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Soil-site suitability evaluation of Alfisols for finger millet

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Abstract : In field trials, the influence of soil and site characteristics on finger millet were studied. Land slope, erosion, soil depth, texture, cation exchange capacity, exchangeable sodium percentage, exchangeable calcium, plant available water holding capacity and length of growing period were found to influence significantly the yield of finger millet in Alfisols. For achieving maximum yield, the optimum values of the above parameters from the fitted quadratic curves, were found to be <3% of slope, erosion rating of 1, soil depth of 1 m, 16% of silt (with >50% clay), 9.0 cmol (p+) kg^{-1} of cation exchange capacity, exchangeable sodium percentage of 1, Exchangeable Ca of 3.5 cmol (p+) kg^{-1} , >120mm of plant available water capacity and length of growing period of 240 days . Among the 13 multiple linear regression (MLR) models established, model no. V (Yield = 685.54 +1.47 erosion ratings on four points scale +0.25 soil depth in cm + 0.09 coarse fragments % (v/v) -1.13 sand % - 3.1 CEC in cmol (P^+) kg^{-1}- 0.73 ESP- 9.45 Exch. Ca in cmol (P^+) kg^{-1} +0.70 PAWC in mm -2.92 LGP in days) was found to be the most reliable in judging the yield potential in Alfisols. However, the user can use any of the 13 models developed depending on the information available for predicting the yield potential of a particular soil.

Additional key words : *Regression models, soil requirements*

Introduction

Finger millet is the staple food crop for millions of people in India and Africa, besides providing straw for domestic animals. It is grown mainly in Alfisols of southern India. Interpretation of these soils in terms of their characteristics for its cultivation, goes a long way in (i) defining the soils of finger millet and (ii) quantifying the limits of soil parameters to achieve the potential yield and hence the present study was undertaken.

Materials and Methods

Field studies on the influence of soil-site characteristics on finger millet were conducted on 11 soil series for four years (1996-98 and 2006) in Kuthanagere watershed near Bangalore during the rainy season (June-November). Before experimentation, the detailed soil survey of watershed was undertaken as per the procedure outlined in Soil Survey Manual (IARI 1971). The site characteristics (erosion and drainage) after judging their extent were numerically rated for statistical analysis like nil to slight erosion as one, moderate as two, severe as three and very severe as four; poorly/ excessively drained as one, imperfectly/well drained as two and moderately well drained as three. The physical and chemical properties of soil (horizon-wise) of the representative pedon (Kuthangere 1 to 13) were analysed using standard procedure and then arrived at single weighted averaged values for each soil series (Table 1). The difference in moisture holding capacity at 33 and 1500 kPa was multiplied by bulk density and soil depth to

Table 1. Salient characteristics of soil series and the corresponding ranges of grain yield of finger millet over four years

Properties	Soil Series										
	Kuthanagere-1	Kuthanagere-2	Kuthanagere-3	Kuthanagere-4	Kuthanagere-6	Kuthanagere-7	Kuthanagere-9	Kuthanagere-10	Kuthanagere-11	Kuthanagere-12	Kuthanagere-13
Slope (%)	2	0.5	0.5	5.5	5.5	3.5	2	2	0.5	0.5	5.5
Erosion rating	2	1	1	2	3	2	2	2	2	2	3
Drainage rating	2	2	2	2	3	2	2	2	2	2	3
Ground water table(m)	12	12	12	12	7.5	20	7.5	12	7.5	12	7.5
Depth (cm)	106	155	140	65	79	90	150	102	150	77	13
Coarse Fragments (%) (v/v)	13.6	14.6	14.4	28.8	16.5	48.4	7.5	45.6	0	30.8	40
Sand (%)	47.4	58.9	52.6	61.9	54.7	61.2	57.5	50.5	75.8	64.3	64.8
Silt (%)	13.5	18.3	14.9	9	13.3	12.5	12.2	16.6	9.7	20.5	9.5
Clay (%)	39.1	22.7	32.5	28.6	31.9	26.3	30.2	37.4	14.5	15.2	25
OC (%)	0.3	0.21	0.24	0.2	0.65	0.41	0.29	0.65	0.21	0.25	0.42
CEC	8.2	6.4	7.6	5.7	7	6.3	8.4	11.6	4.9	4.4	5.1
BS (%)	58.2	85.7	62.9	69	63.8	64	62.5	60.6	66	87.1	75.1
pH	6.5	7.2	6.5	6.2	6.1	6.4	6.5	6.3	5.9	6.4	6.8
EC (dSm^{-1})	0.1	0.1	0.03	0.08	0.1	0.1	0.19	0.13	0.1	0.1	0.23
ESP	1.23	1.65	1.67	2.2	1.44	1.64	2.24	1.6	7.92	2.27	5.6
Av. N $kgha^{-1}$	234.5	212.8	241.9	220.9	182.6	143.8	210.1	232.5	153.2	174.1	174.1
Av. P ($kgha^{-1}$)	22.6	16.4	21.7	25.1	14.1	10.8	22.2	18.8	17.5	15	21.5
exch.K (ppm)	0.1	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.2
Exch.Ca (cmol (p+) kg+)	3.3	3.9	3.1	2.6	2.7	2.6	3.3	3	2.3	2.7	2.5
Exch.Mg (cmol (p+) kg+)	1.3	1.3	1.5	1	1.5	1.3	1.6	1.4	0.8	1.1	0.8
Fe (ppm)	1.51	1.44	1	1.67	1.85	1.46	1.35	1.84	0.85	1.52	0.98
Cu (ppm)	0.14	0.11	0.22	0.22	0.14	0.13	0.14	0.19	0.16	0.14	0.29
Zn (ppm)	0.33	0.58	0.63	0.39	0.2	0.36	0.44	0.63	0.42	0.48	0.87
Mn (ppm)	3.12	2.48	2.01	7.24	6.12	3.6	6.48	4.81	2.78	8.73	2.3
PWAC (mm)	41.4	118.3	108.6	40.4	31.5	43.9	111.7	108.2	68.5	61.2	10.9
LGP (days)	206	224	221	206	202	207	223	221	213	211	195
Grain yield (qha^{-1})	17.1 - 40.8	18.4 - 42.5	37.5-39.8	20.2-26.5	29.0-38.5	07.5-28.5	19.2-28.1	25.0-30.1	20.0-28.0	20.5-23.4	12.5-18.8
Mean grain yield (qha^{-1})	31.85	30.86	38.4	24.2	34.3	18.96	24.62	27.9	24.0	22.24	16.12

calculate the total plant available water holding capacity of each soil series. The length of growing period was calculated following the FAO model (Higgins and Kassam 1981). However, to calculate the

LGP after the cessation of rains, the actual stored soil moisture (PAWC) in each soil unit was used instead of the assumed 100 mm in the FAO model. The crop was raised as per the package of practices recommended by the University of Agricultural Sciences, Bangalore. The grain yield (q ha^{-1}) was calculated from the sun-dried grain weights of harvested net plots.

Correlation matrix was worked out to study the relationship of the soil-site parameters among themselves and on crop yield. In order to find the optimum range of any given soil parameter (x) for obtaining maximum crop yield (y) under both management levels, a quadratic equation ($y = a+bx+cx^2$) was fitted where 'a' is an intercept and 'b' and 'c' are the regression coefficients. Further, the statistical relationships between the soil-site characteristics (x_1 to x_n) altogether and the seed yield were established by multiple linear regression (MLR) equations ($y = a + b_1x_1 + b_2x_2 + …….. + b_nx_n$). Where 'a' is an intercept and 'b_1' to 'b_n ' are the partial regression coefficients of 'x_1' to 'x_n', respectively. The R^2 value obtained, was tested at or below 5 per cent level of significance. Using the step-down regression analysis by least square technique (Barrie *et al.* 1986), the less important soil parameters were dropped one after another and the MLR models with seed yield were developed keeping the remaining important ones. Among the number of models so developed, the best models were chosen based on the following criteria: (a) R^2 value should be higher and significant at or below 5 per cent level of significance, (b) more number of independent variables in the model should also be significant at or below 5 per cent and (c) the SE of 'a', SE of 'y' estimate and the index of multi-colinearity should be comparatively low (d) the intercept 'a' should also be significant at or below 5 per cent.

Results and Discussion

It was observed that among the 26 soil- site characteristics studied (Table 1), 16 of them, particularly the soil depth, coarse fragments, soil texture, CEC, PAWC and LGP had significant correlation with grain yield of finger millet. Soil depth being highly and positively correlated with seed yield, the relationship was more of a quadratic in nature (Table 2). The optimum soil depth from the fitted equation ($y = 12.37 + 0.23x-0.001x^2$) was observed to be around 1m. Coarse fragments in the soil had negative relationship with seed yield ($y = 28.97 + 0.19x- 0.01x^2$, $r = -0.51$**). The silt content had positive and prominently quadratic relationship with seed yield ($y = -49.18 + 10.36x - 0.33x^2$, $r = 0.57$ **) and accordingly the optimum content was worked to be 16 per cent. With an increase in clay from 30 per cent onwards, there was a steep increase in yield. On the other side, below 30 per cent of clay, the yield did not decrease proportionately ($y = 30.35 - 0.88x + 0.02 x^2$). On the contrary, increase in sand up to 50 per cent brought down the yield drastically. Thus, right proportion of sand (<35 %) and clay (>50 %), keeping the optimum silt at 16 per cent, play an important role in determining the yield of finger millet. Cation exchange capacity, showed significant positive and quadratic relationship with finger millet yield ($y = -26.87 + 13.12x - 0.73 x^2$, $r = 0.52$**). Cation exchange capacity greater than 9 cmol (p^+) kg^{-1}, showed an increase in grain yield. Exchangeable calcium showed a significant quadratic relationship with grain yield of finger millet to the extent of 27 per cent ($y = -100.9 + 75.41 x - 10.69 x^2$, R2 = 0.27**), thus showing the importance of calcium nutrition in finger millet. Accordingly, the optimum concentration of exchangeable calcium in the soil was observed to be 3.5 cmol (p^+) kg^{-1}. The results of calcium nutrition are in conformity with the findings of Nathan (1995) who has recommended 16.8 kg calcium per ha in addition to recommended levels of NPK for optimum yield. Plant available water capacity and LGP being the indexes of moisture storage capacity and moisture availability periods were positively correlated with finger millet with optimum values of >120mm and 240 days, respectively. However, the optimum value of LGP depends mainly on the duration of the crop rather than its yield potential.

Table 2. Relationship of significant soil parameters and regression equations established with the seed yield of finger millet

Parameters	Type	r value	Regression Equation	R^2 Value
Slope (%)	Linear	-0.37*	Y=30.48-1.67X	0.14*
	Quadratic	-0.38*	$Y=31.32-0.63X+0.17X^2$	0.14*
Erosion (rating)	Linear	-0.44**	Y=38.14-5.91X	0.20**
	Quadratic	-0.46**	$Y=47.09-15.83X+2.44X^2$	0.22**
Depth (cm)	Linear	0.58**	Y=15.87+0.11X	0.34**
	Quadratic	0.61**	$Y=12.37+0.23X-0.001X^2$	0.37**
Coarse frag. (% v/v)	Linear	-0.48**	Y=33.37-0.21X	0.23**
	Quadratic	-0.51**	$Y=28.97+0.19X-0.01X^2$	0.26**
Sand (%)	Linear	-0.52**	Y=65.62-0.67X	0.27**
	Quadratic	-0.53**	$Y=131.97-2.93X+0.02X^2$	0.28**
Silt (%)	Linear	0.35*	Y=14.10+0.88X	0.12*
	Quadratic	0.57**	$Y=-49.18+10.36X-0.33X^2$	0.32**
Clay (%)	Linear	0.35*	Y=13.48+0.45X	0.13*
	Quadratic	0.39*	$Y=30.35-0.88X+0.02X^2$	0.15*
CEC(cmol (p^+) kg^+)	Linear	0.37*	Y=13.78+1.82X	0.14*
	Quadratic	0.52**	$Y=-26.87+13.12X-0.73X^2$	0.27**
ECe (dSm^{-1})	Linear	-0.56**	Y=36.87-86.41X	0.32**
	Quadratic	-0.57**	$Y=39.04-122.76X+124.51X^2$	0.32**
ESP	Linear	-0.48**	Y=32.23-2.26X	0.23**
	Quadratic	-0.61**	$Y=45.59-11.89X+1.17X^2$	0.37**
Exch.Ca(cmol (p^+) kg^+)	Linear	0.45**	Y=0.87+8.54X	0.20**
	Quadratic	0.52**	$Y=-100.90+75.41X-10.69X^2$	0.27**
Exch.Mg(cmol (p^+) kg^+)	Linear	0.55**	Y=3.83+18.37X	0.30**
	Quadratic	0.56**	$Y=-17.37+57.14X-16.73X^2$	0.31**
Cu (ppm)	Linear	-0.38**	Y=35.90-55.08X	0.14**
	Quadratic	-0.48**	$Y=3.45+302.21X-879.67X^2$	0.22**
Zn (ppm)	Linear	-0.36*	Y=34.48-16.06X	0.13*
	Quadratic	-0.40*	$Y=23.00+30.41X-40.92X^2$	0.16*
PAWC (mm)	Linear	0.45**	Y=19.15+0.11X	0.20**
	Quadratic	0.45**	$Y=-18.19+0.15X-0.0003X^2$	0.20**
LGP (days)	Linear	0.45**	Y=-63.06+0.42X	0.20**
	Quadratic	0.45**	$Y=-326.51+2.93X-0.006X^2$	0.20**

From the correlation matrix, it was observed that the soil depth, clay content, PAWC, LGP and CEC were closely related with each other and altogether on grain yield (Shivaramu *et al.* 1997). Therefore, instead of looking at their individual effects, the overall interaction of different soil parameters on grain yield, seemed to be appropriate and hence 13 MLR equations were worked out. The significant R^2 values of these MLR equations ranged from 0.72 in model no. I (Table 3), when 13 soil parameters were regressed, to 0.34 in model no XIII involving only soil depth. However, the two soil parameters viz. soil depth and sand could explain 47 percent of the variation in grain yield (R^2 = 0.47). Among these 13 models, the better models as per the set out criteria, were found to be model no.V (R^2 =0.61), model VII (R^2 =0.57) and Model XII (R^2 =0.47). However, one can use any of these models for judging the suitability of a land depending on the

Table 3. Multiple linear regression coefficients of soil parameters on yield of finger millet in different models

Parameters	Model No.												
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
Slope	2.8489	11.4405**	1.1686	1.2311									
Erosion	5.9225	-13.0067	-1.2338	0.8731	1.4670	-2.6029							
Depth	0.4425**	0.4161**	0.2282	0.2907**	0.2518*	0.1708	0.1884*	0.0992	0.1018	0.0572	0.0897**	0.0888**	0.1094**
Coarse fragments	0.0479	0.1608	0.2498	0.1714	0.0936	-0.1161	-0.0898	-0.1030	-0.0711	-0.1271			
Sand	7.2924	-7.7471	-1.7511*	-1.4717*	-1.1334	-0.2435	-0.1825	-0.5150	-0.4660	-0.4687	-0.5178	-0.4919**	
Silt	8.9584												
Clay	9.9100	-5.3424											
CEC	-13.5764	0.8149	-4.6161	-4.0496	-3.1046								
ESP	-0.5585	9.7065	2.2128	0.2949	-0.7324	-2.2577	-2.3772	-0.4470	-0.2452	-0.2574	0.1267		
Exch.Ca	-5.9535	-18.8652	-6.7131	-8.9856	-9.4549*	-9.0673	-7.5241	-3.3924					
DTPA-Zn	19.1922	13.7477	-19.8319										
PAWC	0.1720	-0.9577	0.8840	0.5734	0.7040	0.8140*	0.7759*						
LGP	-0.6877	3.6880	-3.2428	-2.2670	-2.9243	-3.6247*	-3.4382*	-0.1081	-0.1824				
a	-627.45	-116.62	782.50	569.82	685.54*	776.81*	724.54*	83.73	84.90	52.24	47.85**	46.77**	15.87**
S.E. of a	714.63	560.84	478.52	325.54	307.12	308.83	299.14	57.61	57.38	14.30	13.73	10.66	2.62
S.E. of Y	5.96	6.00	6.58	6.51	6.52	6.68	6.63	7.01	6.98	6.91	6.93	6.83	7.52
R^2	0.7200**	0.7054**	0.6317**	0.6266**	0.6118**	0.5788**	0.5706**	0.5048**	0.4930**	0.4877**	0.4704**	0.4701**	0.3402**

information generated on soil-site parameters and the management level of the crop, but bearing the risk of associated standard errors.

Sys *et al.* (1993) have attempted to establish the crop requirements by setting the suitability classes and the range of limits of climate, landscape and soil characters for all the important crops including millets, however not specific to finger millet. Further, Naidu *et al.* (2003) attempted to establish the soil-site suitability criteria for finger millet, but seemed to be generalized and hence needs refinement in the light of the present findings particularly of LGP, depth, CEC, drainage, texture, coarse fragments and slope.

Conclusions

The studies conducted on 11 different soil series to screen out the yield contributing soil parameters revealed soil depth, CEC, ESP, Exch. Ca, PAWC, LGP and soil texture as important factors, besides slope and erosion. Therefore, the relationships of above parameters with grain yield of finger millet have been quantified individually and in combination. Model no V (R^2 =0.61) was found to be the best in judging the suitability of land for finger millet.

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