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Soil-Site Suitability for Finger Millet Crop in Kumarband Sub Watershed Area of Dangs District (Gujarat)

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Abstract
The seventeen representative pedons were evaluated for their suitability to finger millet in the soils of different elevation having gently slope (flat plains) to higher degree of sloppy land i.e. at lower <300 m msl (P13 to P17), middle 300-350 m msl (P6 to P12) and upper piedmont >350 m msl (P1 to P5) (higher degree of slope) of Kumarband sub watershed area in the Dangs district of Gujarat. The soils of study area were neutral to slightly alkaline in reaction and low to medium in organic carbon. The study suggests that soils at lower elevation finger millet crops were moderately suitable (S_2), while in soils of middle elevation finger millet are marginally suitable (S_3) except pedon 9 (P_9) i.e. not suitable finger millet cultivation. In case of upper elevation, finger millet was marginally suitable (S_3) but soils of surrounding area of pedon 4 (P_4) are not suitable finger millet cultivation because of higher degree of slope, soil texture, soil depth, stoniness, erosion and soil drainage are the major limitations. Results showed that the suitability classes can be improved if the correctable major limitations of soil erosion of hilly sloppy area were the only option to control the limitations which make them moderately sustainable to suitable class through soil amelioration measures.

Keywords: soil-site suitability, Finger millet, elevations, limitations, potential

1. Introduction
The process of land suitability classification is the evaluation and grouping of specific areas of land in terms of their suitability for defined use. The main objective of the land evaluation is the prediction of the inherent capacity of land unit to support a specific land use for long period of time without deterioration. The topographic characteristics, climatic conditions and soil quality of an area are the most important determinant parameters of the land suitability evaluation. Land suitability evaluation is the process of estimating the potential of land for land use planning (Sys *et al*., 1991) [10]. Several workers have worked out the suitability of soils for various crops such as cotton (Sehgal, 1991; Mandal *et al*., 2002) [7, 4], wheat (Sharma, 1999), sorghum (Pakhan *et al*., 2010) [6], rubber (Kharche *et al*., 1995) [3] and mustard (Gandhi and Savalia, 2014) [2]. However, such in-formation on soils of Kumarbandh Sub watershed in Dangs district of Gujarat in India is very scanty hence, the present study was undertaken to evaluate soil-site suitability for finger millet crop in Gujarat.

2. Material and methods
The study area lies between latitude 20°43´75´´ and 21°39´ 89´´ North, and the meridians of longitude 73°34´89´´ and 73°36´79´´East in south-west part of Dang district. The average rainfall of last ten years (Fig. 1) was found to be 2227 mm with an average of 68 annual rainy days.
The wettest month is July with precipitation of around 500 to 700 mm. The maximum and minimum annual temperature of last ten years was noted to be 29.16ºC and 20.47ºC, respectively. The mean maximum temperature is the highest in the month of May. The entire sub watershed falls under *hyperthermic* temperature regime i.e. the mean annual soil temperature is above 29ºC with an *ustic* moisture regime i.e. a regime between *aridic* and *udic* regime. The relative humidity is the minimum during January and February and it reaches to minimum during the monsoon months and maximum during summer months. In order to get clear idea about the soil resources, to study soil characteristics and to evaluate the land suitability characteristics of sub watershed, two hundred and twenty one surface samples for generating information on fertility and chemical properties of soils of Kumarbandh sub watershed. Apart from surface samples, seventeen soil profiles were dug out depending on landforms in three elevations having gently slope (flat plains)

to higher degree of sloppy land i.e. at lower (P_{13} to P_{17}), middle (P_6 to P_{12}) and upper piedmont (P_1 to P_5) (higher degree of slope) and were examined by following standard procedures (Soil Survey Staff, 2014) [9]. These pedons were evaluated for their suitability using limitation method regarding number and intensity of limitations. Soil suitability for rice crop growing area was evaluated following FAO guidelines (FAO, 1976). Various criteria suitable for finger millet cultivation given by Sys *et al.* (1991) [10] and Shivprasad *et al.* (1998) are presented in table 1, which involves formulation of climatic and soil requirement of the crop as highly suitable (S1), moderately suitable (S2), marginally suitable (S3) and not suitable (N1).

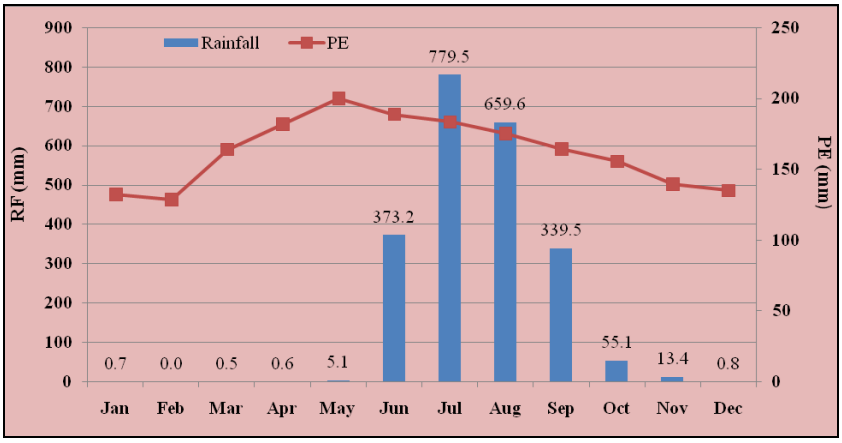

Fig 1: Hydrograph of sub watershed area of Dangs district (1994-2014)

3. Result and discussions

The soil-site suitability for different land uses is very important for suitable and alternate land use planning. Land suitability for different crops and land quality ratings are those as suggested by NBSS & LUP (1994) [5] for Finger millet. The soil-site suitability evaluations based on comparison of land qualities and crop requirements for finger millet crop are presented in Table 1 and Table 2. The inferences drawn based on the land qualities and suitability (Table 4) ratings are described as per elevations following sub heads as under.

3.1 Upper elevation

Pedon-1: The soils associated with the pedon-1, 3 and 5(P_1, P_3 and P_5) were rated marginally suitable (S_3) for finger millet (Table 4) on account of limitations imposed by topography, stoniness, depth and soil texture for finger millet, (Table 3). The soil conservation measures are only the option to control the major limitation of soil erosion in hill slope area which make them unable to be upgraded from current moderately sustainable (S_2) state from marginally (S_3) to moderately suitability class (S_2).

Pedon-2: The soils of the pedon-2 (P_2) were (Table 4) were rated marginally suitable (S_3) for finger millet on account of limitations (Table 3) imposed by topography, stoniness and. All the above limitations need to be corrected to get satisfactory production these crops.

Pedon-4: The soils of the pedon-4 (P_4) were found not suitable (N_1)for finger millet (Table 4), on account of limitations imposed by higher degree of slope, marginal available moisture capacity, soil texture, soil depth, stoniness and soil drainage (Table 3). Because of higher degree of slope, suitability of these soils for the above crops cannot be improved by any means. However, the soils would be suitable for growing grasses and development of pastures and forest plants.

Table 1: Soil Site suitability criteria (crop requirements) for finger millet

Soil- site characteristics		Highly Suitable S1	Moderately Suitable S2	Marginally Suitable S3	Not Suitable N1
Climate regime	Mean Temp. in growing Season ºC (c)	28-34	25-27, 35-38	39-40, 20-24	>40, <20
	Total rainfall(mm)	750-900	600-750	450-600	<450
Land characteristics	Length of growing period (Days) (c)	>100	90-110	60-90	<60
	Soil Drainage class (w)	Well drained; moderately Well drained;	Imperfectly drained somewhat excessively drained	Poorly drained; excessively drained	
Nutrient availability	Texture class (s)	L, sil, sl,cl,sicl,scl	Sic,c, sc	Ls, s, c>60%	
	pH (1:2.5) (f)	5.5-7.5	7.6-8.5;4.5-5.4	8.6-9.5;4.0-4.4	<4.0
Rooting condition (s)	Effective soil depth (cm)	75	51-75	25-50	<25
	Coarse fragments Vol %	15	15-35	35-50	>50
Soil toxicity (n)	Salinity (ECe dS/m)	<1.0	1.0-2.0	2.0-4.0	
	Sodicity (ESP %)	<10	10-15	15-25	>25
Erosion hazards(t)	Slope (%)	<3	3-5	5-10	>10

Table 2: Soil-site suitability evaluation and land qualities of the different pedons in sub watershed area of Dan district

Pedons	Climate regime	Land Characteristics			Nutrient Availability				Effective Rooting Depth	Soil toxicity		Erosion hazards
		Moisture Availability		*Soil Drainage*								
	Rainfall (mm)	AWC	LGP		Texture	pH	OC (%)	CEC (Cmol (p+)kg-^{1})		Salinity (ECe)	Sodicity (ESP)	Slope (%)
Upper Elevation												
P_1	2228	12.72	120	Well Drained	c	5.9	0.68	26.76	80	0.014	6.67	5-8
P_2	2228	9.60	120	Well Drained	l	6.2	0.72	25.37	56	0.015	5.28	$_5$-8
P_3	2228	8.35	120	Well Drained	sc	5.7	0.95	24.01	70	0.051	5.64	5-10
P_4	2228	11.97	120	Excess.Drained	c	6.3	1.01	29.96	65	0.043	4.94	15-25
P_5	2228	9.72	120	Well Drained	l	5.9	0.91	23.10	70	0.077	3.42	5-10
Middle Elevation												
P_6	2228	14.96	120	Mod. Drained	c	6.2	0.41	26.51	40	0.074	4.21	3-5
P_7	2228	13.16	120	Well Drained	sc	6.9	1.08	32.15	55	0.49	7.92	9-10
P_8	2228	15.51	120	Well Drained	c	5.7	2.15	24.70	75	0.051	3.42	5-10
P_9	2228	6.65	120	Mod.Drained	l	6.2	1.7	31.22	50	0.057	3.49	10-15
P_{10}	2228	13.10	120	Mod.Drained	sc	6.4	0.59	32.78	30	0.045	1.89	3-5
P_{11}	2228	12.32	120	Well Drained	cl	6.1	0.87	31.62	30	0.051	1.61	3-5
P_{12}	2228	13.84	120	Well Drained	cl	5.8	0.95	24.90	85	0.053	5.48	5-8
Lower Elevation												
P_{13}	2228	10.17	120	Mod.Drained	l	6.7	1.64	36.86	107	0.047	7.7	3-5
P_{14}	2228	11.96	120	Mod.Drained	c	6.2	1.26	32.99	120	0.061	8.9	3-5
P_{15}	2228	13.13	120	Imp. to Mod. Drained	c	6.3	0.60	36.61	110	0.053	8.5	1-3
P_{16}	2228	12.76	120	Imper. to Mod.Drained	c	6.2	0.57	34.75	45	0.067	5.2	3-5
P_{17}	2228	10.61	120	Imper. to Mod. Drained	sic	6.2	0.66	22.89	69	0.064	6.6	1-3

Table 3: Soil-site Suitability for Finger millet crop in the study area

Pedon no.	Temp. in growing Season (c)	Land Characteristics		Nutrient Availability		Rooting Conditions (s)		Soil toxicity (n)		Erosion hazards (t) Slope (%)
		Length of Growing Period (c)	Soil Drainage (w)	Texture (s)	pH (f)	Effective Rooting Depth	Coarse fragments	Salinity (ECe)	Sodicity (ESP)	
Upper Elevations										
P_1	S1	S1	S1	S2	S1	S2	S3	S1	S1	S3
P_2	S1	S1	S1	S1	S1	S2	S3	S1	S1	S3
P_3	S1	S1	S1	S2	S1	S2	S3	S1	S1	S3
P_4	S1	S1	S3	S2	S1	S2	N1	S1	S1	N1
P_5	S1	S1	S1	S1	S1	S2	S3	S1	S1	S3
Middle Elevations										
P_6	S1	S1	S1	S2	S1	S3	S3	S1	S1	S2
P_7	S1	S1	S1	S2	S1	S2	S3	S1	S1	S3
P_8	S1	S1	S1	S2	S1	S2	S3	S1	S1	S3
P_9	S1	S1	S1	S1	S1	S2	S3	S1	S1	N1
P_{10}	S1	S1	S1	S2	S1	S3	S3	S1	S1	S2
P_{11}	S1	S1	S1	S1	S1	S3	S3	S1	S1	S2
P_{12}	S1	S1	S1	S1	S1	S1	S3	S1	S1	S3
Lower Elevations										
P_{13}	S1	S1	S1	S1	S1	S1	S3	S1	S1	S2
P_{14}	S1	S1	S1	S2	S1	S1	S3	S1	S1	S2
P_{15}	S1	S1	S2	S2	S1	S1	S3	S1	S1	S1
P_{16}	S1	S1	S2	S2	S1	S2	S3	S1	S1	S2
P_{17}	S1	S1	S2	S2	S1	S2	S3	S1	S1	S1

***Source*:** Shivprasad *et al.* (1998)

S1-Highly Suitable, S2- Moderately Suitable, S3-Marginally Suitable, N1-Not Suitable

Table 4: Limitation levels of the land characteristics and land suitability class for Finger millet

Pedon No	Family of soil	Soil-site suitability class for Finger millet
Upper Elevation		
P_1	Sandy Loam-Skeletal, Mixed, *Hyperthermic, Lithic Haplustalf*	S_3 st
P_2	Sandy Clay Loam-Skeletal, Mixed, *Hyperthermic, Lithic Haplustepts*	S_3 st
P_3	Sandy Clay Loam-Skeletal, Mixed *Hyperthermic, Lithic Rhodustalf*	S_3 st
P_4	Sandy Clay Loam-Skeletal, Mixed *Hyperthermic, Fluventic Haplustepts*	N_1 wt
P_5	Loamy-Skeletal, Mixed, *Hyperthermic, Lithic Haplustepts*	S_3 st
Middle Elevation		
P_6	Loamy-Skeletal, Mixed, *Hyperthermic, Lithic Haplustepts*	S_2 st
P_7	Sandy Clay Loam-Skeletal, Mixed *Hyperthermic, Lithic Rhodustalf*	S_3 st
P_8	Loamy-Skeletal, Mixed, *Hyperthermic, Lithic Haplustalf*	S_3 st
P_9	Sandy Clay Loam-Skeletal, Mixed, *Hyperthermic, Lithic Haplustepts*	N_1 st
P_{10}	Sandy Clay Loam-Skeletal, Mixed, *Hyperthermic, Lithic Haplustepts*	S_2 st
P_{11}	Sandy Clay -Skeletal, Mixed, *Hyperthermic, Fluventic Haplustepts*	S_2 st
P_{12}	Sandy Loam-Skeletal, Mixed, *Hyperthermic, Typic Haplustalf*	S_3 t
Lower Elevation		
P_{13}	Fine Loamy Mixed Hyperthermic, *Typic Ustorthents*	S_2 st
P_{14}	Sandy Clay Loam-Skeletal, Mixed, *Hyperthermic, Typic Haplustepts*	S_2 st
P_{15}	Loamy-Skeletal, Mixed, *Hyperthermic, Fluventic Haplustepts*	S_2w st
P_{16}	Sandy Loam-Skeletal, Mixed, *Hyperthermic, Lithic Haplustepts*	S_2w st
P_{17}	Clay Loam-Skeletal, Mixed, *Hyperthermic, Typic Haplustepts*	S_2 wst

S_1 = Suitable, S_2 = moderately suitable, S_3 = marginally suitable, N_1 = Not suitable, w = Wetness, s =texture Physical characteristics, t = erosion hazard

3.2 Middle elevation

Pedon-6 (P_6), 10(P_{10}) and 11(P_{11}): The soils associated with the P_6, P_{10} and P_{11}, were found moderately suitable (S_2) for finger millet (Table 4). Satisfactory production these crops could be achieved along with soil conservation measures in these moderately sloppy areas of middle elevations, as they have limitations of topography, stoniness, depth and soil texture for finger millet (Table 3). Appropriate soil conservation measures in the soils of hill slope area were the only option to control the major limitation of soil erosion which make them unable to be upgraded from moderately sustainable (S_2) to highly suitability class (S_1) for finger millet.

Pedon-7 and 8: The soils associated with the pedon-7, 8 and 12 (P_7, P_8 and P_{12}) (Table 4) came under the rating of marginally suitable (S_3) finger millet on account of limitations imposed by that of topography, soil texture, stoniness and depth for finger millet(Table 3). The suitability classes clearly indicated that all the constraints need to be corrected to get satisfactory production of different crops.

Pedon-9: The soils of the surrounding area of pedon-9 (P_9) were (Table 4) found non-suitable (N_1) for finger millet due to major limitations of marginal slope, soil moisture available during crop growing period, soil texture and soil depth(Table 3).

3.3 Lower elevation

Pedon-13,14 and 15: The soils associated with pedon-13, 14 and 15 (P_{13}, P_{14} and P_{15}) and its surroundings area were (Table 4) observed moderately suitable (S_2) owing to limitations of soil texture, drainage and coarse fragments which are to be corrected to get satisfactory crop production for finger millet (Table 3).

Pedon-16 and 17: The soils of the pedon-16 and 17 (P_{16} and P_{17}) were (Table 4) moderately suitable (S_2) for finger millet on account of limitations of moderate slope and coarse fragments for finger millet (Table 3). Various soil conservation measures were the only option to control the major limitation of soil erosion of hilly sloppy area which make them unable to be elevated from moderately sustainable (S_2) status to highly suitability class (S_1) for finger millet

Based on agro climate, landform, physical and chemical conditions prevailing in the sub watershed, at lower elevation (<350 m msl) existing finger millet crop fall in S_2 (moderately suitable) class indicating very good scope to grow these in soils of lower elevation. However, in middle elevation (350-400 m msl) finger millet comes under class S_3 (marginally suitable at this elevation mainly because of shallow depth and high slope as constraints). In case of upper elevation (>400 m msl), finger millet were found to be suited marginally as they fall in S_3 class of crop suitability.

4. Conclusion

Based on the present study, it can be concluded that the soils of study area were neutral to slightly alkaline in reaction and low to medium in organic carbon. In soils at lower elevation crops like rice and finger millet are moderately suitable (S_2), while in soils of middle elevation finger millet are marginally suitable (S_3) except in surrounding area of pedon 9 (P_{10}). In case of upper elevation, finger millet was marginally suitable (S_3) except pedon 4 (P_4). Corrective measures can be used to improve the suitability for finger millet crop cultivation.

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