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Soil-Site suitability evaluation for soybean and sunflower crops in the soils of north-west Gir Madhuvanti toposequence of South Saurashtra Region of Gujarat

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Abstract
Six representative pedons were evaluated for their suitability of two oilseed crops (Soybean and Sunflower) in the soils of different land slope of north-west Gir Madhuvanti toposequence of south Saurashtra region of Gujarat. The land slopes, lower piedmont belong to Vertic Haplusterts (P_3) were marginally suitable (S_3) for Soybean and Sunflower. The soils plain area belongs to Typic Haplusterts (P_4) and depression area belong to Sodic Haplusterts (P_5) were marginally suitable (S_3) for Sunflower and currently not suitable (N_1) for Soybean. Upper piedmont belongs to Lithic Ustorthents (P_2) were marginally suitable (S_3) for Soybean and permanently not suitable (N_2) for Sunflower. The soils upper coast belong to Fluventic Calciustepts (P_6) were marginally suitable (S_3) for Sunflower and permanently not suitable (N_2) for soybean. The hill slopes belong to Lithic Ustorthents (P_1) were currently not suitable (N_1) for Soybean and permanently not suitable (N_2) for Sunflower. Topography, drainage, shallow soil depth, high $CaCO_3$, poor soil fertility (low O.C. and high soil pH) soil salinity and sodicity are the major limitations in most soils of north-west Gir Madhuvanti toposequence of south Saurashtra. Results showed that the suitability classes can be improved if the correctable limitations (soil fertility characteristics) are altered through soil amelioration measures.

Keywords: soil-site suitability, land slopes, oilseeds, Soybean, Sunflower, north-west Gir Madhuvanti toposequence and Pedons

Introduction
Soil survey provides useful information for planning proper soil management practices, which are play important role in augmenting crop production. For the sustainable use of the natural resources, a detailed charter of land resources giving its potential and constraints becomes pre-requisite for planning. The site specificity of agricultural research and technology is largely determined from differences in two environmental variables, soil and climate.

India is amongst the largest producer and consumer of vegetable oils in the World. The area under oilseeds has been increasing over time and the production has registered many fold increase but its productivity is still low as compared to other oilseed producing countries in the world. The low and fluctuating productivity is primarily because cultivation of oilseed crops is mostly done on marginal lands, which are lacking in irrigation and low levels of inputs. However, India, still imports a significant proportion of its requirement of edible oil. Soybean and Sunflower are grown extensively in different parts of the country.

Yield of any crop is influenced by kind of soils occurring in the area, prevailing climate, topography and management levels. Thus, it is essential to interpret the soil site, characteristics of any place in terms of their suitability for major crops grown in the area and alternative land use planning on sustainable basis. In order to develop some understanding on the nature or the potential for agriculture production such evaluation will help in the future planning for optimum use of natural resources. Soil degradation is a major threat to food security in many areas. The present study was undertaken to evaluate soil-site suitability of Soybean and Sunflower.

Material and method

The study area (north-west Gir Madhuvanti toposequence) was located between $21^0$13' to $21^0$25' N latitudes and $69^0$57' to $70^0$32' E longitudes encompassing parts of the Mendarda, Vanthli, and Keshod tehsils of Junagadh district and Porbandar tehsil of Porbandar district of south Saurashtra at an elevation ranged from 5 to 190 above mean sea level. IRS IA LISS II FCC imagery on 1:50,000 scale in conjunction with Survey of India topographical (SOI) map referred above on 1:50,000 scale were used to select various land slopes of north-west Gir Madhuvanti toposequence of south Saurashtra region of Gujarat namely: hill slope (LS-1), upper piedmont (LS-2), lower piedmont (LS-3), plain area (LS-4), depression area (LS-5) and upper coast (LS-6) (Fig.-1). The mean annual rainfall is 1120 mm and the climate of the area is semi-arid characterized by extremes of temperature and low wind velocity. Horizon-wise soil samples collected from the typifying pedons were analyzed for their physical and chemical characteristics following standard procedure and soils were classified according to Key to Soil Taxonomy (Anonymous, 2003) [1]. The soil-site suitability for oilseeds were carried out using limitation method according to Sys *et al*., 1991 & NBSS & LUP, 1994 [11, 6] for Soybean and FAO, 1976 & Sys *et al*., 1991 [2, 11] for Sunflower matched with generated data (Table: 1 and 2) at different limitation level: S_1- highly suitable, S_2- moderately suitable, S_3- marginally suitable, N_1- currently not suitable and N_2- not suitable (Sys *et al*., 1991) [11].

Table 1: Climate and soil-site suitability criteria for Soybean (Sys *et al*., 1991 & NBSS and LUP, 1994) [11, 6]

Land characteristics	S_1	S_2	S_3	N_1	N_2
1	2	3	4	5	6
Climatic characteristics					
Total rainfall (mm)	> 750	650-750	550-650	< 550	-
Rainfall growing seasons (mm)	> 600	500-600	500-400	< 400	-
Rainfall during critical period	-	-	-	-	-
Length growing period (days)	> 110	110-100	90-100	< 90	-
Mean temp. growing season (^{0}C)	25-28	28-30	30-34	> 34	-
Mean max. temp. grow. Season (^{0}C)	-	-	-	-	-
Mean min. temp. grow. Season (^{0}C)	-	-	< 20	-	-
Mean R.H. in growing season	> 70	50-70	< 50	-	-
Length of dry spells (days)	Flowering to pod filling is critical				
	< 4	4-8	8-12	> 12	-
Site characteristics					
Slope (%)	< 3	3-5	5-8	> 8	-
Erosion	-	-	-	-	-
Drainage	Well to mod. Well	Poor/ excessive	-	-	-
AWC (mm/m)	> 200	150-200	100-150	50-100	< 50
Stoniness % (surface)	5-10	10-15	15-25	> 25	-
Soil characteristics					
Texture	cl, sicl, l, sil, scl	sl, c	cm, ls	s	-
Coarse fragments (vol. %) Within 50 cm Depth (cm)	 < 15 > 60	 15-25 50-60	 25-35 40-50	 > 35 < 40	 - -
$CaCO_3$ (%)	< 10	10-20	> 20	-	-
Soils fertility					
CEC cmol(p^+) kg^{-1}	> 20	20-10	< 10	-	-
B.S. (%)	> 50	50-35	< 35	-	-
Sat. H.C. (0-15 cm)	> 0.5	0.5-0.2	< 0.2	-	-
pH (1:2.5)	6.5-7.5	7.5-8.5	> 8.5	-	-
ECe (dSm^{-1})	< 2	2-3	3-4	4-8	> 8
ESP	< 5	5-10	10-15	> 15	-

Table 2: Climate and soil-site suitability criteria for Sunflower (FAO, 1976 and Sys *et al*., 1991) [2, 11]

Land characteristics	S_1	S_2	S_3	N_1	N_2
1	2	3	4	5	6
Climatic (c)					
Precipitation					
I^{st} month	105-215	> 215	-	-	-
II^{nd} month + III^{rd} month	195-230	> 230	-	-	-
IV^{th} month	250-450	450-750	> 750	-	-
V^{th} month	100-150	> 150	-	-	-
Mean temp. of grain yield (^{0}C)	22-26	26-28	28-30	-	> 30
Topography (t)					
Slope (%)	0-2	2-4	4-6	-	> 6
Wetness					
Drainage	Good to moderate	Imperfect & excessive	Poor & aeric	Poor but drainable	Poor not drainable
Physical characteristics (s)					
Texture / structure	c<60s	c<60v	<cs, fs, s	-	cm, sicm
Coarse fragments (%)	0-15	15-35	35-55	-	> 55
Soil depth (cm)	> 100	100-75	75-50	-	< 50

$CaCO_3$ (%)	0-15	15-25	25-35	-	> 35
Gypsum (%)	0-4	4-10	10-20	-	> 20
Soil fertility characteristics (f)					
CEC cmol (p^+) kg^{-1}	> 16	< 16(-)	< 16(+)	-	-
BS (%)	> 35	35-20	< 20	-	-
pH, H_2O	6.6-7.5	7.5-8.0	8.0-8.5	-	8.5
Organic carbon (%)	> 1.2	1.2-0.8	< 0.8	-	-
Salinity alkalinity (n)					
ECe (dsm^{-1})	0-4	4-9	9-12	-	> 12
ESP (%)	Not specified				

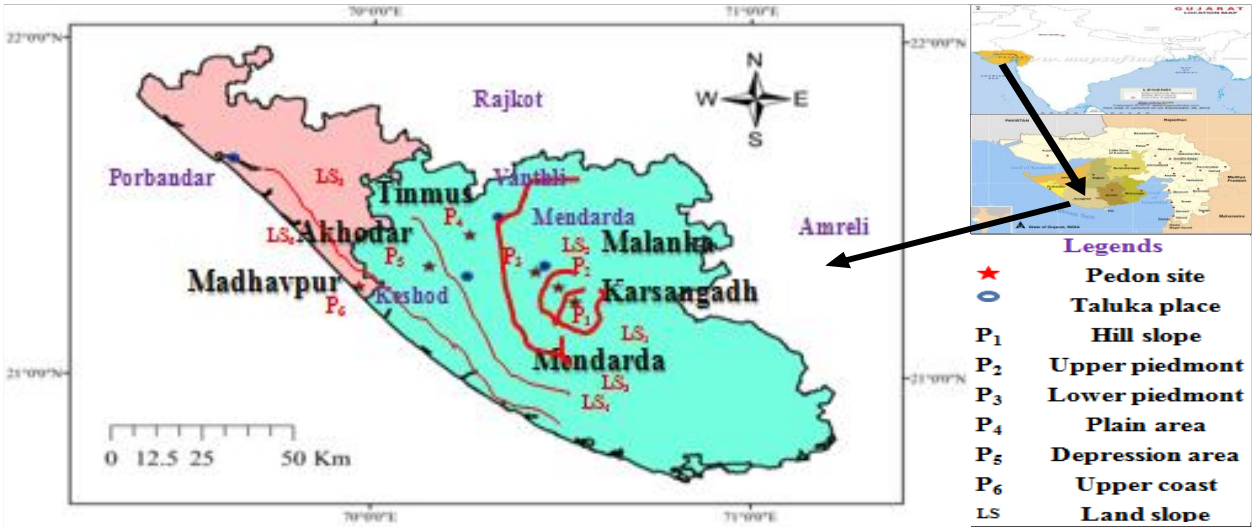

Fig. 1: Site of pedons of north-west Gir Madhuvanti toposequence in South Saurashtra

Result and Discussion

The soils of different pedons of north-west Gir Madhuvanti toposequence of south Saurashtra region, the total sand, silt and clay content mean values of 22.83, 38.90 and 38.26 per cent, respectively indicating dominant of loam to clayey texture. The soil pH, organic carbon, ECe and $CaCO_3$ ranged from 6.79 to 8.28, 0.37 to 0.84 per cent, 0.63 to 11.82 dSm^{-1} and 2.75 to 31.80 per cent with the overall mean value of 7.89, 0.58 per cent, 5.00 $dSm^{-1}$and 19.93 per cent, respectively. The cation exchange capacity, BSP and ESP in the studied soils ranged from 20.60 and 43.96 cmol (P^+) kg^{-1}, 88.73 to 96.31 and 0.51 to 16.93 with the mean value of 33.18 cmol (p+) kg^{-1}, 92.71 and 8.27. In general, the soils of of north-west Gir Madhuvanti toposequence were moderately alkaline in reaction, low in organic carbon and highly calcareous in nature. The soil at higher elevation had low in pH, EC, CEC, BSP and ESP then lower elevation (Savalia, 2005; Leelavathi *et al*., 2009; Gandhi *et al*., 2013 and Shirgire *et al*., 2015) [8, 5, 3, 10].

Soil-site suitability for different land uses is very important for alternate and suitable land use planning. The soils under study have been rated for tow oilseed crops. Land suitability for oilseeds crops and land quality ratings are those suggested by Sys *et al*., 1991 & NBSS & LUP, 1994 [11, 6] for Soybean and FAO, 1976 & Sys *et al*., 1991 [2, 11] for Sunflower. The oilseeds suitability evaluations of pedons P_1 to P_6 of north-west Gir Madhuvanti toposequence are presented in Table 3-6.

Pedon-1 (Karsangadh) from the Hill slope

The soil associated with this pedon (P_1) was currently not suitable (N_1) for Soybean cultivation because of major limitations like topography, somewhat excessive drainage and shallow soil depth. The soil was not permanently suitable (N_2) for Sunflower because of major limitations like high temperature, topography, shallow soil depth and poor soil fertility (low O.C.). Soil conservation measures like graded narrow base terrace bunds or trenches and contour bunding should be adopted (Savalia *et al*., 2009) [9].

Pedon-2 (Malanka) from the Upper piedmont

The soils associated with pedon (P_2) have been found to be marginaly suitable (S_3) for Soybean cultivation because of major limitations like topography, shallow soil depth, high $CaCO_3$ and poor soil fertility (high soil pH). The soils were not permanently suitable (N_2) for Sunflower cultivation because of major limitations like high temperature, topography, shallow soil depth, high $CaCO_3$ and poor soil fertility (low O.C. and high soil pH). On adoption of corrective measures like Graded narrow base terrace bunds or trenches are recommended to increase soil depth/rooting volume, conservation tillage and forage-based crop rotations which reduce erosion and allow soil forming factors to maintain and rehabilitate top soil. Similar results were obtained by Savalia *et al*. (2009), Patel *et al*. (2012) and Gandhi *et al*., (2013) [9, 7, 3].

Pedon-3 (Mendarda) from the Lower piedmont

The soils associated with pedon (P_3) were marginally suitable (S_3) for Soybean and Sunflower on account of limitations like texture, poor soil fertility (high soil pH) and soil salinity for soybean and high temperature, topography, texture, soil depth, high $CaCO_3$ and soil fertility (low O.C. and high soil pH) for sunflower. On adoption of corrective measures like use of organic manures along with balanced fertilizers, zero or minimum tillage, frequent inter culturing operation and application of weathered materials, gypsum and sand in furrow are found to be effective. Similar observations were made by Savalia (2005) and Patel *et al*. (2012) [8, 7].

Pedon-4 (Tinmus) from the Plain area

The soils associated with pedon (P_4) were marginally suitable (S_3) for Sunflower on account of limitations like high temperature, texture, soil depth, high $CaCO_3$, soil fertility (low O.C. and high soil pH) and soil salinity. The soils were currently not suitable (N_1) for soybean on account of limitations like texture, low soil fertility (high soil pH), soil salinity and sodicity. On adoption of corrective measures of mulching, rain water leeching and use of organic manures, continuous cropping with well ranged crops, reduce, zero or minimum tillage, frequent inter, application of tanch (murrum) gypsum and sand in furrow found effective, constant monitoring of soils and entire root zone requires to be flushed for which availability of good quality water is essential. Similar observations were made by Savalia (2005), Patel *et al*. (2012) and Gandhi *et al*. (2013) [8, 7, 3].

Pedon-5 (Akhodar) from the Depression area

The soils associated with pedon (P_5) have been found to be marginally suitable (S_3) for Sunflower on account of limitations like high temperature, texture, high $CaCO_3$, poor soil fertility (low O.C. and high soil pH) and salinity. The soils were currently not suitable (N_1) for Soybean on account of limitations like texture, soil pH as well as salinity and sodicity. On adoption of corrective measures like provision of surface drainage through lateral ditch (Giri *et al*, 1999) [4], adoption of salt tolerant varieties, mulching, use of organic manures, application of tanch (murrum) gypsum and sand in furrow found effective, constant monitoring of soils, soil and water conservation practices could be adopted these soils to make them productive. Similar observations were made by Savalia (2005), Patel *et al*. (2012) and Gandhi *et al*. (2013) [8, 7, 3].

Pedon-6 (Madhavpur) from the Upper coast

The soils associated with pedon (P_6) have been evaluated to be marginally suitable (S_3) for Sunflower on account of limitations like high temperature, texture, drainage, high $CaCO_3$, low soil fertility (low O.C. and high soil pH) and soil salinity. Upper coast were not permanently suitable (N_2) for soybean cultivation on account of limitations like drainage, poor soil fertility (soil high pH) as well as soil salinity and sodicity. On adoption of corrective measures like provision of surface drainage through lateral ditch (Giri *et al*, 1999) [4], adoption of salt tolerant varieties, use of organic manures along with gypsum and nitrogenous fertilizers and soil and water conservation practices, proper sub-surface drainage need to be ascertained, lateral ditches can serve to drain the soils of excessive salts could be adopted these soils to make them productive. For severely degraded soils, xerophytic, halophytic trees, shrubs and grasses should be grown. Similar observations were done by Savalia (2005), Patel *et al*. (2012) and Gandhi *et al*. (2013) [8, 7, 3].

Conclusion

Based on the present study it can be concluded that the soils of study area were moderately alkaline in reaction and highly calcareous in nature. The land slopes, lower piedmont belong to Vertic Haplusterts (P_3) were marginally suitable (S_3) for Soybean and Sunflower. The soils plain area belongs to Typic Haplusterts (P_4) and depression area belong to Sodic Haplusterts (P_5) were marginally suitable (S_3) for Sunflower and currently not suitable (N_1) for Soybean. Upper piedmont belongs to Lithic Ustorthents (P_2) were marginally suitable (S_3) for Soybean and permanently not suitable (N_2) for Sunflower. The soils upper coast belong to Fluventic Calciustepts (P_6) were marginally suitable (S_3) for Sunflower and permanently not suitable (N_2) for soybean. The hill slopes belong to Lithic Ustorthents (P_1) were currently not suitable (N_1) for Soybean and permanently not suitable (N_2) for Sunflower. Corrective measures like use of organic manures along with gypsum and balanced fertilizers, soil and water conservation practices, could be adopted these soils to make them productive.

Table 3: Soil-site suitability evaluation and land qualities for Soybean and Sunflower of the soils of north-west Gir Madhuvanti toposequence of south Saurashtra

Pedon No.	Climate (c)		Wetness (w)		Physical & chemical characteristics (s)			Soil fertility characteristics (f)				Salinity/ alkalinity (n)	
	Rainfall (mm)	Temp. (^{0}C)	Topography (slope %)	drainage	Texture	Soil depth (cm)	$CaCO_3$ (%)	O.C. (%)	BSP	CEC (cmol(p$^+$)kg^{-1})	pH	ECe (dSm^{-1})	ESP
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
P_1	1120	27.31	15-30	Somewhat excessive	l	25	2.75	0.84	88.44	20.60	6.79	0.63	0.53
P_2	1120	27.31	3-8	Well	cl	27	31.80	0.68	91.36	25.78	7.90	0.88	2.56
P_3	1120	27.31	1-3	Well	c	70	19.81	0.60	92.03	30.83	8.04	2.86	5.80
P_4	1120	27.31	0-1	Well	c	94	19.98	0.50	94.04	34.66	8.13	5.95	10.80
P_5	1120	27.31	0-1	Moderately Well	c	105	21.05	0.49	94.10	42.94	8.20	7.86	13.03
P_6	1120	27.31	0-1	Imperfect	sicl	127	25.20	0.37	96.31	43.96	8.28	11.82	16.93

c – Clay, sicl – Silty clay loam, l – Loam, cl – Clay loam

Table 4: Soil-site suitability evaluations for Soybean crops in the soils of north-west Gir Madhuvanti toposequence of south Saurashtra (Sys *et al.*, 1991 & NBSS & LUP, 1994) [11, 6]

Pedon No.	Climate (c)		Wetness (w)		Physical characteristics (s)		Soil fertility characteristics (f)			Salinity/ alkalinity (n)		Crop suitability class
	Rainfall (mm)	Temp. (^{0}C)	Topography (slope %)	drainage	Texture	Soil depth (cm)	BSP	CEC (cmol(p$^+$)kg^{-1})	pH	ECe (dSm^{-1})	ESP	
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
P_1	S_1	S_1	N_1	S_2	S_1	S_3	S_1	S_1	S_1	S_1	S_1	N_1 ws
P_2	S_1	S_1	S_2	S_1	S_1	S_3	S_1	S_1	S_2	S_1	S_1	S_3 wsf
P_3	S_1	S_1	S_1	S_1	S_2	S_1	S_1	S_1	S_2	S_2	S_2	S_3 sfn
P_4	S_1	S_1	S_1	S_1	S_2	S_1	S_1	S_1	S_2	N_1	S_3	N_1 sfn
P_5	S_1	S_1	S_1	S_1	S_2	S_1	S_1	S_1	S_2	N_1	S_3	N_1 sfn
P_6	S_1	S_1	S_1	S_2	S_1	S_1	S_3	S_1	S_1	S_2 N_2	N_1	N_2 wfn

Table 5: Soil-site suitability evaluations for Sunflower crops in the soils of north-west Gir Madhuvanti toposequence of south Saurashtra (FAO, 1976 and Sys *et al*., 1991) [2, 11]

Pedon No.	Climate (c)		Wetness (w)		Physical & chemical characteristics (s)			Soil fertility characteristics (f)				Salinity/ alkalinity (n)	Crop suitability class
	Rainfall (mm)	Temp. (^{0}C)	Topography (slope %)	drainage	Texture	Soil depth (cm)	$CaCO_3$ (%)	O. C. (%)	BSP	CEC (cmol(p$^+$)kg^{-1})	pH	ECe (dSm^{-1})	
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
P_1	S_1	S_2	N_2	S_2	S_1	N_2	S_1	S_2	S_1	S_1	S_1	S_1	N_2 cwsf
P_2	S_1	S_2	S_3	S_1	S_1	N_2	S_3	S_3	S_1	S_1	S_2	S_1	N_2 cwsf
P_3	S_1	S_2	S_1	S_1	S_2	S_3	S_2	S_3	S_1	S_1	S_3	S_1	S_3 cwsf
P_4	S_1	S_2	S_1	S_1	S_2	S_2	S_2	S_3	S_1	S_1	S_3	S_2	S_3 csfn
P_5	S_1	S_2	S_1	S_1	S_2	S_1	S_2	S_3	S_1	S_1	S_3	S_2	S_3 csfn
P_6	S_1	S_2	S_1	S_2	S_2	S_1	S_3	S_3	S_1	S_1	S_3	S_3	S_3 cwsfn

Table 6: Limitation levels of the land characteristics and land suitability class for Soybean and Sunflower

No. of Pedon	Sub group	Soil-site suitability class for Soybean and Sunflower	
		Soybean	Sunflower
Pedon-1	Hill slope (Karsangadh), MSL : 190 m, 21^{0}13' N latitudes, 70^{0}32' E longitude, Lithic Ustorthents	N_1 ws	N_2 cwsf
Pedon-2	Upper piedmont (Malanka), MSL :155 m, 21^{0}16' N latitudes, 70^{0}29' E longitude, Lithic Ustorthents	S_3 wsf	N_2 cwsf
Pedon-3	Lower piedmont (Mendarda), MSL : 92 m, 21^{0}18' N latitudes, 70^{0}25' E longitude, Vertic Haplusterts	S_3 sfn	S_3 cwsf
Pedon-4	Plain area (Tinmus), MSL : 27 m, 21^{0}25' N latitudes, 70^{0}15' E longitude, Typic Haplusterts	N_1 sfn	S_3 csfn
Pedon-5	Depression area (Akhodar), MSL : 13 m, 21^{0}19' N latitudes, 70^{0}08' E longitude, Sodic Haplusterts	N_1 sfn	S_3 csfn
Pedon-6	Upper coast (Madhavpur), MSL : 5 m, 21^{0}16 N latitudes, 69^{0}57' E longitude, Fluventic Calciustepts	N_2 wfn	S_3 cwsfn

S_1 = Highly suitable, S_2 = Moderately suitable, S_3 = Marginally suitable, N_1 = Currently not suitable, N_2 = not permanently suitable, c= climate, w = Wetness, s = Physical characteristics, f = Soil fertility characteristics, n = Salinity/Alkalinity hazard

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