Research Article

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Mapping soil constraints for coconut using RS and GIS for the major coconut growing region of Tamil Nadu

V. Selvamani[1]* and V.P. Duraisami

Tamil Nadu Agricultural University, Coimbatore - 641 003, Tamil Nadu, India
[1]Central Plantation Crops Research Institute, Kasaragod-671 124, Kerala, India

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Abstract

A study was conducted to generate soil constraint maps for coconut using RS and GIS techniques. The study area covered Coimbatore and Tiruppur districts of Tamil Nadu state. A survey was conducted to collect soil samples and other basic data from 110 coconut plantations. Relationships of yield to soil properties were studied through correlation coefficient. Highest, positive and significant correlation was observed between soil depth and coconut yield. Among the physical properties studied *viz.*, clay, silt, sand, bulk density, particle density and porespace, significant and negative correlation was obtained between sand content and yield. Based on these strong correlations, the constraints of soil parameters like soil depth, drainage, soil reaction and soil texture of the soil series were mapped for the coconut land cover of this study area. Under soil series wise constraints mapping, 3.9, 64.4 and 31.5 per cent of the total coconut land cover was found to be moderately suitable, marginally suitable and not suitable class respectively based on the most limiting constraint of the studied soil properties.

Keywords: Coconut, RS and GIS, soil constraints, soil series

Introduction

Soils differ in their properties and in their capacity to fulfill their functions. Consequently, the productive potential of a soil is limited by its inherent constraints. The soil condition requirement differs with different crops. A particular soil property or constraint might be a major problem to the productivity of one crop and it may pose only a minor limitation to another crop. In the case of the standing perennial plantations, it is necessary to identify the existing soil related constraints in order to manage and increase the productivity for the specific crop.

In Tamil Nadu, coconut is grown extensively in Coimbatore, Tiruppur, Thanjavur, Dindigul, Kanniyakumari, Vellore, Erode, Tirunelveli, Theni, Krishnagiri, Salem and Madurai districts. Around 78 per cent of the total area under coconut in Tamil Nadu is from these districts. Considering the larger extent of area under coconut and the coconut based farmer's livelihood, developing site specific soil and nutrient management strategies based on the soil constraints identified to improve the coconut performance will be a major contributor for the region's agricultural growth and strengthening and sustaining farmer's livelihood. Moreover, identification and management of soil constraints will help in increasing the productivity further. Therefore, this study was carried out to identify the major soil series existing under coconut land cover and to map the soil related constraints for coconut performance in Coimbatore and Tiruppur districts using remote sensing (RS) and geographic information system (GIS) techniques.

Materials and methods

The study area covered Coimbatore and Tiruppur districts of Tamil Nadu Geographical area of Coimbatore district is 4,722 km^2, positioned within north latitude of 10°10' and 11°30'and east

Corresponding Author: selvamaniv@gmail.com

longitude of 76°40' and 77°30'. The maximum temperature was 38.0 °C and minimum, 17.4°C. Coimbatore district receives 306.0 mm rainfall from the north east monsoon and 765 mm from south west monsoon. Geographical area of Tiruppur district is 5,186 km^2 with a total cultivated area of 2,28,556 ha. The mean maximum and minimum temperature falls between 35 °C and 18 °C. In the plains of the study area, the average annual rainfall is around 700 mm.

The base map was prepared using the digital map of the study area prepared from the topo sheets. Land cover mapping was done using satellite imagery of the study area available in Google Earth. The elements of visual image interpretation keys of coconut land cover were developed through the ground truth survey of the coconut plantations in the study area. ArcGIS 8.2 software was used to develop coconut land cover map of the study area.

Collection of soil samples and analysis

Soil samples were collected from three soil depths *viz*., 0-30 cm, 30-60 cm and 60-90 cm at one meter away from the bole of the palm. In total 326 soil samples comprising three depths were collected from the two districts. The soil samples collected during the fieldwork were processed after air drying. They were ground using wooden mallet and passed through 2 mm sieve. These soil samples were analyzed for pH and soil texture using standard procedures. Soil texture was determined by international pipette method (Piper, 1966) and soil reaction (pH) using pH meter with glass electrode in the soil water ratio of 1:2.5 (Jackson, 1973).

Yield observation

Nut yield of the palms were collected by counting all the nuts from all available bunches during survey. Total nut yield of the palms were calculated by adding the matured nuts (above fist sized nut) and 30 per cent of the small nuts (below fist sized nut) from each sampled palms as per the setting percentage of the flowers.

Soil constraint mapping using RS and GIS

The map of soil series under coconut plantations was delineated using the coconut land cover map developed in this study and the already available digital soil map of Tamil Nadu at 1:50000 scale (Natarajan *et al.,* 2005). The soil constraints or suitability of the soils for coconut was evaluated by adopting the criteria given by Naidu *et al.* (1997). Constraint maps of the soil properties developed in this study were soil depth, soil drainage, soil reaction and soil texture at soil series level. The suitability classification was done with two orders *viz.,* S - suitability and N - non suitability and with four classes *viz.,* S1 - highly suitable, S2 - moderately suitable, S3 - marginally suitable, and N - not suitable. Soil constraints maps were prepared based on the most limiting soil properties of the soil series.

Results and discussion

Relationship between soil properties and coconut yield

Relationship of coconut yield to soil depth and soil physical properties were studied using correlation coefficients (Table 1). In this study, the highest, positive and significant relationship was observed between soil depth and coconut yield (0.279**). When the soil depth is more, it provides adequate anchorage to the palms and gives more soil volume that can be explored for the nutrients and water (Ohler, 1999), hence, increase in soil depth leads to the increase in nut yield resulting in a significant positive relationship.

Table 1. Correlation coefficients (r) of relationship between soil depth and physical properties with coconut yield (nuts palm^{-1} year^{-1})

Properties	Soil depth		
	(0-30 cm)	(30-60 cm)	(60-90 cm)
Soil depth	0.279**		
Clay	0.087	0.163	0.123
Silt	0.170	0.189	0.170
Total sand	-0.131	-0.199*	-0.172
Bulk density	-0.123	-0.153	-0.094
Particle density	0.057	-0.036	-0.036
Pore space	0.132	0.068	0.030
Soil pH	-0.255**	-0.278**	-0.209*
Nut yield observed in the study area			
	Range	**Mean**	**CV (%)**
Yield (nuts palm^{-1} year^{-1})	48 - 168	90.6	25

*** Correlation is significant at 0.01 level

* Correlation is significant at 0.05 level

N=110

Among the physical properties studied *viz.*, clay, silt, total sand, bulk density, particle density and pore space, significant negative correlation coefficient was observed between sand content at 30-60 cm soil depth and yield (-0.199*). The negative correlation with sand content especially at 30-60 cm depth is due to the decreasing nutrient and water retention with the increasing sand proportion since this soil layer is the most active zone of root activity ensuring productivity. When clay and silt content increased, the nutrient and water retention power of the soil increased, which resulted in reduced leaching loss of nutrients from the root zone. Thus, properties of clay and silt increases the nutrient availability to coconut and results with higher yield. Hence, positive but non-significant correlation was obtained between coconut yield with clay and silt content. This non-significant correlation might be due to the consequence of the variations in the nutrient management and the effect of compaction resulted due to very high clay and silt content which hinders plant growth. Similarly, increase in organic matter, clay and silt content can improve the soil aggregation which in turn can lead to decrease in bulk density incidentally improving the nutrient supply and thereby increased yield. When the sand content increases, bulk density increases and the nutrient supplying power of the soil decreases which leads to the reduction in yield. Thereby, a negative non-significant correlation was found between bulk density and yield. Soil reaction showed significant negative correlation coefficient with yield. Soil pH of the samples ranged from near neutral to alkaline indicating reduced coconut yield with increase in soil pH.

The significant relationship observed between soil depth, soil reaction and soil texture with coconut yield emphasizes the importance of these properties and the related soil properties like, soil drainage, soil texture and soil reaction in coconut productivity apart from the soil fertility. Therefore, soil constraints mapping of these relatively permanent soil properties at soil series level in the existing plantations will be useful for evolving a soil management strategy including nutrient management. In this study, the soil constraint map was created at soil series level and the limitations are defined for the soil series instead of creating continuous data from sampling points using geo-statistical techniques.

Soil series under coconut in the study area

The soil series map of coconut land cover was developed using the soil series map and coconut land cover map. From the developed soil series map of coconut land cover, it was found that, coconut is cultivated in around 60 different soil series. Among them only three soil series *viz.*, Anamalai (23,031 ha: 20.2 %), Attipalaiyam (15,001 ha: 13.2 %) and Pilamedu (14,067 ha: 12.4 %), each one was occupying more than 10 per cent of the coconut land cover and 14 soil series, each one was occupying more than one per cent of the total coconut land cover. They were Irugur (7,053 ha: 6.2 %), Kallivalasu (5,727 ha: 5.0 %), Kanjampatti (4,633 ha: 4.1 %), Vellalur (4,456 ha: 3.9 %), Somayyanur (4,416 ha: 3.9 %), Palathurai (4,117 ha: 3.6 %), Varapatti (3,989 ha: 3.5 per cent), Salaiyur (3,382 ha: 3.0 %), Palaviduthi (2,869 ha: 2.5 %), Ettinayakanpatti (2,281 ha: 2.0 %), Sengalam (2,180 ha: 1.9 %), Kilayur (2,167 ha: 1.9 %), Pichanur (2,137 ha: 1.9 %) and Kattampatti (2,023 ha: 1.8 %) series. In total, these 17 soil series covered around 90.9 per cent of the coconut land cover.

Thematic maps of soil constraints

The soil properties attribute table of the soil series were derived from the soil map of Tamil Nadu. The suitability or constraint classification was made according to the criteria developed for coconut (Table 2). Based on this information along with land cover maps and soil series map, thematic maps for the soil constraints were developed.

Depth

Soil depth of existing coconut land cover was classified into four classes based on their suitability for coconut cultivation *viz.*, highly suitable (>150 cm), moderately suitable (101 to 150 cm), marginally suitable (75 to 100 cm) and not suitable (<75 cm) (Fig. 1 A). The highly suitable class was found only in 6.6 per cent (7,501 ha) of the total coconut land cover, moderately suitable depth observed in 34.0 per cent (38,759 ha), marginally suitable class exists in 44.4 per cent (50,569 ha) and soil depth which is not suitable for coconut cultivation was observed in 14.8 per cent (16,862 ha).

Table 2. Extent of area of different suitability classes of individual soil properties under coconut land cover in Coimbatore and Tiruppur districts

Suitability		Soil drainage	Texture	Soil depth	Soil reaction
Highly suitable	Area (ha)	66389	54000	7501	33021
	(%)	58.3	47.4	6.6	29.0
Moderately suitable	Area (ha)	27113	15984	38759	28482
	(%)	23.8	14.0	34.0	25.0
Marginally suitable	Area (ha)	5414	43734	50596	30932
	(%)	4.8	38.4	44.4	27.2
Not suitable	Area (ha)	14801	-	16862	21283
	(%)	13.0	-	14.8	18.7

Texture

In the existing coconut land cover, three suitability classes of texture for coconut cultivation *viz.,* highly suitable class (sandy clay loam, sandy clay, clay loam), moderately suitable class (sandy loam, clay-nonexpanding) and marginally suitable class (clay-expandable, loamy sand, sand) were found (Fig. 1 B). Around fifty per cent of the coconut land cover soils were having soil texture of highly suitable class (54,000 ha: 47.4 %) followed by marginally suitable class (43,734 ha: 38.4 %) and moderately suitable class (15,984 ha: 14.0 %).

Soil reaction

The existing coconut land cover soils were classified into four suitability classes based on pH status for coconut cultivation. They were highly suitable (pH < 7.5), moderately suitable (pH 7.6 to 8.0), marginally suitable (pH 8.1 to 8.5) and not suitable (pH > 8.5). Nearly 29.0 per cent of the area was under highly suitable class (33,021 ha) which was followed by marginally suitable soils (30, 932 ha: 27.2 %), moderately suitable soils (28,482 ha: 25.0 %) and not suitable class (21,283 ha: 18.7 %) (Fig. 1 C).

Drainage

In Coimbatore and Tiruppur districts, four suitability classes for drainage were found *viz.,* highly suitable (well drained) which is found to exist in 66,389 ha (58.3 %), moderately suitable class (moderately well drained) covered 27,113 ha (23.8 %) and marginally suitable class (imperfectly drained and excessively drained) covered 5,414 ha (4.8 %) (Fig. 1 D).

Overall constraint mapping based on soil depth, drainage, texture and soil reaction of soil series under coconut

The suitability classes were classified based on the most limiting soil constraints *viz.,* soil depth, soil drainage, soil reaction and soil texture. Suitability of the series was based only on the studied soil properties and were defined based on the most limiting property. Similarly, land suitability was characterized by Ritung, *et al.* (2007) based on their most serious limiting factors (Fig. 1E).

Moderately suitable

In the existing coconut land cover, 4,463 ha area was classified as moderately suitable which is 3.9 per cent of the total land cover. Among the soil series found under coconut land cover in Coimbatore and Tiruppur districts, Palaviduthi, Thengampudur, Vandakottai, Mettupalaiyam, Mukkulam, Niravi, Adirampattinam, Attakatti and Kadamparai series were found to be moderately suitable for coconut (Table 3).

Soil texture in Mukkulam and Niravi series, drainage in Thengampudur series, drainage, soil texture and soil reaction in Mettupalayam soil series, soil depth in Attakatti series, soil depth, soil drainage and soil texture in Palaviduthi, Vandakottai and Adirampattinam soil series were found to be the limiting factors for coconut cultivation.

Marginally suitable

Among the soil series found under coconut land cover in Coimbatore and Tiruppur districts, 28 soil series were classified as marginally suitable. The area of existing land cover which was classified as marginally suitable was 73,417 ha (64.4 % of the total coconut land cover). The major soil series classified as marginally suitable for coconut in the

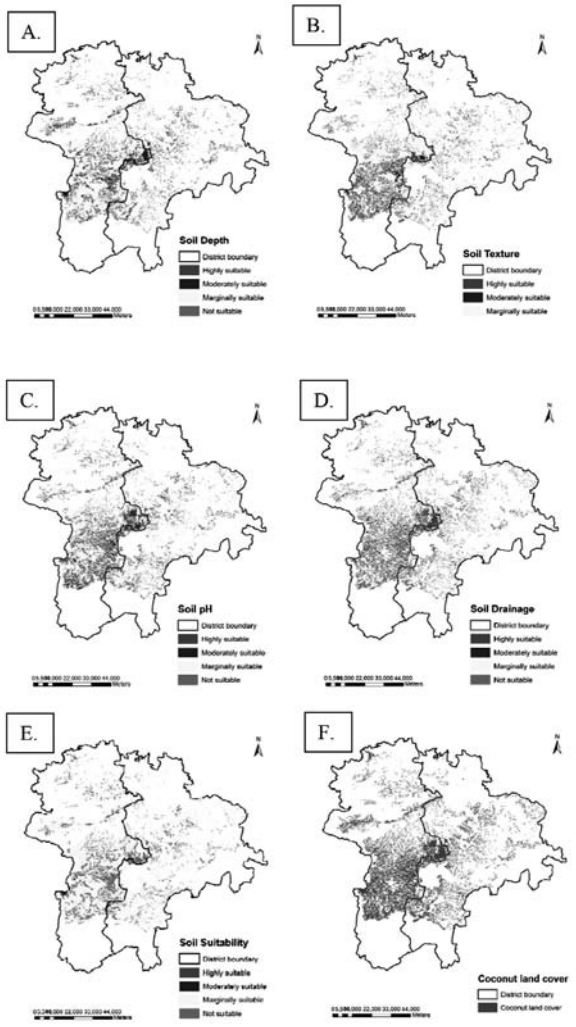

Fig. 1. Soil constraint maps (A. Soil depth, B. Soil texture, C. Soil pH, D. Soil drainage and E. Overall soil suitability map for coconut based on the limitations in soil depth, texture, soil drainage and soil reaction) and coconut land cover map (F)

Table 3. Soil series classified as moderately suitable for coconut and their extent in the existing coconut land cover in Coimbatore and Tiruppur districts

Series	Constraints	Area (ha)	Per cent to the total area
Palaviduthi	T, D, P	2869	2.52
Thengampudur	D	756	0.66
Vandakottai	T, D, P	334	0.29
Mettupalaiyam	R, T, D	295	0.26
Mukkulam	T	163	0.14
Niravi	T	27	0.02
Adirampattinam	T, D, P	17	0.01
Attakatti	P	2	-*
Total		4463	3.92

* 0.002 per cent
P- Soil depth, D- Drainage, T- Soil Texture, R- Soil reaction

existing land cover were Anamalai, Attipalaiyam, Irugur, Kallivalasu, Somayyanur, Palathurai, Salaiyur, Sengalam, Kilayur and Kattampatti. The extent of remaining each soil series were less than one per cent. Soil depth was the constraint responsible for the Marudappapuram soil series to be classified as marginally suitable for coconut. Chickarasampalaiyam series has low soil depth and soil reaction problems as constraints for coconut cultivation. Tiruchuli, Pillayarkulam and Kollankonda series were marginally suitable due to the soil reaction problems as the major constraint (Table 4).

The most limiting constraints of the soil series classified as marginally suitable were soil depth in Anamalai, Marudappapuram and Perundurai, soil

Table 4. Soil series classified as marginally suitable for coconut and their extent in the coconut land cover of Coimbatore and Tiruppur districts

Series	Constraints	Area (ha)	Per cent to the total area
Anamalai	P	23031	20.21
Attipalaiyam	T	15001	13.17
Irugur	R,P	7053	6.19
Kallivalasu	R	5727	5.03
Somayyanur	R	4416	3.88
Palathurai	R,P	4117	3.61
Salaiyur	R, T	3382	2.97
Sengalam	T	2180	1.91
Kilayur	R,T,D	2167	1.90
Kattampatti	R, T	2023	1.78
Basuvapalaiyam	T	685	0.60
Dasarapatti	R, T	660	0.58
Avarangulam	T	558	0.49
Dindugal	R,T,D	531	0.47
Marudappapuram	P	423	0.37
Tiruchuli	R	397	0.35
Panaiyur	T, P	311	0.27
Salapudur	R, T, P	284	0.25
Perundurai	P	236	0.21
Chickarasampalaiyam	R,P	82	0.07
Pudur	T,P,D	52	0.05
Pillayarkulam	R	42	0.04
Sevalpatti	R, D	36	0.03
Kollankonda	R	13	0.01
Karonagipuram	T, P	4	0.01*
Reedinguvayal	D	3	
Pallappatti	T, P	1	
Murugali	T, D, P	1	
Total		73417	64.43

*Total per cent area of four soil series (Karonagipuram, Reedinguvayal, Pallappatti and Murugali)
P- Soil depth, D-Soil drainage, T- Soil texture, R- Soil reaction

texture in Attipalaiyam, low soil depth and soil reaction in Irugur, Palathurai and Chickarasampalaiyam series, soil reaction in Kallivalasu, Somayyanur, Tiruchuli, Pillayarkulam and Kollankonda, soil texture and soil reaction in Salaiyur, Kattampatti and Dasarapatti, soil texture, soil drainage and soil reaction in Kilayur and Dindugal, soil texture in Sengalam, Basuvapalaiyam, and Avarangulam, soil depth and poor soil texture in Panaiyur, Karonagipuram and Pallappatti, soil texture, low soil depth and soil drainage in Pudur; soil drainage and soil reaction in Sevalpatti; soil drainage in Reedinguvayal, soil texture, drainage and soil depth in Murugali series.

Not suitable

Out of the total coconut land cover area, 31.5 per cent (35,838 ha) were in the soil series which were not suitable for coconut cultivation. Around 24 soil series under coconut land cover were classified as non-suitable, among them Pilamedu, Kanjampatti, Vellalur, Varapatti, Ettinayakanpatti and Pichanur were the major soil series found (Table 5).

The major constraints were soil drainage and soil reaction in Pilamedu and Ammapettai, shallow soil depth in Kanjampatti, Vellalur, Pichanur, Annur, Dharapuram, Velakaundanpalaiyam, Anaikkulam, Kunnattur, Elavamalai, Pollachi, Chittodu, Bhavanisagar, Anandur, Tarkadu and Vanavasi, soil reaction in Varapatti and Kottayam, soil depth in Katripatti, and Ilaiyamuttur, soil drainage in Ambasamudram series.

Conclusion

This constraint mapping will enable us to concentrate on developing site specific management practices required to mitigate the existing soil limitations so as to enhance the productivity of the coconut. In the existing soil properties under coconut land cover in the study area, around 3.9, 64.4 and 31.5 per cent of the total coconut land cover was having the constraint level which falls under the classes moderately suitable, marginally suitable and not suitable respectively. Hence, considering the larger extent of soil constraints existing in the study area, there is hope for further improving the productivity of coconut in these areas by imposing suitable soil management practices based on the mapped soil constraints.

Table 5. Soil series classified as not suitable for coconut, their constraints and extent in the coconut land cover of Coimbatore and Tiruppur districts

Series	Constraints	Area (ha)	Per cent to the total area
Pilamedu	R, D	14067	12.35
Kanjampatti	P	4633	4.07
Vellalur	P	4456	3.91
Varapatti	R	3989	3.50
Ettinayakanpatti	R, P	2281	2.00
Pichanur	P	2137	1.88
Annur	P	910	0.80
Ammapettai	R, D	725	0.64
Dharapuram	P	696	0.61
Velakaundanpalaiyam	P	538	0.47
Katripatti	P	358	0.31
Anaikkulam	P	357	0.31
Kottayam	R	186	0.16
Kunnattur	P	174	0.15
Ilaiyamuttur	P	108	0.09
Elavamalai	P	76	0.07
Pollachi	P	66	0.06
Manupatti	R, P	34	0.03
Chittodu	P	23	0.02
Ambasamudram	D	8	0.01
Bhavanisagar	P	7	0.01
Anandur	P	5	0.01*
Tarkadu	P	2	
Vanavasi	P	1	
Total		35838	31.45

* Total per cent area of three soil series (Anandur, Tarkadu and Vanavasi)

P- Soil depth, D- Soil drainage, T- Soil texture, R- Soil reaction

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