Agropedology 2014, 24 (02), 146-156

Assessment of land suitability for soybean (*Glycine max*) in Bundi district, Rajasthan

G. L. MEENA[1], R.S. SINGH[2], SUMAN MEENA[3], R.H.MEENA[4] AND R.S. MEENA[$]

[1]ICAR-Central Soil and Water Conservation Research & Training Institute, Kota-324 002, India
[2]National Bureau of Soil Science and Land Use Planning, Regional Centre, Udaipur-313 001, India
[3]Assistant Directorate, Horticulture, Jhalawar-326 001, India
[4]Department of Agricultural Chemistry and Soil Science, RCA, MPUA&T, Udaipur-313 001, India
[5]Agricultural Research Station, SKRAU, Sri Ganganagar-335 001, India

Abstract: Two transects namely Eastern Rajasthan Upland (ERU) and Vindhyan landscape (VL), both important physiographic units occurring in close association, were selected in the Bundi district of Rajasthan for studying the soil properties variability in relation to soybean crop yield under rainfed. The landforms included were hill, pediments, valley, plain (very gently to nearly gently sloping) and nearly level plain in the Eastern plain and hill, pediments, valley, plain (very gently to nearly gently sloping) and nearly level plain in the Vindhyan landscape. Soil survey identified 14 series in Eastern plain and 18 in Vindhyan landscape of which 6 series each which covering major areas of transect were selected. The soils of Bundi district were evaluated for soybean suitability. The land suitability evaluation of the soils of different landforms was carried out based on the climatic requirements of the crop and soil properties like drainage, slope, texture, soil depth, AWC, calcium carbonate, pH, OC, ESP and CEC reflecting the soil fertility status. The area receives an annual rainfall of 773 mm, soil depth is 100 cm with gravelly sandy clay loam to clayey texture (10 to 49.75 % clay) with good drainage. Area suitable for soybean cultivation was assessed at 50 percent of total geographical area of the Bundi district.

Key words: *Eastern Rajasthan upland, Vindhyan landscape, land evaluation, soil suitability, soybean, clay content*

Introduction

The qualitative and quantitative knowledge of variability among various genesis related soil properties, and their relationship with properties having direct influence on choice of crops, are of paramount importance. This helps to determine the yield controlling factors across sites and their spatial distribution on soil-scape. This also provides a fair opportunity of matching between input resources and yield determining factors so as to maximize plant performance and minimize off site environmental effects. Soil survey, classification and mapping of soil help in understanding potential of soil for the crop. Several workers have worked out the suitability of soils for various crops (Bhaskar *et al.* 1987; Anonymous 1986; Kuhad and Kawasra 1991; Srivastava *et al.* 1991). Soybean (*Glycine max* L.) is an important legume-cum-oilseed crop of the semi-arid tropics grown predominantly under rainfed conditions in India in Inceptisols, Entisols, Alfisols and Vertisols. It is considered as a soil ameliorant due to its high root-shoot ratio and high biological yield which improves soil strength with fertility, prevents soil erosion due to extensive ground coverage of the canopy, besides nitrogen fixation and addition of biomass back to the soil through leaf fall. Assessment of soils for suitability to soybean based on their characteristics for its cultivation goes a long way in (i) defining potential soils for soybean and (ii) quantifying the limits of soil parameters to achieve that potential yield. However such information on soils of Bundi district of Rajasthan is very scanty and it is thus useful to evaluate the soils of this district for their suitability for soybean cultivation. India is the fifth largest producer of soybean in the world. In terms of total oilseeds production it occupies fourth place among the major oilseeds producing countries of the world, next to USA, China and Brazil. Soybean contributed 28% in total oil production at national level, which is 24.2 million tons. The Rajasthan state ranked third in terms of both area and production of soybean in the country with 630715 tonnes of production on 498619 hectares of land in the 1997-98. The productivity of crop in the state was higher (1430 kg per hectare) as compared to the national average (10.23 quintal per hectare). In Rajasthan, the area under soybean increased to 797587 hectares with production of 1071228 tonnes during the year 2007-08. The main soybean growing districts are Jhalawar (28.17%), Baran (25.09%), Chittorgarh (17.55%), Kota (15.59%), Bundi (9%) and others (4.6%). In Bundi district, the area under soybean is 76046 hectare with production of 102919 tonnes. Soybean crop occupied a substantial area in the Southern -Eastern parts of the state particularly in Bundi district with higher levels of production from the minimum use of inputs. To assess the potential soils for soybean, exhaustive soil profile study were carried out in Bundi district of Rajasthan and soil site suitability was worked out for soybean cultivation.

Material and Methods

Bundi district has an area of 5.82 lakh hectares and occupies the south-east part of the state and lies between 24°59'11'' to 25°53'11'' N latitudes and 75°19'30'' to 76°19'30'' E longitude. The moisture regime is Ustic. The climate of the study area is semi-arid, subtropical and is characterized by extremes of temperature and low wind velocity. The monthly data about climatic attributes on rainfall, temperature, relative humidity and potential evapo-transpiration are presented in figure 1. The average annual rainfall is around 773.40 mm, which is marked by high spatial and temporal variability. The monsoon rain (Nearly 90 % of total rain) is received as southwest monsoon, from the June to September. The normal rainy days in district are about 35.4 in a year. The average annual temperature is 25.8°C with annual maximum and minimum temperature 33.02°C and 18.62°C, respectively. The MWST and MSST is greater than 5°C. The temperature regime is hyperthermic. The relative humidity remains least in the hot weather months and highest during the monsoon months. The location map of studied selected pedons points is presented in table 1 and fig. 2.

Table 1. Site Characteristics of different representative pedons in both Eastern Rajasthan Upland and Vindhyan landscape

Pedons	Series Name	Location	Slope %	Landforms
	I. Eastern Rajasthan Upland			
P_1	Umar	25°42'24" N; 75°27'05" E	8-15	Hill
P_2	Sela Ka Data	25°32'27" N; 75°40'39" E	8-15	Pediments
P_3	Khatwada	25°34'08" N; 75°36'19" E	3-8	Valley
P_4	Sawangarh	25°38'46" N; 75°44'36" E	1-3	Plain-very gently to nearly gently sloping
P_5	Kanwar	25°43' 03" N; 76°06'56" E	1-3	Nearly level plain-I
P_6	Raitoda	25°44'11" N; 75°59'18" E	1-3	Nearly level plain-II
	II. Vindhyan landscape			
P_7	Nai Ka Talab	25°07'36" N; 75°36'19" E	15-30	Hill
P_8	Rajpura-B	25°01'37" N; 75°31'11" E	3-8	Pediments
P_9	Talavgoan	25°27'21" N; 75°35'15" E	3-8	Valley
P_{10}	Delunda	25°27'58" N; 75°51'39" E	1-3	Plain-very gently to nearly gently sloping
P_{11}	KVK	25°26'28" N; 75°41'31" E	1-3	Nearly level plain-I
P_{12}	Garjani	25°26'18" N; 76°04'15" E	1-3	Nearly level plain-II

The geology of the study area is quite complex. The rocks of Bundi district belong mainly to the Vindhyan and Aravalli formations. The junction of the upper Vindhyans with the older rocks of the Aravallis reveals an extremely long fault or great through, which has brought almost horizontal strata of the Vindhyan sandstone in contact with the highly folded and foliated schists of Aravallis. The greater fault is roughly parallel to the course of Chambal. An alluvial mantle is superimposed on the older rocks in the valleys of rivers. In the rest of the plain area a thin soil cover has been formed through the weathering and consequent disintegration of the rock strata. The western portion of Bundi is occupied by schists belonging to the Aravalli system, among which are a few outlaying crops of quartzite belonging to the Delhi system. At the capital, sandstones of the upper Vindhyan age are faulted down against the Aravalli schists. Three dominant soil orders were mapped based on the physico-chemical and morphological characteristics (NBSS&LUP approach (1994) for land evaluation was adopted to compute soil suitability classes such as : S1 - highly suitable - land having no significant limitation; S2 - moderately suitable - land having slight limitations causing moderate severity; S3 - marginally suitable - land having aggregation of severe limitations; and N - land having limitations which cannot be overcome at the current level of technology or at currently acceptable costs. The management requirements of soybean for optimum production were identified based on important soil and land characteristics.

Results and Discussions

The important characteristics presented in table 2 indicated that the soils of Eastern Rajasthan Upland as well as in Vindhyan landscape are sandy clay loam on hill top, pediment, valley and very gently sloping plain while clay loam at the surface and clayey in subsurface in nearly level plain-I and clay loam through whole profile in nearly level plain-I and II. The variation in the intensity of erosion and deposition explains the variation in soil texture topographically. Due to rapid downward movement of rain water, the finer particles were readily carried away toward the lower areas while coarse particles remain which could be the main reason for the behavior of texture with change of slope. Similar results were also observed by Gupta *et al.* (1999), Sarkar *et al*. (2001) and Maji *et al.* (2005). Solum thickness is a combined expression of pedogenic horizons and varied from 13-200 cm and 25-180 cm in Eastern Rajasthan upland (P_1-P_6) and Vindhyan landscape (P_7-P_{12}), respectively. Gentle to moderate slope, rapid runoff and severe erosion account for very shallow to shallow soils on the elevated segment of transect. The explanation corroborates with interpretation of Sidhu *et al.* (2000). Available water capacity is an important indicator for sowing seed/or crop planning, irrigation scheduling and crop selection under rainfed conditions/areas like Bundi district. It was observed that soils of Vindhyan landscape had more available water content compared to soils of Eastern Rajasthan upland which could be attributed to the relatively higher finer fraction in these soils.

Table 2. Different soil site properties of representative pedons (weighted mean of parameters)

Pedons	Rain-fall (mm)	Drainage	Slope (%)	Texture	Soil depth (cm)	AWC (M^3/ profile)	$CaCO_3$ (g kg^{-1})	pH	OC (%)	CEC cmol (p^+) kg^{-1}	ESP
I. Eastern Rajasthan Upland											
P_1	773	Somewhat excessive	8-15	Scl	29	0.21	0.00	7.53	0.79	13.95	3.22
P_2	773	Somewhat excessive	8-15	Scl	13	0.14	0.00	8.05	0.42	18.40	2.35
P_3	773	Somewhat Excessive	3-8	Scl	170	0.20	13.84	8.18	0.21	18.52	1.85
P_4	773	Well drainage	1-3	Scl	160	0.17	96.49	8.48	0.32	28.85	1.87
P_5	773	Well drainage	<1	C	200	0.22	80.87	8.80	0.19	36.79	1.73
P_6	773	Well drainage	<1	C	110	0.16	114.57	8.27	0.24	31.79	1.59
II. Vindhyan landscape											
P_7	773	Somewhat excessive	15-30	Scl	25	0.15	0.00	6.96	0.55	16.70	3.89
P_8	773	Somewhat excessive	8-15	Scl	48	0.13	0.00	6.37	0.56	30.10	3.33
P_9	773	Well drainage	3-8	Scl	150	0.21	124.63	8.42	0.58	22.45	1.63
P_{10}	773	Well drainage	1-3	Scl	180	0.19	31.04	8.41	0.31	33.95	2.69
P_{11}	773	Well drainage	<1	C	170	0.22	165.94	9.06	0.35	36.13	1.23
P_{12}	773	Well drainage	<1	C	200	0.24	145.35	8.51	0.32	38.67	1.32

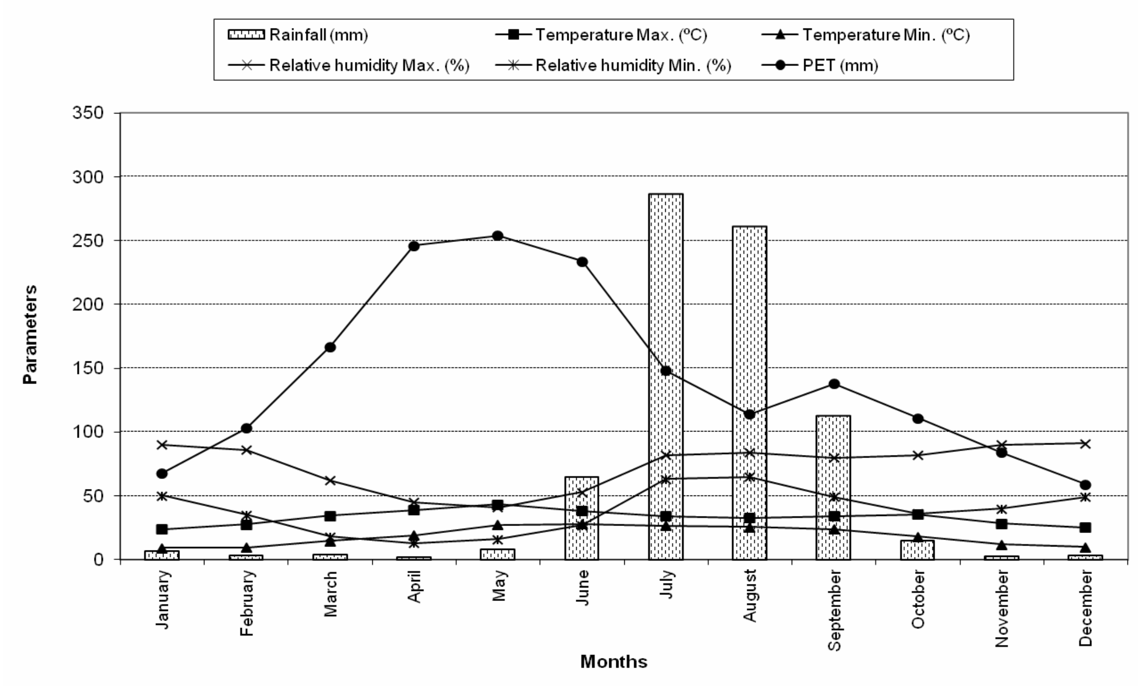

Fig. 1 : Metrological characteristics of Bundi district

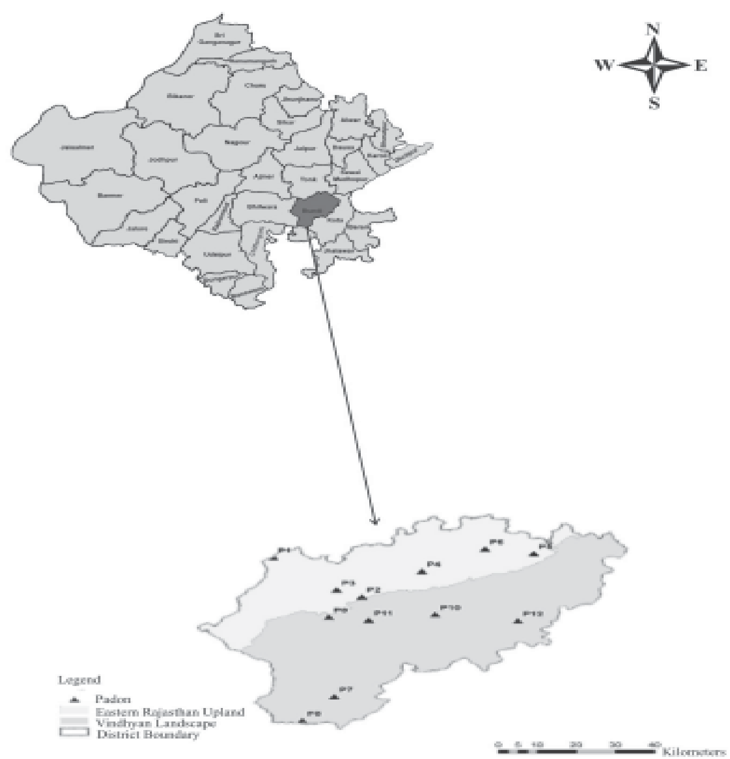

Fig. 2. Location of different geomorphic units in Bundi district of Rajasthan

Free carbonates owe their origin from parent material (Rathore 2003; Gundogan and Yilmaz 2000; West *et al.* 1988), illuviation/leaching process as well as products of weathering. However primary role is being played by parent material. It is a well established fact that leaching of carbonates takes place with soil development. Thus, depth of carbonate leaching is a reliable index of soil weathering and soil development. In present investigation, the content of calcium carbonate of both transects is shown in table 2. It can be seen that the content of calcium carbonate in Eastern Rajasthan upland transect ranged between 0 to 226.0 g kg^{-1} with mean value 50.96 g kg^{-1}. While in Vindhyan landscape transect, its content ranged between 0.00 to 411.70 g kg^{-1} with mean value 77.83 g kg^{-1}. Calcium carbonate content in higher topographic positions *i.e.* hill and pediment (P_1, P_2 and P_7, P_8) in both transects was found absent throughout the profile which could be ascribed to the complete leaching out of the profile as well removal of calcium carbonate and its subsequent deposition in lower topographic positions. Calcium carbonate deposition recorded in lower most horizons could be due to the fact that its content increased with depth and this might be due to leaching of bicarbonates from upper layer during the rainy season and their subsequent precipitation as carbonates in the lower layers. Similar observations were also recorded by Maji *et al.* (2005) and Kumar *et al.* (2010). This may be a function of ESP and weathering index (Al_2O_3/Fe_2O_3) (Singh *et al.* 1999).

Soil reaction (pH) is one of the important parameter controlling availability of plant nutrients in the soils. In the present investigation the pH of the soils in Eastern Rajasthan upland was between 7.53 to 8.88 with a mean value of 8.22, indicating that the soils are slightly alkaline to strongly alkaline. In soils of Vindhyan landscape transect, the pH ranged between 7.16 to 9.57 with a mean value 8.16 (Table 2). A critical examination of data indicates that soil pH in most cases increased with depth in both transects. This increased level of pH down the depth of pedons was mainly due to movement of soluble salts and increased content of calcium carbonate. The higher pH values in soils of lower slopes and its increased value with soil depth could be attributed to the deposition of illuviated bases from surrounding upper slopes. Similar trend in pH was reported by Brown and Olsen (1949) and Sarkar *et al.* (2001 and 2002).

The organic carbon content of the soils is an indication of nitrogen status or total soil fertility. In the soils of the Eastern Rajasthan upland transect, organic carbon content was found to range between 0.133 and 0.794 per cent with a weighted mean value of 0.364 per cent (Table 2). In the soils of Vindhyan landscape transect, the organic carbon content was found to range between 0.115 per cent to 0.945 per cent with a weighted mean value of 0.45 per cent. No specific trend of distribution emerged out with respect to the topography in the soils selected for the study. In general the content of organic carbon was higher at the surface, decreasing down the depth in soil profile. The organic carbon distribution is mainly associated with physiography and land use.

The CEC gives an indication of the soil's potential to hold plant nutrients. CEC is a general indicator of soil storage capacity for available, positively charged plant nutrients such as Ca^{2+}, Mg^{2+}, K^+ and NH_4^+. CEC can also be considered an indication of dominant mineral present in soils, for instance in highly weathered soils; the dominant clay type is kaolinite, which has very little capacity to hold cations compared to other clays. Cation exchange capacity in different pedons found to vary between 11.34 to 39.76 cmol (p^+) kg^{-1} with a weighted mean value of 24.72 cmol (p^+) kg^{-1} in soils of Eastern Rajasthan upland transect. The maximum value of CEC was observed in soils of nearly level plain-I [36.79 cmol (p^+) kg^{-1}] and lowest value [13.95 cmol (p^+) kg^{-1}] in hill top pedon and in pediment [18.40 cmol (p^+) kg^{-1}]. While in soils of Vindhyan landscape transect, cation exchange capacity was found to vary from 14.84 to 41.86 cmol(p^+)kg^{-1} with a weighted mean value of 30.00 cmol(p^+)kg^{-1}. The soils of nearly level plain-II have maximum value of cation exchange capacity followed by the soils of nearly level plain-I, while the soils of hill top have the lowest value of CEC. A critical examination of data indicated that the cation exchange capacity of soils was closely related to the clay content. The drifting of clay along with the bases down the slope might be the factor for the increased level of cation exchange capacity in subsurface layer of soils (Bhatia *et al.* 2005; Maji *et al.* 2005). It can be inferred that increase in clay content provide more exchange sites to get the cations adsorbed on it. In general cation exchange capacity increased with depth except lower most horizons of the both transects.

Sodium saturation in the soils is expressed as exchangeable sodium percentage (ESP) in the soil solution, because of its significance in deteriorating physico-chemical properties of soil and adversely affecting the growth of plants. The values of exchangeable sodium percentage ranges between 1.05 to 3.22 per cent with a weighted mean value of 2.10 per cent in soils of Eastern Rajasthan upland transect. The highest mean value of ESP was found in the soils of hill top (3.22 per cent) followed by pediment soils (2.35 per cent) while the lowest value of ESP was recorded in nearly level plain-II (1.59 per cent) and in nearly level plain-I (1.73 per cent). The soils of very gently sloping plain (1.87 per cent) and valley (1.85 per cent) exhibit intermediate pattern with respect to ESP. In soils of Vindhyan landscape transect, ESP ranged between 0.72 to 4.55 per cent with a weighted mean value of 2.35 per cent. The soils of Vindhyan landscape followed similar pattern of distribution of exchangeable sodium in all topographic positions as in the soils of Eastern Rajasthan upland transect. The variation in ESP in surface soil with respect to slope was similar to exchangeable sodium. Generally, its content was less than 5.17 percent in all the pedons. Similar results were also reported by Saxena and Singh (1982).

Though the rainfall is quite high (773 mm), its distribution is erratic. The most of it is received during July and August. The potential evapotranspiration generally exceeds precipitation for most of the time of year except during the rainy season. The growing period is 100 days (Sehgal *et al.* 1990) thus restricting the choice of rainfed crops. The specific land utilization type in the study area is season cropping of soybean (rainfed) for subsistence by small to marginal farmers with low capital resources, using mostly bullock drawn farm implements

Land use requirements for soybean

In general, soybean requires a well drained, strongly aerated, deep soil (100 cm) without compaction and free from salinity or alkalinity. Soil having moderate texture (clay loam to silty clay laom), porous structure, coarse fragments less than 5 per cent, soil depth more than 0.75 meter, nearly level (less than 3.0 per cent slope), excellent drainage, minimum 0.5-0.75 per cent organic carbon, electrical conductivity less than 1 dSm^{-1}, exchangeable sodium per cent less than 5 and pH in neutral range with appropriate climatic condition (mean temperature in growing season ranged from 25-28°C, mean RH in growing season up to 70-75 per cent and rainfall varies from 600-750 mm in growing season) are found highly suitable for cultivation of soybean. Some of the selected requirements of soil and climate for soybean are listed in table 3 (NBSS&LUP 1994). The ranges have been modified accordingly, after a comprehensive discussion with local agronomists and farmers of the area. Each mapping unit was matched with the requirement for soybean and rating for each of the mapping unit was allotted after considering the land characteristics

Table 3. Criteria and rating of land use requirements for soybean cultivation

Soil site characteristics		Unit	Rating			
			Highly suitable S_1	Moderately suitable S_2	Marginally suitable S_3	Not suitable N
Climate regime	Mean temperature in growing season	°C	25-28	29-32	33-36	>36
	Mean RH in growing season	%	70-75	60-65	50-60	<50
	Total rainfall	mm	600-750	500-600	400-500	<400
Land Quality	Land characteristic					
Moisture availability	Length of growing period	days	>120	100-120	85-100	<85
	AWC	mm/m	>200	150-200	150-50	
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately well drained	Poorly drained to imperfectly drained	
Nutrient availability	Texture	Class	cl,scl,l,sil	sl,c,sic,sicl	c+(ss),ls	s
	pH	1:2.5	6.5-7.5	7.6-8.5 & 6.4-6.0	>8.5	
	OC	%	Medium	High	low	
Rooting Condition	Effective soil depth	cm	>75	50-75	50-25	<25
	Stonnines	%	>15	15-25	25-35	
Soil toxicity	Salinity (EC saturation extract	dS/m	<1.0	1-2	2-4	>4
	Sodicity (ESP)	%	<5	5-10	10-15	>15
Erosion hazards	Slope	%	<3	3-5	5-8	>8

Source: NBSS&LUP (1994); Food and Agriculture Organization of United Nations' Manual, 1976 as described by Sys *et al*. 1991.

Evaluation of soil suitability for soybean crop

The soils of pedon on hill top and pediment (Soils of Umar, Sela ka Data, Nai Ka Talab, and Rajpura-B series) were not found suitable for cultivation Soybean because of excessive slope, coarser texture, severe erosion, droughtiness or low AWC, rapid run-off, poor fertility and especially due to shallow depth (Table 2). The shallow depth of the soil and the excessive slope make them unfit for sustained agricultural use and therefore, should be kept under natural vegetation with proper soil and water conservation practices like contour and stone bounding to prevent further degradation. These soils should be developed as forest or as grass lands. These soils are better suited to silvi-pasture and silvi-horticulture. Soils of most of the pedons (except hilly and piedmont topography) in Bundi district are marginally to moderately suitable for soybean due to different soil profile characteristics. The soils of valley (P_3 and P_9) were found marginally suitable for soybean cropping on account of excessive slope and low organic carbon. The soils of very gently sloping plain to nearly level plains (P_4-P_6 and P_{10}-P_{12}) in both transects were evaluated as moderately suitable for soybean cultivation on account of medium range of available water content, calcium carbonate content, slightly alkaline to alkaline soil reaction and low organic carbon (Table 4). These can easily be amended by alkalinity management practices like application of gypsum to replace sodium on the exchange complex with calcium ions and the replaced sodium can be leached out of the root zone and application of organic manures as well as irrigation and suitability can be upgraded.

Table 4. Suitability of different land units/soil series of Bundi district of Rajasthan for soybean cultivation

Pedons	Rain-fall (mm)	Drai-nage	Slope (%)	Tex-ture	Soil depth (cm)	AWC (M^3/ profile)	$CaCO_3$ (%)	pH	OC (%)	CEC cmol (p^+) kg^{-1}	ESP	Over all suita-bility
I. Eastern Rajasthan Upland												
						Soybean						
P_1	S_1	S_3	N	S_1	S_3	S_2	S_1	S_1	S_1	S_2	S_1	N
P_2	S_1	S_3	N	S_1	N	S_3	S_1	S_2	S_2	S_1	S_1	N
P_3	S_1	S_3	S_3	S_1	S_1	S_2	S_1	S_2	S_3	S_1	S_1	S_3
P_4	S_1	S_1	S_1	S_1	S_1	S_3	S_1	S_2	S_3	S_1	S_1	S_2
P_5	S_1	S_1	S_1	S_1	S_1	S_2	S_1	S_3	S_3	S_3	S_1	S_2
P_6	S_1	S_1	S	S_1	S_1	S_3	S_2	S_2	S_3	S_3	S_1	S_2
II. Vindhyan landscape												
P_7	S_1	S_3	N	S_1	S_3	S_3	S_1	S_1	S_2	S_2	S_1	N
P_8	S_1	S_3	N	S_1	S_3	S_3	S_1	S_1	S_2	S_1	S_1	N
P_9	S_1	S_1	S_3	S_1	S_1	S_2	S_2	S_2	S_3	S_1	S_1	S_3
P_{10}	S_1	S_1	S_1	S_1	S_1	S_3	S_1	S_2	S_3	S_1	S_1	S_2
P_{11}	S_1	S_1	S_1	S_1	S_1	S_2	S_2	S_3	S_3	S_1	S_1	S_2
P_{12}	S_1	S_1	S_1	S_1	S_1	S_2	S_2	S_2	S_3	S_1	S_1	S_2

Land improvement and potential suitability

The mapping units (Table 4) which qualify as marginally suitable suffer from the constraints like drainage and rooting depth and in few cases excessive slope. The management requirements for overcoming the problem of poor moisture retention (due to excessive drainage) includes incorporation of fine clay and silt from the lake floors or areas which have clay texture, straw mulching and higher doses of organic matter. Steeper lands could be made suitable by constructing field bunds across the slope and planting soybean across the slope to check erosion. By adopting these measures, the class S_3 land may be brought to class S_2 land.

Conclusion

Suitability evaluation of major soil series of Bundi district of Rajasthan for cultivation of soybean crop revealed that the soils of hill top (P_1 and P_7) and pediment (P_2 and P_8) in Eastern Rajasthan upland and vindhyan landscape, respectively, were not suitable for its cultivation because of shallow depth (<50 cm), severe erosion, excessive drainage and excessive slope (08-30%). In case of valley soils (P_3 and P_9) of both transects it was found that they had near about same potential for soybean cultivation. The soils of pedon P_4 and P_6 of eastern Rajasthan upland and pedon P_{10} and P_{12} of Vindhyan landscape were rated moderately to marginally suitable for soybean. The reason may be attributed to the fertility status which can be corrected with land management practices and suitability class can be upgraded to highly suitable class. The soils of nearly level plain-I pedon (P_5 and P_{11}) in both transects were rated to be moderately suitable for soybean cultivation because of high pH which could easily be amended by application of gypsum to replace sodium on the exchange complex with calcium ions in root zone and application of organic manures.

References

Anonymous (1986). The soils of Mondha village (Nagpur) for Agrotechnology transfer, *Soil Bull.*, NBSS&LUP publ. p. 65.

Bhaskar, K.S., Lal, S., Chall, O. and Madavi, S.H. (1987). Effect of soil depth on cotton yield. *Journal of the Maharashtra Agricultural Universities* **12**(1): 139-40.

Bhatia, A., Roy, G.B. and Saha, D. 2005. Study on soils of Budhabudhaiani irrigation project in Nayagarh district of Orissa : 1. Characteristics and classification of soils and their productivity potential. *Journal of the Indian Society of Soil Science* **53**: 163-171.

Brown, P.L. and Olson, R.V. (1949). Some soil catena relationship in saline county. Kansas. *Soil Science Society American Proceeding* **14**: 296-299.

Gundogan R. and Yilmar, R. (2000). Effect of landscape position and parent materials on the soil properties in Rahramanmares Borance, Thrky. Paper Presented at the International Symposium on Desertification held at Korya, Turkey.

Gupta, G.P., Tebhare, B.R. and Mishra, S.R. (1999). Characterization and classification of soils of granitic terrain in Jabalpur district of Madhya Pradesh. *Agropedology* **9**: 77-81.

Kuhad, M.S. and Karwasra, S.P.S. (1991). Soil potential ratings for sugarcane in an operational area of sugar factor Palwal, Haryana. *Journal of the Indian Society of Soil Science* **39**(1) : 147-153.

Kumar, H.P.A. and Prasad, J. (2010). Some typical sugarcane growing soils of Ahmednagar distrct of Maharashtra : Their characterization and classification and nutritional status os soils and plants. *Journal of the Indian Society of Soil Science* **58** : 257-266.

NBSS&LUP (1994). Manual Soil-site suitability criteria for major crops.

Maji, A.K., Obi Reddy, G.P., Thayalan, S. and Walke, N.J. (2005). Characteristics and classification of landforms and soils over basaltic terrain in sub-humid tropics of central India. *Journal of the Indian Society of Soil Science* **53**: 154-162.

Rathore, M.S. (2003). Studies on soil genesis and taxonomy of soils associated in toposequence for land use planning in Dungarpur district. Ph.D. thesis submitted to Maharana Pratap University of Agriculture and Technology, Udaipur.

Sarkar, D. Gangopadhyay, S.K. and Velayutham, M. (2001). Soil toposequence relationship and classification in lower outlier of Chhotanagpur plateau. *Agropedology* **11**: 29-36.

Sarkar, D. Baruah, U. Gangopadhyay, S.K. Sahoo, A.K. and Velayutham, M. (2002). Characteristics and classification of soils of Loktak catchment area of Manipur for sustainable land use planning. *Journal of the Indian Society of Soil Science* **50** : 196-204.

Saxena, S.C. and Singh, K.S. (1982). Pedochemical characterization of soils of Rajasthan (semi-arid to humid agroclimatic region). *Journal of the Indian Society of Soil Science* **30** : 515-522.

Sehgal, J.L., Mandal, D.K., Mandal, C. and Vadivelu, S. (1990). Agro-ecological regions of India, *NBSS Bull.* **24**, p. 76.

Sidhu, G. S., Ghosh, S.K. and Majaih (2000). Pedological variabilities and classification of some dominant soils of Aravallies-Yamuna river transect in semi arid tract of Haryana. *Agropedology* **10** : 80-87.

Singh, S.K., Qureshi, F.M., Shyampura, R.L. and Karan, F. (1999). Cenesis and classification of soils derived from lime stone. *Journal of the Indian Society of Soil Science* **47** : 315-322.

Srivastava, R., Omprakash and Sharma, A.K. (1991). Influenced of soil and management on growth and yield of wheat in foot hill region of Uttar Pradesh. *Journal of the Indian Society of Soil Science* **39**(2) : 374-376.

Soil Survey Staff (2000). Key to Soil Taxonomy, 9th edition, USDA National Resource Conservation Service.

West, L.T., Dreas, L.R., Wilding, L.P. and Rebenhorst, M.C. (1988). Differential of pedogenic and lithogenic carbonate forms in Texas. *Geoderma* **43** : 271-287.

Received : Sept, 2013 *Accepted : Aug. 2014*