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Organic carbon stock in soils of Patiala district of the Indo-Gangetic alluvial plain

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Abstract

Basic information on soil organic carbon (SOC) stock plays important role in the management of soil health and its developmental planning for sustainable use. An attempt has been made in this study to generate information on soil organic carbon stock as a case study in the Patiala district of Punjab representing the soils of the Indo-Gangetic alluvial plains. The soils have very low to moderate soil organic carbon content and the total soil organic carbon stock of the district is 15474.4 x 10^6 Kg. The soil organic carbon is found to be quite variable in soils owing to differences in physiography, soil texture, soil colour and soil degradation processes. The soil textural family has been found to have significant influence on the soil organic carbon stock showing 59 % retention by fine loamy, 29 % by clayey and 10 % by coarse loamy soils. Inceptisols have recorded 97 % of the total SOC stock as compared to the Entisols with very low (2 %) SOC. Among the two distinct physiographic zones, the soils of Ghaggar fluvial system are found to be richer in SOC than those of Patialawali fluvial system. On the basis of SOC stock the areas like the plains modified by aeolian activity, the old leeves and dissected uplifted terraces of Ghaggar fluvial system, the sodic soils of the Patialawali fluvial system become the priority areas for immediate rehabilitation to restore the soil health for their sustained use.

Additional keywords: Taxonomic category, C reserve and landforms.

Introduction

The Indo-Gangetic Plain (IGP) with a geographical area of 43.64 m ha is one of the most important agricultural zones of India. During the last four decades due to attempts for targeted yield the land use of the Indo-Gangetic plains especially the north-western part has undergone spectacular changes and this has resulted in depletion of soil organic matter (Abrol and Gupta 1998). In addition to land use changes, unfavourable aridic climatic conditions have further enhanced the rate of decomposition and its further depletion (Velayutham *et al.* 1999). As a result, the biological acivity has been gradually hampered. Such a situation demands the restoration of soil health through application of organic matter (Goswami 1998). However, soil organic matter management finds success when it is performed on the basis of basic information on soil organic matter stock as it can often act as the single diagnostic parameter of soil health in the management of soil resources for the sustainable use and management.

Some attempts have been made in the recent years for the estimation of soil organic carbon stock of the soils of India (Jenny and Raychaudhury 1960; Gupta and Rao 1994; Velayutham *et al.* 1999). Gupta and Rao (1994) have reported 24.3 Pg carbon stock in Indian soils, which can be increased to 34.9 Pg by sequestering additional carbon in soils by restoration, reforestation and adopting soil and water conservation. This study was carried out by using organic carbon data of 32 Benchmark soils and 16 other soils. Velayutham *et al.* (1999) estimated 82 Pg SOC stock in Indian soils based on published and unpublished soil database generated through soil resource mapping of India by the National Bureau of Soil Survey and Land Use Planning, Nagpur through district soil

survey programmes and also from various other sources including research articles. So far the information on organic carbon stock of district level is not available. In view of the need of developmental planning at the district level, the present study was undertaken for Patiala district of Punjab as a case study with a hope that the basic information generated on SOC stock may help the planners to prioritise the areas of restoring soil health by soil organic carbon management and can act as a model for district developmental planning elsewhere in the Indo-Gangetic plains.

Materials and methods

Study area : Patiala district of Punjab is a part of northern Indo-Gangetic Plain and is situated between 29^0 50' to 30^0 48' N latitudes and 75^0 50' to 76^0 57' E longitudes covering an extent of 4,63,426 ha. Physiographically the district can be divided into two distinct regions viz. i) area drained by Patialawali nadi and its tributaries (Patialawali fluvial system), and ii) area drained by Ghaggar river (Ghaggar fluvial system). The alluvium of Patialawali fluvial system is dominantly dark yellowish brown to brown (10 YR) and it is dark brown to reddish brown (7.5 YR and 5 YR) in the Ghaggar fluvial system.

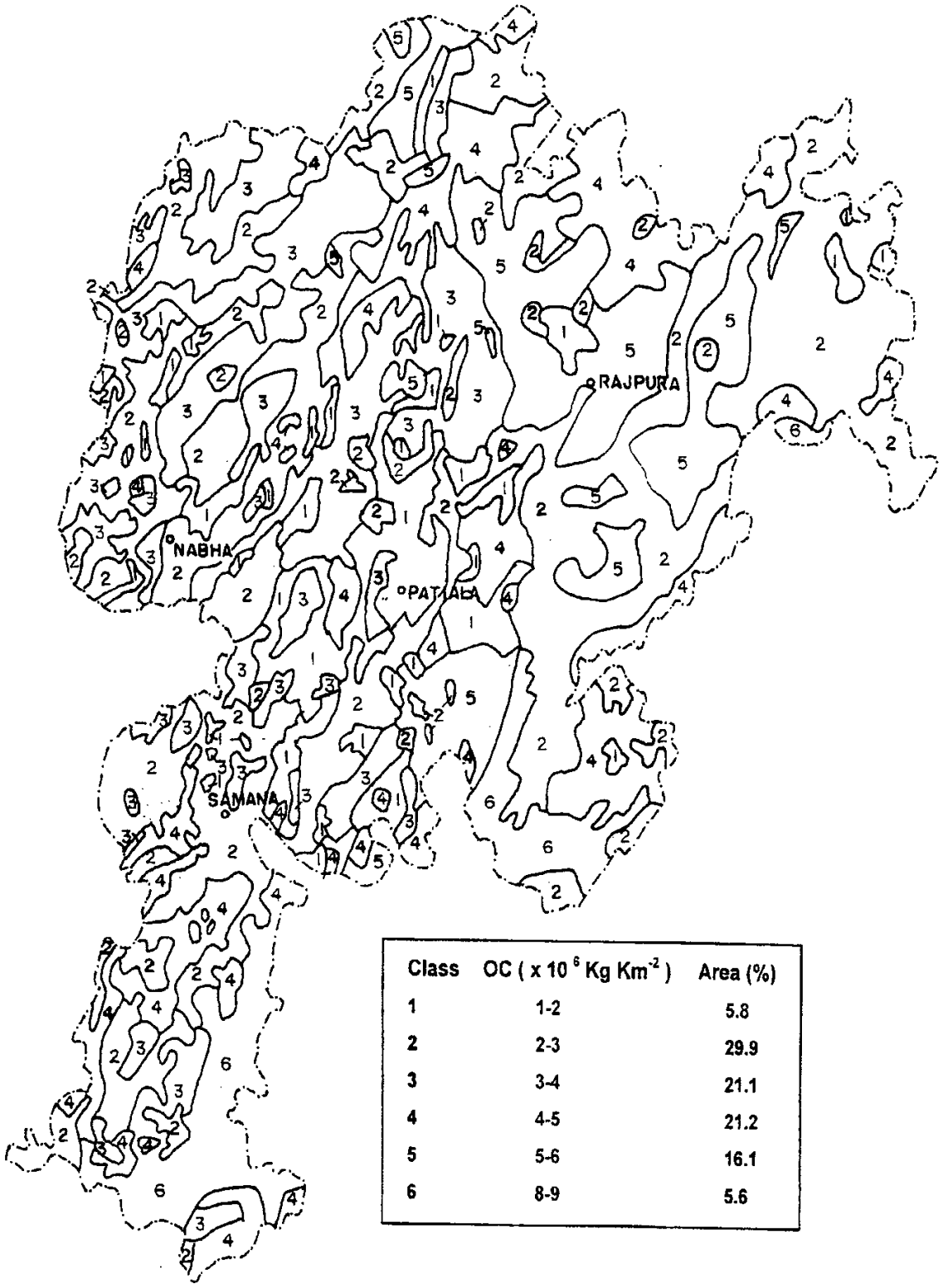
The climate is semi-arid and subtropical with average annual rainfall of 700 mm. The mean annual air temperature is 24.5°C and mean summer and winter air temperatures are 31°C and 16.3°C, respectively. The area falls under hyperthermic temperature regime. Almost all parts of the district are under cultivation except the land that are degraded or submerged under water.

The soil resources map was prepared at 1:50,000 scale showing association of soil series (NBSS&LUP, 1981). The soils of the Ghaggar Plain of Patiala district were mapped, characterised and classified by Saxena (1992). Twenty seven soil series identified in the district were mapped into 21 soil series associations. The occurrence of soil series are in the ratio of 60:40 in case of two series association and a ratio of 50:30:20 in case of three soil series association. Soils were classified as per the Soil Taxonomy (Soil Survey Staff 1998). The soil OC, bulk density, physical and chemical properties were estimated by the standard procedures (Richards 1954). The status of OC was calculated for 1 m depth by multiplying the values of OC, the bulk density and spatial extent of the soils. The OC status map was prepared by grouping the soils of similar C content (Fig. 1). The correlation between OC and silt, clay, silt+clay and pH was worked out using weighted average of the profile data.

Results and discussion

The physical and chemical properties of soil series identified in Patiala district are presented in table 1. It is observed that the soil colour ranges from 10 YR 5/6 to 5 YR 4/4, pH ranges from 7.6 to 10.1, clay per cent from 4.3 to 53.9, silt from 3.8 to 67 and the organic carbon from 0.09 to 0.67 per cent.

Soil organic carbon stock in soil series : Soil organic carbon content of various soils of the Patiala district is very low to moderate (0.1 to 0.67 %).This can be attributed to high rate of decomposition of OC in the prevailing semi-arid climatic conditions (Tables 1 and 2) which results in the formation of $CaCO_3$ (Table 2) with concomitant development of sodicity (Pal *et al.* 1999).



Class	OC (x 10^{6} Kg Km^{-2})	Area (%)
1	1-2	5.8
2	2-3	29.9
3	3-4	21.1
4	4-5	21.2
5	5-6	16.1
6	8-9	5.6

Fig. 1. Distribution of organic carbon, Patiala district, Punjab

Table 1. Soil series of Patiala district and their dominant properties

Soil Series	Colour	Drainage	pH (1:2.5)	Clay (%)	Silt (%)	OC (%)	$CaCO_3$ (%)
				---------(weighted average)------			
Bhanra	10 YR 5/6	Excessively drained	7.6	6.9	3.8	0.09	-
Fatehpur	10 YR 6/4 to 10 YR 6/6	Excessively drained	7.9	4.3	12.7	0.11	-
Samana	7 5 YR 4/4	Well drained	7.3	14.2	12.6	0.14	-
Kakra	7 5 YR 4/4 to 10 YR 4/3	Well drained	7.9	14.0	17 7	0.25	-
Tulewal	10 YR 4/4 to 10 YR 5/4	Well drained	7 7	19	21.6	0.12	1.0
Nabha	10 YR 3.5/3 to 10 YR 4/4	Well drained	8.7	26.4	27.1	0.2	-
Hissar	10 YR 4/4	Well drained	8.4	21.7	39.7	0.29	1.5
Tohana	10 YR 4/2 to 4/3	Mod. Well drained	7.7	47.6	48.2	0.45	0.8
Ranbirpura	2.5 Y 5/2 to 2.5 Y 5/4	Poorly drained	8.3	25.3	49.3	0.37	-
Bazidpur	2 5 Y 4.5/2 to 2.5 Y 5/2	Poorly drained	9 5	20 7	45.3	0.17	1-3 % surface 19-22 % sub soil
Suniarheri	10 Y 5/2 to 10 Y 4/2	Imperfectly drained	10.1	34.3	46 4	0.18	1-2 % surface 18-20 % sub soil (Sodic soils)
Rajendra	10 YR 6/4 to 10 YR 5/4	Imperfectly drained	10 3	23.2	51.4	0.21	3-4 % surface 20-25 % sub soil (Sodic soils)
Todarpur	5 YR 4/4 to 7.5 YR 5/4	Mod. Well to Imperfectly drained	8.3	28.5	43.5	0.31	-
Chataihra	10 YR 3/4 to 10 YR 4/4	Mod Well drained	9.8	26.6	24.9	0.19	1.3
Sanaur	10 YR 5/4	Excessively drained	8 1	6.4	13.7	0.06	0.6
Banru	7.5 YR 5.2 to 10 YR 4/4	Well drained	8.1	7.5	24.4	0.1	0.8
Urdan	5 YR 4/4 to 5 YR 4/3	Well drained	8.5	20.5	55.2	0.32	0.4
Manakpur	5 YR 3/4 to 5 YR 4/4	Well drained	8.8	39.5	57.3	0.25	-
Jalalpur	7.5 YR 4/4 to 5 YR 3/3	Mod. Well drained	7.9	35.4	50.1	0.33	0-8% surface 2-0% subsoil
Bahadurgarh	5 YR 5/4 to 5 YR 3/4	Mod. Well drained	8.0	22.9	60.3	0.24	1-3% surface 2% subsoil
Ghanaur	7.5 YR 5/4 to 5 YR 4/3	Mod. Well drained	8.9	36.9	56.3	0.26	-
Sadhu	10 YR 4/3 to 7.5 YR 4/2	Imperfectly drained	8.8	53.9	32.5	0.35	0-7% surface 2% subsoil
Patiala	5 YR 4/4	Mod. Well drained	7.5	41.2	47.7	0.43	0.5-0.9% subsoil
Rohar	5 YR 4/3	Mod. Well drained	9.3	30.3	52.1	0.67	0.4-0.9% subsoil
Julkan	7.5 YR 4/4 to 10 YR 5/4	Mod. Well drained	7.8	14.7	66.9	0.22	2.5
Daun	7.5 YR 4/4	Well drained	8.1	8	45.4	0.16	1.6
Kapuri	5 YR 4/4 to 7.5 YR 4/4	Mod. Well drained	7.8	16.1	62.4	0.21	1.7

Soil series wise organic stock for one meter soil depth has been calculated and is presented in table 2. Vast variation in organic carbon stock in soil series has been observed. It ranges from 0.9 Kg $Km^{-2}m^{-1}$ in Sanaur series to 9.5 Kg $Km^{-2}m^{-1}$ in Rohar series. The total organic carbon stock in the soils of the district is 15474.4 x 10^6 Kg (Table 2).

Table 2. OC status of different soils, Patiala district, Punjab

Soil classification	Soil series	Area Km^2	OC x 10^6 Km^{-2} m^{-1}	SOC stock x 10^6 Kg
Entisols				
Typic Ustipsamments	Bhanra	27.636	1.30	36.00
	Fatehpur	36.589	1.62	59.27
	Sanaur	21.073	0.896	18.88
	Total	85.298		**114.2**
Typic Ustorthents	Banru	12.2	1.46	17.81
Typic Ustifluvents	Todarpur	46.08	3.071	141.51
	Julkan	11.37	3.06	34.7
	Daun	11.34	2.263	25.66
	Kapuri	11.34	3.091	35.05
	Total	**80.13**		254.73
		177.63		**369.0**
Inceptisols				
Typic Haplustepts	Samana	308.166	1.947	599.99
	Kakra	336.515	2.786	937.53
	Tulewal	220.326	1.796	395.705
	Nabha	466.076	2.95	1374.92
	Hissar	215.56	4.396	947.6
	Urdan	328.05	4.775	1566.44
	Bahadurgarh	312.12	4.163	1299.35
	Total	**2186.813**		**7121.535**
Fluventic Haplustepts	Tohana	199.053	6.675	1328.68
	Chataihra	30.72	2.808	86.26
	Manakpur	54.47	3.671	199.96
	Ghanaur	134.91	6.000	809.46
	Patiala	241.73	7.336	1773.33
	Rohar	90.54	9.497	859.86
	Total	**751.423**		**5057.55**
Aeric Endoaquepts	Ranbirpura	29.24	5.571	162.89
Aeric Halaquepts	Bazidpur	19.49	2.514	48.99
	Suniarheri	438.52	2.671	1171.29
	Total	**458.01**		**1220.28**
Typic Calciustepts	Rajendra	292.28	3.683	1076.46
Lamellic Haplustepts	Jalalpur	61.25	5.413	331.55
Vertic Haplustepts	Sadhu	26.62	5.056	134.59
	Total	**3805.636**		**15104.9**
	Grand Total	**3983.26**		**15474**

SOC Stock in soil taxonomic classes: The estimation of SOC stock in different soil taxonomic classes (Soil Survey Staff 1998) has the advantage of comparing the SOC stock in soils occurring elsewhere. The soils of Patiala district have been classified as Entisols and Inceptisols. The distribution of SOC in different soils is presented in table 2. It is observed that Inceptisols with an area of 3805.63 Km^2 have 15104.84 x 10^6 Kg SOC which is 97 per cent of SOC stock of the district.

SOC stock in physiographic subregions : Soil organic carbon stock in the physiographic regions (Fig. 2) is presented in table 3. It is seen that Patialawali fluvial system with an area of 2782.5 Km^2 contain 8683.13 x 10^6 Kg organic carbon for 100 cm soil depth with an average value of 3.1 x 10^6 Kg $Km^{-2}m^{-1}$. The variation in organic carbon stock ranging from 1.55 x 10^6 Kg $Km^{-2}m^{-1}$ in sand dunes to 4.3 x 10^6 Kg $Km^{-2}m^{-1}$ in old alluvial plain with hydromorphic conditions

Table 3. Distribution of SOC stock in soils of physiographic units

Physiography	Dominant Series	Area Km^2	SOC Stock X 10^6 Kg	Average SOC Kg Km^{-2}
Patialawali fluvial system				
Plain modified by aeolian activity		76.0	118.2	1.55
Sand dunes	Bhanra ; Fatehpur Samana			
Interdunal plains	Samana: Kakra Tulewal	726.0	1607.2	2.2
Old flood plains	Tulewal ; Nabha Kakra : Hissar Tohana	1124.1	4270.2	3.8
Old flood plain with hydromorphic conditions	Ranbirpura Bazidpur	48.7	211.6	4.3
Salinity/Alkalinity induced Old flood plain	Suniarheri Rajendra	730.9	2248.2	3.1
Recent flood plain	Todarpur Chataihra	76.8	227.8	3.0
		2782.5	**8683.2**	**3.1**
Ghaggar fluvial system				
Old leeves	Sanaur : Banru	30.51	34.23	1.1
Well drained old flood plain	Urdan ; Manakpur Bahadurgarh; Jalalpur ; Ghanaur Patiala	832.2	4161.2	5.0
Moderatly to imperfectly drained old flood plain	Patiala; Rohar Sadhu; Jalalpur	279.6	2163.2	7.7
Recent flood plain	Daun : Julkan Kapuri ; Sanaur Bahadurgarh	56.7	152.8	2.7
Dissected uplifted terraces		56.7	142.3	2.7
	Total	**1255.8**	**6653.7**	**5.3**

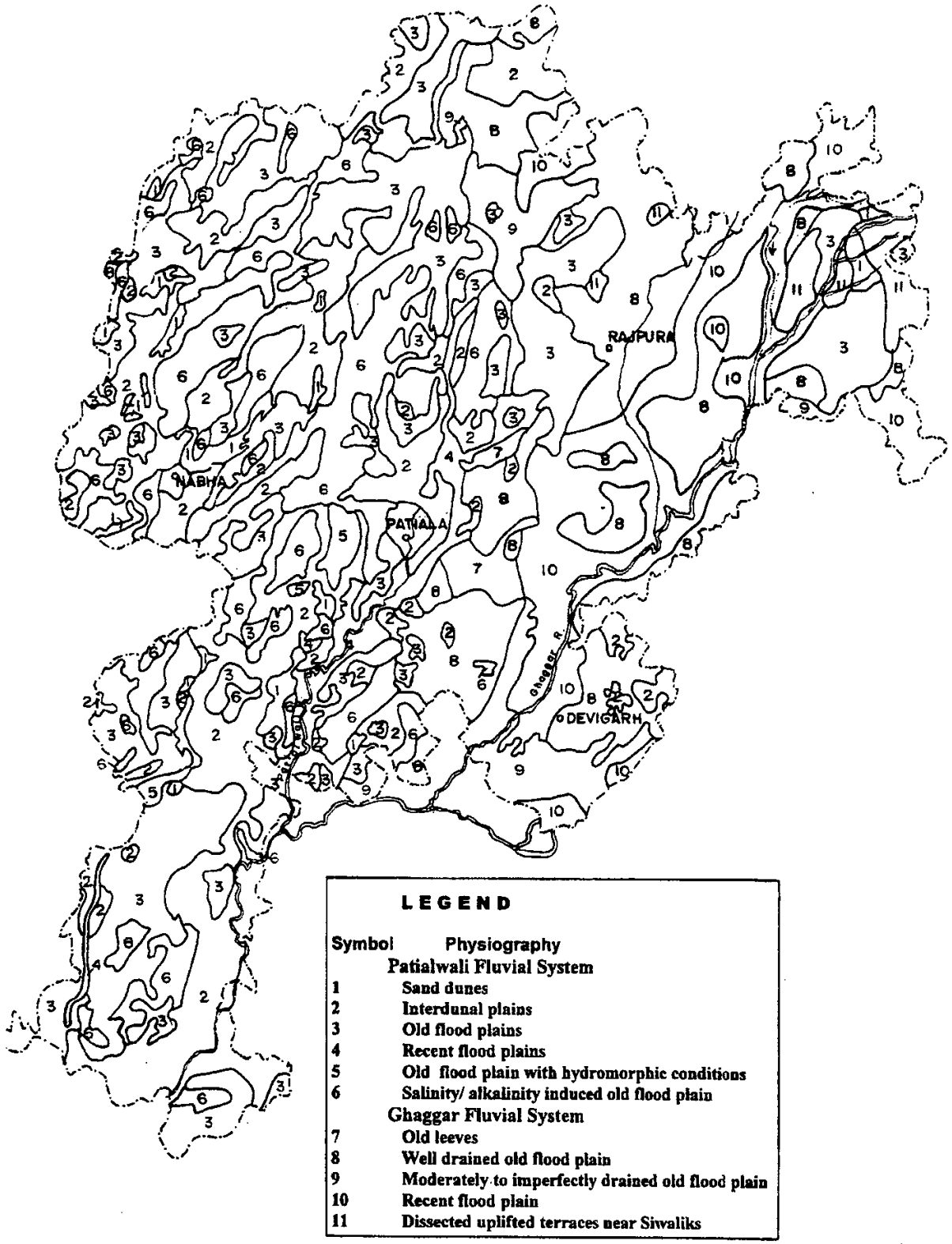


Fig. 2. Physiographic regions, Patiala district, Punjab

The Ghaggar fluvial system with an area of 1255.8 Km^2 have 6653.7 x 10^6 Kg organic carbon per 100 cm soil depth with an average SOC stock of 5.3 x 10^6 Kg $Km^{-2}m^{-1}$ .The impact of soil texture on SOC can be seen in this plain as the SOC ranges from 1.1 x 10^6 Kg $Km^{-2}m^{-1}$ for a 100 cm depth in old levees having sandy texture to7.7 x 10^6 Kg Km^{-2} m^{-1} in moderately to imperfectly drained old flood plain with clayey soils. The Ghaggar fluvial system is richer in SOC than the Patialawali fluvial system.

OC status as influenced by soil properties

It is observed that the textural family influences the SOC stock as 59 per cent of total SOC stock is retained by fine loamy, 29 per cent by clayey and 10 per cent by coarse loamy soils (Table 4).

Table 4. SOC Stock in textural families of Patiala district for 1 m soil depth

Textural Family	SOC Stock (x 10^6 Kg)	% of SOC stock
Sandy	114.8	0.74
Coarse loamy	`563.2	10.1
Fine loamy	9131.3	59.0
Clayey	4577.5	29.6
Coarse silty	87.6	0.6
Total	15474.4	100

The quantity and type of clay in soils have a bearing upon carbon mineralisation and humus content in the soil. It is known that in a given agro-climatic region organic matter and N content of fine textured soils is higher than coarse textured soils. Profile distribution of various forms of nitrogen and OC varies significantly due to influence of landforms (Goyal and Singh 1987), altitude and physiography, (Agarwal and Prakash 1984 ; Verma *et al.* 1990), pedogenic development (Beke *et al.* 1995) and mineralogy (Walia *et al.* 1998).

In the present study the values of OC in coarse loamy soils of aeofluvial system shows significant difference from each other (Table 5). It was observed that the coarse loamy soils of 7.5 YR had low OC content (1.7x10^6 Kg $Km^{-2}m^{-1}$) than the soils of 10 YR (2.3x10^6 Kg $Km^{-2}m^{-1}$) as they are derived mostly from aeolian material (Joshi *et al.* 1981, Joshi 1992, Goyal and Singh 1987).

Table 5. Carbon status of coarse loamy soils in aeofluvial and fluvial systems

Colour	Soil Series	O.C. x 10^6 Kg $Km^{-2}m^{-1}$	SE (t)	CD
Soils of 10 YR hue (Aeofluvial system)	Longwal**	2.307	0.0906	0.209
	Kakra	2.786		
	Tulewal	1.796		
Soil of 7.5YR hue (Fluvial & Aeofluvial system)	Banru	1.460		
	Samana	1.947		

** Source: MOA & USAID (1972)

In the fine loamy class the Nabha, Todarpur and Bazidpur series showed significant differences with Hissar and Ranbirpura series. More OC may be due to addition by frequent floods because of their setting in lower element of topography (Table 6). Similar observations were also made by Dwivedi *et al.* (1983) who indicated that the Ganga flat and western low lands of the U.P. with conditions of submergence generally contained more organic matter than the Ganga upland. In the fine loamy soils of Ghaggar fluvial system, the Urdan is at par with Bahadurgarh series and both differ significantly with Rohar soils. This may be due to high silt content in the later. The soils of 5 YR colour of Ghaggar fluvial system had more OC ($4.5x10^6$ Kg $Km^{-2}m^{-1}$) than 10 YR fine loamy soils ($3.2x10^6$ Kg $Km^{-2}m^{-1}$) of Patialawali fluvial system.

Table 6. OC Status of fine loamy soils of two fluvial systems

Fluvial system	Soil Series	O.C. x 10^6 Kg $Km^{-2}m^{-1}$	SE (t)	CD
Soils of 10 YR hue (Patialawali Nadi)	Nabha	2.950	0.2607	0.5478
	Hissar	4.396		
	Todarpur	3.071		
	Chhataihra	2.808		
	Ranbirpura	5.571		
	Bazidpur	2.514		
	Rajendra	3.683		
Soils of 5 YR hue (Ghaggar River)	Urdan	4.775		
	Bahadurgarh	4.163		
	Rohar	9.497		

Irrespective of parent material and landforms, a significant decrease in the content of SOC of the soils of the same family is observed which is mainly attributed to variation in the level of salinity/alkalinity hazards.

Clayey soils had significantly higher OC ($6.1x10^6$ Kg $Km^{-2}m^{-1}$) as compared to those of coarse loamy ($2.0x10^6$Kg $Km^{-2}m^{-1}$) and fine loamy soils ($3.85x10^6$Kg $Km^{-2}m^{-1}$) (Table 7). The OC and clay content showed significant positive correlation (r=0.57) as also reported earlier by others (Ghosh *et al.* 1981, Joshi *et al.* 1981, Murlidharudu and Omanwar 1987, Room Singh and Omanwar 1987 and Singh and Sinha 1987). Within the clayey group, the soils derived from Ghaggar fluvial system (Table 7) showed significant differences in OC with that of the soils of Patialawali Nadi. Silt content also showed significant positive correlation (r=057) with OC but silt + clay had better positive correlation (r=0.73).This indicates that the OC retention is a function of clay minerals which are mainly concentrated in the finer fractions of soils.The lower value of OC in Suniarheri, Rajendra (Patialawali Nadi) and Manakpur series (Ghaggar fluvial system) with increasing pH showed negative correlation between OC and pH. This indicates that the rate of decomposition of OC is much higher in these soils.

The relationship between OC with clay, silt, silt + clay and pH is expressed in the following equations.

$Y = 0.55 + 0.312$ x clay ($r = 0.57$); $Y = 1.12 + 0.065$ x silt ($r = 0.57$)

$Y = 0.137 + 0.56$ x silt + clay ($r = 0.73$); $Y = 8.8 - 0.12$ x pH ($r = 0.26$)

Table 7. OC Status of clayey soils of two fluvial systems

Fluvial system	Soil Series	O.C. x 10^6 Kg $Km^{-2}m^{-1}$	SE (t)	CD
Soils of 10 YR hue (Patialawali Nadi)	Tohana	6.675	0.222	0.403
	Suniarheri	2.671		
Soils of 5 YR hue (Ghaggar river)	Manakpur	3.671		
	Jabalpur	5.413		
	Patiala	7.336		
	Ghanaur	6.000		
	Sadhu	5.056		

Management of organic carbon : Soils of the Patiala district are improvised with SOC stock. To restore their health the soils of the district are to be rehabilitated so that they can sequester OC. Rehabilitation methods are fairly well known, therefore they need to be practised by prioritising the area. Sequestration of carbon implies not only increasing the amount of carbon entering the soil but also a decrease in the amount leaving either through decomposition or erosion (Gupta and Rao 1994). The increase in organic matter content from 0.4 per cent to 1.4 per cent by growing *Prosopis Juliflora* over a period of seven years in salt affected soils of Etah district has been reported by Sharma *et al.* (1995). In the Patialawali fluvial system an area of 730.9 Km^2 (Suniarheri, Rajendra soil series) which can be easily rehabilitated with the reclamation method for sodic soils. The plain modified by aeolian activity having soils of Bhanra, Fatehpur, Samana, Kakra and Tulewal needs to be protected from wind erosion and practising of green manuring will result in increase of organic matter and stabilisation of soils.The dissected uplifted terraces of Ghaggar fluvial system with an area of 56.7 Km^2 need immediate attention as it is subjected to water erosion. The old leeves of Ghaggar fluvial system with an area of 30.51 Km^2 having sandy soils of Sanaur and Banru needs conservation measures.

Conclusions

The study suggests that although the soils of Patiala district have varying amounts of OC within their textural classes, physiographic units and taxonomic classes, they are deficient in OC status (<1%) and thus are improvised in SOC stock. With suitable soil conservation and rehabilitation measures management of OC is possible. Thus information on SOC stock of soils can provide guidance in prioritising the areas for immediate management of OC to restore soil health at district level.

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