Soil Management Information Linkage Experiment (SMILE) in the Framework of Geographic Information System (GIS)

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Abstract: *The utilitarian aspects of soil studies involving complex decisions are best handled by the state-of-the-art modern tool, Geographic Information System (GIS). Contrary to the traditional approach of thematic map overlays where spatial relationships dissipate as the number of overlays increases, GIS facilitates integration of a total range of variations and allows visualization of their interactions and spatial relationships. The most striking feature is the modelling device permitting a number of valid utilitarian options for a single soil mapping unit with provision for testing their ramifications.*

Soil management Information Linkage Experiment (SMILE) initiated at the Regional Remote Sensing Service Centre (RRSSC), Deptt. of Space, Nagpur is devoted to soils data base management, primarily for complex land use planning decisions. Alike most of the GIS systems, SMILE provides for direct input of thematic digital files. It permits entry of attribute data in free format, fixed format and coded format. Modelling and proximity analysis modules of SMILE are the key functions for land evaluation. These and other features are discussed in the paper and their applications demonstrated.

Precise data on characteristics, classification, spatial distribution and use potential of the soils are basic to many programmes of regional and national development. Some of the major programmes include land use planning, watershed management, reclamation of degraded soils/wastelands, management of forests/grasslands, environmental security and a host of others. All these programmes heavily rely on land evaluation to arrive at proper decisions. There are other land use activities like flood control, laying of roads and railways, planned development of rural and urban growth centres which have a need for proper land evaluation using appropriate models. In practice, limitations of mapping techniques, subjectivity in interpretation of soils (in absence of precise decision rules) and indifference to analytical validation often lead to faulty results.

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Viewed against this background, the emergence of modern, state-of-the-art Geographic Information System (GIS) from the advanced computer technology is a unique multidisciplinary endeavour for timely and efficient decision making process, often based on infeasible analytical tasks. Worldwide efforts are presently converged to develop and adapt different data management systems. Most of these systems are compatible with soils data manipulations to a varying extent. The 'all-purpose' structure of such comprehensive systems is often a limitation to meet the specific needs of soil surveyors.

GLOBAL SCENARIO

The U.S. Department of Agriculture under the Soil Conservation Service (SCS) has established three soil geogrpahical data bases at three levels.These are survey unit, the state and the nation. The multilevel approach enables display and integration of soil data of different taxonomic levels with corresponding levels of other spatially referenced resources and demographic data. The Australian Resources Information System (ARIS) developed by CSIRO has data sets linked to administrative and grid cell mapping units, providing wide range of applications. The system permits linking of soil - vegetation combinations to other attributes of geogrpahical location. In Canada the Geographical Information System (CGIS) and the Canadian Soil Information System (CanSIS) are developed by the government agencies for planning of environmental and agricultural projects.

The co ordinated Information on the European Environment (CORINE) programme is a joint effort of the European countries to create multi disciplinary,spatially linked data base from different sources in text, vector and raster forms for assisting policy making in the region. Here, soils related information is kept as a separate data set. On a global scale, world soils and terrain digital data base (SOTER) programme has been initiated by the International Society of Soil Science (ISSS) on 1:1 million scale and world soil degradation on 1:10 million scale map inputs. Soils and terrain digital data bases have already been accomplished for Argentina, Uruguay and Brazil.

ACHIEVEMENTS IN INDIA

In India, several general purpose as well as specific task oriented systems have been developed over the years. Way back in 1976, the Town and Country Planning Organisation (TCPO) of the Ministry of Housing has made an attempt to evolve an operational framework for establishment of two-tier Urban and Regional Information Systems (URIS). Based on the varied data requirements at urban and regional levels, Urban Information System (URBIS) and Regional Information System (RIS) have been segregated for standardising the data formats from different sources.The Department of Science and Technology has conceptualised the Natural Resources Data Management System (NRDMS) integrating natural resources, demography, infrastructure, agroeconomic and sectoral data sets to aid in systematic planning for resource development at settlement, tahsil, district and major wateshed levels. The National Natural Resources Management System (NNRMS) has been evolved as an integrated system for streamlining the management of natural resources in a comprehensive framework of GIS in collaboration with several ministries/ departments. Indian Geographic Information System (INGIS), developed by the RRSSC, Bangalore and the Geological Survey of India is structured to serve geologic studies. The Department of Environment established a programme of Environmental Information System (ENVIS) for dealing with environmental problems.

BASIC CONCEPTS OF GIS

Geographical Information System (GIS) is a computer assisted system for the capture, storage, retrieval, analysis and display of spatial data. Resources management, planning and policy decisions are based on logical deductions from interplay of the different factors that are relevant to a particular issue. CAD (Computer Aided Design) or DBMS (Data Base Management System) even when linked together through a common interface, constitute only a sophisticated computer mapping system but not a GIS.

Essentially, GIS concept comprises a variety of data sets, derived from systematic surveys, aerial photogrpahs, remotely sensed data from space platforms, topographical and other thematic maps, documents and other sources that are georeferenced for spatial and thematic resolution. Appropriate software to access the data sets to perform logical, statistical and cartographic operations is an indispensable component of the system. The organisational structure of GIS function is defined by the nature and characteristics of data sets. These are :

Availability: The data elements from a particular source should be accessible consistently without abrupt variations. If the existing data are not easily accessible, preprocessed in unexplained ways or are subject to sudden changes in distribution with gaps, alternate data has to be sought or new data has to be employed.

Compatibility: When numerous data elements are to be manipulated in the context of a single system, they must have *inter-se* compatibility. The temporal and spatial variability of the data element are the factors affecting compatibility. Numerical or quantitative data elements, amenable to better manipulation allow better compatibility than the free formatted data.

Reliability: Data collected from an operating environment is generally recorded with different degrees of accuracy. In reliable data elements, the zone of error around the data item is small, while in unreliable data elements the zone of error is large.

Flexibility: This relates to multiple information generation from one specific data element. The remotely sensed data, amenable to generation of multithematic maps is a good example of flexibility of data elements. Flexibility of data elements usually satisfies the needs of compatibility and reliability.

Timeliness: The time that elapses from collection of a data element, till it is available for processing establishes its timeliness.

Processability: The data elements should be properly formatted for machine coding and processing. The numerical data can be readily feature coded. Written statements invariably have to be reformatted before storage.

Sensitivity: The level of consistent details inherent in each data element is referred to as its sensitivity. The more the details, the more sensitivity the data element possesses. A data element may lack sensitivity in space, time or descriptive precision, and any of these may reduce its utility in modelling or simulation for specific purpose.

The sensitivity and reliability of a data element are closely related. Obviously, data reduction (collapse) may appear to be a solution to increased data reliability, but such an effort changes the abstraction level in reducing the sensitivity by making it coarse. Flexibility, timeliness and processability are also closely related. Usually, flexibility should be sacrificed to an extent in favour of timeliness. Increased processability leads to increased timeliness. It is not possible to optimise all the data properties and therefore trade-offs, to some extent, are unavoiable.

In any GIS system data is organised on:

— Spatial objects with locational details and

— Attribute or non spatial data.

VECTOR VS RASTER BASED SYSTEMS

Historically, GIS witnessed a dipole development with emergence of vector based and raster based systems for representing the spatial objects or locational information. The former approach stores information about the boundaries between the regions, whereas the latter stores information on the interiors of the region.

Vector Approach

It is like a conventional map with lines, points and areas. Vectors work well when real world spatial conditions are accurately defined as lines or edges. The vector approach allows realistic capture of important topological information like drainage network which is difficult to differentiate from other linear features in raster mode (unless specifically feature coded). Flexibility in scale projection and symbology are characteristic of vector based systems. It thus readily allows change from one coordinate base to another. A particularly significant feature of this system is economy in data storage.

The vector based approach, however, has some inherent limitations.

In superimposing lines (vectors) on an image which lacks sharp boundaries, vector system tends to introduce an interpretative element into the data with overly precision which is misleading. Besides, isolines interpolated from rectilinear grid or a random set of point observations are rarely infallible in this system. It is generally known that the mathematics of data overlay in vector format for Boolean operations is more complex. Besides, the production of vector records from existing maps or drawings by line scanning techinques is very costly.

RASTER APPROACH

Raster based systems use data which are encoded on the basis of regular geographic units. The individual units are called cells (or pixels in the context of remote sensing). The relatively inexpensive data manipulation is characteristic of raster mode. The raster structured data can be more easily partitioned for multitasking.

The limitations of raster based system are that the nature and position of point and linear features cannot be well defined since all the data are referenced to areas of finite size. There is also loss of spatial accuracy in describing real areas, such as administrative or natural regions when they are approximated as composites of grid cells. The loss of accuracy is directly proportional to the resolution of cell units chosen. On the other hand, high resolution grid cells are beset with problems of effective storage and retrieval of the data. The regions and boundaries generally appear fuzzy in this approach.

Some of the standard packages available in vector mode are ARC/INFO, GIMMS, UDMS and in raster approach GIS, there are ERDAS, USEMAP, MAP, GRIDS, etc.

HYBRID APPROACH

Recent trends in evolution of GIS reveal the efforts to develop 'hybrid' systems. Such systems offer both the raster and the vector modes of operation interchangeably. Conversion from vector to raster is more clear and unambiguous. For a polygon defined by a set of vectors, only one raster representation can exist. In contrast, it is extraordinarily difficult to find the vector polygon which best represents the contiguous area of raster representation. A simple staircase like vector polygon can be defined, but to obtain a minimum set of straight lines, or smooth arcs, to best fit the raster polygon is very complex. More recent developments of hierarchial data structures (eg. quadtrees) may provide access to an integrated model to avoid time consuming and error-prone translation of data from vector to raster and raster to vector modes. However, techniques for extracting hydrologic basins and for delineating drainage networks from raster formatted digital elevation models (DEM) are reported by Jenson (1985) for overlaying on other thematic map data for measuring lengths, areas and streams ordering. David (1987) demonstrated possibilities of raster editing, filling and node detecting for raster to vector conversion satisfactorily.

Developmental and operational remote sensing applications increasingly require integrated vector GIS and raster image analysis procedures. A sophisticated approach using multiple linked data bases is the recent trend for accurate data transfer between the raster and the vector systems with integrated raster/vector analysis capabilities.

SMILE

Consistent with the existing capabilities of the different systems for capture, storage, retrieval, modelling and manipulation, a Soil Management Information Linkage Experiment (SMILE) is conceptualized in the framework of GIS. SMILE is particularly structured with emphasis on multipurpose land evaluation. Storage and archieval of soils data are designed at the survey point level to link with different thematic data sets for manipulation and to obtain reliable and speedy multioptional decisions.

FUNCTIONS AND UTILITIES

Soils data from maps, digital thematic files, satellite imagery and aerial photographs are captured in analog mode and entered into the system in digital format as points, lines or polygons. Edit and update utilities are intended to guard against erroneous entries.

All the input imges are registered to a common origin of geogrpahic location through transformation models with linkage to Survey of India topographical maps. Topologically perfect edge matching to join lines or polygons across map sheet boundaries is achieved by edit/update facilities. Scanner digitized data as well as spectral data of satellite scanner and from other sources are reformatted to SMILE system before entry.

The input of attribute data on site characteristics, soil profiles and their morphological characteristics, physico-chemical properties and other data of nonspatial nature are entered through keyboard. Data recorded by electronic instruments can be directly interfaced with analog to digital convertors. The system has a capability to read a variety of externally supplied attribute data sets that are reformatted to the SMILE system. The system is flexibile to allow input in fixed format, free format and coded data format, utilizing field note books, profile description cards and tabular statements. Among others, soil-site characteristics, soil profile morphological data, analytical data, meteorological data, socio-economic conditions of the different sectors of the survey project area, management practices and existing yield levels can be entered both in the free and the fixed format. Although free format entry is flexibile to utilize data collected by the different surveyors for the different transects of the survey project areas, yet fixed format entry is less error prone and therefore preferred in SMILE system. Coded data entry is advantageous for large data bases with option for both fixed and free formats. The multiple-choice entry is more flexibile but it tends to be bulky for field handling and is therefore avoided in SMILE system. An example of sequential attribute data entry in respect of an available soil map is illustrated in figure 1.

The cataloging ability allows tracking of the spatial and attribute data by basic queries like geogrpahic coverage, origin, project name/number, date of entry, etc. Transfer of spatial and attribute data from disk to tape, disk to disk and tape to disk ensures long term storage and retrieval. Other utilities include general data management like directory display, printout and file statistics. The system facilitates coordinate conversion of lat.– long. measurements to choose the required reference points for transformation or registration.

The following utilities for analysis/geoprocessing of spatial data are implemented in the SMILE.

Mode conversion: Conversion of data from vector to raster form and **vice versa** with specified grid cell size and orientation.

Topological overlay: Integration of multiple maps with a defined algorithm or model to produce a composite output.

Window/Clip: Simple masking of desired pixels for processing.

Contiguity: Tally of the number of pixels constituting each contiguous area.

Proximity: Identification of points, lines or polygons of specified criteria, that are nearest to a point, line or polygon specified by location or attribute.

Measure: Determination of the frequency of occurrences, total area and percentage of total area.

Aggregate: Reduction of matrix dimensions in raster mode by resampling to larger pixel size.

Digital Terrain Model (DTM): Rasterisation of contour data and production of topographic derivations, like elevation, per cent slope and other aspects.

Modelling: Integration of spatial and attribute data following the defined mathematics/statistical rules. It provides options for analysing the covariance and correlation between different layers. Regression analysis enables assessment of dependencies among various data sets and options for predictive modelling by suitably changing the weightages of different attributes.

The SMILE provides for other facilities like, search/querry, reclass/recode, image enhancement, classification, mathematics, two-dimensional graph displays and cluster analysis. Full range of logical, arithmatic and calculative operations to perform analysis/ geoprocessing of attribute data allow statistical parameters like mean, variance, regression and cross-tabulation.

Different symbols (from the symbol library) and colours can be chosen to differentiate boundaries, points, lines and polygons using map composition function. This function is also used for drawing legend, graphic scale, etc. in the output image. Symbol library is flexible to enable move, draw, rotate, reduce/enlarge.

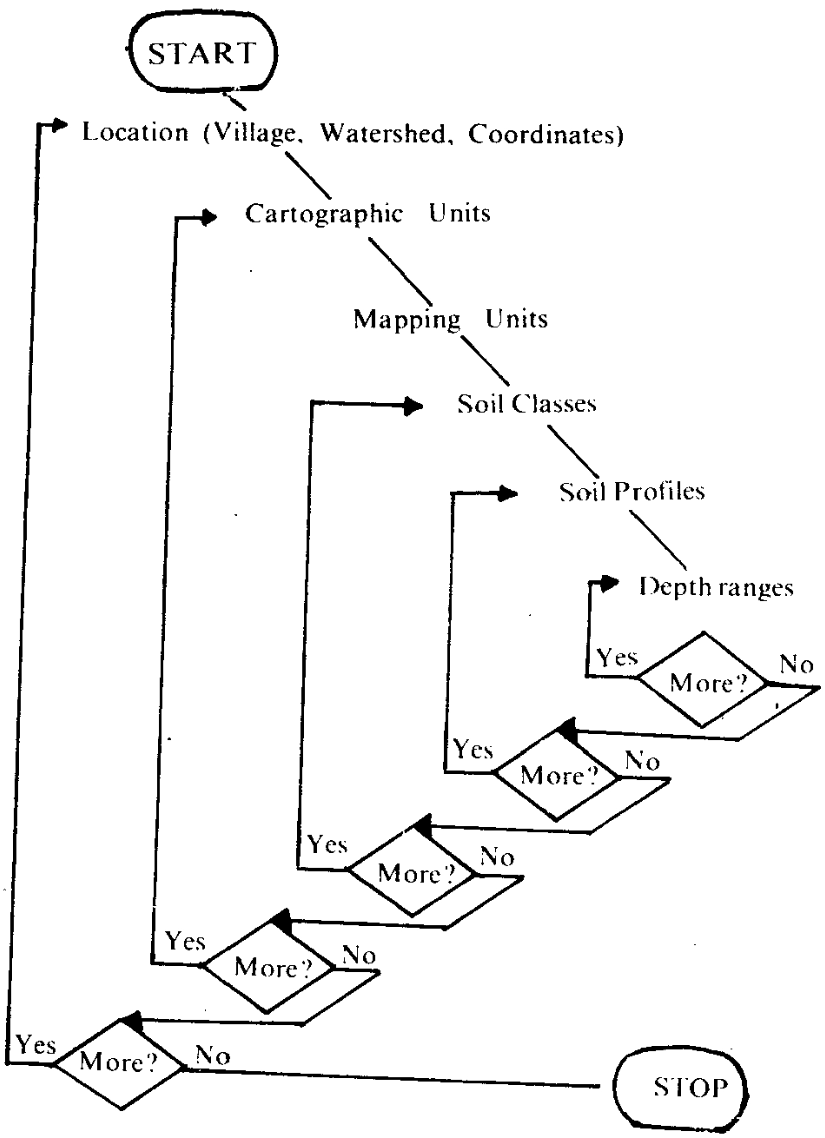


Figure 1. Sequential attribute data entry of soil map

DATA BASE MANAGEMENT

The first approximation of the data base design of SMILE is illustrated in figure 2. Efforts are on to refine it progressively. The capture, storage and manipulations of soil attribute data relating to soil-site characteristics, pedons/auger bores/mini pit descriptions and analytical data are performed through data base management system (DBMS). Data on other pertinent attributes like socio-economic indicators, institutional constraints, complementary determinant resources like availability and quality of water are needed to be captured consistent with the models to be employed for the end results.

The DBMS offers the functions which operate at the database level like initialize, status/statistics, search/query and those operating at the record level within a data base like add, delete, edit, list and print. The system provides for handling attribute data with linkage to spatial data. The linkage is provided to spatial data at sub-watershed (hydrologic unit) or village level (administrative unit) which are collapsed to watershed, subcatchment and catchment in hydrologic reference link and taluk, district and state in administrative reference link.

SMILE is specifically designed with flexibility to allow options of collapsing the results to hydrologic or administrative unit depending upon the purpose to be served by soils data input. This is achieved by referencing data sets to files containing:

a) each block/tahsil coded by watershed,

b) each block tahsil coded by cartographic unit,

c) entire district coded by subwatersheds,

d) entire state coded by cartographic units, and

e) each catchment within a state coded as per the master catchment look-up table.

The digitising requirements for establishing the spatial database are:

- Sub-watershed polygons designated by sequential codes for catchment area data bases.
- All the cartographic units within each sub-watershed polygons for the catchment.

Digitised attribute codes for each cartographic unit are prefixed with the sub-watershed polygon code and numbered sequentially. The cartogrpahic units within all the subwatersheds are collapsed to watershed level and indexed separately. Similar approach is followed for district or state level data base. Depending upon the survey intensity and mapping scale, village, blocks, tahsils constitute the primary geographic reference units. Each block in a tahsil and all the tahsils in a district are assigned unique codes.

Spatial distribution of geographic entities are rastered with specified grid cell size or pixel size defined in terms of unique numeric code or digitized attribute code and should remain the same for all the files. New

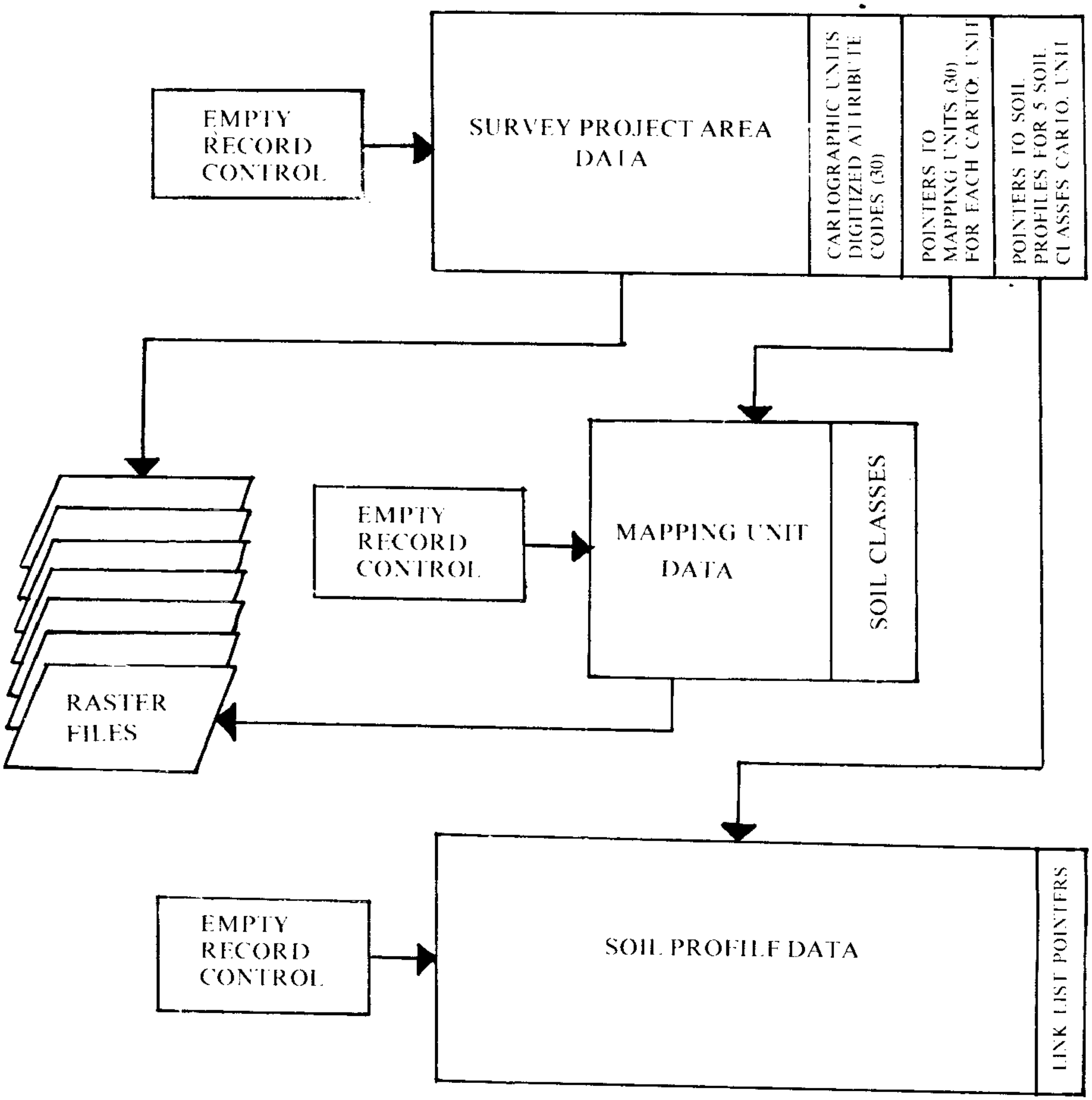
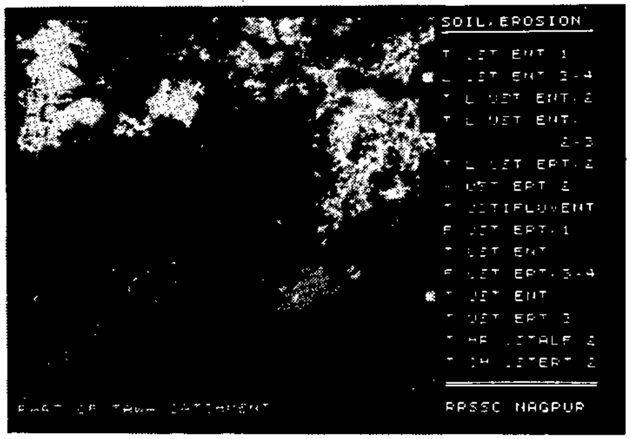


Figure 2. Data base design

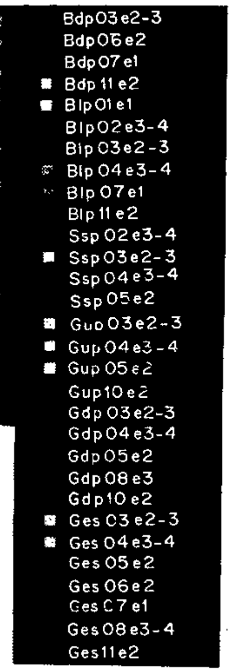


a

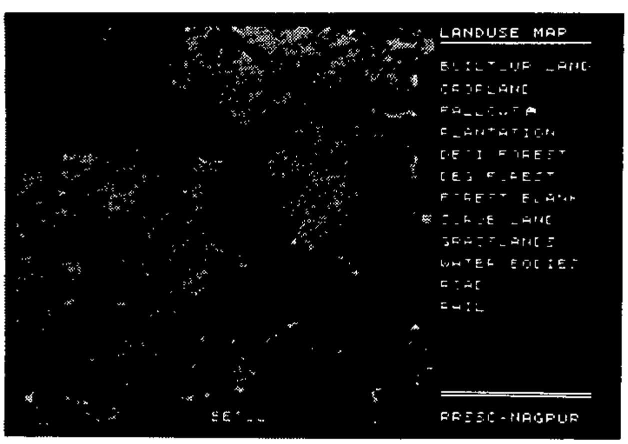
Soil and erosion map

b

Composite geology, land form soil erosion



Geology: B-Basalt; S-Sandstone-Shale; G-Granite gneiss
Geomorphic Unit; ds-dissected plateau; lp-lower plateau; sp-structural plain up-indifferentiated plateau; es-erosional slope
Soil Class; 01-T. Ustorthent; 02-L. Ustorthent; 03-T./L. Ustorthent; 04-T./L. Ustorthent; 05-T./L. Ustochrept; 06-V. Ustochrept; 07-T. ustifluvent, Fluventic Ustorthent; 08-T. Ustorthent, Fluventic Ustochrept; 09-T Ustorthent; T. Ustochrept; 10-T./U. Haplustalf; 11-T. Chromustert
Erosion: 1-Slight; 2-Moderate; 3-Severe; 4-very severe



c

Land use map

Figure 3. Resources Integration Exemplified

TABLE 1. Record layout - soil profiles data file

Byte location	Bytes	Description
1-2	2	Latitude degrees
3-4	2	Latitudè minutes
5-6	2	Latitude seconds
7-8	2	longitude degrees
9-10	2	longitude minutes
11-12	2	longitude seconds
13-62	50	depth range 1
113-162	50	depth range 2
63-112	50	depth range 3
163-212	50	depth range 4
213-262	50	depth range 5
263-312	50	depth range 6
313-362	50	depth range 7
363-412	50	depth range 8
413-462	50	depth range 9
463-464	2	pointer to next associated profile (-9999 = last)
Depth Range Variables - detailed breakdown		
	2	minimum depth
	2	maximum depth
	8	colour
	8	mottles
	2	texture code
	6	structure
	4	soil reaction
	2	Calcareousness code
	2	coarse fragment (nature) code
	2	coarse fragments (abundance) code
	2	cutans (position) code
	2	cutans (thickness, continuity) code
	2	roots (size) code
	2	roots (distribution) code
	2	cracks code

TABLE 2. Resources evaluation for optimal landuse

	Geology, land form, soil, erosion	Present land use	Proposed landuse
	Basalts, Dissected Plateau		
1.	T/L. Ustorthents e_2-e_3	Agriculture, Forests Scrubland & Plantation	Plantations/Grasslands with enclosures/Other non-arable uses consistent with local needs
2.	V. Ustochrepts e_2	Agriculture, Forests	Agriculture with appropriate soil conservation measures-crop options as LUT model
3.	T. Ustifluvents e_1	Agriculture, Forests Scrubland & Plantation	Agriculture- most of the climatically adapted crops
4.	T. Chromusterts e_2	Agriculture & Forests	Agriculture with wider crop options, soil conservation measures
	Basalt, Lower Plateau		
5.	T. Ustorthents e_1	Forests, Plantation and Agriculture	Agriculture, crop options based on LUT
6.	L. Ustorthents e_3-e_4	Agriculture, Forests Plantation & Scrubland	Erosion control, gully plugs, enclosures, natural rejuvenation of vegetation
7.	T/L. Ustorthents e_2-e_3	Agriculture, Forests Plantation & Scrubland	Plantations/Grass lands (enclosures) other non-arable uses
8.	T/L. Ustorthents e_2-e_3	Agriculture, Forests & scrubland	Erosion control, gully plugs, enclosures, natural rejuvenation of vegetation
9.	T. Ustifluvents e_1	Agriculture, Forests Plantation & Scrubland	Agriculture with appropriate soil conservation measures - crop options as LUT model
10.	T. Chromusterts e_2	Agriculture & Forests	Agriculture with wider crop options, soil conservation measures
	Sandstone/Shale, Structural Plain		
11.	L. Ustorthents e_3-e_4	Agriculture, Forests & Scrubland	Erosion control, gully plugs, enclosures, natural rejuvenation of vegetation
12.	T/L. Ustorthents e_2-e_3	Agriculture, Forests Scrubland & Plantations	Plantations/Grass lands (enclosures)/other non-arable land uses
13.	T/L. Ustorthents e_3-e_4	Agriculture, Scrubland Forests & Plantations	Erosion control, gully plugs, enclosures, natural rejuvenation of vegetation
14.	T/U. Ustochrepts e_2	Agriculture, Forests Scrubland & Plantations	Agriculture with appropriate soil conservation measures, crop options based on LUT
	Granite geneiss Plateau		
15.	T/L. Ustorthents e_2-e_3	Agriculture, Forests Scrubland & Plantation	Plantations/Grass lands (enclosures)/other non-arable uses.
16.	T/L. Ustorthents e_3-e_4	Agriculture, Forests Scubland & Plantations	Erosion control, gully plugs, enclousres, natural rejuvenation of vegetation
17.	T/U. Ustocherepts e_2	Agriculture, Forests Scrubland & Plantations	Agriculture with appropriate soil conservation measures, crop options based on LUT

cont. ....

18.	T/U. Haplustalfs	e_2-e_3	Forests. Agriculture Plantation & Scrubland	Agriculture with appropriate soil conservatio measures, crop options based LUT
	Granite Gneiss Dissected Plateau			
19.	T/L. Ustorthents	e_2-e_3	Agriculture, Forests Scrubland & Plantation	Plantations/Grass lands (enclousres)/ other non-arable uses.
20.	"	e_3-e_4	Agriculture, Forests Scrublands & Plantation	Erosion control, gully plugs, enclosures, natural rejuvenation of vegetation
21.	T/U. Ustochepts	e_2	Agriculture, Forests Scrubland & Plantation	Agriculture with appropriate soil conservation measures, crop options based on LUT
22.	T. Ustorthents T. Ustochrepts	e_3	Forests	Marginal agriculture with intensive soil conservation measures/plantations
23.	T/U. Haplustalfs	e_2	Forests, Agriculture Plantation & Scrubland	Agriculture with appropriate soil conservation measures, crop options based on LUT.
	Granite Gneiss Erosional slope			
24.	T./L. Ustorthents	e_2-e_3	Agriculture, Forests Scrubland & Plantation	Plantations/Grass lands (enclosures)/other non-arable uses.
25.	"	e_3-e_4	Agriculture, Forests Scrubland & Plantation	Erosion control, gully plugs enclosures, natural rejuvenation of vegetation
26.	T/U. Ustochrepts	e_2	Agriculture, Forests Scrubland & Plantation	Agriculture with appropriate soil conservation measures, crop options based on LUT
27.	V. Ustochrepts	e_2	Agriculture & Scrubland	Agriculture with appropriate soil conservation measures, crop options as LUT model
28.	T. Ustifluvents/	e_1	Forests, Agriculture Scrubland & Plantation	Agriculture- most of the climatically adapted crops
29.	T.Ustorthents/	e_3-e_4	Agriculture & Scrubland	Plantations/grass lands with intensive soil conservation measures
30.	T. Chromustat	e_2	Agriculture & Forests	Agriculture with wider crop options, soil conservation measures

T— Typic; L— Lithic; V—Vertic; U—Udic; LUT— land utilization type catchment/state data files are created from the established data base. Different resource information in the form of maps can be digitized and geo referred to the existing catchment/state data base. These are stored in vector form and rastered to the pixel size desired during analysis. Besides the catchment/state data base files, the data base has two table files for storage, retrievel and manipulation. These are:

Master catchment look-up tables with information on catchment record, state record and district record, describing the attribute code, name, area, maximum sub watersheds, mapping units and soil profiles.

Look-up tables with numeric codes and textural descriptions for different variables like parent material, physiogrpahy, slope, landuse, erosion, stoniness, soil texture, soil calcareousness, coarse fragments (nature and abundance), cutans (nature and thickness), roots (size and distribution), cracks, etc. Record layout of soil profile data file is shown in table 1.

Mapping interface to enable spatial display of the results obtained by database search/query operations and tabular output.

END RESULTS

The SMILE is conceptualized to respond to the soil related decisions through overlay or intersection procedures by logical, functional and weighted combination of variables or set decision rules as modules. Among others, it would serve decisions on aspects of pedology, taxonomy, spatial relationships among the different taxonomic units of a soil-scape, land use evaluation for various purposes, management prescriptions for the evaluated or permissible land uses, soil conservation measures and alike. The following examples are illustrative.

1. For a given area produce soils record (map and detailed table) showing their characteristics in terms of different entities.

2. For a zone or corridor from a target point produce soils record.

3. For a given geogrpahic area (state, district, catchment, subcatchment) select all polygons that possess the user specified characteristics (climate, physiography, soils, landuse, slope, etc.). Produce tables showing the detailed information regarding these selected entities plus a map illustrating their spatial distribution.

4. Land evaluation for specific objective, based on predetermined model in respect of chosen area.

5. Land use options by integrating relevant soil and non-soil parameters tuned to government policies and regional/locatioal priorities by adopting appropriate comprehensive and versatile model.

The first two options are simply selective retrieval of data files. The other options help to aggregate data sets within the specified areas to generate derived/utilitarian maps. Some of the examples of such derived maps can be land capability classification map, soil irrigability classification map, hydrologic groupings map, specific crop suitability map, potential soil erosion map, soil salinity-sodicity hazard map, trafficability map, etc. Using model utility centred on explicit decision rules and by integration of these derived maps with data from agricultural experimental centres and research farms, several land utilization type options can be derived in consonence with socio-political priorities and evaluated.

Figure 3a through 3c shows

(a) integration of the thematic maps of soils and soil erosion,

(b)integration of geology, land form, soils and soil erosion, and

(c) Present landuse map.

The integrated map of soils, soil erosion, geology, geomorphology when allied with slope map provide optimal land uses at level II using LCC model (table 2).

The results and maps presented in this paper are only illustrative of the SMILE capability. Understandably they are coarse, primarily because of limited data. Application of universal as well as locale specific models backed by full parametric data of requisite resolution and acceptable reliability offer a wide variety of planning decisions with the application of SMILE.

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