Indian Society of Soil Science
Platinum Jubilee Symposium - Proceedings, pp

Soil Information System of the Indo-Gangetic Plains for Resource Management

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Need for Soil Information System

It has long been felt that our natural environment should be mapped and monitored with active participation of agencies responsible for managing natural resources, industry groups and community organizations. This organized information forms a basis for storing soil and land databases for implementation and monitoring various efforts on land resource management. In view of huge demands on natural resources like soil, water, with special reference to environment and its protection there is a need for better information on spatial variation and trends in the conditions of soils and landscapes. It thus becomes imperative to have a clear view of the status of information on various natural resources with special reference to soils. It would not only store the datasets for posterity but also will improve our understanding of biophysical processes in terms of cause-effect relationship in the pedo-environment. Thus, information on soil and land resources is fundamental and therefore soil information system (SIS) plays a pivotal role.

Information on soil is huge but scattered and therefore it requires to be archived. Now since modern day information system of any natural resource requires its physical location in terms of space, exact referencing of important spots has become very necessary. Geographic Information System (GIS) has been an important tool for geo-referencing soil information system (GeoSIS). Since India is a large country for brevity we have decided to restrict this article to Soil Information System for the Indo-Gangetic Plain (IGP) (SISIGP).

Developing Soil Information System (Methodology)

The IGP has been subjected to major agricultural interstratification and high population pressure during the recent past including Green Revolution era and beyond. This vast plain is now witnessing degradation of natural ecosystem, such as soil, water, forest, etc. and declining productivity. The region reflects a close relationship between soil, climate and natural vegetation. The landform and climate change from upper to its lower reaches. It ranges from semi-arid climate in the west to humid to perhumid climate in the east (Bhattacharyya *et al*. 2004, 2005; Bhattacharyya and Pal 2003; Velayutham *et al*. 2002).

The Indo-Gangetic Plains (IGP) with about 13% geographical coverage of India produces nearly 50% of foodgrains to feed 40% of the total population of India. The IGP is an important agricultural region of the country with total area of about 44 Mha represented by well classified agro-ecosubregion (Velayutham *et al*. 1999) and covers the states of Punjab, Haryana, Delhi, Uttar Pradesh, Bihar, West Bengal and part of a few other states (Bhattacharyya *et al*. 2004). The IGP represents one of the most extensive fluvial plains of the world with a vast asymmetric trough with maximum thickness of 10,000 m. The nature and properties of alluvium vary in texture, acidity and calcareousness; the elevation ranges from 150 to 300 m above mean sea level (msl) (Pal *et al*. 2009).

Various countries have developed their own soil information system (Das 1999). For IGP, we used Soil and Terrain Digital Database (SOTER) (1:1 M) which provides data for improved mapping, modelling and monitoring of changes of world soil and terrain resources. The SOTER methodology allows mapping and characterization of areas of land with a distinctive, often repetitive pattern of landform, lithology, surface form, slope, parent material, and soils (van Engelen and Wen 1995). The approach resembles physiographic or land systems mapping. The collated materials are stored in a SOTER database linked to GIS, permitting a wide range of environmental applications (Batjes and Dijkshoorn 1999; Falloon *et al*. 1998). The SOTER is applied at scales ranging from 1:250,000 to 1:5 M (Batjes *et al*. 2004). The SOTER method used for studies on carbon stocks and change in the IGP (India) scenario led to following understanding:

(i) Linkage between soil profile data and the spatial component of a SOTER map for environmental applications requires generalisations of measured soil (profile) data by soil unit and depth zone (Bhattacharyya *et al*. 2005).
(ii) The set of soil parameter estimates for IGP – India should be seen as best estimates, based on the currently available selection of profile data held in IGP – SOTER and WISE (Ray *et al*. 2005; Batjes *et al*.2004a,b, 2007; Bhattacharyya *et al*. 2005).
(iii) The primary and secondary datasets for IGP – India will be useful for agro-ecological zoning, land evaluation, and modelling of carbon stocks and changes at a scale of 1:1M (Batjes *et al.* 2007; Bhattacharyya *et al*. 2007; Chandran *et al*. 2005).

Since SISIGP (SOTER database) was generated in order to cater to the needs of Roth-C and Century C models various datasets were used (Table 1) keeping in view of requirements of the models *viz*. location and relative extent of soil type, soil drainage status (hydricity), content of clay, sand, silt, organic C and bulk density. This set was expanded to include 18 soil parameters (Table 1) to permit a wider range of assessments such as land evaluation, agro-ecological zoning and modelling of food productivity (Batjes *et al*. 2007). In SOTERIGP, physiography and lithology are criteria to differentiate terrains. The IGP has a nearly level physiography and the parent material is alluvial deposits brought down by the Ganges and its tributaries. Therefore, each soil map unit is considered as a separate terrain.

Table 1. Selected soil parameters to develop SISIGP in SOTER

Sl. no.	Soil parameters	Remarks
1	Organic carbon	%
2	Total nitrogen	%
3	Soil reaction	pH (H_2O)
4	Cation exchange capacity	CEC soil
5	Cation exchange capacity of clay	CEC clay[1,2]
6	Base saturation	% of CEC soil[1]
7	Effective cation exchange capacity	ECEC[1,3]
8	Aluminium saturation	% of ECEC[1]
9	$CaCO_3$ content	%
10	Gypsum content	%
11	Exchangeable sodium percentage	ESP[1]
12	Electrical conductivity	ECe
13	Bulk density	Mg m^{-3}
14	Coarse fragments	Volume %
15	Sand	%
16	Silt	%
17	Clay	%
18	Available water capacity	AWC[1,4]

[1]Estimated from measured data; [2] CEC clay was estimated from CEC soil assuming CEC to be contributed by clay and organic matter (@120-750 cmol(p^+)kg^{-1}, [3]ECEC is estimated from (Ca^{2+} + Mg^{2+} + K^+ + Na^+ + H^+ + Al^{3+}) values; [4] AWC, cm to specified depth, from -33 to -1500 kPa, % v/v (Batjes *et al*. 2004a, 2007).

Each map unit of IGP is given a number which is the terrain number of SOTERIGP. A list of terrain number and the soils associated with each terrain at subgroup level of classification (Soil Survey Staff 2006) are shown in table 2, showing association of soils as dominant, subdominant, and inclusion. Since SOTER is a global database, the dominant soil occurring in the terrain is considered as the major soil of the terrain. Total thirty-seven soil series are identified for SOTERIGP (Ray *et al.* 2005; Chandran *et al.* 2005). These soil series data are linked according to their dominance in a particular terrain and are given terrain component number. This indicates that one soil series may have more than one terrain number (Fig. 1).

The status of datasets of SOTERIGP is shown in table 3. Details are shown in Chandran *et al*. (2005).

The data for each component attributes such as terrain, profile and land cover are collected and maintained using SOTER. These data known as non-spatial data or attribute data are used for linking with the map (1:1 million scale) (Chandran *et al.* 2005).

Soil Information System of the IGP

Spatial Hierarchy and Level of Mapping

Soil information has been collected through different sources and at various scales to develop user-friendly datasets. Most have been at small scales since the purpose of these output maps was different (Table 4). The IGP has been mapped using strict soil mapping units (soil family association) depending on scale of mapping and using standard methods of soil survey (NBSS&LUP 2002). This document is mainly concerned with capturing information from soil-landscape surveys since these constitute soil and land use information of the IGP.

The hierarchy of land units and description of legends at various scales of soil-land use survey efforts made so far are shown in table 4. The IGP was part of the All India Soil Information System first in 1985 in a map form and then again in 2002. This was followed by agro-ecological region (AER) and

Table 2. Soil Information System – SOTERIGP datasets (1:1 m scale)

Terrain No.	Soil Association (Subgroup)[1]	Soil Series	Soil Classification (WRB)[2]
1	Typic Ustifluvents [3] - Typic Usorthents - Lithic Usorthents	Sasanga	Haplic-Eutric Fluvisols
2	Typic Haplustepts - Typic Dystrustepts - Typic Ustipsamments	Fatehpur	Eutri-Haplic Cambisols
3	Typic Natrustalfs - Lithic Ustorthents - Typic Haplustalfs	Akbarpur	Eutri-Haplic Solonetzs
4	Typic Endoaquepts - Dystric Eutrudepts - Typic Udorthents	Khowai	Hypoluvic-Endohaplic Gleysols
5	Humic Dystrudepts - Typic Dystrudepts	Barak	Umbri-Dystric Cambisols
6	Vertic Endoaquepts - Typic Epiaquepts - Aeric Epiaquepts	Hangram	Vertic-Endogleyic Cambisols
7	Humic Dystrudepts - Typic Hapludalfs	Barak	Umbri-Dystric Cambisols
10	Typic Haplaquepts - Typic Kandiudults - Typic Dystrudepts	Seoraguri	Hypoluvi-Gleyic Cambisols
11	Typic Endoaquepts - Aeric Fluvaquents - Fluventic Dystrudepts	Nayanpur	Hypoluvi-Dystric Gleysols
12	Typic Haplustepts - Typic Haplustepts	Phaguwala	Hypoluvic-Haplic Cambisols
14	Typic Haplustepts - Udic Haplustepts	Basiaram	Hypoluvi-Eutric Cambisols
15	Fluventic Haplustepts - Typic Haplustepts	Simri 1	Fluvi-Calcaric Cambisols
16	Udic Haplustepts - Vertic Haplustepts	Berpura	Hypoluvi-Eutric Cambisols
17	Typic Haplustepts - Oxic Haplustepts	Amarpur	Hypoluvi-Haplic Cambisols
18	Typic Haplustepts - Vertic Haplustepts	Jagjitpur	Haplic Cambisols
19	Aeric Endoaquepts - Aeric Epiaquepts - Typic Haplustepts	Sarthua	Hypoluvi-Gleyic Cambisols
20	Typic Haplustepts - Typic Hapludalfs	Fatehpur	Eutri-Haplic Cambisols
21	Typic Haplustepts - Typic Ustorthents	Bijaipur	Eutri-Hypoluvic Cambisols
22	Aeric Endoaquents - Typic Ustifluvents - Typic Haplustepts	Nanpur	Calcic-Endogleyic Regosols (Protic)
23	Typic Haplustepts - Aeric Epiaquepts	Dhadde	Hypoluvi-Haplic Cambisols
24	Aeric Ochraqualfs - Typic Plinthaqualfs - Aeric Epiaqualfs	Itwa	Endogleyic Luvisols
25	Vertic Endoaquepts - Aeric Epiaqualfs	Hangram	Vertic-Endogleyic Cambisols
26	Typic Endoaqualfs - Aeric Epiaqualfs - Typic Hapludalfs	Madhpur	Haplic-Endogleyic Luvisols
28	Typic Haplustepts - Typic Paleustalfs - Rhodic Paleustalfs	Amarpur	Hypoluvi-Haplic Cambisols
29	Typic Fluvaquents - Typic Paleustalfs - Typic Rhodustalfs	Konarpara	Haplic-Glyeic Fluvisols
30	Typic Endoaqualfs - Lithic Haplustalfs	Madhpur	Haplic-Endogleyic Luvisols
31	Typic Endoaqualfs - Typic Haplustalfs	Madhpur	Haplic-Endogleyic Luvisols
32	Typic Natrustalfs - Typic Haplustalfs - Typic Haplustepts	Zarifa Viran	Haplic Solonetzs
33	Vertic Hapludalfs - Typic Hapludalfs - Typic Paleudalfs	Belsar	Vertic-Hyposodic Luvisols (Haplic)
34	Ustic Torripsamments - Typic Haplocambids	Jassi Pawli	Yermic-Calcaric Arenosols
35	Typic Ustipsamments - Typic Haplustepts	Bhanra	Ferralicp-Protic Arenosols
36	Typic Ustipsamments - Typic Ustipsamments	Bhanra	Ferralic-Protic Arenosols
37	Typic Natrustalfs - Typic Paleustalfs - Typic Haplustalfs	Akbarpur	Eutri-Haplic Solonetzs
38	Typic Natrustalfs - Typic Rhodustalf - Typic Haplustalfs	Akbarpur	Eutri-Haplic Solonetzs
39	Typic Natrustalfs - Typic Haplustalfs - Typic Rhodustalfs	Sakit	Haplic Solonetzs
40	Typic Fluvaquents - Typic Epiaquents	Simri 2	Proti-Gleyic Fluvisols
41	Aeric Endoaquents - Aquic Udipsamments - Aquic Dsytrustepts	Nanpur	Calcic-Endogleyic Regosols (Protic)

Contd.

Terrain No.	Soil Association (Subgroup)[1]	Soil Series	Soil Classification (WRB)[2]
42	Aeric Endoaquents - Typic Endoquepts - Typic Epiaquepts	Nanpur	Calcic-Endogleyic Regosols
43	Typic Dystrudepts - Fluventic Dystrustepts - Aquic Udifluvents	Singvita	Hypoluvi-Dystric Cambisols
44	Typic Haplustepts - Typic Ustifluvents	Jagjitpur	Haplic Cambisols
45	Typic Fluvaquents - Aquic Ustifluvents	Konarpara	Hapli-Gleyic Fluvisols
47	Aeric Endoaquents - Fluventic Haplustepts	Nanpur	Calcic-Endogleyic Regosols
48	Ustic Torripsamments - Typic Torripsamments - Typic Haplocambids	Jassipawli	Yermic-Calcaric Arenosols
49	Typic Torrifluvents - Typic Ustipsamments - Typic Ustifluvents	Masitawali	Yermic Fluvisols
50	Typic Fluvaquents - Typic Ustipsamments - Aeric Fluvaquents	Simri 2	Proti-Gleyic Fluvisols
51	Ustochreptic Camborthids - Typic Ustipsamments - Typic Haplustepts	Jodhpur Ramana	Aridi-Haplic Cambisols
52	Typic Fluvaquents - Typic Ustifluvents	Simri 2	Proti-Gleyic Fluvisols
53	Typic Fluvaquents - Typic Ustifluvents - Aeric Endoaquepts	Simri 2	Proti-Gleyic Fluvisols
54	Typic Ustifluvents - Aeric Ustifluvents	Bahraich	Haplosodi-Eutric Fluvisols
56	Typic Ustifluvents - Aeric Epiaquepts	Sasanga	Haplic-Eutric Fluvisols
57	Aeric Halaquepts - Aeric Epiaquepts	Hirapur	Hypoluvi-Gleyic Cambisols
58	Typic Ustifluvents - Aeric Epiaquepts - Aquic Ustifluvents	Sasanga	Haplic-Eutric Fluvisols
59	Aeric Endoaquepts - Aeric Epiaquepts - Typic Ustorthents	Sarthua	Hypoluvi-Gleyic Cambisols
60	Aeric Halaquepts - Typic Epiaquepts - Aeric Endoaquepts	Hirapur	Hypoluvi-Gleyic Cambisols
61	Aeric Endoaquepts - Aquic Haplustepts - Aeric Epiaquepts	Sarthua	Hypoluvi-Gleyic Cambisols
62	Typic Haplustepts - Aeric Endoauepts	Amarpur	Hypoluvi-Haplic Cambisols
63	Typic Calciorthids - Ustic Haplocambids - Ustic Torripsamments	Nihalkhera	Aridic Calcisols
64	Vertic Endoaqualfs - Aeric Epiaqualfs - Typic Haplustepts	Eikchari	Vertic-Endogleyic Luvisols
65	Aquic Natrustalfs - Typic Epiaqualfs - Vertic Epiaqualfs	Ghabdan	Gleyic Solonetzs
66	Typic Natrustalfs - Typic Haplustepts	Zarifa Viran	Haplic Solonetzs
67	Typic Haplocambids - Typic Calcigypsids	Jodhpur Ramana	Aridi-Haplic Cambisols
68	Typic Fluvaquents - Aeric Endoaquents - Aeric Epiaquepts	Konarpara	Hapli-Gleyic Fluvisols
70	Typic Fluvaquents - Aeric Endoaquents - Chromic Haplusterts	Konarpara	Hapli-Gleyic Fluvisols
71	Typic Halaquepts - Typic Endoaquepts - Vertic Haplustepts	Sagar	Sodic-Eutric Gleysols
72	Typic Halaquepts - Oxic Haplustepts - Kandic Paleustalfs	Sagar	Sodic-Eutric Gleysols
73	Typic Fluvaquents - Aeric Fluaquents - Aeric Endoauepts	Konarpara	Hapli-Gleyic Fluvisols
74	Typic Endoaqualfs - Typic Plinthustalfs - Typic Plinthaqualfs	Madhpur	Haplic-Endogleyic Luvisols

[1]Soil Taxonomy (Soil Survey Staff 2006); [2]World Reference Base (WRB 1998) [2]underlined soil subgroups are dominant and linked with soil series

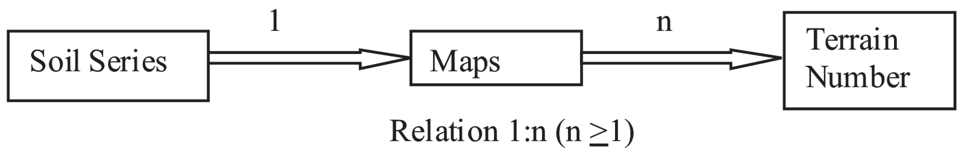

Fig. 1. Entity relation diagram (ERD) Soil Series – Terrain Number

Table 3. SOTERIGP characteristics

Scale	Extent (km^2)	No. of Polygons	SUs[1]	SCs/Su	Profiles	Profile density (per km^2)
1:1 m	4,80,000	497	36	1	36	80

[1] SU : SOTER unit; SC : Soil component (Batjes *et al*. 2007)

agro-ecological subregion (AESRs) where soil and climatic information were used to delineate boundaries of regions. The IGP was curved out at soil family association in connection with GEFSOC project (GEFSOC 2006) followed by refinement of datasets to develop a series of thematic maps using 43 soil series information (Bhattacharyya *et al.* 2005a; Batjes *et al*. 2007).

Level 1 soil information system distinguishes major physiography, AER, AESR in IGP. It provides information on climate such as temperature and rainfall and a few selected physical, chemical and mineralogical properties of soils (Table 5). Soil information for developing a system has been collated from various sources to prepare mapping units of Bio-Climatic Systems (BCSs), AERs, AESRs and Agro-Climatic Zones (ACZs) (Bhattacharyya *et al*. 2004, 2008; Ray *et al*. 2005; Velayutham *et al*. 1999) (Table 6). The climate and soil data also estimate the length of growing period in each region to select crop (Sehgal *et al*. 1992; Velayutham *et al*. 1999). Table 7 shows various descriptions of level 2 soil information system. It subdivides level 1 physiographic unit at a finer level of detail. Slope, relief and vegetations are important considerations at this level. Soil orders and then up to soil series level information are detailed at level 2. Table 8 gives the available datasets of soil information system in northern, central and eastern parts of IGP.

Application of SISIGP

Estimation of SOC stocks

The purpose of generating soil information system in SOTER environment was to compare estimates of national soil organic carbon (SOC) stocks computed with the GEFSOC system with independent estimates obtained by conventional mapping approach. Map-based estimates of base line SOC stocks were available for IGP (Bhattacharyya *et al*. 2000, 2004; Velayutham *et al*. 2002). Using 95% confidence intervals for medium SOC stocks, IGP India datasets showed 630 and 1560 Tg C for 0-30 cm and 0-100 cm soil depth respectively (Batjes *et al*. 2007) These values are lower than earlier estimates (Bhattacharyya *et al*. 2004, 2007).

Soil Quality Assessment in IGP

The IGP soils are under tremendous stress because of high demographic pressure and intensive cultivation. These stresses are manifested in declined productivity of crops due to reduced soil quality. To arrest this, we commonly recommend best management practices for farming as a good land care measure. To meet these we normally take measures to curb soil degradation through erosion, correct deficiency of nutrients, and also take other conservational steps. All these require a holistically concerted effort. General analysis of a few soil parameters (pH, organic C, available P and K) are analysed in routine soil testing programme. Judging by complexity of assessing soil quality such tests for a few parameters appears inadequate to meet the needs of the farmers and take care of the soil health.

Assessment of soil quality, which is "the capacity of the soil to produce safe and nutritious food, to enhance human and animal health and overcome degradative processes" is thought to be a means to this end. Soil quality has been defined by many scientists differently. Some have defined it as "fitness for use", and others as "capacity of the soil to function". However, the Soil Science Society of America came up with a wholesome definition stating it as "the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality

Table 4. Available soil and land information system – spatial hierarchy in the IGP

Level	Land unit	Soil unit	Descriptive legends	Description of map unit[1]	Map Scale	Source/Comments
				Level 1		
1.	Country	Order [2]	Soil Orders	Inceptisol, Entisols	1:25 million	NRCS (1996)
2.	State	Suborder[2]	Soil Suborder		1:7 million	NBSS&LUP (1985) / Map printed by NBSS&LUP, Nagpur
3.	State	Old soil classification	Traditinal soil names	Red and yellow soils, red loamy soils, mixed red and black soils	1:4 million	Govinda Rajan (1971)
4.	State (Region)	—	Agro-ecological region (AER)	[3]Bengal plains, hot subhumid to humid LGP 210-300 days (AER 15)	1:4.4 million	Sehgal *et al*. (1992) / Map printed by NBSS&LUP, Nagpur
5.	State (Sub-region)	~	Agro-ecological subregion (AESR)	[3]Bengal basin and north Bihar plains,, hot moist subhumid with medium to high AWC and LGP (210-300 days) (AER 15.1)	1:4.4 million	Velayutham *et al*. (1999) / Map printed by NBSS&LUP, Nagpur Govind Rajan (1971)
6.	Country	Soil family[2]	Soil family association	Total 1649 units in the country – IGP had 74 no. of units.	1:1 million	NBSS&LUP (2002)/ (printed by NBSS&LUP)
				Level 2		
7.	State (Physiography)	Soil family[2]	Soil family association	Total 74 soil map units showing association of dominant (60% average in polygon) and subdominant (40% in a polygon soils); and 50%, 30% and 20% where 3 soil families exist.	1:250,000	Map generated during GEFSOC Project for IGP, India (Bhattacharyya *et al*. 2005)
8.	District	Soil Series[2]	Soil series association	[4]Total 28 soil units showing association of dominant and subdominant soil series with inclusions	1:50,000	NBSS&LUP (Map of Hooghly district) (Sarkar *et al.* 2001)
9.	Watershed	Soil series	Soil series association	[5] Two soil series and five map units in Chuchura farm	1:2400	NBSS&LUP (Report No 448 (NBSS&LUP 1993)

[1] AWC (Available water holding capacity), LGP (Length of growing period); [2] USDA Soil Taxonomy (Soil Survey Staff 2006), [3] Only one example of AER & AESR shown, [4] Only one example of district is shown, [5] Only one example of watershed is shown here.

Table 5. Description of level 1 spatial information in IGP

Particulars	Example	Remarks
Physiography	Alluvial plains	SISIGP displays such information in selected AESR of India (Velayutham *et al*. 1999)
Climate	Mean annual temperature, mean annual rainfall, rainy days, cloudiness, relative humidity, PET, vapour pressure, wind velocity	SISIGP gives such information (Bhattacharyya *et al*. 2005)
Soil	Physical, chemical and mineralogical properties of soils	Selected soil properties are available at this level (Velayutham *et al*. 1999; Bhattacharyya *et al*. 2005, 2008) (Also see table 6)

Table 6. Soil information System in different agro-eco and climatic zones (Level 1)

Zones	Descriptions	Soil Series[3]
BCSs[1]	• Arid (hot) : MAR[2] <550 mm	• Masitawali, Nihalkhera, Hisar
	• Semi-arid (hot) : MAR 550-950 mm	• Phaguwala, Ghabdan, Bhanra, Patiala, Zarifa Viran, Sonepat, Holambi, Sakit, Hirapur, Itwa, Bara
	• Sub-humid (dry) : MAR 950-1100 mm	• Dhadde, Jagjitpur, Fatehpur, Khiranwali, Berpura, Haldi, Bijapur, Basiaram, Simri, Sarthua
	• Sub-humid (moist) : MAR 1100-1500 mm	• Bahraich, Gaupur, Belsar, Nanpur, Ekchari
	• Sub-humid to humid : 1500-1800 mm	• Madhpur, Hanrgram, Sasanga, Konarpara, Amarpur, Bansghatta, Seoraghuri
	• Per-humid : >1800 mm	• Singhvita, Nayanpur, Khowai
	• Coastal : MAR varies	• Sagar
AERs[4]	• Western Plains, hot arid ecoregion, LGP[5] : <60 days (AER 2)	• Masitawali, Nihalkhera, Jassi Pauwali, Jodhpur Ramana
	• Northern Plains, hot semi-arid ecoregion, LGP 90-150 days (AER 4)	• Fatehpur, Phaguwala, Zarifa Viran, Ghabdan, Bijapur, Hirapur, Sakit
	• Northern Plains, hot sub-humid (dry) ecoregion, LGP 120-180 days (AER 9)	• Dhoda, Jagjitpur, Bhanra, Berpura, Basiaram, Itwa, Simri, Akbarpur
	• Eastern Plains, hot sub-humid (moist) ecoregion, LGP 180-210 days (AER 13)	• Bahraich, Haldi
	• Bengal Plains, hot sub-humid to humid (inclusions of perhumid ecoregion), LGP 210-300 days (AER 15)	• Sasanga, Konarpara, Hanrgram, Amarpur, Madhpur, Barak, Seoraguri
	• Eastern Himalayas, warm per-humdi AER, LGP 270-300 days (AER 16)	• Singvita
	• North-eastern hills (Purvachal) warm, per-humid, LGP >300 days (AER 17)	• Khowai, Nayanpur
	• Eastern Coastal Plain, hot sub-humid to semi-arid, LGP 240-270 days (AER 18)	• Sagar
AESRs[6]	• Marusthali Plains, hot hyper-arid, very low AWC, LGP <60 days (AESR 2.1)	• Masitawali, Nihalkheri
	• Kachch Peninsula, hot hyper-arid, low AWC and LGP <60 days (AESR 2.3)	• Jassi Pauwali, Nihalkheri
	• North Punjab Plain, Ganga-Yamuna Doab, hot semi-arid, medium AWC, LGP 90-120 days (AESR 4.1)	• Fatehpur, Phaguwala, Zarifa Viran, Ghabdan
	• Ganga-Yamuna Doab, Rohilkhand and Avadh Plain, hot moist semi-arid, medium to high AWC, LGP 120-150 days (AESR 4.3)	• Bijapur, Hirapur, Sakit
	• Punjab and Rohilkhand Plains, hot/dry moist sub-humid transition, medium AWC and LGP 120-150 days (AESR 9.1)	• Dhoda, Jagjitpur, Bhanra, Berpura

	• Rohilkhand, Avadh and south Bihar plains, hot dry sub-humid, medium to high AWC and LGP 150-180 days (AESR 9.2)	• Basiaram, Itwa, Simri, Akbarpur
	• North Bihar and Avadh Plains, hot dry to moist sub-humid with low to medium AWC and 180-210 days LGP (AESR 13.1)	• Bahraich
	• Foothills of Central Himalayas, warm to hot moist, high AWC and LGP 180-210 days (AESR 13.2)	• Haldi
	• Bengal Basin and north Bihar Plains, hot moist sub-humid with medium to high AWC and LGP 210-240 days (AESR 15.1)	• Sasanga, Konarpara, Hanrgram, Amarpur, Madhpur
	• Teesta, lower Brahmaputra Plain, hot moist humid to per-humid medium AWC and LGP 270-300 days (AESR 15.3)	• Barak, Seoraguri
	• Foothills of Eastern Himalayas, warm to hot per-humid, low to medium AWC and LGP 270-300 days (AESR 16.1)	• Singhvita
	• Darjeeling and Sikkim Himalayas, warm to hot per-humid, low to medium AWC and LGP 270-300 days (AESR 16.2)	
	• Purvachal (Eastern Range), warm to hot per-humid, low to medium AWC and LGP >300 days (AESR 17.2)	• Khowai, Nayanpur
	• Gangetic delta, hot moist, sub-humid to humid, medium AWC and LGP 240-270 days (AESR 18.5)	• Sagar
ACZs[7]	• Lower Gangetic Plains, cover 3% of TGA of the country (ACZ 3)	• Sasanga, Konarpara, Hanrgram, Amarpur, Madhpur, Sagar
	• Middle Gangetic Plains, cover 5% of TGA of the country (ACZ 4)	• Kesarganj, Bahraich, Sivapande
	• Upper Gangetic Plains cover 4% of TGA of the country (ACZ 5)	• Basiaram, Itwa, Simri, Akbarpur, Pantnagar, Haldi
	• Trans-Gangetic Plains cover 4% of TGA of the country (ACZ 6)	• Dhoda, Jagjitpur, Bhanra, Berpura, Nabha, Sadhu, Zarifa Viran, Fatehpur, Phaguwala, Ghabdan

[1]BCSs: Bioclimatic systems (Bhattacharjee *et al*. 1982); Source of soil information : Ray *et al*. 2005;
[2]MAR: Mean annual rainfall, mm;
[3]The information on soils (mapped as specific soil related properties for developing map units) is organised as soil series;
[4]AERs: Agro-ecological regions (Sehgal *et al*. 1992); (Source of Soil Information : Bhattacharyya *et al*. 2004);
[5]LGP: Length of growing period;
[6]AESRs: Agro-ecological subregions (Velayutham *et* al. 1999) (Source of soil information : Bhattacharyya e*t al*. 2004);
[7]ACZs: Agro-climatic zones (Anonymous 1989); (Source of soil information : Bhattacharyya *et al*. 2004)

Table 7. Description of level 2 spatial information in SISIGP (Also see Table 4)

Particulars	Example	Remarks
		SISIGP: District level (Level 2) (1:50000 scale)
Physiography	Gently sloping with slight erosion at old alluvial plain	Mainly in western part of Hooghly district of West Bengal, SISIGP, Hooghly gives complete description of physiographic classification
Slope	Gentle 1-3%	SISIGP, Hooghly district provides information on slope (quality)
Relief	20 m (above msl)	SIS, Hooghly district displays elevation of each soil of various physiography
Land Use	Mostly agriculture	Details information on vegetation is available in SISIGP, Hooghly district
Soil Order	Entisols, Inceptisols	Also see (Sarkar *et al*. 2001)
Soil Series	Kota, Narahairbati, Arandi, Satmasa, Daulatpur, Chandur, Garmandaran	Also see (Sarkar *et al*. 2001)

	SISIGP: Watershed level (Level 2) (1:2400 scale)	
Physiography	Meander flood plain	Mainly in western part of Hooghli district of West Bengal, SISIGP, Hooghly gives complete description of physiographic classification
Slope	Nearly level 0-1%	SISIGP, Chuchura Farm (Hooghly district, West Bengal) provides information on slope (quality)
Relief	5-10 m (above msl)	SISIGP, Chuchura Farm (Hooghly district, West Bengal) displays elevation of each soils of various physiography
Land Use	Mostly agriculture	Details information on vegetation is SIS, Hooghly district
Soil Order	Entisols, Inceptisols	Also see NBSS&LUP (1983)
Soil Series	Rabindranagar, Chuchura	Also see NBSS&LUP (1983)
Soil Phases[1]	Rabindranagar	
	R1A1	Very deep, imperfectly drained, dominantly fine in control sections (25-100 cm) on A (0-1 %) slope, slightly eroded: *silty clay surface*
	RmA1	Very deep, imperfectly drained, dominantly fine in control sections (25-100 cm) on A (0-1 %) slope, slightly eroded: *clay surface*
	RhA1	Very deep, imperfectly drained, dominantly fine in control sections (25-100 cm) on A (0-1 %) slope, slightly eroded: *clay loam surface*
	RjA1	Very deep, imperfectly drained, dominantly fine in control sections (25-100 cm) on A (0-1 %) slope, slightly eroded: *Silty clay loam surface*

[1] R1A1 where R refers to soil series, 1 the type of texture (say Clay), A represents the slope and 1 shows erosion which is slight for all the phases

and support human health and habitation". Very little efforts are made in this country to assess soil quality that too for the soils of IGP because of its obvious complexities (Mandal 2005; Chaudhury *et al.* 2005; Sharma *et al.* 2005; Masto *et al.* 2007, 2008).

To assess physical, chemical, and biological soil attributes along with nutritional quality of the produce grown on the soils are considered. A schematic framework of soil quality assessment is given in figure 2. The parameters considered are - bulk density, maximum water holding capacity, mean weight diameter (physical); pH, organic carbon, available N, P and K, micronutrients, heavy metals (chemical) and microbial biomass C and N, soil enzymes, mineralizable C and N, soil biodiversity, soil fauna (biological). These attributes are selected based on a few scientific principles *viz*., i) encompass ecosystem process, ii) sensitive to variations in management practices, iii) easily measurable and reproducible, iv) a component of existing soil database, and v) integrate soil physical, chemical and biological properties.

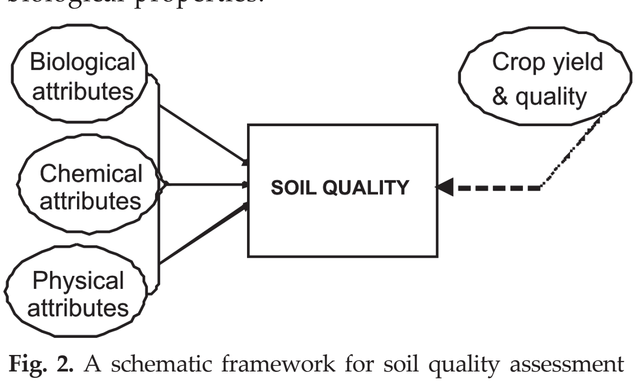

Fig. 2. A schematic framework for soil quality assessment

The attributes are integrated to assess the system as to its fitness status. The purpose was to find out changes due to adoption of different management practices and cropping systems in order to identify the best management practices for future land care programme. The following model was used:

$$\frac{dq}{dt} = \frac{f\left\{\frac{q_{it}-q_{ito}}{q_{ito}} - \frac{q_{nt}-q_{nt}-q_{nto}}{qnto}\right\}}{dt}$$

dq/dt = dynamics of change in soil quality

i - - - - n = no of indicators involved

$_{to}$ and $_{tn}$ = soil quality at initiation of change and current

If, $dq/dt \geq 0$ = aggrading/sustaining system

$dq/dt \leq 0$ = degrading system

However to get such a value for judging the system a rigorous screening of a few indicators from a pool was done to arrive at a unique soil quality index value (Andrews and Carroll 2001). Soil quality indexing involves 3 steps: i) choosing appropriate indicators for a minimum data-set (MDS), ii) transforming indicator scores – linear and non-linear scoring (logarithmic, power function, sigmoid, growth, exponential etc.), and iii) combining the indicator scores into the index – additive and weighted additive. There are a few steps again for MDS formulation viz., i) defining goals, ii) data screening, iii) choosing representative variable, iv) reducing redundancy, and v) MDS validation (Fig. 3).

Table 8. Soil Information System at various levels of mapping (level 2)

Sr. No.	States	Soil map details	Districts	No. of reports [1]
1	Rajasthan	• Soil family (96 Nos.)	[2]	[2]
		• Map units (375 Nos.)		
		• Reference (Shyampura and Sehgal 1995)		
2	Punjab	• Soil family (46 Nos.)	Patiala	(2[a],0[b],0[c],0[d],1[e])
		• Map units (124 Nos)	Hoshiapur	(1,0,0,0,1)
		• Reference (Sidhu *et al*. 1995)	Amritsar	(1,0,0,0,0)
			Jalandhar	(0,1,0,0,0)
			Chandigarh	(0,0,0,1,0)
			Ludhiana	(0,0,01,0)
3	Haryana	• Soil family (41 Nos.)	Karnal	(0,0,1,1,0)
		• Map units (100 Nos)	Gurgaon	(0,0,1,0,0)
		• Reference (Sachdev *et al*. 1995)	Hisar	(0,0,0,1,0)
			Sirsa	(0,0,0,1,0)
4	Delhi	• Soil family (7 Nos.)	Delhi	(1,0,1,2,0)
		• Map units (31 Nos)		
		• Reference (Mahapatra *et al*. 1999)		
5	Uttar Pradesh	• Soil family (145 Nos)	Meerut	(1,0,0,1,0)
		• Map units (321 Nos)	Sultanpur	(1,0,0,0,0)
		• Reference (Singh *et al*. 1999)	Etawah	(1,0,0,0,0)
			Lakhimpur	(0,1,0,0,0)
			Almora	(0,0,1,0,0)
			Lucknow	(0,0,0,2,0)
			Bikaner	(0,0,0,1,0)
			Barbanki	(0,0,0,1,0)
			Jhansi	(0,0,0,0,1)
			Nanital	(0,0,0,1,0)
			Machri	(0,0,0,1,0)
			Baharaich	(0,0,0,1,0)
			Mirzapur	(0,0,0,1,0)
			Saharanpur	(0,0,0,1,0)
			Meerut cantt and Purazi	(0,0,0,1,0)
6	Bihar	• Soil family (72 Nos.)	Champaran	(0,0,0,1,0)
		• Map units (175 Nos)	Pusa	(0,0,0,1,0)
		• Reference (Haldar *et al*. 1996)	Ranchi	(0,0,0,1,0)
7	West Bengal	• Soil family (56 Nos)	Bardhman	(1,0,1,0,0)
		• Map units (115 Nos)	Bankura	(1,0,1,0,0)
		• Reference (Haldar *et al*. 1992)	Hooghly	(1,0,0,1,1)
			Purulia	(1,1,0,0,3)
			Birbhum	(1,0,0,0,0)
			Kuchbihar	(1,0,0,0,0)
			Jalipaipuri	(0,1,0,0,0)
			Midnapore	(0,1,1,0,0)
			Bardhman,	
			Hooghly & South 24	(0,1,0,0,0)
			Parganas	(0,1,0,0,0)
			Haldi	(0,1,0,0,0)
			Jaldupara	(0,1,0,0,0)
			Jaldapaiguri	(0,2,1,0,0)
			Mednipur	(0,0,1,0,0)
			Asansol	(0,0,0,1,0)
			Darjeeling	(0,0,0,1,0)
			Parganas	(0,0,0,1,0)
			Kalyani	
8	Tripura	• Soil family (42 Nos)	West Tripura	(0,0,2,2,0)
		• Map units (43 Nos)	South Tripura	(0,0,2,0,0)
		• Reference (Bhattacharyya *et al*. 1996)	Tripura	(0,2,0,2,1)

[1]*Source:* NBSS&LUP (2008)
[1]Ganganagar and Hanumangarh districts fall in IGP about which information was not available in NBSS&LUP (2008)
[a]district, [b]tahsil, [c]village, [d]farm, [e]watershed reports

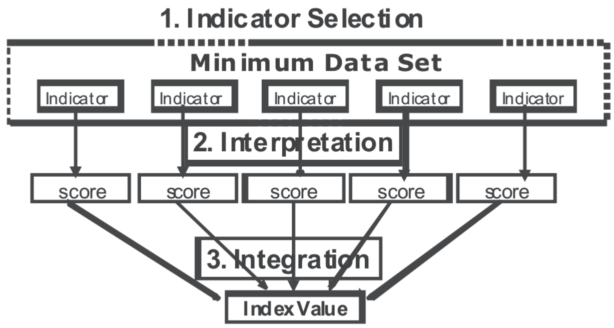

Fig. 3. Schematic diagram for screening indicators, their integration and scoring of soil quality index

Identifying Soil Quality Parameters: A Case Study from IGP

Datasets of IGP from a collaborative study with 8 centres and involving 14 long-term experiments under various agro-climatic zones were screened. A set of master variables under different cropping systems and soil types were developed (Table 9). The study showed that cultivation without any fertilization (control) or only with N caused a net degradation of soil quality. Cultivation even with application of balanced NPK could hardly maintain soil quality as observed in fallow land. Integrated use of organic and inorganic sources of nutrients could aggrade the system soil quality (Table 10).

The results indicate the potential of the method of soil quality assessment. The datasets also show that performance of different cropping systems, soil types and soil management practices for upkeeping and sustainable use of soils. A few of the master variables identified for different soil types and cropping systems through such quality assessment may be included in the current soil testing programme for their analysis to make it a robust one for assessing soil quality. If required, simple, cheap and robust methods for the identified variables should also be developed for easy adoption by the soil testing laboratory.

Other Uses

SOTER datasets on terrain (Table 11) and profile (Table 12) permit to generate different thematic maps of which the following themes are important. Details of these maps are discussed elsewhere (Bhattacharyya *et al*. 2005). These thematic maps may be utilized for monitoring changes in climate, land use and various soil and site parameters. The following theme maps are shown in figures for reference.

- Mean annual rainfall (Fig 4)
- Soil drainage (Fig 5)
- Duration of flooding (Fig 6)

Table 9. Indicators identified for different soil types and cropping systems (Mandal 2005)

Location	Soil classification / textural type	Cropping system	Indicators identified	Indicator's contribution towards SQI		
				> 25%	15-25%	< 15%
Varanasi	Typic Haplustept/ Sandy loam	Rice – lentil	Available P and organic C		Available P	Organic C
Barrackpore	Eutrochrept/ Sandy loam	Jute–rice–wheat	Mean weight diameter, available P, microbial biomass C, and organic C	Mean weight diameter, available P	Microbial biomass C	Organic C
Mohanpur	Aeric Haplaquept/ Sandy loam	Rice – wheat	Alkaline phosphatase, organic C, mineralizable N	Alkaline phosph-atase	Organic C	Minerali-zable N

Table 10. Soil quality change (as % over fallow) under different management practices and cropping systems (Mandal 2005)

Treatment/cropping system	Rice-wheat	Rice-lentil	Jute-rice-wheat
Control	- 56.0	- 8.0	- 49.0
N only	-	- 11.7	- 35.0
NPK only	-10.8	-9.7	19.0
NPK+FYM	18.7	8.6	45.1

Table 11. SISIGP - Terrain information in SOTER

ISO Country code	SOTER unit-ID	Year of data collection	Source map-ID	Minimum elevation	Maximum elevation	Slope gradient	Relief intensity	Major Landform[1]	Regional Slope[2]	Hypsometry[3]	General lithology
IN	1	1982	NBSS 2002	200	250	1	5	LP	F	1	UF
IN	2	1982	NBSS 2002			1	5	LP	F	1	UF
IN	3	1982	NBSS 2002			5	15	LP	G		UF
IN	4	1982	NBSS 2002	50	50	1	5	LP			UF
IN	5	1982	NBSS 2002	230	300	1	5	LP	F		UE
IN	6	1982	NBSS 2002	230	240	1	5	LP	F		UF
IN	7	1982	NBSS 2002	200	250	1	5	LP	F		UF
IN	8	1982	NBSS 2002	240	240	1	5	LP	F		UF
IN	9	1982	NBSS 2002			1	5	LP	F	1	UF
IN	10	1982	NBSS 2002	150	200	1	5	LP	F		UF
IN	11	1982	NBSS 2002	150	200	1	5	LP	F		UF
IN	12	1982	NBSS 2002	240	240	1	5	LP	F		UF
IN	13	1982	NBSS 2002	200	200	1	5	LP	F		UF
IN	14	1982	NBSS 2002	250	260	5	25	S	R		UE
IN	15	1982	NBSS 2002	250	330	1	5	LP	F	1	UF
IN	16	1982	NBSS 2002	75	100	1	5	LP	F		UF
IN	17	1982	NBSS 2002	150	200	1	5	LP	F		UF
IN	18	1982	NBSS 2002	20	20	1	5	LP			UF
IN	19	1982	NBSS 2002	20	20	1	5	LP			UF
IN	20	1982	NBSS 2002	124	124	1	5	LP	F		UF
IN	22	1982	NBSS 2002	60	60	1	5	LP	F		UF
IN	23	1982	NBSS 2002	30	30	1	5	LP			UF
IN	24	1982	NBSS 2002	40	40	1	3	LP			UF
IN	25	1982	NBSS 2002	60	60	1	5	LP	F		UF
IN	26	1982	NBSS 2002	60	60	1	5	LP	F		UF
IN	27	1982	NBSS 2002	20	20	1	5	LP	F		UF
IN	28	1982	NBSS 2002	20	25	1	5	LP			UF
IN	29	1982	NBSS 2002	20	30	1	5	LP	F		UF
IN	30	1982	NBSS 2002	5	10	1	5	LP	F		UF
IN	31	1982	NBSS 2002	15	20	1	5	LP	F		UF
IN	32	1982	NBSS 2002			1	5	LP	F		UF
IN	33	1982	NBSS 2002			1	5	LP	F		UF
IN	34	1982	NBSS 2002			1	5	LP	F		UF
IN	35	1982	NBSS 2002	178	178	1	5	LP	G		UF
IN	36	1982	NBSS 2002	110	110	1	5	LP	F		UF
IN	37	1982	NBSS 2002	3	3	1	5	LP	F		UF

[1]Major landform LP= Plain; S= Sloping land; [2]Regional slope F: 0-2% (Flat); G: 2-5% (gently undulationg); R: 8-15% (Rolling) ; [3]Hypsometry 1: <300 m (very low level, plain etc); [4]General lithology UF: Fluvial

Table 12. SISIGP - Profile information in SOTER

Profile-ID	Profile data base-ID	Latitude	Longitude	Elevation	Sampling year	Sampling month	Lab-ID	Drainage[1]	Infiltration rate[2]	WRBC	National classification	Soil Taxonomy
MSTWLI	IN_1	29.25	74.33	200	1982	1	IN111	W	R	Yermic Fluvisols	Fine loamy soil	Typic Torrifluvents
NHLKRA	IN_2	30.92	74.67	200	1982	1	IN111	I	S	Aridic Calcisols	Sandy loam soil	Typic Calciorthids
JSPW	IN_3	29.92	73.88	225	1973	1	IN111	E	E	Calcaric Arenosols	Retila	Ustic Torripsamments
JDRM	IN_4	29.92	73.88	50	1982	1	IN111	S	R	Haplic Cambisols	Sandy soil	Ustochreptic Camborthids
FTHPR	IN_5	30.90	75.87	265	1982	1	IN111	W	R	Eutri-Haplic Cambisols	Loamy sand soil	Typic Haplustepts
PHWLA	IN_6	30.23	75.98	235	1982	1	IN111	M	D	Hypoluvi-Haplic Cambisols	Sandy loam soil	Typic Haplustepts
ZRFVN	IN_7	29.42	76.92	225	1982	1	IN111	P	S	Haplic Solonetzs	Loam soil	Typic Natrustalfs
GBDN	IN_8	30.25	75.97	240	1982	1	IN111	P	S	Gleyic Solonetzs	Loam soil	Aquic Natrustalfs
BJPR	IN_9	25.93	80.83	114	1982	1	IN111	W	M	Eutric-Hypoluvic Cambisols	Fine loamy soil	Typic Haplustepts
HRPR	IN_10	27.75	78.33	175	1982	1	IN111	P	S	Hypoluvi-Gleyic Cambisols	Loamy soil	Aeric Halaquepts
SKIT	IN_11	27.48	78.22	175	1982	1	IN111	I	S	Haplic Solonetzs	Loamy soil	Typic Natrustalfs
DHD	IN_12	31.32	75.80	240	1982	1	IN111	I	S	Hypoluvi-Gleyic Cambisols	Silt loam soil	Aquic Haplustepts
JGJT	IN_13	31.27	75.78	200	1982	1	IN111	I	S	Haplic Cambisols	Loam soil	Typic Haplustepts
BHNR	IN_14	30.27	76.30	255	1982	1	IN111	E	Y	Ferralic-Protic Arenosols	Sandy soil	Typic Ustipsamments
BRPR	IN_15	30.43	76.97	290	1982	1	IN111	M	D	Hapluvi-Eutric Cambisols	Loamy soils	Udic Haplustepts
BSRM	IN_16	26.25	83.22	88	1982	1	IN111	P	D	Eutri-Hypoluvic Cambisols	Loamy soil	Typic Haplustepts
ITW	IN_17	25.26	83.27	175	1982	1	IN111	P	D	Endogleic Luvisols	Loamy soil	Aeric Endoqualfs
SMR1	IN_18	27.30	80.70		1982	1	IN111	M	M	Calcaric Cambisols		Fluventic Haplustepts
AKBP	IN_19	26.05	83.22	78	1982	1	IN111	I	S	Haplic Solonetzs	Khari zamin	Typic Natrustalfs
BHRC	IN_20	27.57	81.60	124	1982	1	IN111	I	M	Hyposodi-Eutric Fluvisols	Loamy soil	Typic Ustifluvents
BLSR	IN_22	25.18	87.21	60	1982	1	IN111	P	S	Verti-Hyposodic Luvisols (Haplic)	Clay soil	Vertic Hapludalfs
EKCH	IN_23	25.50	87.26	30	1973	1	IN112	W	D	Verti-Endogleyic Luvisols		Vertic Endoaqualfs
NYP	IN_24	25.12	85.43	40	1982	1	IN112	I	S	Calcic-Endogleyic Regosols (Protic)		Aeric Endoaquents

Profile-ID	Profile data base-ID	Lati-tude	Longi-tude	Ele-vation	Sampl-ing year	Sampl-ing month	Lab-ID	Drain-age[1]	Infiltra-tion rate[2]	WRBC	National classification	Soil Taxonomy
SRTU	IN_25	25.49	84.69	60	1982	1	IN112	P	S	Hypoluvi-Gleyic Cambisols	Silty clay soil	Aeric Endoaquepts
SMR	IN_26	25.63	84.13	60	1982	1	IN112	P	S	Proti-Gleyic Fluvisols	Clay soil	Typic Fluvaquents
SSNG	IN_27	23.28	87.73	20	1982	1	IN112	I	M	Haplic-Eutric Fluvisols	Loam soil	Typic Ustifluvents
KNPR	IN_28	23.31	87.98	22	1982	1	IN112	W	R	Haplic-Gleic Fluvisols	Dhani jamin	Typic Fluvaquents
HNGR	IN_29	23.23	87.93	25	1982	1	IN112	I	V	Vertic-Endogleic Cambisols	Clay soil	Vertic Endoaquepts
AMRP	IN_30	22.90	88.35	8	1982	1	IN112	W	M	Hypoluvi-Haplic Cambisols	Loam soil	Typic Haplustepts
MDHP	IN_31	23.43	88.04	18	1973	1	IN112	I	S	Haplic-Endogleic Luvisols	Doans mati	Typic Endoaqualfs
BRK	IN_32	24.82	92.80	29	1982	1	IN112	W	R	Eutric Cambisols	Silty soil	Humic DystrudeptS
SRGR	IN_33	26.33	89.47		1982	1	IN112	I	V	Hypoluvi-Gleyic Cambisols	Silty clay soil	Typic Haplaquepts
SGVT	IN_34	26.64	88.05		1982	1	IN112	W	R	Hypoluvi-Dystric Cambisols	Loamy soil	Typic Dystrudepts
KHWI	IN_35	24.01	91.71	178	1982	1	IN112	I	V	Hypoluvic-Endohaplic Gleysols	Clay loam soil	Typic Endoaquepts
NYNP	IN_36	23.80	91.58	110	1982	1	IN112	P	S	Hypoluvi-Dystric Gleysols	Clay soil	Typic Endoaquepts
SGR	IN_37	21.75	88.05	3	1973	1	IN112	I	S	Sodic-Eutric Gleysols	Silty clay soil	Typic Halaquepts

[1]Drainage W: Well drained, I; Imperfectly drained; E: Excessively drained; s: Somewhat excessively drained; M; Moderately drained; P: Poorly drained; [2]Infiltration rate, R: Rapid; s: Slow; e: Extremely rapid; D: moderately slow; Y; very rapid; M: moderate; V: very slow

- Texture (Fig 7)
- Soil pH (Fig 8)
- Clay mineralogy (Fig 9)
- WRB soils (Fig 10)
- National Soil Classification (Fig 11)
- US Soil Classification (Fig 12)
- IPCC Soil Classification (Fig 13)
- Net irrigated area (Fig 14)
- Old land use (1880) (Fig 15)
- Land use (1975) (Fig 16)

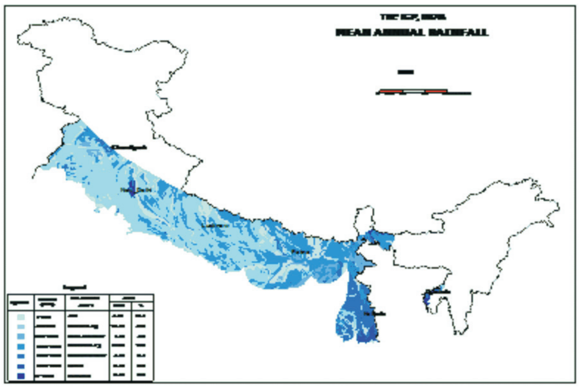

Fig. 4

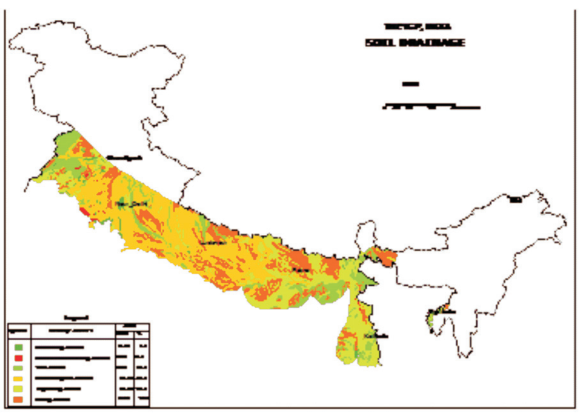

Fig. 5

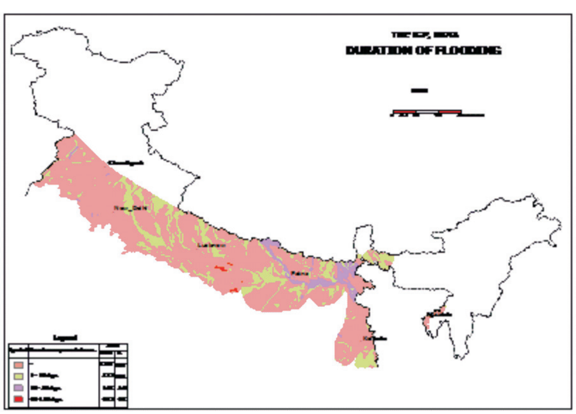

Fig. 6

- Land use (2005) (Fig 17)
- Land use (2030) (Fig 18)

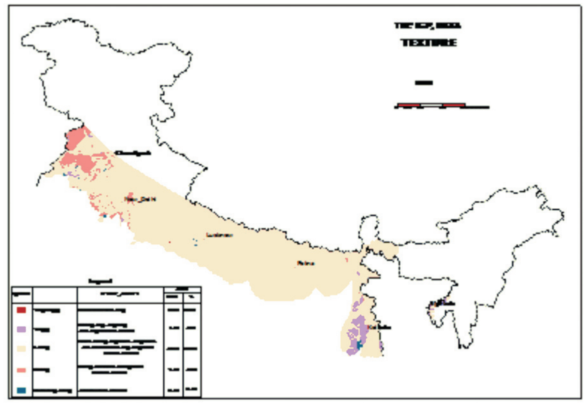

Fig. 7

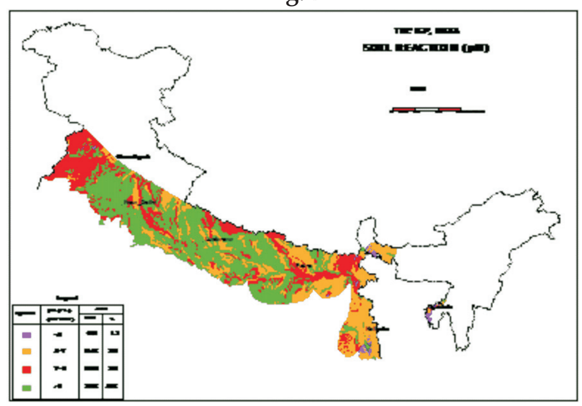

Fig. 8

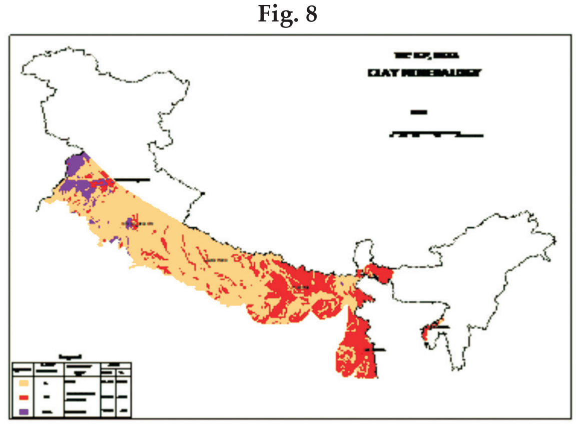

Fig. 9

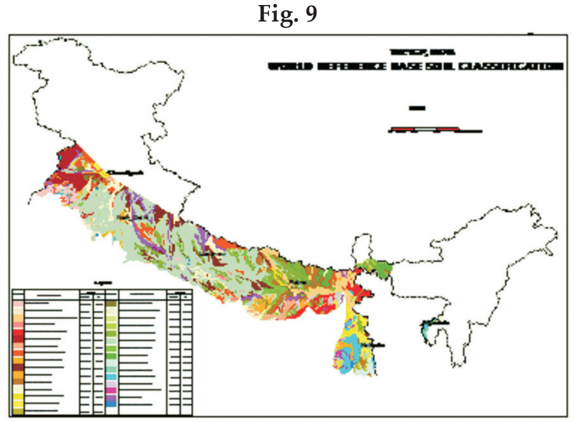

Fig. 10

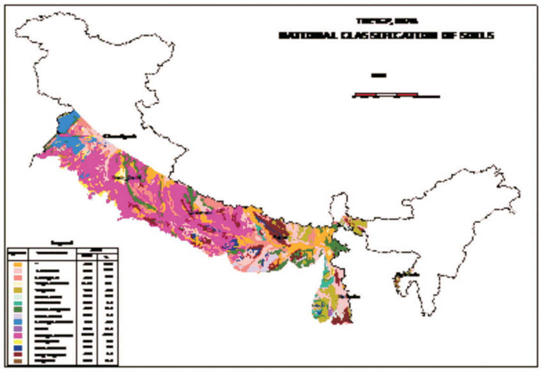

Fig. 11

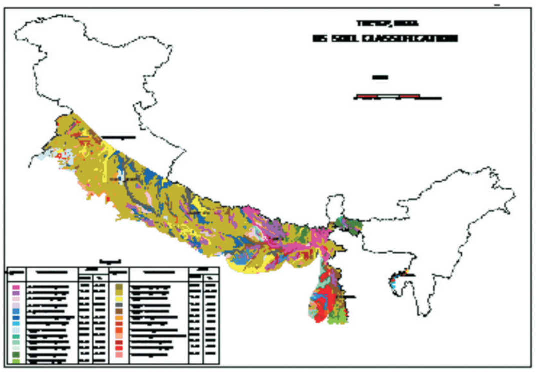

Fig. 12

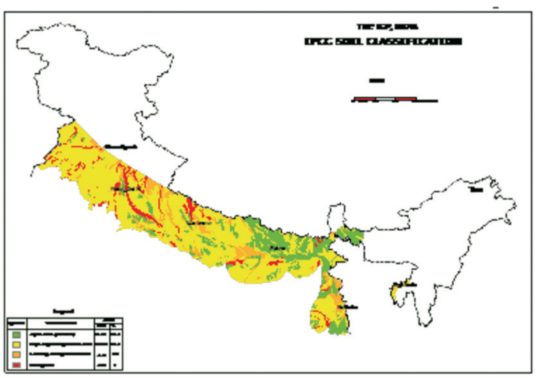

Fig. 13

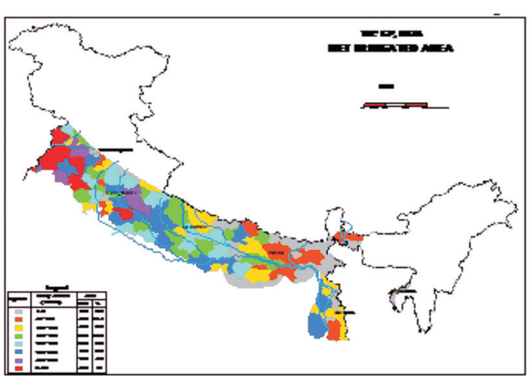

Fig. 14

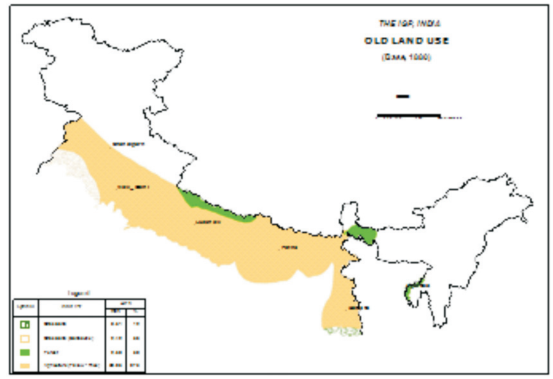

Fig. 15

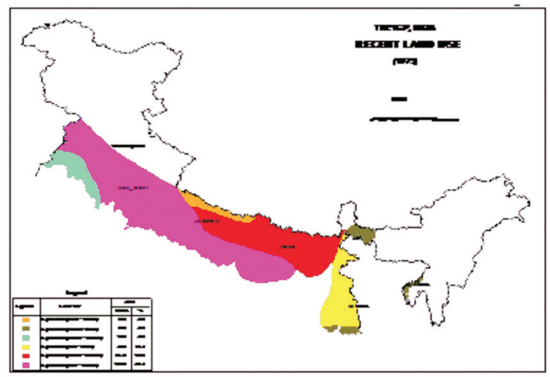

Fig. 16

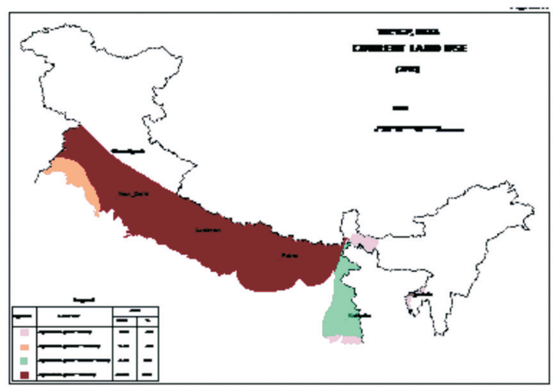

Fig. 17

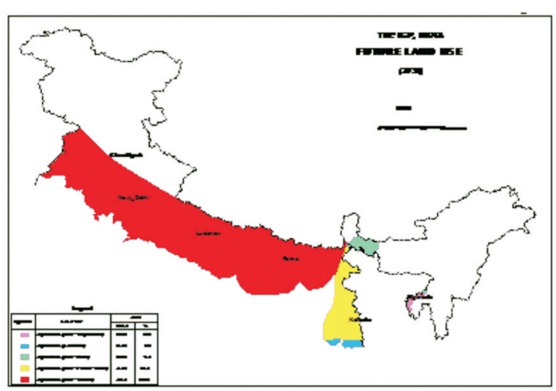

Fig. 18

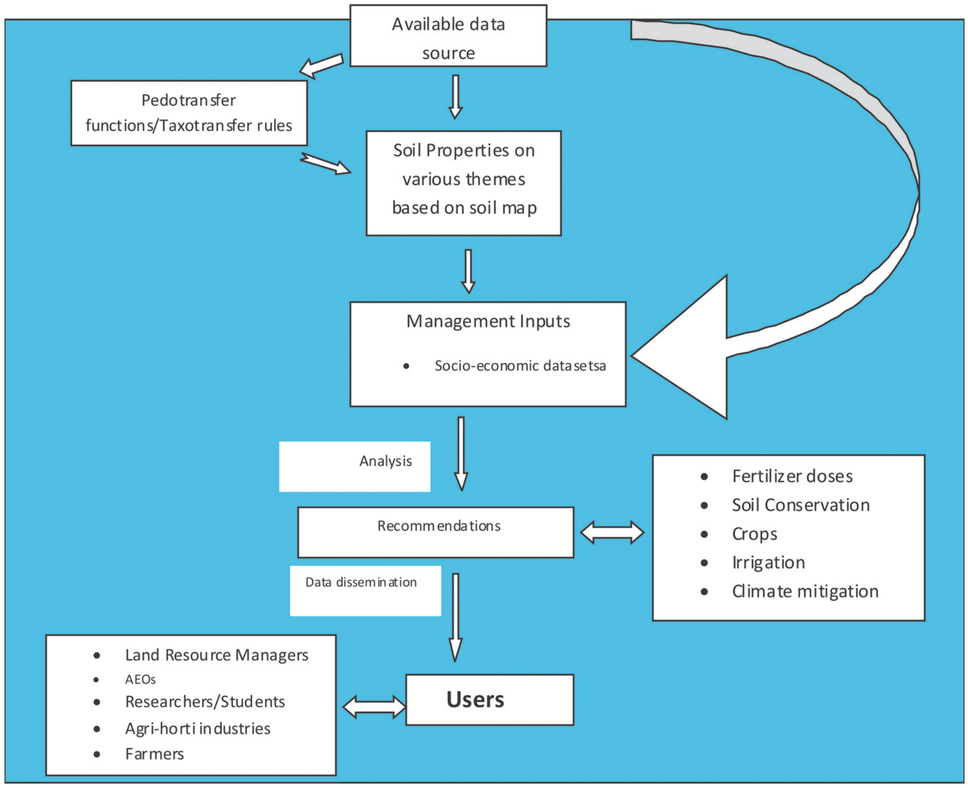

Fig 19. SISIGP (digital) concepts for data framing for end users (adapted from Sanchez *et al.* 2009)

Conclusions

Role of soils in maintaining ecosystem and climate regulation is increasingly recognised. This demands relevant and useful soil information throughout the world. However quantitative data-based soil information could be the appropriate approach for SISIGP. Digital soil maps have been useful in providing information on dynamic soil properties (Sanchez *et al.* 2009). It can be made for Indian IGP as well following the scheme shown in figure 19.

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