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Land suitability evaluation of soils of Dakshina Kannada district of Karnataka for cashew production

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India's share in raw cashew nut production is about 25 per cent of the world production. In recent times, India is facing stiff competition from Vietnam and Brazil in international trade (Bhat, 2007). In India, cashew is mainly grown in Maharashtra, Goa, Karnataka and Kerala along the West coast and in Tamil Nadu, Andhra Pradesh, Orissa and West Bengal along the East coast. This crop is mostly grown on laterite and red soils and coastal sands in the states of Andhra Pradesh, Goa, Karnataka, Kerala, Maharashtra, Tamil Nadu, Orissa and West Bengal. Inappropriate land use leads to inefficient exploitation of natural resources, destruction of land resources, poverty and other social problems and even in the destruction of civilization. Hence, the management of land and soil based on the suitability evaluation is very important to preserve both these resources for future generation. High rainfall, shallow to medium soil depth, presence of coarse fragments, undulating topography and poor soil fertility are the most serious problems influencing growth and performance of cashew in Dakshina Kannada district of Karnataka. In this context, the present study was carried out using remote sensing data along with field survey and laboratory analysis for evaluating the potentials and limitations of soil for suitability to cashew growing in Dakshina Kannada district of Southern Karnataka.

The study was undertaken in six pedons from four taluks of Dakshina Kannada district, Karnataka (Table 1). The area receives a mean annual rainfall ranged from 3,592 to 3,842 mm. The mean annual temperature is 27.6 °C and mean maximum and minimum temperature are 36 °C and 20 °C, respectively. The study area has *ustic* moisture regime and isohyperthermic temperature regime. The soil samples were collected horizon-wise, air-dried, powdered and sieved using 2 mm sieve. The particles larger than 2 mm were washed with water, dried and weighed as coarse fragments. Particle-size analysis of the samples was carried out by international pipette method. Electrical conductivity, pH, organic carbon, exchangeable cations, cation exchange capacity and base saturation were determined by using standard methods (Black *et al*., 1965; Jackson 1973). Land suitability evaluation for cashew was carried out based on the procedure given by FAO (FAO 1976) and as per guidelines described by Sys *et al.* (1991) and modified wherever necessary based on the yield and performance of the cashew crop collected during the field traverse (Naidu *et al.*, 2006; Parthasarathy *et al*., 2006). Modification is based on comparison of site and soil characteristics with the requirements of the crop. Based on the ratings, the cashew growing sites were grouped as highly suitable (S_1), moderately suitable (S_2), marginally suitable (S_3), and unsuitable (N_1 and N_2). The land qualities used for arriving the suitability for cashew cultivation and suitability criteria modified from the study based on the cashew crop performances and yield is given in Table 2.

Table 1. Identification of major cashew growing areas in Dakshina Kannada district, Karnataka

Taluk	Village	Pedon number	Land use
Puttur	Pala hillock	1	Forest with plantation of cashew
Puttur	NRCC-Shanthigodu	2	Well maintained cashew farm with intercrops of pineapple
Bantwal	Muchipadavu	3	Poorly maintained cashew plantation with other tree species
Bantwal	Mulia	4	Degraded cashew plantation in the hillock
Mangalore	ARS-Ullal	5	Well maintained cashew farm
Karkala	Palikudel	6	Patches of cashew plantation with tree species and shrubs

Table 2. Suitability criteria modified from the study based on the cashew crop performances and yield

Soil site characteristics		Unit	Rating			
			Highly suitable	Moderately suitable	Marginally suitable	Not suitable
			S1	S2	S3	N
Climatic regime	Total rainfall	mm	1500-3500	1000-1500 >3500	750-1000	<750
	Mean temperature	°C	25-35	31-40	40-50	<12
	in growing season			15-24	12-14	>50
	Mean RH in growing season	%	60-90	40 to 60	-	-
				>90		
	Dry months		1-4	4-6	6-8	>8
				<1		
Land quality			Land characteristics			
Situation Moisture availability	Length of growing period	Days	>210	150 to 210	90 to 150	-
Situation	Elevation (Altitude)	M	<600	600-900	900-1500	>1500
Topography	Slope	%	<15	15 to 33	33 to 50	>50
Oxygen availability to roots	Depth of water table	M	>3	1 to 3	0.5 to 1	<0.5
	Soil drainage	Class	Well to moderate drained	improper well drained	saturate	-
Nutrient availability	Texture	Class	l, sl, scl, c	cl,sil,ls,s (coastal)	sic, (non swelling)	c (swelling)
	pH	1:2.5	5.0 - 7.3	7.3 - 8.0	3-4	<3.0
				4 to 5	8.0-9.5	>9.5
	EC	(dSm^{-1})	<2	2-4	4-10	>10

(Modified suitability criteria based on the personal experience and published results of local experiments)

Physical, chemical and physico-chemical properties of different pedons are given in Table 3. All the pedons studied were deep to very deep. In general, the hue of soil matrix varied from 2.5 YR to 10 YR with colour varying from dark brown in the surface to red / dark red in the sub soils. This is due to the presence of free iron oxides in the entire horizon. The clay distribution of all the six pedon showed that the surface horizons have low clay content. This is due to the illuviation of clay from the surface to subsurface and also the presence of organic matter. In subsequent horizons the clay gradually increased and then decreased slowly later. The cashew belt lateritic soils have sandy clay loam, clay loam, and clayey texture (Clay percentage varied from 24.5 to 66.4). All the six pedons were moderate to strongly acidic with pH ranging from 4.9 to 6.1. The acidic pH of the soil might be attributed mainly to the leaching of the bases due to the existing high rainfall conditions and to some extent due to the acidic parent materials. The organic carbon content of the soils was found to be high in surface soils and low in sub surface soils, decreasing with increasing depth. This is attributed to the addition of plant residues and farmyard manure to surface horizons. The CEC in all the pedons estimated by ammonium acetate extract varied from 7.60 to 33.6 cmol (p+) kg^{-1} soils which correspond to clay content in the horizons, low organic carbon content and also type of clay mineral present in these soils. Base saturation values varied from 4 to 32 per cent in all the six profiles. Low base saturation might be attributed to the occurrence of high leaching conditions combined with heavy rainfall in the study areas (Table 3).

Land suitability evaluation is one of the most effective methods for agricultural land use planning as it evaluates the suitability of land for a specific crop. Land characteristics are developed based on climatic, soil, and topographic data/maps of study areas. The requirements with respect to climate, site, soil and fertility aspects for the growth of cashew were formulated based on available literature and modified wherever necessary based on the yield and performance of the crop collected during the field traverse. Climatic, site, soil characteristics and their ratings of Major Cashew growing soils in Southern Karnataka are given in Tables 4 and 5. All the study areas were found to have slight limitation because of high rainfall. High rainfall is not a limitation here for productivity due to good management of excess water through drainage. Soil site suitability criteria have been established keeping in view of the requirements of cashew crop, and soil-site characteristics, which pose no limitation or slight limitation to crop production. Based on the modified suitability criteria for the growth of cashew, highly suitable class is one that could give more than 80 per cent of the potential productivity, moderately

Table 3. Physical and physico-chemical characteristics of soils

Horizon	Depth (cm)	Colour (moist)	Texture	Coarse fragment (%)	pH (1:2.5)	OC (%)	CEC (cmol $(p^+)kg^{-1}$)	Base saturation (%)
Pedon-1 (Pala hillock)								
0-21	A1	7.5 YR 3/4	scl	10	5.4	3.07	15.5	25
21-41	Bw/BA	7.5 YR 3/4	gsc	20	5.3	1.53	14.7	7
41-68	Bt 1	5 YR 3/4	vgscl	50	5.6	0.38	13.1	12
68-95	Bt 2	2.5 YR 3/6	vgscl	40	5.6	0.32	11.9	10
95-123	BC	2.5 YR 3/6	vgscl	60	5.7	0.13	7.7	16
Pedon-2 (NRCC-Shanthigodu)								
0-19	Ap	7.5 YR 3/4	gc	30	5.5	1.68	12.4	31
19-42	Bw	2.5 YR 3/6	gc	30	5.6	0.97	11.0	13
42-71	CB	2.5 YR 3/6	egc	80	5.7	0.70	8.6	19
71-90	Cr 1	2.5 YR 3/6	egc	80	6.0	0.14	7.6	26
Pedon-3 (Muchipadavu)								
0-25	Ap	5 YR 4/6	gc	35	5.5	0.97	10.2	20
25-50	Bt 1	2.5 YR 3/6	gc	25	5.3	0.82	8.0	34
50-84	Bt 2	2.5 YR 3/6	gc	20	5.5	0.50	7.8	18
84-128	Bt 3	2.5 YR 3/6	gc	15	5.4	0.40	10.2	13
128-160	Bt 4	2.5 YR 3/6	gc	15	5.4	0.26	9.8	14
160-206	Bt 5	2.5 YR 3/6	gc	15	5.5	0.12	8.0	19
206-210	BC	2.5 YR 3/6	gc	15	5.5	0.14	7.8	16
Pedon-4 (Mulia)								
0-17	A	7.5 YR 3/4	vgc	40	5.5	2.80	19.8	11
17-41	AB/BA	7.5 YR 3/4	vgc	60	5.4	2.04	14.8	15
41-60	Bt 1	2.5 YR 3/6	egc	70	5.5	1.42	14.3	18
60-90	Bt 2	2.5 YR 4/6	egc	70	5.5	0.65	9.1	32
90-215	BC	2.5 YR 4/6	egsc	70	5.3	0.43	10.7	18
Pedon-5 (ARS-Ullal)								
0-20	Ap	5 YR 3/4	gscl	20	4.9	1.56	11.3	9
20-40	BA	2.5 YR 3/6	vgsc	40	4.8	0.83	10.3	4
40-70	Bt 1	2.5 YR 3/6	vgsc	60	5.1	0.13	12.0	12
70-99	Bt 2	2.5 YR 3/4	vgc	60	5.2	0.45	13.8	21
99-127	Bt 3	2.5 YR 4/8	egsc	70	5.3	0.36	11.2	25
127-165	Bt 4	10 R 4/8	vgsc	60	5.1	0.27	10.4	21
165-191	Bt 5	10 R 4/8	vgsc	60	5.3	0.03	9.1	22
191-210	BC	10 YR 4/8	vgsc	60	5.2	0.03	10.2	15
210-220	Cc	10 YR4/8	vgscl	60	5.0	0.22	9.4	14
Pedon-6 (Palikudel)								
0-28	A	7.5 YR 3/4	gscl	30	5.7	1.79	11.8	28
28-55	Bw	5 YR 3/6	gsc	35	5.5	1.30	11.2	20
55-90	Bt 1	2.5 YR 3/6	vgsc	40	5.6	0.73	8.8	25
90-130	Bt 2	2.5 YR4/6	vgc	40	5.4	0.36	9.4	27
130-180	Bt 3	2.5 YR4/6	vgc	50	5.6	0.28	9.5	25
180-210	BC	2.5 YR 3/8	egc	70	5.6	0.23	11.8	16
210-235	C 1	2.5 YR 3/8	egc	80	5.6	0.07	12.1	21

suitable class has moderate limitation to cashew production and the rest were grouped in to marginally suitable class with one or more severe limitations. There is another class, which shows that they are temporarily unsuitable. By correcting one or more of the major limitations it can give satisfactory productivity.

Pala hillock, Muchipadavu and Agricultural Research Station (ARS), Ullal farm soils were highly suitable (>80 %) for cashew cultivation with respect to climate, topography and soil fertility (Table 6). Occurrence of high rainfall (>3500 mm) and also the presence of coarse fragments (40 %) in the above mentioned pedons act as a minor limitations. But these limitations are not affecting the yield and productivity of the crops. Fasina (1998) evaluated the major soils of Lagos on three land types in SW Nigeria for their suitability for cashew. The result indicated that about 63 per cent, 7 per cent and 9 per cent of the total area were highly suitable (S_1), moderately suitable (S_2) and marginally suitable (S_3) for cashew cultivation while 21

Table 4. Climatic, site and soil characteristics of major cashew growing soils in Dakshina Kannada district of Karnataka

Study sites	Pala hillock	NRCC	Muchi padavu	Mulia	ARS-Ullal	Palikudel
CLIMATE						
Alititude(m)	90	90	100-120	100-120	15	50-75
Rainfall (mm)	3796	3796	3756	3756	3592	3842
Temperature (°C)						
Max. in summer	30.4-36.5	30.4-36.5	30.4-36.5	30.4-36.5	28.8 -36.0	28.5-35.0
Min.in winter	21.1-26.1	21.1-26.1	21.1-26.1	21.1-26.1	19-25.0	20-25.0
Humidity (%)	70-80	70-80	70-80	70-80	>90	70-80
Moisture availability (days)	203	203	203	203	193	191
Soil characteristics depth of soil (cm)	123	90	210	215	220	235
Texture	gScl, gsc	gc	gc	gc,gsc	gsc,gscl	gc,gsc,gscl
EC (dSm^{-1})	0.010	0.012	0.015	0.025	0.25	0.35
pH	5.30-5.75	5.52-6.06	5.36-5.53	5.30-5.57	4.88-5.36	5.46-5.75
Coarse fragments (%)	30	40	20	50	50	50
Land features slope (%)	10-15	5-10	3-5	5-10	3-5	5-10

Table 5. Rating for Climatic, site and soil suitability of major cashew growing areas in Dakshina Kannada district of Karnataka

Study sites	Pala hillock	NRCC	Muchi padavu	Mulia	ARS-Ullal	Palikudel
Climate						
Alititude (m)	1	1	1	1	1	1
Rainfall (mm yr^{-1})	2	2	2	2	2	2
Temperature (°C)						
Max. in summer	1	1	1	1	1	1
Min.in winter	1	1	1	1	1	1
Humidity (%)	1	1	1	1	1	1
Moisture availability (days)	1	1	1	1	1	1
Soil depth (cm)	1	2	1	1	1	1
Texture	1	1	1	1	1	1
Reaction (pH)	1	1	1	1	1	1
Coarse fragments (%)	1	2	1	2	1	2
Land features slope (%)	1	1	1	2	1	2
Suitability subclass	S1	S2 c, s	S1	S2 c, s, t	S1	S2 c, s, t

Table 6. Land suitability classification of cashew growing areas of Dakshina Kannada district of Karnataka

Land suitability unit	Interpretation	Pedons
S_1	No or slight limitations	Pala hillock, ARS-Ullal and Muchipadavu
S_2 c,s	Moderate limitation of rainfall , soil depth and coarse fragments	NRCC-Puttur
S_2 c,s,t	Moderate limitation of rainfall, coarse fragments and slope	Laterite quarry-Mulia and Palikudel

S_1 - Highly suitable c - Limitation of climate s - Limitation of soil S_2 - Modrately suitable t - Limitation of topography

per cent of the total area was not suitable (N) for cashew cultivation. Coastal soils ecosystem are found to be highly suitable for cashew cultivation (Sehgal *et al*., 1998).

Soils which were moderately suitable for cashew includes NRC for cashew, Mulia and Palikudel study areas with occurrence of high rainfall (>3500 mm), coarse soil texture, coarse fragment and topography which are moderately severe for the growth of cashew. Apart from the above limitations, NRCC farm was also found to have shallow depth and charnockite parent material. Coastal soils evaluated by Fasina (1999) in Southern Nigeria for their suitability found to be marginal (S3) on most of the tree crops. However, two of the coastal soils (Iweke and Indaloke series) were highly suited to cashew. The major limitations to sustainable tree crop production on these coastal soils were poor soil texture, high acidity, low cation exchange capacity and poor soil fertility.

The important observation that is arrived from the results is that Pala hillock, Muchipadav and ARS-Ullal areas are highly suitable whereas NRCC-Puttur, Laterite quarry-Mulia and Palikudel are moderately suitable for growing cashew nut. As per the field information, the main crops of Dakshina Kannada district are Paddy, Coconut, Arecanut, Black Pepper and Cocoa. However, the results of the present study indicate that the maximum area in Dakshina Kannada is potentially suitable for

growing cashew nut. Such information could be very beneficial for the farmers and land managers for taking measures to grow cashew in highly suitable areas and also for improving the moderately suitable areas to cultivate cashew crop, so as to derive optimum production.

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