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Characterization of soils of Talaulim watershed, North Goa and their suitability for cashew production

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Abstract

Talaulim watershed, North Goa located between 15º 27' N to 15º 29' N latitude and 73º 53' E to 73º 55' E longitude with an elevation of 2 to 90 m MSL, represents land area typical of West Coast as well as midlands and western foot slopes of Western Ghats, supposed to be ideal for cashew-growing. The climate is humid tropical with mean annual rainfall 2932 mm and temperature 27.3 ºC. A high intensity soil survey (1:5000 scale) was carried out in the watershed to characterize the land and soils. The data generated was used to assess the suitability for growing of cashew in those lands. The climatic characteristics like high rainfall, high mean annual temperature and appreciable dry season favour the growing of the crop. Slope (0-5 %), coarse fragments (0-60 % by volume), soil depth (>75 cm), AWC (> 75 mm/m), pH (5.5-7.5) and high organic carbon (> 0.8 %) are the congenial land qualities for cashew. The survey results revealed that, out of 597 ha surveyed, 133.7 ha (22.4 %) is highly suitable, 287.2 ha (48.1 %) moderately suitable and only 2.0 ha (0.3 %) marginally suitable. The remaining area of 65.7 ha (11.0 %) apart from marshy land (10.8 %), water body (4 %), salt pan (2.6 %) and settlements (0.8 %) is unsuitable. Interspersing cashew in the originally forested, but slightly degraded landscape is viable from soil conservation point of view.

Keywords: Cashew, soil survey, soil suitability, watershed

Introduction

Cashew is an important dollar earning and leading plantation crop of the coastal region with 8.54 lakh ha area and 6.2 lakh tonnes annual production of nuts in India (Abdul Salam and Peter, 2010). Huge quantity of raw cashew nut (6.1 lakh tonnes) is still being imported from Tanzania, Guinea-Bissau, Mozambique, Indonesia and Ivory Coast every year to cater the needs of the world class cashew processing factories (3650 in number) mainly situated in the West Coast, as the domestic production is quite insufficient to run the factories, which at present having a capacity to process 1.5 million tonnes raw nuts per year. Cashew can be grown successfully in dry tracts and hilly regions. It is known for its delicious and nutritive kernels (Ohler, 1979), rich in fatty acids (46 %), protein (21 %), carbohydrates (25 %) and high iron content (5.3 mg per 100 g). Among the fatty acids, MUFA oleic (73.3 %) dominate over stearic (11.2 %) and PUFA linoleic (7.7 %) acids, whose requirement in the body can be met only through diet. High proportion of MUFA oleic and stearic acid contents may limit its use in low energy diets, but beneficial in case of bowel enteropathy (Gafoorunissa, 1989). Cashew apple, a rich source of Vitamin C (240 mg per 100 g) in tropics and good quality health drink rich in antioxidants and other anti-aging factors, ethanol and its nut shell oil is a good source of raw material for several industries.

Cashew crop can withstand hot humid tropical climate with temperature around 27 °C, 4-6 dry months and a rainfall of 1000 to 2000 mm. The best soil for cashew need be deep, friable, well drained, non-saline, non-sodic, non-flooding, slightly acidic, medium base saturated, red loamy soils developed on level to very gently sloping topography and without compacted hard pan within rooting depth (Sys *et al*., 1993; Naidu *et al*., 2006).

The Talaulim watershed represents vast areas on western slopes of Western Ghats, its foot hills, midlands and West Coast, which are supposed to be ideal for growing cashew, by virtue of hot humid tropical climate, good rainfall and with deep, well drained, medium to fine textured soils rich in organic carbon having acidic soil reaction. Compact subsoil or hard pan impedes root

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penetration. Cashew cultivation and distillation and brewing industry based on cashew apple is predominant in surveyed (Anil Kumar *et al.*, 2003) watershed area, which is facing threat from environmental hazards owing to mining for iron and manganese ores. The current vegetation is either sparse thin forests with few cashew trees or thinly populated cashew plantations on hills, coconut and vegetables on midlands and paddy on low lands leaving aside water bodies, marshy lands and salt pans. Hence, a study was undertaken along with detailed soil survey to characterize the soils of Talaulim watershed and to assess the suitability for cultivation of cashew in the watershed to improve cashew production and to provide ecological stability of the area with a broader idea to extrapolate the information to similar areas.

Materials and Methods

The soil survey was carried out using cadastral map of the area as base at 1:5000 scale in Talaulim watershed comprising Talaulim and Goa-Lim-Moula villages and parts of Gancim, Batim and Curca of Tiswadi taluk, North Goa district, Goa. It is located between 15º 27' N to 15º 29' N latitude and 73º 53' E to 73º 55' E longitude. The soil series and phases were identified following AIS & LUS (1970) and classified following Soil Taxonomy (Soil Survey Staff, 1992). Total area of the watershed is 597.0 ha as per cadastral data. Though the elevation is in the range of 2 to 90 m above MSL, the watershed is having hills with nearly level to strongly sloping lands, mean temperature of 27.3 ºC and mean annual rainfall of 2932 mm (Fig 1).

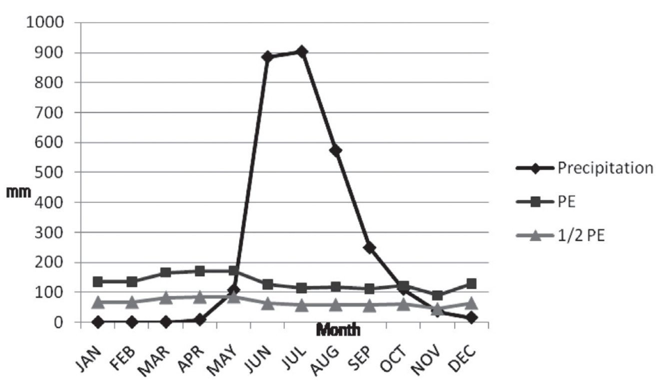

Fig. 1.Climate and water balance of Talaulim watershed

The site and soil characteristics were recorded on standard proforma as per guidelines given in USDA Soil Survey Manual (Soil Survey Staff, 1951 and Soil Survey Division Staff, 1995). The soil samples were collected horizon-wise and analysed following standard procedures as outlined in Laboratory Manual (Sarma *et al.*, 1987) and Jackson (1973). The soil characteristics identified were matched with the standard criteria (FAO, 1976) developed for cashew suitability (Naidu *et al.*, 2006) and were grouped according to their classification as highly suitable, moderately suitable, marginally suitable and non-suitable for cashew cultivation.

Results and Discussion

Detailed climatic analysis indicated that the area is having a hot humid tropical climate with a length of growing period of 180-210 days starting from middle of May to middle of November with peak rainfall in the month of July from South West Monsoon. There is around 5-6 months dry period from December to May every year having less than 50 mm rainfall per month or having precipitation less than half of potential evapo-transpiration (Fig. 1). The analysis is similar to that of Venkataraman (2003) on proneness of crops to drought.

Moderately shallow soils dominated the area along with moderately deep soils with dark brown to reddish brown in colour at the surface and red to dark reddish in subsoil (Tables 1 and 2; Fig 2). Phases of 10 soil series (TA, TB,….,TJ) identified and mapped, in which shallow soils in mounds were relatively of coarser textures (gravelly loam to gravelly clay loam) and in other soils at the surface, while clayey in subsurface and subsoil with clay content increasing with depth in all upland soils. All the upland soils were very gravelly and rocky except soil TJ which was not rocky. Soils TA, TB, TC and TD have an altered B horizon, in terms of texture, structure and arrangement and classified under Inceptisols and having low CEC and base saturation. Appearance of thin and patchy clay cutans in soils TI and TJ at lower soil layers indicated the active clay illuviation process in these soils and hence these soils classified into Ultisols, again because of low CEC and base saturation. Krishnan *et al*. (2000) explained the expression of physicochemical properties of red and lateritic soils following this logic.

Upland soils were very strongly to moderately acid in reaction, pH 4.8 – 5.8 at surface and 4.0-5.5 in subsoil (Table 3). It indicated that leaching of the exchangeable bases from exchange site along with percolating water as evidenced by the low concentration of exchangeable cations on the soil complex. The $BaCl_2$ TEA acidity exceeding CEC along with considerable amounts of KCl-extracable Al in the exchange complex also point to the fact that the area is base poor and dominated by H^+ and Al^{3+} cations. Dominant basic cation of exchange complex is calcium followed by magnesium, potassium and sodium, however the entire area is deficient in exchangeable basic cations. The CEC of soil ranges from 4.7 to 13.4 cmol (p+) kg^{-1} of soil and its distribution

Table 1. Characteristics of soil series under study

Soil series	Depth (cm)	Colour (moist) Surface/ Sub-surface	Texture	Gravel (vol %)	Surface features	Cutan	Horizons	Soil Classification (Based on Soil Survey Staff, 1992)
Upland soils								
TA	50-75	7.5YR 4/4 to 5YR 4/4 2.5YR 4/6 to 5YR 4/4	gl gc	40	Rockiness	Nil	A-Bw-C (laterite)	Clayey-skeletal, Oxic Dystrustepts
TB	75-100	5YR 3/3 to 7.5YR 4/4 2.5YR 3/6 to 5YR 4/4	gc gc	50	Rockiness	Nil	A-(AB)-Bw-(BC)-C (laterite)	Clayey-skeletal, Oxic Dystrustepts
TC	50-75	7.5YR 4/4 to 5YR 4/6 2.5YR 4/4	gcl gc	20	Rockiness	Nil	A-Bw-C (laterite)	Fine-loamy, Oxic Dystrustepts
TD	25-50	7.5YR 4/4 to 5YR 4/4 5YR 4/6	gcl gc	40	Rockiness	Nil	A-Bw-BC-C (laterite)	Loamy-skeletal, Lithic Dystrustepts
TI	100-150	7.5YR 4/4 to 5 YR 4/4 5YR 4/4 to 2.5YR 4/6	gc gc	40	Rockiness	tn p	A-(AB)-Bt -(BC)-C	Clayey-skeletal, Kanhaplic Haplustults
TJ	>150	7.5YR 4/4 to 5YR 4/4 2.5YR 4/6	gc gc	40	-	tn p	Ap-(AB)-Bt-(BC)	Clayey-skeletal, Kanhaplic Haplustults
Lowland soils								
TE	100-150	2.5Y 4/4 to10YR 4/4 2.5Y 4/3 to 5YR 4/3	gc gcl	40	Mottling Gleying	Nil	Ap-Bw-Cg	Clayey-skeletal Typic Dystrustepts
TF	100-150	10YR 4/3 to10YR 4/4 10YR 4/2 to 10YR 4/4	c c	Nil	Mottling Gleying	Nil	Ap-Bw-Cg	Fine, Aquic Dystrustepts
TG	100-150	10YR 5/6 to 10YR 4/4 10YR 5/3 to 10YR 4/4	c c	Nil	Mottling Gleying	Nil	Ap-Bw-Cg	Fine, Aeric Endoaquepts
TH	100-150	10YR 4/4 to 2.5 YR 4/4 2.5Y 5/4 to 10YR 5/6	scl-cl sl	Nil	Mottling Gleying	Nil	Ap-AC-Cg	Coarse-loamy, Aquic Ustifluvents

largely depends on clay and organic carbon content of soil. The low CEC/clay ratio (0.20 to 0.30), indicated the dominance of non-swelling clay minerals like kaolinite in the soil (Eswaran *et al.*, 1992). All the upland soils have a very good organic carbon status owing to good vegetative cover, high rainfall, long dry spell and high temperature.

Soils of the low land (TE, TF, TG and TH) showed signs of mottling and gleying in deeper layers because of water logging owing to lower position in the landscape and soil TF expressed potential acid sulfate condition with ultra acidic reaction owing to accumulation of marine sediments through sea water inundation. All the low land soils are classified into Inceptisols owing to

Table 2. Physical properties of soils

Series	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Coarse fragments (vol. %)	BD (Mg m^{-3})	Available water capacity (mm m^{-1})
				Upland soils			
TA	0-13	18.8	34.3	46.9	27.0	1.5	163.1
	13-73	19.3	16.9	63.8	66.0	1.2	
TB	0-13	50.2	21.8	28.0	60.0	1.6	96.8
	13-87	25.1	25.7	49.3	46.1	1.5	
TC	0-12	39.7	31.1	29.2	10.0	1.2	188.7
	12.-63	20.3	28.0	51.7	5.0	1.1	
TD	0-10	50.3	14.1	35.6	40.0	1.6	107.7
	10.-47	34.3	15.9	49.9	39.7	1.3	
TI	0-19	51.0	12.4	36.6	30.0	1.6	80.2
	19-106	31.2	31.5	37.4	39.3	1.4	
TJ	0-15	33.3	36.6	30.1	30.0	1.5	109.4
	15-151	34.5	24.6	40.9	43.6	1.5	
				Lowland soils			
TE	0-13	54.1	24.2	21.7	25	1.7	84.3
	13-87	21.6	29.1	49.3	35.0	1.5	
TF	0-18	6.5	41.8	51.7	0.0	1.3	150.3
	18-116	2.6	30.2	67.4	0.0	1.0	
TG	0-11	33.0	44.6	22.4	0.0	1.2	119.7
	11-97	45.9	30.0	24.1	0.0	1.7	
TH	0-10	80.2	7.0	12.8	0.0	1.7	48.1
	10-126	86.0	4.1	9.9	0.0	1.7	

presence of an altered B horizon due to water action except in soil TH, which have no diagnostic horizon and in early stages of soil profile development and hence classified under Entisols (Soil Survey Staff, 1998).

The upland soils were medium in available N, low in available P and K (Except soil TD, which is very poor in available N and very rich in available K) and rich in all micronutrients like Fe, Mn, Cu and Zn barring few exceptions (Table 4). It is possibly due to acidic environment that favours the release of these micronutrients from the exchange sites. Low land soils are low to medium in available N and K and low in available P and rich in micronutrients except Mn in soil TH, which is very low in Mn, owing to very coarse texture and poor drainage (Aubert and Pinta, 1977).

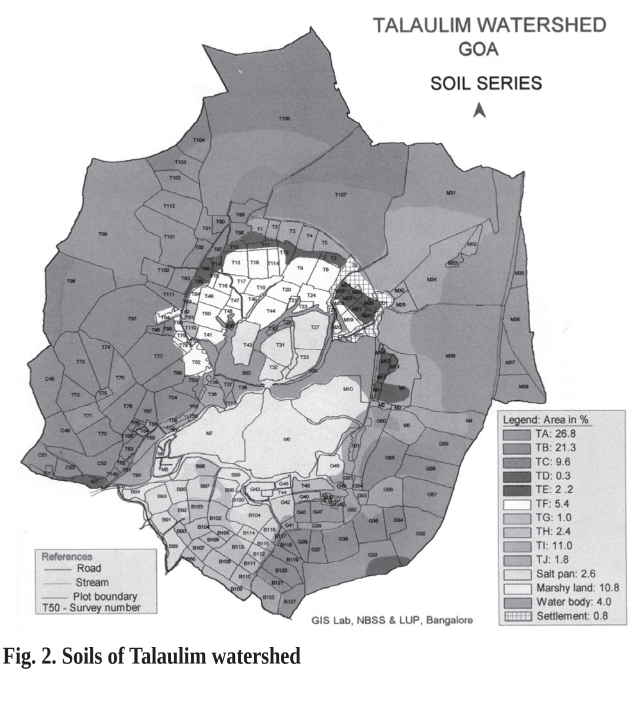

Fig. 2. Soils of Talaulim watershed

The land suitability criteria and factor ratings for cashew are presented in Table 5. The climatic characteristics like high rainfall, high mean annual temperature and appreciable dry season favour the growing of cashew crop. Slope (0-5 %), coarse fragments (0-60 % by volume), soil depth (>75 cm), AWC (> 75 mm/m), pH (5.5-7.5) and high organic carbon (> 0.8 %) are the congenial land qualities deciding high suitability of cashew (Naidu *et al.*, 2006). The survey results revealed that, out of 597 ha surveyed, 133.7 ha (22.4 %) was highly suitable, owing to little or no site, soil or fertility associated limitations. 48.1 per cent of total area (287.2 ha) was rendered moderately suitable owing to slight site, soil or fertility limitations, and only 2.0 ha (0.3 %) marginally suitable owing to moderate to strong soil limitations (Fig. 3). High suitability for cultivation of cashew is governed by hot humid tropical climate with appreciable rainfall and temperature, very gentle slopes, moderately deep, gravelly clayey soil, high organic

Table 3. Chemical properties of soils

Series	Depth (cm)	OC (%)	pH (1:2.5)	EC (dS/m)	Ca	Mg	Na	K	CEC	$BaCl_2$ TEA Acidity	KCl Exch. Al	CEC/ clay	Base saturation (%)
								(cmol (p+) kg^{-1} soil)					
						Upland soils							
TA	0-13	3.9	5.6	0.4	8.6	3.8	0.2	0.6	23.9	28.6	0.1	0.5	55.0
	13-73	0.5	5.5	0.1	3.9	4.1	0.1	0.2	14.5	18.7	0.2	0.2	57.3
TB	0-13	6.2	5.7	0.2	1.9	3.0	0.2	0.4	23.6	37.1	0.4	0.8	23.0
	13-87	1.9	5.5	0.0	3.6	2.0	0.2	0.1	18.7	29.4	1.7	0.4	32.5
TC	0-12	4.1	5.6	0.4	4.2	1.7	0.2	0.4	16.7	24.7	0.2	0.6	39.0
	12.-63	1.1	5.3	0.1	2.7	1.9	0.1	0.1	12.4	20.1	0.8	0.2	41.1
TD	0-10	4.1	5.7	0.3	4.6	1.8	0.1	0.7	15.7	22.4	0.1	0.4	46.0
	10.-47	1.4	5.3	0.0	1.2	0.4	0.1	0.1	11.7	22.4	1.6	0.2	24.5
TI	0-19	1.5	4.8	0.7	3.6	1.3	0.1	0.5	12.6	18.4	0.5	0.3	44.0
	19-106	0.3	4.9	0.0	4.8	2.6	0.1	0.1	11.1	14.9	0.1	0.3	57.6
TJ	0-15	1.4	5.8	0.2	3.4	1.2	0.1	0.2	10.9	13.6	0.1	0.4	45.0
	15-151	0.3	4.0	0.1	2.2	1.1	0.1	0.1	7.2	13.6	0.1	0.2	34.8
						Lowland soils							
TE	0-13	1.2	4.5	0.0	1.9	0.9	0.2	0.1	6.1	8.2	0.3	0.3	27
	13-87	0.2	5.6	0.0	4.1	3.6	0.3	0.3	12.6	7.8	0.0	0.3	51
TF	0-18	1.8	5.3	0.5	4.1	2.9	5.4	0.6	16.5	17.5	0.0	0.3	43
	18-116	0.9	3.9	4.2	5.3	6.1	12.0	1.1	27.2	28.3	5.3	0.4	47
TG	0-11	1.9	4.5	0.0	2.8	0.9	0.7	0.3	7.3	9.3	0.7	0.3	34
	11-97	0.2	6.5	0.0	2.0	2.2	0.2	0.1	5.0	4.0	0.0	0.3	54
TH	0-10	0.6	4.6	0.1	1.8	1.1	0.9	0.3	5.5	5.6	0.3	0.6	42
	10-126	0.1	7.6	0.1	1.4	1.4	1.0	0.2	4.6	0.9	0.0	0.5	77

carbon status, moderately acidic reaction, good drainage and a good available water holding capacity. In the moderately suitable plots, gentle to moderate slopes, moderately shallow soil depth, moderate soil acidity or moderate fertility status or all in combination affects the cashew suitability. In marginal suitability plots moderate soil limitations of shallow soil depth, gravelliness and rockiness and severe acidic soil reaction make the suitability marginal. However, 11 per cent (65.7 ha) area apart from the marshy land (10.8 %), water body (4 %), salt pan (2.6 %) and settlement (0.8 %) were rendered unsuitable, owing to flooding and wetness associated limitations (Sys *et al*., 1993).

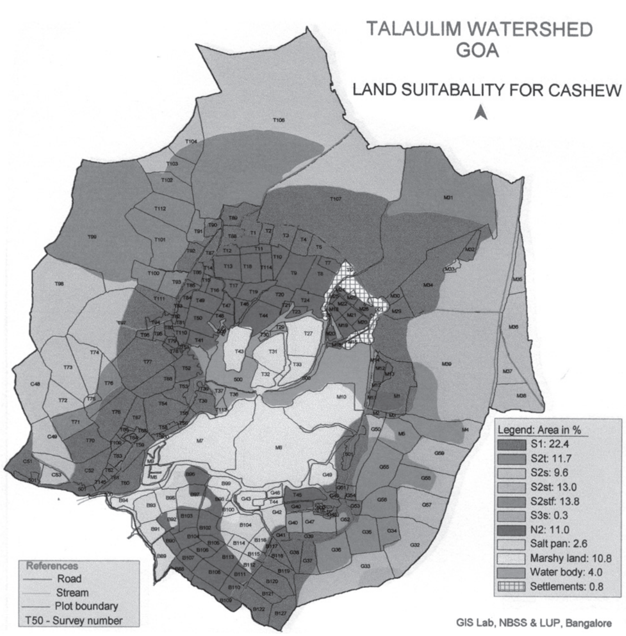

Fig. 3. Suitability of soils for cashew

Interspersing cashew in the originally forested, but slightly degraded landscape will be a viable preposition in the soil conservation point of view also. This suitability will work well only when supplemented with proper soil and water conservation structures, wherever needed like bench terracing, bunding, trenching, mulching, providing vegetative ground cover and grassed waterways apart from harvesting and in situ storing of rain water and making it use for protective or micro irrigation, during the long dry spell. Wide gap exists between production of cashew nut and the requirement (Abdul Salam and Peter, 2010), and hence, the highly and moderately suitable areas of the watershed can be brought under high yielding cashew plantations and also by gap filling and replacing the senile and unproductive trees in thinly populated cashew plantations and the same can be extended to similar areas of West Coast and western stretch of Western Ghats to bring back greenery and to provide ecological stability of the area, apart from contributing to foreign exchange by import substitution of raw cashew nuts and export of processed kernels in the long run.

Table 4. Plant available major and micronutrients of soils

Series	Depth (cm)	N	P	K	Fe	Mn	Cu	Zn
		--------------------------(kg/ha)---------			----------------(ppm)--------------------------------------			
				Upland soils				
TA	0-13	589.6	3.2	145.6	177.0	33.0	6.8	4.3
	13-73	529.3	3.6	45.8	45.8	13.0	2.0	0.7
TB	0-13	551.9	3.4	84.0	76.0	4.0	3.1	1.1
	13-87	365.7	3.8	30.6	30.6	1.9	1.4	0.4
TC	0-12	451.6	3.9	56.0	70.0	4.0	1.9	0.6
	12.-63	476.9	3.6	32.3	32.3	2.3	0.7	0.3
TD	0-10	62.7	5.0	940.8	64.0	0.6	1.8	1.2
	10.-47	61.0	4.1	36.6	36.6	0.7	1.1	0.9
TI	0-19	439.0	4.1	84.0	181	5.0	5.1	1.7
	19-106	341.4	3.0	8.8	8.8	1.0	0.3	0.2
TJ	0-15	464.1	3.8	28.0	99.0	14.0	5.8	1.8
	15-151	288.0	2.7	38.9	38.9	2.0	2.9	0.7
				Lowland soils				
TE	0-13	376.3	4.0	280.0	194.0	1.0	3.7	1.1
	13-87	175.6	3.2	84.0	15.0	4.0	1.4	0.7
TF	0-18	326.1	3.5	256.8	55.0	3.0	4.8	4.5
	18-116	140.0	3.0	145.7	76.0	2.0	1.6	2.3
TG	0-11	187.8	0.4	229.6	221.0	1.4	6.3	4.1
	11-97	62.7	0.1	50.4	26.0	0.8	2.3	0.7
TH	0-10	75.3	0.7	97.9	193.0	0.2	3.0	1.8
	10-126	37.6	0.3	33.3	12.0	0.3	0.9	0.7

Table 5. Land suitability criteria for cashew

Climatic and Soil Characteristic	Highly suitable		Moderately suitable	Marginally suitable	Unsuitable
	S0 (No limitation)	S1 (slight)	S2 (moderate)	S3 (high limitation)	N1/N2
Rainfall (mm) of growing season	>2500	1500-2500	1300-1500	500-1300	<500
Temperature regime (ºC)	32-34		28-32 34-38	24-28 38-40	<20 >40
Relative Humidity (%)	70-80		65-70 80-85	50-65 85-92	<50 >92
Length of growing period	>210		150-210	90-150	<90
Topography slope (%)	<5		5-15	15-30	>30
Texture	l, sl, scl		cl, sil, ls	s, sic, c (non-swelling)	c (swelling)
Drainage	Well drained		Moderately well drained	Imperfectly drained	Poorly drained
Depth of water (m)	>3		2-3	1-2	<1.0
Coarse fragments	<15		15-35	35-50	>50
Depth to root limiting layer including compacted substratum or hard pan/plinthite (cm) *	>150	100-150	75-100	50-75	<50
pH	6.3-7.3	5.5-6.3	5.0-5.5 7.3-7.9	4.5-5.0 7.9-8.4	<4.5 >8.4
Elevation (m)	<20		20-450	450-960	>960
Distance from coast (km)	<5	5-80			

*: The suitability will shift one column left if machinery is used to break hard pan before planting

(Modified from Naidu *et al*., 2006)

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