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Land suitability evaluation for major crops adopted to tropical humid region of Kerala, India

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Abstract
Land suitability evaluation is a specific type of method to assess the land resources of an area for specific local crops rather than for a general use. Using the soil site suitability criteria, land resources of the Elamdesam block, Idukki ditrict, Kerala was assessed for their suitability for the major crops adopted. Results revealed that, paddy is highly suitable in 14.79 per cent, moderately suitable in 5.39 per cent and marginally suitable in 32.18 per cent of total geographical area. Coconut is highly suitable in 11.6 per cent, moderately suitable in 18.99 per cent and marginally suitable in 28.35 per cent of total geographical area and 5.44 per cent of total area is unsuitable. Arecanut is moderately suitable in 17.57 per cent; marginally suitable in 35.36 per cent of total area and 11.46 per cent of total area is unsuitable. Pepper (*Piper nigrum* L.) is highly suitable in 14.4 per cent of the area, moderately suitable in 29.74 per cent of total area and marginally suitable area is occurring in 20.23 per cent of total geographical area. Banana a plantain (Musa sp. L.) is marginally suitable area in 54.16 per cent of total geographical area and 10.22 per cent of total area is unsuitable. Pineapple is moderately suitable in 22.09 per cent of total area, marginally suitable area is occur in 37.52 per cent of total geographical area. Tapioca (*Manihot esculenta* L.) is moderately suitable in 12.27 per cent of total area and marginally suitable area is occurring in 32.96 per cent of total geographical area. Teak is moderately suitable in 23.4 per cent and marginally suitable in 35.54 per cent of total geographical area, respectively. However, paddy, coconut, arecanut, pepper, banana, pineapple, tapioca, teak are the major crops adopted in the tropical humid region of Kerala apart from rubber. Better yield of those crops can be achieved by correcting soil acidity including external mineral plant nutrient supplements along with soil conservation measures.

Keywords: Land suitability, crops, tropical humid region, Kerala

Introduction
Land evaluation is defined as "the process of assessment of land performance when used for specific purposes." The FAO land evaluation framework has been the primary method practiced worldwide to address local, regional, and national land use planning (FAO, 1976) [2]. The increased necessity for food production and the limited resources stimulate a need for sophisticated methods of land evaluation to aid decision-makers in their role to both preserve highly suitable lands and satisfy producers' demands for enhanced profits (Bagherzadeh and Daneshvar, 2011) [11]. Land suitability assessment is a specific type of land evaluation method, proposed by FAO (FAO 1976 & 1983) [2, 3] to assess the resources of an area for specific crop rather than for a general use, it integrates soil characteristics with climate and land use. Soil-site characteristics identifies the degree of suitability for land use which aids in planning expansion of area under a suitable site specific crop (Singh *et al*. 1998 and Sharma *et al*. 2001) [16, 14]. Plant available nutrients, crop protection, irrigation and high labor costs needs high investments requiring proper land suitability determination so that cost effective, economical and profitable to farmers (Naidu *et al.* 2009) [11]. For deriving crop suitability of a particular area detailed soil information is essential. By using detailed soil survey data we have arrived with soil mapping units. Assigning soil site suitability criteria to particular mapping units, soil suitability maps have been generated in the GIS environment. In order to assess the suitability of crops adopted to tropical humid region of Kerala, India, we have selected Elamdesam block of Idukki district, Kerala, India in the present study.

Materials and methods

Details of the study area

Elamdesam block falls under the agro-ecological zone foot hills and high hills, the agro ecological units 12 and 14 i.e. southern and central foot hills and southern high hills, respectively. These units are subdivided in to forests, denudational hills, lateritic terrain and lateritic valley lying between north latitudes 9^0 46' 38.2" and 10^0 2' 18.14" and east longitudes 76^0 42' 59.49" and 76^0 53' 46.99". There are seven panchayats namely Vannapuram, Kodikulam, Karimannor, Udumbannoor, Alakode, Velliyamattom and Kudayathoor in the Elamdesam block and eight villages covering a total geographical area of 40,307 ha. Location map given in the Figure 1. Geology of the area is charnockite and granite gneiss of the Archaen age. Elevation ranges from 30 m in low land to 850 m in high hills. Climate is tropical humid monsoon type. Rainfall ranges from 3462 mm to 3602 mm and mean annual temperature varies between 22 ^oC to 27 ^oC. Length of dry period is two to two and a half months. High hills are covered by mixed forest whereas foot hills and midlands have plantation of rubber, coconut, pepper, banana, pineapple, arecanut, cocoa, nutmeg, cashew. Low land is occupied by paddy and tapioca, banana, coconut arecanut and rubber were also cultivating in raised beds.

In Elamdesam block agriculture is the fundamental livelihood activity among the people. Detailed soil survey (*Soil Survey Manual*, 1993) [17] conducted during 2016, studied 134 soil profiles. 12 soil series and 31 soil mapping units identified in the study area. Ultisols, Inceptisols and Alfisols forms the major soil type. Physical and chemical properties of soils of the study area are given in the table 1. The soils, are shallow to very deep, though strongly acid low-activity clay, is fairly rich in organic matter. Correction of soil acidity and external mineral plant nutrient supplements are necessary. Soil conservation measures like cover crops, strip terracing, stone pitched contour bunds, earthen bunds are adopted in the moderately sloping to steeply sloping land.

Table 1: Physical and chemical properties of soils of the Elamdesam block, Kerala, India

Depth cm	Horizon	Particle size distribution (% of <2 mm)			Organic Carbon (%)	pH	EC (dS m^{-1})	Exchangeable bases (cmol (p+) kg^{-1})				CEC	CEC/ Clay (%)	B.S (%)
		Sand	Silt	Clay				Ca	Mg	Na	K			
Pedon 1: Loamy mixed, isohyperthermic family of acid active Ustic Haplohumults														
0-18	Ap	53.73	17.85	28.42	2.68	4.16	0.18	0.59	0.12	0.08	0.20	13.93	0.49	7
18-42	Bt1	45.91	21.54	32.55	1.95	4.45	0.08	0.23	0.04	0.07	0.08	14.47	0.44	3
42-79	Bt2	51.70	23.43	24.87	0.97	4.75	0.03	0.17	0.01	0.03	0.04	9.29	0.37	3
79-111	2BC1	67.80	16.82	15.38	0.73	5.20	0.02	0.20	0.01	0.04	0.05	9.18	0.60	3
111-135	2BC2	71.69	13.20	15.12	0.40	5.05	0.02	0.09	0.01	0.04	0.06	8.53	0.56	2
135-160	CB	63.11	17.02	19.87	0.36	5.00	0.01	0.16	0.00	0.03	0.03	6.91	0.35	3
Pedon 2: Loamy mixed isohyperthermic family of acid semiactive Humic Dystrustepts														
0-14	Ap	59.23	14.52	26.24	1.79	4.61	0.04	0.26	0.08	0.05	0.13	8.64	0.33	6
14-30	AB	69.96	9.51	20.54	1.79	4.36	0.19	1.02	0.27	0.09	0.21	9.29	0.45	17
30-54	BW	58.41	13.70	27.89	1.47	4.49	0.05	0.23	0.01	0.04	0.12	8.75	0.31	5
Pedon 3: Loamy skeletal mixed isohyperthermic family of acid semiactive Humic Dystrustepts														
0-15	Ap	64.30	15.30	20.40	2.68	5.37	0.03	0.87	0.21	0.04	0.17	10.51	0.51	12
15-34	AB	62.18	15.89	21.93	1.76	5.18	0.02	0.27	0.06	0.00	0.09	7.75	0.35	5
34-75	BW	57.74	17.00	25.26	0.8	5.08	0.01	0.25	0.05	0.15	0.07	7.55	0.30	7
Pedon 4: Clayey mixed isohyperthermic family of acid semiactive Ustic Haplohumults														
0-10	Ap	43.40	15.00	41.60	3.39	4.44	0.14	0.60	0.18	0.09	0.27	15.12	0.36	8
10-30	Bt1	47.77	15.09	37.14	3.07	4.20	0.17	0.65	0.11	0.07	0.14	13.18	0.35	7
30-50	Bt2	46.09	15.32	38.59	3.03	4.57	0.11	0.64	0.11	0.05	0.10	13.28	0.34	7
50-70	Bt3	44.31	18.47	37.22	3.23	4.81	0.10	0.58	0.09	0.07	0.11	14.04	0.38	6
70-90	Bt4	37.68	22.99	39.33	2.06	4.97	0.03	0.22	0.05	0.05	0.10	12.74	0.32	3
90-110	Bt5	36.83	23.43	39.74	2.3	4.87	0.03	0.31	0.00	0.06	0.13	13.93	0.35	4
110-150	Bt6	37.63	22.98	39.39	1.74	5.00	0.03	0.31	0.05	0.04	0.11	11.66	0.30	4
Pedon 5: Clayey kaolonitic isohyperthermic family of Ustic Kandihumults														
0-16	Ap	53.4	10.8	35.8	1.59	5.22	0.05	0.97	0.12	0.05	0.10	5.94	0.17	21
16-35	Bt1	47.5	16.8	35.6	1.23	5.42	0.02	0.70	0.00	0.04	0.04	4.75	0.13	17
35-57	Bt2	42.8	17.3	39.9	0.99	5.11	0.02	0.42	0.00	0.03	0.02	4.86	0.12	10
57-96	Bt3	44.6	13.9	41.5	0.91	4.87	0.02	0.32	0.00	0.03	0.02	4.10	0.10	9
96-125	Bt4	44.7	15.9	39.5	0.91	4.89	0.02	0.32	0.00	0.02	0.02	4.00	0.10	9
125-151	Bt5	55.8	6.6	37.6	0.79	4.85	0.02	0.11	0.00	0.02	0.02	3.35	0.09	5
151-177	Bt6	38.9	17.5	43.6	0.59	4.81	0.02	0.10	0.00	0.02	0.02	3.78	0.09	4
177-210	Bt7	40.7	21.3	38.0	0.51	5.23	0.01	0.13	0.00	0.02	0.02	2.48	0.07	7
Pedon 6: Clayey mixed acid isohyperthermic family of semiactive Ustic Haplohumults														
0-15	Ap	45.89	16.51	37.61	3.17	4.55	0.08	0.61	0.22	0.12	0.38	13.93	0.37	10
15-31	Bt1	46.70	15.31	38.00	2.1	4.52	0.04	0.13	0.03	0.09	0.17	11.66	0.31	4
31-65	Bt2	54.63	7.38	38.00	1.27	4.62	0.03	0.08	0.00	0.08	0.12	8.86	0.23	3
65-100	Bt3	58.89	4.23	36.88	0.83	4.54	0.03	0.08	0.00	0.07	0.11	10.37	0.28	3
Pedon 7: Fine loamy mixed isohyperthermic family of acid semiactive Humic Dystrustepts														
0-12	Ap	54.67	13.83	31.50	1.61	5.01	0.09	2.17	0.52	0.03	0.31	10.30	0.33	29
12-30	AB	51.53	16.36	32.11	1.32	4.93	0.05	1.79	0.32	0.01	0.10	10.61	0.33	21
30-51	BW1	51.00	14.38	34.61	1.4	4.9	0.03	1.12	0.20	0.00	0.10	11.0	0.32	13
51-63	BW2	50.48	12.41	37.12	1.44	4.93	0.02	0.71	0.15	0.09	0.10	10.51	0.28	10

Pedon 8: Loamy mixed isohyperthermic family of acid semiactive Lithic Dystrustepts														
0-12	Ap	65.24	13.15	21.61	1.99	4.96	0.05	0.81	0.35	0.08	0.17	10.04	0.46	14
12-22	BW	61.56	15.08	23.36	1.59	5.04	0.04	0.50	0.20	0.04	0.09	8.86	0.38	9
22-35	BC	69.33	10.62	20.05	1.03	5.25	0.03	0.43	0.19	0.04	0.08	7.99	0.40	9
Pedon 9: Loamy mixed isohyperthermic family of acid semiactive Ustic Haplohumults														
0-16	Ap	42.54	19.74	37.72	2.51	5.63	0.03	1.65	0.71	0.22	0.90	14.58	0.39	24
6-38	Bt1	42.90	20.55	36.55	2.07	5.24	0.03	0.53	0.13	0.11	0.35	13.39	0.37	8
38-65	Bt2	46.94	16.67	36.39	1.55	5.15	0.02	0.28	0.14	0.10	0.15	11.88	0.33	6
65-83	2Bt3	56.04	18.45	25.52	0.83	5.12	0.02	0.14	0.11	0.08	0.15	11.45	0.45	4
83-102	2BC	65.50	16.14	18.36	0.67	5.22	0.02	0.12	0.13	0.10	0.19	8.40	0.46	6
Pedon 10: Clayey kaolinite isohyperthermic family of acid subactive Ustic Haplohumults														
0-11	Ap	55.56	15.78	28.66	1.99	5.56	0.08	2.74	0.82	0.19	0.51	9.72	0.34	44
11-32	Bt1	52.22	13.29	34.49	0.95	5.26	0.04	2.51	1.24	0.17	0.35	7.99	0.23	53
32-58	Bt2	41.42	19.69	38.89	0.71	5.53	0.03	2.01	1.65	0.18	0.43	7.78	0.20	55
58-82	Bt3	44.35	16.92	38.73	0.67	5.65	0.02	1.15	1.41	0.15	0.32	7.67	0.20	39
Pedon 11: Sandy mixed isohyperthermic family of acid subactive lithic Ustorthents														
0-13	Ap	75.65	12.98	11.37	2.55	5.18	0.06	1.16	0.48	0.10	0.15	8.96	0.79	21
13-32	AC	71.16	19.89	8.95	2.19	5.60	0.02	3.59	0.94	0.07	0.06	9.40	1.05	50
Pedon 12: Fine, mixed, acid, isohyperthermic sub-active family of Oxyaquic Haplustalfs														
0-11	Ap	45.48	16.47	38.05	1.19	4.9	0.04	1.86	0.63	0.07	0.12	9.08	0.24	30
1-27	BW1	42.63	19.84	37.53	1.39	4.16	0.15	1.17	0.15	0.25	0.05	8.57	0.23	19
27-41	BW2	47.81	19.24	32.94	1.35	4.42	0.07	0.76	0.14	0.15	0.03	7.45	0.23	14
41-54	Bt1	39.17	19.12	41.71	0.99	5.3	0.03	1.72	0.66	0.05	0.04	7.14	0.17	35
54-70	Bt2	40.48	15.01	44.51	0.8	5.33	0.03	1.65	0.85	0.03	0.05	7.55	0.17	34
70-81	Bt3	47.36	11.53	41.11	0.83	5.33	0.03	1.56	0.88	0.15	0.07	6.53	0.16	41
81-95	BC1	17.91	18.58	63.52	2.59	4.77	0.06	1.97	1.09	0.13	0.12	16.22	0.26	20

Structure of the Classification for Soil suitability Evaluation

The land suitability classification is a four tier system i.e., orders, classes, subclasses and units. At the order level, the land units are grouped into suitable or not suitable based on kinds of suitability for the selected land use. The orders are further divided into classes based on degrees of suitability and the classes are further divided into subclasses based on the kinds of limitations, subclasses are divided into land suitability units based on specific management requirements (Sys, 1993; NBSS&LUP, 1994 and Naidu *et al.*, 2006) [18, 9, 10].

A brief description of the orders and classes used in the suitability assessment for major crops grown in the area is given below.

Order S (Suitable)

Class S1 (Highly suitable) - Land having no or slight limitations for sustainable use

Class S2 (Moderately suitable) - Land with moderate limitations for sustained use.

Class S3 (Marginally suitable) Land with severe limitations for sustained use.

Order N (Not Suitable)

Class N1 (Currently not suitable) - Land with severe or very severe limitations that may be overcome in time but cannot be corrected with existing knowledge at current acceptable cost.

Class N2 (Permanently not suitable) - Land having limitations that appear so severe as to prelude any possibility of use of the land.

Classes S2 and S3 were further divided into sub classes based on the specific limitations encountered in the area. There are no subclasses within suitability class S1. The specific limitations affecting crop production in the area are indicated below with their symbols.

Climate: temperature, rainfall total and distribution, dry months and growing period -	c
Topography	l
Erosion	e
Soil depth or rooting condition	r
Soil texture (sandy or heavy clay)	t
Coarse fragments	g
Soil fertility (calcareousness)	s
Nutrient status (CEC/BS)	n
Drainage	w
Flood	f
Depth to water table	d

Limitations are indicated in lower case letters after the class symbol. For example moderately suitable land with low rainfall/short growing period as a limitation is designated as S2c. Normally two and sometimes three limitations are indicated at sub class level. The Arabic numbers, wherever used, indicates land suitability units, after the limitation symbol.

Land suitability assessment for major crops adopted to the area.

Using the soil site suitability criteria (NBSS&LUP, 1994 & Naidu *et al.*, 2006) [9, 10] land resource of the Elamdesam block was assessed for their suitability for the following crops.

Cereals:	Paddy.
Plantation Crops: Oil seeds/Fibre:	Coconut.
Chewing/Paint Industry:	Arecanut
Spices:	Pepper
Horticultural crops: Fruit crops:	Banana, Pineapple
Tuber Crops:	Tapioca (Cassava)
Forest Plantations:	Teak

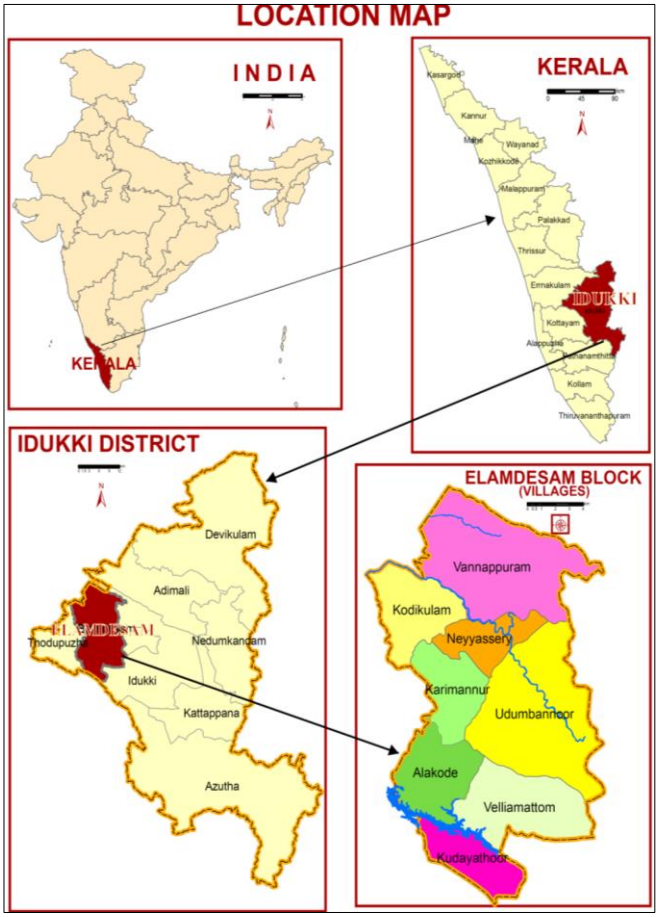


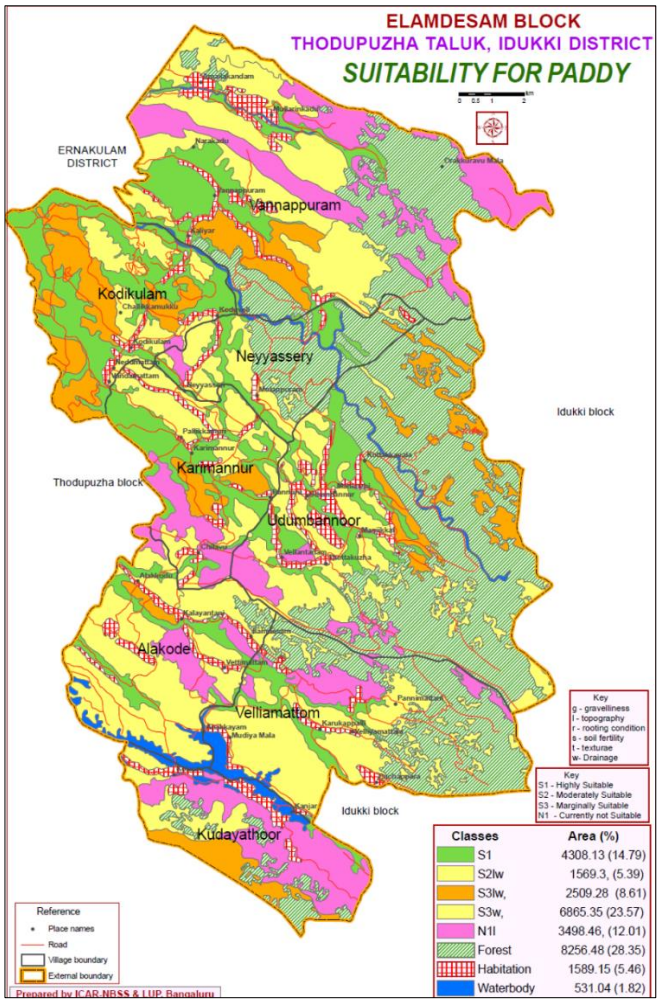
Fig 1: Location map of the study area (Elamdesam block)

Result and discussion

Land suitability for Paddy (*Oryza sativa* L.)

Rice is the staple food crop of this region. In Kerala it is cultivated in about 2.87 lakh hectares and commercial cultivation is restricted to Palakkad, Trissur Kole lands and Kuttanadu area. The production is about 5.70 lakh tons with an average productivity of 1986 kg per ha. Rice is a water-loving plant requiring abundant water supply. The average temperature required throughout the life period of the crop ranges from 21 to 35 ºC. It can be grown on a variety of soils ranging from waterlogged and poorly drained soils to well drained soils (Murthy, 1978). In India, rice is grown under diverse soil conditions and over a wide range of soil reaction from pH 4.5 to 8.0. The soils most suited for its cultivation are heavy soils (clay or clay loam) and loam soils (Jha *et al.*, 1999) [5].

Highly suitable area occupies nearly 14.79 per cent (Map 1) and moderately suitable area constituted 5.39 per cent of total area with limitation of topography and drainage. Marginally suitable area is present in 32.18 per cent of total geographical area with limitation of topography and drainage and 12.01 per cent of total area is unsuitable. Land suitability assessment of Rice Crop in Sheikhupura and Nankana Sahib Districts of Punjab was studied and inferred that 72.2% of the total agri-land is generally suitable for rice crop in the study area (Waqar *et al.*, 2014) [6]. Generally, majority of the area in central Guilan, Iran are marginally suitable for rice (Soltani *et al.*, 2013) [15]. Areas that are classified as highly suitable and suitable for rice cultivation constitute about 59.8% of the total area of central part of Amol District, Iran (Maddahi *et al.*, 2017) [19]. In Chamarajanagar district, Karnataka, India, the hilly areas and sloping upland areas were permanently not suitable due to very severe limitations of drainage and slope where as the other uplands and midlands were marginally suitable, due to slope, erosion and drainage. Lowlands were moderately to highly suitable due to moderate limitations of climate and fertility factors (Rahman *et al.*, 2016) [7].



Map 1: Soil suitability for Paddy

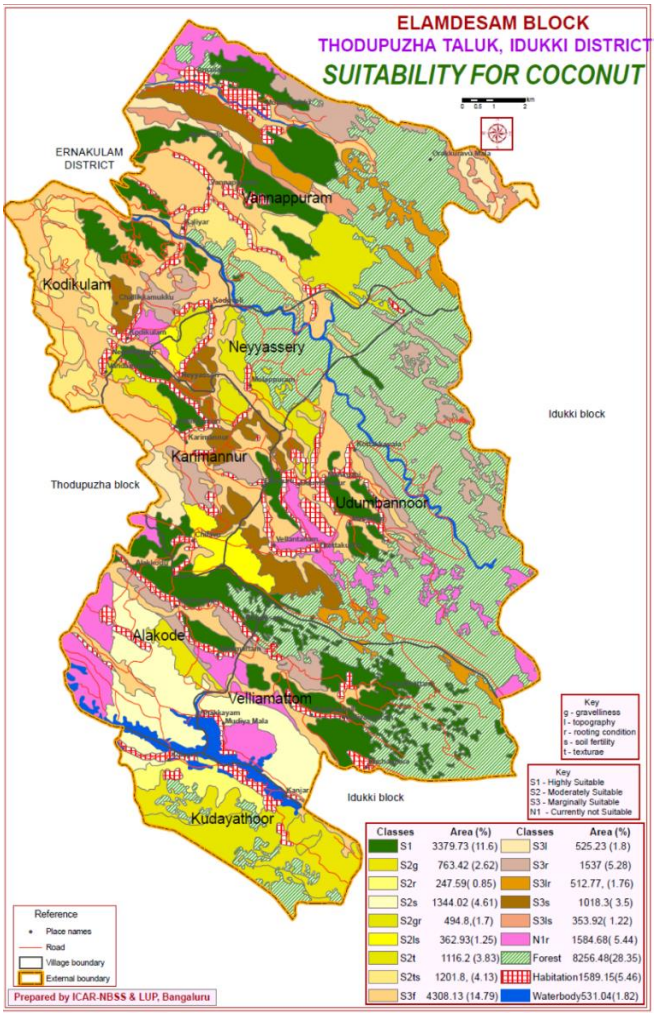
Land suitability for coconut (*Cocos nucifera L.*)

In Kerala coconut is grown in about 8.99 lakh hectares, and production is 5876 million nuts with an average productivity of 6536 nuts per ha. It is the most important perennial plantation and oil cum fibre yielding crop of the state. Areas receiving good rains throughout the year (1500-2500 mm) and high relative humidity (>80%) and preferably with a dry period of less than 3 months are favourable if temperature ranges from 26 to 29 ºC.

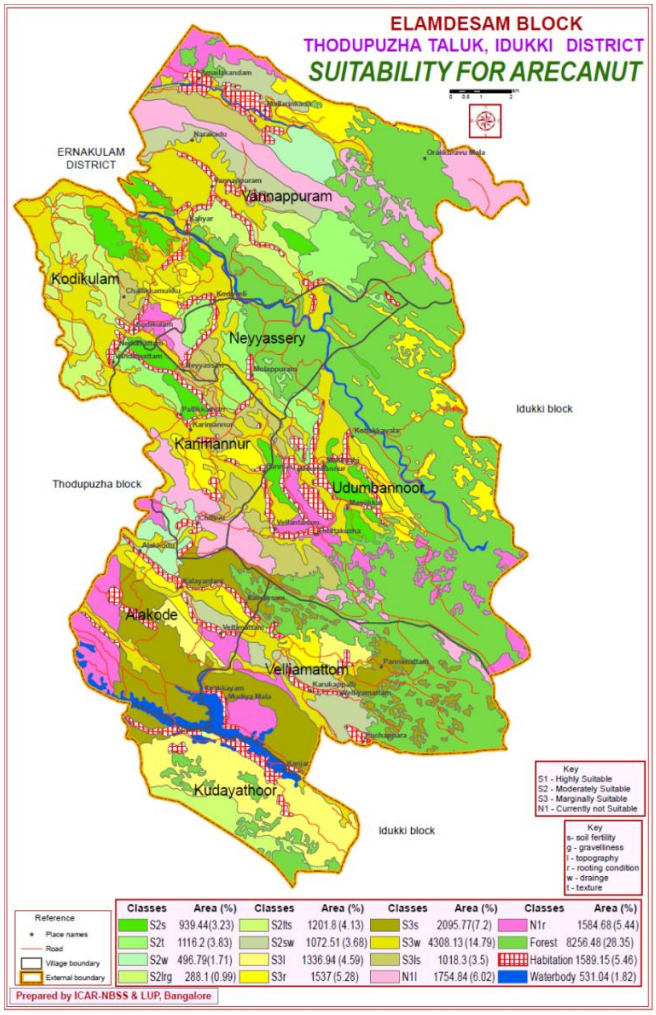
Coconut is grown at elevations of less than 600 m and on less than 8 per cent slopes on a wide variety of soil types, ranging from heavy clay to sandy soils, however deep to very deep; welldrained and medium textured soils are most suitable. Soil pH from 5.1 to 6.5 is ideal and the crop is sensitive to poor drainage and waterlogging, presence of free iron and aluminium, low pH in the subsoil, extreme gravelly and stony soils, sodicity and salinity.

Highly suitable area occupies nearly 11.6 per cent (map 2) and moderately suitable area constituted 18.99 per cent of total area with limitation of gravelliness, root restriction, soil fertility, topography and soil texture. Marginally suitable area is present in 28.35 per cent of total geographical area with limitation of flooding, topography, root restriction and soil fertility and 5.44 per cent of total area is unsuitable. The suitability of land for coconut in Giddadapalya micro

watershed, Tumkur District, Karnatak indicated that the main constraints are topography and rooting depth in moderately suitable soils. Sub surface gravels, topography are the main constraints in marginally suitable land (Geetha, *et al.*, 2017) [4]. In soils of Ozat River Valley of Southern Saurashtra Region of Gujarat were marginally suitable (S3) for coconut. Topography, drainage, shallow soil depth, low rainfall, texture, poor soil fertility (soil pH) soil salinity and alkalinity are the major limitations for cultivation of coconut in the region (Savaliya *et al*., 2018). In Chamarajanagar district, Karnataka, India, the upland area was marginally suitable due to severe limitations in topography and texture; midlands were also marginally suitable whereas, lowlands were suitable for coconut. The area represented by uplands, midlands and lowlands was marginally suitable due to severe climatic limitations such as rainfall and mean maximum temperature (Rahman *et al.*, 2016) [7].



Map 2: Soil suitability for coconut



Map 3: Soil suitability for arecanut

Land suitability for arecanut (*Areca catechu L.*)

In Kerala arecanut is grown in about 1.03 lakh hectares, and production is 1.05 lakh tons of betel nuts with an average productivity of 1029 kg per ha. It is the most important pan and paint ingredient yielding crop of the state. Areas receiving good rains throughout the year (1500-4500 mm) and high relative humidity (>80%) preferably with a dry period of less than 3 months are favourable if temperature ranges from 25 to 30 ºC and can bear extremes upto 15-40 ºC, but with out wide diurnal variations.

Arecanut is grown at elevations of less than 600 m on less than 3 per cent slopes on a wide variety of soil types, ranging from heavy clay to sandy soils, however deep to very deep; welldrained and medium textured soils are most suitable. Soil pH from 5.0 to 6.5 is ideal and the crop is sensitive to poor drainage and waterlogging, presence of free iron and aluminium, low pH in the subsoil, extreme gravelly and stony soils, sodicity and salinity.

Moderately suitable area constituted 17.57 per cent of total area with limitation of topography, root restriction, gravelliness, soil fertility and soil texture (Map 3). Marginally suitable area is present in 35.36 per cent of total geographical area with limitation of topography, root restriction, drainage and soil fertility and 11.46 per cent of total area is unsuitable. The suitability of land for arecanut in giddadapalya micro watershed, Tumkur District, Karnataka indicated that about 72.09% of area (351 ha) is highly suitable and 24.07% of the area (117 ha) is moderately suitable due to limitations like gravelliness (Geetha, *et al.*, 2017) [4].

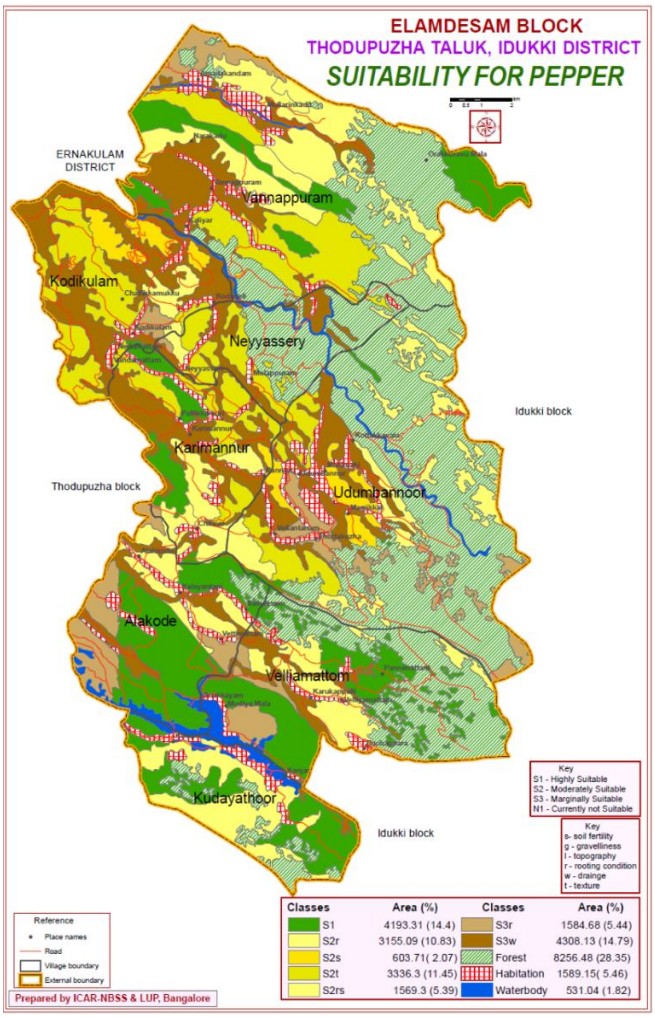
Land suitability for pepper (*Piper nigrum L.*)

In Kerala pepper is grown in about 2.2 lakh hectares, and production is 0.7 lakh tons of black pepper with an average productivity of 319 kg per ha. It is the most pan important spice crop of the state. Areas receiving good rains throughout the year (2500-3000 mm) and high relative humidity (>80%) and preferably with a dry period of less than 3 months with day temperature ranging from 28 to 35 ºC are favourable.

Pepper is a climber grown at elevations of less than 1500 m on less than 8 per cent slopes on trees like erythrina, silver oak or even arecanut or coconut with partial shading on a wide variety of soil types, ranging from heavy clay to sandy

soils, however deep to very deep, welldrained huimus rich red and lateritic soils on hillslopes of Western ghats are most suitable environment. Soil pH from 6.0 to 6.5 is ideal and the crop is sensitive to poor drainage and waterlogging, presence of free iron and aluminium, low pH in the subsoil, extreme gravelly and stony soils, sodicity and salinity.

Highly suitable land occupies 14.4 per cent of the area and moderately suitable area constituted 29.74 per cent of total area with limitation of root restriction, soil fertility and soil texture (map 4). Marginally suitable area is present in 20.23 per cent of total geographical area with limitation of root restriction and drainage.



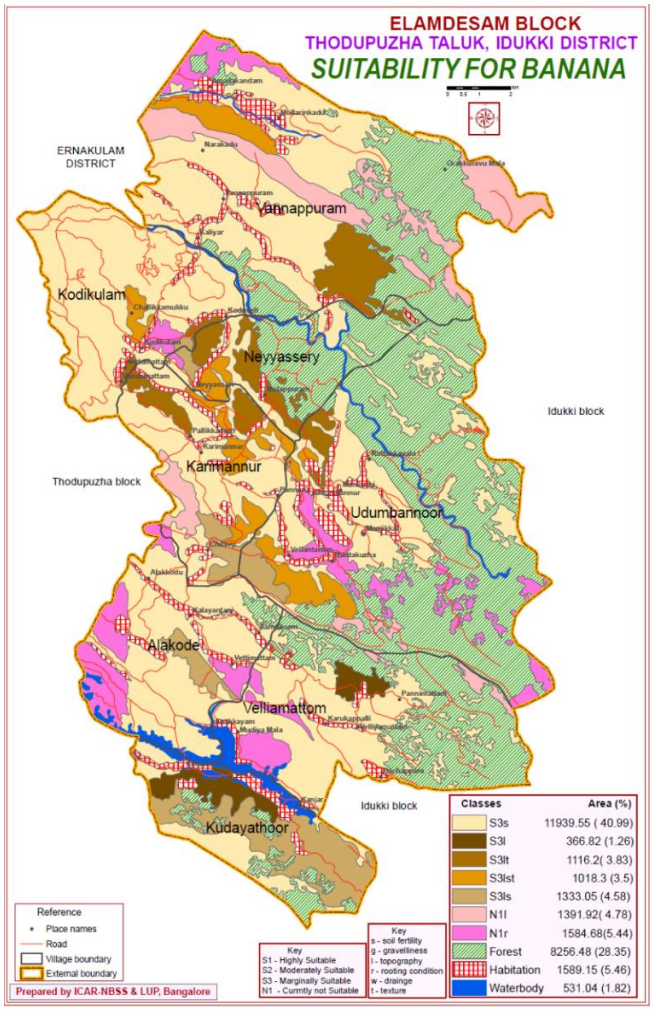
Map 4: Soil suitability for pepper

Land suitability for banana plantains (*Musa sp. L.*)

In Kerala banana is grown in about 1.1 lakh hectares, and production is 8.4 lakh tons of banana with an average productivity of 7724 kg per ha. It is the most important fruit crop of the state. Banana is strictly a tropical crop. Areas receiving good rains throughout the year (100 mm per month) and high relative humidity (>80%) are favourable if temperature ranges from 26 to 33 ºC and can bear extremes upto 10-38 ºC, but with out wide diurnal variations. Wind velocity should not exceed 40 km per hour, which may cause either uprooting, breakage of pseudostem or immature bunches.

Banana is grown at elevations of less than 1500 m on less than 3 per cent slopes on a wide variety of soil types, ranging from heavy clay to sandy soils, however deep to very deep; welldrained and medium textured soils are most suitable. Soil pH from 5.5 to 7.0 is ideal and the crop is sensitive to poor drainage and waterlogging, presence of free iron and aluminium, low pH in the subsoil, extreme gravelly and stony soils, sodicity and salinity.

Marginally suitable area is present in 54.16 per cent of total geographical area with limitation of topography, soil fertility and soil texture (map 5) and 10.22 per cent of total area is unsuitable. Considering the soil-site suitability criteria, Bharuch, Palsana and Jalalpore are identified as highly suitable talukas of south Gujarat, India for banana cultivation. While the Narmada, Jhagadia, Kamrej, Bardoli, Navsari and Valsad were categorized in moderately suitable class (S2). The suitability class can be improved if the correctable limitations (soil fertility characteristics) are altered through soil amelioration measures (Kumar, *et al*., 2017) [13]. In Chamarajanagar district, Karnataka, India, the upland areas were marginally suitable due to moderate limitations in rainfall, temperature, erosion, depth, coarse fragments and CEC. Similarly, midlands were also marginally suitable, whereas lowlands were presently not suitable but potentially suitable due to moderate drainage (Rahman *et al.*, 2016) [7].

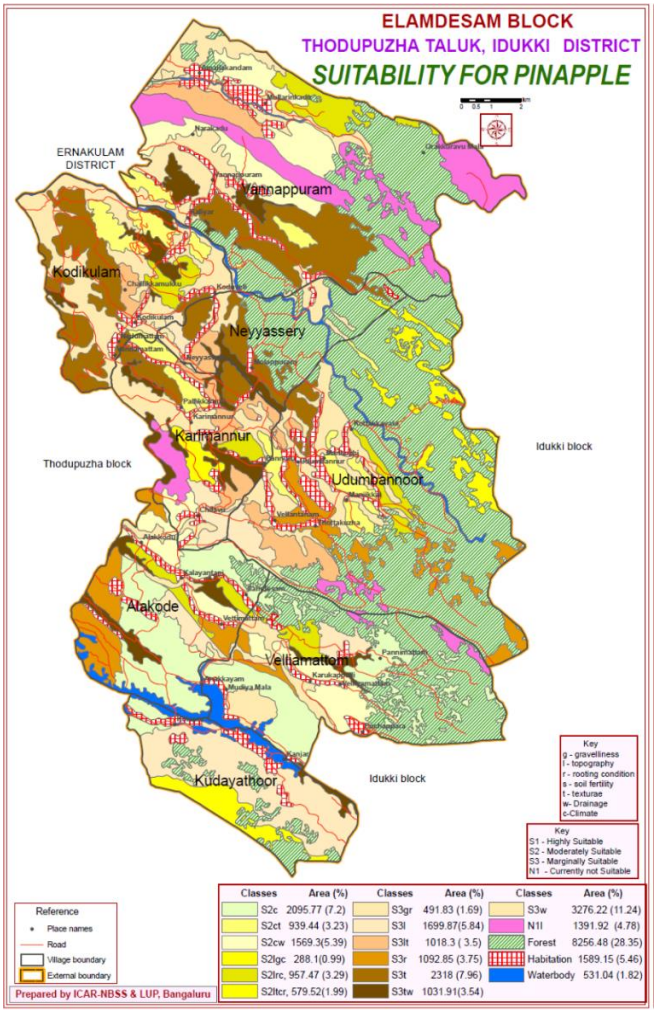


Map 5: Soil suitability for banana

Land suitability for pineapple

Moderately suitable area constituted 22.09 per cent of total area with limitation of climate, drainage, soil texture, topography, gravelliness and root restriction (map 6). Marginally suitable area is present in 37.52 per cent of total geographical area with limitation of gravelliness, root restriction, topography, soil texture and drainage. In East Khasi Hills district of Meghalaya, land suitability analysis for pineapple showed that 81% area of total geographical area of

the district is marginally suitable and 19% area is not suitable to support the crop. The district is marginally suitable because of topography (slope and erosion), soil fertility (base saturation and CEC) and climate (Das and Sudhakar, 2014) [12].



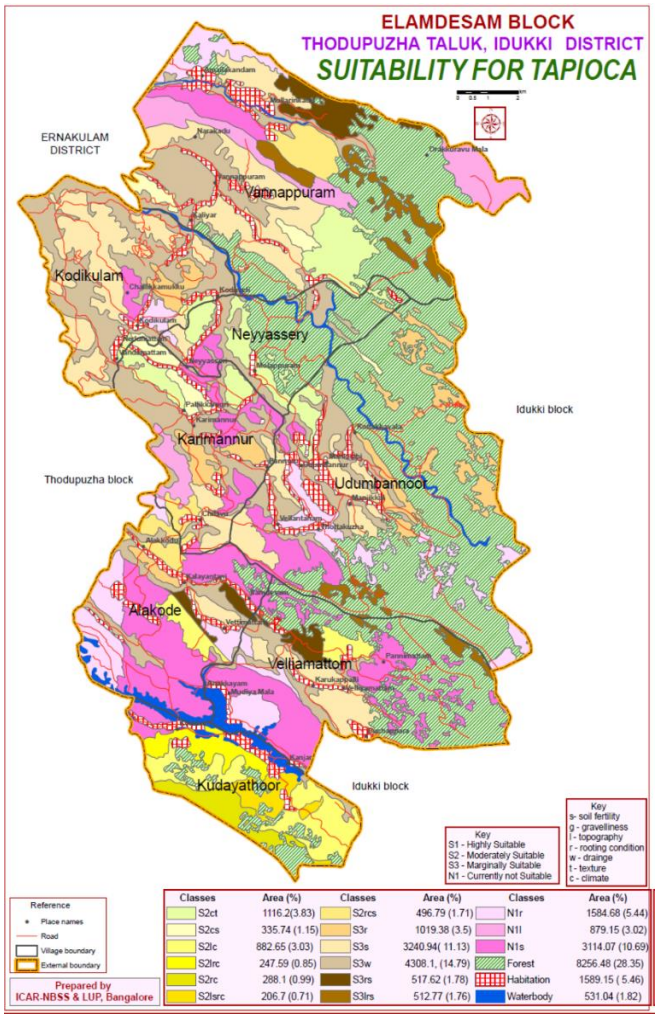
Map 6: Soil suitability for pineapple

Land suitability for tapioca (*Manihot esculenta L.*)

In Kerala tapioca is grown in about 0.9 lakh hectares, as all season crops and a production is 25.4 lakh tons of tuber with an average productivity of 26.6 tons per ha. It is the most important tuber and starch yielding crop of the state. Tapioca is strictly a tropical crop. Areas having annual temperatureof 15-35 ^{o}C and receiving annual precipitation of 1400-1800 mm is good for its cultivation, but can be extended to areas receiving 500-5000 mm and having an insolation ratio of more than 0.6 and can afford a dry period of maximum 7 months in a year.

Tapioca is grown at slopes of nearly level to 30 per cent slopes on a wide variety of soil types, ranging from heavy clay to sandy soils except on swelling clay or silty clays, however deep to very deep; well drained and medium textured soils are most suitable. Soil pH from 4.5 to 8.3 is needed for cultivation and the crop is sensitive to poor drainage and waterlogging, presence of free iron and aluminium, extreme gravelly and stony soils, sodicity and salinity.

Moderately suitable area for tapioca constituted 12.27 per cent of the total area in the block with limitation of climate, topography, root restriction, soil fertility and soil texture (Map 7). Marginally suitable area is occurring in 32.96 per cent of total geographical area with limitation of root restriction, soil fertility, topography and drainage.

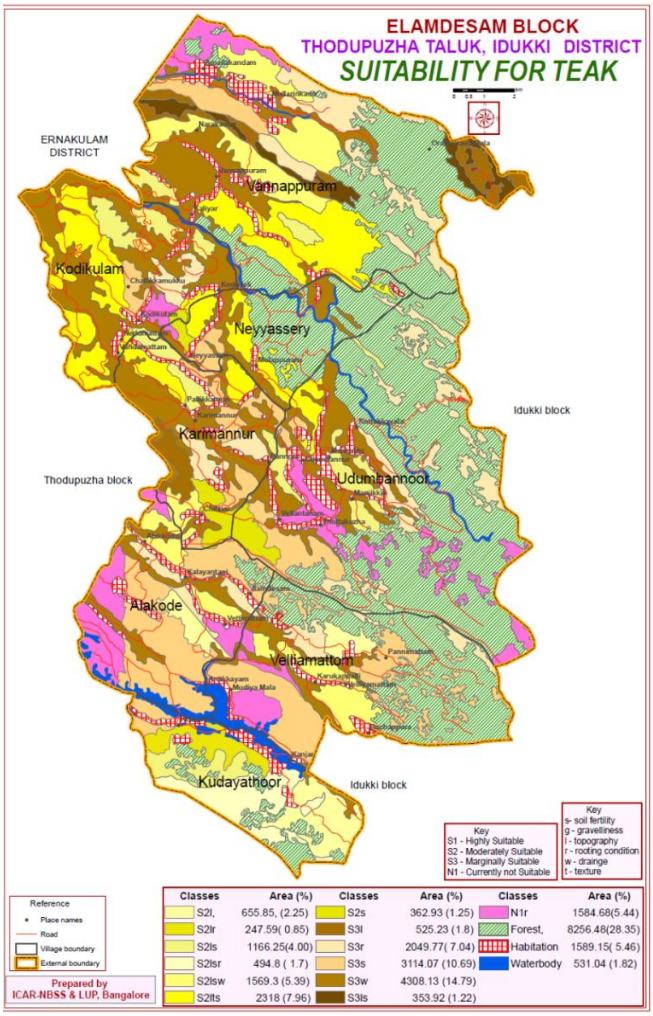


Map 7: Soil suitability for tapioca

Land suitability for Teak

There is considerable area under teak in the Western Ghats region, foot hill region as well as lateritic midlands, either as protected forest trees or as forest plantations. Generally teak prefers a well-drained soil with wide climatic range and prefers acidic soil reaction and can afford to grow under high free aluminium containing soils but reports of its tolerance to aluminium toxicity is seldom seen. Leaf litter restrict undergrowth as well as poor micro floral and faunal population and there by the teak plantations are subjected threats of high splash and sheet erosion with crusting and compaction.

Moderately suitable area constituted 23.4 per cent of total area with limitation of topography, root restriction, soil fertility, drainage and soil texture (Map 8). Marginally suitable area is present in 35.54 per cent of total geographical area with limitation of root restriction, soil fertility, topography and drainage. To know the suitability of teak, mahogany and silk tree, a research was conducted on four districts In Buton regency, is situated in the southeastern part of Sulawesi Island, Indonesia. Based on land suitability classification, there are two classes found in the Kalalassi region, namely: moderately suitable (S2) which were located 3,836.05 ha for teak and mahogany and marginally suitable (S3), which are located 3,343.45 ha for teak, 3,467.20 ha for mahogany, and 10,106.22 ha for silk tree (Kandari *et al*., 2015).



Map 8: Soil suitability for Teak

Conclusion

The land suitability evaluation provided the information on soil properties that limits crop growth. Therefore, it is suggested that farmers can cultivate paddy in low land whereas coconut, arecanut, pepper, banana, pineapple and tapioca, in the upland and midland. However, area under these crops can be expand by correcting soil acidity including external mineral plant nutrient supplements along with soil conservation measures like cover crops, strip terracing, stone pitched contour bunds and earthen bunds. Teak can be grown in the hilly areas and ghats. Forest plantation planning of teak, if properly managed can bring about change of local farmers' prosperity through job creation and an increase of long term incomes.

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