Soil information system for resource management – Tripura as a case study

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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 the implementation and monitoring of various efforts on land resource management. In view of huge demands on natural resources like soil and water, with special reference to the environment and its protection, there is a need for better information on spatial variation and trends in the conditions of soils and landscapes. It suggests the necessity to have a clear view of the status of information on various natural resources, with special reference to the soils. Such information would not only store the datasets for posterity, but will also improve our understanding of biophysical processes in terms of cause–effect relationship in the pedo-environment. Information on soil and land resources is thus fundamental where the soil information system plays a pivotal role.

Keywords: Database, land use, resource management, soil information system.

THE basic requirement to develop a soil information system (SIS) is to have large datasets. Such datasets are not generally available for all the states and Union Territories of the country. Tripura is one of the states for which relevant and pertinent datasets on natural resources are made available by the National Bureau of Soil Survey & Land Use Planning (NBSS&LUP; ICAR), Nagpur, during the past decade. While reviewing and interpretating the published data on the 1 : 50,000 scale, it was realized that a SIS can be developed which can serve as an example as to how such a system could be built for other States and Union Territories. Tripura was surveyed earlier by the All India Soil and Land Use Survey (AISLUS) and later by NBSS&LUP to develop soil datasets. Since the modern-day information system of any natural resource requires its physical location in terms of space, exact referencing of natural resources has become necessary. The geographic information system (GIS) has been an important tool for geo-referencing the soil information system (GeoSIS).

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Soil information system elsewhere

Various countries have developed their own SIS[1]. The most widely used system is the Soil and Terrain Digital Database (SOTER; 1 : 1 m). It 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[2]. The approach resembles physiographic or land systems mapping. The collated materials are stored in a SOTER database linked to the GIS, permitting a wide range of environmental applications[3,4]. The SOTER is applied[5] at scales ranging from 1 : 250,000 to 1 : 5 M. The SOTER method used for studies on carbon stocks and their changes in the Indo-Gangetic Plains (IGP), led to the following, viz. (i) linkage between soil profile data and spatial component of a SOTER map for environmental applications requires generalizations of measured soil (profile) data by soil unit and depth zone, (ii) the set of soil parameter estimates for the IGP should be seen as best estimates, based on the currently available selection of profile data held in IGP–SOTER and World Inventory of Soil Emission Potential (WISE), and (iii) the primary and secondary datasets for IGP will be useful[6] for agro-ecological zoning, land evaluation and modelling of carbon stocks and changes at a scale of 1 : 1 M.

Soil information system in India

Recently, the National Agricultural Innovative Project (NAIP) has sponsored a NBSS&LUP-led project of geo-referenced soil information system (NAIP–GeoSIS) on the soils of the IGP and those of the black soil regions (BSR)[7]. Various research projects in the field of natural resource management funded by the World Bank, Department of Science and Technology (DST), New Delhi and the Indian Council of Agricultural Research, New Delhi have produced datasets on soils which lay the foundation

Table 1. Available soil and land information system – spatial hierarchy in Tripura

Land unit	Soil unit	Descriptive legends	Description of map unit	Map scale	Source/comments
Level 1					
State	Suborder	Soil suborder		1 : 7 million	NBSS&LUP[15]/Map printed by NBSS&LUP, Nagpur
State	Soil spot data	Degree and amount of soil erosion	Degree of soil loss with a range of < 5 to > 80 t ha^{-1} yr^{-1} soil erosion	1 : 5 million	Bhattacharyya[11]
State	Old soil classification	Traditional soil name	Red and yellow soils, red loamy soils, mixed red and black soils	1 : 4 million	Govinda Rajan[16]
State (region)	–	Agro-ecological region (AER)	Assam and Bengal plain; hot sub-humid to humid (inclusion of per-humid) eco-region (AER 15) Northeastern hills (Purvachal), warm per-humid ecoregion (AER 17)	1 : 4.4 million	Sehgal *et al.*[17]/Map printed by NBSS&LUP
State (sub-region)	~	Agro-ecological subregion (AESR)	Teesta, lower Brahmaputra plain and Barak Valley; hot, moist, humid to per-humid ESR with deep, loamy to clayey, alluvium-derived soils; medium AWC[a] and LGP[b] 270–300 days (AESR 15.3). Purvachal (Eastern Range), warm to hot, perhumid ESR with medium to deep loamy red and yellow soils, low to medium AWC and LGP > 300 days (AESR 17.2).	1 : 4.4 million	Velayutham *et al.*[18]/ Map printed by NBSS&LUP
Country	Soil family[c]	Soil family association	Total 1649 units in the country; Tripura had 28 no. of units.	1 : 1 million	NBSS&LUP[19]/Map printed by NBSS&LUP
Level 2					
State (physiography)	Soil family[c]	Soil family association	Total 43 soil map units showing association of dominant (60% average in polygon) and subdominant (40% in a polygon) soils	1 : 250,000	NBSS&LUP, Rubber Board and Government of Tripura. Total 19 window areas (~ 5000 ha) each were surveyed in 1 : 50,000 scale. The grids (at 5 km intervals) are in 1 : 250,000 scale/map printed in 1 : 250,000 scale[8].
District	Soil series[c]	Soil series association	Total 43 soil units showing association of dominant and subdominant soil series	1 : 50,000	Bhattacharyya *et al.*[12]
Watershed	Soil series	Soil series association	–	1 : 4000 1 : 15840	AISLUS[20]

[a]AWC, Available water holding capacity; [b]LGP, Length of growing period; [c]USDA Soil Taxonomy[21].

in GeoSIS in Tripura[8–14]. The present study is an effort to show how these datasets may be used for sustainable agriculture and in a few other allied fields.

Soil information system in Tripura

Available soil information and spatial hierarchy

Soil information has been documented through different sources and at various scales to develop user-friendly datasets. Most have been at a small scale since the purpose of these output maps was different (Table 1)[8,11,12,15–21]. The entire state of Tripura has been mapped using soil mapping units (soil family, soil series association) depending on the scale of mapping and method of soil survey[8,11]. This article is mainly concerned with capturing information from soil-landscape surveys, since these constitute soil and land use information of Tripura.

The hierarchy of land units and description of legends at various scales of soil and land-use survey efforts made so far are shown in Table 1. Tripura 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 agro-ecological subregion (AESR) maps, where soil and climatic information were used to delineate boundaries of regions. The state was mapped at soil family association in connection with rubber expansion project[8], followed by refinement of datasets to develop soil series association map[12]. Later soil information was used for grid data to develop a map on soil loss in Tripura[11] (Table 1).

Level 1 soil information system distinguishes major physiography, AER, AESR in Tripura. It provided information on climate such as temperature and rainfall and a few selected soil properties. The climate and soil data also estimate the length of growing period in each region to select crops[17,18]. Level 2 soil information system, subdivides level 1 physiographic unit at a finer level. Slope, relief, vegetation and detailed soil information (soil series, phases) are important considerations at this level.

Soils of Tripura

Soils of Tripura have been studied in detail earlier[8,12–14]. The data generated through field observations and laboratory analyses helped in compiling the information on 48 soil series in the state. The soils are acidic throughout the profile. Due to high rainfall they are intensely leached exhibiting poor base saturation with low cation exchange capacity (CEC) and therefore possessing poor nutrient-holding capacity. These soils have been grouped into five classes according to their pH[12,13]. Nearly 46% soils are very strongly acidic (pH 4.5–5.0), followed by extremely (23.5%), strongly (12.0%), moderately (9.6%) and slightly (2.5%) acidic. On the basis of parameters of different soil series as influenced by their landscape position each soil series has been linked with a particular land use and/or crop. The choice of land use as has been detailed later, has been made keeping in view the present pattern of land use and crops cultivated. In general, extremely acidic to strongly acidic soils are found in the moderate to moderately steeply sloping hills and dissected lands. These soils have loam to sandy clay loam texture. The organic carbon level is high with CEC ranging from 5.3 to 9.7. The acidity is reflected in poor base saturation in the extremely acidic to strongly acidic soils.

Usefulness of soil series information

Soil series provide first-hand information on soil resources of the state in terms of morphological, physical, chemical and mineralogical properties. As discussed earlier, such information helps understand the nature and extent of a particular soil under different categories of acidity, physiographic position and land use. This soil information can be systematically arranged according to the users' demand. The soil information developed for Tripura has helped include 15 soil series in the National Register maintained by NBSS&LUP; also see Table 2.

Application of soil information system

The SIS contains datasets on soil, landscape, land use, water and climate and as such provides a spatial framework for managing natural resources. The SIS of Tripura integrates outputs from various sources across the state and may be considered useful for monitoring natural resources, modelling soil physiographic relation, finding crop suitability, land-use options, estimating soil loss and conservation of natural resources. Modelling soil carbon and crop performances can also be a continuous exercise to comprehend the soil health and related changes in soils due to climate change. In isolation, each activity may not justify to provide appropriate information for natural resource management and planning, but in combination they provide a powerful tool to address the following issues for posterity (Figure 1).

Soil information system – soil degradation

Two categories of soil degradation are recognized in Tripura. The first category deals with degradation by displacement of soil material, principally by water. The second one deals with the internal soil deterioration resulting from loss of nutrients (chemical deterioration) or through physical processes, including waterlogging and flooding (physical deterioration). SIS indicates that as much as 60% area of the state is under various types of degradation[8]. If slight and moderate degrees of degradation are ignored, the extent of degradation is nearly 21% area of the state.

Soil information system to develop soil loss and crop productivity model

Since soil erosion is the major reason for soil loss and consequent decline in soil productivity, it becomes

Table 2. Total annual soil loss in Tripura[a]

Erosion class	Range (t ha^{-1} yr^{-1})	Soil loss (mt yr^{-1})
Slight	<5	–2.15
Moderate	5–10	–1.62
Moderately severe	10–20	–2.22
Severe	20–40	–2.04[a]
Very severe	40–80	–5.41[a]
Extremely severe	>80	–7.72[a]
		15.17
Effective soil loss	–	

Source: Bhattacharyya *et al.*[22]; [a]Considered to estimate effective soil loss every year.

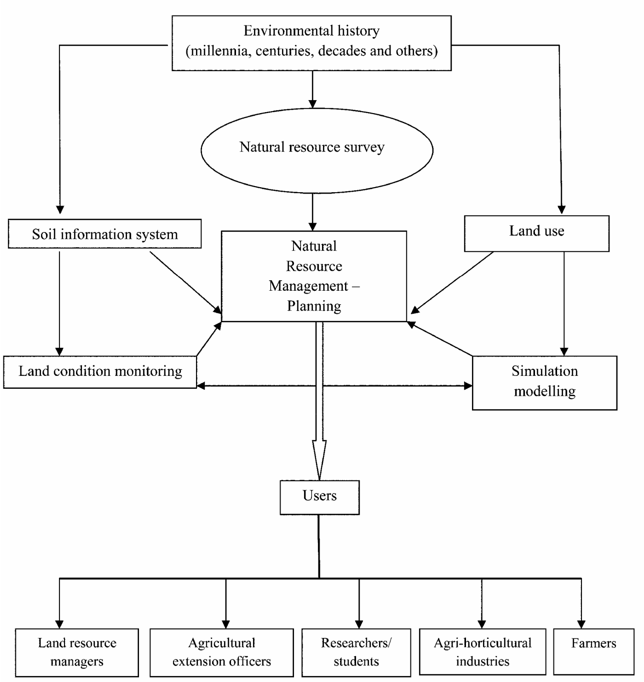

Figure 1. Mapping, monitoring and modelling are complementary activities to use and update the soil information system against the backdrop of landscape and land-use history in Tripura (also see Sanchez *et al.*[28] and ASRIS[30]).

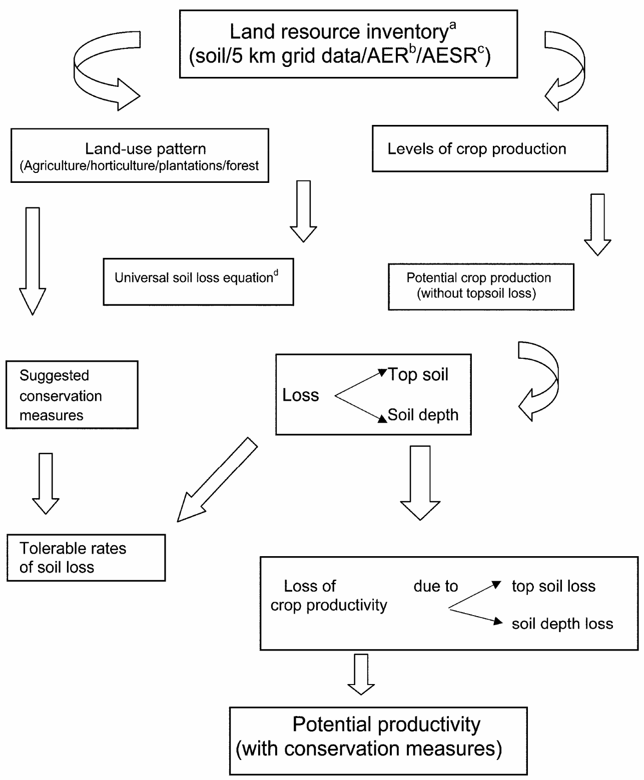

Figure 2. Soil erosion–crop productivity model for Tripura. Source: Bhattacharyya *et al.*[22]; [a]Land resource inventory[8–10]; [b]AER, Agro-ecological region[17]; [c]AESR, Agro-ecological subregion[18]; [d]Modified keeping in view the cropping and conservation practices in each grid point.

imperative for the land-use managers and planners to adopt appropriate soil conservation measures. The soil loss and crop productivity model (Figure 2) explains the development of regional-level methodology for estimation of actual soil loss in Tripura using the 5 km × 5 km grid points[11,22] (Figure 3).

Loss of crop yield due to loss of topsoil is compensated by the use of manure and fertilizer. At the same time, loss of topsoil by soil erosion is also compensated by the formation of fresh soil layers through the process of pedogenesis. To calculate loss of topsoil it is necessary to take into account the amount of soil regenerated, keeping in view the difference in the rate of soil formation under different types of climatic conditions[11]. On the basis of available soil information[8,11,14] and the rate of topsoil formation at each grid point, various soil loss limits were developed (Table 3).

The estimates of soil erosion sometimes appear exaggerated when factual information is scarce. To make the generated output more factual, SIS developed by NBSS&LUP was utilized[8–11,14]. The SIS can thus generate soil erosion datasets to enrich it and also make it more useful for soil conservation. Totally seven classes of soil erosion were identified. Taking the medium values of the soil erosion range, the total soil lost under different erosion classes was estimated (Table 3). For humid, tropical climate like Tripura, an annual addition of 29 tonnes soil

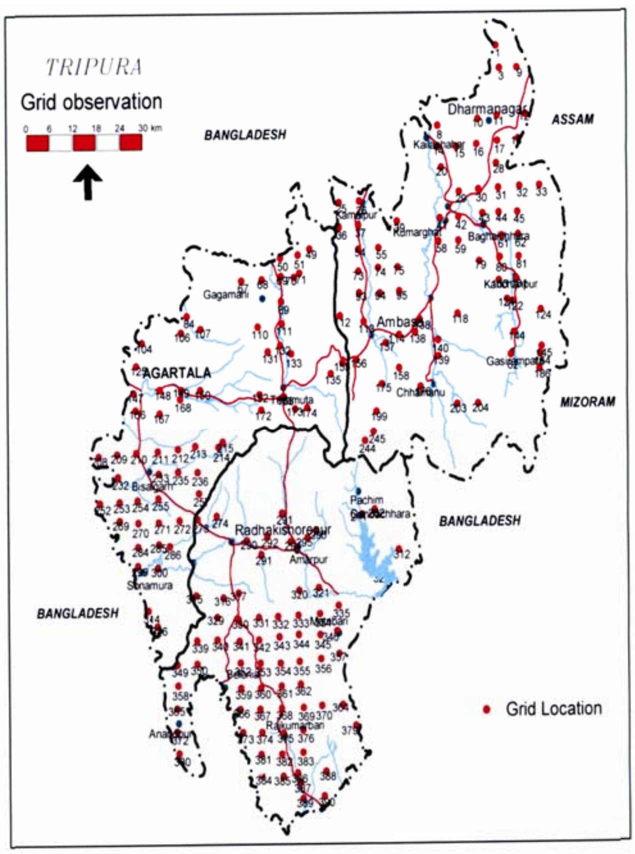

Figure 3. Grid point observations (5 km intervals) in Tripura.

Table 3. Estimation of conservation need through soil loss values

Year	Land use	Soil loss (t/ha)		Conservation need (*P* factor)
		Annual	Total	
1–4	Fallow	4[a]	16	
5	Crop – 1st year	12[a]	12	
6	Crop – 2nd year	18[a]	18	0.37
7–10	Crop – 3rd to 6th year	25[a]	100	
Total soil loss over 10 years			146	
Tolerable rate of soil loss		9.75[b]	97.5	

[a]Also see Bhattacharyya *et al.*[22]; [b]For moderately deep soils in Tripura (Bhattacharyya *et al.*[25]).

was estimated[23]. In view of this the soil erosion class indicating ≤ 29 t ha^{-1} yr^{-1} was not considered while computing the effective soil loss. The estimated annual loss of soil was nearly 15 million tonnes (mt) every year[23] (Table 3).

Soil information system vis-a-vis conservation measures

While applying the soil loss and crop productivity model (Figures 2 and 3), potential erosion losses for each desired land use may be evaluated assuming that no specific soil conservation measures are applied, which indicates that the protection factor (*P*) is one (Table 3). These results could be compared with what are considered as acceptable rates of soil loss under various levels of inputs[23], that are followed for estimation of the required conservation needs and their associated costs. Soil conservation need is estimated as the protection factor (*P*) when lands are not under any conservation programmes. The average rate of erosion covers both the cultivated and the uncultivated parts of the crop and fallow-period cycle. Estimation of conservation need showed that the required soil loss reduction was 48.5 t ha^{-1} (146–97.5 t ha^{-1}). In land under cultivation, the total soil loss over 6 years was 130 t ha^{-1} (12 + 18 + 100 t ha^{-1}). Therefore, the conservation need (*P* factor) required to achieve this is 48.5/130 = 0.37 (Table 3).

Soil conservation helps achieve three types of benefit, viz. (i) long-term reduction in checking the decline of agricultural production; (ii) gradual increase in agricultural production, and (iii) other non-agricultural benefits such as improved flow to the river during summer, reduction in periodicity and severity of flooding, reduction in siltation of reservoirs, reduction in damage of various costly infrastructure and low harmful impacts on farm lands. In Tripura many areas in the higher and middle elevations are under forest (58% TGA)[8]. The tilla lands and the lower foothills are used for plantation of rubber and/or for agricultural and horticultural crops. These lands are highly susceptible to soil erosion, and therefore require soil conservation measures such as bench-terracing. Most of the areas showing nearly 15 mt soil erosion every year (Table 2) occupy the degraded uplands and forest areas used for jhumming. In rainfed areas like Tripura, terraces may be constructed on slopes ranging from 6% to 33%. The value of supporting conservation practice (*P* factor) using bench-terracing technique (0.5% longitudinal gradient, 2.5% inward gradient) is quite low (0.027) for very deep red soils in Ooty hills, with a slope of 25%. Judging by similar terrain conditions, such efforts could be recommended for Tripura. However, appropriate techniques could be evolved by the conservation experts. Tilla lands and part of the degraded lands with shrubs and bushes are now exposed to erosion due to lack of vegetation. These areas need proper afforestation programmes. Part of these areas may be recommended to be brought under rubber cultivation and other plantation and horticultural crops[8,9]. Such practice will be doubly beneficial since it will save the loss of the most valuable natural resources like soil and would also generate income source among the local people.

Soil information system for suitability of different land uses

Eighteen model study areas and 390 grid-point observations were analysed in terms of 16 identified soil series vis-a-vis the suitability of land uses like horticulture and agriculture (Figures 3 and 4). Soil parameters vis-a-vis different selected crops indicated a general relationship of crop/land-use selection, elevation and KCl-extractable Al in the soils. Forest species predominate up to about 400 m elevation which includes oranges. The 400–250 m elevation could be ideal for plantations and horticultural crops, whereas 250–150 m may be ideal for upland paddy and other horticultural crops. Low lands (150 m) should be earmarked for lowland paddy and vegetables (Figure 5). It is interesting to note that the plantation and horticultural crops are suitable for those soils where KCl-extractable Al is very high. Forest and upland paddy soils have a medium range of KCl–Al and the soils suitable for lowland paddy and vegetables contain very low amount of KCl-extractable Al (Figure 5).

Table 4. Soil information system and related land, soil and crop quality parameters in Tripura

Soil information system	Parameters influencing crop performance
Climate	Available moisture
Rainfall	
Temperature	
Topography and landscape	Resistance to erosion and loss of plant nutrients
Slope	Landscape position – availability of moisture
Physical condition(s) of soil	
Texture	Water availability, soil aeration and soil structure
Depth	Available space for root development
Groundwater table	Landscape position – availability of moisture
Soil fertility	
pH (soil reaction)	Availability of plant nutrients
Silt and clay content	Availability of moisture and plant nutrients
Cation exchange capacity and base saturation	Soil health and structure/availability of plant nutrients
Organic matter	

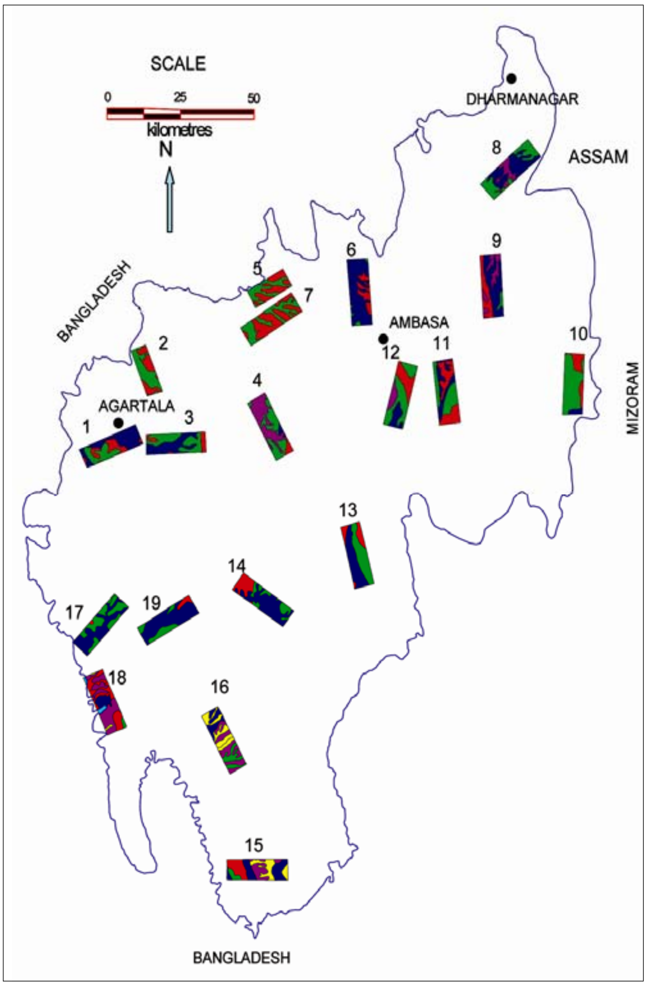

Figure 4. Thematic soil map and location of selected study areas in Tripura. 1, Jirania; 2, Mohanpur; 3, Champaknagar; 4, Teliamura; 5, Khowai; 6, Chebri; 7, Kamalpur; 8, Panisagar; 9, Kanchanpur; 10, Jampui; 11, Chhamanu; 12, Sikaribari; 13, Gandachherra; 14, Amarpur; 15, Satchand; 16, Bogafa; 17, Sonamura; 18, Jatrapur; 19, Radhakishorpur.

Soil information system for crop suitability

Each plant requires definite soil and climatic conditions for optimum growth. Since the availability of both water and plant nutrients is largely controlled by the physical and chemical properties and micro-environments of soils, the success and failure of any species in a particular area is governed by soil characteristics, which indicates the significance of SIS (Table 4). SIS was extensively used for evaluating lands for suitability of different types of crops and plantation species.

Suitability criteria for rubber plantations in Tripura showed most of the areas as moderately suitable in the undulating plains and uplands without forests. It should be mentioned that most of the horticultural crops have similar soil-site requirements, which naturally compete with the rubber growing areas. It was, therefore, recommended that the rubber might be restricted to the marginal areas with further higher slopes. Using SIS the probable expansible area for rubber plantation was estimated[8,10] as 5.11%.

Soil information system – clay minerals vis-a-vis crop suitability

The soil series association map (1 : 50,000 scale) was used as a base map to establish the relation between clay mineralogy and crop suitability. Clay samples (< 2 μm) of the selected soil series were analysed using X-ray diffraction techniques to estimate clay mineral content. Soil parameters such as CEC, clay and organic matter content were used to correlate the mineral make-up in the clay fractions. Data on clay minerals for 48 soil series from Tripura were utilized to generate a clay mineral map for the state. The data indicated dominance of hydroxy-interlayered vermiculites (HIV), mica (M) and kaolinite

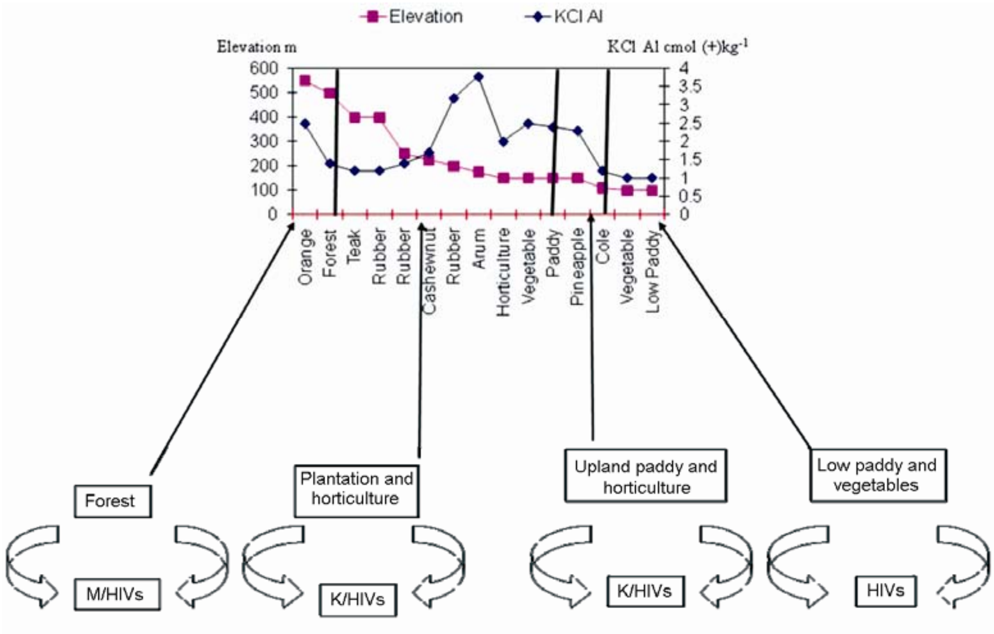

Figure 5. Soil information system in terms of its various parameters and land-use options in Tripura. (M/HIVs: Mica-hydroxy-interlayered vermiculite; K/HIVs: Kaolin-hydroxy-interlayered vermiculite mineral in clay fractions.)

Table 5. Soil information system vis-a-vis clay mineralogy and land use in Tripura

Physiographic position	HIS[a] (%)	HIV[b] (%)	Kl/HIV[c] (%)	Land use	Elevation ranges (m amsl)	KCl–Al cmol (+) kg^{-1}
High hills	10–20	17–20	35–50	Forest	> 400	1.5–2.5
Tilla lands	< 10	< 17	< 35	Horticulture, plantation, agriculture	400–250	2.0–4.0
Valleys	> 20	> 20	> 50	Agriculture	< 250	< 1.0

[a]HIS, Hydroxy-interlayered smectites; [b]HIV, Hydroxy-interlayered vermiculites; [c]Kl/HIV, Kaolin interstratified with HIV.

(Kl) in fine and total clay fractions. Presence of hydroxy interlayered smectites (HIS) was also noticed. Interestingly, mica and kaolinite minerals are also present as interstratified minerals with HIV as M/HIV and Kl/HIV[12,24–26].

On the basis of mineral make-up of different soil series, clay mineralogy maps of various combinations were generated. Tilla lands used mostly for rubber and horticultural crops, are dominated by soils with less than 10% HIS, high hills (forests) are dominated by soils with less than 10–20% HIS and inter-hill valleys (agricultural crops) are dominated by soils with more than 20% HIS (Table 5). Tilla lands are also dominated by soils with less than 17% HIV, high hills with less than 17–20% HIV and inter-hill valleys with more than 20% HIV (Table 5). Tilla lands, used mostly for rubber and horticultural crops, are dominated by soils with less than 35% Kl/HIV; high hills covered under forests are dominated by soils with less than 35–50% Kl/HIV and inter-hill valleys growing paddy and other agricultural crops are dominated by soils with more than 50% Kl/HIV (Table 6)[26].

In the humid tropical weathering environment of Tripura, the presence of vermiculite/low charge smectites is common. Minerals in clay fractions have not yet weathered to reach the stage of kaolinite. Thus the mineralogy class of these soils as mixed appears to be more appropriate. During humid tropical weathering, huge quantity of Al^{3+} ions are liberated to cause higher acidity (H^+), which was estimated as 149 kg ha^{-1}. It is interesting to note that vermiculites adsorb Al^{3+} ions as hydroxy-cations to form HIV/HIS. The vermiculite minerals thus act as a natural sink to sequester Al^{3+} ions. A representative acid soil of Tripura can sequester Al in the first 30 cm depth[25,26] to the tune of 65 kg ha^{-1}. This is the reason why Tripura soils show relatively higher proportion of hydroxy interlayered vermiculites effecting lower concentration of Al^{3+} ions in the soil solution. This fact may possibly help in removing a myth about Al-toxicity in acid soils in general and in acid soils of Tripura in particular.

Soil information system – soil health vis-a-vis organic carbon in soils

The SIS of Tripura helps to find out the soil health in terms of soil organic carbon (SOC). In Tripura, SOC content varies from 0.34% to 1.88%. Relatively high SOC is

Table 6. Soil organic carbon stock in Tripura[a]

Soil series	Classification[b]	SOC stock (Tg) Soil depth (cm) 0–30	0–50	0–100	0–150
Kathalia	Fine, kaolinitic Typic Kandiudalfs	0.997	1.536	2.234	2.567
Gandhigram	Fine, kaolinitic Typic Kandihumults	0.135	0.204	0.305	0.369
Shibbari[c]	Fine, kaolinitic Typic Kandihumults	1.891	2.938	5.154	6.568
Fisherypara	Fine, kaolinitic Typic Kandiudults	0.190	0.294	0.485	0.621
Mohanpur	Fine, kaolinitic Typic Kandiudults	0.093	0.126	0.208	0.265
Ramnagar	Fine, kaolinitic Typic Kandihumults	0.167	0.253	0.423	0.536
Rangthang	Fine, kaolinitic Typic Palehumults	0.510	0.709	1.016	1.206
West Gandachherra	Fine, kaolinitic Typic Palehumults	0.207	0.313	0.469	0.542
Anandanagar	Fine-loamy, kaolinitic Typic Kandiudults	0.056	0.091	0.141	0.160
Monaipathar	Fine-loamy, kaolinitic Typic Paleudults	0.615	0.968	1.602	1.957
Birchandra Manu	Fine, kaolinitic Typic Kanhapludults	0.375	0.576	0.832	1.216
Chhailengta-II	Fine, mixed Typic Paleudults	1.055	1.860	3.566	4.736
Jagabandhupara[c]	Fine-loamy, kaolinitic Typic Hapludults	3.014	4.339	6.991	8.802
Khowai[c]	Fine-loamy, mixed Typic Endoaquepts	0.645	0.786	1.139	1.765
Dukli-II	Fine-loamy, kaolinitic Fluvaquentic Endoaquepts	0.098	0.144	0.244	0.323
Dharaichherra	Fine, vermiculitic Typic Endoaquepts	0.509	0.661	1.004	1.276
Nayanpur[c]	Very fine, mixed Typic Endoaquepts	3.640	5.011	10.345	15.518
Dukli-I	Fine-loamy, kaolinitic Typic Endoaquepts	2.593	3.704	5.464	5.629
Anurchherra	Fine-loamy, mixed Typic Dystrudepts	0.304	0.397	0.690	1.036
Bijaynagar	Fine-loamy, kaolinitic Typic Palehumults	1.689	2.530	4.084	5.292
Dhanpur[c]	Fine-loamy, kaolinitic Fluventic Dystrudepts	0.598	0.897	1.984	3.885
Goachand[c]	Fine-loamy, kaolinitic Aquic Dystrudepts	1.508	2.399	4.634	6.761
Paschim Manu[c]	Fine, mixed Oxyaquic Dystrudepts	1.449	2.150	3.227	3.993
Netajinagar[c]	Fine, mixed Fluventic Dystrudepts	0.989	1.176	2.674	5.353
Betaga	Fine, kaolinitic Typic Paledults	0.611	0.933	1.591	2.207
Gamaibari	Fine, kaolinitic Rhodic Paleudults	0.142	0.227	0.354	0.565
Harimangalpara	Fine-loamy, kaolinitic Typic Paleudults	3.552	6.083	11.205	14.905
Nagichherra	Fine-loamy, kaolinitic Oxic Dystrudepts	0.034	0.050	0.075	0.082
Paschim Karbok	Fine-loamy, kaolinitic Oxic Dystrudepts	0.602	0.908	1.503	1.994
Bhaktikumarpara	Fine, kaolinitic Humic Hapludults	0.105	0.143	0.199	0.225
Gynama[c]	Fine, kaolinitic Humic Hapludults	1.630	2.412	4.225	5.444
Uttar Nalichherra	Fine-loamy, kaolinitic Oxic Dystrudepts	0.199	0.290	0.444	0.522
Belianchef[c]	Loamy-skeletal, kaolinitic Oxic Dystrudepts	1.037	1.444	2.279	3.094
Bilthai[c]	Fine-loamy, kaolinitic Typic Dystrudepts	1.235	1.660	2.590	3.304
Bagaichherra[c]	Fine-loamy, mixed Typic Dystrudepts	3.509	5.385	8.536	10.760
Bagbassa	Fine, mixed Typic Dystrudepts	1.971	2.776	4.327	5.415
Chebri[c]	Fine-loamy, mixed Typic Dystrudepts	4.881	8.337	14.731	18.191
Krishnapur	Coarse-loamy, mixed Typic Dystrudepts	0.134	0.165	0.220	0.252
Barabil	Fine-loamy, kaolinitic Aeric Fluvaquents	0.016	0.019	0.028	0.040
Mynama	Fine-loamy, kaolinitic Aeric Endoaquents	0.023	0.033	0.058	0.084
Manpui	Clayey, mixed Lithic Dystrudepts	0.676	0.925	1.949	2.923
Patichheri	Coarse-loamy, kaolinitic Typic Kandiudults	0.050	0.077	0.142	0.197
Karbok	Fine-loamy, kaolinitic Aquic Udorthents	0.035	0.051	0.089	0.125
Manikyadeb	Fine-loamy, kaolinitic Aquic Udorthents	0.022	0.034	0.058	0.080
Chhailengta-I[c]	Fine-loamy, mixed Oxyaquic Dystrudepts	0.372	0.641	1.175	1.624
Hamori	Loamy-skeletal, mixed Typic Dystrudepts	2.116	2.949	4.699	6.361
Ganganagar[c]	Fine-loamy, kaolinitic Ruptic-ultic Dystrudepts	1.274	2.097	3.894	5.430
Trigunchherra	Coarse-loamy, mixed Typic Udorthents	0.683	0.917	1.114	1.586
	Total	48.231	72.618	124.403	165.788

1 Tg = 10^{12} g.
[a]Bhattacharyya *et al.*[14]. [b]Temperature regime of all the soils is hyperthermic[21]. [c]Soil series entered in the National Register at NBSS&LUP.

found in deep to very deep, well to excessively drained loamy hill soils. The North Eastern Region (NER) in India has been declared as a green belt. Earlier SOC level of 1.0% was shown as a threshold limit for soils with good health[21,27,28]. SIS of Tripura helps estimate SOC stock. The data show that nearly 58% area in Tripura has more than 45 kg ha^{-1} SOC stock in the first 30 cm depth of soils (Figure 6). The SOC stock of Tripura in various soil depths is shown in Table 6. Total estimated SOC stock in India and Tripura is 9.55 Pg and 0.05 Pg, respectively[23]. It shows that SOC stock in Tripura is maintained at 0.046 Pg ha^{-1} compared to the all-India average of

0.029 Pg ha^{-1}. Earlier, using the 14 agro-climatic zones (ACZs) of the Planning Commission, ACZ 2, representing the entire NER was found to store organic carbon @0.064 Pg/m ha of soils[29] (Table 7). Such threshold values of SOC stock ranging from 0.05 to 0.06 Pg/m ha should, therefore, be maintained in areas declared as the green belt to protect natural ecosystems.

Pedonwise soil database

Soil information of Tripura contains the soil database as detailed soil series information showing 30 parameters of site information, 17 morphological properties, 3 physical characteristics and 6 chemical properties[12,14]. It also shows details of mineralogical properties of various particle size fractions and soil groupings (Table 8).

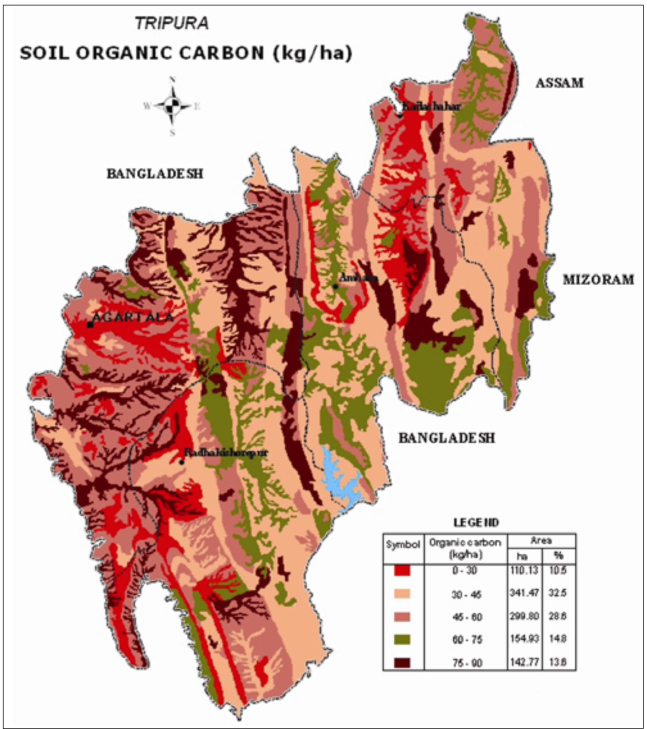

Figure 6. Distribution of soil organic carbon stock in Tripura.

Table 7. Soil organic carbon (SOC) stock in Tripura and India – a comparison to fix threshold value for the green belt[a]

SOC stock	Soil depth (0–30 cm) SOC stock (Pg)	SOC stock (Pg/m ha)
India	9.550	0.029
ACZ 2[b]	1.792	0.064
Tripura	0.05	0.046

[a]Bhattacharyya *et al.*[29]; [b]ACZ 2 (agro-climatic zone 2 representing the entire NER; also see Bhattacharyya *et al.*[29]).

Table 8. Structure of SIS Tripura database

Component	Attributes
Site	Observation no. Toposheet no. Author and date of examination Location (latitude, longitude) Village Tehsil District State Physiographic unit Geology Parent material Climate Rainfall Topography Elevation Slope – gradient, length Erosion Run-off Drainage Groundwater depth Flooding Salt/alkali (% surface coverage) Stone size Stoniness (% surface coverage) Rock outcrop Natural vegetation Crop yield (kg/ha), crop management Present land use, forest, cultivated, terraces, pasture land, degraded culturable, degraded unculturable Land capability class Land irrigability class
Morphological properties	Horizon Depth Boundary Diagnostic horizon Matrix colour Mottle colour Texture Coarse fragment Structure Consistence Porosity Cutans Nodules Roots Effervescence Other features (slickensides, cracks, etc.) Sample bag no.
Physical properties	Sand (50 μm) (%) Silt (2–50 μm) (%) Clay (< 2 μm) (%)
Chemical properties	Organic carbon pH (water, KCl) Extractable bases (Ca, Mg, Na, K, H, Al) Cation exchange capacity (CEC) (soil, clay) Base saturation Clay ECEC
Mineralogical properties	Quality and quantity of different minerals in sand, silt and clay fractions
Soil Taxonomy	US Taxonomy

Concluding remarks

This article projects the need of relevant and pertinent datasets to develop a SIS for a state. In view of the global changing scenario the need of the hour is to produce a fresh group of earth scientists with specialization in soil and crop science, geology and geography with appreciable knowledge in GIS and other information technology software. They will be equipped to deal with data storage, and retrieval in a user-friendly mode for management recommendations, so that issues like land degradation, biodiversity, food security and climate change can be addressed adequately.

In view of the global changing scenario with the developments of GIS and other web technologies, dissemination of spatial information is getting a paradigm shift. Natural resource information is an essential pre-requisite for monitoring and predicting global environmental change with special reference to climate. This article may not only serve as a 'handbook' for development purposes for the state, but may also encourage specialists in the subject to document natural resource information in a similar way.

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ACKNOWLEDGEMENT. A part of this study was funded by the NRDMS, DST, New Delhi sponsored project.

Received 8 December 2009; revised accepted 27 September 2010