Journal of the Indian Society of Soil Science, Vol. 58, No. 4, pp 428-435 (2010)

Soil Fertility Capability Classification in a Semi-arid Region in Haryana with Special Reference to Soil Biological Condition Modifier

Partha Pratim Adhikary*, H. Biswas, S.M. Trivedi[1] and H. Chandrasekharan[2]
Central Soil and Water Conservation Research and Training Institute, Research Centre, Datia, 475 661, Madhya Pradesh

The soil fertility capability classification system is an approach to bridge the gap between soil taxonomy and soil fertility. Accordingly, an attempt has been made to classify soils of different physiographic units in southern part of Haryana, a semi-arid tropical region in India, on the basis of soil fertility capability classification and to map by using remote sensing and geographic information system. Eight physiographic units, namely point bars, levee complexes, recent flood plains, basins with relict channels, slightly undulating sandy plains with few hummocks, plains with aeolian activity, old level plains and low lands were identified and delineated. For soil fertility capability classification, along with the established condition modifiers such as gleying condition 'g', dry condition 'd', low cation exchange capacity 'e', basic reaction 'b', saline condition 's' and natric condition 'n', a new local biological soil condition modifier 'm' was introduced keeping in view the soil organic carbon deficiency in the study area to represent the real picture of soil fertility and its relation with soil taxonomy. The soil fertility capability classification units identified were: 'SSebm' (point bars), 'SSdebm' (levee complexes, undulating sandy plains with few hummocks and plains with aeolian activity), 'SLdeb' (Yamuna plains), 'LLgb' (basins with relict channels), 'SLdebm' (old level plains) and 'LLbsnm' (low lands).

Key words: Soil taxonomy, soil fertility capability classification, biological condition modifier, soil physiographic units, GIS

www.IndianJournals.com
Members Copy, Not for Commercial Sale
Downloaded From IP - 14.139.224.82 on dated 9-Mar-2015

The variability in soil influences the use of different soils for different purposes and application of suitable management practices for maximizing the agricultural production. Site-specific knowledge of these resources is necessary for sustainable developmental activities. As the sub-surface soil characteristics cannot be manipulated within the limited management practices, any management activity is confined only to the surface layer. Soil fertility management at optimum level is the most important single factor for sustainable and time-demanding management practice. The soil classification system like soil taxonomy gives relatively more emphasis on sub-soil rather than on top soil properties, and the soil fertility is characterized from top soil properties. The concept of Soil Fertility Capability Classification (SFCC) system was developed as an attempt to bridge the gap between sub-disciplines of soil classification and soil fertility, especially to interpret soil taxonomy and additional soil attributes in a way that is directly relevant to the plant growth (Buol *et al.* 1975; Buol and Couto 1981; Sanchez *et al*. 1982; Denton *et al*. 1987; Zehetner and Miller 2006; Geissen *et al*. 2009).

The SFCC is a classification of soils on the basis of fertility constraints, quantified from condition modifiers (Rao and Jose 2003). The original version of SFCC (Buol *et al.* 1975; Buol and Couto 1981; Sanchez *et al*. 1982) was modified to include specific interpretations for wetland rice soils (Buol 1986; Sanchez 1997) and was further modified by Smith *et al*. (1990) to include condition modifier for permafrost and for subdivision of some existing ones. Smith (1989) also developed a thorough rationale for each SFCC class and provided detailed interpretations for tropical food crops, pastures and tree crops. An algorithm of this third version was later developed by

*Corresponding author (Email: ppadhikary@gmail.com)
Present address
[1] Water Technology Centre, Indian Agricultural Research Institute, New Delhi, 110 012
[2] Unit of Simulation and Informatics, Indian Agricultural Research Institute, New Delhi, 110 012

Yost *et al*. (1997) with software that converts soil profile data into SFCC units plus a series of automatic interpretations and recommendations.

In the original version of SFCC there was no indication of soil organic matter (SOM) content (except for O soils). This may be due to no clear evidence of threshold levels of SOM that define the point at which processes become dysfunctional in a soil and affect plant growth (Sanchez and Miller 1986; Sanchez *et al.* 1989). But the economic conditions of the farmers in the tropics force them to rely largely on organic inputs for managing soil fertility, with mineral fertilizer inputs playing a secondary role or no role at all (Palm *et al.* 2001).

Soil organic carbon saturation deficit is the ratio of present topsoil total SOC level to the SOC level in the soil in its undisturbed state (Hassink 1997; van Noordwijk *et al.* 1997). The threshold value is the per cent carbon (%C) saturation at which the soil is reaching limits in terms of its capacity to maintain many of its productive functions and can be used as a biological condition modifier in SFCC. A relative threshold value (%C saturation) is dimensionless and probably a more robust indicator than absolute values, expressed as concentration (g C kg^{-1}) (Sanchez *et al.* 2003). Relative values are used in SFCC for the 'a', 'i' and 'n' modifiers for similar reasons. van Noordwijk *et al.* (1997) calculated the reference values by regression equations for Sumatra. Lepsch *et al.* (1994) calculated the SOM content in the top 20 cm of soils that had been cropped for many years in Oxisols and Ultisols of Brazil without the 'd' modifier by an equation having textural data as dependent variables.

Blair *et al*. (1997) proposed a measure of soil organic matter through the use of a fraction extracted by a dilute (333 *mM*) $KMnO_4$ that represents the combined components of labile carbon in the soil. Carbon management index is the fraction of the dilute $KMnO_4$–SOC in a soil relative to that in an undisturbed or control soil (Blair *et al.* 1997). Murage *et al.* (2000) found the $KMnO_4$ technique was sensitive to differences in land use and was also more convenient and reliable than other determinations such as light fractions and soil microbial biomass.

In SFCC, biological soil condition modifier 'm' was first introduced by Sanchez *et al.* (2003) by using the concept of organic carbon saturation deficit (Hassink 1997; van Noordwijk *et al*. 1997). Sanchez *et al.* (2003) proposed a value of 80% of the original topsoil total soil organic carbon as a trial indicator that the soil is reaching a threshold in terms of its capacity to maintain many of its functions. They also proposed that the 'm' modifier should also be alternatively measured by the $KMnO_4$-extractable C method proposed by Blair *et al.* (1997). In the present study we used the same biological soil condition modifier 'm', proposed by Sanchez *et al.* (2003) to classify and map the soils of different physiographic units of southeastern part of Haryana state using remote sensing (RS) and GIS.

Materials and Methods

Study Area

The study area covers the southern part of Faridabad district of Haryana state having the administrative blocks of Palwal and Hodal and lies between 27°51′40″ and 28°10′24″ N latitude, and 77°07′30″ and 77°32′25″ E longitude and covers almost 1086 km^2 (Fig. 1). It is surrounded by Ballabhgarh block in the north, Uttar Pradesh in the east, Rajasthan and Gurgaon district in the south and west. Geologically, it forms a part of the deep Indo-Gangetic alluvial plain and the alluvial thickness varies from 100 m to more than 300 m. The area is overlain by sand predominantly in the top 20 to 30 m and clay and *kankar* below that. The aquifer is mainly semi-confined type and the average groundwater level ranges between 10–20 m below ground level (Central Ground Water Board 2004). The western part of the region is occupied by diversified geological formations consisting of unconsolidated recent and older alluvium and quartzite. Quartzite rocks which occupy the maximum part, have limited source of availability of groundwater confining largely to fracture planes and the weathered zone. Yield potential of the fracture zones varies from 100 to 200 liters per minute. Thickness of alluvium is highly variable because of presence of sub-surface ridges and faults in the area. Groundwater level in the area is declining with rates

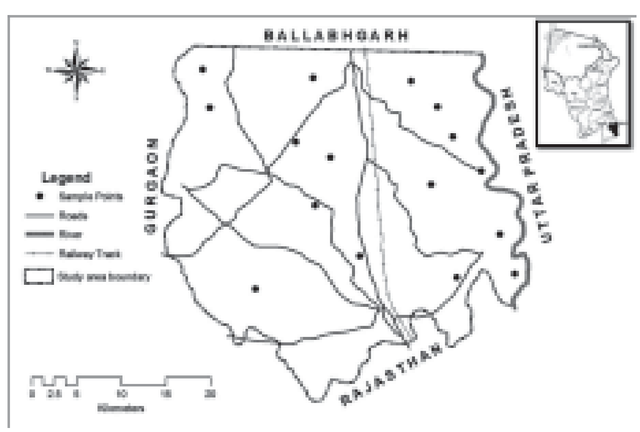

Fig. 1. Map of study area sowing location of sampling points

www.IndianJournals.com
Members Copy, Not for Commercial Sale
Downloaded From IP - 14.139.224.82 on dated 9-Mar-2015

varying between 1 to 4 m per annum. In few pockets in the area, the rate of decline has been alarming at 3 to 4 m per annum (Central Ground Water Board 2004).

The climate of the area is semi-arid sub-tropical and monsoon-driven with average annual rainfall of about 545.8 mm and the annual evaporation is about 2548 mm. Out of total rainfall, 85% is received from south-west monsoon during the months of July, August and September and the rest is received in the form of winter rain. The average annual temperature is 31.6 °C with January being the coldest month with mean daily maximum and minimum temperatures of 21.3 and 2.3 °C, respectively. June is the hottest month with maximum temperature going up to 47 °C. The study area is under hyper-thermic temperature regime. April and May are the driest months with relative humidity of about 30% in the morning and less than 20% in the afternoons.

Data Collection and Analysis

For generating maps, we used aerial photographs, the National Remote Sensing Agency (NRSA) IRS 1C False Colour Composites (FCC) (1:50,000). We also used the Survey of India Topographic Sheet (1:50,000) to get a physiographic map of the area. Detailed field survey was made to correlate the image characteristics with the physiographic features in the field. The delineated base map (polygon feature class) of study area and the location of sixteen soil sampling points within the area (point feature class) were generated using GIS software Arc-GIS 9.1/Arc-View as two different coverage feature classes. The base map and the soil sampling point coverage map were overlaid. In each physiographic unit soil profiles were studied for detailed morphological (FAO 1996) and physico-chemical characteristics using standard procedures. The analyzed parameters were soil texture, soil colour, pH, electrical conductivity (EC), sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), and magnesium (Mg^{2+}) ions, cation exchange capacity (CEC), exchangeable sodium percentage (ESP) and soil organic carbon (SOC). The soil texture was determined by international pipette method (Piper 1966) and textural classes were determined by using USDA textural triangle. Soil colour was measured by using Munsell colour chart. Soil pH was measured by pH meter with glass electrode (Richards 1954). The electrical conductivity was determined by using Eutech-Cybernetics EC meter (Richards 1954). Sodium and potassium concentrations were determined using ELICO CL-220 flame photometer (Jackson 1967). Calcium and magnesium concentrations were determined by complexo-metric titration method using ethylene diamine tetra-acetic acid (EDTA) (Barrows and Simpson 1962). Cation exchange capacity was determined by neutral normal ammonium acetate method (Richards 1954). The ESP was calculated by using the formula from the United States Salinity Laboratory (Richards 1954). Soil organic carbon (SOC) was determined by Walkley and Black (1934) rapid titration method. The soils were classified according to soil taxonomy (Soil Survey Staff 1999).

www.IndianJournals.com
Members Copy, Not for Commercial Sale
Downloaded From IP - 14.139.224.82 on dated 9-Mar-2015

Development of SFCC

Each physiographic unit was further classified under SFCC. The system consists of three categorical levels: type (texture of upper 20 cm of surface soil), sub-strata type (sub-soil texture between 20 and 50 cm depth), and condition modifiers (physical and chemical properties which influence the interaction between soil and fertilizer materials). The type levels are of four types: sandy top-soils (S), loamy top-soils (L), clayey top-soils (C) and organic top-soils (O). Similarly the sub-strata type levels are also of four types: sandy sub-soils (S), loamy sub-soils (L), clayey sub-soils (C) and rock or other hard root restricting layer (R). In the original version of SFCC there were fifteen condition modifiers: gley (g), dry (d), low CEC (e), aluminium toxicity (a), acid (h), high P fixation by iron (i), X-ray amorphous (x), Vertisol (v), low K reserves (k), basic reaction (b), salinity (s), natric (n), cat clay (c), gravel (‘) and slope (%). A biological soil condition modifier (m), proposed by Sanchez *et al.* (2003) was used in this study to address the growing need of the farmers of the tropical and sub-tropical regions for maintaining productivity and sustainability.

Results and Discussion

The range, arithmetic mean, standard error of mean and standard deviation for the soil properties used to identify the soil physiographic units and to develop the SFCC for surface and sub-surface soils, respectively are presented in tables 1 and 2. Based on the analytical data (Table 3), following physiographic units were mapped: (i) point bars, (ii) levee complexes, (iii) recent flood plains, (iv) basins with relict channels, (v) slightly undulating sandy plains with few hummocks, (vi) plains with aeolian activity, (vii) old level plains, and (viii) low lands (Fig. 2). These were further classified into different SFCC units. The type, sub-strata type and condition modifiers were identified for each physiographic unit. The condition modifiers relevant to the area were (i) gleying condition ‘g’, where soils or mottles have ≤ 2 chroma

Table 1. Descriptive statistics of the soil parameters in the surface soil (0-20 cm)

Parameters	Maximum	Minimum	Average	SEM ±	SD
Sand (%)	86.80	53.10	71.67	3.45	9.75
Silt (%)	25.10	8.50	16.26	1.74	4.92
Clay (%)	21.80	4.70	12.06	1.94	5.51
pH	10.50	7.70	8.50	0.29	0.85
EC (dS m^{-1})	11.90	0.12	1.91	1.43	4.05
Ca^{2+} [cmol(p^+)kg^{-1}]	5.82	1.01	2.57	0.54	1.52
Mg^{2+} [cmol(p^+)kg^{-1}]	2.44	0.71	1.24	0.19	0.56
Na^+ [cmol(p^+)kg^{-1}]	2.59	0.24	0.82	0.27	0.76
K^+ [cmol(p^+)kg^{-1}]	0.78	0.17	0.35	0.07	0.19
CEC [cmol(p^+)kg^{-1}]	10.30	2.50	5.84	0.98	2.78
ESP	54.00	7.80	16.08	5.47	15.48
SOC (g kg^{-1})	5.30	1.00	3.16	0.53	1.50

Table 2. Descriptive statistics of the soil parameters in the sub-surface soil (20-50 cm)

Parameters	Maximum	Minimum	Average	SEM ±	SD
Sand (%)	86.30	51.60	69.37	4.02	11.39
Silt (%)	25.90	9.20	17.44	2.13	6.01
Clay (%)	22.50	4.50	13.18	2.17	6.13
pH	10.30	7.40	8.50	0.28	0.81
EC (dSm^{-1})	4.24	0.18	1.15	0.47	1.34
Ca^{2+} [cmol(p^+)kg^{-1}]	5.72	1.10	2.99	0.51	1.43
Mg^{2+} [cmol(p^+)kg^{-1}]	2.56	0.76	1.44	0.21	0.56
Na^+ [cmol(p^+)kg^{-1}]	2.03	0.24	0.82	0.23	0.64
K^+ [cmol(p^+)kg^{-1}]	0.53	0.14	0.29	0.05	0.14
CEC [cmol(p^+)kg^{-1}]	11.90	2.40	6.49	1.13	3.19
ESP	32.80	4.50	13.17	3.01	8.52
SOC (g kg^{-1})	4.20	0.80	2.43	0.37	1.06

www.IndianJournals.com
Members Copy, Not for Commercial Sale
Downloaded From IP - 14.139.224.82 on dated 9-Mar-2015

within 60 cm of the soil surface and below all A horizons, (ii) dry condition 'd', having ustic moisture regime, (iii) low cation exchange capacity 'e', having CEC <7 cmol(p^+)kg^{-1} of soil at pH 7, (iv) basic reaction 'b', having pH >7.3, (v) saline condition 's', having EC ≥ 4 dS m^{-1} in saturation extract at 25 °C within 1 m of soil surface, and (vi) natric condition 'n', having exchangeable sodium percentage (ESP) ≥ 15 within 50 cm of the soil surface (Table 4).

Data show that more than 90% of the study area is having soil organic carbon (SOC) deficiency, with a newly introduced local condition modifier 'm', because farmers are forced to rely largely on organic inputs, and mineral fertilizer inputs are playing either a secondary or no role at all (Palm *et al*. 2001). This local SFCC biological condition modifier 'm' can be applicable where the SOC is < 5 g C kg^{-1} soil within 20 cm depth, and forms a basis of SFCC units in the study area (Table 5).

The SFCC map (Fig. 3) showed that in the physiographic unit of point bars, the surface and sub-surface soils were non-saline loamy sand with low cation exchange capacity (e), basic in reaction (b), moderately drained, calcareous, and deficient in SOC (m). The soils were coarse loamy, Typic Ustifluvents. Based on the above parameters the soils of the point bars were classified under the fertility capability unit 'SSebm'.

The soils of levee complexes were nearly flat and developed/originated from the flood deposition of the coarser materials parallel to the river. Taxonomically these soils are coarse loamy, Typic Ustorthents. The condition modifiers identified were dry soil moisture condition (d), low cation exchange capacity (e), basic reaction (b), and deficient SOC (m). The soil fertility capability unit was 'SSdebm'.

The recent flood plain soils could be classified as coarse loamy, calcareous, Typic Haplustepts. The condition modifiers identified were dry soil moisture condition (d), low cation exchange capacity (e) and basic reaction (b). The soils were classified according to the soil fertility capability unit as 'SLdeb'.

The basins with relict channels were natural low-lying areas with poor drainage and micro-relief where finer materials were deposited during heavy floods in the past. Due to seasonal flooding and in-

www.IndianJournals.com
Members Copy, Not for Commercial Sale
Downloaded From IP - 14.139.224.82 on dated 9-Mar-2015

Table 3. Relevant average values of soil properties for soil fertility capability classification (SFCC)

Physiographic units	Depth (cm)	Particle size (%)			Texture	pH	EC_e (dS m^{-1})	Exchangeable cations [cmol (p^+) kg^{-1}]				CEC [cmol(p^+) kg^{-1}]	ESP	SOC (g kg^{-1})	Colour (moist)
		Sand	Silt	Clay				Ca^{2+}	Mg^{2+}	Na^+	K^+				
Point bars	0-20	77.4	13.5	9.1	Loamy sand	8.4	0.37	2.25	1.04	0.32	0.17	4.1	7.9	1.00	10YR6/3
	20-50	75.7	14.3	10.0	Loamy sand	8.2	0.24	2.95	1.46	0.24	0.20	5.2	4.5	0.80	10YR5/3
Levee complexes	0-20	77.3	13.4	9.3	Loamy sand	7.7	0.12	2.78	1.02	0.36	0.29	4.6	7.8	2.70	10YR5/3.5
	20-50	80.0	11.7	8.3	Loamy sand	7.4	0.18	2.34	1.15	0.30	0.20	4.2	7.1	2.00	10YR5/4
Recent flood plains	0-20	70.6	19.1	10.3	Loamy sand	8.3	0.54	1.65	1.07	0.55	0.78	4.2	13.1	5.20	10YR5/3.5
	20-50	61.0	24.7	14.3	Loam	8.5	1.03	3.38	1.58	0.92	0.53	6.5	13.3	2.60	10YR4.5/4
Basins with relict	0-20	53.1	25.1	21.8	Loam	8.4	0.53	5.82	2.44	1.05	0.46	10.3	10.2	5.30	10YR4/2
channels	20-50	51.6	25.9	22.5	Loam	8.6	0.75	5.72	2.56	1.51	0.46	11.9	12.7	4.20	10YR4/2
Slightly undulating	0-20	86.8	8.5	4.7	Loamy sand	8.1	0.16	1.19	0.74	0.24	0.19	2.5	9.6	2.40	10YR6/4
sandy plains with few hummocks	20-50	86.3	9.2	4.5	Loamy sand	8.4	0.20	1.10	0.76	0.27	0.14	2.4	11.2	1.70	10YR5/4
Plains with	0-20	70.4	17.5	12.1	Loamy sand	8.1	0.29	2.82	1.48	0.69	0.29	5.6	12.4	3.80	10YR4.5/4
aeolian activity	20-50	73.3	16.5	10.2	Loamy sand	8.3	1.13	2.11	1.08	0.58	0.26	4.4	13.3	3.50	10YR4/5
Old level plains	0-20	71.1	18.2	10.7	Loamy sand	8.5	1.37	3.02	1.46	0.76	0.28	5.6	13.7	2.70	10YR4.5/3
	20-50	63.4	21.3	15.3	Loam	8.3	1.47	4.12	1.85	0.74	0.20	7.1	10.5	2.00	10YR4.5/4
Lowlands	0-20	66.7	14.8	18.5	Loam	10.5	11.9	1.01	0.71	2.59	0.37	9.8	54.0	2.20	10YR6/2.5
	20-50	63.7	15.9	20.4	Loam	10.3	4.24	2.18	1.06	2.03	0.34	10.2	32.8	2.60	10YR4/3.5

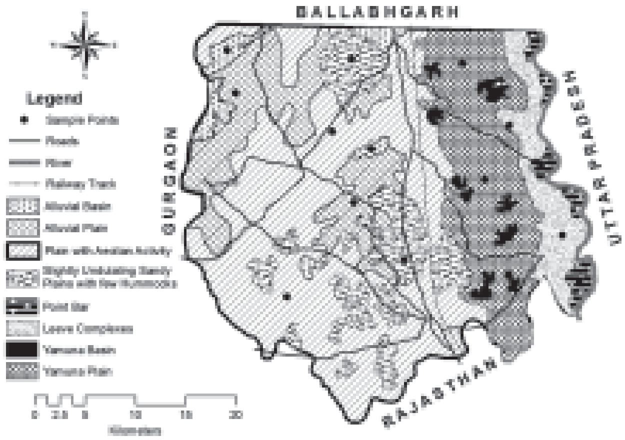

Fig. 2. Physiographic map of the study area

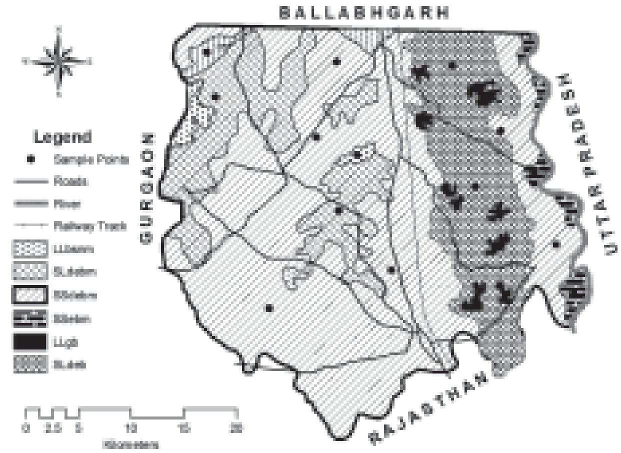

Fig. 3. Soil fertility capability classification (SFCC) map of the study area

Table 4. Coding of type, substrata type and condition modifiers for soil fertility capability classification (SFCC)

Physiographic unit	Type	Substrata	Modifiers type	Check list g	d	e	b	s	n	m	FCC unit
Point bars	S	S	ebm	-	-	X	X	-	-	X	SSebm
Levee complexes	S	S	debm	-	X	X	X	-	-	X	SSdebm
Recent flood plains	S	L	deb	-	X	X	X	-	-	-	SLdeb
Basins with relict channels	L	L	gb	X	-	-	X	-	-	-	LLgb
Slightly undulating sandy plains with few hummocks	S	S	debm	-	X	X	X	-	-	X	SSdebm
Plains with aeolian activity	S	S	debm	-	X	X	X	-	-	X	SSdebm
Old level plains	S	L	debm	-	X	X	X	-	-	X	SLdebm
Lowlands	L	L	bsnm	-	-	-	X	X	X	X	LLbsnm

Table 5. Description of the soil fertility capability classification (SFCC) units and their comparison with soil taxonomy

Physiographic units	Taxonomic classification	SFCC Unit	Description
Point bars	Coarse loamy, Typic Ustifluvents	SSebm	Sandy surface and subsurface soils having low cation exchange capacity. Alkaline soils deficient in soil organic carbon.
Levee complexes	Coarse loamy, Typic Ustorthents	SSdebm	Sandy surface and subsurface soils. Dry soils with low cation exchange capacity. Alkaline soils deficient in soil organic carbon.
Recent flood plains	Coarse loamy, calcareous, Typic Haplustepts	SLdeb	Sandy surface and loamy subsurface soils having dry condition. Low cation exchange capacity, alkaline in reaction.
Basins with relict channels	Fine loamy, calcareous, Aquic Haplustepts	LLgb	Loamy surface and subsurface with gleying condition, alkaline in reaction.
Slightly undulating sandy plains with few hummocks	Typic Ustipsamments	SSdebm	Sandy surface and subsurface with dry condition. Soils have low cation exchange capacity, are alkaline in reaction and are deficient in soil organic carbon.
Plains with aeolian activity	Coarse loamy, calcareous, Typic Ustorthents	SSdebm	Sandy surface and subsurface with dry condition. Soils have low cation exchange capacity, are alkaline in reaction and deficient in soil organic carbon.
Old level plains	Fine loamy, Typic Haplustepts	SLdebm	Sandy surface and loamy subsurface with dry condition. Soils have low cation exchange capacity, are alkaline in reaction and deficient in soil organic carbon.
Lowlands	Fine loamy, calcareous, Typic Haplustepts	LLbsnm	Loamy surface and subsurface soils with alkaline reaction. Problem of soil salinity with sodium saturation at the surface. Soils are deficient in soil organic carbon.

www.IndianJournals.com
Members Copy, Not for Commercial Sale
Downloaded From IP - 14.139.224.82 on dated 9-Mar-2015

www.IndianJournals.com
Members Copy, Not for Commercial Sale
Downloaded From IP - 14.139.224.82 on dated 9-Mar-2015

tensive irrigation, salts leached down to deeper depths. The surface and sub-surface soils were loamy in texture, calcareous, non-saline but alkaline in nature. Taxonomically there soils were fine loamy, calcareous, Aquic Haplustepts. The condition modifiers identified were presence of gley at subsurface layer (g), and basic soil reaction (b). The soils were classified as fertility capability unit 'LLgb'.

The soils of slightly undulating sandy plain with few hummocks were mostly affected by aeolian sand. Taxonomically, the soils were classified as coarse loamy, calcareous, Typic Ustipsamments. The condition modifiers identified were dry soil moisture (d), low cation exchange capacity (e), basic reaction (b), and deficient SOC (m). The soil fertility capability unit was 'SSdebm'.

Plains with aeolian activity had sandy and calcareous soil with leaching of clay, and a hard layer of $CaCO_3$ concretions at shallow depths. Taxonomically, the soils were classified as coarse loamy, calcareous, Typic Ustorthents. The condition modifiers were dry soil moisture condition (d), low cation exchange capacity (e), basic reaction (b), and deficient SOC (m). The soil fertility capability unit was 'SLdebm'.

The soils of low lands with moderate to poor drainage could be taxonomically classified as fine loamy, calcareous, Typic Haplustepts. The condition modifiers identified were basic soil reaction (b), saline soils (s), natric (n), and deficient SOC (m). Soil fertility capability unit was 'LLbsnm'.

The SFCC unit 'SSdbem', comprising of the physiographic units of levee complexes, slightly undulating sandy plains with few hummocks and plains with aeolian activity occupied the maximum area, which is nearly 63% of the study area. After incorporation of soil biological condition modifier 'm', the SFCC became more robust and the soil physiographic unit recent flood plain has come out of the SFCC unit 'SSdbem', because of its high SOC content. On the other hand, three physiographic units like levee complexes, slightly undulating sandy plains with few hummocks and plains with aeolian activity are coming under same SFCC class SSdebm. Thus the real picture of soil fertility condition in the study area and its relation with soil taxonomy has become more pronounced.

Conclusions

Soil is a complicated three phase system and the solid phase consists of both inanimate compounds and live organisms and the latter play an important role especially in the tropical soils. The aim to develop and map the soil fertility capability classification (SFCC) in arid and semi-arid tropics to bridge the gap between soil fertility and soil taxonomy for optimum and sustainable development cannot be fully realized without the incorporation of soil organisms in the classification system. In the SFCC system, there may be many different SFCC classes in one soil taxonomic unit and *vice versa*, but the number of SFCC classes can be changed depending upon the number of condition modifiers used relevant to the soil related problems of a particular area. In the present study, as maximum part of the area is deficient in soil organic carbon, the incorporation of newly introduced soil biological condition modifier 'm' has helped to represent the real picture of soil fertility and its relation with soil taxonomy. Thus a classification approach where the local soil problems are incorporated can be more useful for the scientific community, planners and decision makers to adopt better management practices.

References

Barrows, H.L. and Simpson, E.C. (1962) An EDTA method for the direct routine determination of calcium and magnesium in soils and plant tissues. *Soil Science Society of America Proceedings* **26**, 443-445.

Blair, G.J., Lefroy, R.D.B., Singh, B.P. and Till, A.R. (1997) Development and use of a carbon management index to monitor changes in soil C pool size and turnover rate. In *Driven by Nature: Plant Litter Quality and Decomposition* (G. Cadisch and K.E. Giller, Eds.), pp. 273-281. CAB International, Wallingford, UK.

Buol, S.W. (1986) Fertility capability classification system and its utilization. *Soil Management under Humid Conditions in Asia and Pacific*. ASIALAND, IBSRAM, Bangkok, pp. 318-331.

Buol, S.W. and Couto, W. (1981) Soil fertility capability assessment for use in the humid tropics. In *Characterization of Soils in Relation to their Management for Crop Production: Examples from the Humid Tropics* (D.J. Greenland, Ed.), pp. 254-261. Clarendon Press, London.

Buol, S.W., Sanchez, P.A., Cate, R.B. and Granger, M.A. (1975) Soil fertility capability classification. In *Soil Management in Tropical America* (E. Bornemisza and A. Alvarado, Eds.), pp. 126-141. North Carolina State University, Raleigh.

Central Ground Water Board (CGWB) (2004) Development and augmentation of groundwater resources in and around of National Capital Territory of Delhi. *Report of the Government of India*.

Denton, H.P., Peedin, G.F., Hawks, S.N. and Buol, S.W. (1987) Relating the fertility capability classification system to tobacco response to potassium fertilization. *Soil Science Society of America Journal* **51**, 1224-1228.

FAO (1996) *Guidelines for Soil Profile Description*. FAO, Rome.

Geissen, V., Sánchez-Hernándeza, R., Kampichlerb, C., Ramos-Reyesa, R., and Sepulveda-Lozadaa, A. (2009) Effects of land-use change on some properties of tropical soils — An example from Southeast Mexico. *Geoderma* **151**, 87-97.

Hassink, J. (1997) The capacity of soils to preserve organic C and N by their association with clay and silt particles. *Plant and Soil* **191**, 77-87.

Jackson, M.L. (1967) *Soil Chemical Analysis*. Asia Publishing House, New Delhi.

Lepsch, I.F., Menk, J.R.F. and Oliveira, J.B. (1994) Carbon storage and other properties of soils under agriculture and natural vegetation in Sa˜o Paulo State, Brazil. *Soil Use and Management* **10**, 34-42.

Murage, E.W., Karanja, N.K., Smithson, P.C. and Woomer, P.L. (2000) Diagnostic indicators of soil quality in productive and non-productive smallholders' fields of Kenya's Central Highlands. *Agriculture, Ecosystems and Environment* **79**, 1-8.

Palm, C.A., Gachengo, C.N., Delve, R.J., Cadisch, G. and Giller, K.E. (2001) Organic inputs for soil fertility management in tropical agro-ecosystems: Application of an organic resource database. *Agriculture, Ecosystems and Environment* **83**, 27-42.

Piper, C.S. (1966) *Soil and Plant Analysis*. Hans Publishers, Bombay.

Rao, D.V.K.N. and Jose, A.I. (2003) Fertility capability classification of some soils under rubber in Kerala. *Journal of the Indian Society of Soil Science* **51**, 183-188.

Richards, L.A. (1954) *Diagnosis and Improvement of Saline and Alkali Soils*. *USDA Handbook No.* **60**, Washington, USA.

Sanchez, P.A. (1997) Changing tropical soil fertility paradigms; from Brazil to Africa and back. In *Plant-Soil Interactions at Low pH* (A.C. Moniz *et al.*, Eds.), pp. 19-28. Brazilian Society of Soil Science, Piracicaba, SP.

Sanchez, P.A., Couto, W. and Buol, S.W. (1982) The Fertility capability soil classification system: interpretation, applicability and modification. *Geoderma* **27**, 283-309.

Sanchez, P.A. and Miller, R.H. (1986) Organic matter and soil fertility management in acid soils of the tropics. In *Transactions 13th Congress of the International Society of Soil Science.* pp. 609-625. Hamburg, Germany.

Sanchez, P.A., Palm, C.A. and Buol, S.W. (2003) Fertility capability soil classification: a tool to help assess soil quality in the tropics. *Geoderma* **114**, 157-185.

Sanchez, P., Palm, C.A., Szott, L.T., Cuevas, E. and Lal, R. (1989) Organic input management in tropical agroecosystems. In *Dynamics of Soil Organic Matter in Tropical Ecosystems* (D. Coleman, B. Bohlool and G. Uehara, Eds.), pp. 125-152. University of Hawaii Press, Honolulu.

Smith, C.W. (1989) The fertility capacity classification system (FCC) — 3rd approximation: a technical soil classification system relating pedon characterization data to inherent fertility characteristics. *PhD Dissertation*, 430 pp. North Carolina State University, Raleigh.

Smith, C.W., Sanchez, P.A. and Buol, S.W. (1990) Implications of soil mineralogy in the soil fertility capability classification system. In *Transactions 14th International Congress of Soil Science (Kyoto).* pp. 4-9. Japanese Society of Soil Science, Kyoto, Japan.

Soil Survey Staff (1999) Soil Taxonomy, a basic system of soil classification for making and interpreting soil surveys. *USDA Agricultural Handbook*, **2nd Ed.** Natural Resources Conservation Service, Vol. 436, 86 p. US Department of Agriculture, Washington.

van Noordwijk, M., Cerri, C., Woomer, P.L., Nugroho, K. and Bernoux, M. (1997) Soil organic carbon dynamics in the humid tropical forest zone. *Geoderma* **79**, 187– 225.

Walkley, A. and Black, I.A. (1934) An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science* **37**, 29-38.

Yost, R.S., Li, Z.C., Smith, C.W., Benites, J. and Nachtergaele, F. (1997) *Merging Databases and Decision-Aids: Linking an Updated Soil Fertility Capability Classification (FCC) with the WISE (World Inventory of Soil Emission Potential) Database FAO, Rome.*

Zehetner, F and Miller, W.P. (2006) Soil variations along a climatic gradient in an Andean agro-ecosystem. *Geoderma* **137**, 126-134.

Received March 2009; Accepted July 2010

www.IndianJournals.com
Members Copy, Not for Commercial Sale
Downloaded From IP - 14.139.224.82 on dated 9-Mar-2015