Agropedology, 1999, 9, 125-130

Application of geographic information system in soil productivity assessment and mapping

Suresh Kumar and D. Mitra

Indian Institute of Remote Sensing, Dehradun 248 001, India

Abstract
Soil productivity serves as rational indicator to land use planners and decision makers for the sustainable use of soil resources. Geographic Information System (GIS) has emerged as an efficient tool in recent years for spatial analysis of natural resources data. In the present study an attempt has been made to describe the use of the Geographic Information System in soil productivity assessment using available model. Soils of denuded hills, weathered pediments and valley fills are rated as extremely poor to poor in productivity whereas buried pediment soils have average to good productivity. Spatial modelling and cartographic capabilities of GIS software in generation of thematic maps have been highlighted.

Additional keywords: Natural resources, thematic maps.

Introduction

The need of efficient management of natural resources is widely recognized. The optimum use of land has never been greater than at present, when rapid population growth and urban expansion are making available agricultural land a relatively scarce natural resource. The evaluation of soil potential is a major tool in soil survey interpretations and natural resource management (Sombroek and Eger 1996). There is no universal method for assessing soil potential, but parametric approach can be applied if few factors are involved, and if the number of those factors remain constant (Verheye 1996).

The study was carried out to make use of Geographic Information System in soil productivity assessment. GIS has emerged as an unique tool for spatial analysis of natural resources and data base management. It is an efficient and versatile tool to automate the transformation of soil data into soil information. Its analytical capability helps resource planners to integrate non-spatial and spatial natural resource data to predict future state of condition of natural resources and their availability for optimal use. The parametric model developed by Requier *et al.* (1970) has been applied for assessment of soil productivity which provides a rational basis for land use planning.

Materials and methods

Study area : The study area is situated in parts of Puruliya, Bankura and Medinipur districts of West Bengal which lies between 22°45' and 22°50'N latitudes and 86°35' and 86°40'E longitudes. Physiographically, the area is a part of Chhotanagpur plateau with undulating and rolling topography. The highest and lowest elevations in the area are 270 and 190 metres, respectively. The climate of the area is semi-arid with average rainfall of 1320 mm. The maximum and minimum temperatures are 42.2°C and 10.2°C, respectively. Major crops grown in the area, are rainfed paddy, wheat, gram, mustard, sunflower and linseed.

Soil map generation : The satellite data (IRS 1B LISS II), geocoded standard false colour composites (March, 1994 and May, 1995) at 1:50,000 scale were visually interpreted in conjunction with Survey of India topographic maps of same scale. Field investigations were carried out to check physiographic boundaries and to observe site and soil morphological characteristics of representative profiles in mapping units. Soils were classified as per Soil Taxonomy (Soil Survey Staff 1992) and soil samples were analyzed for physical and chemical properties. Soil map of the area and their composition is shown in figure 1 and table 1, respectively.

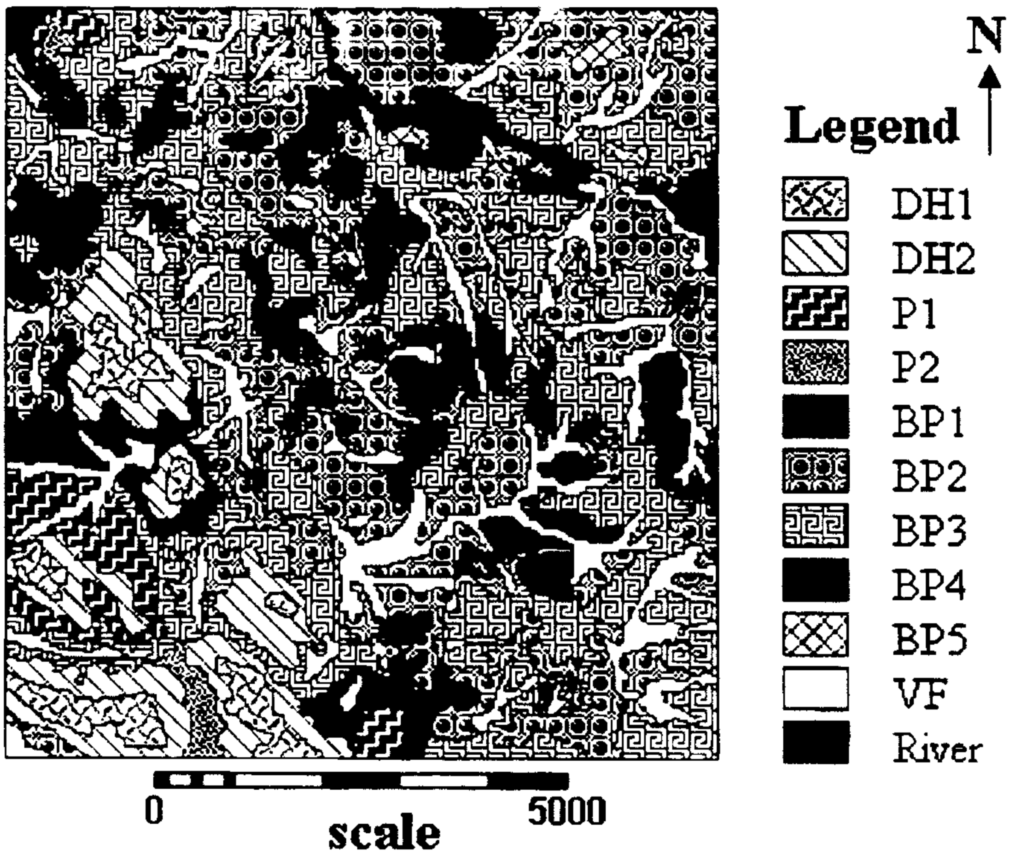

Fig. 1. Physiographic-soil map of the study area

Methodology : Soil productivity was assessed by employing Requier *et al.* (1970). It is parametric model which takes into account of six factors (land quality) viz. soil moisture (H), drainage (D), effective soil depth (P), texture and structure (T), base saturation (S), and organic matter (O). Each factor was rated on a scale from 0 to 100 and the soils were rated in the light of above properties. The actual factorwise score was multiplied by each and expressed in percentage to derive final index of soil productivity (IP).

Index of productivity (IP) = H x D x P x T x N x O

Where,

H = percent of soil moisture
D = percent rating of drainage condition
P = percent rating of effective soil depth
T = percent rating of soil texture
N = percent rating of base saturation
O = percent rating of organic matter content

These decimal equivalents were reconverted to a percentage multiplying by 100. The resulting index values were categorized/classified into four major soil productivity classes.

Table 1. Physical and chemical characteristics, and soil productivity class of mapping units

S.No.	Physiographic-soil mapping unit	Soil association	Area		Soil depth	Drainage	Erosion class	Soil pH (1:2)	Org. carbon (%)	Base saturation (%)	Soil productivity class (Index value)
			Ha	%							
1	Gently undulating denuded hills forested (DH1)[1]	[2]C.L. Typic Ustorthents L.S. Typic Ustorthents	245.4	3.1	51-55	Well	e1	5.7	0.42	56-62	Poor (8)
2.	Steep to very steep side slope of denuded hills-forested (DH2)	L.S. Typic Ustorthents C.L. Typic Ustorthents	582.1	7.4	60-70	Some what excessive well	e2	5.7-6.0	0.46	54-67	Extremely poor (7)
3.	Gently to moderate sloping weathered pediments-forested (P1)	L.S. Typic Ustorthents F.L. Typic Ustorthents	255.2	3.2	52-70	Well	e2	5.8-6.0	0.46	53-68	Poor (14)
4.	Moderate to strong sloping weathered pediments-forested (P2)	L.S. Typic Ustorthents L.S. Typic Ustochrepts	61.81	0.8	60-108	Well to somewhat excessive	e2/e3	5.8	0.37	62-68	Poor (17)
5.	Very gentle sloping buried pediments-cultivated (BP1)	F.L. Aquic Haplustalfs F.L. Typic Endaqualfs	576.5	7.3	>150	Mod. Well to imperfect	e1	6.2-6.8	0.58	60-75	Average (25)
6.	Gentle sloping buried pediments-cultivated (BP2)	F.L. Typic Haplustalfs F.L. Typic Ustochrepts	2097.0	26.6	84-165	Moderately well	e1	5.8-6.1	0.56	55-60	Average (32)
7.	Moderate sloping buried pediments-cultivated (BP3)	C.L. Typic Ustochrepts F.L. Typic Ustochrepts	2038.0	25.8	65-150	Well	e1	5.2-6.0	0.50	57-65	Average (36)
8.	Moderate sloping buried pediments-forested (BP4)	F.L. Typic Ustochrepts F.L. Aquic Haplustulfs	950.8	12.1	95-155	Well	e1/e2	5.8-6.0	0.54	55-60	Average (30)
9.	Moderate sloping buried pediments-scurbs (BP5)	F.L. Typic Ustochrepts L.S. Typic Ustochrepts	66.2	0.8	85-135	Well	e2	5.6-6.0	0.12	45-57	Average (27)
10.	Nearly levelled valley fills (VF)	F.L. Aquic Ustochrepts F.L. Typic Endoaquepts	1005.0	12.7	120	Imperfect	e1	6.0-6.7	0.48	62-92	Poor (17)
	River	--	15.52	0.2							
	Total	--	7893.5	100.0							

1. Soil mapping unit codes are given in parenthesis which were used in GIS analysis.
2. L.S. : Loamy skeletal; C.L. = Coarse loamy; F.L. = Fine loamy

Spatial database : The physiographic-soil map (Fig. 1) comprising of polygons (mapping units) were digitized which forms the spatial database. The map was digitized in segment mode called segment map which in turn used to create polygon map. The polygon map, then, rasterized to carry out spatial analysis in GIS environment.

Non-spatial database : Non-spatial database in the present study consists of land quality factor ratings of soil moisture, drainage, soil depth, texture/structure, base saturation and organic matter of each soil mapping unit. These ratings were derived considering site, soil morphological, physical and chemical properties of soils. ILWIS GIS system has inbuilt table data structure to store the non-spatial data. Thus, one dimensional attribute table was created to store these non-spatial informations. This attribute table was linked to spatial data (physiographic-soil map) to carry out the spatial analysis.

Spatial analysis : Spatial analysis is the most important part of GIS applications. Map calculation of ILWIS has been used to carry out the spatial analysis. It integrates the spatial (soil map) and non-spatial (land quality attribute table) data to generate various land quality factor maps. Thus, soil map was reclassified using attribute table to generate six land quality rating factor maps viz. (i) soil moisture factor map, (ii) drainage factor map, (iii) effective soil depth factor map, (iv) soil texture/structure factor map, (v) base saturation factor map, and (vi) organic matter factor map.

Requier *et al.* (1970) model was employed in GIS environment to assess the soil productivity with reference to their spatial distribution and extent. The above generated factor maps were put into model to get index of soil productivity. This map was stored as integer value map. The map was classified into four soil productivity classes using "slicing" operation. It operates as a special attribute table which define range of index values to classify into one class value. Index values were categorized into four productivity classes (i) extremely poor (0-7), (ii) poor (8-19), (iii) average (20-34), (iv) good (35-64). A generalized flow diagram is shown in figure 3, applied to generate soil productivity map.

Results and discussion

Soil productivity class and their index value of various physiographic-soil mapping units are given in table 1 and figure 2. Soils in steep to very steep side slopes of denudational hill (DH2) map unit characterized by skeletal soils of coarse texture, deficient in soil moisture with moderate erosion show the lowest productivity index of 7 and classified as extremely poor in productivity. Soils of denuded hill top (DH1) are poor in productivity. Soils of weathered pediments have productivity index of 14 and 17 rated as poor in productivity because of coarse texture, low soil moisture content and moderate soil erosion of soils in the unit. Productivity of buried pediment soils are classified as average to good class. Very gentle to gentle sloping buried pediments have productivity index of 25 and 32 which fall under average productivity class due to imperfect to moderate drainage as major limitation for crop production. Soils of moderate sloping buried pediment map unit (BP4 and BP5) also fall under average productivity class (index value 27 to 30) whereas soils of moderate sloping buried pediments (BP3) are good in productivity (index value 36). Valley fills soils having productivity index of 17 rated as poor in productivity due to poor soil drainage condition limit the effective soil depth for cultivation of crops.

Soil productivity map provide valuable information to resource planners and decision makers with reference to spatial distribution and extent (Fig. 2 and Table 2) of productive soil to support increased food production. It helps in guiding them in input allocations as per soil productivity.

Table 2. Soil productivity classes and their aerial extents

Sr. No.	Soil productivity class	Area (ha)	Area (%)
1	Good	2038.0	25.8
2	Average	3690.5	46.7
3.	Poor	1567.4	19.9
4	Extremely poor	582.1	7.4
5.	River	15.5	0.2
	Total	7893.5	100.0

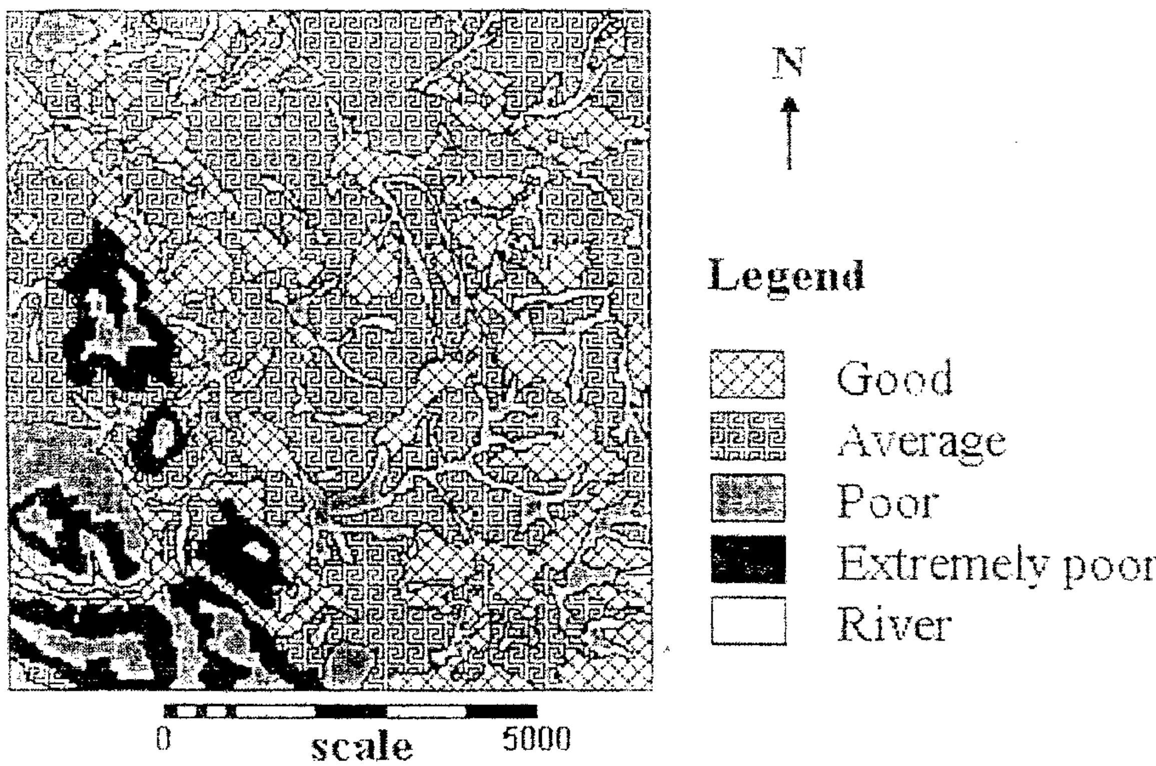

Fig. 2. Soil productivity map of the study area

The study concluded that Geographic Information System offers a effective approach to assess the soil productivity with reference to their spatial extent and distribution. Spatial modelling in GIS serve as an effective tool for planners and decision makers in making sustainable land use plan of an area. Its cartographic operation generates various thematic maps which help in understanding themes with reference to their spatial distribution and extent.

References

ITC (1997). The Integrated Land and Water Information System (ILWIS) : version 2.1 for windows. International Institute for Aerospace Survey and Earth Sciences (ITC), Enschede, The Netherlands.

Requier, J. Bramao, D.L., and Cornet, J.P. (1970). A new system of soil appraisal in terms of actual and potential aproductivity". (FAO:Rome).

Soil Survey Staff (1992). "Keys to Soil Taxonomy". (Soil Management Support Services (SMSS) Technical Monograph, 19 : Blackburg, Virginia.)

Sombroek, W., and Eger, H. (1996). What do we understand by land use planning : state of art report. *Entwicklung and Landlicher Raum* **2**, 3-7.

Verheye, W.H. (1996). Rating and definition of suitability classes : FAO approach for land evaluation. *Agropedology* **6**, 1-12.

Received: July, 1997; Accepted : October, 1999