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Soil taxonomy, physicochemical characteristics and mineralogy under Syzygium travancoricum a critically endangered and endemic tree species from Kerala part of Western Ghats, India

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Research Article

Keywords: Endangered tree species, Soil taxonomy, Soil mineralogy, Soil physico- chemical characteristics, Soil available nutrients

Posted Date: July 24th, 2025

DOI: https://doi.org/10.21203/rs.3.rs-7119510/v1

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Additional Declarations: No competing interests reported.

Abstract

Soil properties are important indicators of plant growth as well as soil health. *Syzygium travncorium* is an endangered species as well as an indigenous tree to the South Western Ghats, India on which few studies have been conducted related to the properties of soil under it. The current study was conducted at Kalasamala, a temple grove lying near Kunnamkulam at Thrissur district, Kerala, where the soil taxonomy, physicochemical properties, mineralogy, of soil under two types of vegetation systems viz., *Syzygium travancoricum* (profile-1) and heterogeneous tree species (profile-2) grown there by taking soil profiles at depth 1.5m. The soils under two types of vegetations were classified under the order ultisol and sub-classified as ustic Palehumults in profile A and typic Haplustolls in profile B. Identification of mineralogy in profile A finds quartz in the sand fractions; chlorite mica, kaolinite, gibbsite and quartz in silt fractions; chlorite, kaolinite, gibbsite and quartz in clay fractions. In contrast profile B, exhibits quartz and feldspars in sand fractions; chlorite, Hydroxy Interlayered Vermiculate, mica, kaolinite, gibbsite, and quartz in silt fractions; chlorite, Hydroxy Interlayered Vermiculate, kaolinite, gibbsite, and quartz in clay fractions. Profile A has three classes of soil textures; sandy loam, sandy clay loam, sandy clay, whereas two textural classes, sandy loam, sandy clay loam were found in profile B. Furthermore, it has been observed that the process of laterization results accumulation of clays at the bottom horizons in these systems, thus enhancing Cation Exchange Capacity (CEC), Total Exchangeable Acidity (TEA) and Soil Organic Carbon (SOC) except the illuvial layer (Bt2) of profile B. This study recognized typical characteristics of tropical humid soils, including leaching, low nutrient levels, and acidity. The decline of *Syzygium travancoricum*, by low seedling and poor regeneration, may be partly due to these limiting edaphic conditions.

INTRODUCTION

Syzygium travancoricum (local name: Kulvetti, Vathamkollimaram), belonging to the family Myrtaceae, is a Western Ghats endemic and IUCN critically endangered evergreen tree species. *Syzygium travancoricum*, restricted to relict wetland patches and sacred groves, may both impact and be inhibited by specific edaphic conditions. The species is prominent for its astringent, hypoglycemic, bactericidal, antifungal, and neuropsychopharmacological effects, and traditionally this plant species is used by local people for curing diabetes and arthritis (Rajalakshmi et al., 2016). The study by (Sreekumar et al., 2020) from different localities of Kerala recorded a total of 465 individuals of *Syzygium travancoricum* in which the maximum number of sapling density was recorded in Kalasamala sacred grove followed by patches of Myristica swamps of Kulathupuzha in Kollam district of Kerala. Recent studies highlighted the decline of this species population in Kalasamala due to the alteration of swampy habit, low seedlings, and moderate regeneration. Over- exploitation and habitat destruction are the main reasons for the degradation of this swampy wetland.

Myristica swamps are wetlands having tree covered within the evergreen forests of Western Ghats, India, which are distinguished for their endemic, relic, and rare species. These ecosystems, once were part of a large hydrological network, are now isolated and threatened due to human activity. Ecological uniqueness, biodiversity importance, and their involvement to watershed processes make urgent research and conservation efforts essential to save the wetlands. Research exists on the flora and fauna of these swamps, but additional studies on their hydrology, soil, and ecosystem services are required to support their conservation (Ranganathan et., al 2022).

Soil is the foundation of the terrestrial ecosystem and the majority of the ecosystem services needed for human survival arise from soil (Kibblewhite et al., 2008). From the environmental standpoint, soil quality is described as the ability of soil to promote plant growth, manage watersheds by controlling how precipitation is absorbed and distributed, and prevent contamination of water and air by acting as buffers against potential pollutants such as agricultural substances, organic matter, and industrial chemicals (National Research Council, 1993 as cited in (Sims et al., 1997)). Besides, the major ecosystem services and functions furnished by soil comprise climatic regulation, nutrient cycling, acting as a carbon pool, and providing habitat for soil organisms.

According to FAO, soil degradation is a change in the status of soil health that results in a reduced ability of the ecosystem to deliver goods and services to its beneficiaries. Soils are susceptible to degradative processes by natural (climate change and related factors) and anthropogenic factors (land misuse and soil mismanagement). Theoretically, the four types of degradation are; physical, chemical, biological, and ecological. Among them, the major degradative processes that soil undergoes includes; erosion, compaction, acidification, salinization, contamination, loss of biodiversity, decline in nutrients and SOC, and disruption of nutrient

cycling (Lal, 2015). Knowing the intricate spatial relationship between soil quality index (SQI) and soil ecosystem services (SESs) with respect to social-ecological factors is vital for attaining sustainable soil utilization and management (Guo et al., 2024).

Wetland soils represent predominant ecosystems with rich biodiversity, and research into the chemical characteristics of moist soils and their response to dryness is essential (Sahu et al., 2024; Kou et al. 2023; Jansson and Hofmockel 2020; Ma, Jiang, and Liu 2020). Freshwater wetland ecosystems inland areas are recognised for most important carbon sinks of earth (Sahu et al., 2024 ; Taran et al. 2023).

The present study investigated the soil taxonomy, physicochemical properties, nutrient status, and mineralogy under *Syzygium travancoricum* and heterogeneous plant populations, including *Syzygium travancoricum*, Caryota urens and Holigarna caustica. The current study on soil properties under *Syzygium travancoricum* determines the present soil scenario such as; soil classification, soil quality, fertility range, weathering rate of soil and thereby provides vital information on conservation strategies. Despite the ecological importance of S. travancoricum, limited studies exist on the soil quality, taxonomy, and mineralogy of its swamp habitats. This study delivers the first integrated soil assessment under these endangered populations in Kerala."

MATERIALS AND METHODS

Study area and sample collection: The study was conducted at Kalasamala (10°40'27"N and 76°05'26"E), a temple groove situated near Kunnamkulam in Thrissur district, Kerala with an area of about 3.5 acres characterised by *Syzygium travancoricum* populations (Fig. 1). Soil samples were collected horizon wise up to 1.5 m depth from the area dominated with *Syzygium travancoricum* profile A (Fig. 2) and an adjacent location with heterogeneous plant species that included *Syzygium travancoricum*, Caryota urens and Holigarna caustica profile B (Fig. 3). Soil samples collected from each horizon were air-dried, gently powdered, sieved (2mm sieve) and used for laboratory analysis.

Analytical methods: The soil colour was determined using the Munsell color chart. Soil bulk density was determined by the core method (Jackson,1958). Soil texture was identified using the hydrometer method, which works on the principle of sedimentation called Stokes law (Bouyoucos,1962). Soil pH was determined in 1:2.5 soil - H_2O and soil - KCl suspensions (Jackson,1973). Soil conductivity was estimated by conductivity meter using the clear supernatant of soil water suspension (1:2.5) prepared for pH measurement. Organic carbon was determined by the Walkely – Black wet digestion method (Walkely and Black, 1934) and Cation Exchangeable Capacity (CEC) was estimated by leaching a known amount of soil by neutral ammonium acetate and then by distillation, estimating the quantity of cation (NH_4) adsorbed by the soil (Schollenberger and Simson, 1945). Available Nitrogen in soil was estimated using Kelpus apparatus (Kelpus Classic DX VATS) by the alkaline permanganate method (Subbiah and Asija, 1956). Available phosphorous was extracted by Bray no: 1 method (Bray and Kurtz, 1945) and assessed in a UV– VIS Spectrophotometer UV 3200 (Labindia). Neutral normal ammonium acetate (NH_4OAc) was used for extracting the cations Na, K, Ca, and Mg from the soil and were Na and K were estimated using a flame photometer (ELICO CL 378) and Ca and Mg using Atomic Absorption Spectrometer (Varian AA240). Total Exchangeable Acidity (TEA) was determined using the barium chloride–triethanolamine method. Exchangeable H^+ and Al^{3+} were extracted with K C L solution and total exchangeable acidity was calculated from the same extract by NaOH titration. The extracted Al^{3+} was determined by adding potassium fluoride solution followed by titrating with H_2SO_4 (Sarma et al., 1987).

For mineralogical studies, sand (coarse 2–0.6 mm and fine 0.6 – 0.02 mm), silt (0.02–0.002 mm) and clay (< 0.002 mm) fractions were separated by sedimentation after sodium citrate-bicarbonate-dithionite treatment (Jackson, 1979). The separated sand and silt fractions were subjected to randomly oriented powder X-ray diffraction (Bruker AXS D8 Advance) with a Ni-filter and Cu-Kα radiation at a scanning speed of 2°2θ/min. Clay samples were saturated with (1) Ca and solvated with ethylene glycol, (2) K at 25°C and heated to 110°C, 300°C, and 550°C. Identification of clay minerals in different fractions were done following the criteria laid down by Jackson (1979) and estimated semi- quantitatively with standard samples (Dixon and Weed, 1989). Heavy metal contents in the soil were estimated using AAS (Varian AA240) by extraction of soil with HCl (Lindsay and Norverll,1978). Soil taxonomy was identified using the protocols framed by USDA (Key to soil taxonomy twelth edition,2014)

RESULTS AND DISCUSSIONS

Physical and chemical characteristics: Soil colour ranged from 7.5YR 4/6 to 10YR 4/6 in profile A and 7.5YR 4/6 to 10YR 5/6 in profile B which shows, a wide range of brown colors in both profiles at different depths. In profile A, soil textures were found as three classes vis – a – vis sandy loam, sandy clay loam and sandy clay, whereas profile B with a heterogenous mix of plants had two textural classes: sandy loam and sand clay loam. The textural analysis indicates a high percentage of sand 66–82% followed by clay in both soil profiles. Bulk density in profile A ranged from 1.09–1.52 g/cm³ and in profile B it varied from 0.83 to 2.00 g/cm³. The results of this physical properties were represented in (Table. 1). The critical value of bulk density for restricting root growth varies with soil type (Hunt and Gikes, 1992) and generally, bulk densities greater than 1.6 g/cm³ limit root growth (McKenzie et al., 2002). Accordingly, the bulk density of the present study area deviates from ideal bulk densities, especially in profile B which may result in compaction and erosion. In profile A, soil pH ranged from5.5 in A horizon to 4.6 in Bt2 while the profile B showed an increasing trend in soil pH with depth (4.8 in A horizon to 5.2 in Bt2 horizon) (Table.2). The soil acidity values indicate strongly to moderately acidic reaction in these profiles. Soil pH around (5.5–6.5) supports growth and survival of Syzygium species in freshwater wetland systems, here the pH levels below ~ 5.0 can delay its establishment and survival. The negative ΔpH value ranges from – 0.8 to -1.4, indicating that the soil contains an appreciable amount of amorphous materials with relatively variable surface charge (Blecker and Sageman, 1990, Chandran et., al 2004). The negative ΔpH in profile A shows a gradually decreasing trend with depth whereas profile B shows an increase in the values from Bt1 (-0.82) to Bt2 (-0.91) is shown in (Table. 2). This variation shows an illuviation of the amorphous minerals from BA and Bt1 and a subsequent accumulation of the minerals in the illuvial Bt2 horizon. In humid tropical regions, fine particles in the soil tend to disperse partially when exposed to rainwater, and they gradually filter down into the subsoil soil. It was observed that nearly all subsoils in humid areas contain significantly higher amount of clay compared to the topsoil counterparts. Consequently, subsoil in such regions are more compact and less porous (Merrill, 1906; Bockheim and Hartemink, 2013). Electrical conductivity ranged from 0.02 to 0.04 dSm – 1in both profile A and B (Table.2) indicating that the soil is non-saline. Organic carbon (OC) content ranges from 0.47 to 2.07%, (Table.2) which includes low, optimum and above-optimum levels in both profiles (KAU POP, 2016). CEC values of both profiles were found varying from 9 to 16.2% (Table. 2). Compared to other horizons, the CEC value was comparatively higher in the lower horizons of two soil profiles with more than 30% clay. Clay sized colloidal particles can be attributed to the higher CEC because of the presence of a large number of negative charges on their surface, which can attract and hold cations (Suman et al,2019). This could be the result of clay particles shifting from the surface to lower layers of the soil. In profile A, the organic carbon content was slightly greater in these lower horizons compared to the remaining horizons. Likewise, the Total Exchangeable Acidity (TEA) is also more prominent in these lower horizons. Clay content and chemical composition are more influential in the subsoil when it comes to the aggregation. In the subsoil, the presence of clay and its chemical composition exert a greater influence on the aggregation process and play substantial role in the sequestration of soil organic carbon (SOC) (Schrumpf et.,al 2013). While in profile B, the SOC content was found reduced in illuvial (Bt2) horizon. Reduced proportions of SOC in the microaggregates and silt plus clay in tiny macroaggregates were found in soil with clay illuviation under reduced conditions. This could be on account of combination of i) reduced process of mineralization followed by the integration of POM into microaggregates and the silt and clay components of macroaggregates ii) decreased incorporation of SOC into smaller fractions, this could be due to soil saturation limiting root growth and thereby reducing the input of POM (Torres-sallan et., al 2017).

Available nutrients

(Table. 2) shows available nutrients present in soil. Available nitrogen in different depths of both soil profiles A and B ranged from 100.3 to 188.1 kg/ha, indicating lesser values than the threshold of 280 kg/ha. Available phosphorous was found optimum and high in both two profiles A and B, ranging between 19.1 to 53.8 kg/ha. Available potassium ranged from 28 to 118.8 kg/ha. In profile B, only the upper horizon was found to have a medium range of potassium availability, and all other remaining horizons have a low K value ‹ 115 kg/ha. Calcium level widely varied from 59 to 296 mg/kg, which indicates that all horizons from profile A and profile B were deficient of Ca which was ‹ 300 mg/kg. Similar to calcium, magnesium contents were also found to widely vary from 6.07 to 107 mg/kg indicating both profile A and profile B horizons were deficient in Mg ‹120 mg/kg (KAU POP, 2016). Sodium level varied from 86 to 500 mg/kg, indicating that the profiles belonged to the medium, high and very high categories.

Soil taxonomy

On the basis of field data and systematic laboratory analysis the soils were classified in accordance with the protocols provided by USDA (Keys to soil taxonomy, 2014). From the two soil profiles taken from the study area, the soil profile under *Syzygium*

travancoricum was characterised by the presence of argillic horizons and CEC < 16% hence, this soil profile was placed under order Ultisols. Presence of 0.9 percent or more organic carbon in the upper 15 cm and ustic soil moisture regime enables the soil to be classified as fine loamy, acid, mixed, semiactive, isohypothermic, ustic Palehumults. Similarly, the soil profile from heterogeneous tree populations was placed under order Ultisols and classified as fine loamy, acid, mixed, active, isohypothermic, typic Haplustults

Soil mineralogy: In profile A, the XRD patterns identifies quartz as the dominant mineral in both the sand fractions (< 0.6mm and > 0.6 mm) (Fig. 6a & b). Chlorite (14.2 Aº), mica (10.02 Aº), kaolinite (7.12Aº), gibbsite (4.8 Aº) and quartz (4.2, 3.3 Aº) were found to be the dominant minerals in silt fractions (Fig. 5a,b,c). And in clay fractions chlorite (14.2 Aº), kaolinite (7.12Aº), gibbsite (4.8 Aº) and quartz (4.2, 3.3 Aº) were found to be the dominant minerals (Fig. 4a, b, c). In profile B, the XRD patterns of both fine and coarse sand fractions showed quartz as the dominant mineral and the presence of a primary mineral feldspars (3.10 Aº). Chlorite (14.2 Aº) (Fig. 9. A & b). Hydroxy Interlayered Vermiculate (11.8 Aº), mica (10.02 Aº), kaolinite (7.12Aº), gibbsite (4.8 Aº) and quartz (4.2, 3.3 Aº) were found to be the dominant minerals in silt fractions (Fig. 8a,b,c,d). And in clay fractions chlorite (14.2 Aº), Hydroxy Interlayered Vermiculate (11.8 Aº), kaolinite (7.12Aº), gibbsite (4.8 Aº) and quartz (4.2, 3.3 Aº) were found to be the dominant minerals (Fig. 7a,b,c,d). At (4.8Aº) the Ca saturated shows peaks and it gets disappeared by heating it with K saturated from 300º and in some cases 550º onwards this indicates presence of gibbsite. The presence of gibbsite is commonly an indication of earlier weathering products of primary aluminosilicates or gibbsite along with sizable quantity of 2:1 mineral contradicts the hypothesis of anti-gibbsite effect (Bhattacharyya et., al 2000). Ca saturated sample exhibited a well-defined peak at 7.12 (Aº) but further, during K treatment at 550°C the peak collapsed, which confirmed the presence of kaolin.

The mineral composition in profile A and B exhibited differences in the proportions of sand, silt and clay fractions. In profile A, the sand fraction was primarily composed of quartz (4.2, 3.3 Aº), whereas, in profile B, quartz was the dominant mineral, and there were minor quantities of feldspars (3.10 Aº) found in the upper soil horizon. Likewise, it has been observed that Hydroxy Interlayered Vermiculate (11.8 Aº) is detected in the silt and clay fractions of profile B, whereas it is absent in profile A. The semi quantification of minerals in (Table. 4) reveals that, quartz and kaolinite as dominant minerals in (both profile A and B). Actively weathered soils have domination of kaolin with 1:1 ratio of layers indicating a greater loss of Si (Ouyang et., al 2021). Generally, soil with high kaolinite is less fertile when compared to soil having 2:1 clay mineral (Kome et., al 2019). Both profiles A and B had abundance of of 1:1 minerals than 2:1 mineral indicating a high rate of weathering in these soils.

CONCLUSION

Soil taxonomy, mineralogy and physico-chemical characteristics reveals that soil under two vegetation system (Syzygium travancoricum and heterogeneous plant population) shows variations in genesis and classification. The two studied pedons were placed under Ultisols with difference in subclassification ustic Palehumults in Syzygium travancoricum and typic Haplustults in heterogeneous plant populations. The semi quantification of minerals in both pedons reveals that, quartz and kaolinite are the dominant minerals, despite significant variations in the mineral assemblage among vegetation systems. The presence of 1:1 minerals in excess of 2:1 minerals indicated high rate of weathering in both vegetation systems. The present study observed the critical issue of lack of available macronutrients in soils and characteristic features of tropical humid soil such as leaching, low nutrient content, acidity. Such edaphic conditions may constrain seedling establishment and the poor regeneration of S. travancoricum. The system being in the humid tropics are expected to have degradation factors similar to other ecosystems in region, thereby indicating a high risk for this pristine ecosystem.

Declarations

Acknowledgements

The Authors would like to thank Dr. Vishnu P.S. for his valuable input and suggestions for this work. We would also like to express our thank to Mr Tomjo C.P. for field assistance and Sophia Baby for proof reading. In addition, the authors would like to acknowledge infrastructure facilities provided by KSCSTE-Kerala Forest Research Institute, Peechi, Thrissur, Kerala, India

Contributions of authors

N. S. Amrutha drafted the manuscript with the valuable guidance and mentorship of S.Sandeep .

Funding

This research received no external funding.

Data availability

Data will be made available on request

Competing interests

The authors declare no financial and nonfinancial competing interests.

Ethical approval

All authors have read and approved the final manuscript and have complied as applicable with the statement on “Ethical responsibilities of Authors” as found in the Instructions for Authors.

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Tables

Table: 1 Physical properties of soil under *Syzygium travancoricum* (profile A) and heterogeneous tree species (profile B) including *Syzygium travancoricum*, Caryota urens, Holigarna caustica

Depth (cm)	Horizon	Colour	Sand (%)	Silt (%)	Clay (%)	Texture class	Bulk density (g/cm³)	Roots
Soil profile under *Syzygium travancoricum* (profile A)								
0-15	A	7.5YR 4/6	80	4	16	sl	1.52	Medium
15-63	Bt1	10YR 4/6	70	4	26	scl	1.17	Medium
63-150	Bt2	10YR 4/3	60	4	36	sc	1.09	Fine
Soil profile under Heterogeneous plant species which include tree species such as *Caryota urens , Holigarna caustica* includimg *Syzygium travancoricum* (profile B)								
0-11	A	10YR 5/6	82	2	16	sl	0.83	Fine
11-49	BA	10YR 4/6	66	4	30	scl	0.86	Medium and Fine
46-72	Bt1	7.5YR 4/6	74	4	22	scl	2.00	Absent
72-150	Bt2	7.5YR 5/8	72	4	24	scl	1.28	Absent

Table:2 Chemical properties of soil under *Syzygium travancoricum* (profile A) and heterogeneous tree species including *Syzygium travancoricum*, Caryota urens , Holigarna caustica (profile B)

Horizon	OC (%)	pH		ΔpH	EC (dSm -1)	N (kg/ ha)	P (kg /ha)	Exchangeable bases (cmol (+) kg -1)				CEC	BS (%)	CEC/ Clay
		H2O	KCl					Na	K	Ca	Mg			
Soil profile under *Syzygium travancoricum* (profile A)														
A	1.29	5.5	4.2	-1.29	0.03	100.3	26.3	2.11	0.11	0.95	0.35	9.0	39.1	0.56
Bt1	0.91	5.0	3.8	-1.15	0.02	112.9	19.1	0.54	0.05	0.14	0.05	9.5	8.21	0.36
Bt2	2.07	4.6	3.6	-1.05	0.04	137.9	53.8	0.62	0.04	0.30	0.26	13.3	9.17	0.37
Soil profile under Heterogeneous plant species which include tree species such as Caryota urens, Holigarna caustica includimg *Syzygium travancoricum* (profile B)														
A	0.47	4.8	3.36	-1.44	0.03	112.9	32.3	2.17	0.13	1.48	0.90	11.5	40.7	0.71
BA	1.95	4.5	3.71	-0.82	0.04	188.1	19.6	0.84	0.05	0.32	0.27	16.2	9.13	0.53
Bt1	1.61	4.6	3.79	-0.82	0.02	137.9	19.7	0.38	0.03	0.40	0.18	11.2	8.83	0.50
Bt2	0.94	5.2	4.34	-0.91	0.01	137.9	17.2	0.40	0.03	0.41	0.14	12.5	7.84	0.52

Table: 3 Cation exchange properties of soil under *Syzygium travancorium* (profile A) and heterogeneous tree species including *Syzygium travancoricum, Caryota urens , Holigarna caustica* (profile B)

Horizon	$BaCl_2$ – TEA acidity	H^+	Al^{3+}	CEC, sum of cations (Total+TEA acidity)	ECEC (Total+Al)	BS (Total /CEC sum of cations)
	(cmol (+) kg^{-1} soil)					
Soil profile under *Syzygium travancoricum* (profile A)						
A	19	0.14	0.19	22.52	3.71	15.6
Bt1	26	1.2	1.16	26.78	1.94	2.91
Bt2	27.2	1.81	3.24	28.42	4.46	4.29
Soil profile under Heterogeneous plant species which include tree species such *as Caryota urens , Holigarna caustica includimg Syzygium travancoricum* (profile B)						
A	14.4	0.27	0.71	19.08	5.39	24.5
BA	29.4	1.17	1.41	30.88	2.89	4.79
Bt1	24	0.51	0.94	24.99	1.93	3.96
Bt2	23.2	0.16	0.21	24.18	1.19	4.05

Table :4 Quantification of soil minerals under Syzygium travancorium (profile A) and heterogeneous tree species including *Syzygium travancoricum*, Caryota urens, Holigarna caustica (profile B)

Horizon	Fraction	C (%)	HIV (%)	M (%)	K (%)	G (%)	F (%)	Q (%)
Soil profile under *Syzygium travancoricum* (profile A)								
A	Clay	9.94	-	-	21.49	5.15	-	20.91
	Silt	1.47	-	3.50	7.18	9.41	-	37.81
	F.Sand	-	-	-	-	-	-	46.60
	C.Sand	-	-	-				75.13
Bt1	Clay	9.25	-	-	20.99	5.17	-	21.88
	Silt	3.66	-	2.30	9.41	9.14	-	36.64
	F.Sand	-	-	-	-	-	-	36.88
	C.Sand	-	-	-	-	-	-	52.69
Bt2	Clay	9.64	-	-	18.78	6.10	-	29.63
	Silt	2.73	-	3.13	7.73	8.66		45.34
	F.Sand	-	-	-	-	-	-	48.90
	C.Sand	-	-	-	-	-	-	55.35
Soil profile under Heterogeneous plant species which include tree species such as *Caryota urens*, *Holigarna caustica* includimg *Syzygium travancoricum* (profile B)								
A	Clay	12.18	5.40	-	20.34	4.8	-	26.63
	Silt	7.34	6.10	4.58	9.54	8.29	-	52.30
	F.Sand	-	-	-	-	-	30.38	24.19
	C.Sand	-	-	-	-	-	16.44	40.65
BA	Clay	5.77	-	-	20.06	5.32	-	26.41
	Silt	3.68	-	2.58	10.19	9.30	-	42.50
	F.Sand	-	-	-	-	-	-	42.44
	C.Sand	-	-	-	-	-	-	46.39
Bt1	Clay	4.79			22.94	5.15	-	24.24
	Silt	2.93		2.24	12.39	7.31	-	37.68
	F.Sand	-	-	-	-	-	-	48.49
	C.Sand	-	-	-	-	-	-	50.45
Bt2	Clay	7.38	-	-	20.60	4.25	-	25.61
	Silt	2.18	-	3.99	8.43	10.33	-	43.52
	F.Sand	-	-	-	-	-	-	50.45

Minerals are denoted using specific letter codes within table 5: C - chlorite, HIV - Hydroxy Interlayered Vermiculate, M mica, K – Kaolinite, G – gibbsite, F – feldspar, Q – quartz)

Figures

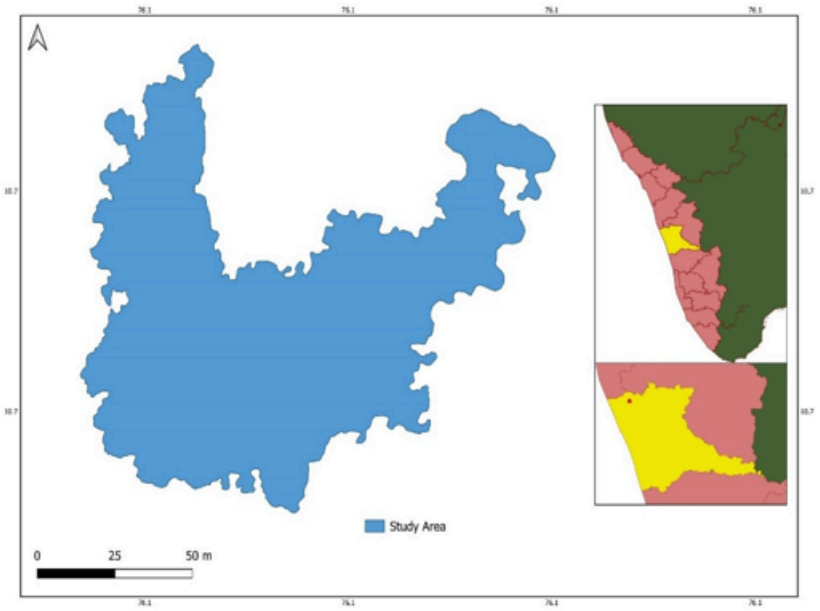


Figure 1

Study area showing *Syzygium travancoricum*and heterogeneous plant population in Kalasamala



Figure 2

(profile 1) Soil profile under *Syzygium travancoricum*



Figure 3

(profile 2) Soil profile under Heterogeneous plant species which include tree species such as Caryota urens, Holigarna caustica including *Syzygium travancoricum*

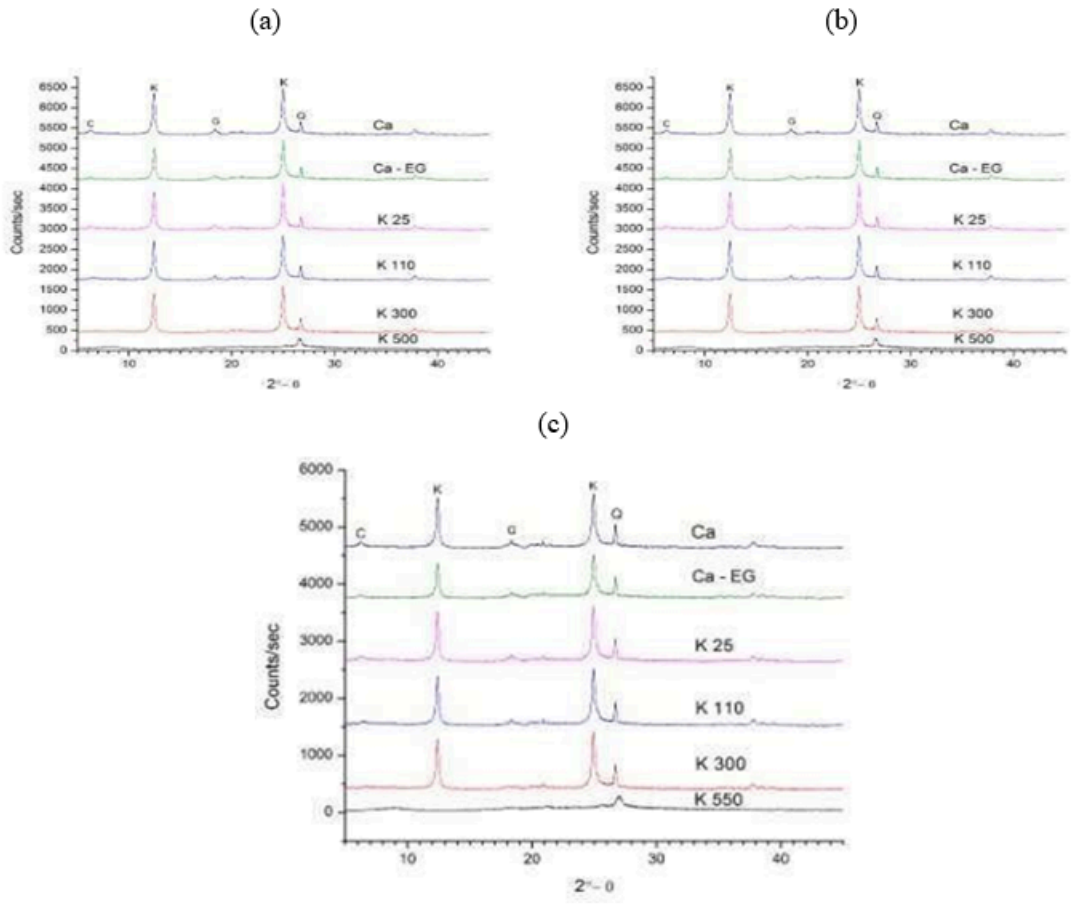


Figure 4

(Profile A) XRD patterns of clay fraction under *Syzygium travancoricum* (a) At depth 0- 15cm, (b) At depth 15 -63 cm, (c) At depth 63-150 cm

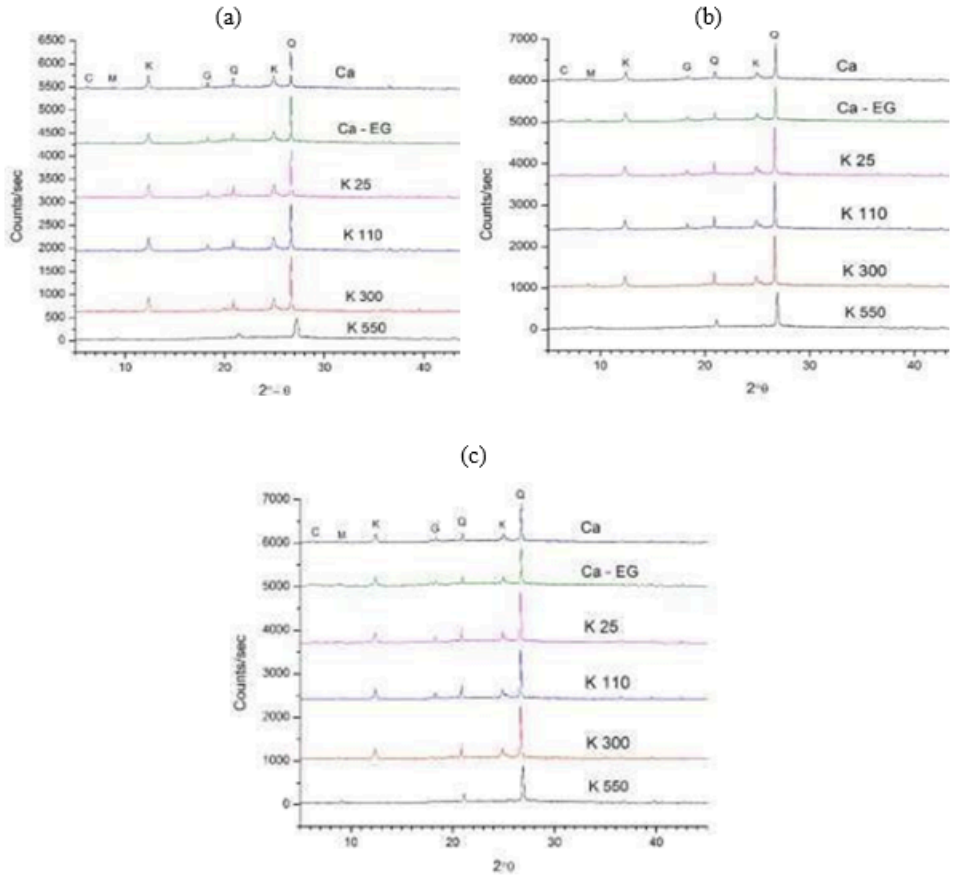


Figure 5

(Profile A) XRD patterns of silt fractions under *Syzygium travancoricum* (a) At depth 0-15, (b) At depth 15-63, (c) At depth 63-150

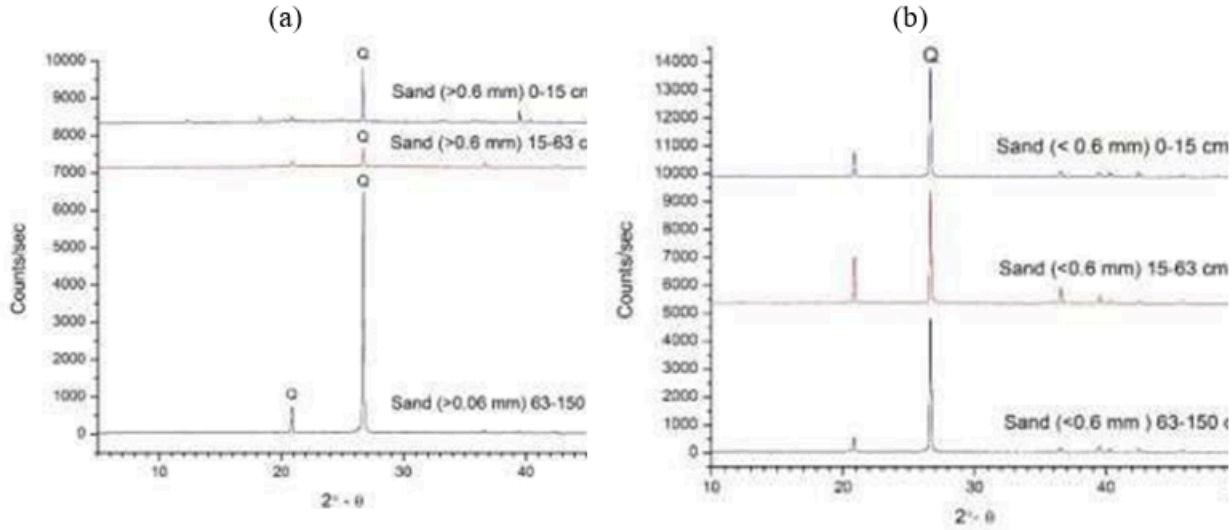


Figure 6

(Profile A) XRD patterns of sand under *Syzygium Travancoricum* (a) Sand fraction above 0.6mm, (b) sand fraction below 0.6mm

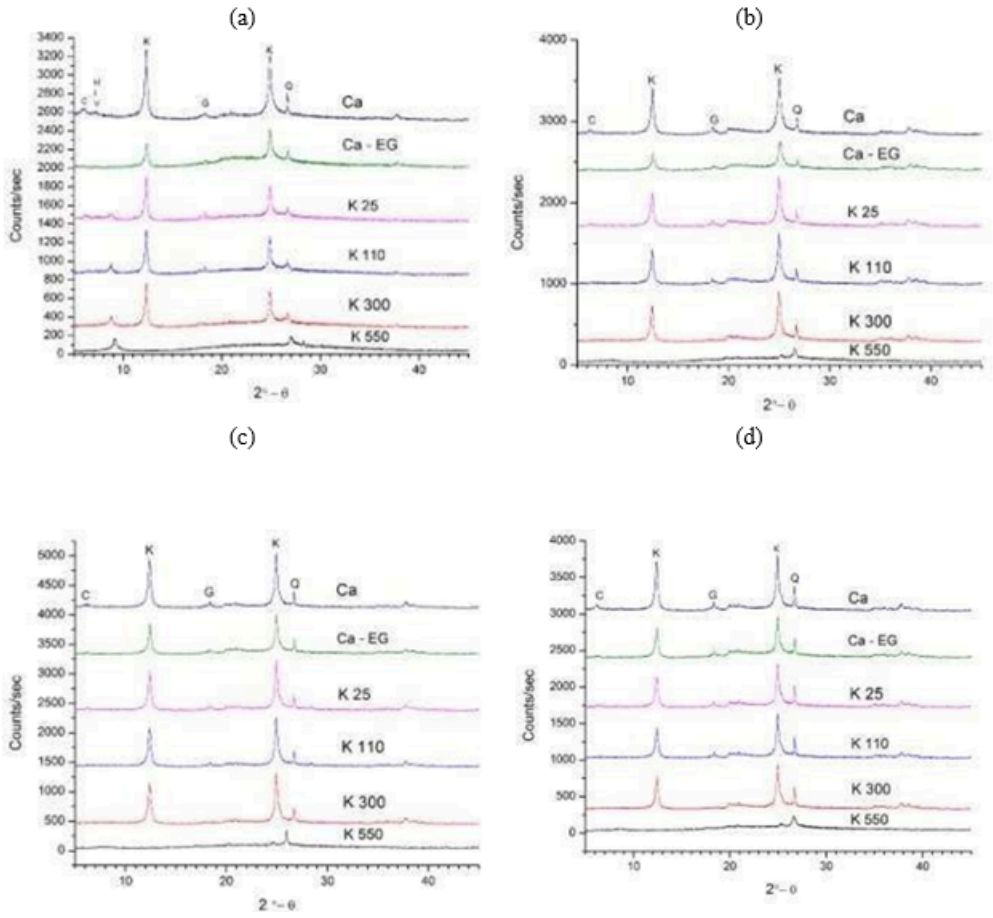


Figure 7

(Profile B) XRD patterns of clay fraction under heterogeneous tree species (a) At depth 0- 11 cm, (b) At depth 11-49 cm, (c) At depth 49 -72 cm, (d) At depth 72-150 cm

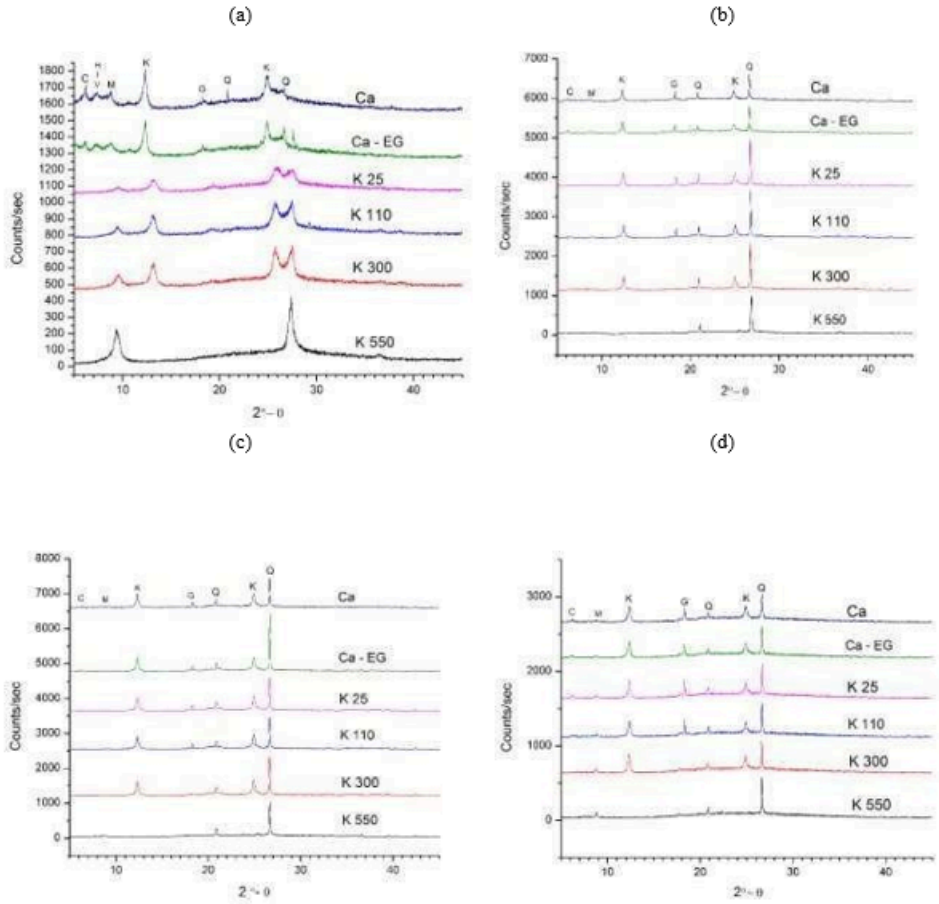


Figure 8

(Profile B) XRD patterns of silt fraction under heterogeneous tree species (a) At depth 0- 11 cm, (b) At depth 11-49 cm, (c) At depth 49-72 cm, (d) At depth 72-150 cm

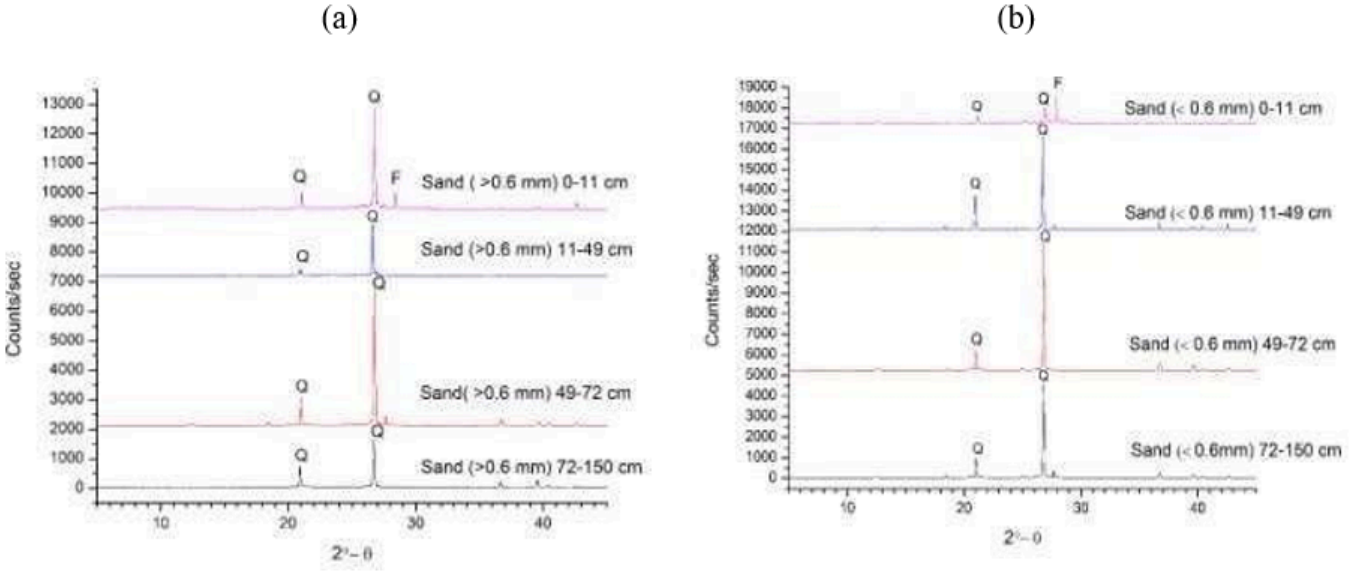


Figure 9

(Profile B) Soil profile under profile 2 - heterogeneous tree species (a) sand fraction above 0.6 mm, (b) sand fraction below 0.6 mm