow region on the eastern slopes, the environment drastically shifts into the dry deciduous forests of Chinnar and the highly aromatic, closely guarded sandalwood reserves of Marayur.

Finally, climbing back to the highest ridges, you emerge into the breathtaking Shola-grassland complex. These are 'sky islands'—stunted, moss-draped evergreen forests nestled tightly in the valleys of rolling, high-elevation grasslands. This is the domain of the Nilgiri Tahr and the legendary Neelakurinji, a shrub that paints the hillsides in a carpet of purplish-blue once every 12 years. Nowhere else on Earth can such a dizzying multitude of diverse forest types be experienced in such a short distance.

The Western Ghats are a geological edge—a towering wall of basaltic and metamorphic rock rising abruptly from the Arabian Sea.

Rivers, Backwaters, and Human Habitation

This highly vegetated topography acts as a gigantic sponge, giving birth to 41 west-flowing rivers. The thick forest soils of the Ghats absorb the monsoon downpours and slowly release water into a deeply complex network of streams and aquifers. These rivers ultimately empty into Kerala's famous backwaters (the Kayals), a sprawling estuarine system where fresh mountain water meets the saline Arabian Sea. The sediment carried down by these rivers over millennia formed rich agricultural bowls, most notably Kuttanad, where farming is uniquely done below sea level, sustained entirely by the silt of the Ghats.

This ubiquitous availability of fresh water fundamentally altered human geography. In most other parts of India, harsh dry seasons forced human settlements to cluster tightly around singular,

reliable water sources, creating distinct, isolated villages. In Kerala, because fresh water was historically available in almost every backyard well, human habitation spread out evenly across the landscape. This gave rise to Kerala's unique rural-urban continuum— a continuously inhabited landscape where it is almost impossible to tell where one town ends and the next village begins.

A Landscape on the Brink

However, the very mechanisms that built and sustained this unique geography are currently under severe threat. Climate change has drastically altered the monsoon pattern; instead of a steady, distributed rainfall over months, the state now faces erratic, intense cloudbursts. When this extreme weather hits a mountain range that has been heavily deforested and structurally compromised, the results are catastrophic.

We are currently witnessing the rapid, violent washing down of the Western Ghats through massive landslides and lethal floods. The structural integrity of the mountains is being hollowed out by rampant, unregulated granite quarrying, which shatters the bedrock and destabilises steep, rain-soaked slopes. Down in the midlands, aggressive laterite mining is systematically levelling the porous hills that act as the region's water-holding sponge, irreparably damaging the subterranean hydrology. Furthermore, historically replacing the water-retaining Shola grasslands with commercial monocultures like Eucalyptus has severely reduced the dry-season flow of our rivers.

The Imperative for Conservation

A paradigm shift toward aggressive, science-backed conservation is no longer an environmental luxury; it is a matter of state survival. The conflicts Kerala faces today are deeply interconnected symptoms of a dying landscape. We suffer from devastating floods during the monsoons, followed paradoxically by acute water scarcity just weeks after the rains stop, simply because the battered, paved-over land has lost its capacity to hold water. Simultaneously, habitat fragmentation and the loss of forest food sources are forcing wild elephants, leopards, and boars out of the Ghats and into agricultural lands, escalating deadly human-wildlife conflicts.

Eminent scientific panel like the Gadgil committee, have warned of these exact scenarios, stressing that ecologically sensitive zones cannot sustain heavy human interference. Conserving the Western Ghats is not merely a moral obligation to protect flora and fauna. It is the fundamental prerequisite to preserving the geological stability, the fresh water security, and the very human habitability of Kerala itself. Without the Western Ghats, the geographical miracle of Kerala simply ceases to exist.

Aggressive laterite mining is systematically levelling the porous hills that act as the region's water-holding sponge.

Where Mountains Meet Monsoon

Prof. Abhilash S.
Director
Advanced Center for Atmospheric Radar Research
Cochin University of Science and Technology

From mountain crest to coastal plain, the journey of cloud and river under the monsoon's rhythm makes Kerala's climate truly one of a kind.

The Western Ghats act as the primary climatic regulator of Kerala, functioning both as a barrier and, through key gaps, as a corridor that allows influences from northern and eastern India to modify local weather. By intercepting moisture-laden winds, the Ghats enhance rainfall, moderate temperature, and sustain high humidity, thereby supporting the state's rich biodiversity from the high ranges to the midlands and coastal plains. The spatial distribution of rainfall across Kerala is strongly controlled by the altitude and orientation of the Ghats, with the highest rainfall along the windward slopes and a gradual decrease toward the eastern rain-shadow regions. The abundant monsoon rainfall captured by the Western Ghats is stored within the mountain ecosystem and released through an extensive network of 44 rivers, maintaining their perennial nature and supporting the flora and fauna, as well as the lives and livelihoods of over 35 million people. These processes also drive a dynamic system of erosion, transport, and deposition, linking Kerala's highlands, midlands, and lowlands into an integrated physiographic unit.

Kerala receives high annual rainfall of about 2500–3500 mm, mainly due to the southwest monsoon and the orographic effect of the Western Ghats. Around 70–75% of the rainfall occurs during the southwest monsoon (June–September), followed by 15–20% during the northeast monsoon (October–November), with minor contributions from pre-monsoon showers. Rainfall is highest along the Western Ghats and decreases towards the eastern rain shadow regions. Together, these factors highlight the central role of the Western Ghats in shaping Kerala's climate, hydrology, and ecological balance.

The monsoon is the defining feature of the climate of Kerala, usually arriving around June 1 each year and marking the start of the rainy season. As explained by Colin Stokes Ramage, a true monsoon climate involves a major shift in wind direction between winter and summer—something clearly experienced in Kerala.

The importance of these winds has been recognized for centuries. The ancient Greek text Periplus of the Erythraean Sea describes how the navigator Hippalus understood these seasonal wind patterns, making it possible to sail directly across the Indian Ocean from the Red Sea to ports like Muziris on the Kerala coast. This discovery not only transformed maritime trade but also highlights how closely Kerala's history and livelihood have been tied to the rhythm of the monsoon.

The South Asian monsoon we experience today is the result of a long geological journey shaped by Plate Tectonics. Over millions of years, the movement of continents, the rise of mountains, and changes in the oceans have all played a role in building the modern monsoon system. A key turning point came about 50 million years ago, when the Indian plate drifted northward and collided with Eurasia. This collision led to the formation of the Himalayas and the uplift of the Tibetan Plateau, which significantly altered atmospheric

circulation and strengthened the monsoon.

At its core, the Indian summer monsoon is driven by the contrast in heating between land and sea. As the Sun moves northward during summer, the vast landmass stretching from East Africa to northern India heats up rapidly, creating a strong low-pressure area. In contrast, the surrounding oceans remain relatively cooler, drawing in moisture-laden winds toward the land. While this land–sea temperature difference is the primary driving force, the monsoon's behavior is further shaped by Earth's rotation and major mountain barriers like the Himalayas and the Western Ghats, which guide and intensify rainfall patterns.

Kerala's climate and landscape are deeply shaped by its unique location along the Arabian Sea and the towering Western Ghats. The highlands, formed by the uplifted Western Ghats, are the first to receive the force of the monsoon. Heavy rains here lead to continuous weathering of rocks and soil erosion. The eroded material is carried downhill by numerous rivers, gradually shaping the midlands with rolling terrain and lateritic soils formed through prolonged leaching. Further downstream, these sediments are deposited in the lowlands and coastal areas, creating fertile alluvial plains that support agriculture and settlements. This natural cycle of erosion, transport, and deposition connects Kerala's landscapes into a dynamic and interdependent system.

During the southwest monsoon, the Western Ghats act as a massive barrier to moisture-laden winds from the Arabian Sea. As these winds are forced to rise along the mountain slopes, they cool and condense, producing intense rainfall, through a process known as orographic precipitation. This is why Kerala receives some of the highest rainfall in India. At the same time, the Western Ghats also block hot winds from the interior, helping Kerala stay relatively cool, humid, and comfortable compared to many other regions.

The monsoon is central to life in Kerala. It replenishes rivers, recharges groundwater, and sustains agriculture. It also supports the region's rich biodiversity, from dense forests in the high ranges to wetlands and backwaters along the coast.

During the hot pre-monsoon months, the Western Ghats shape the weather of Kerala in two contrasting ways. For most of the state, the Ghats act like a barrier, blocking hot, dry winds from the interior and helping maintain humid conditions. But the natural breaks such as the Palakkad Gap and Punalur Gap, acts as corridors. Through these gaps, hot diverging air from the anti-cyclonic

circulation move main land flows into Kerala, raising temperatures, reducing humidity at times, and intensifying heat-wave conditions in certain regions.

At the same time, the Ghats play a key role in triggering pre-monsoon rainfall. Along their foothills, a "wind discontinuity" often forms where moist winds from the Arabian Sea meet the hot, dry easterly winds coming through the gaps. This collision of air masses forces air to rise, and the mountains further enhance this upward motion. Combined with strong daytime heating, this creates unstable conditions that quickly build towering cumulonimbus clouds. As a result, many areas, especially along the foothills in districts like Kottayam, Idukki, and Pathanamthitta experiences frequent thunderstorms with lightning, thunder, and gusty winds. These short but intense showers, popularly known as "mango showers," bring the first relief from the heat and play an important role in preparing the land for the coming monsoon and agricultural season.

The Western Ghats modulate the northeast monsoon over Kerala primarily through a rain-shadow effect, as the northeasterly winds lose much of their moisture on the eastern side of the mountains. As a result, Kerala receives less direct rainfall from the northeast monsoon compared to regions on the eastern side. However, the state still experiences rainfall during this period due to moisture picked up from the Arabian Sea, local convective activity, and the influence of cyclonic systems. Easterly waves play a major role in bringing widespread post-monsoon rain, while the Western Ghats enhance this rainfall through orographic uplift and the formation of localized thunderstorms along the foothills. This leads to rainfall that is often uneven, scattered, and intense across South and central Kerala.

With the onset of the southwest monsoon, the Ghats force moisture-laden winds from the Arabian Sea to rise, producing heavy rainfall that defines Kerala's hydrology and sustains its ecosystems. In the post-monsoon period, they create a rain-shadow effect for northeasterly winds, yet still support localized rainfall through convection and cyclonic influences. Overall, the Western Ghats regulate temperature, humidity, and rainfall distribution, making them fundamental to Kerala's climate and environmental stability. From mountain crest to coastal plain, the journey of cloud and river under the monsoon's rhythm makes Kerala's climate truly one of a kind.

The Veins of Kerala

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The geographic identity of Kerala is inextricably linked to its immense abundance of water bodies, a feature that distinguishes it as a unique 'hydro-geographic' landscape within the Indian subcontinent.

Periyar

Kerala is etched with a dense network of 44 rivers, which, combined with a 590 km coastline and approximately 4,650 km2 of brackish lagoons and estuaries (backwaters), creates a high-moisture environment that dictates everything from local weather to soil chemistry. This 'aqueous geography' acts as a massive thermal regulator, buffering the region against extreme temperature swings and maintaining the high humidity essential for the survival of the tropical evergreen forests and the rare 'Shola' ecosystems of the Western Ghats. Thus Kerala represents one of the most hydrologically dynamic regions in the humid tropics. Despite its relatively small geographical extent, the state sustains a dense population through a complex and highly responsive water resource system governed by monsoonal variability, physiographic gradients and the dominant influence of the Western Ghats.

However, this abundance also makes the state's geography highly sensitive to environmental shifts. The intricate connection between the surface rivers and the underground aquifers, which fulfill 75% of the state's drinking water needs, means that any change in river discharge directly impacts the water table. The sheer volume of these water bodies ensures that Kerala's terrain remains lush and fertile, but it also creates a landscape that is uniquely vulnerable to the twin threats of seasonal flooding during the monsoons and saltwater intrusion in the coastal lowlands during the dry summer months. The river system of Kerala, comprising 44 rivers – 41 westward-flowing and three eastward-flowing (Kabani, Bhavani, and Pambar) – is fundamentally distinct from the large alluvial river systems of peninsular India. These rivers are short, steep, and monsoon-fed, originating in the elevated terrains of the Western Ghats and descending rapidly towards the Arabian Sea. This geomorphic configuration results in high runoff efficiency but low water retention, a paradox that explains the coexistence of flood abundance during monsoon and acute water scarcity during summer. Rivers such as Periyar, Bharathapuzha, and Pamba function as hydrological lifelines, yet their basin-scale dynamics reveal a system highly sensitive to both climatic fluctuations and anthropogenic disturbances.

Kerala, located at the southwestern tip of India between 8°15'N and 12°50'N latitudes, experiences a humid tropical climate characterised by high temperatures and intense monsoonal rainfall, making its hydrological cycle particularly dynamic and climate sensitive. Consequently, the impacts of climate change are expected to be pronounced in the region.

Unlike perennial snow-fed rivers, Kerala's rivers lack sustained baseflow buffering, making them increasingly vulnerable to seasonal flow intermittency under changing climate regimes.

Major Westward Flowing Rivers

- **Periyar:** The longest river and "lifeline of Kerala".
- **Bharathapuzha:** Also known as the Nila.
- **Pamba:** Known as the Dakshina Ganga.
- **Chaliyar**
- **Chalakudypuzha**
- **Kadalundipuzha**
- **Valapattanam**
- **Achankovil River**
- **Kallada River**
- **Muvattupuzha River**

Eastward Flowing River

- **Kabani**
- **Bhavani**
- **Pambar**

Terrain Control

The topographic and geomorphological configuration of Kerala plays a decisive role in shaping its hydrology. The sharp transition from highlands to coastal plains within a narrow width creates intense hydraulic gradients, promoting rapid surface runoff and limited infiltration. In the highlands, mechanical weathering and slope processes dominate, generating coarse sediments that are transported downstream during high-flow events. In contrast, the lowlands function as zones of deposition, forming floodplains, estuaries, and backwater systems.

Western Ghats: The Water Tower

At the core of Kerala's hydrological sustainability lies the Western Ghats, a globally recognized biodiversity hotspot and a critical orographic barrier that regulates monsoonal precipitation. Beyond their role in rainfall generation, the Ghats function as hydrological regulators, modulating streamflow through forest-mediated infiltration, subsurface storage, and delayed release mechanisms. Emerging research increasingly frames the Western Ghats as a climate-sensitive 'water tower', whose degradation directly translates into downstream water insecurity. This ecosystem is the backbone of the region's socio-economic survival, supporting industries and agriculture through its natural resources.

Water Quality and Sediment Dynamics

The hydrochemical characteristics of Kerala's water resources further reflect the interplay between geology, climate, and anthropogenic inputs. Waters

are generally soft and slightly acidic, particularly in lateritic terrains, where intense leaching under high rainfall conditions removes base cations.

Sediment dynamics in Kerala's rivers provide another lens through which environmental change can be understood. Under natural conditions, sediment transport is episodic but balanced, driven by high-intensity rainfall events. However, large-scale and unregulated sand mining and flood plain mining had disrupted this equilibrium, transformed rivers from sediment-transport systems into sediment-deficient channels. The natural riverbed condition was totally changed, and this may take many years to regain its normal substratum. The resulting channel incision, bank instability, and lowering of the alluvial aquifer interface have profound implications for groundwater recharge and river-aquifer interactions.

Water Resources and Climate Change Impacts

Kerala's recent history of extreme hydrological events underscores the growing influence of climate change on its water systems. The catastrophic floods of 2018 and 2019, preceded by drought conditions and followed by recurrent landslides, exemplify a hydrological regime shift towards extremes. Intensification of short-duration, high-intensity rainfall events has increased runoff generation beyond the absorptive capacity of soils and reservoirs, while altered monsoon patterns have reduced temporal predictability. These changes challenge conventional water management approaches, which were historically designed for more stable climatic conditions.

Studies indicate that there is an increase in the speed of hydrologic cycle for about 24% within the previous 50 years. In future it is expected for the incidences of uncertain and unexpected events on the earth which are totally unexperienced for us. According to

reports by the Intergovernmental Panel on Climate Change (IPCC), the frequency and intensity of heavy precipitation events have increased globally, with human-induced greenhouse gas emissions identified as the primary driver. Further global warming is expected to amplify both the frequency and intensity of such events. Kerala,

Hydroclimatic Shifts and Sustainable Water Management in Kerala:

Kerala's water systems are increasingly influenced by hydroclimatic non-stationarity, with unpredictable monsoons and intense short-duration rainfall replacing stable historical patterns. At the same time, river–aquifer interactions are weakened due to unscientific sand mining once prevailed and resulted in alarming channel deepening, irregular substratum, reduced baseflow during dry periods. In response, management is shifting towards ecohydrological approaches, emphasising restoration of natural flow regimes, even sandy beds, riparian zones, and floodplain connectivity. Alongside this, nature-based solutions, such as wetland restoration, afforestation in the Western Ghats, and river corridor protection, are being promoted to enhance long-term water sustainability.

located at the southwestern tip of India between 8°15'N and 12°50' N latitudes, experiences a humid tropical climate characterised by high temperatures and intense monsoonal rainfall, making its hydrological cycle particularly dynamic and climate sensitive. Consequently, the impacts of climate change are expected to be pronounced in the region. We know that climate change–induced floods and droughts are already affecting water availability and security in Kerala. Measures such as the construction of check dams, reservoirs, and other storage structures, along with the identification and protection of natural water retention systems, are essential as per the suitable terrain condition for the sustainable water resource management.

Water Abundance and Controlling Factors

Despite its apparent water abundance, Kerala faces a paradox of seasonal water scarcity, driven by rapid runoff, inadequate storage infrastructure, and degradation of natural recharge systems. Urbanisation, wetland reclamation, and riverbank encroachment have further reduced the landscape's capacity to store and regulate water. Pollution from domestic, agricultural, and industrial sources continues to degrade water quality, while salinity intrusion threatens coastal aquifers. These interconnected challenges highlight the need for a paradigm shift from sectoral water management to integrated river basin management (IRBM), which considers hydrological, ecological, and socio-economic dimensions simultaneously.

In this context, modern technological tools are playing an increasingly important role. Remote sensing and Geographic Information Systems (GIS) enable high-resolution mapping of watershed characteristics, land-use changes, and hazard zones, facilitating the conservation measures through evidence-based planning and protection. In Kerala, these tools have been effectively applied in real-time studies, including flood inundation mapping during the 2018 floods using Sentinel satellite data, land-use change detection in the Western Ghats highlighting forest loss and plantation expansion, and groundwater potential zonation through multi-criteria GIS modeling. More recently, the integration of Machine Learning (ML) and Artificial Intelligence (AI) have transformed hydrological modeling in the region. Data-driven approaches such as Artificial Neural Networks (ANN) for groundwater level prediction, Random Forest and Support Vector Machine (SVM) models for water quality classification, and deep learning techniques for rainfall–runoff simulation are increasingly being employed, offering improved accuracy over traditional deterministic methods.

Sustainability Thoughts

In conclusion, Kerala's water resources represent a complex interplay of natural processes and human interventions, characterised by both richness and fragility. Safeguarding the ecological integrity of the Western Ghats through climate-resilient strategies, watershed conservation, afforestation, and regulation of land-use change, will be essential to sustain hydrological processes. By establishing a Geo Environmental Observatory (GEObs) in the pristine forested areas of the Western Ghats, the continuous monitoring of greenhouse gases and air pollutants will be possible. The GEObs will have to serve as the reference station for all river basins of Western Ghats with its prime location in the highest possible location adjacent to Anaimudi hills. Till now, a full-fledged instrumentation system meant for studying the climate, weathering and near surface processes is lacking in the Western Ghats. Kerala can thus stand at a crossroad, where the choices made today will define the sustainability of its natural resources for generations to come.

The Life-sustaining Ecosystems

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Wetlands are one of the prime life supporting ecosystems of nature having high biological richness and diversity

In the simplest way, one can define a wetland as an area of land that is transitional between terrestrial and aquatic ecosystems where the water table is usually at or near the surface or covered by water whose depth is less than 6m. It is one of the prime life-supporting ecosystems of nature having high biological richness and diversity. Wetlands include a variety of forms - marsh, fen, peatland,river, lake, paddy land, mangrove swamp, coral reef and several others. Geological records reveal that wetlands are formed on the earth subsequent to the initial rainfall events on earth. The time span of 225 – 345 million years of the earth's history, known in the geological calendar as Permo-Carboniferous Period, had many wetlands of the peatland type containing economically viable coal deposits across the world. Wetlands are seen throughout the world, and the only exception is Antarctica, where the land is covered essentially by glacial ice. According to one estimate, the world's wetlands together cover about 5% of the land surface.

Wetlands provide many services to mankind. Among the services, the two most important services that are directly linked to human well-being are food supply and water availability. Food supply is essentially through fish production. It is a fact that a major portion of animal protein comes from the wetland ecosystem. Wetland related fisheries contribute a major share of the local and national economy of many countries, including India. Coming to water, the principal supply of renewable fresh water is from wetland sources. Ground water recharged through wetlands also plays an important role in water supply. Wetlands are often called the 'kidney lands' of nature. This is because of its ability to purify water and detoxify waste. Studies revealed that some of the wetlands have the ability to reduce nutrient loads (eg., nitrates and phosphate) in water to a significant level.

Wetlands sequester a major proportion of carbon, which otherwise reaches the atmosphere through various means. The peatland type of wetlands holds about 1.5% of the total estimated global carbon storage. This clearly indicates the role of wetlands in climate regulation and also regulation of greenhouse gas emissions. Further, wetlands like mangroves and floodplain swamps play a critical role in physical buffering of climate change impacts. Wetlands also provide significant aesthetic, educational, cultural, and spiritual benefits as well, in addition to providing a vast array of opportunities for recreation and tourism. It is now well established that the total economic value of unconverted wetlands is many times higher than the converted wetlands.As per a study report, an intact wetland is found to be worth 6000 dollars per hectare, while it is just 2000 dollars per hectare when cleared and converted for intensive agriculture. Tropical mangroves are estimated to be worth around 1000 dollars per hectare, but when cleared for shrimp farms, the value would just be 200 dollars per hectare.

Ramsar wetlands and Monteaux Record

Considering the importance

of wetlands and its ecosystem services, a total of 2500 wetlands of international importance are enlisted by the Ramsar Secretariat for special care and conservation. Out of these, 98 are from India, and the maximum number (20) is in Tamil Nadu State. The total area of Ramsar wetlands comes to about 14 lakh hectares. The Patna Bird Sanctuary in Uttar Pradesh and Chhari-Dhand wetland in Gujarat are the latest additions to the Ramsar list from India. These wetlands are added to the Ramsar list in January, 2026. Among the Ramsar Wetlands in India, the Sundarbans wetland in West Bengal has the highest areal extent (4230 km2) and the VembanadKol wetland in Kerala is the second largest wetland, covering about 2,033 km2. The Renuka wetland in Himachal Pradesh and the Vembannur wetland in Tamil Nadu have the smallest areal coverage of about 20 hectares. Among the Indian wetlands, the Keoladeo National Park in Rajasthan and Loktak Lake in Manipur are currently enlisted under Montreaux Record maintained by the Ramsar Secretariat. Montreaux Record is nothing but a register containing wetlands of international importance where changes in ecological character have occurred or are occurring or are likely to occur as a result of technological developments, pollution, and other human interferences. The Chilka Lake in Orissa was once placed in the Montreaux record but later removed from the list as the lake recouped its ecological character. India is one of the countries that are very keen on protecting their wetland wealth. The National Wetland Conservation programme launched in 1986 identified 115 wetlands for urgent protection and conservation. Amidst all these efforts, many wetlands in the country, including that of Kerala, are still under immense ecological stress due to various reasons.

Wetlands are often called the 'kidney lands' of nature. This is because of its ability to purify water and detoxify waste.

The Quiet Lifelines of Kerala

It will be quite interesting to have a case analysis of Kerala Wetlands, as an example.The wetlands in the state are under stress due to the adversities of urbanisation and economic development. The state has a total of 217 wetlands, including the three Ramsar wetlands such as Ashtamudi, Sasthamkotta and Vembanad – Kole wetlands to its credit. The total area of Kerala's wetlands comes to about 0.128 million hectares, and these wetlands are under immense stress due to various reasons. Pollution, eutrophication, encroachment,

reclamation, mining, biodiversity loss, etc., are some of the environmental threats that are leading to degradation of these wetlands.

As per the study of Dr. V.S. Vijayan, former chairman of Kerala State Biodiversity Board, the total ecosystem service values of all the wetlands of Kerala, including the paddy lands, come to about 231 billion rupees per year, which is almost equal to that of the annual revenue receipt of the state. It should be realised that the expenditure projected in each year's budget would have been much higher if the state had not received the services of its wetlands. Wetlands not only ensure water availability for agriculture and drinking but also enhance the economic base of the people in the fishery and tourism sectors. All these point to the imminent need for protecting the wetland ecosystems of the state from the adversities of rapid urbanisation and economic development.

Wetlands also provide significant aesthetic, educational, cultural, and spiritual benefits as well, in addition to providing a vast array of opportunities for recreation and tourism.

Today, about half of the world's population lives in urban areas. As per projections, the number of megacities across the world with more than 10 million inhabitants will rise from 31 to 41 by the year 2030. Urbanisation is at a faster rate in our country as well. The urban population in India, according to the 1901 census, was about 11%.But it was raised to 29% in 2001 and now crossed 31%. In the case of Kerala, the number of cities and townships has risen from 197 in 1991 to 520 in 2011. It has to be ensured that the cities have to deliver not only the basic services such as accommodation, transport ,and water but also must provide safe, resilient, and environment-friendly livable space to the people. A healthy urban wetland absorbs excess rainfall, reduces flooding, mitigates pollution, improves water quality, provides water and space for recreation, and so on and so forth. It should be noted that the flood hazard of the Kerala Flood, 2018 ,was not much more vigorous in river basins having intact wetlands in their overbank areas. The wetlands provided room for floodwaters, thereby reducing the flood hazards. Wherever the floodplain wetlands are reclaimed, the fury of flood waters becomes severe and fatal. It is now well understood that when preserved and sustainably used, wetlands offer multiple economic, social, and cultural benefits to the people in the area. No doubt, all the wetlands should be treated as prize lands, not as wastelands. Take adequate measures and action plans to retain, restore, and preserve all our wetlands and integrate them into the development and management plans of the state.

The Restless Edge

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The Kerala coast is not a fixed boundary between land and sea; it is a dynamic, ever-changing system shaped by geological forces, monsoon winds, flowing rivers, and human history.

A Coast That Never Stands Still

On a humid evening along the Kerala coast, as waves roll gently onto the shore and fishing boats return against a glowing sunset, it is easy to believe that this landscape has always been the same. The coconut palms, sandy beaches, and quiet backwaters appear timeless. Yet, this apparent stability is an illusion. The Kerala coast is not a fixed boundary between land and sea; it is a dynamic, ever-changing system shaped by geological forces, monsoon winds, flowing rivers, and human history. It is a living, breathing laboratory of coastal geomorphology, a landscape in constant dialogue with the forces of the ocean and the legacy of ancient cataclysms. From the legendary disappearance of ancient ports to the birth of vast below-sea-level wetlands, the story of Kerala's coast is one of relentless dynamism.

Ancient Foundations and a Faulted Origin

The geological story of Kerala began roughly three million years ago. While most of the state sits on Precambrian crystalline rocks (dating back 0.5 billion years), the specific strip we call the coast was likely forged by faulting during the late Pliocene. This tectonic rift created a unique Western-sloping landscape where 75% of the land has a seaward slope greater than 15%, causing water, sediments, and history to rush toward the Arabian Sea. Throughout the Quaternary period, the shoreline has been a moving target, oscillating with the rise and fall of global sea levels. During the Last Glacial Maximum (~18,000 years ago), the sea was roughly 120 meters lower than it is today. As the ice melted and the sea marched inland, it carved out the bays, lagoons, and sandy barriers that define the modern landscape of Keralam.

A Dynamic Shoreline: Erosion and Creation

Waves, tides, and currents constantly reshape the Kerala coastline. The shoreline shifts over time as sediments are eroded from one place and deposited in another. In some stretches, the sea gradually eats away the land, while in others, new land is formed through deposition.

Studies show that the shoreline can move significantly over decades, sometimes by hundreds of metres. Large sections of Kerala's coast are highly vulnerable to erosion, highlighting the delicate balance between natural forces that shape the coast.

From Mountains to Sea: A Connected Landscape

Kerala's geography is often described as a sequence of highlands, midlands, and coastal lowlands. However, these are not isolated regions. They are deeply interconnected through rivers and sediment flows.

The Western Ghats act as the source of numerous rivers that carry sediments downstream. These sediments are deposited along the coast, helping to build beaches, sustain wetlands, and maintain the coastal balance. Without this continuous supply, the coastline would erode much faster. Thus, the coast is not just

shaped by the sea but also by the mountains far inland. The monsoon rains in Kerala are, in essence, a gift from the sea, carried inland as water vapour and returned to the sea through the rivers, completing a continuous cycle. Similarly, the richness and productivity of coastal waters are sustained in part by organic matter transported from forested landscapes to the ocean, linking land and sea in a vital ecological exchange.

The Birth of Backwaters and Vembanad Lake

One of Kerala's most distinctive features is its network of backwaters, including the vast Vembanad Lake. These systems are formed through the interaction of marine and riverine processes. Sandbars and barrier spits developed parallel to the coast, trapping water behind them and creating lagoons.

Over time, rivers deposited sediments into these lagoons, forming wetlands and deltaic plains. In regions such as Kuttanad, this process, combined with human intervention, has resulted in land lying below sea level. These landscapes are constantly evolving, shaped by both natural forces and human activities.

Monsoon Winds: Nature's Architect and Navigator

For centuries, the Monsoon was the engine of Kerala's economy. Driven by ocean-atmosphere interactions, the monsoon influences rainfall, wave patterns, and sediment movement. It is a key factor in coastal erosion and deposition. Sailors from distant lands used these predictable winds to travel to Kerala. The predictable shift in winds allowed Roman, Arab, and Chinese navigators to sail across the ocean to the bustling port of Muziris. Muziris was the "first emporium of India," a multicultural hub where gold was exchanged for "black gold" (pepper). The coast thus became not only a physical boundary but also a gateway connecting Kerala to the wider world.

As the ice melted and the sea marched inland, it carved out the bays, lagoons, and sandy barriers that define the modern landscape of Keralam.

The Great Flood of 1341: A Turning Point

History records a dramatic example of coastal change: the great flood of 1341 CE. This event is believed to have altered river courses and reshaped the coastline. It played a significant role in the decline of the ancient port of Muziris, once a thriving hub of Indo-Roman trade.

Geological Evidence suggests that changes in river channels, combined with sea-level fluctuations and climatic variability, transformed the region. Old waterways were buried, and new ones formed. In the aftermath, ports such as Kochi emerged, demonstrating how natural forces can reshape both landscapes and history.

The Highland-Coast Connection: A Sand River

The health of a beach in Thiruvananthapuram or Alappuzha begins in the Western Ghats. Of Kerala's 44 rivers, 41 flow westward, acting as conveyor belts for sediments and nutrients. This flow feeds the "longitudinal drift"—essentially a river of sand

that flows parallel to the coast.

May to September: Monsoon waves cause erosion, moving sand away from the shore.

November to March: The reverse flow regains the sand, naturally rebuilding the beaches.

Today's Coast: Beauty Under Pressure

Kerala's coast today is a landscape of immense beauty, but it is also under increasing stress. Coastal erosion, rising sea levels, and human activities such as harbour construction and seawalls are disrupting natural processes.

The balance between sediment supply and wave action is being altered, leading to accelerated erosion in many areas. A significant portion of the coastline is now vulnerable, posing risks to livelihoods, infrastructure, and ecosystems.

Oceans, Climate, and the Future

The ocean plays a vital role in regulating climate and sustaining life. It influences monsoon patterns, supports fisheries, and provides numerous ecological services. However, climate change is intensifying storms, warming ocean waters, and causing sea levels to rise.

The monsoon rains in Kerala are, in essence, a gift from the sea, carried inland as water vapour and returned to the sea through the rivers, completing a continuous cycle.

These changes are particularly concerning for low-lying regions like Kerala. Coastal communities face increasing risks from flooding, erosion, and habitat loss. The close relationship between the ocean and human well-being makes it essential to address these challenges urgently.

As climate change brings more frequent hurricanes to the Arabian Sea and rising sea levels threaten to submerge Kochi and Kuttanad by the century's end, the need for healthy ecosystems has never been more urgent.

Modern science is moving away from "hard armouring" (seawalls), which often aggravates erosion in neighbouring areas. Instead, the focus is shifting to nature-based solutions:

Living Shorelines: Restoring mangroves, dunes, and native vegetation to absorb wave energy. For example, 330 feet of mangroves can reduce wave force by 66%.

Room for the Sea: Adopting a "coastal buffer zone" of 50 meters where natural processes can occur without human interference.

Sand Bypassing: Manually moving sand trapped by harbours to the eroded northern sides to mimic natural drift.

A Coast that Teaches Us

The story of Kerala's coast is a story of constant change and deep connections. It is shaped by the interplay of mountains, rivers, oceans, and winds. It has influenced history, culture, and livelihoods, and continues to do so.

As we stand by the sea, watching the waves reshape the shore, we are reminded that the coast is not a boundary but a living system.

"The coast is not where the land ends, but where Earth's story is continuously rewritten." To secure our future, we must learn to live with nature's rhythms, not against them.

Palakkad Gap
The Geographical Marvel of Kerala

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Carved into the majestic Western Ghats, the Palakkad Gap emerges as a remarkable low-level landscape in the mountain chain.

One of the striking features of the Western Ghats is the presence of a low-level landscape known as the Palakkad Gap. The gap has an average width of about 32 km and a length of over 50 km and is bordered by the Nilgiri Hills to the north and the Anaimalai Hills to the south. It covers an area of 980 km², of which 52.4% lies within the district of Palakkad in Kerala, while the remaining approximately 47.6% is located within the district of Coimbatore in Tamil Nadu. Located on the corridor linking the states of Kerala and Tamil Nadu, the Gap region benefits from a dynamic network of roads and railways, providing excellent connectivity to key cities on both sides of the Western Ghats. The gap also affects the weather patterns in Southern India as it allows the moisture-laden Southwest monsoon winds into western Tamil Nadu, moderating summer temperatures and generating greater rainfall in the region relative to the rest of Tamil Nadu. It also allows the hot winds coming from Tamil Nadu, which warm the eastern part of Kerala compared to the rest of the state.

A Natural Corridor of Exceptional Significance

The Palakkad Gap constitutes the only significant break in the continuity of the Western Ghats and is unique in many aspects. The dominant lithology of the region is Hornblende Biotite Gneiss, bordered by Charnockite formations. Geomorphologically, the Palakkad Gap represents a micro-unit shaped by structural influences, differential erosion, and sedimentary dynamics. Geochemical and petrographic analyses of the rocks in this region suggest their origin in a tectonic environment associated with a volcanic arc subduction system, most likely during the supercontinent assembly that took place in the Paleoproterozoic (2,500 to 1,600 million years ago). This terrain amalgamation occurred along a suture zone now known as the Palghat Cauvery Shear Zone (PCSZ). The continuation of the PCSZ can be seen in Madagascar (in the Indian Ocean, in the vicinity of Africa) in the form of the Betsimisaraka suture of eastern Madagascar.

The Hf isotopic ages of rocks within the Palakkad Gap region show evidence of a high-grade metamorphism during 777±18 Ma. These ages are connected with the crustal extension and rifting during the final stages of the breakup of the Rodinia supercontinent. The geochemistry and petrography of the rocks of the region also manifest the fact that the area underwent multiple stages of deformation. These rocks exhibit signs of high-grade metamorphism, indicating significant geological activity over time.

Geomorphology

The geomorphic diversity of the Gap reflects a combination of natural processes and human influence. The gap region represents an area of low undulating relief, with convex gently graded inter-stream tracts sloping down to broad valley floors. Denudational landforms

dominate, with pediplains forming the largest proportion of the landscape. Fluvial incision, pediplanation, and tropical weathering progressively lowered the relief, transforming the tectonic lineament into the present physiographic gap. Fluvial processes contribute to valley fills and floodplains, while structural controls like lineaments influence drainage systems. This varied landscape illustrates the intricate interaction between geology, climate, and tectonic activity over time, establishing the uniqueness of Palakkad Gap.

Soil Mineralogy

The varied physical settings have played a fascinating role in bestowing nature's bounty by providing moderately deep to deep soils in the area. The major part of the Palakkad Gap region (94.22 percent) is having good-depth soils. The analysed soil samples from the Palghat gap show a predominant occurrence of primary minerals like quartz and feldspar with a notable presence of gibbsite and kaolinite-illite as secondary/alteration minerals. The gibbsite and kaolinite-illite minerals form as the third and fourth-ranking minerals in the analysed soil showing that these minerals form as an alteration product of feldspar and biotite. The gibbsite most likely forms in the early weathering process in an alkaline environment, and the kaolinite-illite forms in slightly acidic to neutral environments.

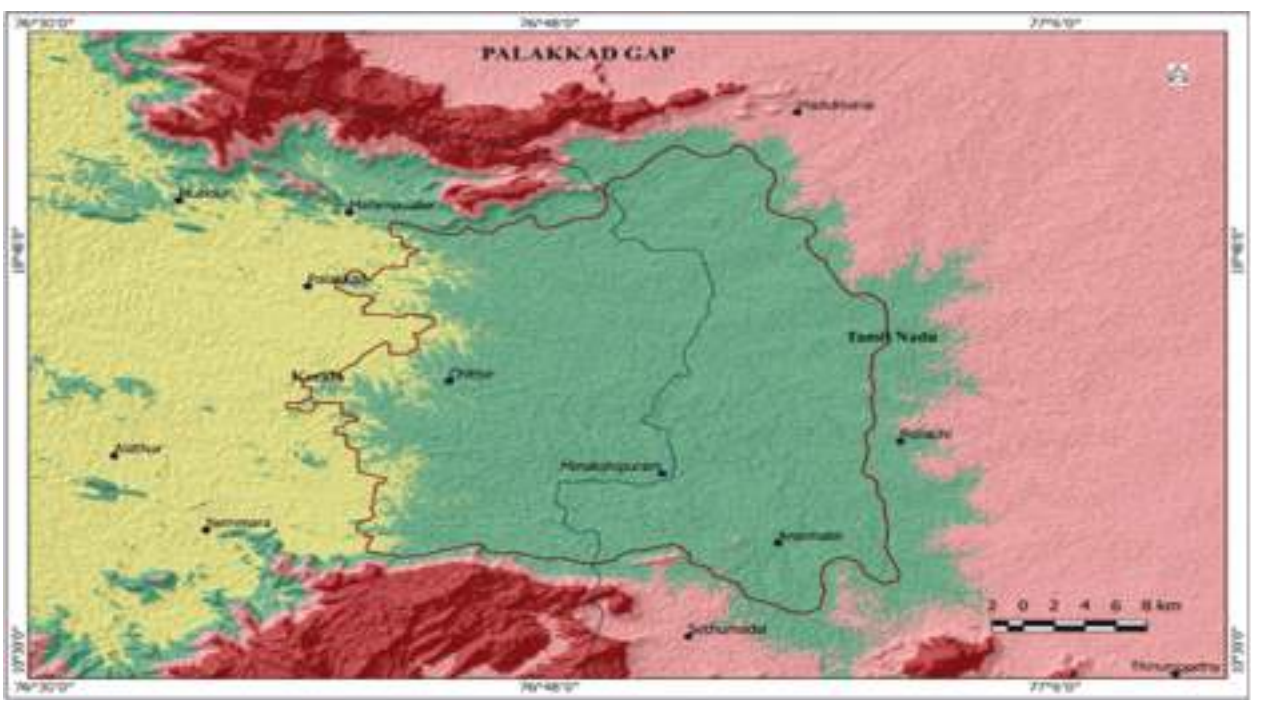
River Network of the Gap

The gap region is drained by the river Bharathapuzha. This river originates from the Anamalai Hills at about 610 meters above mean sea level. It is also known as the Ponnani River or 'Nila Nadi'. The river sprawls through Pollachi Taluk of Tamil Nadu before entering in Palakkad District. The main river passes through Chittur, Palakkad, and Ottappalam Taluks, and finally, it falls into the sea at Ponnani in Malappuram District. The main tributaries are Kalpathypuzha or Korayar, Chittur puzha or Amravathi, Gayathri and Thootha puzha.

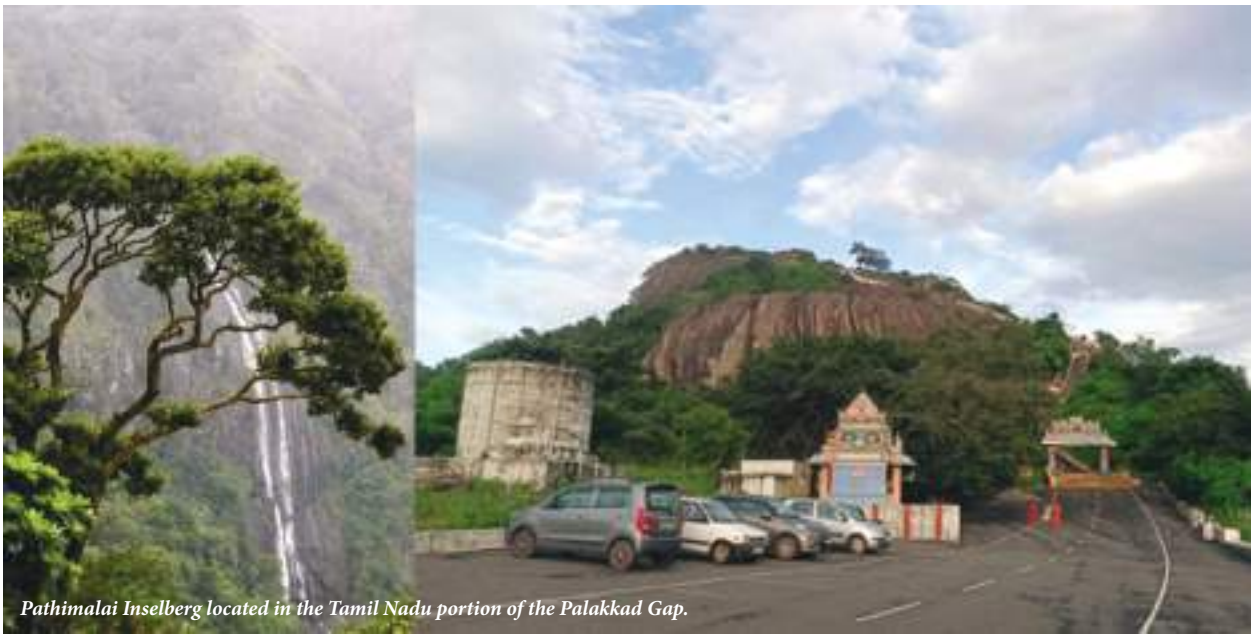
The Palakkad Gap region is highly diverse in terms of flora, and it harbours many rare and endemic species.

The Flow Beneath

The groundwater condition in the region is normal for most of the regions, except for a few alkaline problems. The weathered zone and fracture system in crystalline rocks form the repositories of groundwater in the area. The deeper fracture zone exhibits significant potential for groundwater occurrence due to its tectonically disturbed nature and the presence of semi-confined to confined aquifer conditions. Repeated episodes of tectonic deformation in the area have resulted in the development of an extensive network of interconnected fractures, which



Palakkad Gap - Location



Pathimalai Inselberg located in the Tamil Nadu portion of the Palakkad Gap.

serve as effective conduits for groundwater flow and provide substantial storage capacity.

A Haven of Flora

The Palakkad Gap region is highly diverse in terms of flora, and it harbours many rare and endemic species. The wetlands of Palakkad gap harbours 170 species of angiosperms belonging to 44 families and 101 genera, and 7 species of pteridophytes belonging to 6 families. The hillocks of the gap region are highly diverse with seasonal vegetation, and they are found to be home for 89 plants belonging to 39 families and 68 genera. Eruthempathy panchayath exhibited the highest crop richness, and Vadakarapathy Panchayath showed the greatest Simpson index and species divergence, both located within the Gap. Large-scale cultivation of 13 varieties of food and cash crops has been identified within the Gap area.

Towards Geo-Heritage Recognition

The Palakkad Gap stands as a remarkable testament to Earth's geomorphic artistry, a living corridor where landscapes, ecosystems, and human histories converge. Owing to its exceptional origin, ecological richness, and enduring role as a natural passage, it deserves formal recognition as a geo-heritage site, ensuring its preservation for generations to come. Such recognition, however, rests upon the committed support of the state government, whose role is pivotal in safeguarding its scientific and cultural legacy. At the same time, the intricate tapestry of physical and cultural landscapes woven across the Gap invites deeper, more nuanced inquiry, urging scholars to explore how nature's forces continue to shape livelihoods, traditions, and the rhythms of community life.

The Palakkad Gap stands as a remarkable testament to Earth's geomorphic artistry, a living corridor where landscapes, ecosystems, and human histories converge.

A Landscape of Abundance

Blessed with rich biodiversity, fertile soils, and a favourable climate, the Palakkad Gap unfolds as a distinctive agro-ecological region where natural endowments and human intervention harmoniously converge. These favourable conditions make it especially suited for the cultivation of high-value ayurvedic herbs, medicinal plants, and horticultural crops, fostering agricultural diversity and economic vitality. The widespread presence of perennial crops further enhances this landscape, not only sustaining long-term productivity but also gently moderating the local microclimate, reducing heat intensity during the summer months and contributing to a more stable and hospitable environmental setting. When the unique natural and cultural assets of a region are preserved and promoted in an inclusive and sustainable way, they become powerful tools for local livelihood enhancement.

Kuttanad:
A Timeless Waterbound Landscape

K.V. Divyasree
Writer

Kuttanad stands as a unique geographical landscape where land and water exist in delicate balance, shaping a distinctive identity that makes it one of Kerala's most remarkable natural settings.

Kuttanad, often called 'The Rice Bowl of Kerala,' is a unique and picturesque region located around the vast Vembanad Lake. Its formation and existence is defined by a rare phenomenon: it is one of the few places in the world where farming is carried out successfully at 1.2 to 3 meters below sea level.

A Landscape Below Sea Level

Kuttanad's landscape is defined by its unusual topography, with vast stretches of land lying up to two meters below sea level. This creates a fascinating environment where land and water coexist in delicate balance. The area is interwoven with a network of rivers, canals, lakes, and backwaters, forming a water-dominated ecosystem. Vembanad Lake, the longest lake in India, acts as the lifeline of Kuttanad. The region's wetlands are rich in biodiversity and are recognised as part of the Vembanad-Kol wetland system, which is of international ecological importance. The interplay of water and land gives Kuttanad a distinctive identity that sets it apart from other agricultural regions.

Reclaimed Deltaic Formation

Kuttanad was not always dry land. A significant portion of the region was originally part of Vembanad Lake and shallow marshlands. Over centuries, but specifically during the 19th and 20th centuries, large areas were reclaimed through human intervention. Local farmers created "Padasekharams" (paddy fields) by constructing massive bunds and embankments to keep the tidal waters out. Farmers have reclaimed land from the lake by constructing bunds (embankments) using mud dredged from the lakebed. These 'padashekharam,' are enclosed areas where water is pumped out to make cultivation possible. Since these fields lie below the water level, continuous efforts are required to prevent flooding. Traditional water wheels have largely been replaced by modern pumping systems that help regulate water levels efficiently. This method of below-sea-level farming showcases the ingenuity and resilience of the local farmers. Paddy is the principal crop grown here. Indigenous varieties such as 'Pokkali,' which can tolerate salinity and waterlogging, are particularly significant.

Often referred to as the "Netherlands of the East," Kuttanad stands out for its uniquely inverted geography, unlike most coastal regions. This low-lying delta is shaped by four major rivers—the Pamba, Meenachil, Achankovil, and Manimala—which deposit rich alluvial silt into the basin, creating fertile but flood-prone lands that lie below sea level. To sustain agriculture in such conditions, the region depends on an ingenious system of traditional and modern water management practices. Bio-bunds, constructed using river mud, coconut fiber, and clay, form protective embankments around polders, while continuous dewatering through pumping mechanisms removes excess water from the fields into the surrounding canals and backwaters. Together, these methods enable cultivation in one of the most challenging yet productive landscapes in India.

The region is nourished by four major rivers—Pamba, Meenachil, Achankovil, and Manimala. These rivers flow through the region and eventually drain into Vembanad Lake, maintaining a delicate hydrological balance. These rivers bring nutrient-rich sediments that enhance soil fertility, making the land highly suitable for cultivation.

Backwater Tourism and Rural Charm

The daily life of the people reflects a deep harmony with nature, as they adapt to the rhythms of water levels and seasonal changes. The region is a major attraction for both domestic and international tourists who seek to experience Kerala's famous backwaters. A journey through Kuttanad's backwaters offers a unique glimpse into this lifestyle—lush green paddy fields, narrow canals, coconut groves, and small villages create a serene and captivating environment. Eco-tourism initiatives have also gained importance, promoting sustainable travel while preserving the natural environment. The combination of natural beauty and cultural richness makes Kuttanad a key contributor to Kerala's tourism industry.

A Globally Recognised Agricultural Heritage

Recognised as a Globally Important Agricultural Heritage System (GIAHS) by the Food and Agriculture Organisation, Kuttanad exemplifies an extraordinary model of sustainable human adaptation to a challenging environment. Its below-sea-level farming system, shaped by centuries of traditional knowledge and community-driven water management, has transformed a fragile wetland into a highly productive agricultural landscape while preserving its natural hydraulic balance. Rather than altering or degrading the ecosystem, local practices have worked in harmony with sediment deposition and water flow, making Kuttanad a rare and globally significant example of how cultural heritage and ecological wisdom can coexist to ensure both productivity and sustainability.

Sacred Groves:

The Sanctum Sanctorum of Bio-wealth

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Sacred groves, which are relics of the forests of the Western Ghats, are remarkable for their plant diversity. These unique ecosystems not only preserve a wide variety of known flora but also harbour countless species yet to be identified by science, making their biodiversity truly unparalleled.

It was from a sense of insecurity that humans began to worship the mysterious forms and expressions of nature without prejudice. This evolved as a means to protect and conserve nature-or its manifestations-through worship, becoming a cultural and religious practice within a complex social context. Aboriginal societies, which lived in forests without significantly impacting nature, must have developed these cults with the intention of preserving natural resources in a sustainable manner. As a realisation of this philosophy, urban communities set aside relic patches of forest and conserved them alongside human habitation as places of worship, known as sacred groves (Kavus). Through these traditional practices, even in an era of science and technology, a large number of diverse biota continue to be protected amid urbanisation. These groves remain largely immune to adversities created by civilization and urban expansion.

Sacred groves, which are relics of the forests of the Western Ghats, are remarkable for their plant

diversity. The floristic elements are mostly evergreen and hygrophilous in nature, resembling the forests of the Western Ghats. The trees occur in three indistinct layers and are rich in woody lianas, parasites, and epiphytes. The ground vegetation is enriched with herbaceous elements, including angiosperms, pteridophytes, bryophytes, and fungal fruiting bodies. The vegetation is tropical and phanero-therophytic, showing high structural resemblance to the forests of the Western Ghats, predominantly evergreen, semi-evergreen, and moist deciduous types, and rarely freshwater swamp and mangrove types.

There are more than five thousand sacred groves, and it is estimated that about 500 hectares of forest area fall under these groves, contributing approximately 0.05% of the total forest area of the state. More than 750 flowering plant species have been recorded, reflecting remarkable local bio-wealth and diversity, of which 40% fall under rare, endemic, and threatened categories. Paradoxically, more than half of these have nearly disappeared from the suburbs of Kerala due to anthropogenic activities.

Within a grove, the number of species varies from 26 to 216, with a predominance of tree species. The floristic wealth includes more than 480 genera, among which only 1.3% are very common, 5.2% common, and 9.3% seldom present. Meanwhile, 19.6% occur rarely and 64.6% very rarely. This scientific analysis reveals that most plant species in sacred groves have a rare distribution, indicating that the destruction or disturbance of these groves could lead to the extinction of a large number of wild species in urban Kerala.

These sanctum sanctorums of bio-wealth are also noted for their extraordinary plant diversity. If one observes 100 plants in a row, more than 90 will likely belong to different species. An average of 190 to 358 plant individuals can be found in a 100-square-meter area, representing 105 to 209 genera. One hectare of grove land can support 480 to 1120 trees at various stages of growth. The gymnosperm Gnetum ula is an integral part of these groves, while another genus, Cycas (Cycas circinalis), is rarely seen. In addition to this diverse gene pool of flowering plants, a wide array of non-flowering plants is also present. The ponds commonly associated with groves are notable for their rich aquatic biota.

Sacred groves also serve as habitats for a wide array of fauna and function as refuge centres of urban faunal diversity. Monkeys are among the most common mammals found in Kerala's sacred groves. In recent times, they have disappeared from several major groves in southern and central Kerala due to human interference, though they still roam freely in some well-protected groves, particularly in northern Kerala. Other animals such as wild hares, otters, foxes, boars, and civets also inhabit these forest refuges. Wild cats, mice, squirrels, and mongooses are also found here, along with various species of bats.

Numerous avian species are also present, using these groves as habitats for feeding, breeding, and nesting. Rare birds such as silver owls and silver-bellied hawks have also been recorded. At a time when large trees have largely disappeared from open areas, homesteads, and backyards in Kerala, these green patches serve as crucial feeding and breeding grounds for bird communities.

Other faunal groups, including reptiles and amphibians, also find shelter in sacred groves. The biotic associations and abiotic conditions, combined with minimal external interference and proximity to water bodies, make these groves ideal natural habitats. They also serve as highly favourable breeding grounds due to their ecological balance. Reptiles include various species of snakes (such as rat snakes), lizards, and turtles. Amphibians are also well represented, with frogs being particularly abundant. Legless amphibians belonging to caecilian groups are also found in the topsoil.

The protected ponds associated with sacred groves act as reservoirs for freshwater fish species—one of the most depleted components of Kerala's bio-wealth due to environmental degradation, including water pollution, habitat loss, overexploitation, and biological invasion. It is estimated that a significant proportion of these fish are preserved in serpent ponds without human interference.

Lower groups of organisms are also prominently represented in these groves and are central to biodiversity analysis. A wide range of insects inhabit these ecosystems, including butterflies, thrips, bees, wasps, beetles, spiders, and grasshoppers. Their life cycles are closely tied to the ecological balance of the grove. Other organisms such as millipedes, centipedes, and snails are abundant in the organic debris. Earthworms, termites, and ants further contribute to the biotic wealth. The groves are also home to countless species that remain unidentified by science, making their biodiversity truly unparalleled.

Traditionally managed sacred groves of Kerala, locally known as Kavus, represent a quintessential example of the Indian ethos in in situ conservation and environmental protection. These traditional worship sites and their associated practices demonstrate a deeply rooted, organic relationship between humans and nature. However, socio-political changes and the expanding demands of modern lifestyles have altered the traditional landscape of the state, including its sacred groves. Despite these changes, existing grove ecosystems continue to provide significant environmental and conservation services.

Therefore, it is the responsibility of collective community consciousness to protect these sacred groves and ensure the preservation of their rich and diverse biological heritage.

From Hills to City:

The Urban Landscape of Thiruvananthapuram

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Sree Padmanabha Swamy Temple

The urban landscape of Thiruvananthapuram is an entrancing example of how the spatial structure of a city is carved out by its geography, history, culture, and political change over time.

Bordered by the Lakshadweep Sea to the west and the Peroorkada hills to the east, the Thiruvananthapuram city boasts a picturesque landscape of rolling hills, serene valleys, and gentle plains. The eastern part of the city has an undulating terrain, while the western coastal area features broad, flat stretches, with most of the city displaying lower lateritic dissected plateau regions. The city is adorned by small hills, which served as vantage points and seats of power during historical times.

Historical Foundations of a Sacred Geographical Landscape

The history of Thiruvananthapuram dates back to prehistoric times, as evidenced by the discovery of "Nannangadis" in parts of Sasthamangalam in 1891, suggesting that human habitation in the city is more than 3,000 years old.The ancient kingdom of Travancore, which evolved from the earlier kingdom of Venad, stands as one of the most venerable dynasties in the history of India. During its formative years, the region held allegiance to the cultural and geopolitical milieu known as "Tamilakom" until the 10th century. The Ay kingdom was the earliest ruling tribe in South Kerala, while Venad later emerged in the region formerly associated with Ay rule and related chieftaincies.

Initially, the region of Thiruvananthapuram functioned as a sub-town of the ancient port of Vizhinjam. The earliest spatial identity of Thiruvananthapuram as an esteemed temple town emerged around the sacred precincts of the Sree Padmanabhaswamy Temple. In the 9th century C.E., Thiruvananthapuram emerged as a prominent cultural and religious centre with the presence of Sree Padmanabha Swamy Temple, Valiyasala Temple, Mithranandapuram Temple, Palkulangara Temple, and Kanthalur Salai. The place was initially called "Tiru Ananthapuram, "the sacred city of Anantha, the serpent on which Lord Vishnu lies" (Ananthasayanam), and for some historians, it was "Aanandapuram," "the land of happiness".

The ancient Tamil Sangam literature outlined the territories as Thinai, a classification of five landscape categories, "Ainthinai" (ain = five, thinai = land), and denoted them as Kurinji, Neithal, Mullai, Marutham, and Palai. Thinais were not merely indicating their geographical features; instead, they represented the nature of the people and their mode of living in the respective landscapes. Kurinji denoted hilly or mountainous regions, and the city is blessed with a number of small hills. Neithal denoted coastal regions, and formed the base of trade and the point of contact for foreign powers at Vizhinjam, Poonthura, and Poovar, Mullai denoted forests and pasture lands. Marutham denoted cultivated areas, while Palai denoted deserted arid lands. Dense forests representing Mullai were located throughout the city in historic times, whereas settlements and agricultural zones occupied Marutham. The symbolic landscape

characterisation of the Sangam age can be well attributed to the regions in Thiruvananthapuram, except for Palai.

Venad Period: Expansion of Ritual Landscape and Early Urban Form

During the Venad supremacy (12th-17th century), Thiruvananthapuram evolved into a more organised sacred and settlement complex. The sacred geography of this period is evident in the literary work of "Ananthapuravarnanam," which describes a landscape dotted with ritual tanks or theerthams, markets, and associated settlements, indicating early urban clustering around religious institutions. Many of these ponds, now extinct or transformed, once formed part of an integrated hydrological and spiritual landscape, reinforcing the inseparability of water systems in the early urban formation.

The emergence of areas like Pazhavangadi as probable market zones reflected the beginning of functional differentiation within the urban space. Though fortifications were minimal or absent in early phases, the gradual emergence of defensive structures by the late medieval period marked the beginning of spatial, strategic,and administrative consolidation.

Colonial and Travancore Period: Institutionalisation of Urban Landscape

A major transformation in the urban morphological evolution occurred in 1750 when Thiruvananthapuram emerged as the political capital of the Travancore Kingdom under the reign of Anizham Thirunal Marthanda Varma. This marked the beginning of the city's journey in its dual role as a spiritual and administrative hub. The city during this period was characterised by a hierarchical spatial organisation, and the construction of the Fort area complex formalised the spatial boundary between the sacred core and the expanding urban periphery. The centralcity zone consisted of the temple and royal structures, outlined by Brahmin agraharams, and then gradually expanding to residential settlements. Roads such as "Irayaperuvazhi" and "Nadakavus"enabled movement and connectivity.

The colonial period introduced new spatial dynamics, particularly in administration, education, and infrastructure. Western influences led to the development of hilltop palaces such as Kowdiar Palace, Kanakakkunnu Palace, and Satelmond Palace, reflecting a shift towards aesthetic structures blending colonial and traditional architectural styles, enabled with ventilation and climatic adaptations. Areas like Palayam and Vazhuthacaud gave way to military camps, administrative buildings, and later educational institutions, marking a transition from ritual-centred to governance-centred urban spaces. River Karamana and the man-made canal, Parvathy Puthanar functioned as important inland water transport corridors. Chalai market became a critical economic node linking the city core with regional trade networks and evolved into a multicultural commercial

Napier Museum, Thiruvananthapuram

Kovalam Beach

hub integrating Tamil merchant communities, Muslim traders, and artisan communities, demonstrating the socio-economic diversification of the city.The city flourished as a culturally diverse urban space with Brahmins concentrating around the Sree Padmanabhaswamy Temple, and other temples of the city core, while Muslim traders and Tamil merchant communities prospered in commercial areas such as Chalai and Pettah, alongside expanding Christian settlements and institutions.

Spatial Expansion and Functional Differentiation (1901–1960s)

With the Sree Padmanabhaswamy Temple acting as the central spatial generator, surrounding areas such as Palayam, Vanchiyur, Karamana, and Vazhuthacaud developed distinct functional identities. Karamana and Pettah functioned as transport and residential nodes along riverine and coastal corridors. Meanwhile, hilltop settlements such as Vellayambalam, Kowdiar, and Nanthancode displayed low-density residential layouts.

The 1966 city master plan marked a significant milestone in regulating land use, though unplanned growth continued along major transport corridors.This phase also witnessed increasing reclamation of wetlands, particularly in Thampanoor, which transitioned from an ecological buffer zone into a transportation nucleus following the establishment of the railway station in 1931.

Post-Independence Urban Expansion

After independence, the city experienced accelerated spatial expansion driven by administrative restructuring and planning interventions. The emergence of nodal development centres at Kesavadasapuram and Peroorkada signified a shift toward polycentric urban growth. Simultaneously, coastal zones like Poonthura, Kovalam, and Shanghumugham began to transform from traditional livelihoods to tourism and service-based economies.

The city expanded, reflecting rapid suburbanisation. However, the spatial distribution remained uneven, with dense development concentrated in core areas like Fort, Karamana, and Manacaud, while peripheral regions remained underdeveloped. The continued presence of paddy fields (about 8–9% of the city area) highlighted the persistence of agrarian landscapes within an urbanising matrix.

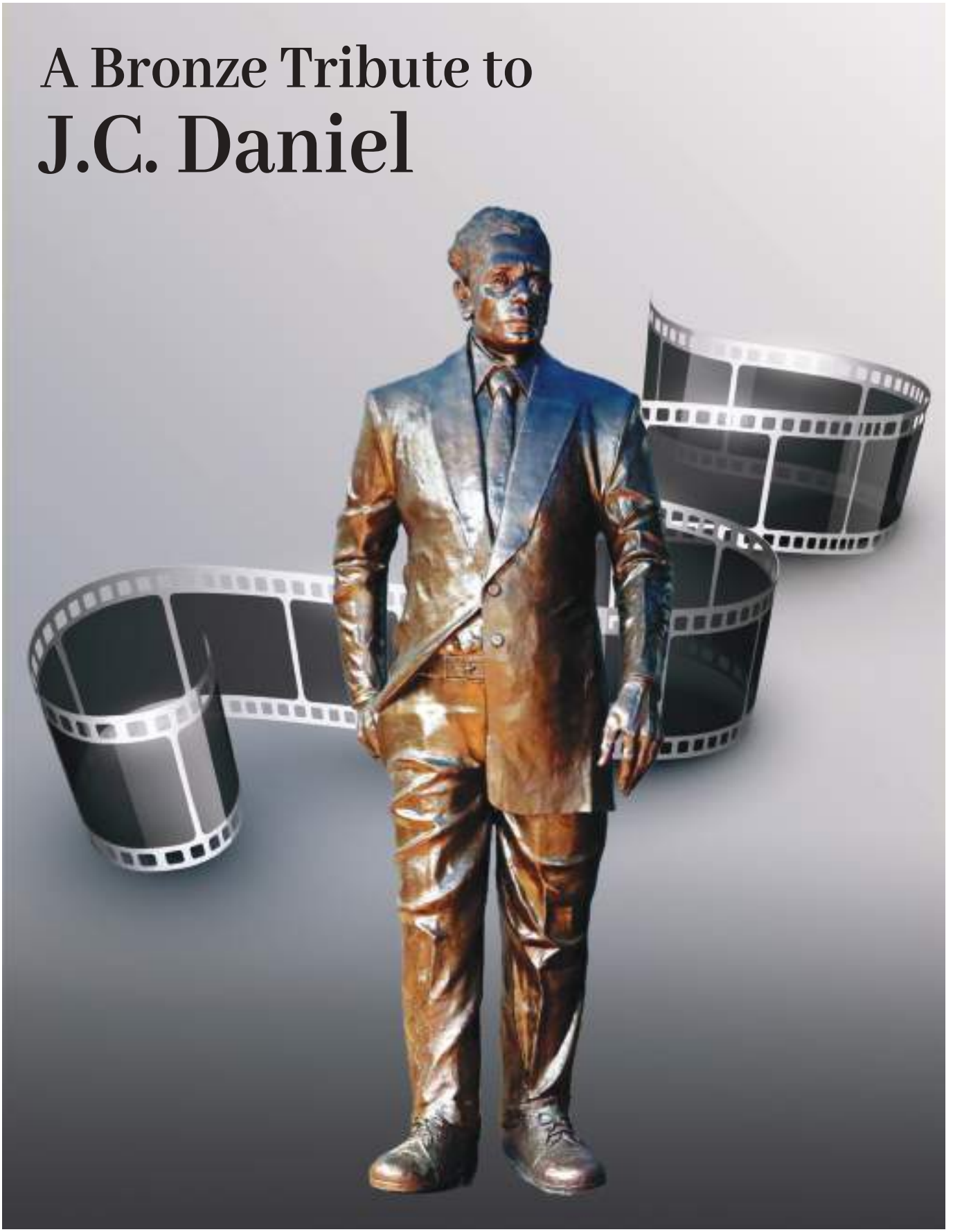
Period of Accelerated Urbanisation and Modernisation

With the incorporation of panchayats such as Nemom, Kazhakkoottam, and Vizhinjam, the city grew into a metropolitan region characterised by rapid urban sprawl, infrastructure development, and functional specialisation. Kazhakkoottam emerged as an IT hub, while Vizhinjam evolved into a strategic port development zone. Medical College and Akkulam developed as institutional and recreational nodes, respectively, reflecting diversified urban functions. At the same time, older ecological systems such as wetlands and ponds were largely reclaimed, leading to increased vulnerability to urban flooding and environmental stress.

Conclusion

The geo-historical continuum of Thiruvananthapuram demonstrates a layered urban morphology where geography, royal patronage, colonial planning, and modern urbanisation intersect.From a temple-centred settlement, the city has transformed into a complex metropolitan region. Yet, beneath its modern urban form, traces of its historical landscapes continue to define its spatial identity. This continuity amid transformation showcases Thiruvananthapuram's unique position as a living historic urban landscape, where past and present coexist within a dynamically evolving urban fabric.

A Bronze Tribute to J.C. Daniel



At the entrance of Chitranjali Studio in Thiruvananthapuram, a majestic figure now stands in silent contemplation. Perched upon a 7.5-foot pedestal of Krishnashila (Black Granite), the 10-foot bronze statue of J.C. Daniel captures the Father of Malayalam Cinema in a poignant, creative pause—brooding over his next shot during an interval. This statue is more than just a monument; it is a long-overdue tribute to a man who sacrificed everything for the love of celluloid.

The Man and His Legacy

Born into a wealthy family of medical professionals in Agastheeswaram, J.C. Daniel was the son of a prominent doctor. However, his heart belonged to the arts. Driven by a vision to bring cinema to Kerala, Daniel sold 108 acres of his ancestral land to establish Travancore National Pictures, a studio modelled after those he had seen in Mumbai.

In 1930, he produced and directed the first Malayalam film, Vigathakumaran (The Lost Child). The film's production was a testament to Daniel's resilience. After being swindled by a prospective heroine from Mumbai, he cast P.K. Rosi, a Dalit woman, to play the lead role of a Nair woman named Sarojini.

Sculptor: Kunnuvila M. Murali

J.C. Daniel (seated in the middle) with his family.

This act of progressive casting met with violent backlash. During the film's premiere on October 23, 1930, at the Capital Theatre, an angry mob, incensed by Rosi's presence and her portrayal of an upper-caste character, tore down the screen and attacked the venue. Though the film was screened elsewhere, the financial losses were catastrophic. Daniel was forced to sell his wife's property and his beloved studio to settle debts. He eventually left for Chennai to practice dental medicine, passing away in 1975, long before his contributions were fully recognised.

A Befitting Homage

Decades later, at the request of Daniel's family, measures were taken to commission a monument to rectify history's silence. The task fell to Kunnuvila Murali, a celebrated sculptor and retired lecturer from the Government College of Fine Arts. A winner of the Kerala State Award for art metal ware, Murali is a seasoned sculptor known for his statues of Mahatma Gandhi, B.R. Ambedkar, and Thakazhi Sivasankara Pillai.

The creation of the 1.5-tonne bronze statue was a meticulous eight-month journey:

- **Research:** With no full-length photos available, Murali studied family group photos and childhood pictures from age three to reconstruct Daniel's likeness.
- **Design:** Six miniature models were submitted, from which the brooding posture-complete with 1930s-style tailoring and period-accurate shoes—was selected.
- **Execution:** A clay model was first prepared for approval. Upon seeing it, Daniel's son C J Harris Daniel remarked that it perfectly captured his father's "majestic posture." Once approved, the final bronze casting began.

Immortalising the Legend

The highest award in Malayalam cinema now bears the name of J. C. Daniel—a fitting tribute to the man who once stood alone in the interval between a dream and a revolution. Commissioned by the Department of Culture at the behest of Daniel's family, the statue stands as a reminder of the courage of the man who gave everything to start an industry that now defines Kerala's cultural landscape. Today, as filmmakers pass the gates of Chitranjali Studio, they are greeted by the man who started it all, forever poised at the "interval," dreaming of the next frame in the history of Malayalam cinema.

The Distinctive Terrain

- Kerala lies on the southwest coast of India, curving along the Arabian Sea; forms a narrow strip between the Western Ghats and Arabian Sea.
- Latitude: 8° 18' N to 12° 48' N
- Longitude: 74° 52' E to 77° 22' E
- Divided into three zones—highlands (eastern, dominated by Western Ghats), midlands, and lowlands (coastal).
- Covers 38,863 sq km, representing 1.18% of India's total land area.
- Stretches 590 km north-south, with width varying from 32 to 120 km
- Features an unbroken 580 km coastline along the Arabian Sea.
- Towering mountains with average elevation of 1,500 m (rising to 2,000–2,500 m); includes dense tropical evergreen forests, misty peaks, ridges, and ravines. Highest peak: Anamudi (2,775 m); second highest: Agasthyarkoodam.
- 44 rivers total—41 west-flowing, 3 east-flowing. Longest: Bharathapuzha (251 km); others include Periyar (228.5 km) and Pamba (177 km).
- 34 backwaters, with Vembanad Lake as the largest (200 sq km).
- Forest covers 15,560 sq km, featuring evergreen forests in highlands.

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