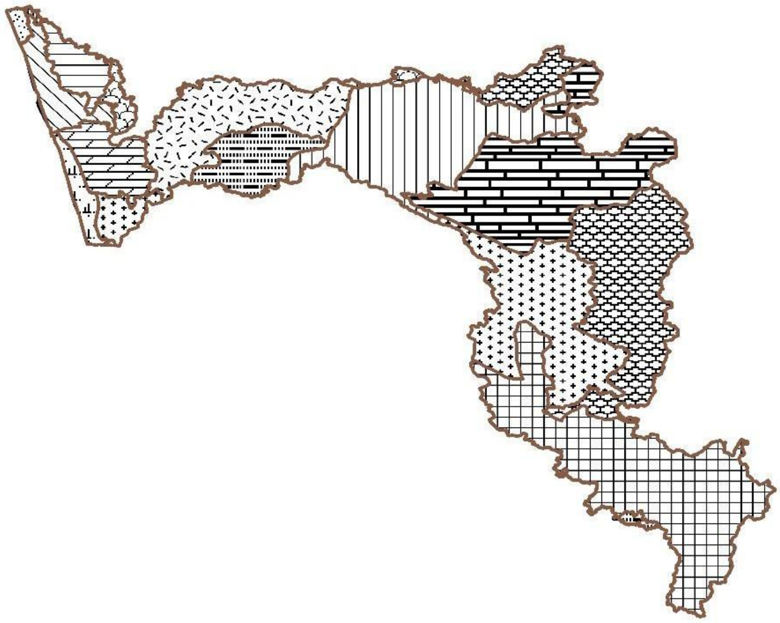
National River Conservation Directorate
Ministry of Jal Shakti,
Department of Water Resources,
River Development & Ganga Rejuvenation
Government of India

Lithological Profile of

Periyar River Basin



December 2024

Lithological Profile

Periyar

National River Conservation Directorate (NRCD)

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

www.nrcd.nic.in

Centres for Periyar River Basin Management and Studies (cPeriyar)

The Center for Periyar River Basin Management and Studies (cPeriyar) is a Brain Trust dedicated to River Science and River Basin Management. Established in 2024 by IIT Palakkad and NIT Calicut, under the supervision of cGanga at IIT Kanpur, the center serves as a knowledge wing of the National River Conservation Directorate (NRCD). cPeriyar is committed to restoring and conserving the Periyar River and its resources through the collation of information and knowledge, research and development, planning, monitoring, education, advocacy, and stakeholder engagement.

www.cPeriyar.org

Centres for Ganga River Basin Management and Studies (cGanga)

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

www.cganga.org

Acknowledgment

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

Team Members

Athira P, cPeriyar, IIT Palakkad
Neenu K, cPeriyar, IIT Palakkad
Akhil Ridhi Ravi, cPeriyar, IIT Palakkad
Santosh G Thampi, cPeriyar, NIT Calicut
Pramada S K, cPeriyar, NIT Calicut
Mridul K, cPeriyar, NIT Calicut
Rajith K, cGanga, IIT Kanpur

Preface

In a time marked by significant environmental transformations, the understanding of river systems and their ecosystems has become increasingly vital. This report endeavors to provide a thorough examination of our rivers, emphasizing their ecological significance, current conditions, and the myriad challenges they confront. As we navigate through the various dimensions of river systems, our goal is to equip readers with the insights necessary to appreciate and safeguard these essential waterways.

Within the pages that follow, you will find a detailed analysis of the principles and practices that underpin healthy river ecosystems. Our dedicated team of experts has meticulously gathered data, case studies, and firsthand accounts to illustrate the profound impact rivers have on both natural environments and human communities. By disseminating these insights, we aspire to inspire and empower our readers to actively participate in river conservation initiatives.

This report transcends mere statistics and theoretical discussions; it serves as a clarion call for action. We implore all stakeholders—environmental professionals, policymakers, and concerned citizens alike—to recognize the intrinsic value of our rivers and take proactive measures to ensure their preservation. This guide is designed to support your efforts in protecting these vital resources.

We extend our sincere gratitude to the numerous contributors who have generously shared their knowledge and experiences. Their invaluable contributions have enriched this report, transforming it into a beacon of information and a practical resource for all readers. It is our hope that this document will act as a catalyst for positive environmental action, fostering a culture of stewardship that benefits both present and future generations.

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

Centres for Periyar River Basin
Management and Studies (cPeriyar)
IIT Palakkad & NIT Calicut

Contents

SI No.	Title	Page No.
1	Introduction	1
1.1	Basin Overview	1
1.2	Source of Data	2
2	Lithological Characteristics of the Periyar River Basin	3
2.1	Lithology of the Periyar River Basin	4
2.1.1	Charnockite and Migmatic Gneissic complex	4
2.1.2	Intrusive Rocks	5
2.1.3	Fluvial deposits of Periyar	6
2.2	Litho-Logs	10
2.3	Geological History and Chronology of the Periyar River Basin	19
2.4	Lithological Cross-sections	21
3	Soil Characteristics of the Periyar River Basin	24
3.1	Soil Nutrient	24
3.2	Soil Classification	34
3.3	Soil Series in Periyar River Basin	35
3.3.1	Anamudi Series	36
3.3.2	Pampadumpara Series	36
3.3.3	Venmani Series	38
3.3.4	Thommankuthu Series	38
3.3.5	Odakkali Series	39
3.3.6	Perumbavoor Series	39
3.3.7	Punnamattom Series	40
3.3.8	Ikkaranad Series	40
3.3.9	Vypeen Series	41
3.3.10	Udayamperoor Series	41
3.3.11	Koratty Series	42
3.3.12	Manathala Series	43
4	Principal Aquifers of Periyar River Basin	43
4.1.1	Alluvium	44
4.1.2	Banded Gneissic Complex	44
4.1.3	Charnockite	44
4.1.4	Gneiss	44

4.1.5	Laterite	45
4.1.6	Granite	46
4.2	Groundwater Yield	46
4.2.1	Laterites	46
4.2.2	Weathered Crystalline Rock	47
4.2.3	Deeper Fractured Crystalline Rock	47
5	Landslide Susceptibility of Periyar River Basin	47
6	Report Summary and Recommendations	50
7	References	55

List of Figures

Figure	Caption	Page No.
1	Location of Periyar River Basin along with sub basins	2
2	Major Lithological Classification of Periyar River Basin	5
3	All major rock types constituting the Lithology of Periyar Basin	7
4	Location of litholog wells in the Periyar river basin	10
5a	Litholog of Kattapana, Vandiperiyar and Thankamaoni	13
5b	Litholog of Sandanapara and Mundiremma	14
5c	Litholog of Illithode and Malayattur	15
5d	Lithology of Kovapady, Mullankunnu and Kodussery	16
5e	Lithology of Srimulanagaram and Desham	17
5f	Lithology of Narrakal, Peeringanam, Cherrai and Eriyad	18
6	Age of lithologic units	20
7	Location of the Lithological Profile generated in the Periyar River Basin	22
8a	Lithological Cross section of Ernakulam and Thrissur	23
8b	Lithological Cross section of Idukki	23
9	Soil pH Variablity in Periyar River Basin	26
10	Electrical Conductivity Variation across the Periyar River Basin	27
11	Soil Organic Carbon levels in the Periyar River Basin	28
12	Soil Phosphorous levels in the Periyar River Basin	29
13	Soil Potassium levels in the Periyar River Basin	30
14	Soil Sulphur levels in the Periyar River Basin	31
15	Soil Copper levels in the Periyar River Basin	32
16	Soil Boron levels in the Periyar River Basin	33
17	Soil based on Benchmark Identification	37
18	Principal Aquifers of Periyar River Basin	45
19	Elevation and occurrences of landslides in Periyar River Basin	49
20	Landslide Susceptibility Map of Periyar River Basin	50

List of Tables

Table	Caption	Page No.
1	List of data collected from various sources	3
2	Soil pH classification	25
3	Soil Phosphate levels	29
4	Soil Potassium levels	30
5	Name and Important properties of the main Orders	34

1. Introduction

Lithological composition of the river basin provides the necessary framework toward the understanding of the environmental and hydrological processes that shaped the characteristics of a basin and its characteristics. The geological composition within the basin affects water quality, sediment movement, and the development of landforms. With the increasing human activities coupled with climate change, lithological assessments for effective river basin management have become crucial.

Tectonics, geology, and climate are the key factors that dictate the lithological makeup of a basin. Their differences influence the rate of erosional processes, the rate of sediment deposition, morphology of the river, and groundwater recharge ability of the catchment. Such parameters lead to variations affecting erosion, sediment transport, river morphology, and the ability to recharge groundwater resources. The rock types determine the water's mineral content, sediment's behaviour, and the weathering processes which are important in creating the floodplains, deltas and river terraces. Moreover, the lithological structure of a river basin determines the soil fertility, groundwater potentials, and general ecosystem sustainability.

This report is a comprehensive attempt to document various lithological factors and the influences of these factors on the Periyar River basin. Several factors like the lithology of the top surface, bedrock characteristics, soil nature, and aquifer characteristics are the key parameters discussed in this study. Various schematic representations including maps, diagrams, and other illustrations represent complex data in simpler forms and describe the variation and influences of these factors.

1.1 Basin Overview

Periyar River is the longest river of the state stretching a length of 244 km (PWD, 1974; CESS,1984) and is the second largest basin in Kerala. Periyar River flows majorly through Idukki Ernakulam and Thrissur. Being the longest river, it acts as the lifeline of central Kerala, providing water for wide applications ranging from drinking, hydroelectricity generation, navigation, agriculture, etc.

The Periyar originates from the Shivagiri hills. During its course from its place of origin important tributaries join to form the river. They are Mullayar, Chinnar, Panniyar, Muthirapuzha in Idukki District, Deviyar and Edamalayar in Ernakulam district. From its place of origin to Malayattoor, the river is joined by numerous small streams and its tributaries along its course. When it reaches Alwaye, it divides itself into two branches. The principal branch flows northwest joins with the

Chalakkudi River at Puthenvelikkara and then expands itself to a broad sheet of water at Munambam. The other takes a southerly direction and is broken up into several small channels falling into the Vembanad Lake at Varappuzha. The basin is divided into nine sub basins namely Mullayar, Perinjankutty, Muthiranpuzha, Pullut, Mangalapuzha, Marthandavarma, Idamalayar, Pooyamkutty, and Deviyar sub basins, each having its own distinctive feature. Figure 1 represents the location of The Periyar River Basin along with the sub basin.

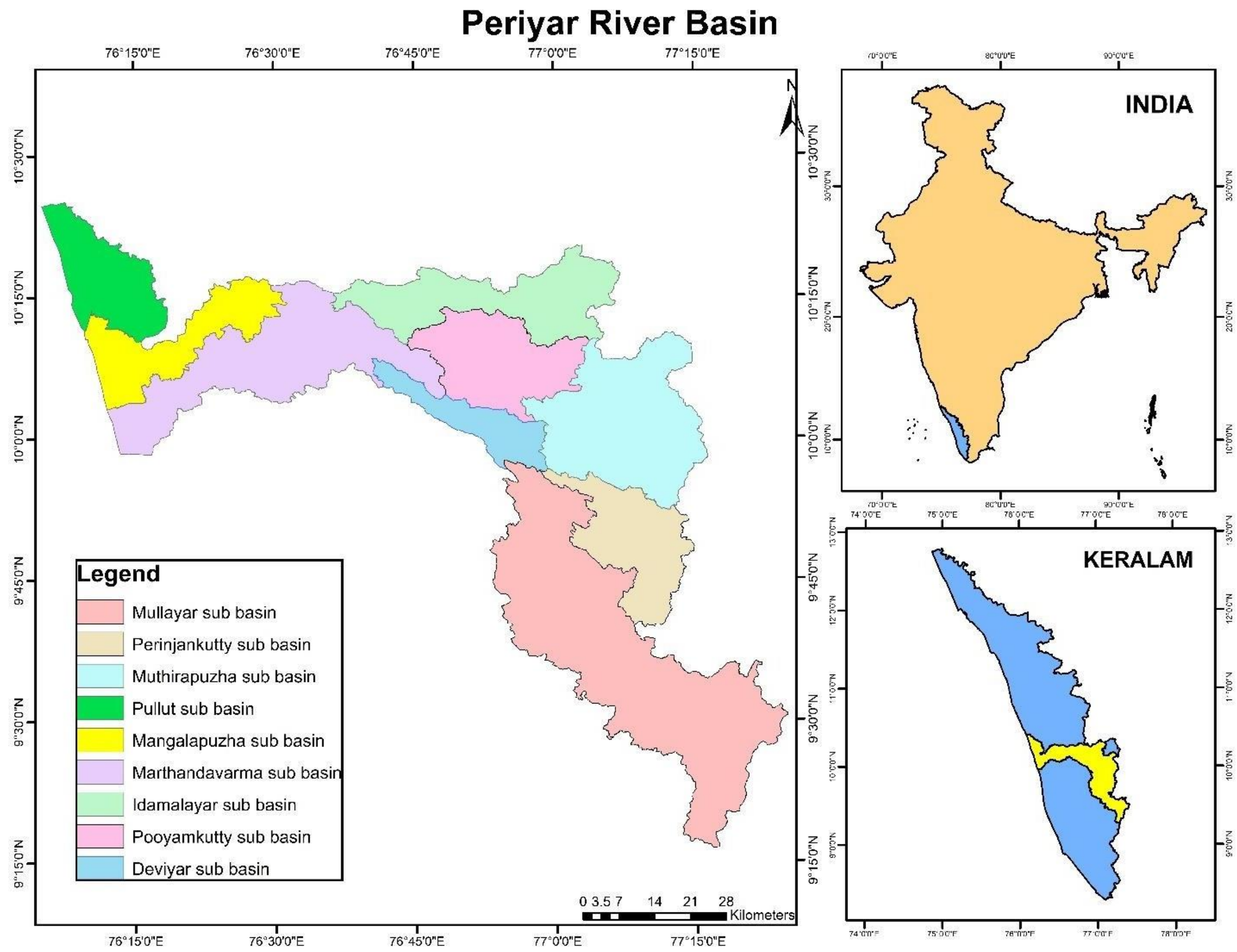


Figure 1: Location of the Periyar River Basin along with sub basins

The basin lies between 09°15’30’’N to 10°24’41’’N Latitude 76°5’10’’E to 77°24’44’’E Longitude and has a wide variety of physiographic features across its length and breadth with the highest point of 2695 m Annamudi (Padmalal et al., 2008) in the east to coastal plains in the west.

1.2 Source of Data

The source of data for the report preparation of Lithological Profile of the Periyar River Basin and extensive study is tabulated in Table 1 as follows.

Table 1: The list of data collected from various sources.

S. No.	Type of Data	Source
1	Lithological Maps	GSI Bhokosh Portal
2	Lithologs	Central Ground Water Board
3	Soil Nutrient levels	Department of Soil Survey and Soil Conservation, Kerala
4	Aquifer Data	Central Ground Water Board
5	Landslide Susceptibility	Geological Survey of India

2. Lithological Characteristics of the Periyar River Basin

The term lithology refers to the study and description of the physical characteristics of rocks, especially in hand specimens and outcrops (Bates and Jackson, 1980). It encompasses various physical traits such as rock type, color, mineral composition, and grain size. One of the most essential types of stratigraphic study involves recognizing, subdividing, and correlating sedimentary rocks based on their lithology, which is known as lithostratigraphy.

Lithostratigraphic units are bodies of sedimentary, extrusive igneous, metasedimentary, or metavolcanic rock that are distinguished by their lithologic characteristics. Typically, a lithostratigraphic unit adheres to the law of superposition, which states that in an undisturbed sequence of strata, younger rocks are found above older ones. These units are often stratified and take on a tabular form.

The primary lithostratigraphic unit is the formation. Formation is a lithologically distinctive stratigraphic unit that is large enough to be mapped at the surface or traced in the subsurface. Some formations can be further divided into smaller stratigraphic units known as members, which can also be subdivided into even smaller units called beds. Beds represent the smallest formal lithostratigraphic units. Formations that exhibit stratigraphic unity can be grouped together to form groups, and these groups can be combined to create supergroups. All formal lithostratigraphic units are assigned names derived from geographic features in the area where they are studied.

2.1 Lithology of the Periyar River Basin

Geologically, the Periyar River Basin has three distinct formations; crystalline rocks of Precambrian age, the Tertiary formations, and the Recent alluvium (Soman, 2002; GSI, 1976; Paulose and Narayanaswami, 1968). Much of the river basin is primarily formed of Gneissic complexes, other major rock type are costal sediments and intrusive rocks. However, due to weathering and erosion such a complete sequence may not be present uniformly throughout the basin. Figure 2 represents the major Lithological classification of the Periyar Basin. The Basin is part of the Southern Granulite Terrain super group and sub-classfied into different groups namely Charnockite Complexes, Migmatic rocks, and recent formations include Laterites and Alluvium found as deposits along the downstream side of the river basin. Detailed study of the rock types are in the following sub-section.

2.1.1 Charnockite and Migmatite Gneissic complex

Charnockite and Migmatite complex are the most wide spread lithological formation in the periyar river basin.They are Precambarian Charnockite are found in southern part of Idukki district and the eastern side of Ernakulam district, which is part of the Periyar Basin.

In Idukki the Charnockitic Group comprises of pyroxene granulite, magnetite quartzite and charnockite among which the charnockite is dominant and widespread. Pyroxene granulite and magnetite quartzite occur as linear bands of a few metres width and a few tens of metres in length within the gneissic terrain. They are aligned generally parallel to the trend of foliation. Charnockite occurs as continuous rock unit covering the hilly region in the south and northwest. . It is mostly massive but gneissic varieties are also seen, with intermediate to acidic in composition (District Survey Report Idukki, 2019). In Ernakulam the charnockite group is composed of pyroxene granulite, magnetite quartzite and charnockite. Charnockite, which is very widely distributed, is coarsegrained, granulitic and dark coloured. Pyroxene granulite and magnetite quartzite occur as linear bands (District Survey Report Ernakulam, 2019).

Migmatite Complex is found in the central part of Idukki region to the north of charnockite group eastern part of Ernakulam district, and sothern parts of Thrissur district. In Idukki migmatitic

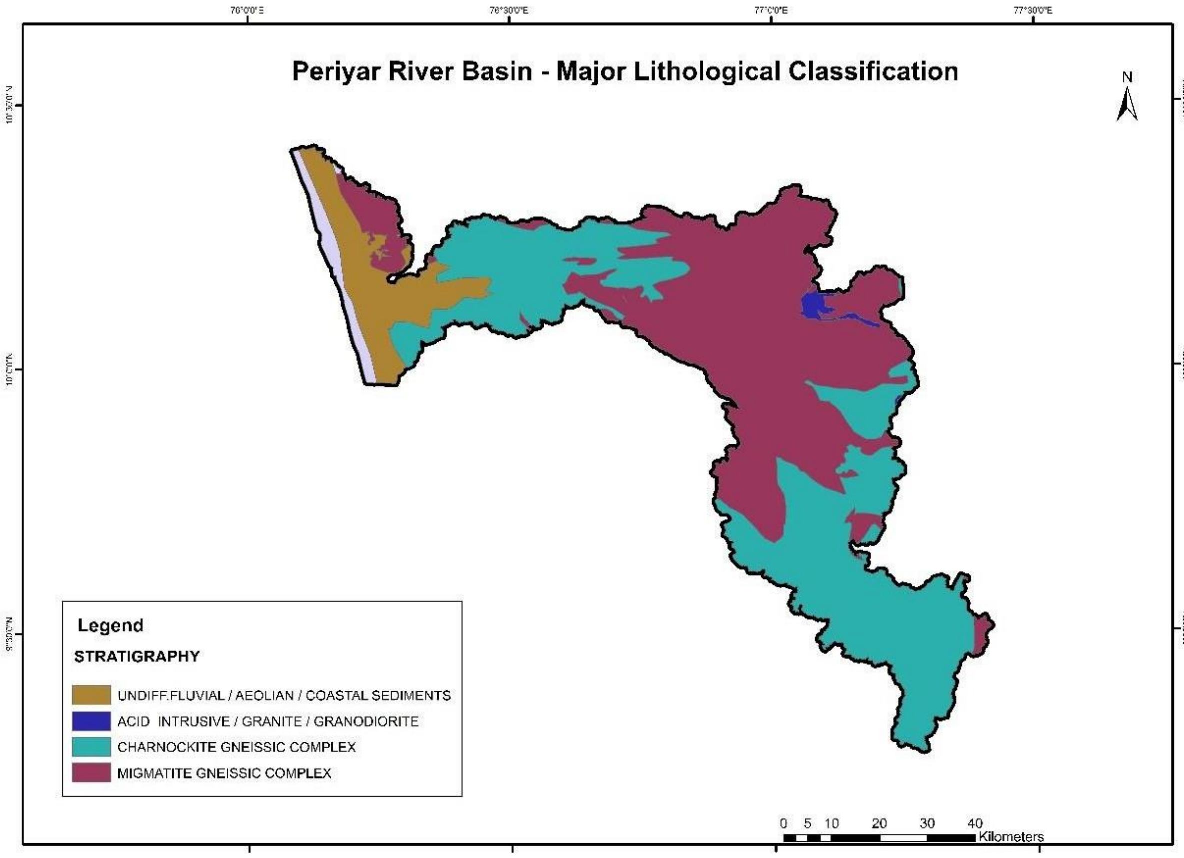


Figure 2: Major Lithological Classification of the Periyar River Basin

complex comprising of biotite gneiss and hornblende-biotite gneiss (composite gneiss). The biotite gneiss has plenty of restites of older Khondalite and Charnockite Groups of rocks occurring as lensoidal and linear bodies, conformable with the trend of foliation. Granite emplacement is seen around Munnar, Devikolam and along the eastern boundary. Both pink and grey varieties are observed. The older rocks are traversed by pegmatites and quartz veins and basic intrusive dolerite and gabbro (District Survey Report Idukki, 2019). In Ernakulam the migmatite group includes biotite gneiss and quartzofeldspathic gneiss which are next to charnockite in abundance. These older rocks are intruded by both acid (syenite) and basic (gabbro and dolerite) intrusive (District Survey Report Ernakulam, 2019). In Thrissur Biotite gneiss of Migmatite Complex is next to charnockite in abundance. The other members of the Migmatite Group namely quartzo-feldspathic gneiss and hornblende biotite gneiss have restricted distributions (District Survey Report Thrissur, 2019).Charnockite rock complex has an area of 2210.05 km^2 and Migmatite group of rocks cover an area of 2422.35 km^2 approximately, of the basin.

2.1.2 Intrusive Rocks

There are acidic intrusive rocks basic intrusive rocks ultra basic intrusive rocks and alkaline intrusive rocks that are being present acrsoss the basin.The unmetamorphosed Idamalayar gabbroic dyke, basic intrusive rock. The rock is mesocratic, medium-grained, porphyritic and is composed of plagioclase (andesine to labradorite), hornblende and opaques. The reported age of 75 million years (M.Y) for the Idamalayar dyke (Subramaniam, 1976) links it in time-relationship with Deccan Trap volcanism(Soman, 2002). The Munnar 10°75'00" N;77°05'00" E granite with an areal extent of 50 km^2 is an E-W trending irregular body emplaced within the migmatite and apophyses extend into the surrounding gneisses. The granite dated to be 740 m.y (Odom, 1982) is traversed by pegmatite, aplite and quartz veins. Three types of granite are recorded, foliated granite, coarse pink granite and medium grey granite.The foliated granite consists of stringers and streaks of mafics consisting of biotite, hornblende, chlorite and magnetite alternating with felsics consisting of quartz and potash feldspar. Potash feldspar is predominantly orthoclase. The closely spaced foliations are persistent but discontinuous. This granite forms a domal structure south of Munnar. It has a sharp contact with the migmatite. Coarse pink granite consists of pink feldspar, quartz and a little amount of mafics. Mafics are biotite, sphene and hornblende. Medium grained grey granite, consists of quartz, feldspar, biotite, chlorite, zircon, sphene, epidote, calcite and sericite (Soman,2002). Major element data of Munnar granites do not show any significant variation amongst the three granites. Content of iron is more in medium grey granite and foliated granite. Different variation diagrams reveal a slight tendency towards alkali granite. The foliated granite shows more percentage of orthoclase than the other two granites (Nair and Anil Kumar, 1990). These intrusive rocks cover a small part of the basin and covers merely 38.25 km^2.

2.1.3 Fluvial deposits of Periyar

These are the yonger formations or Quaternary Sediments, found along side the coasts of Ernakulam and Thrissur. This includes peat beds of both marine and fluvial environments, sand bars and sandy flats alternating with lagoonal clays and shell deposits. The Quaternary formations are separated from the underlying Tertiary rocks by ferruginous clay layer. The black clays with brackish water molluscan shells are comparable to those living in the present day lagoons of the area. This indicates that a major part of the Quaternary sediments were deposited in lagoonal-brackish water environments, got filled up and uplifted later (Soman, 1997).These fluvial deposits form a major part of the lithology of Periyar basin and covers an extent of 482.43 km^2.

Figure 3 is representation of all the major rock types that are found in the Periyar River Baisin Each major Rock type in the Periyar River Basin is discussed in detailed in the following section

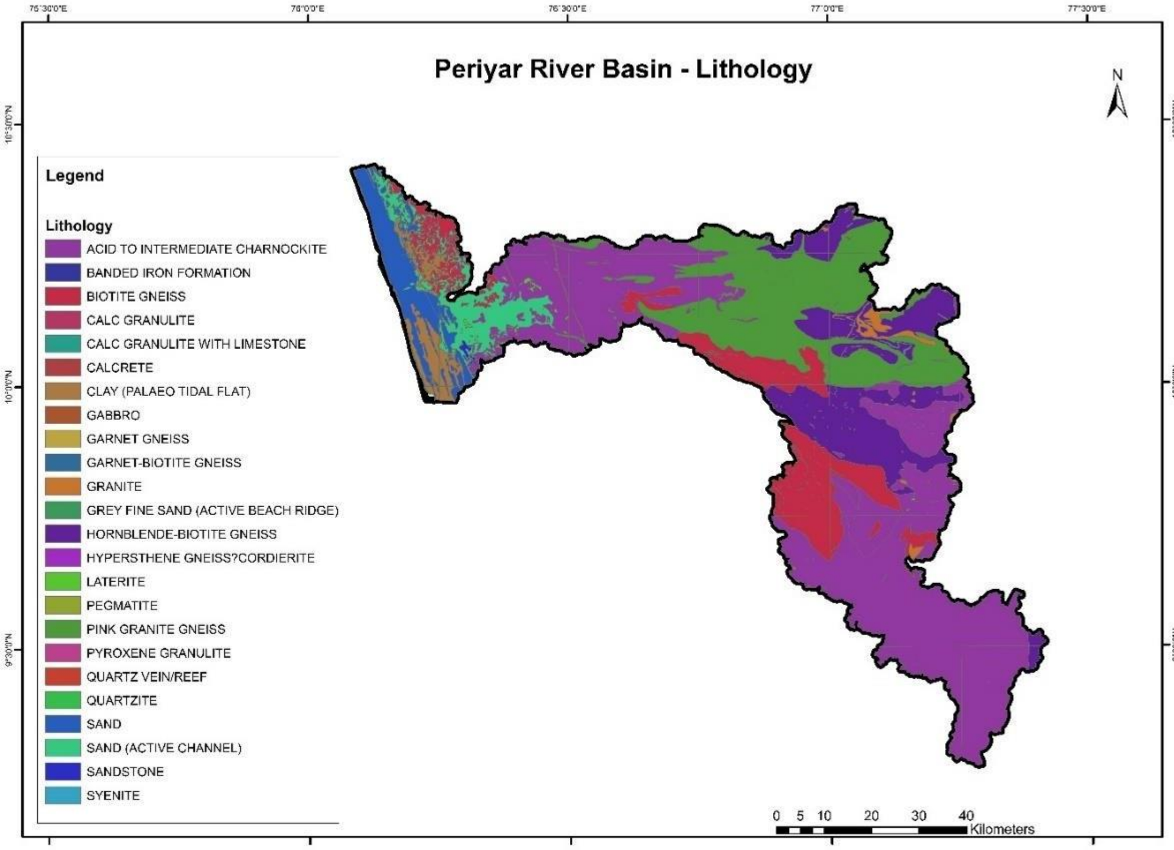


Figure 3: All major rock types constituting Lithology of the Periyar Basin

Acid to Intermediate Charnockite

Charnockite forms a significant part of Kerala's Precambrian crystalline terrain, covering 2146.70 km² in area and distributed in the upstream areas of Idukki and downstream midlands of Ernakulam district. These rocks exhibit mineralogical diversity, including quartz, feldspar, pyroxenes, and occasional garnet. The presence of massive and gneissic varieties highlights the polygenetic origins of Charnockite, ranging from deep magmatic to high-grade metamorphic processes. The Charnockite of Kerala, including those in the Periyar Basin, are key contributors to the rugged terrain of the Western Ghats and serve as fractured aquifers for groundwater recharge.

Banded Iron Formation

Banded Iron Formations (BIFs) in the region, although limited to 0.71 km² and found as enclaves in Hornblende Biotite Gneiss, are significant as markers of ancient marine sedimentary environments. These formations occur as part of the Wynad Supracrustals, characterized by high-grade metamorphism and intense deformation. They indicate ancient depositional conditions rich in silica and iron, which later underwent significant tectonothermal alteration.

Biotite Gneiss

Biotite gneiss, occupying 646.31 km², is a key component of the Peninsular Gneissic Complex. These medium- to coarse-grained foliated rocks consist primarily of biotite, quartz, and feldspar. Found across the Periyar valley in its western water divide as well as in the coastal zones of Thrissur district. Biotite gneiss serves as a fractured aquifer system and represents a critical lithologic unit in Kerala's Precambrian terrain.

Calc-Granulite and Calc-Granulite with Limestone

Calc-Granulites and their limestone-associated variants span 0.50 km² and 5.52 km², respectively. These rocks are typically medium- to coarse-grained and granoblastic in texture. Found in bands interspersed with Charnockite and Khondalites, they contain minerals like diopside, plagioclase, and garnet. These lithologies highlight the region's metamorphic history, with remnants of ancient carbonate depositional systems.

Calcrete

Calcrete formations, covering 0.72 km², are secondary sedimentary deposits resulting from calcium carbonate precipitation in soil or alluvial settings. These deposits are associated with arid to semi-arid conditions and provide evidence for paleoenvironmental conditions in the Periyar Basin.

Clay (Palaeo Tidal Flat)

Spanning 125.12 km², these clay deposits indicate the presence of paleo tidal flats, formed during marine transgressions in the Quaternary period. They are significant for understanding the evolution of Kerala’s coastal geomorphology and sedimentary history.

Gabbro

Gabbro, a coarse-grained intrusive igneous rock, occupies 4.59 km² in the basin. These rocks, consisting primarily of pyroxenes and plagioclase, are often associated with basic intrusive bodies in Kerala, such as the meta-gabbro and meta-pyroxenite units observed in the state’s granulite terrain.

Garnet Gneiss and Garnet-Biotite Gneiss

These metamorphic rocks collectively span 1.83 km² and represent high-pressure metamorphic conditions. Garnet-bearing rocks are typically associated with the Khondalite and Charnockite groups, indicating intense tectonic and thermal activities during their formation.

Granite and Pink Granite Gneiss

Granites and their pink gneissic variants together cover 1067.48 km². These rocks are primarily observed in areas like Munnar and Devikulam, forming part of younger granitic intrusions along shear zones. They are significant as aquifers and are extensively used in construction.

Grey Fine Sand (Active Beach Ridge)

These deposits, covering 6.19 km², are part of Kerala's coastal sedimentary systems. The sand formations represent the Kadappuram Formation, characterized by coastal dynamics and lagoonal processes.

Hornblende-Biotite Gneiss

Hornblende-biotite gneiss, covering 711.30 km², is a dominant lithologic unit in the basin. It forms part of the Peninsular Gneissic Complex and represents medium- to high-grade metamorphism.

Laterite

Laterite, distributed across 16.01 km², is extensively observed in Kerala's midland regions. Formed through tropical weathering processes, laterite is a significant aquifer and a source of bauxite in the region.

Pegmatites

Pegmatites, occupying 1.51 km², are coarse-grained igneous rocks rich in quartz, feldspar, and mica. These intrusions are associated with granitic bodies and are often economically significant for hosting minerals such as mica, feldspar, and rare earth elements.

Sand and Sand (Active Channel)

These fluvial deposits collectively span 503.58 km². Found in active channels and alluvial plains, these sand formations are critical for aquifer recharge and sediment transport dynamics.

Syenite

Syenite, a coarse-grained intrusive rock, occupies 0.40 km². Associated with Mannapra and Angadimugar intrusions, syenites are notable for their alkali feldspar dominance and provide insights into the magmatic history of the region.

2.2 Litho-Logs

Lithologies reflect different hydrodynamic conditions and sediment transporting mechanisms. As lithology controls the distribution of petrophysical properties (e.g., porosity and permeability), a good understanding of the spatial variation of lithologies is of great significance for the exploration of underground reservoirs (Depo chen et al, 2019). Initial information of subsurface lithology is typically obtained from the observation of well cores and the analysis of well logs.

A typical litholog represents the different physiographic unit and helps us get an insight of various parameters like fracture zones, presence of water taped in the fracture zone etc. There are 17 wells that are within the Periyar basin, which is distributed as 5 in Idukki 3 in Thrissur and 9 in Ernakulam. Figure 4 illustrates the various locations of litholog wells available across the Periyar River Basin.

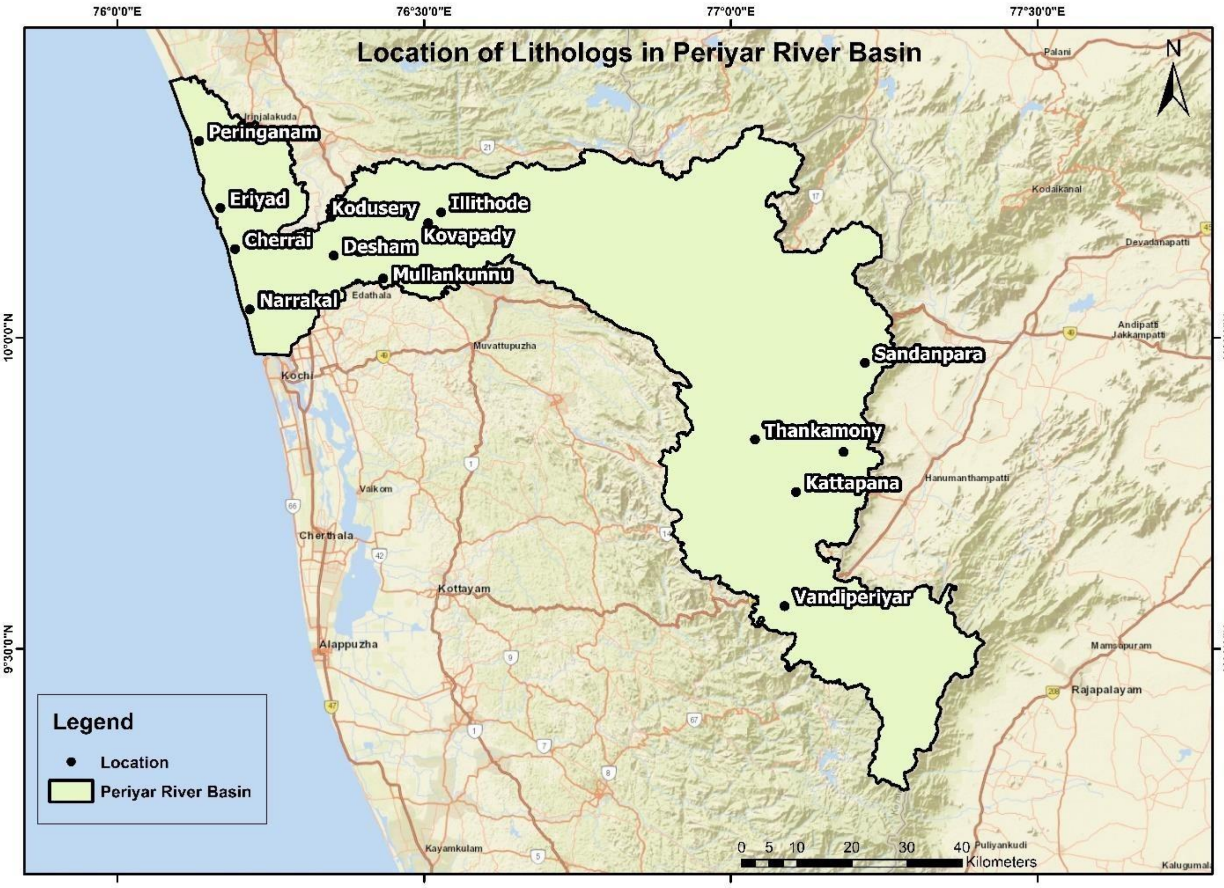


Figure 4 : Location of litholog wells in the Periyar river basin.

Vandiperiyar

Here the deepth of the Well is 30 m below ground level and has fracture at around 23 – 29 m bgl, the Top soil has a deepth of about 2 m and Granite Gniess is the basement rock from 4.5 to 30 m bgl. Figure 5 (a) represents the Litholog.

Kattapana

The depth of well is 50 m bgl where in top soil has a depth of about 8 m, below which a layer of Micalaseous clay is found and fracture is found around 42 – 42.5 m bgl in charnockite basement rock which has a depth of 36 m and starts from around 14 m bgl extends to 50 m bgl. Figure 5(a) represents the Litholog.

Thankamoni

The depth of well is 30 m bgl where in top soil has a depth of about 2 m and along with that Sandy clay also rocks in this well are calc – granulated and had strips of paegmetite veins. No fractures are found, charnockite is the basement rock which has a depth of 15 m and starts from around 15 m bgl extends to 30 m bgl. Figure 5(a) represents the Litholog

Mundiremma

The depth of well is 40 m bgl where in top soil which also conatins laterite has a depth of about 5 m and multiple fracture is found around 10 - 10.3, 20 - 21and 36 - 40 m bgl in charnockite basement rock which has a depth of 32 m and starts from around 8 m bgl extends to 40 m bgl. Figure 5(b) represents the Litholog.

Sanadanapara

The depth of well is 60 m bgl where in top soil has a depth of about .6 m and fracture is found around 6 – 6.5 m bgl in charnockite basement rock which has a depth of 53 m and starts from around 6 m bgl extends to 60 m bgl. Figure 5(b) represents the Litholog.

Illithode

The depth of well is 60 m bgl where in top soil has a depth of about 3 m and Granite Gniess is the basement rock which has a depth of 10 m and starts from around 50 m bgl extends to 60 m bgl. Figure 5(c) represents the Litholog.

Malayattur

The depth of the well 60 m bgl and the top soil has a deepth of 2.5 m bgl below which lithomargic clay is found there are no fractures and basement rock is granite gniess with a depth of 15 m. Figure 5(c) represents the Litholog.

Koovapady

The depth of well is 60 m bgl where in top soil has a depth of about 5m and no fracture is found in charnockite basement rock which has a depth of 53.5 m and starts from around 6.5 m bgl extends to 60 m bgl. Figure 5(d) represents the Litholog.

Mullankunnu

The depth of well is 40 m bgl where in top soil has a depth of about 6 m and fracture is found around 21-21.75 m bgl in charnockite basement rock which has a depth of 29 m and starts from around 11 m bgl extends to 8 m bgl. Figure 5 (d) represents the Litholog.

Kodussery

The depth of well is 40 m bgl where in top soil has a depth of about 7 m below which a layer of clay of 11 m thickness and fracture is found around 22.50 – 23 m bgl gniess complex is basement rock which has a depth of 2 m and starts from around 38 m bgl extends to 40 m bgl. Figure 5(d) represents the Litholog.

Desham

The depth of well is 200 m bgl where in top soil has a depth of about 7 m and is clayey in nature, no fracture is found, charnockite basement rock which has a depth of 21 m and starts from around 179 m bgl extends to 200 m bgl. The basement rcok is fractured in nature. Figure 5(e) represents the Litholog.

Srimulanagaram

The depth of well is about 200 m where in the top soil has a depth of 15 m and has multiple fractures (3 in number) at various depths the basement rock is 58 m thick and is hard and masive charnockite. Figure 5(e) represents the Litholog.

Narrakal

The well has a depth of 118 m bgl has alternating layers of sand clay and fracture of 6.5 m from 93 – 99.5 m bgl, the basement rock is khondalite rock and is part of Vaikom formations. Figure 5(f) represents the Litholog.

Cherrai

The well has a depth of 102 m bgl the top soil has a depth of 4 m bgl and there are are no fractures

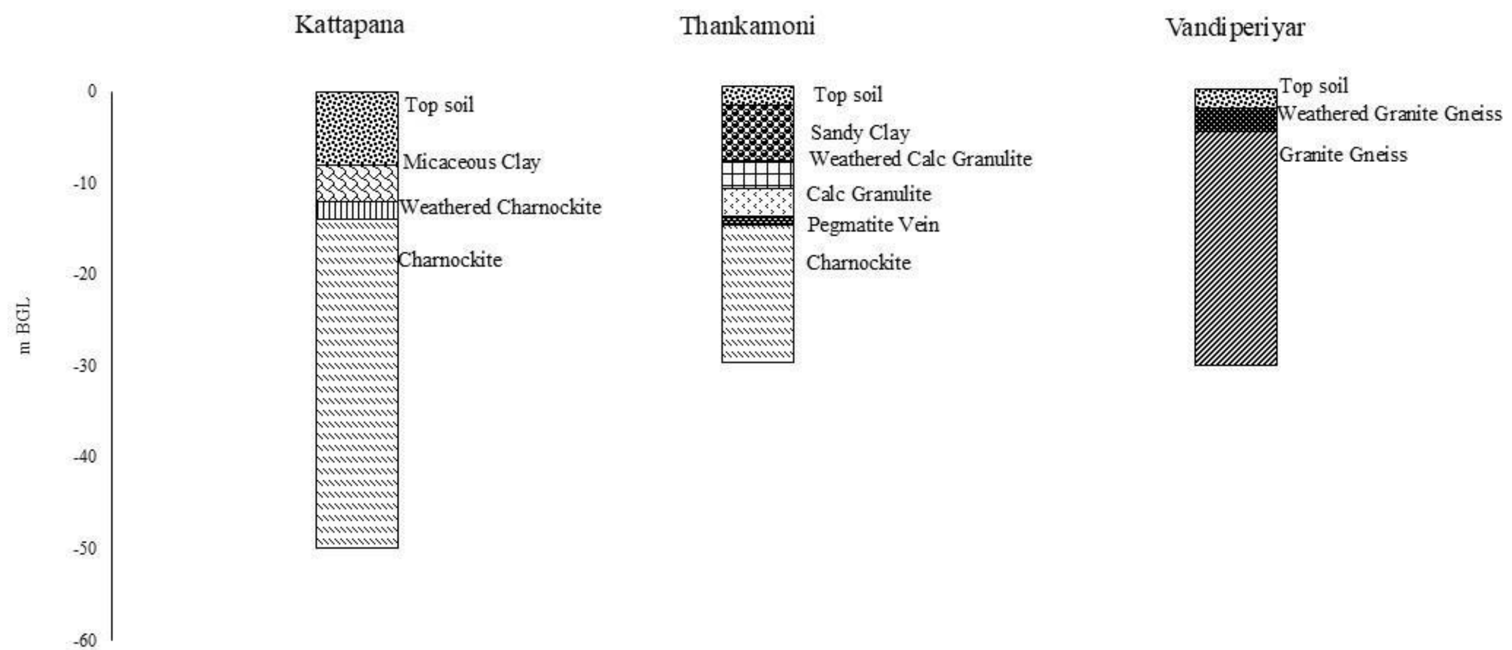


Figure 5(a): Litholog of Kattapana, Vandiperiyar and Thankamaoni

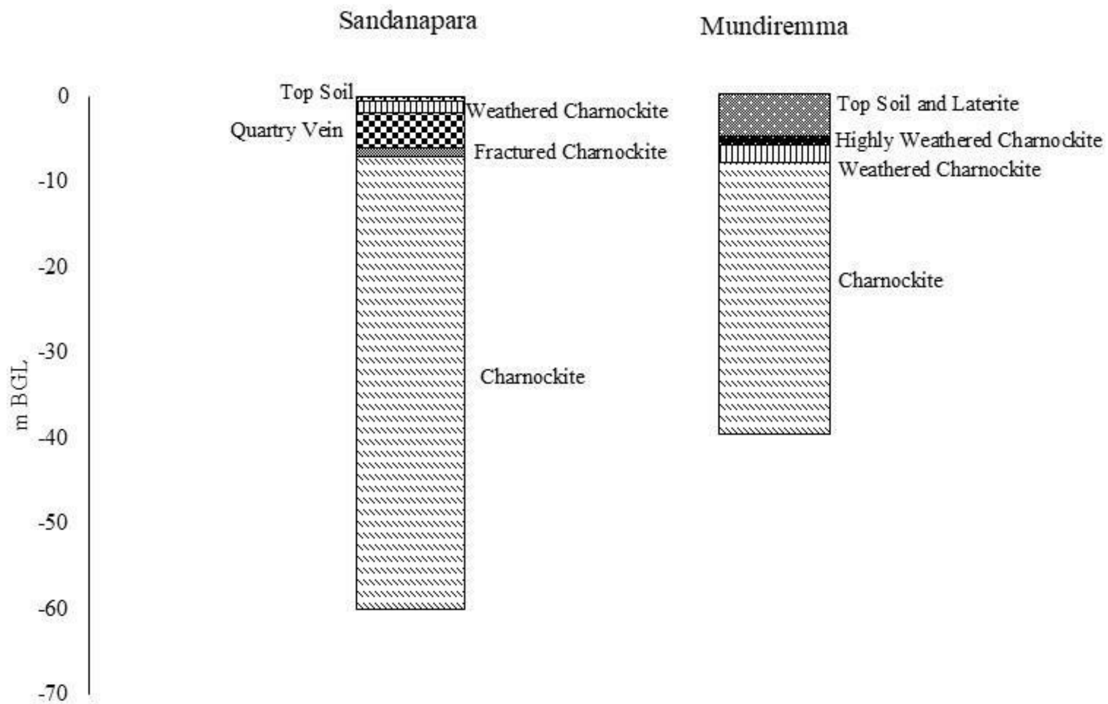


Figure 5(b) : Litholog of Sandanapara and Mundiremma

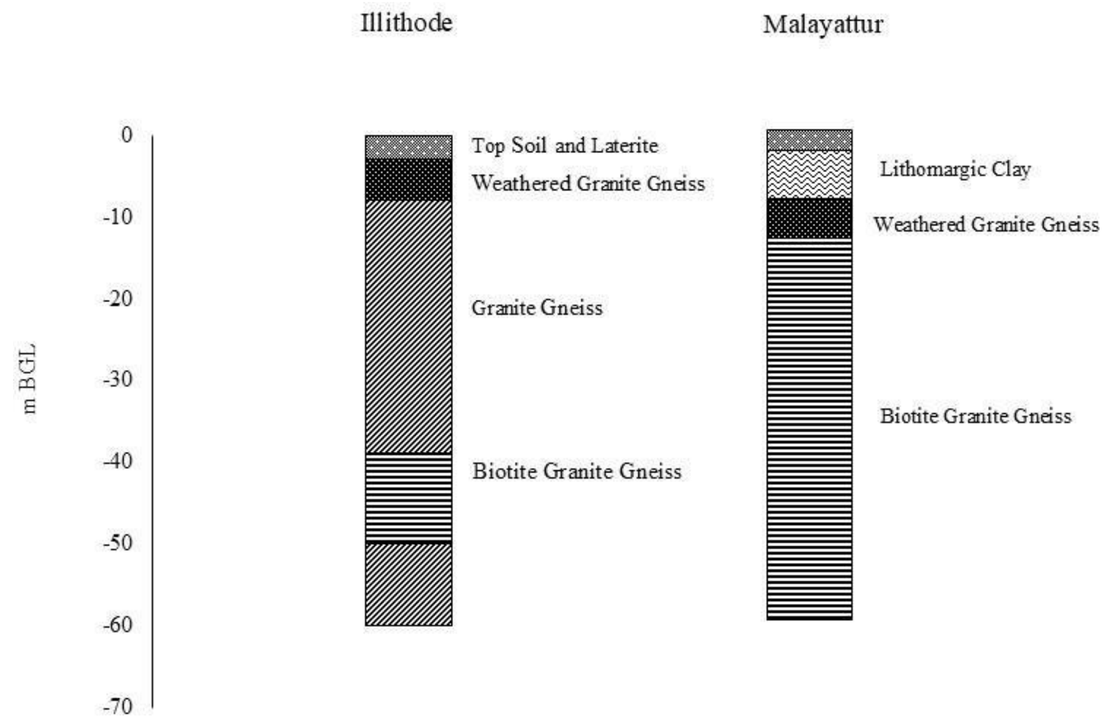


Figure 5(c) :Litholog of Illithode and Malayattur

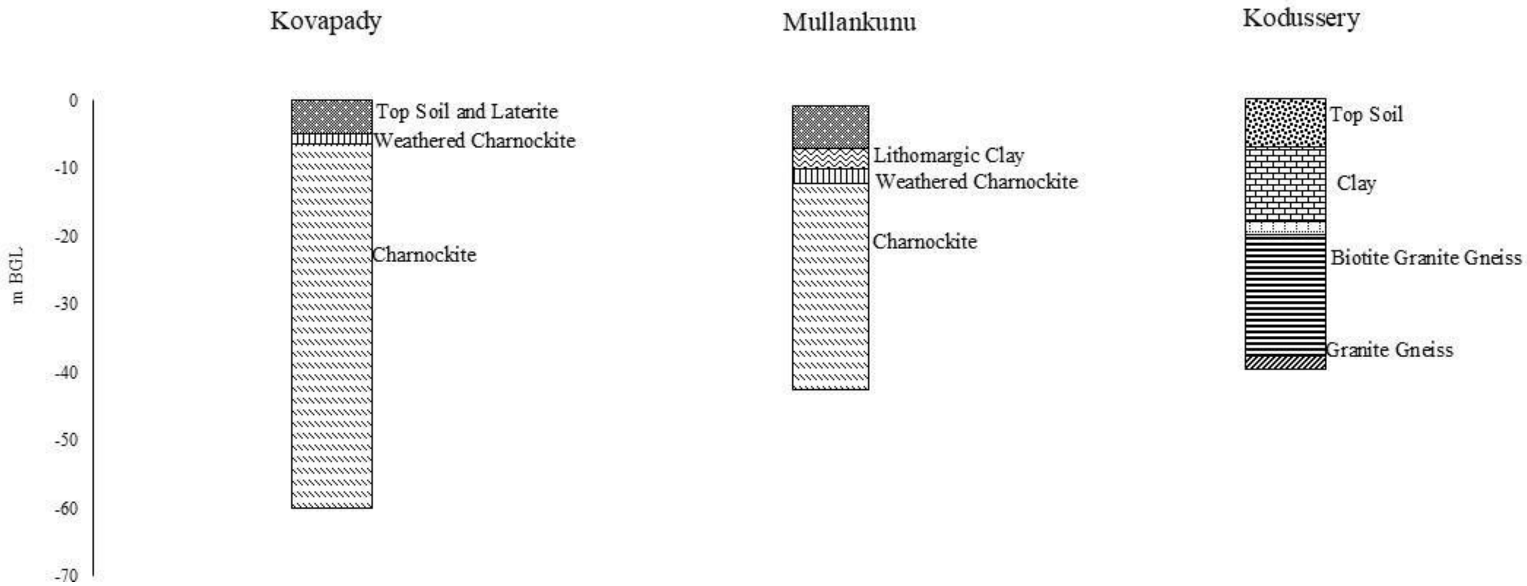


Figure 5(d) : Lithology of Kovapady, Mullankunnu and Kodussery

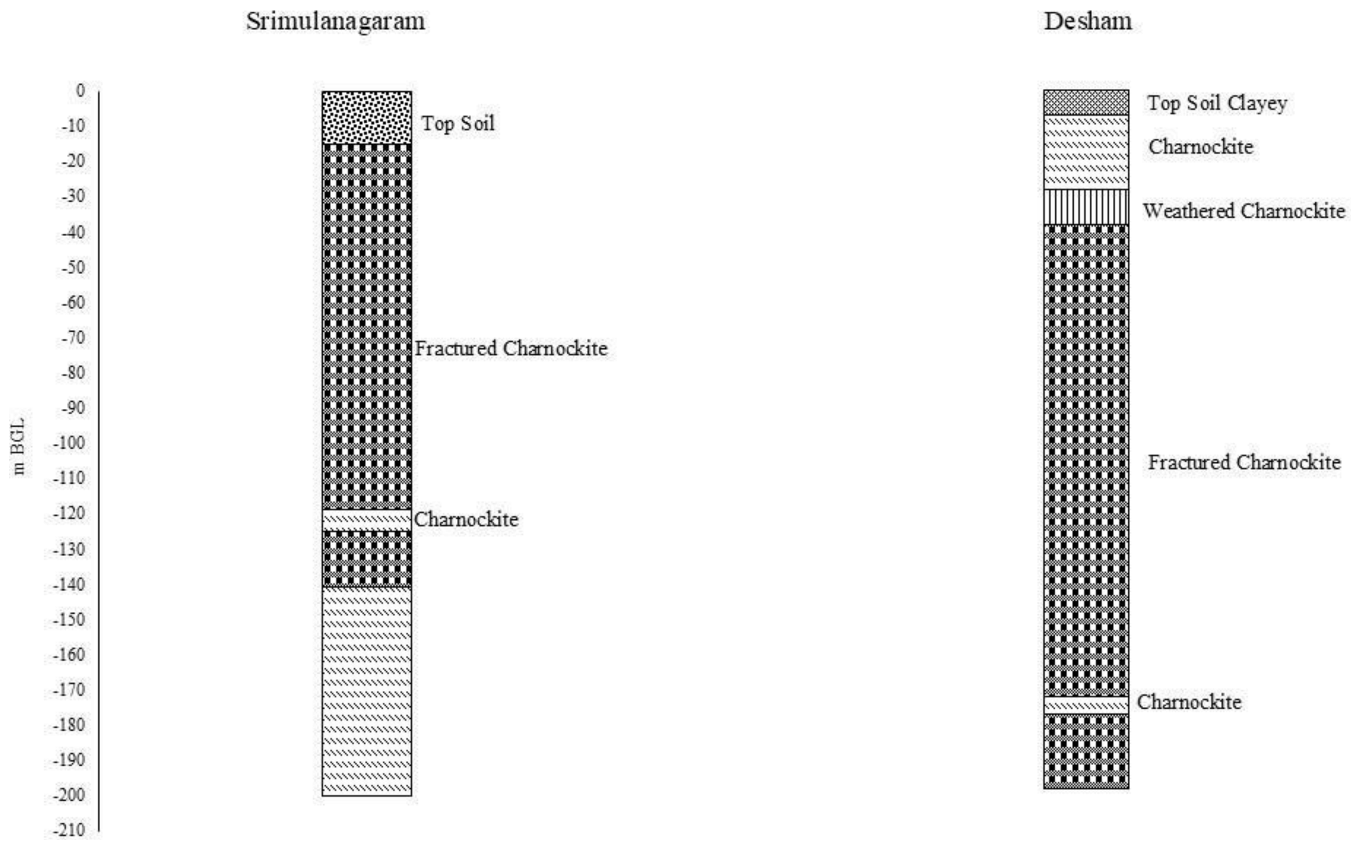


Figure 5(e) : Lithology of Srimulanagaram and Desham

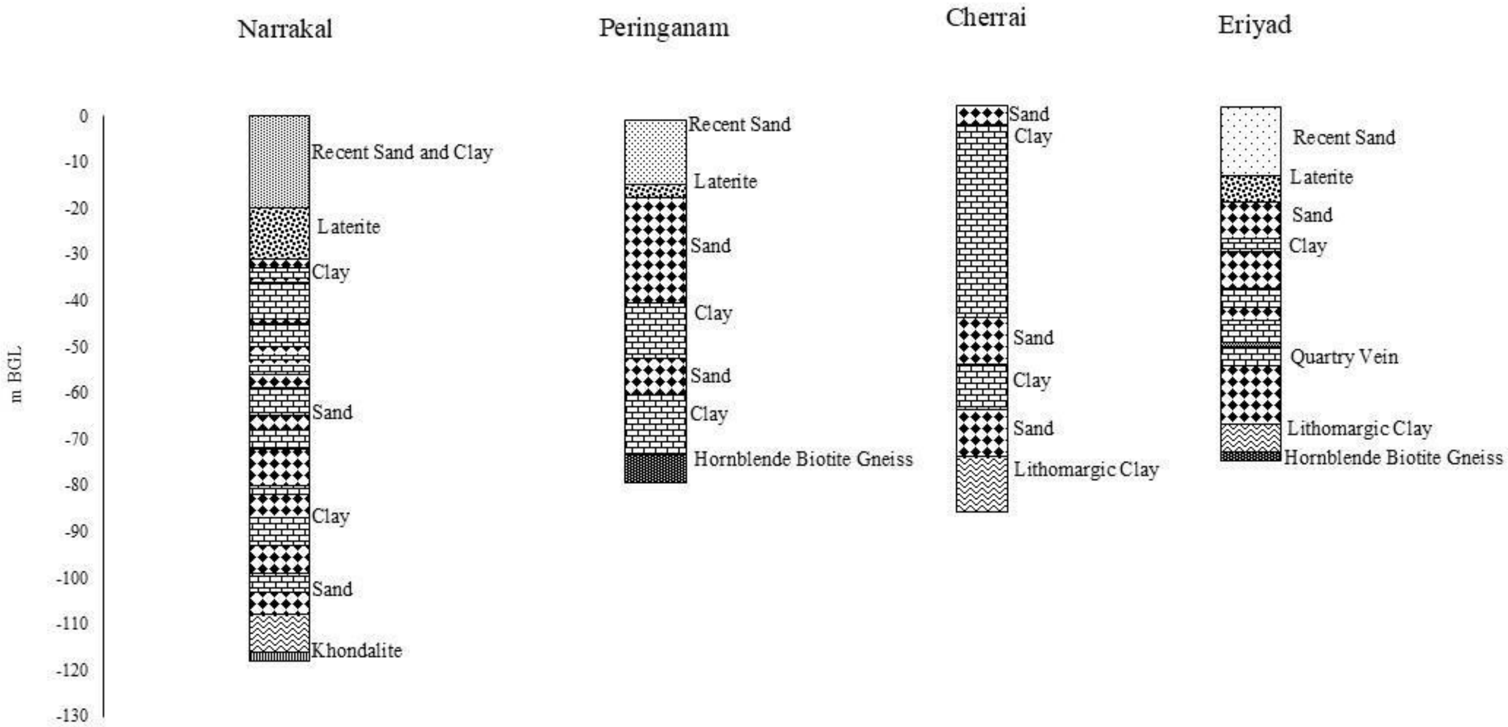


Figure 5 (f) : Lithology of Narrakal, Peeringanam, Cherrai and Eriyad found Lithomargic Clay is the basement material of thickness 12 m. Figure 5(f) is the Litholog.

Eriyad

The well is 78.5 m deep bgl and the top soil is 15.24 m thick there are mutliple fractures that are capable of holding water. The basement is of biotite gniess and 2.3 m thick. Figure 5(f) represents the Litholog.

Peringanam

The well has a depth of 79.25 m bgl and the top soil is 14 m thick.The basement rock is of hornblend biotite Gniess and is 6 m in thickness from 73 to 79 m bgl. Alternate layers of sand and clay is found between the topsoil and the basment rock. Figure 5(f) represents the Litholog.

2.3. Geological History and Chronology of the Periyar River Basin

The Periyar River Basin comprises lithologic units ranging from the Archean (4000–2500 million years ago, MYA) to the Holocene (11,700 years ago–present)**.** These units include high-grade metamorphic rocks, magmatic intrusions, sedimentary formations, and recent alluvial deposits. Each geological age contributes uniquely to the landscape and resources of the basin. Figure 6 represents the age of rock units in the Periyar River basin.

Archean (4000–2500 MYA)

Rocks from the Archean era in the Periyar River Basin are primarily represented **by** Banded Iron Formation (BIF)**.** These iron-rich sedimentary deposits signify high-grade metamorphism and tectonic activity. Their limited occurrence highlights the geological antiquity of the region.

Archean-Proterozoic (4000–541 MYA)

This broad period represents further stabilization of the crust, with rocks like Charnockite, Biotite Gneisses, Garnet-bearing gneisses and calc Granulites. These formations reflect prolonged tectonic activity, including folding, faulting, and regional metamorphism, which shaped the rugged terrain of the Western Ghats and serve as the backbone of the basin.

Neoproterozoic (1000–541 MYA)

The Neoproterozoic era is marked by the intrusion of pegmatites and quartz reefs and granites which are commonly associated with economic mineralization. These intrusions often occupy fractures in older gneissic or charnockitic terrains.

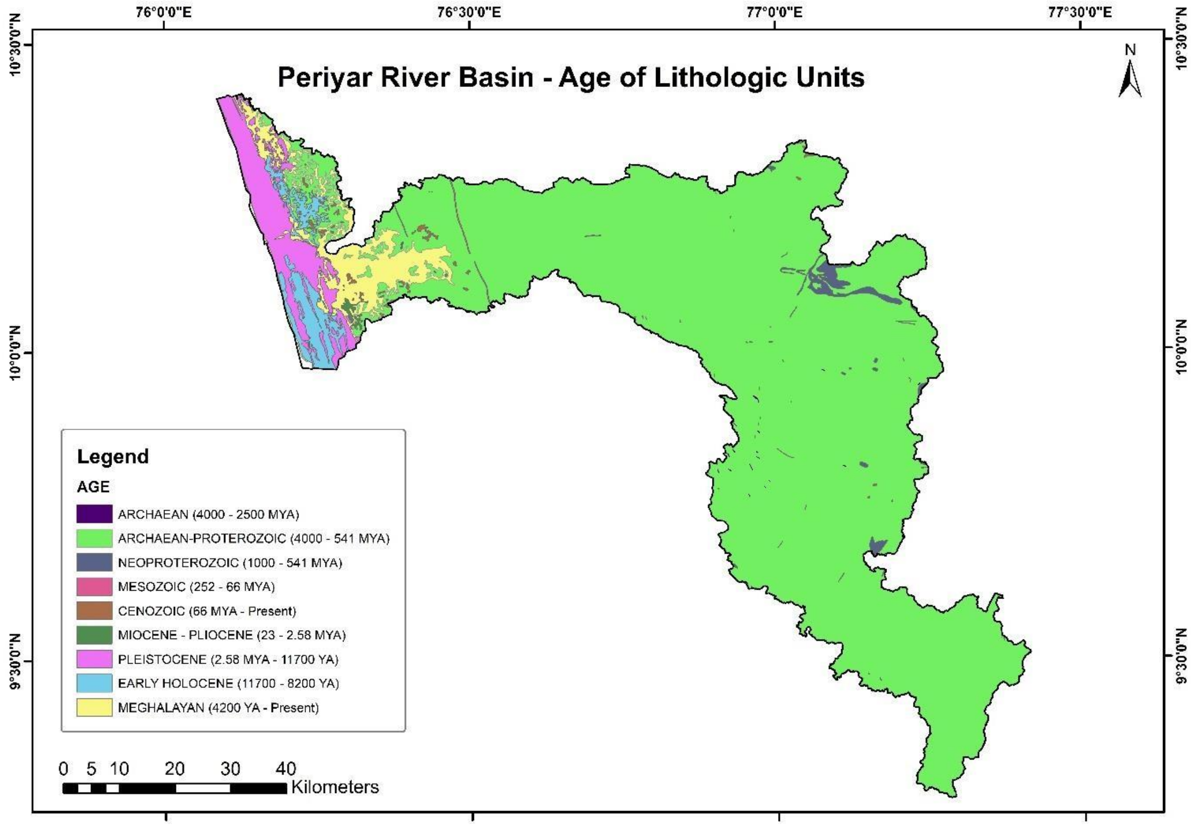


Figure 6: Age of lithologic units

Mesozoic (252–66 MYA)

Represented by gabbroic intrusions and basic dyke swarms, the Mesozoic era highlights magmatic activity related to tectonic reactivation. These rocks provide evidence of mantle-derived magmatism and crustal extension events.

Cenozoic (66 MYA–Present)

The Cenozoic period includes sedimentary deposits such as laterite and calcrete, which are widespread in the midlands and foothills. These formations resulted from prolonged tropical weathering and mark significant climatic changes over time.

Miocene-Pliocene (23–2.58 MYA)

This period is characterized by the Warkallai Formation, comprising sedimentary rocks like variegated clays, lignite seams, and marly sands. These deposits represent fluvial and lagoonal conditions during this time.

Pleistocene (2.58 MYA–11,700 years ago)
The Pleistocene epoch saw the deposition of fluvial and coastal sediments, including sand and clay in tidal flats. These deposits form the backbone of the Periyar Formation, highlighting significant hydrological activity.

Early Holocene (11,700–8,200 years ago) and Meghalayan (4,200 years ago–Present)
The youngest sediments in the Periyar Basin include alluvial deposits and sands from active channels and floodplains. These deposits represent recent geological activity and ongoing sediment transport processes.

2.4 Lithological Cross-sections

Lithological cross sections are graphical representations that illustrate the vertical distribution of different rock layers and their spatial relationships within a specific area. These sections provide a detailed view of subsurface geology, depicting the arrangement, thickness, and contact boundaries of lithologic units. Given in the Figure 7 are regions in which lithological cross-sections are illustrated inside the Periyar River basin. These cross-sections are developed from the bore-well logs collected from Central Groundwater Board. It can be noted from the Figure that the underneath the coastal edge, the layer is composed of a distinct intercalation between sand and clay deposits – typical of Warkalli formation. The Warkalli Formation is of Mio-Pliocene age and extends all along the Kerala coast. Unconsolidated Quaternary sediments overlie these basements unconformably. The sediments are classified into different morpho stratigraphic units based on their lithic content and environment of formation. Guruvayur Formation is an older marine deposit while Periyar Formation, Viyyam Formation and Kadappuram Formation are the contemporary fluvial, fluvio-marine and marine deposits.

Moving away from the coastal zone, almost abrupt changes from sedimentary to metamorphic facies of rocks are observed. Unlike the tertiary and quarternary sedimentary deposits seen in the coastal front, these rocks of Precambrian origin and include rocks like Charnockite, Gneisses, Migmatite. The Charnockitic Group comprises of pyroxene granulite, magnetite quartzite and Charnockite among which the Charnockite is dominant and widespread. Pyroxene granulite and magnetite quartzite occur as linear bands of a few metres' width and a few tens of metres in length within the gneissic terrain. They are aligned generally parallel to the trend of foliation.

Charnockite occurs as continuous rock unit covering the hilly region in the south and northwest of Idukki district. It is mostly massive but gneissic varieties are also seen, with intermediate to acidic in composition. Central, Northeast and southeast parts of the district are dominated by rocks of migmatitic complex comprising of biotite gneiss and hornblende-biotite gneiss. The biotite gneiss has plenty of restites of older Khondalite and Charnockite Groups of rocks occurring as lensoidal and linear bodies, conformable with the trend of foliation. Granite emplacement is seen around Munnar, Devikulam and along the eastern boundary. Both pink and grey varieties are observed. The older rocks are traversed by pegmatites and quartz veins and basic intrusive (dolerite and gabbro). The cross section of Idukki is represented in Figure 8. The thickness of the weathered crystalline rock overlying the basement in the Idukki region varies by lithology. Charnockite and Charnockite Gneiss exhibit an average weathered zone thickness of 6.95 m, while Horblende-Biotite Gneiss has a higher average of 11.12 m. Granite Gneiss, with the thickest weathered zone

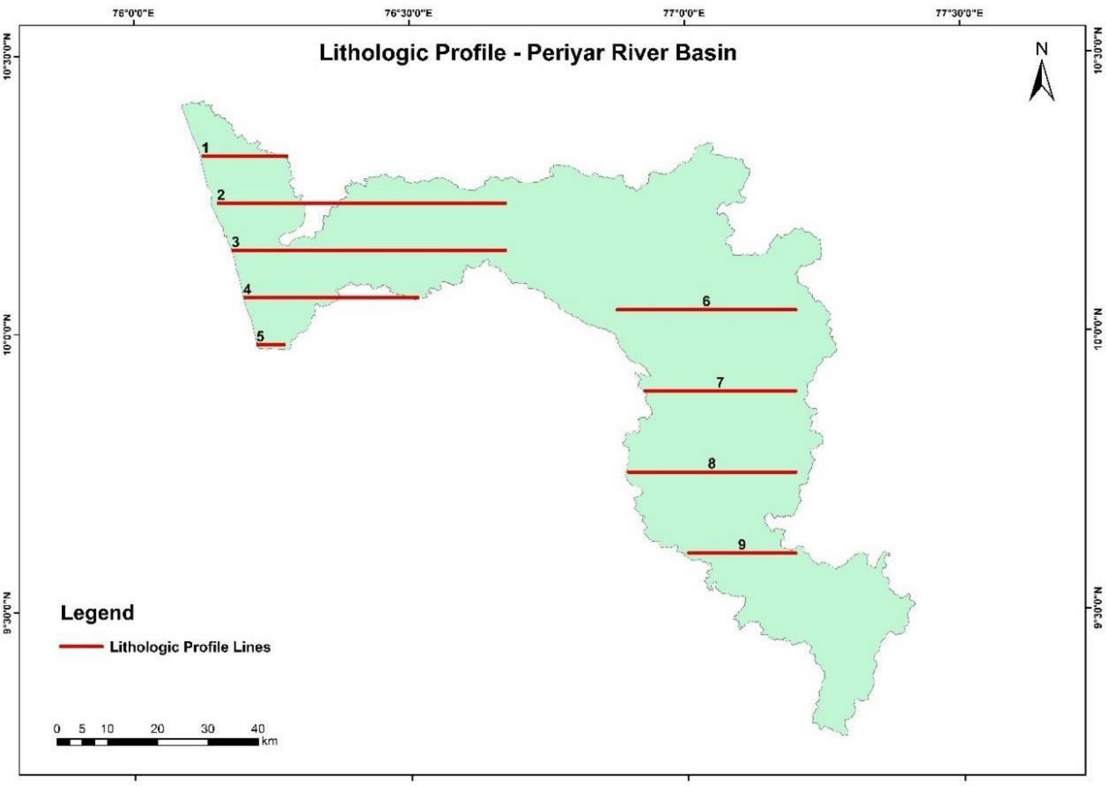


Figure 7: Location of the Lithological Profile generated in the Periyar River Basin

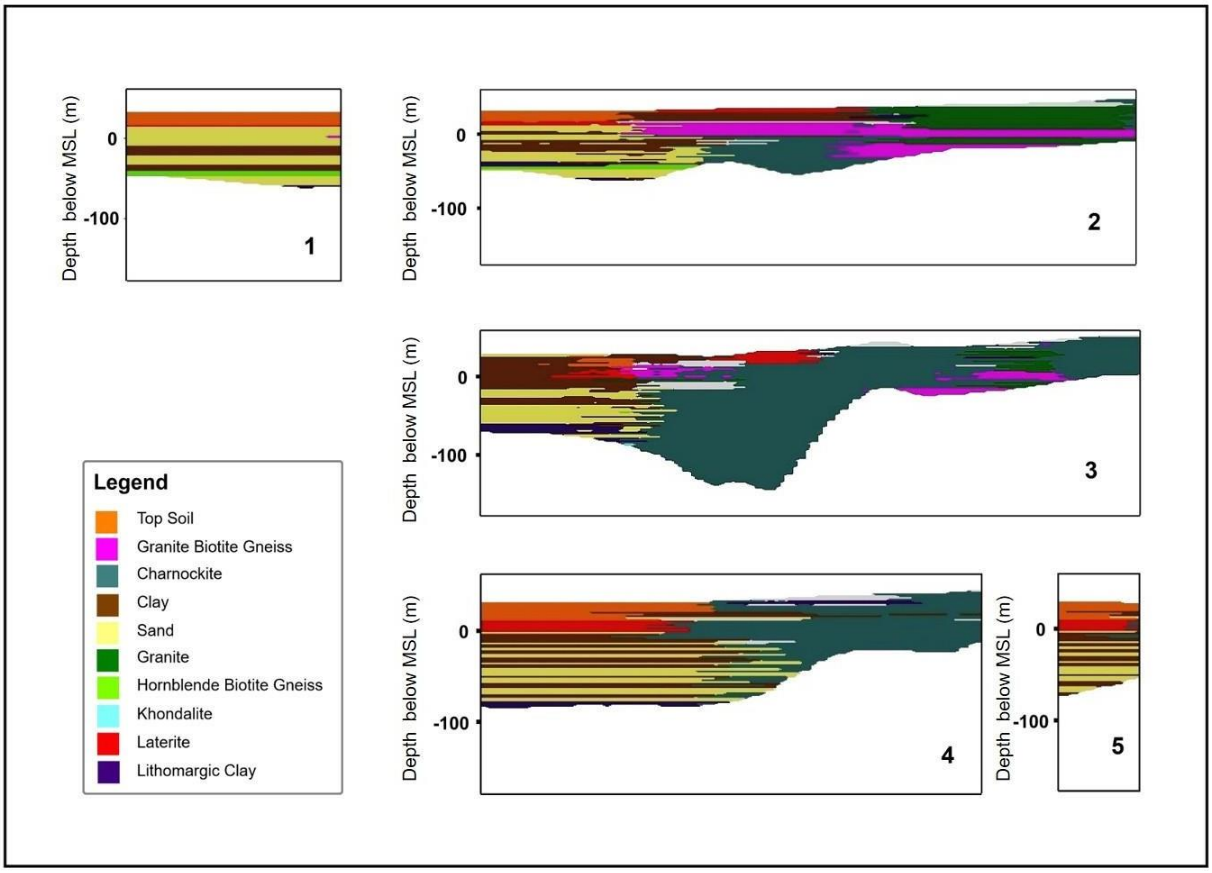


Figure 8(a): Lithological Cross section of Ernakulam and Thrissur

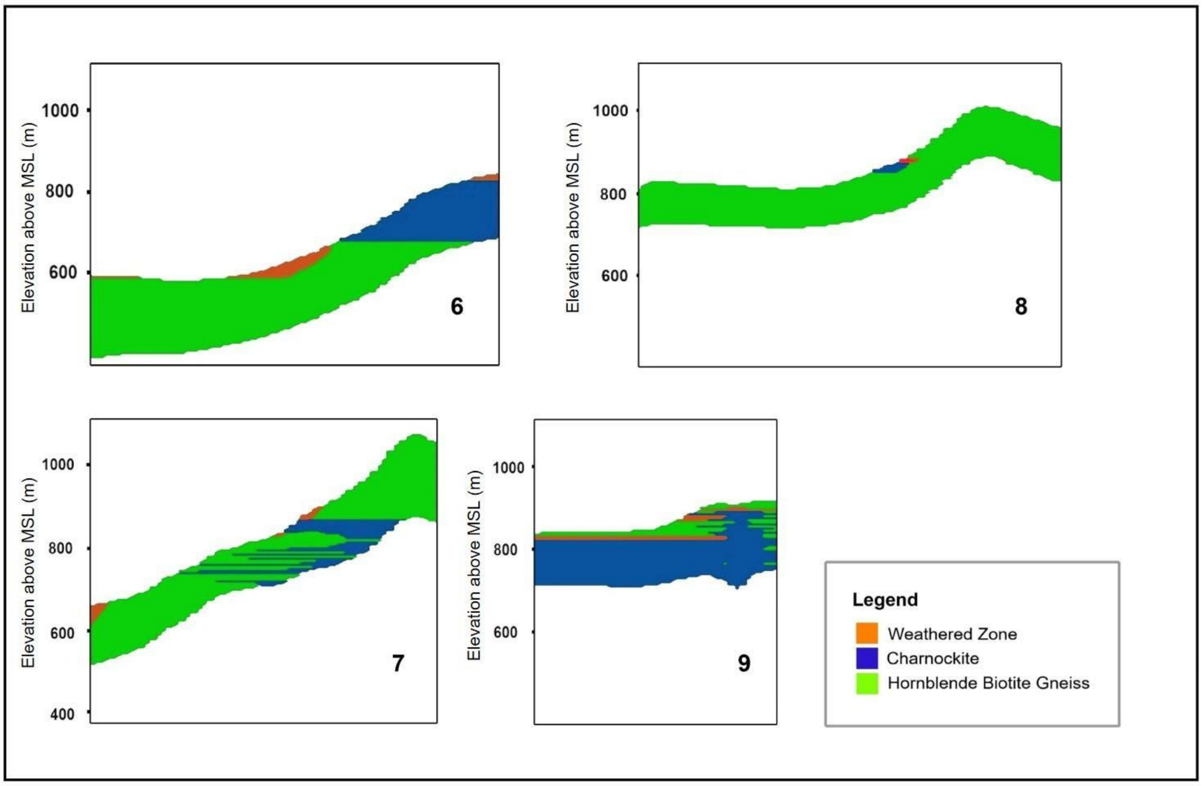


Figure 8(b): Lithological Cross section of Idukki

3. Soil Characteristics of the Periyar River Basin

Soil is one among the cardinal resources that sustains life**,** recycles nutrients, plays a significant role water filtration and storage, and carbon sequestration. Soil formation or 'pedogenesis' is intrinsically related to (a) The chemical composition of Parent rock, (b) Hydrological influences, (c) climate, (d) Topographical variability, and (e) Biotic factors.

The formation of soils incorporates a combination of processes including the weathering of parent material, the structural development of the soil, the differentiation of this structure into distinct horizons or layers, and the subsequent movement or translocation of soil materials. Soil can often be transported from its original site of formation through various mechanisms.

3.1 Soil Nutrient

Soil nutrients is the heart of life in a river basin. They provide essential ingredient for plant growth, which have an influence on water quality, and sustain the biodiversity that thrives around the river and its surrounding environment. To understand why the complexity of a river basin is so complex is to understand how these nutrients are formed, how they interrelate with the region's geology, and the roles they play in sustaining a healthy ecosystem.

The essential nutrient found in soils can be further classified as

- Macronutrient – This includes Majorly three elements Nitrogen (N) Phosphorous (P) and Potassium (K) as they are required by the plants in large quantities for photosynthesis, energy transfer, and overall functioning.
- Secondary nutrient – Calcium (Ca) Magnesium (Mg) and Sulphur (S) are the secondary nutrients that are required by the plants as they support essential functions.
- Micronutrient - Iron (Fe), manganese (Mn), zinc (Zn), and others are needed in trace amounts for specialized physiological functions.

The type of rocks in a river basin greatly influences the soil's nutrient content. Different rocks release different nutrients as they break down:

- Basalt and Granite: These rocks are rich in potassium and magnesium, which are essential for plant growth.
- Limestone: Soil in limestone tends to provide a good availability of calcium, which would help build strong cell walls in the plants.

- Shale and Schist These rocks provide phosphorus, sulfur, as well as micronutrients such as zinc and manganese, critical for enzymes and plant metabolism.

Soil nutrients like Potassium, Phosphorous, Copper, Sulphur, and Boron and soil parameter like pH, Electrical conductivity, Organic content of Carbon are being discussed in detail in following sections.

pH

Soil pH is a basic indicator of soil health that is involved in determining soil suitability for plant growth and microbial activity as well as nutrient availability. Within a river basin, the soil pH is influenced by multiple natural and anthropogenic factors, reflecting the dynamic interaction of geological, hydrological, and ecological processes. Soil pH is depended on nature of parent rock, organic matter decomposition, ground water characteristics and other anthropogenic factors, while it affects microbial activity, nutrient availability, plant growth, and nutrient cycling of the soil.

In the basin the soil pH Ranges from 3.3 (upstream region) to 7.6 (downstream region). The acidic nature is helpful for planation crops like coffee, cardamom etc, the acidity of soil is to be neutralized with application of Lime. Moving downstream the pH increases making soil slightly less acidic to neutral level. The higher levels of pH in highlands of Idukki can be attenuated to the heavy rainfall that the region receives, also the heavy forest covers, and organic biodiversity also adds to the higher levels of acidity. Flooding and sediment deposits make the soil less acidic which is visible in the downstream part of the basin. According to the Kerala Soil health information appropriate levels of pH are:

Table 2: Soil pH classification (*Source: Kerala Soil Health* Information *System)*

Soil pH Levels	Nomenclature
<3.5	Ultra acidic
3.5-4.4	Extremely acidic
4.5-5	Very strongly acidic
5.1-5.5	Strongly acidic
5.6-6	Moderatly acidic

6.1-6.5	Slightly acidic
6.6-7.3	Neutral
7.4-.78	Slightly alkaline
7.9-8.4	Moderately alkaline
8.4-9	Strongly alkaline
>9	Very Strongly alkaline

The soil pH distribution across the Periyar River Basin is being represented as a map in Figure 9.

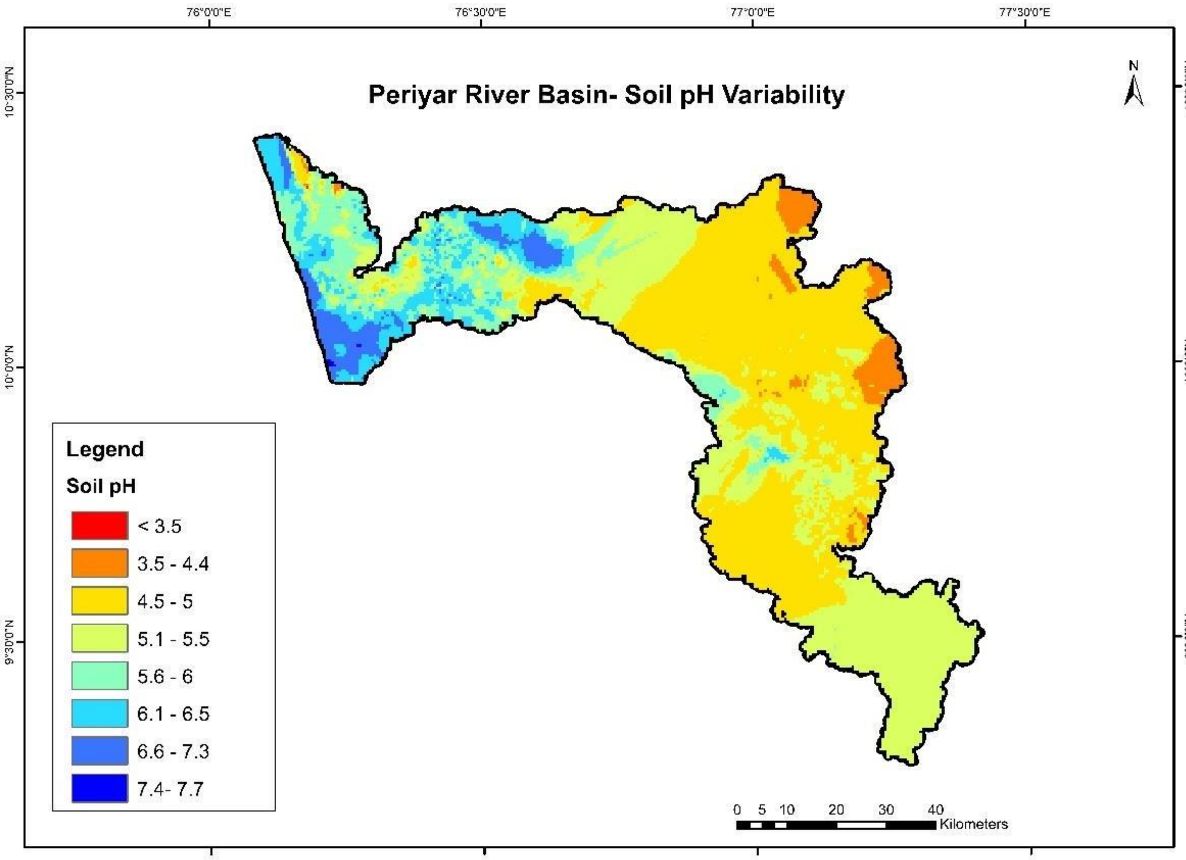


Figure 9: Soil pH Variablity in Periyar River Basin

Electrical Conductivity

Soil Electrical Conductivity (EC) acts as a reliable soil health indicator as the levels of soil electrical conductivity is representative of soil salinity and number of dissolved ions in the soil. It is due to the presence of soluble salts and its interaction with water. Also, it affects various parameters like soil fertility, nutrient absorption by plants, water availability for plants. In Periyar basin number of factors like geological nature of rocks, deposition by river, organic matter decomposition, fertilizer application rainfall etc plays a role in determining soil EC.

Soil EC levels fluctuate from 0.035 to 2.093 in the basin. The basin overall has low EC aside from regions near the coast where it is on moderate level and very few high regions of EC. The lower levels EC conductivity suggests that soil might require nutrient supplementation for ideal growth of diverse crops. The soil EC variation map is given below representing the distribution of Electrical Conductivity in Figure 10.

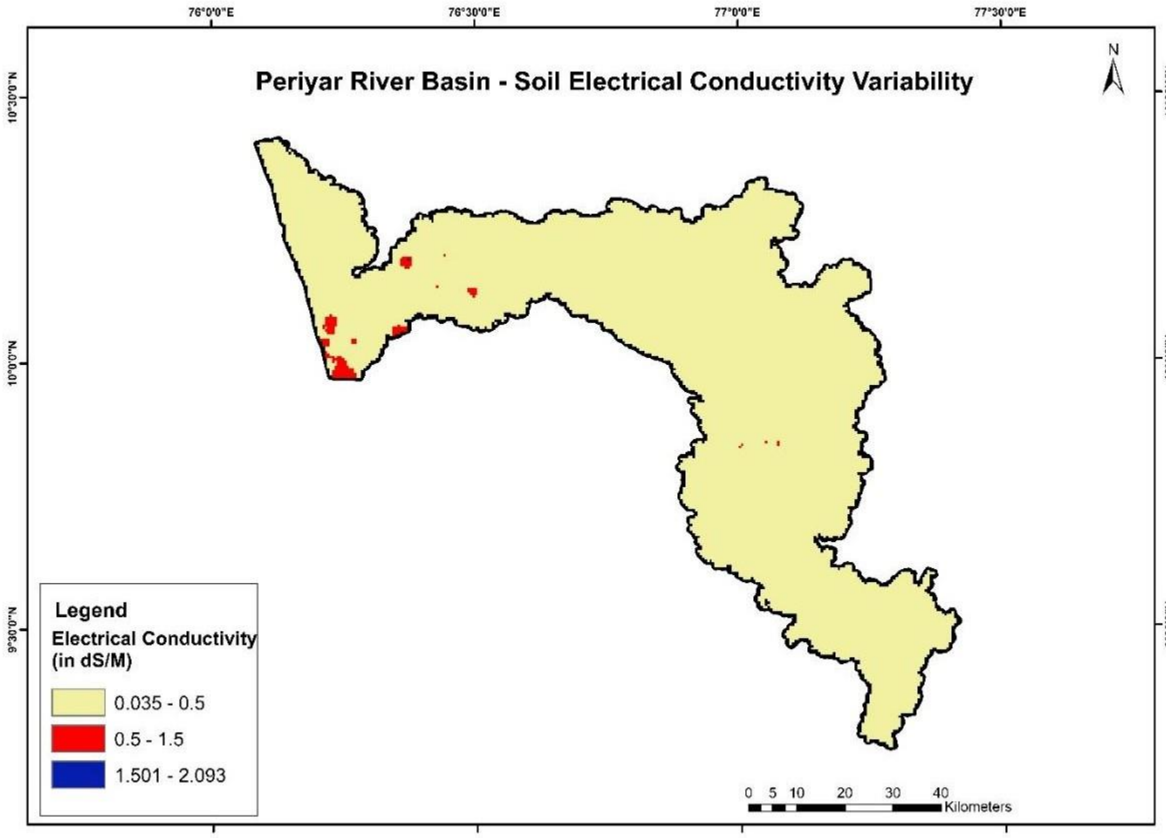


Figure 10: Electrical Conductivity Variation across the Periyar River Basin

Organic Carbon

Soil organic carbon being a store of nutrients, an essential player in soil structure, and an important component of the global carbon cycle, conserving agriculture, preserving biodiversity, and minimizing climate change. Soil Organic Carbon also acts as pH buffer stabilizing the pH of the soil. It is accumulated in the soil because of decomposition of organic matter over period, addition of organic matter and other geological activities like the deposition of alluvium during floods makes the soil rich in organic matter. A map of soil organic carbon distribution is given below in the Periyar river basin in Figure 11. In Periyar River basin the lowest value of organic carbon ranges from 0.28% to 3.56%. The majority of river basin has medium levels of soil organic carbon preceded by low and then high. Lower levels of soil organic carbon make it difficult for plants to have proper nutrient uptake and weakens the soil structure, lowers microbial activity, and makes soil more vulnerable to erosion and degradation of soil over time.

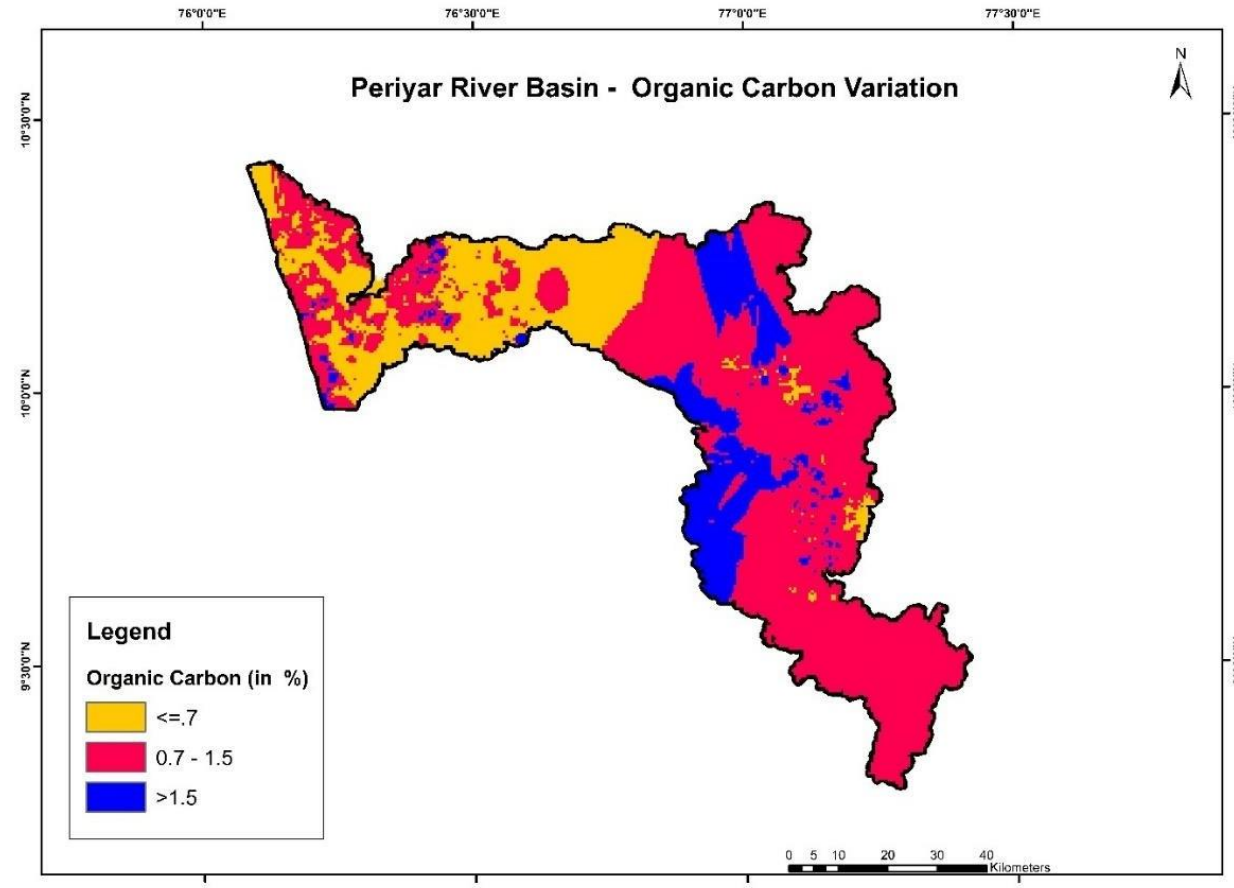


Figure 11: Soil Organic Carbon levels in the Periyar River Basin

Phosphorous

Phosphorus is critical in determining in plant productivity because the anionic form in which Phosphorous is assimilated by plants, is extremely insoluble in the soil solution. This insolubility is due to the affinity of P to cations such as Ca, Mg and Al, and its ready conversion into organic forms that are not amenable to plant uptake. (Herrera et al, 2003).

Also, it plays a vital role in the reproductive health of plants, energy synthesis through photosynthesis, and improves stress relief of plants against unfavourable condition like fluctuating rainfall droughts etc.

Phosphorous levels vary from 3.2 to highest of 306 Kg per hectare in the Periyar river basin.

According to the Kerala Soil health information appropriate levels of phosphorus are.

Table 3: Soil Phosphate levels (Source: Kerala Soil Health Information System)

Available Phosphorous (kg/ha)	Levels
Less than 11	Deficient
11-24	Adequate for growth of most plants
Greater than 24	Sufficient, Excess levels lead to run off

While the major portion of river basin has a phosphate level of higher than 24 indicating high amount of phosphorus is present in the soil, especially the downstream side of the basin. Soil Phosphorous Distribution across the basin is represented in the form a map given in Figure 12.

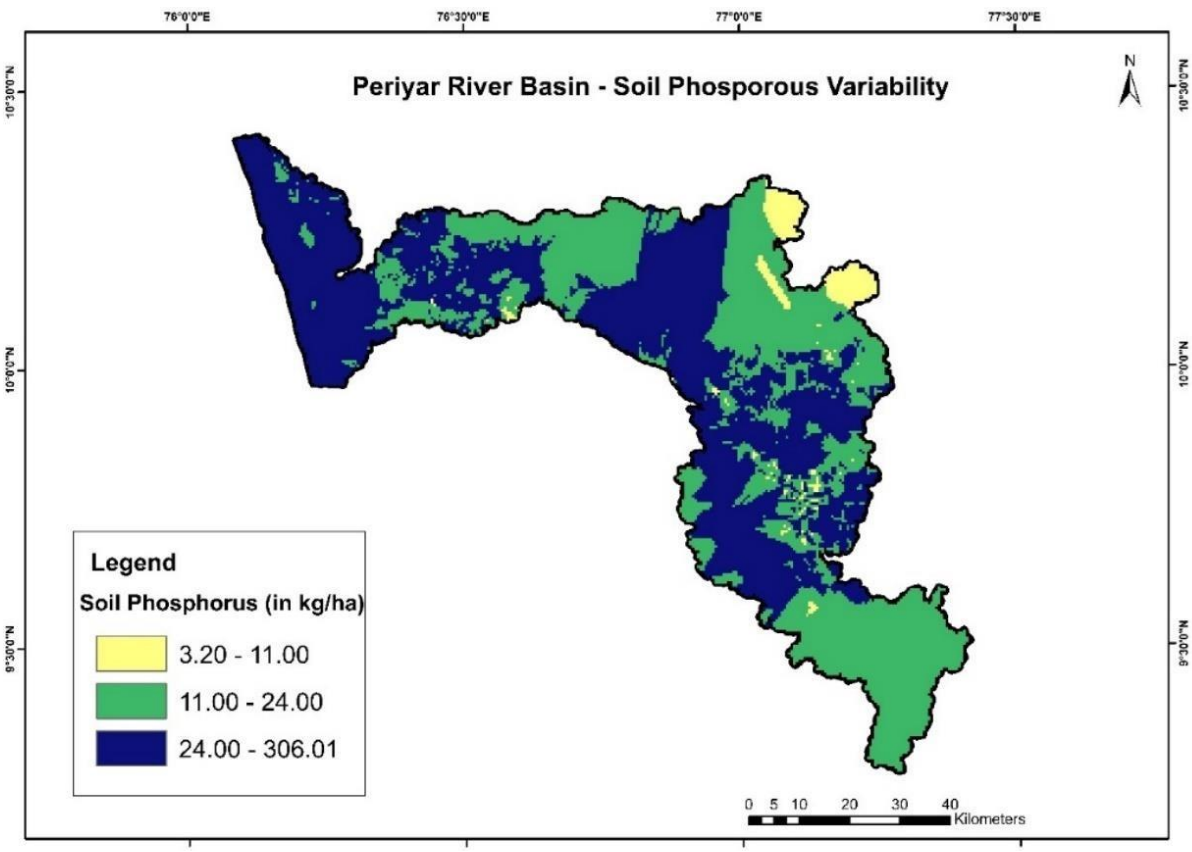


Figure 12: Soil Phosphorous levels in the Periyar River Basin

The excess levels in the soil phosphorous levels are primarily due to extensive use of fertilizers and manure rich in protein and the pH of soil also impacts soil phosphorous level.

Potassium

Potassium is a macronutrient which is also known as "quality nutrient" because of its significant impact on crop yield and quality. In soil Potassium is found in three forms (a) Unavailable Potassium (b) Slowly Available Potassium (c) Readily Available Potassium. Potassium enhances photosynthesis, improves soil stability, supports root development, boosts nutrient transport, increases Plant Resistance, and improves Water Use Efficiency. Kerala Soil Health Information system makes the classification of available potassium into three categories:

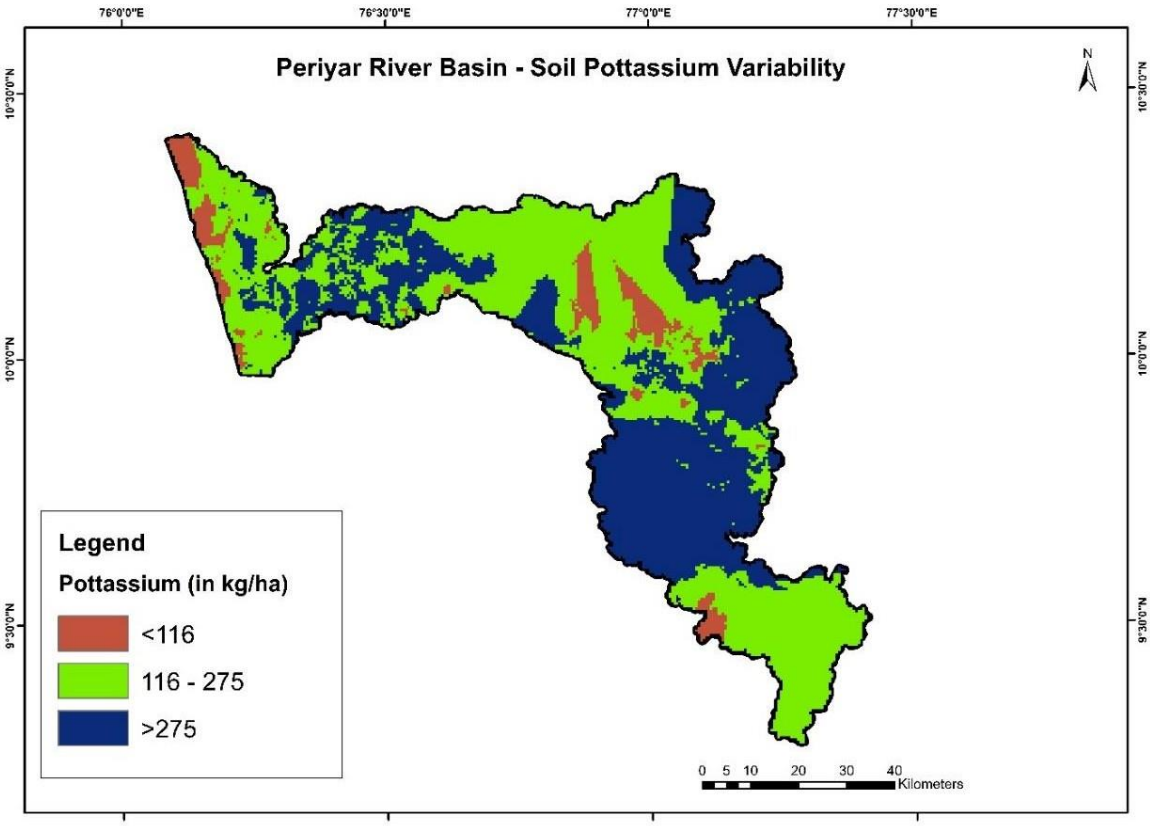


Figure 13: Soil Potassium levels in the Periyar River Basin

Table 4: Soil Potassium levels (Source: Kerala Soil Health Information System)

Available Potassium (kg/ha)	Levels
Less than 116	Low

116 - 275	Adequate
Greater than 275	High

In Periyar Basin Potassium ranges from 45 to 672 kg/ha. Large extent of the basin has soils that have adequate amount of soil Potassium required to support plant growth, also lower levels of Potassium are more concentrated towards the coastal sides due to saltwater intrusion and other associated triggering mechanisms. Figure 13 a Map of spatial distribution of Potassium across the Periyar basin.

Sulphur

Sulphur is a secondary macro nutrient. It not only plays an important role in nutrition of plant, also in complete physiology of plant and soil health. Sulphur is essential for protein and enzyme synthesis, chlorophyll formation, soil fertility and structural strength. Sulphur if found in soil from weathering

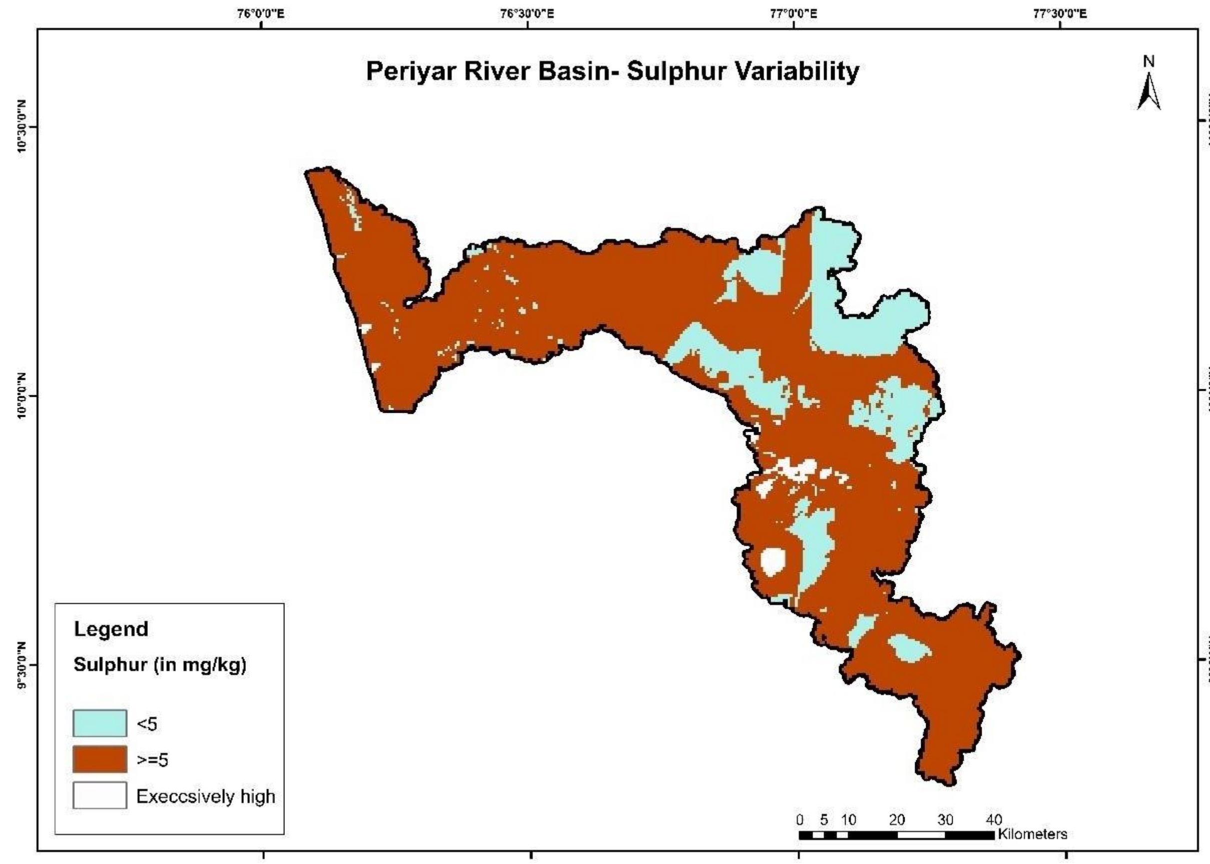


Figure 14: Soil Sulphur levels in the Periyar River Basin

of rocks and minerals rich in sulphur like pyrites and gypsum, riverine deposition and atmospheric deposition resulting from industries and biomass around. According to Kerala soil health information system the level of sulphur is classified into (a) deficient if sulphur level is less than 5 mg/kg and, (b) adequate if above 5 mg /kg. In the basin the soil sulphur levels vary from 0 to 354 mg/kg. Upstream region in Idukki majorly suffers from deficiency of sulphur. Extensive agriculture and heavy rainfall are two main factors of depletion deficiency of sulphur. Excessive sulphur leads to toxicity and leads to accumulation which is harmful for soil and plant growth all together. The spatial distribution of sulphur levels is illustrated with the help of a map in Figure 14.

Copper

Copper is a micronutrient required by plants in trace quantities and plays a big role in enzymatic processes, disease resistance, and soil microbial activity. Copper is formed because of weathering of rocks (accelerated by highly intensified rains in the Periyar basin) also minerals like chalcopyrite ($CuFeS_2$) and bornite (Cu_5FeS_4) adds to the copper levels in the soil.

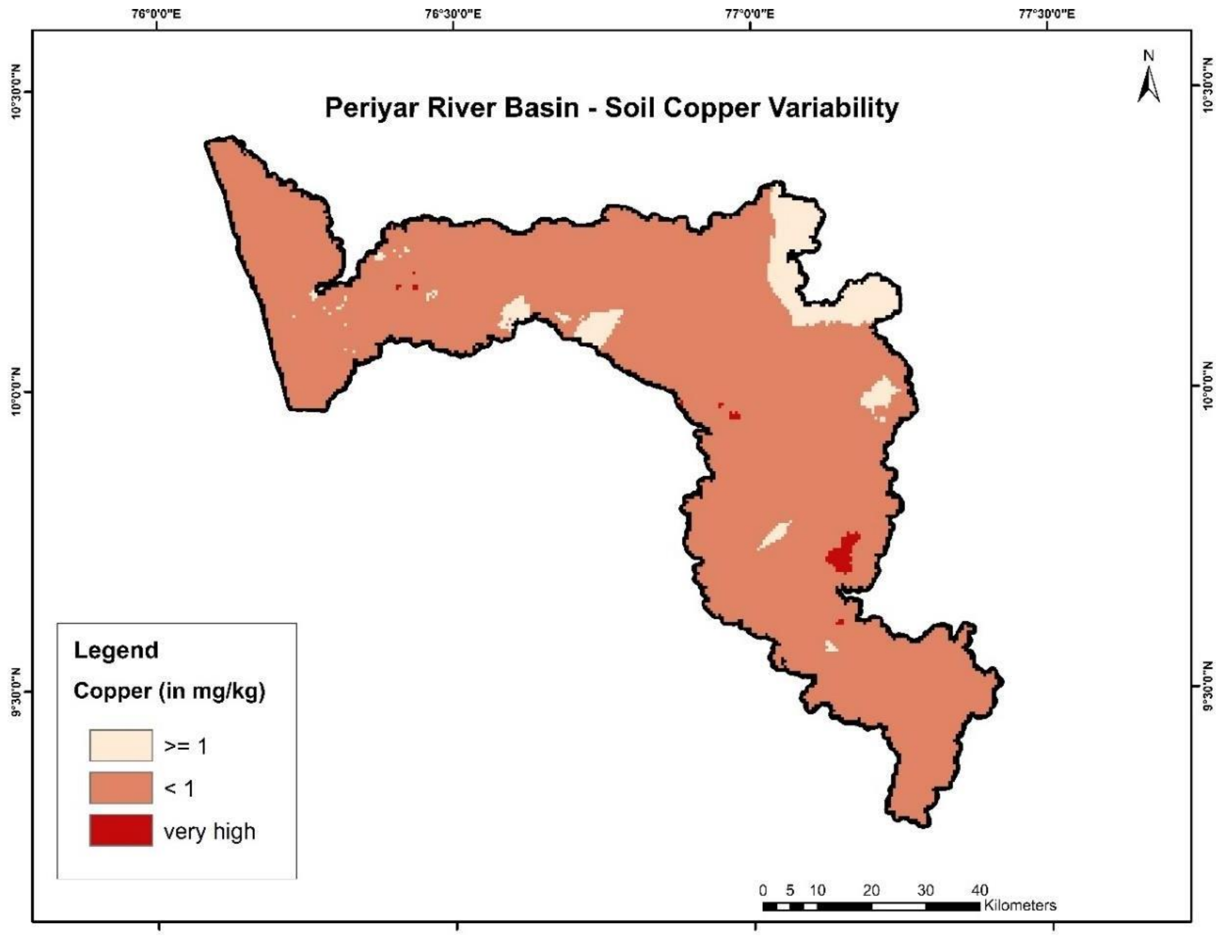


Figure 15: Soil Copper levels in the Periyar River Basin

The soil Copper varies from 0.06 to 57.22 in mg/kg. The soil is largely rich in copper across the basin, lower levels of copper might lead to stunted plant growth, reduced crop yields, and poor reproductive development, these conditions prevail in soils with intense leaching or depleted organic matter. Excessive copper can be toxic to plants and soil microbes, often resulting from overuse of copper-based agrochemicals. A map of spatial distribution of copper variability across the basin is represented in Figure 15.

Boron

Boron is a micronutrient that supports plant health, soil fertility, and ecosystem functions, reproductive health of plant, and cell wall structural integrity. Boron in soil is maintained majorly by weathering action of boron containing silicates, organic matter, sediment transport and use of boron rich fertilizers.

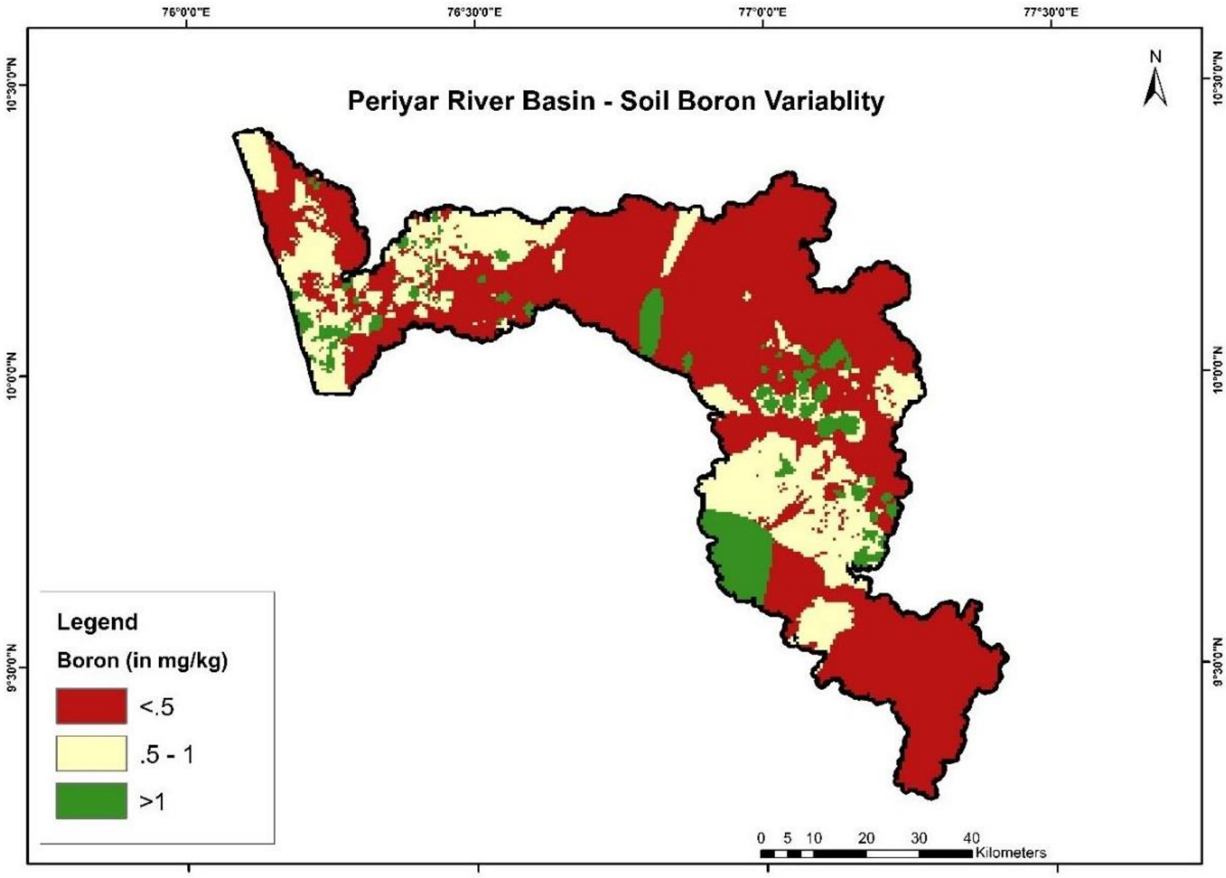


Figure 16: Soil Boron levels in the Periyar River Basin

Boron is ranged from 0 to 7.54 mg/kg in the eriyar basin. The Periyar basin has an acute deficiency of Boron content in soil. Some regions have excessive boron which may lead born intoxication in the soil. Lower levels of Boron affect the productivity of crops like tapioca which is highly sensitive to Boron. The deficiency of Boron is consistent throughout the basin, with few areas rich in boron to adequate or excessive levels. These irregular levels of Boron make it important to have a practice and management of soil nutrients to adequate levels. A map showing the distribution of soil Boron health is given in Figure 16:

3.2 **Soil Classification**

The scientific classification of soils of Kerala is made based on the system developed by USDA. Soil Taxonomy provides an elaborate classification of soil types according to several parameters and in several levels; Order, Suborder, Great Group, Subgroup, Family, and Series, of which 8 Orders are encountered in Kerala. They are Histosols, Spodosols, Vertisols, Ultisols, Mollisols, Alfisols, Inceptisols and Entisols (SSO, 2007). The name and important properties of the soil under USDA classification is tabulated in the form of a table in table 5.

Soils are classified on the basis of the characteristic horizontal layers or horizons that are visible in road cuts, pits, and so on. The thickness and nature of these soil horizons are determined by the various soil-forming processes mentioned and may vary widely. Soil profiles can be divided crudely into five major horizons: 0,A, E, B, and C The 0 horizon is the surface accumulation of mainly organic matter. The A horizon, which occurs at the surface or below the 0 horizon, consists of a dark-colored accumulation of organic matter (e.g., leaf litter) that is decaying and mixing with mineral soil. The E horizon, which underlies an 0 or A horizon, is a light colored eluvial horizon (a horizon from which material was removed by downward movement) characterized by less organic matter, fewer iron and aluminum compounds, and/or less clay than the underlying horizon. The B horizon underlies an 0, A, or E horizon and may contain illuvial (added material derived from an upper horizon) concentrations of fine organic matter, clay, etc.; most of the original rock structures have been obliterated by soil-forming processes. The C horizon, which lies above bedrock, is partly altered bedrock that can be deeply weathered but is relatively unaffected by soil-forming processes. Studies of soil profiles show, however, that soil layers are commonly much more complex than indicated by this simple scheme (Boggs, 2006).

Table 5: Name and Important properties of the main Orders (Source: USDA,1995)

Order	Properties

Alfisols	Mineral soils relatively low in organic matter with relatively high base saturation. Contains horizon of illuvial clay. Moisture is available to mature a crop
Aridisols	Mineral soils relatively low in organic matter. Contain developed soil horizons. Moisture is inadequate to mature a crop without irrigation in most years.
Entisols	Mineral soils lacking developed soil horizons. Moisture content varies.
Histosols	Soils composed mostly of organic matter. Moisture content varies.
Inceptisols	Mineral soils containing some developed horizons other than one of illuvial clay. Moisture is available to mature a crop.
Mollisols	Mineral soils with thick, dark surface horizons relatively high in organic matter and with high base saturation
Oxisols	Mineral soils with thick, dark surface horizons relatively high in organic matter and with high base saturation
Spodosols	Soils that contain an illuvial horizon of amorphous aluminum and organic matter, with or without amorphous iron. Usually moist or well leached.
Ultisols	Mineral soils with an illuvial clay horizon. Has low base saturation. Generally found in humid climates
Vertisols	Clayey soils with deep wide cracks at some time in most years. Moisture content varies.
Gelisols	Soils of very cold climates which are defined as containing permafrost.
Andisols	Soils formed in Volcandanic defined as soils containing high proportions of glass and amorphous colloidal materials.

3.3 Soil Series in Periyar River Basin

Soil "series" is the most detailed classification level in the taxonomic hierarchy. All series bear names associated with the original description area. When more than one series occurs within a given topographic unit, the smaller series is called the associated series with that unit. Within the Periyar River Basin, 12 Orders, 6 Suborders, and 12 distinct soil series have been reported. Figure 17 shows the classification of soils according to benchmark classification used by Department of Soil Survey and Soil Conservation Kerala.

The different soil series that are found in the Periyar River Basin are discussed in the further section of the report.

3.3.1 Anamudi Series

The Anamudi series consists of well-drained, typic kandhihumults, very deep for soil found in steep to very steep mountainous regions at elevations above 1200m above MSL. These soils feature a dark reddish-brown to dark brown, highly acidic surface layer of silt loam to clay loam, and a dark reddish-brown to reddish yellow, highly acidic subsoil of silty clay loam to clay. The subsoil contains weathered gneissic material and approximately 15-30% stones. The region experiences a humid tropical climate, with an average annual temperature of 20.3°C and average annual rainfall of 5555mm.

The solum thickness exceeds 150cm, and the moisture control section remains moist for at least 90 cumulative days per year. The surface horizon is 18 to 25 cm thick, with a color ranging from 5 Yellow Red to 10 Yellow Red hue, value 2 to 3, and chroma 2 to 3. Its texture varies from silty loam to clay loam. The subsurface horizon extends to 160 cm in depth, with a color ranging from 5YR hue, value 3 to 6, and chroma 2 to 6. The texture ranges from silty clay loam to clay, with clay being the predominant component. Fine gravels (<5%) are present in the subsoil, along with weathered gneissic material and stones up to 25cm in diameter found below 60cm. The soil is well-drained with moderately rapid permeability. Anamudi soils are highly acidic and are highly susceptible to severe erosion.

3.3.2. Pampadumpara Series

The Pampadumpara series is a clayey, mixed, isohyperthermic Ustic Kandihumult. These soils feature dark reddish-brown to dark brown, very strongly acidic surface horizons of silty clay to clay, and yellowish red to red, extremely acidic to strongly acidic subsurface horizons of clay. They are formed on gneissic material found on steep to very steep hillsides and hilltops in Idukki district, at elevations ranging from 600 to 1200 m above MSL. The region experiences a humid tropical climate, with an average annual temperature of 21.3°C and an average annual rainfall of 1903 mm.

The soil remains moist for more than 180 cumulative days per year. The surface horizon is 25 to 32 cm thick, with a color in the 5YR to 10YR hue, value 3 to 4, and chroma 2 to 3. Its texture

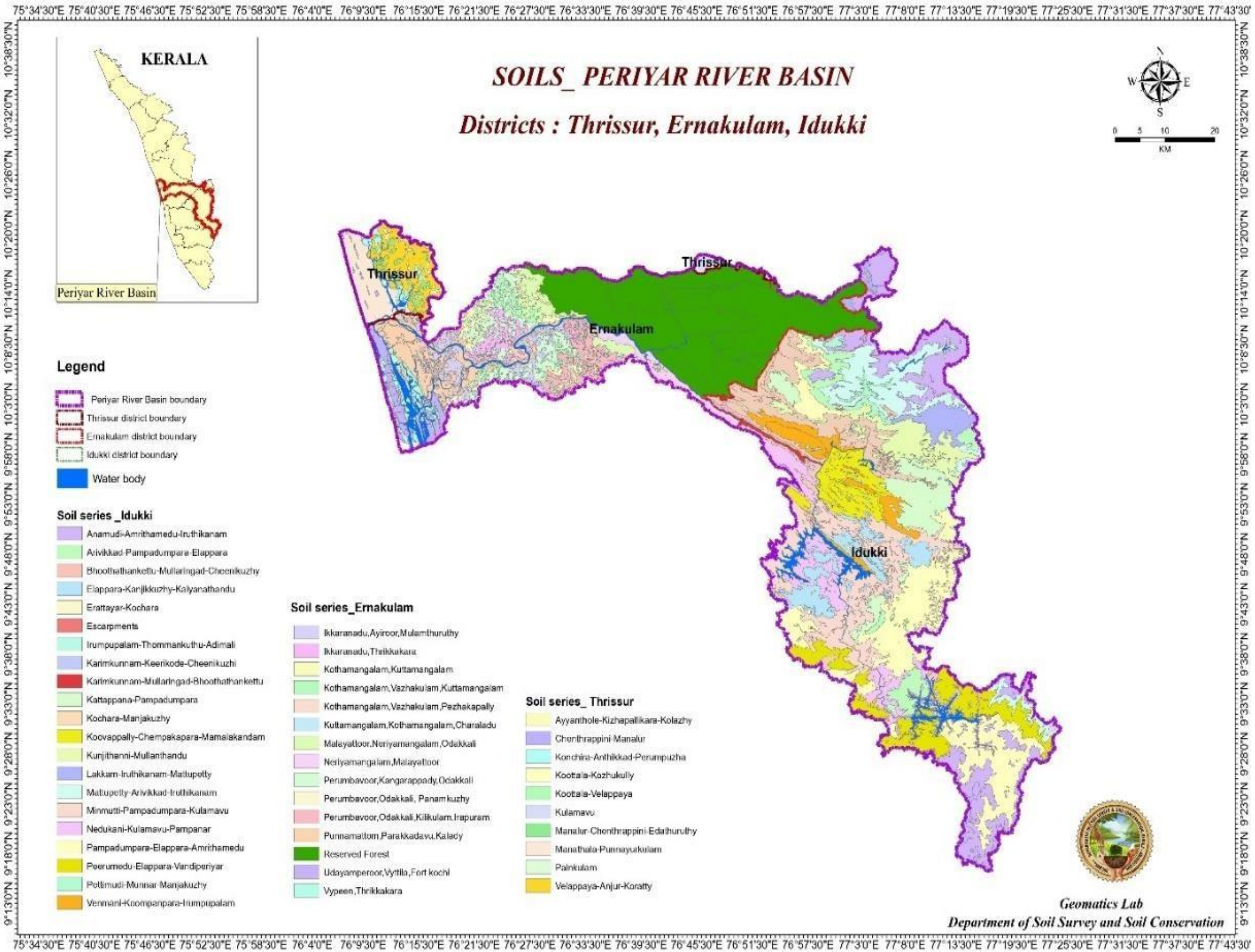


Figure 17: Soil based on Benchmark Identification (Source: Department of Soil Survey and Soil Conservation)

ranges from silty clay to clay. The subsurface horizon extends from 168 to 175 cm in depth, with a color in the 10YR to 5YR hue, value 4 to 5, and chroma 4 to 6. The texture is clay. Fine gravels, making up less than 15%, are present below 75 to 100 cm. The soil is moderately well-drained with moderate permeability and is commonly used for cardamom cultivation. The Pampadumpara soils are extremely acidic, have a low nutrient-holding capacity, and are highly prone to severe erosion. Erosion control measures, liming, and the application of manures and fertilizers are crucial for management. The steep slopes are unsuitable for sustainable agriculture.

3.3.3. Venmani Series

The Venmani series is an affine, mixed, isohyperthermic Oxic Dystrustept. These soils have a reddish-brown to dark reddish-brown, very strongly acidic surface horizon with loam to clay texture, and a reddish-brown to red, very strongly acidic to strongly acidic subsurface horizon that is gravelly sandy clay. The upper layer of the subsurface horizon is non-gravelly. These soils are formed on gneissic material found on moderately to steeply sloping hillsides in Idukki district, at elevations between 600 and 900 m above MSL. The region experiences a humid tropical climate, with an average annual temperature of 21.3°C and average annual rainfall of 3010 mm.

The solum thickness exceeds 150 cm, and the soil remains moist in certain parts of the moisture control section for over 180 cumulative days each year. The surface horizon is 18 to 25 cm thick, with a color ranging from 2.5YR to 5YR hue, value 3 to 5, and chroma 2 to 4. The texture varies from clay loam to clay. The subsurface horizon extends from 165 to 175 cm in depth, with a color in the range of 2.5YR to 5YR hue, value 3 to 5, and chroma 4 to 8. Its texture is gravelly sandy clay to gravelly clay. The gravel content in the surface horizon is between 5-15%, while in the subsurface horizon, it ranges from 15-45%. The soil is well-drained with moderately rapid permeability. The primary agricultural products include coconut, with intercropping of arecanut, tapioca, cocoa, pepper, turmeric, ginger, and rubber.

3.3.4. Thommankuthu Series

The Thommankuthu series is a clayey, mixed, isohyperthermic Ustic Palehumult. Thommankuthu soils feature a black to brown, very strongly acidic, gravelly loam to gravelly clay loam A horizon, and a dark reddish-brown to red, very strongly acidic to strongly acidic, gravelly sandy clay loam to gravelly clay B horizon. These soils are derived from gneissic parent material and are found on moderately to steeply sloping foothills of the Western Ghats in Idukki district, at elevations ranging from 300 to 600 m above MSL. The region experiences a humid tropical climate, with a mean annual temperature of 22.8°C and an average annual rainfall of 3585 mm.

The solum thickness exceeds 150 cm. The surface soil is black to brown, with a hue ranging from 5YR to 7.5YR, value 2 to 5, and chroma 0 to 4, and has a loam texture. The subsoil is dark reddish- brown to red, with a hue of 2.5YR to 5YR, values 3 to 4, and chroma 3 to 8, and its texture ranges from clay loam to clay. Fine gravels are present, comprising 15 to 20% in the surface soil and 40 to 70% in the subsoil. Weathered gneissic material makes up 20 to 30% below 90 cm, while lateritic material occupies about 50% below 100-125 cm. The soil is well-drained with moderately rapid permeability and is suitable for forest growth.

3.3.5. Odakkali Series

The Odakkali series is a clayey-skeletal, mixed, isohyperthermic Oxic Dystrustept. Soils in this series are moderately deep to deep, well-drained, gravelly, fine-textured, reddish-brown, and strongly acidic. They are formed from gneissic parent material and are found on gently sloping to steep lands with rolling topography, typically at elevations ranging from 20 to 200 m above MSL. The region has a humid tropical climate, with a mean annual soil temperature (MAST) of 28.8°C. The solum thickness ranges from 90 to 135 cm, and the soil remains moist in certain parts of the moisture control section for over 180 cumulative days per year.

The A horizon is 10 to 20 cm thick, with a colour that varies from reddish-brown to yellowish-red, in hues of 5YR, value 4 to 5, and chroma 4 to 6. The texture is gravelly sandy clay loam to gravelly clay, and the soil is very strongly acidic. The B horizon is 100 to 120 cm thick, with colours ranging from reddish-brown to yellowish-red, in hues of 5YR, value 4 to 6, and chroma 4 to 8. Its texture is gravelly clay loam to gravelly clay, and the soil is strongly acidic. The C horizon consists of weathered gneiss, and the B horizon is characterized by gneissic boulders in various stages of weathering, with relic mottlings showing variegated colours in the subsoil. The soil is well-drained with moderate permeability and is commonly cultivated with crops such as coconut, rubber, tapioca, and cocoa.

3.3.6. Perumbavoor Series

The Perumbavoor series is a clayey-skeletal, mixed, isohyperthermic Typic Plinthustult. Soils of this series are moderately deep to deep, well-drained, gravelly, fine-textured, reddish-brown, and acidic. These soils are derived from gneissic rocks and are found on gently sloping to moderately steep mounds, with slopes not exceeding 25%. The general elevation ranges from 20 to 100 m above sea level, and the climate is humid and tropical. The solum thickness ranges from 90 to 110 cm, with a mean annual soil temperature (MAST) of 28.8°C. The soil remains moist in some parts of the moisture control section for over 180 cumulative days per year. The A horizon is 15 to 20 cm thick, with colors ranging from reddish-brown to yellowish red, in hues of 5YR, value 4 to 5, and chroma 6 to 8. Its texture varies from gravelly clay loam to gravelly clay, and the soil is strongly acidic. The B horizon extends more than 75 cm thick, with colors ranging from red to yellowish red, in hues of 2.5YR to 5YR, value 4 to 5, and chroma 6 to 8. The texture is gravelly clay, and this horizon is very strongly acidic. The C horizon consists of quarriable laterite. The soil is well-drained with moderate permeability and is cultivated with rubber, coconut, spices, tapioca, pineapple, and weeds such as eupatorium.

3.3.7. Punnamattom Series

The Punnamattom series consists of coarse loamy, mixed, isohyperthermic, Typic Ustifuvents. These soils are very deep, well-drained, medium-textured, yellowish-brown, and acidic. They are formed from riverine alluvial sediments and are found on gently sloping lands along riverbanks and streams, with slopes ranging from 3 to 5%. The general elevation ranges from 10 to 100 m above sea level, and the climate is humid and tropical. The soil column has a thickness of more than 180 cm, with a mean annual soil temperature (MAST) of 27.7°C. The soil remains moist for over 180 cumulative days each year. The A horizon is 20 to 25 cm thick, with colors ranging from yellowish-brown to pale brown, in hues of 10YR, value 5, and chroma 4 to 6. The texture ranges from loam to sandy clay loam, with slight acidity. The C horizon is 150 to 180 cm thick, with colors ranging from yellowish-brown to strong brown, in hues of 7.5YR and 10YR, value 5 to 6, and chroma 3 to 6. Its texture varies from sandy loam to sandy clay loam. The C horizon is strongly acidic, and the soil is moderately well-drained with moderately rapid permeability.

3.3.8. Ikkaranad Series

The Ikkaranad series consists of fine, mixed, isohyperthermic, Oxyaquic Ustifluvents. These soils are very deep, imperfectly drained, fine-textured, yellowish-brown to yellow, and acidic.

They have developed from alluvio-colluvial deposits and are typically found in low-lying, flat paddy fields along the banks of rivers and streams in the lowland and midland areas, with slopes ranging from 3 to 5%. The general elevation is between 10 to 80 m above sea level, and the climate is humid and tropical. The soil column thickness exceeds 150 cm, and the mean annual soil temperature (MAST) is 27.7°C. The soil remains moist for more than 180 cumulative days each year.

The A horizon is 15 to 20 cm thick, with colors ranging from yellowish-brown to yellow, in hues of 10YR, value 5 to 7, and chroma 6 to 8. The texture varies from clay loam to clay, with a predominance of silty clay. The soil shows strong acidity. The C horizon extends more than 100 cm in thickness, with colors ranging from yellowish-brown to brown, in hues of 7.5YR and 10YR, value 5 to 7, and chroma 4 to 8. The texture of the C horizon ranges from silty clay to clay, and it is slightly acidic, with imperfectly drained, moderately slow to slow permeable soils

3.3.9. Vypeen Series

The Vypeen series consists of fine, mixed, isohyperthermic Typic Sulfaquents. These soils are very deep, poorly drained, with a very fine texture, grayish to black color, and extremely acidic properties. They are developed from coastal alluvium and are found on flat to concave coastal belts with slopes ranging from 0 to 5%. The general elevation is between 1 to 1.5 m below sea level, and the climate is humid and tropical. The soil column thickness exceeds 150 cm, with an estimated mean annual soil temperature (MAST) of 27.7°C. The moisture regime is aquic.

The A horizon is 7 to 30 cm thick, with colors ranging from very dark gray to black, in hues of 7.5 YR and 10 YR, value 2 to 3, and chroma 0 to 2. The texture is clay, and the soil is extremely acidic. The C horizon extends beyond 140 cm in thickness, with colors ranging from dark gray to black, in hues of 7.5 YR and 10 YR, value 2 to 4, and chroma 0 to 2. The texture is clay, and the C horizon is extremely acidic. In some profiles, a sandy loam textural phase is observed in the subsoil, along with organic debris in advanced stages of weathering. The general water table fluctuates between 0.7 and 1.8 m. The soil is poorly drained with slow permeability and has a medium to high nutrient-holding capacity.

3.3.10. Udayamperoor Series

The Udayamperoor series consists of coarse, loamy, mixed, isohyperthermic, Oxyaquic Ustorthents soils. These soils are very deep, well-drained, coarse-textured, brownish, and acidic. They are formed from coastal alluvium and are found on nearly level to gently sloping plains along the coast of Vembanad Lake, with slopes ranging from 0 to 5%. The general elevation is less than 5 m above sea level, and the climate is humid and tropical. The soil column thickness exceeds 200 cm, and the estimated mean annual soil temperature (MAST) is 27.7°C. The soil remains moist in some areas of the moisture control section for over 180 cumulative days per year.

The A horizon is 20 to 25 cm thick, with colors ranging from dark brown to dark yellowish brown in hues of 10 YR, with values of 3 to 5 and chroma of 4 to 6. The texture ranges from sand to loamy sand, with occasional sandy loam texture. The soil is strongly acidic. The C horizon extends more than 175 cm, with colors ranging from dark yellowish brown to light gray, in hues of 7.5 YR to 10 YR, with values from 4 to 7 and chroma from 1 to 8. The texture varies from sand to sandy loam, and the C horizon is strongly acidic. Mottles are observed in the subsoil, and orange or yellow clods measuring 2 to 5 mm in size are found in the lower horizons. The general water table fluctuates between 0.7 and 1.8 m. The soil is well-drained with rapid to very rapid permeability and is used for coconut-based mixed cropping, including banana, cocoa, and vegetables.

3.3.11. Koratty Series

The Koratty series is a member of the clayey-skeletal, mixed, isohyperthermic, Typic Dystropepts. These moderately deep to deep soils feature a surface horizon that is brown to dark brown, slightly acidic, and has a texture ranging from loam to sandy clay loam. The subsoil is dark reddish brown to red, strongly acidic, and consists of gravelly clay loam to gravelly silty clay. These soils have developed from gneissic parent material and are found on gently sloping to moderately sloping plains and flat-topped ridges in the south-central part of the district. The solum sits above a laterite formation. The climate is humid and tropical. The solum depth ranges from 70 to 100 cm.

The 'Ap' horizon is 15 to 25 cm thick, with a color varying from brown to dark brown in hue 7.5 YR, value 3 to 5, and chroma 2 to 4. Its texture ranges from loam to sandy clay loam. The 'B' horizon has a color range of dark reddish brown to red, with hues of 2.5 YR, values from 2 to 5, and chroma from 4 to 5. Its texture varies from gravelly clay loam to gravelly silty clay. The lowest horizon is red laterite with a few medium mottlings. The soil is moderately well-drained with moderate permeability.

3.3.12. Manathala Series

The Manathala series belongs to the mixed, isohyperthermic family of Oxyaquic Ustipsamments. These very deep soils are yellowish brown to brownish yellow, slightly acidic to neutral, and sandy in texture. They are found in the coastal regions of Chavakkad and Kodungallur taluks. A distinctive feature of these soils is the presence of oyster shells within the sandy profile. Being recently developed, these soils do not show clear horizon differentiation. They are prone to flooding during the monsoon season. The climate is humid and tropical. The solum thickness ranges from 155 to 160 cm.

The 'Ap' horizon is 16 to 19 cm thick, with a color ranging from yellowish brown to dark yellowish brown in hue 10YR, value 4 to 5, and chroma 4 to 6. The texture ranges from sandy loam to sand. The 'AC' horizon extends beyond 100 cm in thickness, with color ranging from greyish brown to brownish yellow in hue 10YR, value 5 to 6, and chroma 2 to 8. The texture is predominantly sand. The soil is moderately drained with rapid permeability (Department of Soil Survey and Soil Conservation, Kerala).

4. Principal Aquifers of Periyar River Basin

An aquifer system refers to a subsurface geological formation or group of formations capable of storing, transmitting, and yielding significant amounts of groundwater. Principal aquifer systems are those that serve as primary sources of groundwater, playing a vital role in meeting water demands for domestic, agricultural, industrial, and ecological needs. These systems are characterized based on their geological setting, hydrogeological properties, and the nature of the rocks or sediments they comprise.

Although about 88% of Kerala's total geographical area is underlain by crystalline rocks with limited groundwater prospects, groundwater remains the primary source for drinking and domestic needs across the state. Similarly, in the Periyar River Basin, 88% of the total area is underlain by crystalline rocks, including Charnockite, Banded Gneissic Complex, Granite, and Gneiss. The remaining 12% consists of alluvium and laterite. In sedimentary regions, aquifers generally comprise unconsolidated or semi-consolidated materials like sand, gravel, and silt, which have high porosity and permeability, making them highly productive for groundwater storage and movement. In contrast, crystalline basement rocks such as Charnockite, Granite, and Gneiss rely on secondary porosity developed through weathering, fracturing, and jointing to store and transmit groundwater. These crystalline aquifers are often localized and discontinuous, with groundwater yields dependent on the degree of weathering and fracturing. Figure 18 shows the principal aquifers of the Periyar River Basin. The different types of aquifers found in Kerala are discussed in detail in the following sections:

4.1.1 Alluvium

Alluvial deposits along the Periyar River consist of unconsolidated sediments such as sand, silt, and clay. These deposits, derived from both coastal and fluvial origins, form highly productive aquifers due to their high porosity and permeability. Key formations include the Guruvayur Formation, Periyar Formation, Warkalli Formation, and West Coast deposits (both active and paleo). In the Periyar basin, alluvium is predominantly found at the western end where the river meets the sea. These aquifers play a crucial role in supplying water for domestic and agricultural needs in lowland areas.

4.1.2 Banded Gneissic Complex

The Banded Gneissic Complex comprises a heterogeneous mix of granitoid materials, including hornblende-biotite gneiss, foliated granite, and pink granite gneiss. These rocks are predominantly found in the northeastern regions of the Periyar basin, occupying about 19% of the total area. Structural deformation and migmatitic textures are characteristic features of these rocks. Groundwater is confined to weathered zones and fractures, making the Banded Gneissic Complex a significant aquifer system within the basin

4.1.3 Charnockite

Charnockite is the most dominant aquifer system in the Periyar River Basin, covering approximately 41% of the basin. These rocks, found primarily in the central and upstream portions of the basin, exhibit diverse lithology, including pyroxene granulite, hornblende pyroxenite, and hypersthene-diopside gneisses. Groundwater in these aquifers depends heavily on fractures for storage and movement due to the limited primary porosity of the rock.

4.1.4 Gneiss

In the Periyar River Basin, gneisses are treated as a separate principal aquifer system distinct from the Peninsular Gneissic Complex. This is due to differences in their stratigraphic position and age of formation, with gneisses being younger Proterozoic rocks. The gneisses include Garnet-Biotite Gneiss, Hornblende Gneiss, Hornblende Biotite Gneiss, Quartz Mica Gneiss, and Quartzo-feldspathic Gneiss. Covering 26% of the basin, gneiss aquifers are distributed in the central and western regions of the basin. Groundwater storage and movement in these aquifers rely on secondary porosity developed through weathering and fracturing.

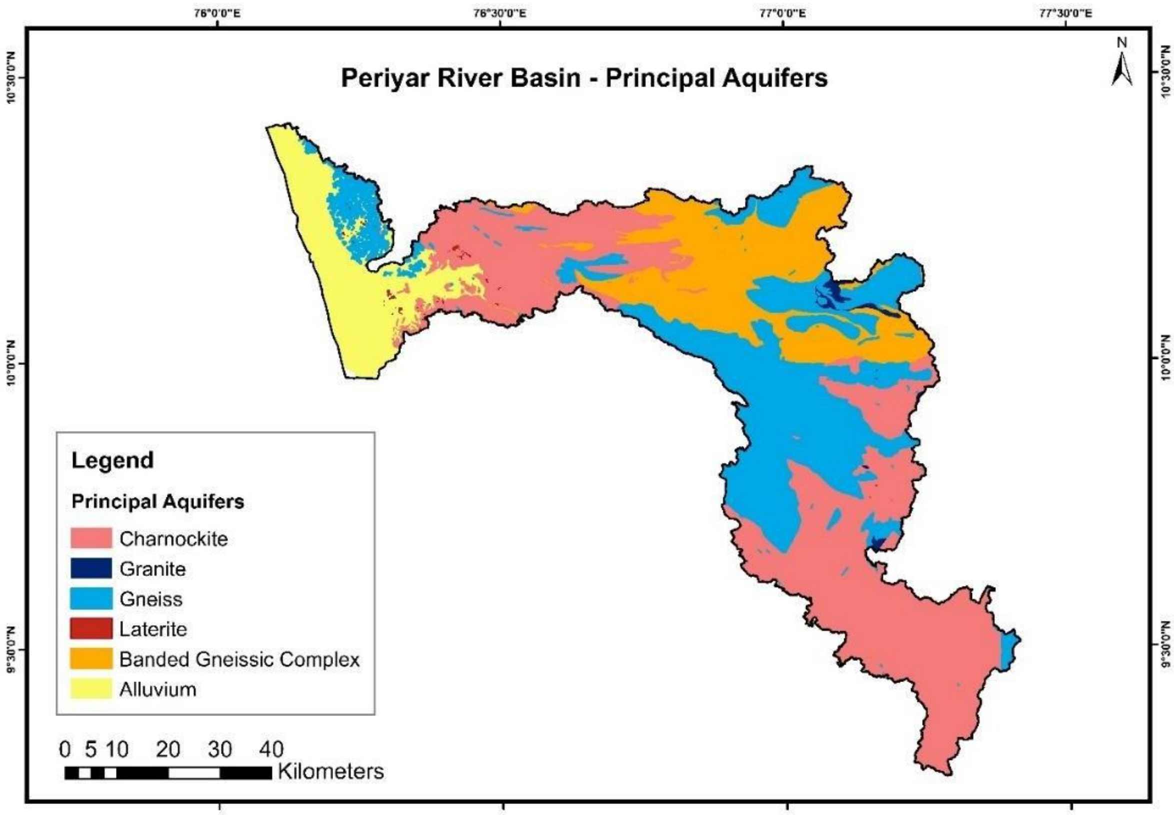


Figure 18: Principal Aquifers of the Periyar River Basin.

4.1.5 Laterite

In the context of the Periyar River Basin, laterite aquifers occupy minimal or negligible areas, forming small, isolated patches often associated with gneisses and alluvium. Laterites are residual deposits formed through intense weathering of parent rocks. Despite their limited extent in the basin, laterite aquifers are significant across Kerala for their high porosity and permeability, making them excellent sources of groundwater in areas with high recharge potential.

4.1.6 Granite

Granite aquifers in the Periyar River Basin are found associated with the Peninsular Gneissic Complex of the Archean Eon. In this basin, granites are found as Neoproterozoic acidic intrusions and occupy only about 1% of the basin area. Groundwater storage in these aquifers is confined to weathered and fractured zones, contributing to secondary porosity. Despite their limited extent, these aquifers are crucial in localized water supply systems.

4.2 Groundwater Yield

The hydrogeological characteristics of the Periyar River Basin in Idukki district are influenced by the region's diverse lithological features, which include laterites, weathered crystalline rocks, and deeper fractured crystalline formations. These formations collectively support aquifers with varying yields and groundwater storage capacities.

4.2.1. Laterites

Laterites are predominantly found in the plateau regions of the Periyar River Basin, particularly in the Panchayats of Adimali, Rajakkad, Nedumkandam, Kattappana, Chakkupallam, and Vandanmedu. These formations are primarily formed by the weathering of crystalline rocks and occur as perched aquifers in some areas. In the coastal belt, laterites are found at depth within sedimentary formations, where they are generally discontinuous due to erosion. They are typically located between the Recent alluvium above and the Warkali or Vaikom beds below, at depths ranging from 20 to 56 mbgl.

Laterites are underlain by lithomargic clay in in midland areas of idukki, with thicknesses varying from 0.5 to 4.0 m, and are highly porous and permeable. These characteristics make them significant aquifers, where they are extensively developed through dug wells for domestic use and, to a limited extent, for irrigation. The depth of dug wells in laterite ranges from 3.4 to 14.8 mbgl, with water levels generally between 1.55 and 11.06 mbgl. The yield of these wells typically ranges from 0.5 to 6 cubic meters per day (m^3/day), sustaining pumping for 3 to 4 hours daily.

However, wells located on slopes or elevated areas often run dry or maintain minimal water columns during the summer season due to the reduced recharge and limited aquifer thickness. In areas with significant lateral clay horizons, laterites contribute to localized groundwater storage, but their aquifer potential is often limited.

4.2.2. Weathered Crystalline Rock

Weathered crystalline rocks form crucial aquifers across the basin. The thickness of the weathered zone ranges from less than 2.0 m to around 20 m, varying significantly across the region. The shallow phreatic aquifers of weathered Crystallines are generally developed through dug wells. The depth of dug wells ranges from 4 to 15 mbgl. Generally, dug wells tapping aquifers in charnockites are found to be shallower than that of in gneisses. The yield of dug wells ranges between 500-6000 lpd (along hill slopes and high ranges) to 15000-20000 lpd (along valley portions) The weathered mantle is most prominent in granitic terrains, particularly in the blocks of Devikulam, Adimali, and Nedumkandam, where weathering depths are greater, resulting in higher groundwater potential. Conversely, in steep slopes and high ranges, where the weathered mantle is thin or absent, perennial phreatic aquifers are virtually nonexistent.

4.2.3. Deeper Fractured Crystalline Rock

Deeper fractured crystalline aquifers, primarily in hornblende biotite gneiss, charnockite, and granite gneiss formations, are under semi-confined to confined conditions. These aquifers are tapped through bore wells for domestic, agricultural, and public water supply purposes. Fracture zones are typically encountered at depths ranging from 10 to 120 mbgl, with potential fractures encountered within 87 m of depth. Random chances of getting deeper fractures upto 170 m is noticed in the Idukki district by CGWB. These aquifers often yield substantial groundwater, depending on fracture density and connectivity.

5. Landslide Susceptibility of Periyar River Basin

Landslides are a significant natural hazard in the Periyar River Basin, one of the most dynamic and ecologically critical regions in Kerala. Characterized by a diverse landscape of steep slopes, dense forests, agricultural land, and human settlements, the basin is particularly vulnerable to landslides due to a combination of natural and anthropogenic factors. The elevation within the basin varies dramatically, ranging from the towering Anamudi peak at 2,695 m above sea level to the Vembanad Lake at sea level, creating steep slopes that significantly influence slope stability and increase the susceptibility to landslides. These events often lead to severe consequences, including loss of life, damage to infrastructure, disruption of livelihoods, and long-term environmental degradation.

Landslide susceptibility refers to the likelihood of landslides occurring in an area based on local terrain conditions, geological features, and climatic influences. It serves as a critical tool

for identifying high-risk zones and formulating effective mitigation strategies. The assessment of susceptibility integrates a variety of influencing factors, such as slope steepness, geological formations, hydrological conditions, land-use practices, and rainfall intensity. In Periyar River Basin, where monsoonal rains are both a lifeline and a potential trigger for disasters, understanding these interconnections is crucial. Landslides are frequently triggered by excessive rainfall, unscientific land modifications, and changes in land-use patterns. The resulting slope instability not only threatens the ecological balance but also poses significant risks to the densely populated and agriculturally dependent regions of the basin.
Geological survey of India dataset about landslides provides an extensive account of 1,268 landslide events, offering rich details about their locations, dimensions, and causative factors. The geographic scope is well-documented, with longitude values ranging from 76.48° to 77.26° and latitudes spanning 9.57° to 10.33°. The Landslide inventory in the Periyar River basin is reported with the help of a map using data from Geological Survey of India (GSI) in Figure 19.

The average affected area is recorded at 561.68 m^2, while the mean landslide volume is calculated to be 7,515.45m^3. These metrics collectively underscore the significant impact of landslides on the terrain and infrastructure in the region.

Rainfall emerges as the principal triggering factor for all the landslide occurrences in the dataset. The intense and often prolonged rainfall in the Periyar River Basin acts as a catalyst, initiating landslides through multiple interrelated processes. Excessive rainfall saturates the soil, leading to the development of pore water pressure, which significantly reduces the strength of the soil and underlying materials. This condition, commonly referred to as super saturation, causes the soil to lose cohesion, particularly in areas with weathered rock or weak geological formations.

Rainfall not only triggers landslides but also interacts with other factors like slope steepness, geological weaknesses, and human interventions to magnify the scale and frequency of landslides. The reasons for failure, as derived from the dataset's remedial recommendations, point to systemic issues in slope management and drainage systems. Many landslides result from inadequate structural reinforcements, such as the absence of retaining walls or gabion systems at slope toes. Poor drainage management leads to water accumulation, further destabilizing slopes by increasing pore water pressure. Remedial measures often emphasize

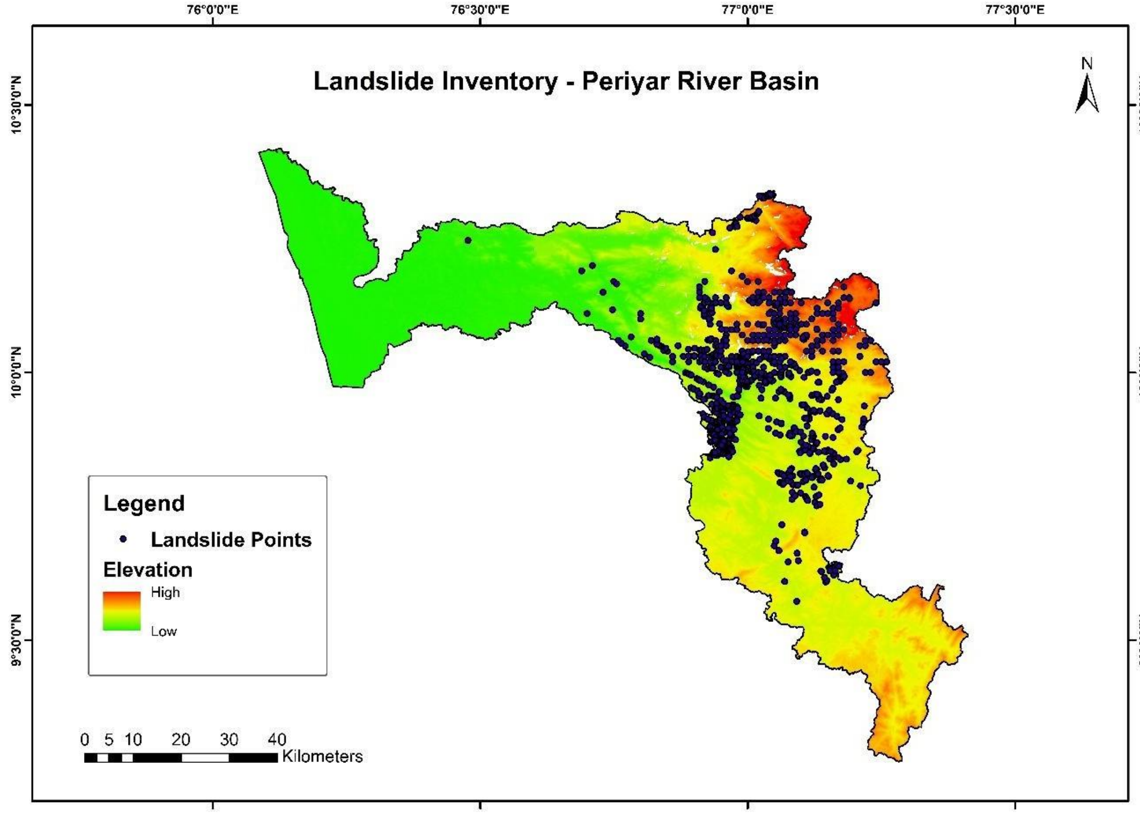


Figure 19: Elevation and Landslide occurrences in Periyar River Basin

the need for comprehensive slope stabilization, incorporating proper drainage solutions, toe reinforcement, and zoning restrictions to limit habitation and cultivation in high-risk areas. The Geological Survey of India (GSI), through its National Landslide Susceptibility Mapping (NLSM) program, has also developed high-resolution landslide susceptibility maps for Kerala and Tamil Nadu. These maps categorize regions into varying susceptibility zones based on geospatial analysis and field investigations. Using this data, in Figure 20 detailed landslide susceptibility map for the Periyar River Basin was derived to assess the basin's vulnerability to landslides.

The Periyar River Basin has been classified into the following zones based on susceptibility levels:

Low Susceptibility: Covering 2,829.99 km^2 (54%), these areas have minimal landslide risk, characterized by stable geological conditions and topography.

Moderate Susceptibility: Spanning 1,766.73 km^2 (33%), these regions exhibit moderate risk, often influenced by rainfall and localized human activities.

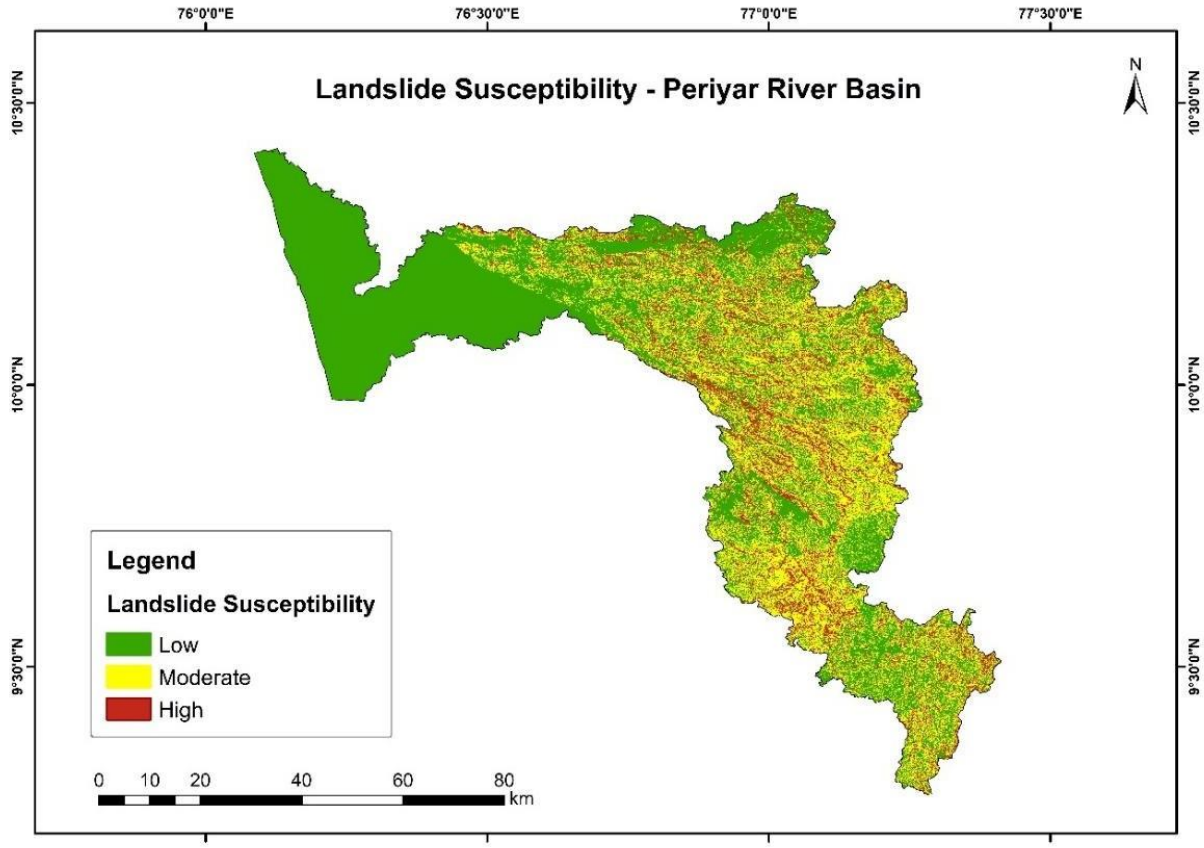


Figure 20: Landslide Susceptibility Map of Periyar River Basin

High Susceptibility: Accounting for 684.27 km^2 (13%), these zones are highly prone to landslides due to steep terrain, weak geological structures, and intense monsoonal rains.
By identifying areas with varying levels of risk, it becomes possible to prioritize interventions such as slope stabilization, improved drainage, and sustainable land use practices. Special attention must be given to high susceptibility zones, where the combination of steep terrain, fragile geology, and heavy rainfall poses significant threats to lives and infrastructure.

6. Summary and Recommendations

After the thorough study of the Periyar River Basin here are the few major takeaways in the form of a summary of the report.

Lithology

In lithological standpoint of the Periyar River Basin, the major formation is: Charnockite, Migmatite Gneiss, and fluvial deposits comprise the lithological dominants, along with other features: banded iron formations, laterites, and granites. Geologically Periyar River Basin is classified into three distinct divisions: Precambrian crystalline rocks, Tertiary formations, and

Recent alluvial deposits**.** They play a significant role in the development of Landforms of the basin, also influence the hydrology, sediment transport, as well as groundwater recharge process.

Soil

From the analysis of the soil nutrient data, it is found that, pH varies from ultra-acidic in the upstream to slightly alkaline in the downstream, high phosphorus levels are found in the downstream possibly due to extensive use of fertilizers, Potassium levels are adequate over the basin with few regions of deficiencies especially in the coastal region. Electrical conductivity also a key parameter indication of soluble salts in soil, while the upstream is low in EC the levels are high in downstream and the coastal side. The OC levels are moderate to high generally over the entire basin with certain regions where there is a dip in soil OC levels, micronutrients like sulphur are deficient in upstream and boron is deficient majorly across the basin with few regions where it reaches toxic levels affecting the productivity and soil fertility.

Aquifer

Periyar Basin's Aquifer is covered by Crystaline rocks where the groundwater is stored in the weathered and fractured zones. A small portion of the basins' aquifer also has alluvial aquifers majorly in lowlands rich in yield. A variety of factors comes into play while contributing to the yield of the Aquifer. The major Geological formations holding water found in the regions are Laterites, Alluvium, Charnockites and Gniess, Granites and Banded Gneissic complex.

Landslides

Periyar basin's steep topography coupled with heavy intensity rains are a major trigger for the landslide. Also, various human activities like mining makes the region much more vulnerable to landslides. Over 1,200 landslide events have been recorded, underscoring the need for robust risk assessment and mitigation strategies.

Recommendations based on the study for the Periyar River Basin are:

The lithological profile report provides detailed insights about the subsurface, including its composition, variations, and geological characteristics. This report integrates datasets from various departments, including the Geological Survey of India, Central Groundwater Board, Soil Survey and soil Conservation Department etc. While individual stakeholder departments namely KSDMA, Groundwater Board, and the Department of Agriculture might already possess specific datasets or products relevant to their domains, this report combines all the datasets into a single report. The inclusion of lithological profiles, aquifer maps, soil nutrient distributions, and landslide susceptibility maps within a single report provides stakeholders with a holistic view of the basin lithology. This comprehensive compilation makes it easier to assess interdependencies and use the data effectively for basin-level decision-making and planning.

Lithology of the basin helps us get an understanding of the rock type in the basin, which is predominantly Migmatite complex followed by Charnockite complex, these rock type indicate the type of rock they belong from and thus helping us understanding the geological cycles of changes the rock went through and possibility of further changes and the nature of the change. This rock type data is essential for study of stability of hilly regions of Idukki especially in Munnar region which is an extensive centre of tourism and plantations. They are key factors influencing soil type of the basin, nature of minerals found and the type and yield of aquifer in the region. The Lithology of the region can play a crucial role in development planning of the Periyar region, and the District Development Authorities of Idukki, Ernakulam and Thrissur can use this data for better planning and management of the resources available in the region sustainably.

Litholog data is a visual illustration of the rock structure data, and the location of fractures can be found using lithology data, which helps us get an insight into the possibility of artificial recharge of groundwater if possible. The visual representation of fractures and the water bearing structures helps us to devise appropriate steps for water conservation and groundwater recharge. After the plotting of Litholog it is observed that in upstream the regions like Thankamony, Vandiperiyar the hard bedrock comes at lower depths and water retaining is majorly through fractures which makes it difficult for having appropriate ground water recharge strategy. While downstream the Periyar River Basin, the water bearing structures like sand and laterite are found in points like Desham and Sreemoolanagaram and can be used for groundwater recharge. These inferences are useful for the Groundwater Board and Kerala Water Authority to plan and make appropriate steps in making efficient groundwater recharge policies and programs to reduce the excessive depletion of groundwater.

The data is invaluable for landslide and soil erosion studies. It is very important for geotechnical investigation for the design of various infrastructure projects. The report is valuable for stakeholders namely Kerala State Disaster Management Authority in identifying disaster-prone areas, designing disaster risk management strategies and reducing potential impacts on communities and infrastructure. In landslide susceptibility map preparation, lithology is one of the important inputs. Landslide susceptibility study led us to identify the regions that are disaster sensitive and require a special attention in the activity being carried in the region. The most high-risk areas are in the Idukki region of the basin, about 13% of the area majorly covering the higher altitude regions of Idukki including tourist attractions like Munnar are included in the region. With this data Kerala State Disaster Management Authority can focus their efforts and strategize required plans to mitigate and reduce the impact of future landslides and possible catastrophe.

The aquifer characteristics are a key factor in determining the water conservation strategies and to determine the yield of each aquifer. The alluvial type of aquifer found in downstream of Periyar River Basin spread over Marthandavarma, Pullut and Mangalapzuha have the highest capacity for recharge in the basin, while the Charnockite type of aquifer which is the most widespread aquifer type in Periyar basin, found in Muthirapuzha sub-basin and in Central part of basin consisting of parts of Marthandavarma, Mangalapuzha and Pooyamkutty sub-basin area depends heavily on cracks and fractures. This is helpful for Kerala Water Authority and related administrative units to devise and implement proper plans for groundwater management including the recharge and restoration of groundwater levels.

For the Department of Agriculture, the lithological and soil information presented in the report provides critical inputs for agricultural planning. For instance, the downstream of Periyar River Basin is alkaline in nature due sediment deposit and flooding in the region. While studying the soil nutrient data it is observed that pH, and Phosphorous in Perinjanakutty and Mullayar is acidic and on excessive levels of Phosphorous indicating the acidic rock nature and the excessive use of fertilizers in the regions accounting for the plantation characteristics. Also sub basins in the downstream of Periyar River Basin including Pullut, Marthandavarma, similar pattern is observed for various nutrient studies, this variation is represented in form maps. The data can guide crop selection based on soil fertility, groundwater availability, and nutrient content, ensuring that farming practices are environmentally sustainable and economically viable. The detailed mapping of nutrient-deficient or erosion-prone areas supports targeted soil conservation efforts and irrigation strategies, enhancing productivity while mitigating environmental degradation. By addressing the unique needs of each domain, the lithological profile report becomes a versatile tool for fostering sustainable development, resource optimization, and resilience across the Periyar River Basin.

References

Bates, R.L. and Jackson, J.A. (1980) Glassary of Geology. 2nd Edition, American Geological Institute, Virginia.

Central Ground Water Board (CGWB). (2013). *Ground water information booklet of Idukki district, Kerala state.* Kerala Region. Ministry of Water Resources, Government of India.

Central Ground Water Board. (2022). *Aquifer mapping and management of groundwater resources: Idukki District, Kerala, Kerala Region, Trivandrum*. Trivandrum, India: CGWB.

Central Ground Water Board. (2022). *Aquifer mapping and management plan of Thrissur District, Kerala*. Ministry of Jal Shakti, Department of Water Resources, River Development and Ganga Rejuvenation, Government of India, Kerala Region.

Central Ground Water Board. (2019). *Aquifer mapping and management plan for hard rock terrains of Ernakulam District, Kerala*. Ministry of Jal Shakti, Department of Water Resources, River Development and Ganga Rejuvenation, Government of India.

Central Ground Water Board. (2013). *Groundwater information booklet of Ernakulam District, Kerala*. Ministry of Water Resources, Government of India.

Central Ground Water Board. (2013). *Groundwater information booklet of Thrissur District, Kerala State*. Ministry of Water Resources, Government of India, Kerala Region.

CESS. (1984). Resource Atlas of Kerala. Centre for Earth Science Studies, Thiruvananthapuram, 39p.

Department of Mining and Geology. (2016). *District survey report of minor minerals (except river sand), Idukki District*. Prepared as per Environment Impact Assessment (EIA) Notification, 2006, issued under Environment (Protection) Act, 1986. Thiruvananthapuram, India: Department of Mining and Geology. Retrieved from www.dmg.kerala.gov.in

Department of Mining and Geology. (2016). *Government of Kerala district survey report of minor minerals (except river sand) Ernakulam District*. Prepared as per Environment Impact Assessment (EIA) Notification, 2006 issued under Environment (Protection) Act, 1986. Thiruvananthapuram: Government of Kerala. Retrieved from www.dmg.kerala.gov.in

Department of Mining and Geology. (2016). *Government of Kerala district survey report of minor minerals (except river sand) Thrissur District*. Prepared as per Environment Impact Assessment (EIA) Notification, 2006 issued under Environment (Protection) Act, 1986. Thiruvananthapuram: Government of Kerala. Retrieved from www.dmg.kerala.gov.in

Geological Survey of India. (2024). *Kerala Susceptibility*. Government of India, Kolkata, India. Retrieved 7 August 2024.

Geological Survey of India. (2024). *Landslide Points*. Government of India, Kolkata, India. Retrieved 7 August 2024.

Geological Survey of India. (2024). *Lithology*. Government of India, Kolkata, India. Retrieved 7 August 2024.

Geological Survey of India. (2024). *Tamil Nadu Susceptibility*. Government of India, Kolkata, India. Retrieved 7 August 2024.

P. Balakrishnan (2009), Hydrological and Hydrochemcial Studies of the Periyar River Basin, Central Kerala. Department of Marine Geology and Geophysics Cochin University of Science and Technology, Kochi.

Padmalal, D., Maya, K., Sreebha, S., & Sreeja, R. (2008). Environmental effects of river sand mining: A case from the river catchments of Vembanad lake, Southwest coast of India. Environmental Geology, 54, 879–889

PWD. (1974). Water Resources of Kerala. Public Works Department, Government of Kerala, Thiruvananthapuram, 125p.

Sam Boggs. (2006). Principles of Sedimentology and Stratigraphy, Fourth Edition, Pearson Education, INC, Upper Saddle River, NJ.

Soman, K. (2002). Geology of Kerala, 2nd edition, Geological Society of India, Bangalore, 335p.

SSO (2007) Soil Survey Organisation, Agriculture (S.C. Unit) Department, Kerala. Benchmark soils of Kerala. 623p.

Sudharmma, A., S. G., A., & Retna Kumari, R. G. (2020). Macroscale (1:50,000) landslide susceptibility mapping in parts of toposheet nos. 58B/08, 58B/12, 58B/16, 58F/04 and 58F/08 in Ernakulam and Idukki districts, Kerala.

Xiaoxu Rena, Jiagen Houa, Suihong Songa, Yuming Liua, Depo Chenc, Xixin Wanga, Luxing Doua (2019), Lithology identification using well logs: A method by integrating artificial neural networks and sedimentary patterns. Journal of Petroleum Science and Engineering. 182.

\