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Soil Fertility Constraints and Land Suitability Assessment Using SFCC and Modified Storie Index in a Humid Tropical Hill Ecosystem of Kerala

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ABSTRACT

A detailed soil survey was conducted in Elamdesam block, Idukki district, Kerala (tropical humid region), to assess soil fertility constraints and agricultural potential using soil fertility capability classification (SFCC) and a modified storie index rating (MSIR). Twelve soil taxonomic units were identified and evaluated through qualitative (SFCC) and quantitative (MSIR) approaches. Key soil constraints identified through SFCC included dry moisture regime (100%), low cation exchange capacity (98.4%), and aluminium toxicity (50.2%). The MSIR categorized land into fair (2,107 ha), poor (2,279.4 ha), very poor (6,901.8 ha), and non-agricultural (7,461.8 ha) classes. Fair-grade lands are suitable for plantations like coconut, banana, and pepper; poor-grade lands for rubber and teak; and inferior lands for forestry. This study demonstrates the practical utility of combining SFCC and MSIR approaches for site-specific land use planning in humid tropical hill ecosystems. It provides a baseline for guiding sustainable crop and plantation choices on marginal lands. However, further field validation and monitoring of productivity outcomes are necessary to refine the recommendations and enhance their relevance under changing land use and climate conditions.

1 | INTRODUCTION

One of the most critical challenges in global agriculture today is the ongoing conversion of arable land to non-agricultural uses, significantly reducing net sown and gross cropped areas. Sustainable agricultural development requires that land units be allocated to appropriate uses based on their inherent potential and limitations. This necessitates a detailed understanding of soil resources and their constraints, particularly in ecologically sensitive and productivity-challenged regions.

Traditional soil taxonomic classifications provide valuable information on soil genesis but are limited in their direct applicability to agronomic planning. To bridge this gap, the soil fertility capability classification (SFCC) system was developed to translate taxonomic data into actionable soil fertility information (Buol & Couto, 1981; Sanchez *et al.,* 1982; Sanchez *et al.,* 2003). Originally proposed by Buol *et al.* (1975) and refined over subsequent decades, the SFCC evaluates measurable soil fertility constraints using "condition modifiers" based on surface (0–20 cm) and subsurface (20–50 cm) soil attributes. It emphasizes inherent soil properties that are largely unalterable, such as texture, pH, and base saturation (Sanchez *et al.,* 1982; 2003). This approach is particularly valuable in tropical humid regions, like the Elamdesam block in Idukki district, Kerala, where annual rainfall exceeds 3,900 mm. Such climatic conditions cause intense leaching of base cations, leading to soil acidity, aluminum toxicity, low cation exchange capacity (CEC), and poor nutrient reserves. These areas are further constrained by steep slopes and erosion, demanding site-specific soil management and conservation strategies. Generalized soil maps from small-scale surveys (>1:50,000) are inadequate for farm-level planning, whereas detailed soil surveys (1:10,000 or finer) provide spatially explicit and agronomically useful information (Gasparatos & Kairis, 2022; Kairis *et al.,* 2020).

To complement the SFCC, the storie index rating (SIR) and its modified version (MSIR) offer a quantitative measure of soil suitability for agriculture. Originally introduced by Storie (1933; 1978), the index rates land productivity from "excellent" to "extremely poor" based on factors like soil depth, texture, drainage, and slope. Unlike SFCC, which focuses on qualitative fertility constraints, the MSIR assigns numerical ratings, facilitating classification of land into categories such as arable, marginal, or non-agricultural (Gasparatos & Kairis, 2022).

This study conducted a detailed soil survey in the Elamdesam block of Idukki district, a typical humid tropical hill ecosystem. The soils were classified into taxonomic units and mapped using ArcGIS. These units were then assessed using the SFCC to identify soil condition modifiers and further evaluated using MSIR to determine their agricultural value. Given the region's steep slopes (>30%), high rainfall, and soil acidity, informed soil and agronomic management practices, along with soil and water conservation measures, are essential for sustainable land use. The study is based on the hypothesis that Elamdesam soils, although rich in organic matter, suffer from key constraints including soil acidity, Al toxicity, low base status, high gravelliness, and low CEC due to low-activity clays and ustic moisture regime. These factors, along with variable topography, limit the agricultural potential of the area. Objectives of the study included a) to apply the soil fertility capability classification (SFCC) to the taxonomic units/soil series of the Elamdesam block to identify fertility constraints using condition modifiers, and b) to evaluate the agricultural value of these soils using the modified storie index rating (MSIR) to guide suitable agronomic and conservation interventions for improved productivity.

HIGHLIGHTS

- Integrated use of SFCC and MSIR provided a comprehensive evaluation of soil fertility and land suitability across twelve taxonomic units in the tropical hill ecosystem of Kerala.
- Key soil constraints identified include low cation exchange capacity, aluminum toxicity, and high P-fixation, with implications for land use planning and crop selection.
- Findings support the strategic allocation of marginal lands for plantations or forestry, with a need for further field validation to guide sustainable livelihoods and conservation.

2 | MATERIALS AND METHODS

2.1 | Study Area

The study was conducted in the Elamdesam block of Thodupuzha taluk, Idukki district, Kerala (*Fig. 1*), situated within the hot, wet, sub-humid to humid ecoregion of the

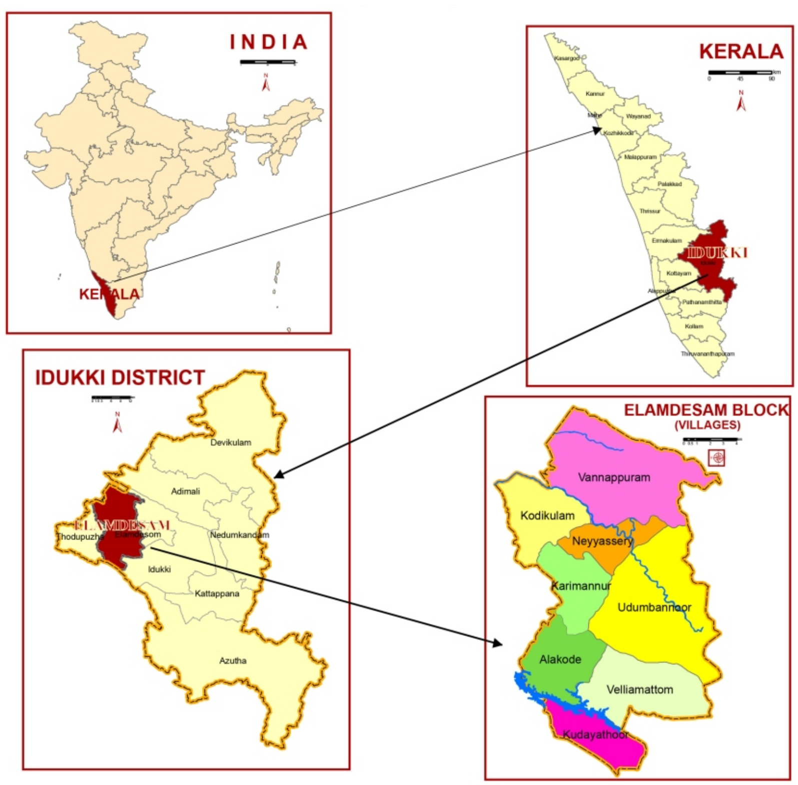

FIGURE 1 Location map of the study area Elamdesam block, tropical humid region, Kerala

central and southern Sahyadris (Agro-Ecological Sub Region 19.2). The landscape comprises diverse physiographic units, including forests, denudational hills, lateritic terrain, and valleys, with elevations ranging from 30 to 850 m above mean sea level. Geographically, the area spans 9°46′38.2″ to 10°2′18.1″N latitude and 76°42′59.5″ to 76°53′47.0″E longitude. The block covers an area of 29,127 ha, with 18,750 ha under arable land, and includes seven gram panchayats. The geology is dominated by charnockite and granite gneiss of the Archaean age. The region experiences a humid monsoonal climate, with a mean annual rainfall of 3911 mm, temperatures ranging from 22°C to 27°C, and a growing season exceeding nine months. Topographically, the block is divided into four land units, which include lowlands with submerged paddy fields, midlands or foothills (30–300 m MSL), high hills (300–600 m MSL and the western Ghats (>600 m MSL) with exposed rocks. Agriculture is diversified: lowlands support paddy, tapioca, banana, coconut, and arecanut, while foothills and midlands are used for plantations of rubber, pepper, banana, pineapple, arecanut, cocoa, nutmeg, and cashew. On steeper slopes, mixed forests dominate, and rubber is occasionally cultivated on elevated beds in shallow water table zones.

2.2 | Soil Survey, Laboratory Analysis, and Mapping

A detailed soil survey was carried out at a 1:10,000 scale using base maps derived from google earth imagery, open-source satellite data, and Survey of India toposheets (58C/13 and 58B/16) at 1:50,000 scale. Although high-resolution Cartosat-1 and IRS LISS IV P6 (5.8 m) data were procured, these proved ineffective due to dense vegetation in the study area, which rendered all false colour composite (FCC) images homogeneously red, impeding visual interpretation. Key features such as roads, settlements, water bodies, and forest areas were digitized from google imagery and toposheets. Contour information was used to derive slope classes, which were validated through ground-truthing. These layers facilitated the delineation of four distinct landforms as listed above. These landforms, developed over charnockite and granite-gneissic formations, range from steep slopes in the hills to nearly level terrain in the lowlands. A total of 134 soil profiles were examined through seven transects based on variations in slope, geology, land use, and soil-site characteristics. From these, 28 representative profiles (*Fig. 2*) were selected for laboratory analysis of surface and subsurface soils using standard methods such as the measurement of particle size by the international pipette method (Piper, 1966), the estimation of gravel content by the gravimetry method (Govindarajan & Koppar, 1975), the measurement of soil pH and electrical conductivity (EC) using the 1:2.5 soil to water ratio (Jackson, 1973), and the determination of organic carbon (OC) by Walkley and Black (1934) method. The neutral normal ammonium acetate technique was used to determine the cation exchange capacity (CEC) and exchangeable cations (Schollenberger & Dreibelbis, 1930). Soil series boundaries were delineated using base maps, GPS-located soil profile points, and lab data, and digitized using ArcGIS 10.7.1. Descriptive statistics were computed using XLSTAT.

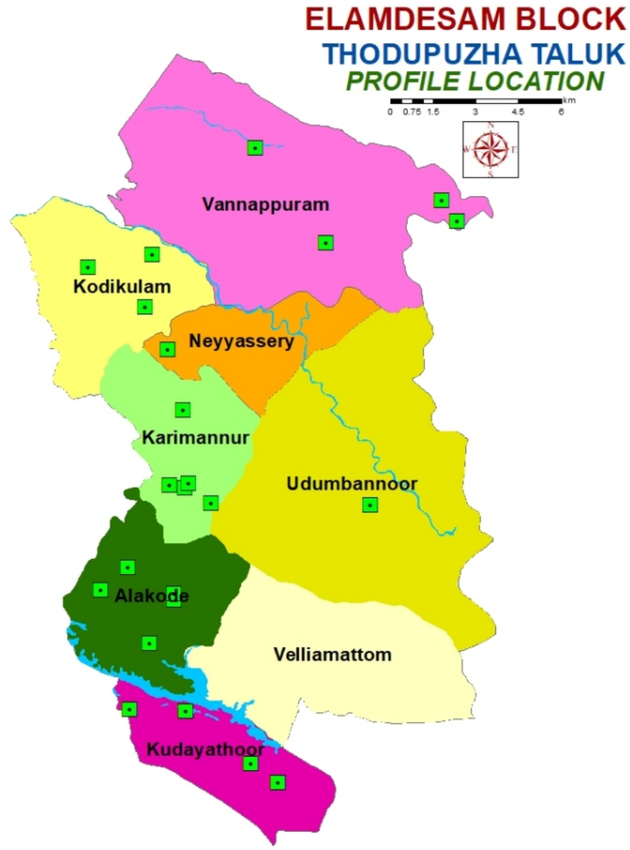

FIGURE 2 Study area Elamdesam block, tropical humid region, Kerala showing representative soil profile locations

2.3 | Soil Fertility Capability Classification (SFCC)

SFCC was performed following the methodology proposed by Sanchez *et al.* (1982, 2003), using both surface (0-20 cm) and subsurface (20-50 cm) soil physicochemical data. The SFCC system categorizes soils based on three components: the surface soil "type," the subsoil "substrata type," and soil condition modifiers. Surface soils are classified as sandy (S), loamy (L), clayey (C), or organic (O), while the subsoil follows the same texture classes with the addition of a restrictive layer (R) for hard or root-limiting layers. In addition, soil condition modifiers describe key fertility constraints such as aluminium toxicity (a), strong acidity (h), low cation exchange capacity (e), dry soil moisture regime (d), high phosphorus fixation or low potassium reserves (k), gravel content (r+ for 10-35% and r++ for >35%), gleying (g), and erosion risks linked to steep slopes or shallow soil depth (R or slope >30%). Each taxonomic

TABLE 1 Descriptive statistics of the soil properties in Elamdesam block, Tropical Humid Region, Kerala

Soil properties	Surface soil (0-20 cm)					Subsurface soil (20-50 cm)				
	Average	Min.	Max.	SD	SE (m)	Average	Min.	Max.	SD	SE (m)
Sand (%)	54.72	42.70	75.60	10.08	2.91	53.30	43.50	71.20	10.09	2.91
Silt (%)	15.42	12.00	20.10	2.31	0.67	16.12	10.60	21.50	3.51	1.01
Clay (%)	29.84	11.40	39.40	8.66	2.50	30.55	8.90	38.00	9.32	2.69
Gravel (%)	7.60	0.00	30.00	12.16	3.51	11.50	0.00	45.00	15.94	4.60
pH	4.89	4.16	5.44	0.46	0.13	4.95	4.39	5.60	0.42	0.12
EC (dS m^{-1})	0.08	0.03	0.18	0.05	0.01	0.05	0.02	0.14	0.04	0.01
OC (%)	2.07	1.29	3.23	0.62	0.18	1.59	0.83	3.05	0.61	0.18
CEC (cmol(p+)kg^{-1})	10.40	5.35	14.20	2.73	0.79	9.62	4.81	14.50	2.80	0.81
Exchangeable Ca (cmol(p+) kg^{-1})	1.05	0.37	2.63	0.68	0.20	0.98	0.11	3.59	1.03	0.30
Exchangeable Mg (cmol(p+) kg^{-1})	0.31	0.06	1.03	0.27	0.08	0.31	0.00	1.45	0.44	0.13
Exchangeable Na (cmol(p+) kg^{-1})	0.09	0.02	0.18	0.05	0.02	0.07	0.01	0.18	0.04	0.01
Exchangeable K (cmol(p+) kg^{-1})	0.22	0.07	0.63	0.16	0.05	0.13	0.03	0.39	0.10	0.03

SD: Standard deviation; SE(m): Standard error mean

soil unit or series was evaluated using this framework, enabling precise identification of fertility-related limitations and guiding the delineation of the block's final SFCC map.

2.4 | Parametric Modified Storie Index Soil Rating (MSIR)

MSIR is a widely adopted semi-quantitative method for assessing the agricultural potential of soils based on their inherent characteristics. Originally developed for Californian soils (Storie, 1933; 1978), the original Storie Index was later refined to reduce subjectivity and expand its applicability to diverse geographic contexts (Gasparatos & Kairis, 2022; O'Geen *et al.,* 2008). The MSIR employs a parametric and multiplicative model to calculate soil productivity, as defined by Equation (1):

$$MSIR = A \times B \times C \times X\,(or\,D) \quad ...(1)$$

In this formulation, Factor A reflects the general characteristics of the soil profile excluding the surface texture; Factor B represents the texture of the surface soil; Factor C accounts for the land surface slope; and Factor X (or D) incorporates various yield-limiting or modifying conditions such as soil acidity, drainage limitations, erosion risk, salinity or alkalinity, nutrient deficiencies, and micro-relief variability. Each factor is scored individually, with 100% indicating optimal conditions. The composite index, expressed as a percentage from 0 to 100, serves as a basis for soil classification.

Based on the final MSIR value, soils are grouped into six productivity classes. Soils with ratings between 80% and 100% are classified as very high grade, representing excellent arable land suitable for a wide range of crops. High-grade soils, with ratings of 60 to 79%, are good arable lands with strong yield potential for many field crops. Medium grade soils, falling between 40 and 59%, are of fair quality and moderate productivity. Low-grade soils, rated between 20 and 39%, are only marginally arable and typically suited for limited purposes such as rubber plantations. Soils rated between 10 and 19% are designated as very low grade, suitable mainly for pasture or grazing due to severe constraints such as shallow depth, rough topography, or chemical limitations. Finally, soils with MSIR values below 10% are classified as Extremely Low Grade; these are highly constrained soils, such as those on steep, fractured slopes or with extreme acidity, rendering them virtually unsuitable for most forms of cultivation (Gasparatos & Kairis, 2022; Gogoi, 2022). This classification framework objectively assesses soil productivity potential, independent of external biophysical or socio-economic influences.

3 | RESULTS AND DISCUSSION

The soils of the Elamdesam block were predominantly sandy in texture (54-55%) with moderate clay (17-21%) and low silt content (8-10%) (Table 1 & 2). The subsoil layers generally had a higher clay content, likely due to translocation from surface horizons Chandrakala *et al.,* 2023 and erosion-related removal of the Ap horizon. Gravel content was observed up to 45%, further limiting water and nutrient retention capacity. Organic carbon was found to be higher in the surface horizons, reaching up to 2.9%, but declined with depth, which can be attributed to reduced organic matter input and the decomposition of fine root biomass. This vertical distribution was consistent across all soil taxonomic units and indicated progressive pedogenic development.

Soil reaction ranged from strongly to extremely acidic (pH 4.2-5.6) throughout upland, midland, and lowland areas. The pronounced acidity was associated with high rainfall and leaching, which led to the accumulation of hydrogen and aluminium ions. The base saturation showed

TABLE 2 Relevant average values of surface (0-20 cm) and subsurface (20-50 cm) soil properties for fertility capability classification in Elamdesam block, Tropical Humid Region, Kerala

Soil series	Depth	Sand (cm)	Silt (%)	Clay (%)	Gravel (%)	pH (%)	EC	SOC (dS m^{-1})	CEC (g kg^{-1})	Ex.Ca (cmol(p+) kg^{-1})	Ex. Mg (cmol(p+) kg^{-1})	Ex. Na (cmol(p+) kg^{-1})	Ex. K (cmol(p+) kg^{-1})
Loamy mixed, isohyperthermic acid	0-20	53.7	17.8	28.4	0	4.16	0.18	26.8	13.9	0.59	0.12	0.08	0.2
active Ustic Haplohumults (Ptk)	20-50	45.9	21.5	32.5	0	4.45	0.08	19.5	14.5	0.23	0.04	0.07	0.08
Loamy mixed isohyperthermic acid	0-20	64.6	12	23.4	0	4.485	0.115	17.9	8.965	0.64	0.175	0.07	0.17
semiactive Humic Dystrustepts (Kbk)	20-50	64.15	11.6	24.2	0	4.425	0.12	16.3	9.02	0.625	0.14	0.065	0.165
Loamy skeletal mixed isohyperthermic	0-20	63.25	15.6	21.15	30	5.275	0.025	22.2	9.125	0.57	0.135	0.02	0.13
acid semiactive Humic Dystrustepts (Acd)	20-50	59.95	16.45	23.6	45	5.13	0.015	12.8	7.65	0.26	0.055	0.075	0.08
Clayey mixed isohyperthermic acid	0-20	45.55	15.05	39.4	0	4.32	0.155	32.3	14.2	0.625	0.145	0.08	0.205
semiactive Ustic Haplohumults (Vnp)	20-50	46.9	15.2	37.8	0	4.385	0.14	30.5	13.25	0.645	0.11	0.06	0.12
Clayey kaoloniticisohyperthermic Ustic	0-20	50.45	13.8	35.7	0	5.32	0.035	14.1	5.345	0.835	0.06	0.045	0.07
Kandihumults (Vlc)	20-50	45.15	17.05	37.75	13	5.265	0.02	11.1	4.805	0.56	0	0.035	0.03
Clayey mixed acid isohyperthermic	0-20	46.3	15.9	37.8	23.75	4.535	0.06	26.35	12.75	0.37	0.125	0.105	0.275
semiactive Ustic Haplohumults (Kmn1)	20-50	50.65	11.35	38	22.5	4.57	0.035	16.85	10.23	0.105	0.015	0.085	0.145
Fine loamy mixed isohyperthermic acid	0-20	53.1	15.1	31.8	0	4.97	0.07	14.65	10.45	1.98	0.42	0.02	0.205
semiactive Humic Dystrustepts (Ckz)	20-50	51.25	15.4	33.35	0	4.915	0.04	13.6	10.8	1.455	0.26	0.005	0.1
Loamy mixed isohyperthermic acid	0-20	63.45	14.1	22.5	10	5	0.045	17.9	9.48	0.655	0.275	0.06	0.13
semiactive Lithic Dystrustepts (Nys)	20-50	69.3	10.6	20.1	32.5	5.25	0.03	10.3	7.99	0.43	0.19	0.04	0.08
Loamy mixed isohyperthermic acid	0-20	42.7	20.1	37.1	27.5	5.435	0.03	22.9	14	1.09	0.42	0.165	0.625
semiactive Ustic Haplohumults (Kdy)	20-50	44.9	18.6	36.45	25	5.195	0.025	18.1	12.6	0.405	0.135	0.105	0.25
Clayey kaolinite isohyperthermic acid	0-20	53.9	14.55	31.6	0	5.41	0.06	14.7	8.855	2.625	1.03	0.18	0.43
subactive Ustic Haplohumults (Adm)	20-50	46.8	16.5	36.7	0	5.395	0.035	8.3	7.885	2.26	1.445	0.175	0.39
Sandy mixed isohyperthermic acid	0-20	75.6	12.9	11.4	0	5.18	0.06	25.5	8.96	1.16	0.48	0.1	0.15
subactive lithic Ustorthents (Acr)	20-50	71.2	19.9	8.9	0	5.6	0.02	21.9	9.4	3.59	0.94	0.07	0.06
Fine, mixed, acid, isohyperthermic	0-20	44.05	18.15	37.8	0	4.53	0.095	12.9	8.825	1.515	0.39	0.16	0.085
sub-active OxyaquicHaplustepts (Kmn^2)	20-50	43.5	19.25	37.3	0	4.86	0.05	11.7	7.295	1.24	0.4	0.1	0.035

TABLE 3 Type, substrata and condition modifiers and final fertility capability classification in Elamdesam block, Tropical Humid Region, Kerala

Landform	Taxonomic units with soil series name	Type / Sub strata	Check list										Modifiers	Slope (%)	FCC unit	Area in hectares (% area)
			g	d	e	a	h	i	k	r	R	>30%				
Uplands	Loamy mixed, isohyperthermic acid active Ustic Haplohumults (Ptk)	L	-	×	×	×	-	-	×	-	-	×	deak	>30	Ldeak (>30)	716.71 (2.46)
	Loamy mixed isohyperthermic acid semi-active Humic Dystrustepts (Kbk)	L	×	×	×	×	-	-	×	-	-	×	gdeak	>30	Lgdeak (>30)	512.77 (1.76)
	Loamy skeletal mixed isohyperthermic acid semiactive Humic Dystrustepts (Acd)	L	×	×	×	×	-	-	×	++	-	-	gdeakr++	3-5	Lgdeakr++(3-5)	288.10 (0.99)
	Clayey mixed isohyperthermic acid semi-active Ustic Haplohumults (Vnp)	C	×	×	×	×	-	×	×	-	-	-	gdeaik	1-15	Cgdeaik (1-15)	1463.43 (5.02)
	Clayey kaoloniticisohyperthermic Ustic Kandihumults (Vlc)	C	-	×	×	×	-	×	×	-	-	-	deaik	1-5	Cdeaik (1-5)	3726.25 (12.79)
	Clayey mixed acid isohyperthermic semi-active Ustic Haplohumults (Kmn1)	C	-	×	×	×	-	×	×	+	-	-	deaikr+	1 - >33	Cdeaikr+ (1- >30)	2051.72 (7.04)
	Fine loamy mixed isohyperthermic acid semiactive Humic Dystrustepts (Ckz)	L	-	×	×	×	-	-	×	-	-	-	deak	1-5	Ldeak (1-5)	1536.99 (5.28)
	Loamy mixed isohyperthermic acid semi-active Lithic Dystrustepts (Nys)	L	-	×	×	-	×	-	×	+	-	-	dehkr+	1-10	Ldehkr+ (1-10)	1042.69 (3.58)
	Loamy mixed isohyperthermic acid semiactive Ustic Haplohumults (Kdy)	C	-	×	×	-	×	×	-	+	-	-	dehir+	1-10	Cdehir+ (1-10)	2107.0 (7.0)
	Clayey kaolinite isohyperthermic acid subactive Ustic Haplohumults (Adm)	LC	-	×	-	-	×	-	-	-	-	-	dh	5-10	LCdh (5-10)	454.29 (1.56)
Lowlands/ Valley plains	Sandy mixed isohyperthermic acid sub-active lithic Ustorthents (Acr)	S	×	×	×	-	×	-	×	-	×	-	gdehkR	1-3	SgdehkR (1-3)	541.98 (1.86)
	Fine, mixed, acid, isohyperthermic sub-active OxyaquicHaplustepts (Kmn^2)	C	-	×	×	×	-	×	×	-	-	-	deaik	0-1	Cdeaik (0-1)	4308.12 (14.79)

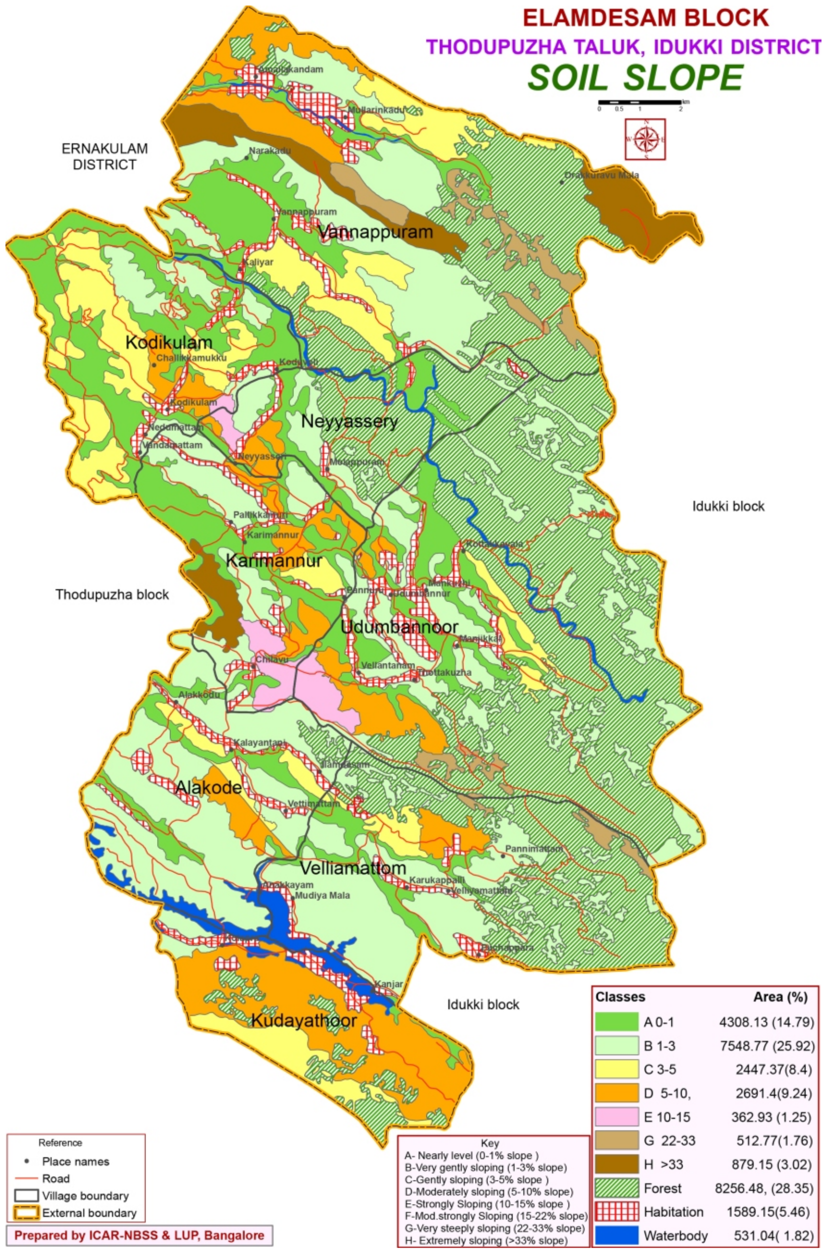

FIGURE 3 Slope classes in Elamdesam block, tropical humid region, Kerala

TABLE 4 Extent of soil condition modifier/ limitation in Elamdesam block, Tropical Humid Region, Kerala

Soil condition modifier	Limitation	Area in hectare (% area)
d^+	Dry soil moisture (ustic) regime	29127.16 (100)
e	Low cation exchange capacity	28672.87(98.44)
k	Low K reserves	16188.76 (55.58)
a	Aluminium-toxicity	14604.09 (50.14)
i	High P-fixation by iron	13656.52 (46.88)
r^+	Gravel content (10-35 %)	5201.41 (17.86)
h	Acidic soil reaction	4145.96 (14.24)
g	Gley	2806.28 (9.64)
30%	High erosion risk (>30% slope)	1229.48 (4.22)
R	High erosion risk (shallow depth)	541.98 (1.86)
r^{++}	Gravel content (> 35%)	288.1 (0.99)

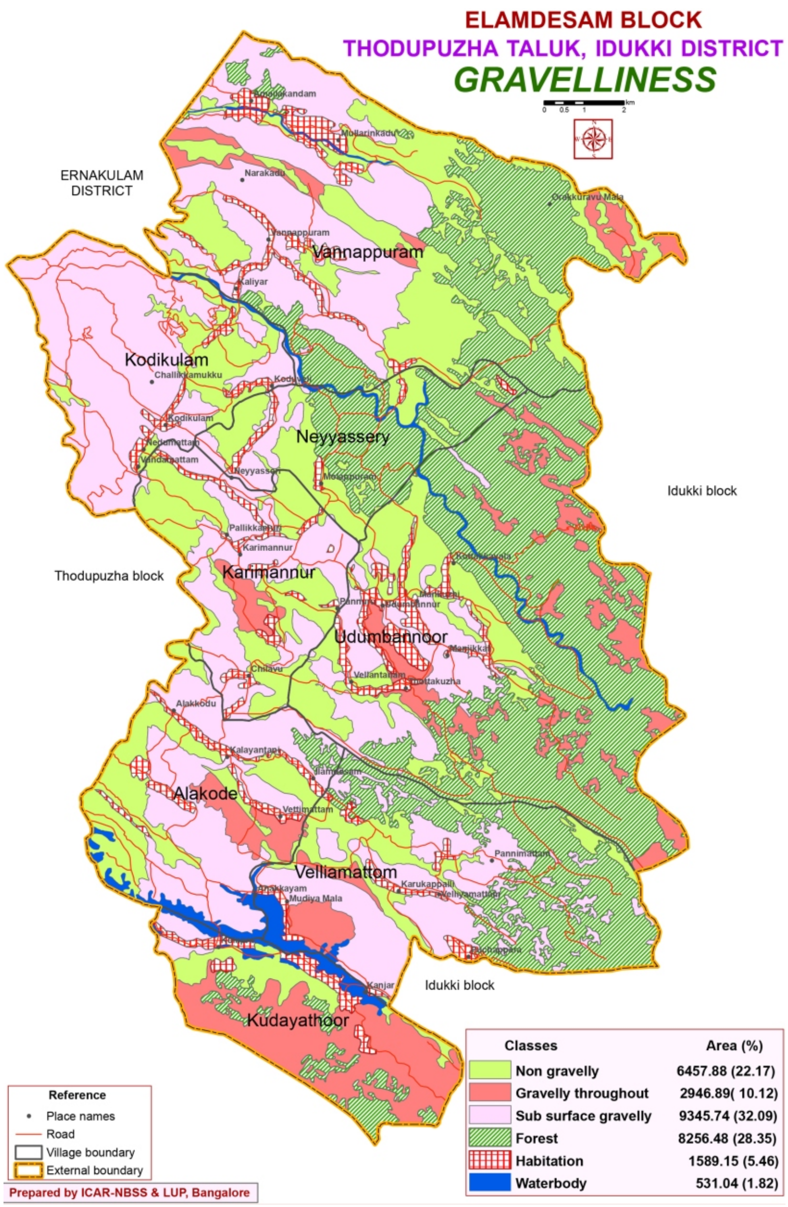

FIGURE 4 Soil gravelliness in Elamdesam block, tropical humid region, Kerala

the dominance of calcium followed by magnesium, sodium, and potassium. A significant negative correlation between pH and clay content (r = -0.522**), as observed by Gogoi et al. (2022), supports the hypothesis that clay surfaces retain acidic cations, which influence active acidity. Cation exchange capacity (CEC) values were low, ranging from 4.8 to 14.5 cmol(+) kg^{-1}, due to the presence of low-activity clays. Among the exchangeable bases, calcium and magnesium were more prevalent, yet all were generally low, indicating the necessity of soil amendments for sustainable cropping.

Using soil fertility capability classification (SFCC), the study identified loamy and clayey types as most suitable for cropping, provided appropriate tillage is practiced (Table 3). Among the ten soil condition modifiers recognized, dry soil moisture status was universal due to the ustic moisture regime Chandrakala *et al.,* 2021; however, this constraint is partially alleviated by high annual rainfall and short dry spells. Low CEC was identified in 98.4% of the soils (Table 4), a consequence of low-activity clay minerals, which could be managed by increasing organic matter through biomass recycling. Potassium reserves were low in 55.6% of the soils, mainly due to the dominance of kaolinitic minerals in the parent material. This constraint necessitates the application of potassic fertilizers to maintain crop productivity.

Aluminium toxicity was found in about half of the studied area (Table 4), resulting from prolonged acid

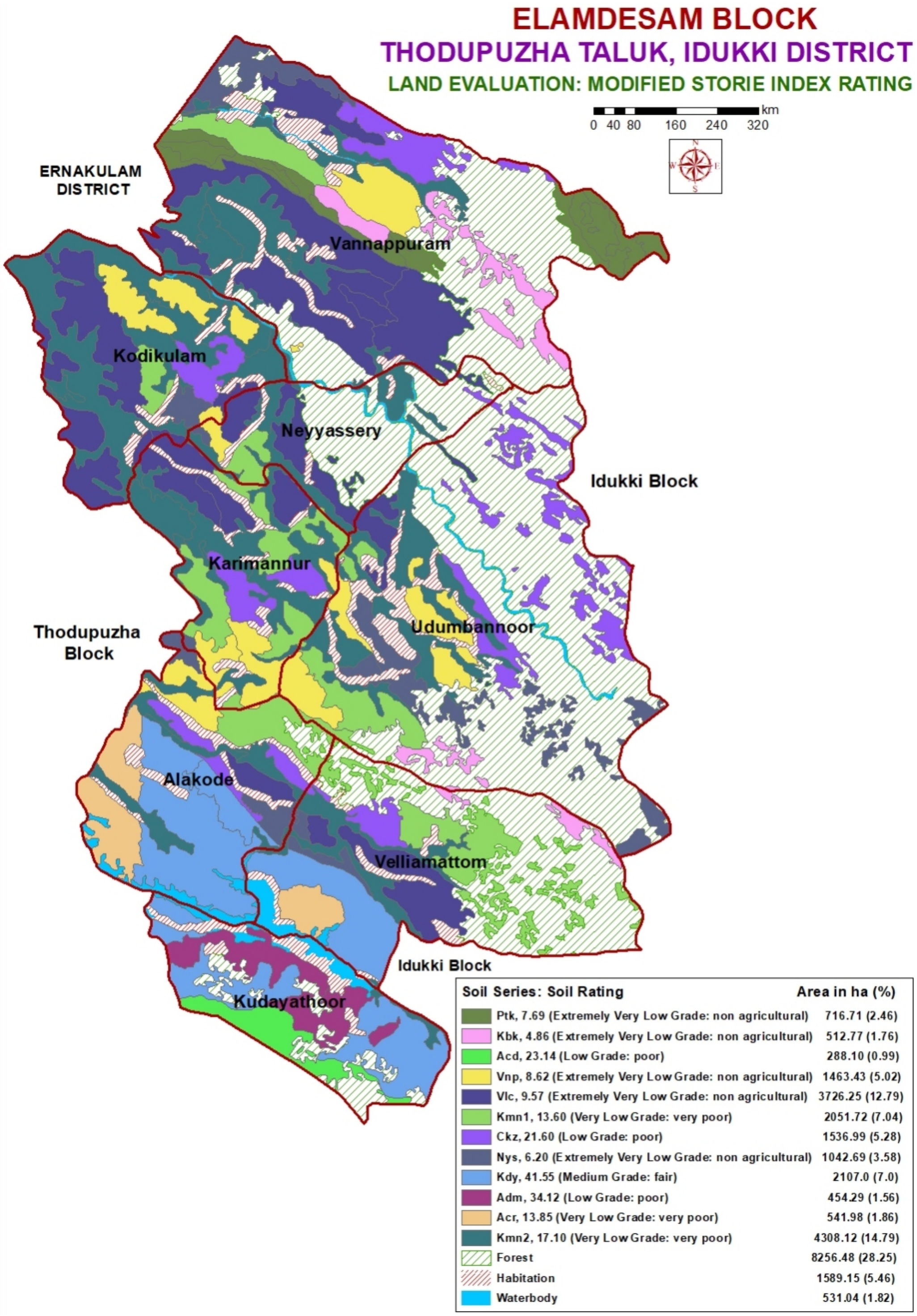

FIGURE 5 The modified Storie Index soil rating (MSIR) for the soils of Elamdesam block, Tropical Humid Region, Kerala

leaching. While aluminium is known to inhibit root growth and nutrient uptake, its presence has been linked to enhanced latex flow in rubber plantations, which dominate more than 60% of the area. High phosphorus fixation was observed in 46.9% of soils due to the presence of ferric oxides. This issue can be mitigated through split phosphorus application and the use of phosphate-solubilizing biofertilizers and P-mobilizers.

Other limiting factors included high gravelliness (*Fig. 4*), which reduces nutrient and water retention and can be managed by incorporating tank silt or fine-textured materials. The acidic reaction is manageable through lime application.

TABLE 5 The modified Storie Index soil rating (MSIR) for the soils of Elamdesam block, Tropical Humid Region, Kerala

Soil Taxonomic units/series (model Pedons)	Factor A Physical profile (%)	Factor B Surface Texture (%)	Factor C Slope (%)	Factor X Soil condition (%)					Soil Rating (%)	Area in ha (%)
				Drainage	Acidity	Fertility status	Erosion	Micro-relief		
Pattekudi (Ptk): Pedon 1	80-95	100	50	100	20	90	90	100	7.69 (Extremely Very Low Grade: non agricultural)	716.71 (2.46)
Kambaka Kanam (Kbk): Pedon 2	40	100	50	100	30	90	90	100	4.86 (Extremely Very Low Grade: non agricultural)	512.77 (1.76)
Arcade (Acd): Pedon 3	95	100	95	100	30	95	90	100	23.14 (Low Grade: poor)	288.10 (0.99)
Vannappuram (Vnp): Pedon 4	80	70	90	100	20	95	90	100	8.62 (Extremely Very Low Grade: non agricultural)	1463.43 (5.02)
Vellanchara (Vlc): Pedon 5	80	70	100	100	20	95	90	100	9.57 (Extremely Very Low Grade: non agricultural)	3726.25 (12.79)
Karimannor-1 (Kmn1): Pedon 6	90	70	80	100	30	100	90	100	13.60 (Very Low Grade: very poor)	2051.72 (7.04)
Chinikuzhi (Ckz): Pedon 7	80	100	100	100	30	100	90	100	21.60 (Low Grade: poor)	1536.99 (5.28)
Neyyessery (Nys): Pedon 8	30	100	90	100	30	85	90	100	6.20 (Extremely Very Low Grade: non agricultural)	1042.69 (3.58)
Kudayathoor (Kdy): Pedon 9	90	90	95	100	60	100	90	100	41.55 (Medium Grade: fair)	2107.0 (7.0)
Adurmala (Adm): Pedon 10	70	100	95	100	60	95	90	100	34.12 (Low Grade: poor)	454.29 (1.56)
Ancheri (Acr): Pedon 11	60	90	100	100	20	90	95	100	13.85 (Very Low Grade: very poor)	541.98 (1.86)
Karimannoor-2 (Kmn^2): Pedon 12	95	70	100	90	30	95	100	100	17.10 (Very Low Grade: very poor)	4308.12 (14.79)

Soils showing gleying features posed challenges for upland crops due to water stagnation but remained suitable for rice cultivation. A small portion of the area (4.2%) had slopes exceeding 30% (*Fig. 3*), and shallow rooting depths were observed in 1.9% of soils, both of which limit the choice of crops and increase vulnerability to erosion, particularly in rubber plantations. These constraints call for effective soil and water conservation measures (Jayaraman *et al.,* 2024). Recommendations include graded bunds, contour farming, vegetative barriers, and trench-cum-bund systems, aligning with strategies proposed by Mandal and Sharda (2011) and Mandal *et al.* (2021) for sustainable land use planning.

The modified storie index rating (MSIR) provided a quantitative assessment of soil productivity (*Fig. 5*). Medium-grade soils, such as those in the Kudayathoor series, exhibited fair productivity with MSIR around 41.6% (Table 5), making them suitable for plantation crops like coconut, banana, and cocoa, provided gypsum and external nutrients are applied. Low-grade soils, including the Adurmala, Chinikuzhi, and Arcade series, showed MSIR values between 21.6 and 34.1%. Despite their limitations in acidity and depth, these soils supported acid-tolerant crops such as rubber and teak. Very poor soils, such as those in the Karimannoor-2 series with MSIR as low as 17.1%, were deemed unsuitable for general agriculture. Although rubber is cultivated in these areas, productivity remains low and suboptimal (Table 5).

Comparable studies in India and abroad have reported similar variability in MSIR. Gogoi *et al.* (2022) highlighted a range of productivity potentials across different agro-ecologies of Assam. International findings from Libya and Egypt (Gasparatos & Kairis, 2022) also showed wide variation in productivity due to inherent soil constraints. Although the MSIR method does not incorporate socio-economic factors like irrigation access or market proximity, it remains a useful tool for estimating land suitability and correlates well with actual yields.

Overall, the identified soil limitations can be overcome through targeted interventions. Long-term strategies for managing acidity, correcting nutrient imbalances, and implementing effective soil and water conservation practices are essential (Chandrakala *et al.,* 2024). These measures are crucial not only for improving soil productivity but also for conserving biodiversity, maintaining ecosystem services, and achieving land degradation neutrality.

While the present study provides valuable insights into the soil productivity and fertility limitations of the elamdesam block using SFCC and MSIR frameworks, it is not without limitations. The evaluation was based primarily on pedological and physico-chemical attributes, without incorporating dynamic biological indicators such as microbial activity or enzymatic functions that can influence soil health and productivity. Moreover, temporal variations due to seasonal changes in moisture, temperature, and land use patterns were not fully captured in the static sampling design. The modified storie index, though useful for comparative productivity appraisal, does not account for socio-economic variables such as farmer resource availability, input access, or land tenure security, which significantly influence land use decisions and actual crop performance. Future research should adopt a more holistic approach, integrating remote sensing and GIS for dynamic monitoring, and include participatory methods to align land evaluation outcomes with farmers' practical constraints and preferences. Longitudinal studies that track the impact of land management interventions on soil properties and crop yields over time will also enhance the utility of such assessments for sustainable agricultural planning.

4 | CONCLUSIONS

This study evaluated the soils of the elamdesam block using SFCC and MSIR, revealing widespread limitations including strong acidity, low cation exchange capacity, aluminium toxicity, phosphorus fixation, and physical constraints such as shallow depth and steep slopes. These factors collectively restrict crop productivity, although certain soils show moderate suitability for perennial plantations like rubber and coconut with appropriate management interventions. While correctable constraints such as acidity and nutrient deficiencies can be addressed through lime and fertilizer application, enduring issues like slope and shallow depth require integrated soil and water conservation measures. Although the MSIR offered a useful framework for quantifying soil suitability, its limitations in accounting for biological and socio-economic variables suggest a need for more holistic land evaluation approaches.

Future research should include dynamic soil health indicators, farmer perspectives, and long-term monitoring to guide sustainable land use planning. Through targeted interventions, the identified soil constraints can be managed to enhance productivity, support resilient agriculture, and contribute to land degradation neutrality in the humid tropics.

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CONFLICT OF INTEREST

There are no conflicts of interest.

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DATA AVAILABILITY STATEMENT

Data is available with the corresponding author and will be provided if it's required.

AUTHOR'S CONTRIBUTION

CM is the principal investigator of the present study who have conducted the investigation and wrote the manuscript. GAT contributed in Turnitin checking. SGC contributed in formal analysis of the paper. HS and PMV prepared the maps in GIS.

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