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Application and validation of FAO-framework and soil potential ratings for land suitability evaluation of sugarcane soils of Karnataka,

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Abstract

The land suitability evaluation was carried out following FAO and Soil Potential Rating (SPR) approaches to evaluate shrink-swell, lateritic and loamy soils of Karnataka for their suitability to grow sugarcane. The FAO approach that considers individual land/soil parameters has underestimated the land suitability potentials. The SPR evaluation based on yield criteria is a more realistic assessment. Management measures have overcome dry period and soil fertility limitations, and also the production potential of the soils for cane production. Crop yield, management response and land suitability class showed an inverse relationship to total number of soil site limitations.

Additional key words : Shrink-swell soil, lateritic soil and loamy soil.

Introduction

Land evaluation is a process of assessment of land performance when used for specified purposes involving the execution and interpretation of survey data like landforms, soils, vegetation, climate and other aspects of land in order to identify and make a comparison of promising land uses in connection with specific land units (FAO, 1976). It is well established that each plant species requires specific soil and climatic conditions for its optimum growth. Water, temperature, sunlight, soil aeration, availability of plant nutrients directly act on crop growth. These parameters vary from habitat to habitat and determine the suitability of a plant or a crop to any particular environment.

Sugarcane is one of the most important commercial crops in Karnataka, and grown over an area of 0.35 million ha in different agro-climatic conditions and wide range of soils, with yields ranging from 70 to 103 t/ha (DES, 1995-96). The major cane growing soils in the north of the state are shrink-swell (fine, smectitic, calcareous, Vertic Haplustepts and very fine, smectitic, calcareous, Typic Haplusterts) and lateritic soils (fine, kaolinitic, Rhodic Paleustalfs). Deep, well-drained, loamy soils (fine-loamy, mixed, Typic Haplustepts and fine-loamy, mixed, Typic Tropaquepts) are dominant in the southern parts of the state (Naidu, 1999). Soil crop suitability studies provide information on choice of crops to be grown for maximizing crop production per unit of land, labour and inputs, and for sustainable use of land.

This paper compares the application of the FAO and SPR approaches for assessing suitability of major sugarcane growing soils of Karnataka.

Materials and methods

Five sites (Fig. 1) representing major cane growing soils of the state were characterized and classified according to Soil Taxonomy (Soil Survey Staff 1994). Cane yield, management and climatic data(1994-97) were collected from regional sugarcane research stations. Land suitability evaluation was carried out following the FAO framework (FAO 1976) and SPR (Mc Cormack 1974).

The FAO framework involves formulation of climatic and soil-site criteria to meet the requirements of crops and rating of these parameters for highly suitable (S1), moderately suitable (S2), marginally suitable (S3) and unsuitable (N) classes. These are matched with the existing land qualities to arrive at a suitability class. Table 1 summarises the land suitability criteria for sugarcane, following Clements (1980), Bull and Glasziou (1963), Gascho *et al.* (1970), Waldron *et al.* (1967), Blackburn (1984), Kakde (1985), Hunsigi (1993), Humbert (1968), Sys (1993), Sund and Clements (1974), Tandon and Srivastava (1981), Mehrad (1968) and Valdivia (1977).

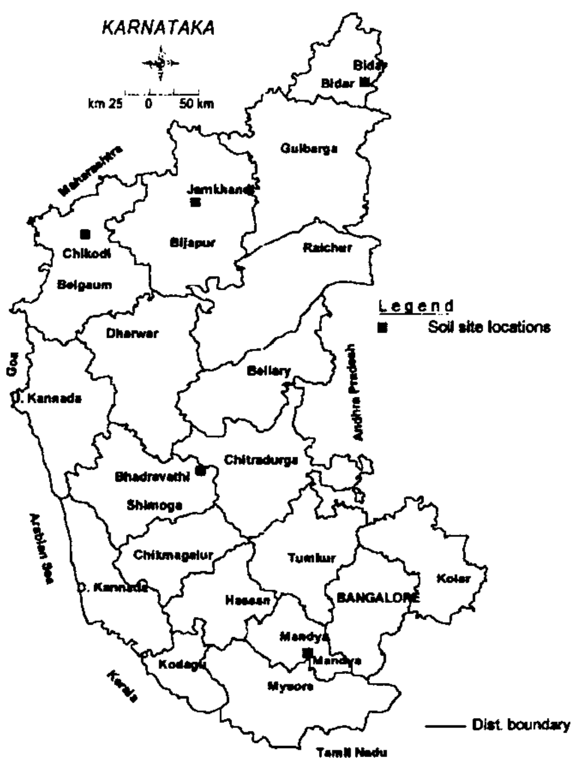

Fig.1. Site locations of sugarcane growing soils

Table 1. Suitability criteria and ratings for sugarcane

Parameters	Suitability class			
	Highly	Moderately	Marginally	Not suitable
Climate				
Temperature(°C)				
Growth stage	30-34	26-30/34-38	26-20/38-40	< 20
Ripening stage	10-20	20-30	10-5	
Solar Radiation (cal/cm²/day)	400-600	300-400	200-300	< 200
Relative humidity(%)				
Growth stage	70–85	60-70/85–90	60–50/>90	< 50
Ripening stage	55-76	75-90	<55/>90	
Soil/Site				
Drainage class	Well drained	Moderately/ imperfectly drained	Poorly drained	Very poorly/ excessively drained
Depth of water table (m)	>1.0	1.0-0.5	< 0.5	
Soil texture	l,cl,sil, sicl,sc	c,sl	c+(vf), s	
Soil depth (m)	>1.0	1.0-0.75	0.75-0.50	<0.5
Coarse fragments (%)	<15	15-35	35-50	>50
CaCO3 (%)	<10	10-25	25-40	>40
CEC ($cmol/kg^{-1}$)	>20	0-20	10-5	<5
pH	6-8	5 - 6 / 8 - 9	4-5/9.0-9.5	<4, >9.5
Salinity (dSm^{-1})	<2	2-4	4-9	>9
Exchangeable Sodium Percent	<10	10-15	15–25	>25

Soil Texture : s-sand, sl-sandy loam, sc-sandy clay, l-loam, sil-silt loam, cl-clay loam, sicl-silty clay loam, c-clay, c+(vf)-clay (smectitic >60% clay)

In SPR approach, individual parameters (climate and soil) are not considered, instead the performance of each individual soil is rated in terms of yield under a defined level of management. The yield standard is established on one of the most productive soils in an area specifying the optimum level of inputs. Considering the yield standard and optimum level of management, soils that produce more than 80% of standard yield are grouped as highly suitable, 40 to 80% yield level as moderately suitable and 20-40% yield level as marginally suitable and soils that yield <20% of standard yield are not suitable (Dent and Young 1981). After arriving at the suitability class by each of these approaches, they were further correlated with crop yields to judge the suitability of the methods.

Results and discussion

The dominant cane growing soil types (Fig.1) are Chikodi, Jamkhandi and Bidar in northern parts of Karnataka, and Mandya and Bhadravathi in southern areas. Nearly 80% of the crop acreage is confined to five districts: Belgaum, Bijapur and Bidar in the north; and Mandya and Shimoga in the south (Table 2).

Table 2. Area and productivity trends of sugarcane in Karnataka

District	1979-80		1983-84		1988-88		1994-95		Mean crop productivity	RYI	RSI
	A	Y	A	Y	A	Y	A	Y	Y		
Belgaum	42.5	61.0	59.4	64.6	85.5	74.1	115.1	80.8	70.1	88	392
Bidar	11.2	63.7	14.5	52.3	18.1	71.3	20.9	95.9	70.8	83	314
Bijapur	7.7	80.7	18.6	64.6	28.2	62.7	64.4	107.3	78.8	98	97
Mandya	23.7	77.0	23.8	103.6	30.8	99.8	35.3	131.1	102.8	128	574
Shimoga	5.7	53.2	7.8	71.3	17.4	77.9	17.3	114.0	79.1	97	172
State	135.3	71.5	172.7	74.8	238.9	78.2	344.9	96.0	80.1		

Source : DES, 1979-80 to 94-95

A : Area in '000 ha, Y : Yield in t/ha
Relative yield index (RYI) : >125 High, 75-125 Medium, <75 Low
Relative Spread Index (RSI) : >100 High, 75-100 Medium, <75 Low

Trends in cane area and productivity

The long term (16 years) data on crop acreage and productivity trends show a progressive increase in the area under cane whereas cane productivity has been variable. Mandya district, on the whole, registered the highest yield (102.8 t/ha) and also a high spread index (Kulkarni *et al.*1988). Therefore, the cane yield obtained on Mandya soils under the recommended agronomic package is set as yield standard for sugarcane crop in the state.

Sugarcane growing soils and climate

The morphological, physical and chemical properties of the various soils are summarised in table 3. Their potentials for cane production are discussed.

Chikodi soils: They are deep, moderately well-drained, clayey, calcareous in nature, with high cation exchange capacity. They are classified as fine, smectitic, calcareous, Vertic Haplustepts. Cane root and stem growth is poor in clayey soils which will result in reduced cane growth. Soil depth and nutrient status are in desirable range. The rainfall distribution, relative humidity and maximum temperature during the vegetative phase (Table 4) are unfavourable and the same at grand growth period are favourable for rapid growth and cane elongation.. The soils yielded 90-126 t cane/ha (Table 5) with 108.6 t/ha mean cane yield and productivity of 212 kg cane/kg nutrient under recommended agronomic package:variety-CO-M-88121, planting season (Dec-Jan), irrigation schedule (25 days interval) with 250-75-187.5 kg/ha/NPK fertilizer application (Annonymous, 1994-97a).

Jamkhandi soils : They are deep, moderately well -drained, clayey, strongly alkaline, calcareous with high cation exchange capacity . They are classified as very fine, smectitic, calcareous, Typic Haplusterts. Soil thickness and nutrient status are favourable whereas heavy texture, drainage, and presence of lime are limitations. The rainfall distribution, relative humidity and maximum temperature during the vegetative phase (Table 4) are unfavourable and the same at grand growth period are congenial for rapid cane growth. Long dry spells and lack of sufficient rains during the monsoon period result in reduction of cane yield. The soils yielded 83-110 t cane/ha (Table 5) with 95.7t/ha mean cane yield and productivity of 187kg cane /kg nutrient under recommended agronomic package: variety-CO-85004, planting season (Dec-Jan), irrigation schedule (15 days interval) with 250-75-187.5 kg/ha/NPK fertilizer application (Annonymous, 1994-97b).

Bidar soils : They are deep, well-drained, clayey , neutral with low cation exchange capacity, with gravel content (60 to 10%) that decreases with depth. They are classified as fine, kaolinitic, Rhodic Paleustalfs. Soil thickness, drainage and neutral reaction are congenial whereas fine texture, gravelly rooting medium and poor nutrient status are limitations. The rainfall distribution, relative humidity and maximum temperature during the vegetative phase are unfavourable and the same at grand growth period are congenial for rapid cane growth. The soils yielded 98-120 t cane/ha (Table 5) with 109 t/ha mean cane yield and productivity of 273kg cane/kg nutrient under recommended agronomic package:variety-CO-8014, planting season (Jan-Feb), irrigation schedule (7 days interval) with 250-75-75 kg/ha/NPK fertilizer application (Annonymous, 1994-97c).

Bhadravathi soils : They are deep, moderately well-drained, clay loam, neutral with medium cation exchange capacity and with water table at 110 cm depth. They are classified as fine-loamy, mixed, Typic Tropaquepts. Soil depth, texture and neutral reaction are in desirable range whereas nutrient status is the major limitation. The rainfall distribution during the vegetative growth phase is unfavourable and the same at grand growth period are favourable. The mean maximum temperature and relative humidity remains favourable throughout the cropping period. The soils yielded 164 - 217 t cane/ha with 188.3 t/ha mean cane yield and productivity of 418kg cane/kg nutrient under recommended agronomic package:variety-CO-62175, planting season (Nov), irrigation schedule (15 days interval) with 250-100-100 kg/ha/NPK fertilizer application (Annonymous, 1994-97d).

Mandya soils : They are deep, well-drained, sandy clay loam , strongly alkaline with low cation exchange capacity especially in low lying areas. However, a large extent of Mandya soils which occur on higher ground are neutral in reaction. They are classified as fine-loamy, mixed, Typic Haplustepts. Soil depth, drainage, reaction and texture are desirable for sugarcane whereas nutrient status is a limitation. The rainfall distribution and relative humidity at the vegetative phase are unfavourable and the same at grand growth period are favourable. The mean maximum temperature is favourable throughout the cropping period. The soils yielded 140 - 197 t cane/ha with 170.7 t/ha mean cane yield and productivity of 359kg cane/kg nutrient under recommended agronomic package:variety-CO-62175, planting season (Nov), irrigation schedule (7-10 days interval) with 250-100-125 kg/ha/NPK fertilizer application (Annonymous,1994-97e).

In all cane growing regions, the minimum temperature (>18^{0} C) and daily incident solar radiation (>250 cal/ cm^{2}/ day) throughout the year are favourable.

Table 3. Physical and chemical properties of soils

Horizon	Depth (cm)	Particle size class (mm) (%)			Texture	Organic carbon (%)	$CaCO_3$	Coarse fragments (%)	pH (water) (1:2.5)	E.C. (dSm^{-1}) (1:2.5)	ESP	CEC ($cmol(p+)kg^{-1}$)
		Sand	Silt	Clay								
BHADRAVATHI SOILS												
Ap	0-12	46.7	23.3	30.0	cl	0.7	-	10	6.4	0.38	3.9	12
A2	12-28	45.8	24.2	30.0	cl	0.6	-	10	7.4	0.23	3.9	12
Bw1	28-56	44.1	20.9	35.0	cl	0.5	-	10	7.7	0.19	3.1	13
Bw2	56-86	44.8	18.2	35.0	cl	0.2	-	10	7.7	0.17	2.6	15
Bw3	86-110	49.6	17.3	33.1	cl	0.1	-	10	8.3	0.22	2.8	13
water	110+											
BIDAR SOILS												
Ap	0-14	49.9	16.4	33.7	gscl	0.5	-	60	6.4	-	0.4	10
Bt1	14-30	36.6	11.1	52.3	gc	0.4	-	60	6.6	-	0.4	9
Bt2	30-55	13.4	18.4	68.2	c	0.4	-	10	6.6	-	0.6	9
Bt3	55-80	15.5	23.9	60.6	gc	0.3	-	15	6.7	-	0.5	9
Bt4	80-113	16.1	24.3	59.6	c	0.3	-	-	6.7	-	0.4	9
Laterite	113-125											
CHIKODI SOILS												
Ap	0-12	28.6	22.1	49.3	c	0.8	6	5	8.2	0.62	4.0	21
A2	12-32	31.1	19.4	49.5	c	0.7	20	5	8.2	0.45	3.0	25
Bwk2	32-46	31.1	18.9	50.0	c	0.6	23	10	8.4	0.33	2.3	37
Bwk3	46-58	40.4	9.3	50.3	c	0.3	24	10	8.3	0.35	2.0	41
Bwk4	58-74	24.4	27.0	48.6	gc	0.3	30	20	8.6	0.33	2.0	43
Bwk5	74-102	23.1	32.4	44.6	c	0.3	28	5	8.2	0.35	1.8	44
Bwk6	102-150	26.8	23.2	50.0	c	0.3	26	5	8.4	0.36	1.8	45
JAMKHANDI SOILS												
Ap	0-18	15.4	20.2	64.4	c	0.7	14	<5	8.7	0.15	9.7	58
A2k	18-45	10.2	20.2	69.6	c	0.6	13	<5	8.9	0.16	9.8	63
A3ssk	45-78	10.4	15.8	73.8	c	0.4	12	<5	8.6	0.17	9.6	65
A4ssk	78-107	11.0	14.5	75.5	c	0.4	12	<5	8.7	0.15	9.6	64
A5ssk	107-150	8.0	12.1	79.9	c	0.3	12	<5	8.6	0.16	9.2	66
MANDYA SOILS												
Ap	0-16	68.5	8.5	23.0	scl	0.3	5	-	8.6	0.20	5.9	12
Bw1	16-34	68.6	7.2	24.2	scl	0.3	4	-	8.8	0.23	5.9	12
Bw2	34-66	70.7	4.4	24.9	scl	0.3	4	-	8.8	0.29	6.2	12
Bw3	66-91	58.5	13.0	28.5	scl	0.3	5	-	9.0	0.20	5.9	14
Bw4	91-121	60.6	10.2	29.3	scl	0.2	4	-	9.1	0.25	6.0	15

Table 4. Average weather conditions for sugarcane (194-1997) at different study locations

Place	Vegetative Phase (March to June)					Grand growth Phase (July to October)					Ripening Phase (Nov to Feb)				
	SR	RF	MAX	MIN	RH	SR	RF	MAX	MIN	RH	SR	RF	MAX	MIN	RH
Bhadra-vathi	384	158	33.2	20	71	273	557	31.4	19.4	78	374	28.9	29.1	15	74
Bidar	410	171	36.7	23	55	291	448	33	21.2	74	372	47.5	28.6	17	48
Chikodi	455	323	35.9	18	60	305	480	30.2	18.9	74	425	72.8	31.3	10	66
Jamkhandi	432	146	37.1	23	50	313	265	33	21.8	74	389	72.8	30.8	18	57
Mandya	490	223	31.9	20	64	399	392	29.8	19.8	76	440	109	28.7	16	68

Table 5. Sugarcane yield potential on different soils under recommended agronomic practices

Soils	No. of ploughings	Variety	Planting season	Irrigation interval (days)	Fertilizer dose-NPK (kg/ha)	Cane yield potential (t/ha)	Mean cane Yield (t/ha)	Cane productivity (kgcane/ kg nutrient)
Mandya1	3-4	CO-62175	November	7-10	250-100-125	140-197	170.7	359
Kathalgare2 (Bhadravathi)	4-5	CO-62175	November	15	250-100-100	164-217	188.3	418
Sankeshwer3 (Chikodi)	3-4	COM-88121	Dec.-Jan.	25	250-75-187.5	90-126	108.6	212
Jamkhandi4	4-5	CO-85004	Dec.-Jan.	15	250-75-187.5	83-110	95.7	187
Bidar5	4-5	CO-8014	Jan.- Feb.	7	250-75-75	98-120	109	273

Source: 1.Annual report 1994-97 AICRIP, Mandya, 2. Annual report 1994-97 ARS,Kathalagere, 3. Annual report 1994-97 ARS,Sankeshwar, 4. Annual report 1994-97 RRS, Jamkhandi, 5. Annual report 1994-97 ARS, Bidar.

Land suitability evaluation

Application of the FAO framework(Table 6) has grouped soils of Mandya (Typic Haplustepts) and Bhadravathi (Typic Topaquepts) as moderately suitable with moderate limitations of nutrient status and relative humidity. Chikodi soils (Vertic Haplustepts)are grouped as moderately suitable with moderate limitations of temperature, drainage, texture and presence of lime. Bidar soils (Rhodic Paleustalfs) and Jamkhandi soils (Typic Haplusterts) are categorized as moderately to marginally suitable with poor nutrient status, texture, gravelly subsoil and mean maximum temperature.

Table 6. Sugarcane soils and their suitability ratings

Soil	Parameters												Management Response		Suitability class	
	Climate		Site		Soil											
	Max. temp.	RH	Drainage	Water table	Thickness	Texture	Gravel	EC	ESP	$CaCO_3$	pH	CEC	No. of limitations	Cane yield (t/ha)	FAO	SPR
Bhadravathi	S1	S1	S1	S2	S1	S1	S1	S1	S1	S1	S1	S2	2	188.3	S2	S1
Bidar	S2	S2-S1	S1	S1	S1	S2	S3	S1	S1	S1	S1	S3	5	109.0	S2-S3	S2
Chikodi	S2	S2-S1	S2	S1	S1	S2	S1	S1	S1	S2	S2	S1	6	108.6	S2	S2
Jamkhandi*	S2	S3-S2	S2	S1	S1	S3	S1	S1	S1	S2	S2	S1	7	95.7	S2-S3	S2
Mandya	S1	S2-S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S2	2	170.7	S2	S1

Note: S1-Highly, S2 moderately, S3-Marginally suitable, * - Long dry spells and low rainfall is another limitation

Comparison of crop yield and soil suitability class (Table 6) shows no logical correlation between soil suitability class, cane yield, management response and number of limitations. However, soils with fewest limitations show high yield potential and are highly responsive to management. As the number of limitations increase, the crop productivity and fertilizer use efficiency sharply declined. Lack of good correlation between suitability class and crop yield potential may be attributed to agronomic management that has overcome the limitations e.g.the dry period is overcome by frequent irrigations in soils of Bidar and Jamkhandi and nutrient status limitation by fertilizer application in Mandya, Bhadravathi and Bidar soils.

The SPR approach, on the contrary, has grouped the soils of Mandya and Bhadravathi as highly suitable, and Chikodi, Jamkhandi and Bidar soils as moderately suitable based on crop yield potential and management response. Comparison of suitability class and crop performance show strong correlation indicating the fitness of the method. Nonetheless, the simplicity of the SPR approach and direct assessment of productive capacity through measure of productivity are attractive. Crop yield is found to be a better index to judge the productive capacity of soil than the individual land/soil parameters or commbination of these. These findings are in conformity with the observations made by Aitken (1983) for sugarcane in Nigeria.

Conclusions

The results of the present study indicate that the crop yield is a better index to judge the productive capacity of the soil than the individual land/soil parameters. Combination of soil potential rating approach is a better approach to assess the land suitability for crops compared to FAO approach.

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