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Integration of physiological and phenological attributes of coffee species with land and climate to maximize coffee production in Karnataka

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ABSTRACT

A study was conducted to characterize coffee-growing soils of Karnataka and to evaluate their climatic, soil site and chemical attributes for coffee-growing. Land and soil attributes for successful coffee-growing have been arrived at by matching the physiological and phenological requirements of both coffee species. Major climatic limitations experienced in the study area were long dry season, low total rainfall, and low relative humidity as in Belur and Arasinguppe. Major terrain limitations were high elevation and steep slope as in Madikeri and Kalasa. Major soil limitations identified were light texture as in Mudigere and coarse fragments in most locations. Acidic soil reaction and low base saturation were the limitations experienced in perhumid zone soils. Land suitability classification of the soils of coffee growing areas indicated that major soils of Sakleshpur and Chethalli were highly suitable and Kalasa, Koppa, Belur, Arasinguppe, and Balehonnur were moderately suitable for *Arabica* coffee, whereas major soils of Chethalli were highly suitable and Koppa, Balehonnur, Sakleshpur, Belur and were moderately suitable for *Robusta* coffee in the increasing order of limitations in respect of climate, terrain, soil and fertility. Severe limitations for coffee growing for *Arabica* coffee included coarse soil texture and gravelliness as in Mudigere and low base saturation in Madikeri soils, where as that of *Robusta* coffee were steep topography and elevation in Kalasa, Arasinguppe and Madikeri and soil limitations of sandy loam texture in Mudigere. Most of the soils studied were moderately suitable for *Arabica* and *Robusta* coffee. Total rainfall as well as that of different growth phases such as blossoming, fruit set, fruit swell period were congenial in most locations and a specified period of dry months, to cater the dormancy requirements of flower buds and fruits and for their maturity determine the productivity of coffee crop.

KEYWORDS

Physiological attributes;
Arabica coffee;
Robusta coffee;
Climate and soil characterization;
Land evaluation;
Coffee productivity.

INTRODUCTION

Coffee or 'brown gold' is the most traded commodity in the world, next only to petroleum. World coffee output is 6.9 million tons. Brazil tops in area, production and export of coffee followed by Vietnam and Co-

lombia[29]. Presently coffee is cultivated on 0.35 million ha in India with a production of 0.33 million tonnes. In Karnataka, *Arabica* coffee is grown in an area of 1.10 lakh ha and produce 0.99 lakh tons. *Robusta* coffee occupies 0.92 lakh ha giving a production of 1.09 lakh tonnes. As coffee is cultivated aiming at international markets, the coffee crop output should have top quality which can be ensured by blending the knowledge of climate, land quality and physiology of crop. There was an attempt by Kharche[14,15] in the similar line.

The present study is aimed to characterize land and soil attributes of coffee-growing areas of Karnataka and to evaluate their suitability for growing coffee.

EXPERIMENTAL

Coffee-growing soils of Karnataka, lie in Chickmagalur, Kodagu and Hassan districts between 11°58′ to 13°40′ N latitude and 75°05′ to 76°10′ E longitude and experience a perhumid to dry subhumid tropical climate with annual rainfall ranging from 1045 mm to 3311 mm, temperature from 20.4°C to 23.2°C and relative humidity from 69 per cent to 86 per cent. The study area is having an elevation ranging from 860m to 1330 m above MSL and derived from granitic gneiss, ferruginous quartzite or schistose parent material. The method suggested by Thornthwaite and Mather[34] was used for climatic interpretations of nine stations selected. Twenty-four soil profiles have been studied, sampled[30], characterized and matched[9] with land and soil requirements and crop physiological attributes. The laboratory characterization was done following Jackson[12] and Sarma[26]. The suitability criteria for both the species of coffee are evolved and given in TABLE 1 and 2. Land suitability evaluation can be used as a tool for assessing the suitability or potentiality of land[15,28] for a specific use.

RESULTS AND DISCUSSION

Crop specialities

Major part of the root system of coffee is concentrated in the top 30cm layer and distributed in a circle of diameter 1.5m around the trunk[19]. Cannell[3,4] reported that each plagiotropic shoot usually produce flowers only once and hence pruning has to be done to ensure continuous supply of flowering nodes. A period of dormancy is associated with a drought period to complete some subtle physiological or morphological events that make the flower bud ready to respond to external stimulus to resume growth[27] and react quickly to water[6]. Browning[2] observed that blossoming of *Arabica* coffee occurred only when there was a temperature drop of 3°C or more within a period of not more than 45 minutes. Mes[20] reported that sudden drop of temperature is always associated with rains in tropical regions. The fruits will remain as pinheads for a period of 6-8 weeks, due to dormancy offered by high levels of endogenous abscissic acid and low levels of active gibberellic acid. The size of beans is determined by the swelling of beans triggered by amount of rainfall during the 6-16 weeks long bean expansion stage[3,4]. Irrespective of the species, the effect of previous year's crop level is a significant factor which negatively affects current year's production and yield. Radhakrishnan[24] reported an increase in yield by 1 kg in the previous year bring down the yield of crop year by 0.68kg ha^{-1} due to the most efficient conversion and translocation of metabolites to coffee beans to that level, which can even induce dieback of most productive branches.

Crop climatic and soil requirements

Ideal climatic, site and soil requirements for coffee are given in TABLE 1. Total rainfall requirement and dry spell to cater dormancy requirement of flower buds for *Arabica* coffee are more than 1400m and 2 to 3 months and for *Robusta*, they are 1550 to 2000mm and 1.5 to 2.5 months respectively. Ideal rainfall during February-March or March-April is more than 10 mm to cater blossoming, more than 50 mm during March-April or April-May to assist fruit set and more than 300 mm during June-July for fruit swelling for both *Arabica* and *Robusta* coffee. The preferred annual temperature maximum, mean and minimum of coldest month are 24-27°C, 20-22°C and >13°C and 29-32°C, 25-30°C and >13°C respectively for both *Arabica* and *Robusta* coffee. Relative Humidity requirements are as high as 70-80 and 80-90 per cent respectively through out the year for *Arabica* and *Robusta* coffee. Ideal site characteristics identified for both species are elevation (1000-1200 and 500-700m above MSL) and slope

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TABLE 1 : Ideal climatic, site and soil physical and chemical characteristics for *Arabica* and *Robusta* coffee

Sl. No.	Characteristic	Ideal for arabica coffee	Ideal for robusta coffee
		Climatic	
1	Total rainfall (mm)	>1400[1], 1600-1800[5,12], 1400-1600[2], 1600-2500[7,10,11]	1550-2000[1], 1800-2000[7,12], 1000-2000[2]
2	Blossom period rainfall (mm)	(March-April) >10[1], 25-40[4,5]	(Feb- March) >10[1], 25-40[2]
3	Fruit set period rainfall (mm)	(April-May) >50[1],	(March-April) >50[1], 50-75[2]
4	Fruit swell period rainfall (mm)	(June-July) >300[1]	(June-July) >300[1]
5	Dry period (Months)	2-3[1,4,5]	1.5-2.5[1], <1[9]
6	Mean Annual Temperature (°C)	20-22[1], 15-24[6,10], 17-23[8], 20-24[4,5]	25-30[1], >15[6,10,11], 20-30[2], 18-32[7]
7	Mean annual maximum Temp. (°C)	24-27[1], 26-28[4,5]	29-32[1], >29[10,11]
8	Average daily min. of coldest month (°C)	>13[1], 10[7], >15[6]	13[1], >20[10,11]
9	Relative Humidity (%)	70-80[1], 70-95[8], 80-95[4,5]	80-90[6], 95[8]
		Site	
10	Elevation (m above MSL)	1000-1200[1], 1000-1500[6], <1650[3]	500-700[1], 500-1000[2]
11	Slope (%)	3-8[1], 5-8[5], 0-4[11], <40[12]	3-8[1], 0-4[10,11], <8[9]
		Soil physical	
12	Drainage	Well[1]	Well[1]
13	Texture	Cl, l[1], Cl, l, SCl, SiCl, SC, SiC, C[4]	Cl, l[1]
14	Depth (cm)	>150[1], >200[5]	>150[1]
15	Available Water Capacity (mm m^{-1})	>100[1]	>100[1]
16	Coarse fragments (Vol. %)	<15[1], 0-5[4]	<15[1], 0-3[10,11]
		Soil chemical	
17	pH	5.5-6.5[11], 5.0-6.0[8], 6.0-6.5[6]	5.5-6.5[1], 5.0-6.0[7], 5.5-5.8[10,11]
18	CEC per kg clay (cmol (p+) kg^{-1})	>24[5,11]	>24[1], >16[11]
19	Base Saturation (%)	65[1], 80[11]	35[11], 65[1]
20	Organic Carbon (%)	1.5-2.0[1], 1.5-2.4[4], >2.5[11] (Top 25cm)	1.5-2.0[1], >1.5[11] (Top 25cm)

REFERENCES: [1] Anil Kumar (2002), [2] CCRI (1997), [3] Harrer (1962), [4] Kharche (1996), [5] Kharche et al. (1999), [6] Krishnamurthy Rao (1993), [7] Landon (1984), [8] Muller (1966), [9] Sys (1985), [10] Sys et al. (1991), [11] Sys et al. (1993), [12] Wellman (1961)

per cent (3-8 and 0-4). Both species require very deep, well drained, non-gravelly, fine-loamy to clayey soils having slightly to moderately acid reaction, rich in organic carbon and base saturation and good available water capacity and a CEC of more than 24cmol (p+) per kg clay. Land suitability criteria have been arrived at and put in TABLE 2 and 3 respectively for *Arabica* and *Robusta* coffee.

Climatic soil site and fertility characteristics of the study area have been studied and put in TABLE 4. Madikeri, Koppa and Balehonnur experience perhumid climate with total annual precipitation ranging from 2791.9mm to 3311.1mm (mean 3035.4mm), Sakleshpur, Kalasa and Mudigere experience humid climate with annual precipitation ranging from 2338mm to 2350mm (mean 2344mm). Chethalli and Arasinguppe have moist subhumid climate with mean annual precipitation ranges from 1591.6mm. to 1607.0mm (mean 1599.3mm). Belur represent the dry subhumid climate with mean annual precipitation is 1045.4mm (TABLE 3 & 4). The requirement of rainfall for breaking dormancy of buds (February-March for *Robusta* and March-April for *Arabica*) is satisfied in all the coffee-growing areas. Rainfall ranged from 44.6 to 138.5mm in March-April and from 6.1 to 26.2mm in February-March. As per Dublin[8], 5 to 10mm of rainfall is sufficient to induce blossoming in both the species of coffee. Fruit set period rainfall of the study area ranged from 44.6 to 138.5mm during March-April period and 126.2 to 252.5mm during April-May. Fruit set period rainfall of 50 to 75mm during a month enables the setting of fruits[5,13]. Fruit swelling period rainfall of the study area ranged from 311.3 to 1712mm during the months

TABLE 2 : Soil-site suitability criteria for *Arabica* coffee

Characteristics	Degree of limitation				
	(none)	(slight)S1	(moderate)S2	(severe)S3	(v. severe) Unsuitable N
Climatic characteristics (c)					
rainfall (mm)	>1400	1100-1400	1000-1100	800-1000	<800
Rainfall (mm) during blossom period (Mar-April)	>10	5-10			<5
Rainfall (mm) during fruit setting (April-May)	>50	25-50			<25
Rainfall (mm) during fruit swelling (June-July)	>300	200-300	100-200	50-100	<50
Length of dry season (months)	2.0-3.0	3.0-4.0; 1.5-2.0	4-5, 1.0-1.5	5.0-6.0, <1.0	>.6
Mean annual temp. (°C)	20-22	15-20 22-24	14-15 24-26	12-14 26-28	<12 >28
Mean annual max. temperature (°C)	24-27	27-29	29-31	31-33	>33
Mean min. temperature (°C) of coldest month	>13	10-13	9-10	7-9	<7
Mean R.H. growing season (%)	70-80	80-90	60-70, >90	<60	-
Site characteristics (t)					
Elevation (m above the MSL)	1000-1200	800-1000 1200-1500	700-800 1500-1800	300-700 1800-2000	<300 >2000
Slope (%)	3-8	1-3 8-15	<1(concave slope) 15-35	35-50	- >50
Drainage	Well	Well	Well	Moderately well	Imperfect to very poor
Soil characteristics(s)					
Texture	Cl, l	SiCl, SC, .SCl, C (<60 % clay)	C (>60 % clay), SiC	Sl	lS, S, C (>60 % clay, swelling type)
Depth (cm)	>150	100-150	100-75	75-50	<50
PAWC (mm m^{-1})	>100	75-100	50-75	25-50	<25
Coarse fragments (Vol. %)	<15	15-35	35-60	60-75	>75
Soil fertility characteristics (f) (surface 0-25 cm)					
Soil pH	5.5-6.5	5.0-5.5, 6.5-7.0	4.5-5.0, 7.0-7.5	4-4.5.0, 7.5-8.5	<4.0, >8.5
CEC cmol (+) kg^{-1} clay	>24	16-24	12-16	<12	-
Base saturation (%)	>65	50-65	35-50	<35	-
Organic carbon (%)	1.5-2.0	1.0-1.5	0.6-1.0	<0.6	-

of June-July. Fruit swell period rainfall of the perhumid region ranged from 1408 to 1712mm. In case of humid region the range is 1164 to 1257mm. In case of subhumid region the range was 658.1 to 745.3mm. In dry subhumid zone it was only 311.3mm just satisfying the minimum requirement but with an uncertainty of receipt every year. This is the most critical period and satisfied at all the locations. Length of dry season in the study area ranged from 4.0 to 5 0 months. Robinson[25] recommended that not more than 4 months dry weather should occur at one stretch for successful coffee production.

Mean annual temperature of study area ranged from 20.4 to 23.6°C and mean annual maximum temperature from 24.7 to 30.9°C. Optimum temperature range for *Arabica* is 15-24°C, whereas that of *Robusta* is 24-30°C. Maximum temperature range for *Arabica* is 24-29°C, whereas that of *Robusta* is 29-33°C. Mean relative humidity of study area ranged from 69.0 to 86.0 per cent. For *Arabica* optimum is 70-80 per cent[16,24] and in case of *Robusta*, it is 80-90 per cent[5]. Shade grown leaves are photosynthetically more active in case of *Arabica*. To maximize production and to distribute radiation and heat load coffee has to be grown in

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TABLE 3 : Soil site suitability criteria for *Robusta* coffee

Characteristics	Class and degree of limitation				
	(none)	(slight)S1	(moderate)S2	(severe)S3	(v.severe)Unsuitable N
Climatic characteristics (c)					
Annual precipitation (mm)	1550-2000	1250-1550	1000-1250	950-1000-	<950-
Rainfall (mm) blossom period (Feb-Mar)	>10	5-10			<5
Rainfall (mm) fruit setting period (Mar-April)	>50	25-50		<10	<25
Rainfall (mm) fruit swelling period (June-July)	>300	200-300	100-200	50-100	<50
Length of dry season (months with P < ½ PE)	1.5-2.5	1.0-1.5-, 2.5-4.0	0.5-1.0, 4.0 to 4.5	<0.5, 4.5 to.5.0	>5.0
Mean annual temp. (°C)	25-30	22-25, 30-32-	20-22	18-20	<18, >32
Mean annual max. temp. (°C)	29-32	32-33	33-35	35-36	<22, >36
Average daily min. temp. coldest month (°C)	>13	10-13	9-10	7-9	<7
Mean R.H. driest month (%)	80-90	90-95, 70-80	>95, 60-70	50-60	<50
Site characteristics (t)					
Elevation (m above MSL)	500-700	700-1000 200-500	1000-1200 100-200	1200-1400 <100	>1400
Slope (%)	3-8	1-3, 8-15	<1, 15-35	35-50	>50
Drainage	Well	Well	Well	Moderately well	Imperfect to very poor
Soil characteristics(s)					
Texture	Cl, l	SiCl, SC, .SCl, C (<60 % clay)	C (>60 % clay), SiC	Sl	lS, S,C (>60 % clay, swelling type)
Coarse fragments (Vol. %)	<15	15-35	35-60	60-75	>75
Soil depth (cm)	>150	100-150	75-100	50-75	<50
PAWC (mm m^{-1})	>100	75-100	50-75	25-50	<25
Soil fertility characteristics (f) (surface 0-25 cm)					
Soil pH	5.5-6.5	5.0-5.5 6.5 -7.0	4.5-5.0 7.0-7.5	4.0-4.5 7.5-8.5	<4 >8.5
Apparent CEC (cmol (p+) kg^{-1} clay)	>24	16-24	12-16	<12	-
Base saturation (%)	>60	50-65	35-50	<35	-
Organic carbon (%)	>1.5	1.5-1.0	1.0-0.6	<0.6	-

hedges[22].

Terrain analysis

The site characteristics of soils are given in TABLE 4. Elevation of the study area ranged from 860 to 1380m above MSL. Study area can be grouped to three elevation ranges, Kalasa and Madikeri with very high elevations (1280-1380m), Sakleshpur, Arasinguppe and Belur with moderate elevations (1010-1180m) and Koppa, Balehonnur, Mudigere and Chethalli with lower elevations (860-920m). cIn all the locations of last group, elevation is ideal for *Robusta* coffee, which suits an elevation of 500 to 1000m above MSL[5]. In the case of *Arabica*, the elevation requirement (1000-1500m above MSL) is met in all the locations of first and second groups[14-16,24]. In the locations of Sakleshpur, Belur and Arasinguppe (1010m and 1180m) both *Arabica* and *Robusta* coffee are cultivated but only for *Arabica* the conditions were met but *Robusta* also can come up well. Elevation is important in deciding period of availability of photosynthetically active solar radiation to coffee leaves and fruits. Elevational zonation in the study area corresponds closely to a mean annual temperature of 17 to 23°C, a temperature range, which can be considered optimum for *Arabica* coffee and 24 to 30°C for *Robusta* coffee[4,23,36]. For coffee high average yield is seen at elevations of more than 1200m above MSL Krishnamurthy Rao[16,24] reported an optimum elevation 1000 to 1500mm above MSL for *Arabica* coffee. In case of *Robusta* coffee, CCRI[5] reported that an elevation of 500 to 1000m above MSL is optimum.

TABLE 4 : Climatic, site and soil characteristics of coffee plantations

Soils parameters	Koppa	Balehonnur	Madikeri	Kalasa	Mudigere	Sakleshpur	Arasinguppe	Chethalli	Belur
Climatic characteristics ©									
Rainfall (mm): Annual	3003	2792	3311	2338	2338	2349	1592	1607	1045
Blossom period (mm) (Feb.-March) *Robusta*	12.7	26.2	15.3	26.2	15.8	15.0	6.1	14.4	23.3
Blossom period (mm) (March-April) *Arabica*	59.5	138.5	96.6	77.5	77.5	61.7	44.6	66.0	93.7
Fruit set period (mm) (March-April) *Robusta*	59.5	138.5	96.6	77.5	77.5	61.7	44.6	66.0	93.7
Fruit set period (mm) (April-May) *Arabica*	137.2	249.6	252.5	175.7	175.7	165.3	126.2	198.5	191.2
Fruit swell period (mm) (June-July)	1668	1408	1712	1164	1164	1257	745.3	658.1	311.3
Dry season (months)	4.0	4.0	4.0	4.0	4.0	4.0	5.0	4.0	4.0
Mean Annual T (°C)	22.2	22.3	20.4	22.5	22.2	22.7	22.9	22.6	23.2
Mean annual max. temperature (°C)	26.9	28.0	24.7	27.6	27.6	28.5	30.9	27.1	28.5
Mean min T (°C) coldest month	14.8	14.8	14.2	13.8	13.8	14.7	15.0	14.7	14.7
Mean RH (%)	84.6	86.0	82.3	75.0	75.0	75.0	69.0	85.7	69.0
Site characteristics (t)									
Elevation (m) MSL	940	900	1380	1300	920	1010	1160	940	1100
Slope (%)	10.0	10.0	11.5	16.0	8.0	3.0	5.0	10.0	5.0
Drainage	Well	Well	Well	Well	Well	Well	Well	Well	Well
Soil characteristics (s)									
Texture	C	SCl	C	C	Sl	SCl	l	C	SCl
Depth (cm)	160+	154+	165+	101	151+	151+	85	151+	151+
PAWC (mm m^{-1})	104.1	106.0	89.6	119.4	61.6	108.0	109.5	99.7	101.7
Coarse fragments (vol.%)	59.0	45.7	27.4	34.7	45.3	0.0	33.6	16.9	39.9
Soil fertility (surface 0-25 cm) (f)									
pH (1:2.5 water)	6.6	4.9	5.1	6.0	6.0	5.9	5.6	6.2	6.2
CEC (cmol p (+) kg^{-1} clay)	22.0	31.0	23.3	56.0	72.0	47.0	64.5	82.0	48.0
Base saturation (%)	83	35	32.	65	91	84	84	92	93
Organic carbon (%)	1.63	2.03	2.00	4.76	4.72	1.91	2.31	4.35	1.82

In the study area, the slope varied from 5 per cent to 16 per cent and three slope classes were noticed in coffee-growing areas: very steep slopes as in Kalasa and Mudigere, comparatively gentle slopes in case of Belur, Sakleshpur and Balehonnur and moderate slopes in all other areas. Except in first group the slope attribute was met for *Arabica* by second and last groups[14,15] and *Robusta*[31-33] only in second group. The drainage in most of the locations are optimum[1] and was found to be well drained. Doan Trieu Nhan[7] reported that flat to gentle slopes of undulating topography are ideal for coffee. Gowda[10] was also of the same view and recommended conservation measures to safeguard against erosion hazards.

Soil characteristics

A deep soil, preferably over 180 cm is desirable for coffee[37]. The coffee roots have high oxygen requirement[17]. Ideal soils suggested for coffee are loamy[18,21]. The colour of the surface layer varied from reddish brown to very dark grayish brown and the structure of all soils were subangular blocky. This could be attributed to the high amount of organic matter in these soils. Thin patchy clay cutans were observed in most of the pedons indicating the formation of argillic subsurface horizons. The soils on which coffee is grown are slightly to strongly acid and soil reaction of surface horizon ranged from 4.8 to 7.1. Organic carbon of surface (0-25cm) ranged from 1.23 to 5.00 per cent (mean 2.81%) and in subsoil (25-100cm) ranged from 0.55 to 2.08 percent (mean 1.03%). Present study revealed that surface soils have sufficient content of organic carbon for coffee cultivation and subsoils have enough reserve to replenish them in all the pedons barring a few. Cation exchange capacity of surface soil ranged from

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TABLE 5 : Land suitability classification of coffee soils (*Arabica* coffee)

Land Suitability unit	Interpretation	Pedons
S1	Highly suitable with no or slight limitations	Sakleshpur and Chethalli
S2 t	Moderately suitable with moderate limitation of slope	Kalasa
S2 s	Moderately suitable with moderate limitation of soil coarse fragments	Koppa-
S2 c,s1	Moderately suitable with moderate limitation of climate -annual rainfall and humidity and soil coarse fragments	Belur
S2 c,s2	Moderately suitable with moderate limitation of climate-dry months, mean annual temperature-maximum and soil depth	Arasinguppe
S2 s,f	Moderately suitable with moderate limitation of soil coarse fragments, pH and base saturation	Balehonnur
S3 s	Marginally suitable with severe limitation of soil texture and coarse fragments	Mudigere
S3 f	Marginally suitable with severe limitation of soil fertility -base saturation	Madikeri

S1-Highly suitable, c-Limitation of climate, t-Limitation of terrain, s-Limitation of soil, f-Limitation of fertility, S2-Moderately suitable, S3 Marginally suitable

TABLE 6 : Land suitability classification of coffee soils (*Robusta* coffee)

Land Suitability unit	Interpretation	Pedons
S1	Highly suitable with no or slight limitations	Chethalli
S2 s	Moderately suitable with moderate limitation of soil available water holding capacity	Koppa
S2 s,f	Moderately suitable with moderate limitation of soil coarse fragments, pH and base saturation	Balehonnur
S2 t,s	Moderately suitable with moderate limitation of elevation	Sakleshpur
S2 c,t,s	Moderately suitable with moderate limitation of climate-relative humidity, elevation and soil coarse fragments	Belur
S3 s	Marginally suitable with severe limitation of soil texture and coarse fragments.	Mudigere
S3 t	Marginally suitable with severe limitation of elevation and slope	Kalasa
S3c,t,s	Severe limitation of climate-dry months, relative humidity, elevation and soil depth.	Arasinguppe
S3 t,f,c	Severe limitations of elevation soil fertility -base saturation and mean annual temperature.	Madikeri

S1-Highly suitable, c-Limitation of climate, t-Limitation of terrain, s-Limitation of soil, f-Limitation of fertility, S2-Moderately suitable, S3-Marginally suitable

3.6 to 30.7cmol (p+) kg^{-1} (mean 15.7 cmol (p+) kg^{-1}) and that of subsoil from 3.7 to 28.7cmol (p+) kg^{-1} (mean 11.4cmol (p+) kg^{-1}). Present study revealed that CEC per kg clay of surface soil is sufficient to cater the requirements of both the species of coffee. Base saturation of surface (0-25cm) ranged from 56 to 93 per cent (mean 78.1%) and in subsoil (25-100cm) ranged from 42 to 86 percent (mean 67.7%) barring few exceptions. Present study revealed that surface soils have sufficient base saturation for coffee cultivation and subsoils have enough reserve to replenish them in all pedons barring a few.

Land suitability evaluation

Suitability criteria have been established keeping in view the requirements of *Arabica* and *Robusta* species of coffee separately. Land suitability classification of the soils of coffee growing areas indicated that major soils of Sakleshpur and Chethalli were highly suitable and Kalasa, Koppa, Belur, Arasinguppe, and Balehonnur were moderately suitable for *Arabica* coffee, whereas major soils of Chethalli was highly suitable and Koppa, Balehonnur, Sakleshpur and Belur were moderately suitable for *Robusta* coffee in the increasing order of limitations in respect of climate, terrain, soil and fertility (TABLE 4 & 5). Steep slope and very high content of coarse fragments of Kalasa soils have more than one severe limitation to make the coffee cultivation marginally suitable there. Sandy loam texture as in Mudigere and limitations of low base saturation as in Madikeri were the other major limitations for *Arabica* coffee.

Severe limitations for coffee growing for *Robusta* coffee included steep topography and elevation as in Kalasa, Arasinguppe and Madikeri and soil limitations of sandy loam texture in Mudigere. Most of the soils studied were moderately suitable for *Arabica* and *Robusta* coffee.

Total rainfall as well as that of different growth phases such as blossoming, fruit set, fruit swell period are congenial in most locations and a specified period of dry months, to cater the dormancy requirements of flower buds and fruits and for their maturity determine the productivity of coffee crop.

CONCLUSIONS

To maximize production of quality coffee, its cultivation should be restricted to highly or moderately suitable sites for respective species with minor modifications to alleviate slight limitations, where as cultivation of that species of coffee on marginal lands with severe limitations can be discouraged. It is also important to replenish the soils with balanced nutrients to wean away the strain of excess production of coffee beans during the preceding year and to avoid consequent die back of most productive branches.

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