The Journal of Rural and Agricultural Research Vol. 20 No. 2, 6-12 (2020)
Received September 2020; Acceptance November 2020

Soil-Site Suitability Evaluation for Mustard, Groundnut and Sesame 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 three oilseed crops (Mustard, Groundnut and Sesame) 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), plain area belong to Typic Haplusterts (P_4) and depression area belong to Sodic Haplusterts (P_5) were moderately suitable (S_2) for Mustard and marginally suitable (S_3) for Groundnut and Sesame. Upper piedmont belongs to Lithic Ustorthents (P_2) were marginally suitable (S_3) for Mustard, Groundnut and currently not suitable (N_1) for Sesame. The soils upper coast belongs to Fluventic Calciustepts (P_6) were marginally suitable (S_3) for Mustard, currently not suitable (N_1) for Groundnut and permanently not suitable (N_2) for Sesame. The hill slopes belong to Lithic Ustorthents (P_1) were currently not suitable (N_1) for Mustard and Sesame and permanently not suitable (N_2) for Groundnut. Topography, drainage, shallow soil depth, high $CaCO_3$, poor soil fertility (low O.C.) 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: *Groundnut and Sesame, land slopes, oilseeds, Mustard, soil-site suitability*

Introduction

India is amongst the largest producer and consumer of vegetable oils in the World. Oilseeds have been the backbone of agricultural economy of India since long. 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. Mustard, Groundnut and Sesame are grown extensively in different parts of the country. 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 Mustard, Groundnut and Sesame.

Materials and Methods

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). The soil-site suitability for oilseeds were carried out using limitation method according to Sys et al., 1991 & NBSS & LUP, 1994 for Mustard, Sys et al., 1991 & FAO, 1976 for Groundnut and Sesame and matched with generated data (Table: 1, 2 and 3) 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).

Results 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).

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 oilseeds. Land suitability for oilseeds crops and land quality ratings are those suggested by Sys et al., 1991 & NBSS & LUP, 1994 for Mustard, Sys et al., 1991 & FAO, 1976 for Groundnut and Sesame. The oilseeds suitability evaluations of pedons P_1 to P_6 of north-west Gir Madhuvanti toposequence are presented in Table 4-8.

Pedon-1 (Karsangadh) from the Hill slope:

The soils associated with this pedon (P_1) were currently not suitable (N_1) for Mustard cultivation

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

Land characteristics	S_1	S_2	S_3	N_1	N_2
Climatic (c)					
Precipitation (mm)	250-350	150-250	100-150	< 100	-
Mean temp.(^{0}C)	20-28	18-20	16-18	< 16	-
Topography (t)					
Slope (%)	< 3	3-8	3-8	> 8	-
Wetness					
Drainage	Moderately well drained	Imp./somewhat excessive	Very low V excessive	-	-
Physical characteristics (s)					
Texture / structure	cl,l	sl	ls	s	-
Coarse fragments (%)	< 15	15-35	> 35	-	-
Soil depth (cm)	> 75	75-50	50-25	< 25	-
$CaCO_3$ (%)	< 20	20-30	30-40	> 40	-
Gypsum (%)	< 3	3-5	5-10	> 10	-
Soil fertility characteristics (f)					
CEC cmol (P^+) kg^{-1}	> 16	8-16	< 8	-	-
B.S. (%)	> 50	50-35	< 35	-	-
Organic carbon (%)	> 0.4	0.2-0.4	0.1-0.2	-	-
Salinity alkalinity (n)					
ECe (dsm^{-1})	< 8	8-12	12-16	> 16	-
ESP (%)	< 15	15-25	25-35	> 35	-

Table 2: Climate and soil-site suitability criteria for Groundnut (Sys *et al.*, 1991 & FAO, 1976)

Land characteristics	S_1	S_2	S_3	N_1	N_2
Climatic (C)					
Precipitation (mm)	700-400	400-300	300-200	-	< 200
Mean precipitation of Ist month (mm)	165-70	70-60	60-50	-	< 50
IInd month (mm)	175-100	100-75	75-50	-	< 50
IIIrd month (mm)	175-100	100-75	75-50	-	< 50
IV month (mm)	145-275	275-400	400-475	-	> 475
Mean temperature (^{0}C)	24-18	18-14	14-10	-	< 10
Mean maxi. temp. of growing cycle (^{0}C)	35-38	38-40	40-42	-	> 40
Mean min. temp. of growing cycle (^{0}C)	19-14	14-10	10-6	-	< 6
Topography (t)					
Slope (%)	0-2	2-4	4-6	-	> 6
Wetness (w)					
Drainage	Good	Moderate	Imperfect/ some what excessive	Poor drain-ability	Poor not drainable
Physical characteristics (s)					
Texture / structure	L	c<60s	c>60v	-	cm, sic
Coarse fragments (%)	0-3	3-15	15-35	-	> 35
Soil depth (cm)	> 75	75-50	50-25	-	< 25
$CaCO_3$ (%)	0-25	25-35	35-50		
Gypsum (%)	0-4	4-10	10-20		
Soil fertility characteristics (f)					
CEC (cmol (P^+) kg^{-1})	> 16	> 16(-)	C16(+)	-	-
B.S. (%)	35	< 35	-	-	-
pH, H_2O	6.8-7.5	7.5-8.0	8.0-8.2	-	-
Organic carbon (%)	> 0.8	0.8-0.4	< 0.4	-	-
Salinity alkalinity (n)					
ECe (dSm^{-1})	0-4	4-6	6-8	8-12	> 12
ESP (%)	0-10	10-15	15-20	-	> 20

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

Table 3: Climate and soil-site suitability criteria for Sesame (Sys *et al*., 1991 & FAO, 1976)

Land characteristics	S_1	S_2	S_3	N_1	N_2
Climatic (c)					
Precipitation (mm)					
I[st] month	100-300	300-475	>475	-	-
II[nd] month	175-100	100-50	50-25	-	<25
III[rd] month	<200	>200	-	-	-
Mean maximum temperature (^{0}C)	35-38	38-40	40-42	-	>42
Mean maximum temperature (^{0}C)	19-16	16-14	14-12	-	>12
Topography (t)					
Slope (%)	0-2	2-4	4-6	-	>6
Wetness (w)					
Drainage	Well to good	Imperfect/ some what excessive	Poor	Poor but drainable	Poor not drainable
Physical characteristics					
Texture / structure	l	Cs, co	C > 50 s	-	Cm , sicm
Coarse fragments (%)	0-15	15-35	35-55	-	>55
Soil depth (cm)	>75	75-50	50-35	-	<30
$CaCO_3$	-	-	-	-	-
Gypsum (%)	-	-	-	-	-
Soil fertility characteristics					
CEC cmol (p^+) kg^{-1}	>16	<16 (+)	<16(+)	-	-
B.S. (%)	>50	50-55	<35	-	-
pH, H_2O	6.3-7.0	7.0-7.5	7.5 8.2	-	>8.2
Organic carbon (%)	>1.2	1.2-0.8	<0.8	-	-
Salinity/alkalinity (n)					
ECe (dSm^{-1})	0-4	4-6	6-8	-	>8

Table 4: Soil-site suitability evaluation and land qualities for Mustard, Groundnut and Sesame 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
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

because of major limitations like topography, somewhat excessive drainage and shallow soil depth as well as Sesame also currently not suitable (N_1) because of major limitations like excessive rainfall in month of July, topography, somewhat excessive drainage, shallow soil depth and low soil fertility (low organic carbon). Pedon (P_1) was not permanently suitable for Groundnut cultivation because of major limitations like topography, somewhat excessive drainage and shallow soil depth. Soil conservation measures like graded narrow base terrace bunds or trenches and contour bunding should be adopted (Savalia *et al*., 2009).

Table 5: Soil-site suitability evaluations for Mustard crops in the soils of north-west Gir Madhuvanti toposequence of south Saurashtra (Sys *et al.*, 1991 & NBSS & LUP, 1994)

Pedon	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 ($cmol(p^+)kg^{-1}$)	ECe	ESP	
P_1	S_1	S_1	N_1	S_2	S_1	S_3	S_1	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_3	S_1	S_1	S_1	S_1	S_1	S_3 ws
P_3	S_1	S_1	S_1	S_1	S_2	S_2	S_1	S_1	S_1	S_1	S_1	S_1	S_2 s
P_4	S_1	S_1	S_1	S_1	S_2	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_2 s
P_5	S_1	S_1	S_1	S_1	S_2	S_1	S_2	S_1	S_1	S_1	S_1	S_1	S_2 s
P_6	S_1	S_1	S_1	S_2	S_2	S_1	S_2	S_2	S_1	S_1	S_2	S_2	S_3wsfn

Table 6: Soil-site suitability evaluations for Groundnut crops in the soils of north-west Gir Madhuvanti toposequence of south Saurashtra (Sys *et al*., 1991 and FAO, 1976)

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})	ESP	
P_1	S_1	S_1	N_2	S_3	S_1	S_3	S_1	S_1	S_1	S_1	S_1	S_1	S_1	N_2 ws
P_2	S_1	S_1	S_3	S_1	S_1	S_3	S_2	S_2	S_1	S_1	S_2	S_1	S_1	S_3 wsf
P_3	S_1	S_1	S_2	S_1	S_2	S_2	S_1	S_2	S_1	S_1	S_3	S_1	S_1	S_3 wsf
P_4	S_1	S_1	S_1	S_1	S_2	S_1	S_1	S_2	S_1	S_1	S_3	S_2	S_2	S_3 sfn
P_5	S_1	S_1	S_1	S_2	S_2	S_1	S_1	S_2	S_1	S_1	S_3	S_3	S_2	S_3 wsfn
P_6	S_1	S_1	S_1	S_3	S_2	S_1	S_2	S_3	S_1	S_1	S_3	N_1	S_3	N_1 wsfn

Table 7: Soil-site suitability evaluations for Sesame crops in the soils of north-west Gir Madhuvanti toposequence of south Saurashtra (Sys *et al*., 1991 and FAO, 1976)

Pedon	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	O C. (%)	pH	CEC ($cmol(p^+)kg^{-1}$)	ECe (dSm^{-1})	
P_1	S_3	S_1	N_1	S_2	S_1	N_1	S_1	S_2	S_1	S_1	S_1	N_1 cwsf
P_2	S_3	S_1	S_3	S_1	S_1	N_1	S_1	S_3	S_3	S_1	S_1	N_1 cwsf
P_3	S_3	S_1	S_2	S_1	S_2	S_2	S_1	S_3	S_3	S_1	S_1	S_3 cwsfn
P_4	S_3	S_1	S_1	S_1	S_2	S_1	S_1	S_3	S_3	S_1	S_2	S_3 csfn
P_5	S_3	S_1	S_1	S_1	S_2	S_1	S_1	S_3	S_3	S_1	S_3	S_3 csfn
P_6	S_3	S_1	S_1	S_2	S_2	S_1	S_1	S_3	N_1	S_1	N_2	N_2 cwsfn

Pedon-2 (Malanka) from the Upper piedmont:

The soils associated with pedon (P_2) have been found to be marginaly suitable (S_3) for Mustard cultivation because of major limitations like topography, shallow soil depth, high $CaCO_3$ as well as Groundnut also marginaly suitable (S_3) for cultivation because of major limitations like topography, shallow soil depth, high $CaCO_3$, low organic carbon as well as high soil pH. Sesame was currently not suitable (N_1) because of major limitations like excessive rainfall in month of July, topography, shallow soil depth, low organic carbon as well as 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

Table 8: Limitation levels of the land characteristics and land suitability class for oilseeds

No. of Pedon	Sub group	Soil-site suitability class for oilseeds		
		Mustard	Groundnut	Sesame
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 ws	N_1 cwsf
Pedon-2	Upper piedmont (Malanka), MSL :155 m, 21^{0}16' N latitudes, 70^{0}29' E longitude, Lithic Ustorthents	S_3 ws	S_3 wsf	N_1 cwsf
Pedon-3	Lower piedmont (Mendarda), MSL : 92 m, 21^{0}18' N latitudes, 70^{0}25' E longitude, Vertic Haplusterts	S_2 s	S_3 wsf	S_3 cwsfn
Pedon-4	Plain area (Tinmus), MSL : 27 m, 21^{0}25' N latitudes, 70^{0}15' E longitude, Typic Haplusterts	S_2 s	S_3 sfn	S_3 csfn
Pedon-5	Depression area (Akhodar), MSL : 13 m, 21^{0}19' N latitudes, 70^{0}08' E longitude, Sodic Haplusterts	S_2 s	S_3 wsfn	S_3 csfn
Pedon-6	Upper coast (Madhavpur), MSL : 5 m, 21^{0}16 N latitudes, 69^{0}57' E longitude, Fluventic Calciustepts	S_3 wsfn	N_1 wsfn	N_2 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

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).

Pedon-3 (Mendarda) from the Lower piedmont:

The soils associated with pedon P_3 were moderately suitable (S_2) for mustard on account of major limitations like texture and soil depth. Groundnut and sesame were found to be marginally suitable (S_3) on account of limitations like topography, soil depth, soil pH, low soil fertility (low O.C.) and texture for groundnut and excessive rainfall in month of July, topography, soil depth, soil pH, low soil fertility (O.C.), texture and soil salinity for sesame. 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).

Pedon-4 (Tinmus) from the Plain area:

The soils associated with pedon P_4 were moderately suitable (S_2) for mustard on account of limitations like texture. The soils were marginally suitable (S_3) for groundnut and sesame on account of limitations like soil pH, low soil fertility (low O.C.), texture, soil salinity for Groundnut and excessive rainfall in month of July, soil pH, low soil fertility (low O.C.), texture, soil salinity for Sesame. 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).

Pedon-5 (Akhodar) from the Depression area:

The soils associated with pedon P_5 have been found to be moderately suitable (S_2) for mustard on account of limitations like high $CaCO_3$, texture and high $CaCO_3$. The soils were marginally suitable (S_3) for groundnut and sesame on account of limitations like drainage, texture, poor soil fertility (low O.C.), high pH as well as high soil salinity for groundnut and excessive rainfall in month of July, texture, poor soil fertility (low O.C.), high pH, soil salinity for sesame. On adoption of corrective measures like provision of surface drainage through lateral ditch (Giri *et al*, 1999), 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).

Pedon-6 (Madhavpur) from the Upper coast:

The soils associated with pedon P_6 have been

evaluated to be marginally suitable (S_3) for mustard on account of limitations like drainage, texture, high $CaCO_3$, poor soil fertility (low O.C.) and soil sodicity. The soils were currently not suitable (N_1) for groundnut on account of limitations like drainage, texture, high $CaCO_3$, poor soil fertility (low O.C.), soil pH as well as soil salinity. The soils associated with upper coast were not permanently suitable (N_2) for sesame cultivation on account of limitations like excessive rainfall in month of July, drainage, texture, poor soil fertility (low O.C.), high pH as well as soil salinity. On adoption of corrective measures like provision of surface drainage through lateral ditch (Giri *et al*, 1999), 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).

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