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Original Research Paper

Land Resources Information System for Sustainable Land Use Planning

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ABSTRACT

Earth observation satellites provide the vantage point and coverage necessary for studying our planet as an integrated physical and biological system. Land use planning involves the inventory of the land resources and taking stock of the present scenario. Land use planning does not only involve suggesting alternate land use but also should consider factors, which affect the other types of land use. The present study can help in the reconnaissance survey of the area as well as integrating the information to look at different scenarios in the landscape and plan for sustainable use of the land. The approach has given good insight into the areas potential for alternate land use. The action plan prepared using this approach shall help the administrators in taking decisions regarding resource use and mobilization of support for a change. The action plan not only serves as a guide but also as a blue print for natural resource management for sustainable development. Compilation and collation of information of the area under study is the preliminary task in planning. The availability of remotely sensed data at high spatial and temporal resolutions has facilitated the planners to access natural resource information at a rate faster than never before. Land use map is the first map, which any planner would need to look at the extent of use to which the land is put. For purposes of planning at the district level the 1:50,000 maps generated using the IRS-P6 data were found to be suitable. Soil map and hydrogeomorphology map were the preliminary dataset generated from the satellite data. Information derived by integrating and analysing the above factors was produced as derivative maps which are the action plan maps.

INTRODUCTION

Till the recent past, land was looked in a narrow perspective of being a physical entity in terms of its topography and spatial nature. But the broader, integrative or holistic view, takes into account both, a vertical aspect-from atmospheric climate down to groundwater resources, and a horizontal aspect an identifiable repetitive sequence of soil, terrain, hydrological, vegetative and land use elements. Soil, water, flora and fauna are the important land resources, which together influence the survival of human beings by supporting food production and providing a congenial living environment. There was harmony among the mankind, the other living beings and the surrounding environment. Increasing needs of the growing population inevitably lead to agriculture and industrial development through haphazard usage of land resources which eventually disturb the ecological balance through pollution and declining quality of soil, water and atmosphere. In developing countries, especially in the most densely populated countries like India, there is an urgent need for immediate action as there will be pressure to make ad-hoc decisions and to push forward development schemes for social or political reasons.

For optimal utilization of available natural resources and for taking up any preventive or curative measures, timely and reliable information on natural resources with respect to their nature, extent and spatial distribution; and nature, magnitude and temporal behaviour of various type degraded lands, is a pre-requisite. Hitherto, such information has been generated through conventional approach using topographical sheets or areal photographs. Remote sensing has provided opportunity with synoptic view of a fairly large area with multi-spectral measurements at regular intervals and enabled generating information on natural resources in a timely and cost-effective manner.

Land Resources Information System: Advances in geo-information technology have created exciting possibilities of collecting and managing large amounts of data from earth resource processes in various forms and scales. Also social and economic data are increasingly available from census, development and health surveys, etc. For improved decision-making, the required information, tools, techniques, models and decision-making procedures have to become integrated in a user-friendly information processing system called "Land Resources Information System" (LRIS). In spatial modelling, multiple criteria methods allow for the presence of more than one objective or goal in a complex spatial problem. However, they assume that the problem is sufficiently precise that the goals and objectives can be defined exactly. Such problems require a flexible approach. The system should assist the user by providing a problem-solving environment. LRIS generally provides a framework for integrating: 1. Analytical modelling capabilities, 2. Database management systems, 3. Graphical display capabilities, 4. Tabular reporting capabilities, and 5. The decision-makers expert knowledge.

The objectives of the study: The main objective of the present study is to generate information/databases on 1:50,000 scale pertaining to drainage, surface water bodies, watershed, transport network, land use land cover, hydrogeomorphology, slope, soil and its related parameters like soil depth, water depth, gravelliness, etc. using multi-temporal satellite data. These databases are converted into digital form for future analysis and utilization and to prepare location specific land and water resources development plans by integrating with socio-economic data and contemporary technology in the GIS environment such that control of soil and moisture conservation and land degradation, optimal management of croplands and conservation and management of land and water resources can be achieved.

THE STUDY AREA

Zaheerabad mandal lies in the Medak district, which is situated in the Telangana region of Andhra Pradesh, India. Zaheerabad is located about 100 km from Hyderabad on the Mumbai-Hyderabad national highway (NH-9). The mandal is bounded on the north by Nyalkal, northeast by Jharasangam, southeast by Kohir mandals of Andhra Pradesh, and Gulbarga and Bidar of Karnataka state in west. The mandal lies between north latitudes 17°46' 22’ and 17°32' 32’ and east longitude 77°26' 42’ and falls in Survey of India Toposheet Nos. 56G/6, 56G/9 and 56G/10 of scale 1:50000 published by Survey of India in 1973. The total area of the study area is 392.15 sq. km.

MATERIALS AND METHODS

The following methodology was adopted in the present study to meet the objectives of the study. The base map is generated at 1:50,000 scale from the SOI Toposheet. The thematic layers like LULC, hydrogeomorphology, soil, slope, etc. are generated using the IRS P6 LISS IV images. Taking the SOI toposheets as source, the thematic layers like drainage and contours are prepared at 1:50,000 scales. The slope map is derived using Survey of India topographical sheets at 1:50000 scale with 20-metre contour interval. The rainfall, temperature and other collateral data of the study area were collected and integrated in the GIS domain. The DEM (Digital Elevation Model) was generated from the contours. The soil map was taken as the base for integration.

A scheme for thematic data integration and recommendation for various combinations of land parameters was evolved by observations in the field. Following the scheme of data integration, action plan maps were generated giving suitable site-specific recommendations for alternate land use and water conservation measures. While formulating the locale-specific action plan, the earlier research carried out by various research centres in the field of agriculture, etc., were taken into consideration along with the prevailing socioeconomic conditions. All these data, which are generated in the GIS domain, are used as inputs in the LRIS developed using the Map objects and VB. The LRIS is a package, which works independent of the GIS software and tools were created in the package in such that any user without the technical knowledge can also operate the package and can perform some of the functions like displaying the data, querying the data, overlay and union which are there in the GIS software.

RESULTS AND DISCUSSION

Sustainable agricultural land use and cropping pattern plans of the area are generated by GIS based logical integration of crop suitability, land productivity, land capability, socio-economic, and terrain characteristics information. Specific action plans are devised for optimum management of land and water resources through integration of information on natural resources, socio-economic and meteorological data and contemporary technology. An important task of LRIS is to facilitate the linkage between non-spatial data and the spatial data. The non-spatial data like census, socioeconomics, agricultural inputs, etc. would be available in tabular form and have to be retrieved from the relational database management system (RDBMS). On the other hand, the spatial information is in the form of maps, referenced to the geographic latitudes-longitudes. The non-spatial tabular information is linked to the spatial information through a customized GIS approach. This query shell facilitate data handling. The strength of GIS is the integration of multilayered data from different sources and various scales. The integration of different layers of information has been a difficult task manually until the maps were drawn on a transparent film. With the availability of GIS, which takes the data into digital space, the ability to see through maps, which are overlaid one over the other digitally, and analyse the maps is achieved. Database management systems integrated with graphic interface have a powerful query capability. This will finally give the analytical ability to pose complex query and extract information spatially.

Land Use/Land cover

The knowledge of spatial distribution of land cover/land use of large area is of great importance to regional planners and

Table 1: Areal extent of land use land cover classes.

Land use/Land cover category (LULC)	Area in sq.km	Area in %
Forest Plantation	3.00	0.76
Kharif Unirrigated	188.83	48.13
Scrub Forest	31.20	8
Double Crops	42.46	10.9
Land with Scrub	115.14	29.3
Land Without Scrub	5.71	1.5
Deciduous Forest	3.52	0.9
Fuel Wood species	0.96	0.2
Plantation	1.27	0.3
Barren rocky & Stony waste	0.04	0.01
Total	392.13	100

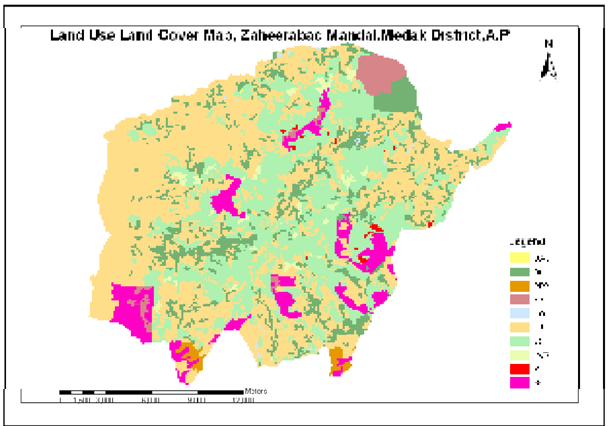

Fig. 1: Land use/land cover map of Zaheerabad mandal.

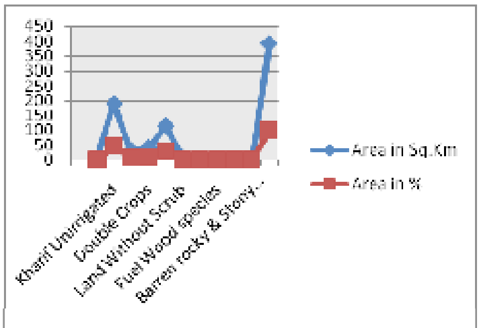

Fig. 2: Areal extent of land use land cover classes.

administrators. Conventional ground methods are time consuming and no uniform classification system was used in the preparation of maps, but with the advent of remote sensing technology the above problems have been solved to quite some extent. Satellite data can provide information on large areas and the temporal data can be utilized for change detection and updating old data. The land use/ land cover categories that can be obtained from the remotely sensed data include level I classes of land use classification system such as water bodies, forest, grassland, agricultural land, barren land and scrub land. The spatial distribution of the various land use land cover classes found in the study are given in Table 1 and Figs. 1 and 2.

Geology

The mandal is characterized by gently undulating topography with low hills, the highest elevation being 660m above M.S.L. at the central parts of Zaheerabad, and lowest 540m above M.S.L. at the southern part of this mandal. Highest elevation is extending from Gopanpalli in the central to Asadganj in the north; other one extends from Mugdampalli in the south-east to the Dhanaseri in the west in the district. Precambrian rocks, such as granite, adamellite, tonalite, amphibolite, and homlende boitite schist occupy a major part of the mandal. These formations were subjected to tectonism and greenschist facies metamorphism. Except for a portion in the western part of the mandal, most of the area is occupied by granites. All these rock formations are traversed by NE-SW and N-S trending dolerite dykes and vien quartz. The Deccan Traps and intertrappeans are seen at the central part of the mandal, extending up to the northern and western border of the mandal. The laterite copings are seen extensively around Zaheerabad. Two major lineaments are trending NE-SW direction from Hotibuzurg to Hyderabad and the another one is trending in the same direction near to Zaheerabad.

Geomorphology and Geohydrology

The mandal is covered under Godavari basin. Karanja Vagu is a major small river, which flows NW-NE direction in this mandal. The drainage pattern is dendritic in granite terrain and parallel in Deccan Traps. The hard rocks viz., Archeans and Deccan Traps occupy 79.35%, soft rocks viz., laterites 20.63%, and alluvium 0.2%. The depth to water table in granite varies from 4.5 to 199 m, in laterites from 5 to 30m and in alluvium from 0.5 to 7.5m. In Deccan Traps, water occurs in fractures, crevices and joints. A number of lineaments form the promising zones for groundwater development. Laterites are highly porous and permeable and possess good water bearing capacity. Groundwater is moderately hard and required to be softened before use. The land forms in the district are mostly structural, denudation and fluvial in origin. In the northern parts, crystalline complex represented by meta sediments, gneisses and granite forms a distinct pediplain. This unit resulting out of the denudational process comprises landforms like residual hills, inselberg and shallow weathered pediplain. In the western part, landforms are of moderately dissected plateau.

Hydrogeomorphology: Hydrogeomorphology deals with the study of landform in relation to groundwater occurrence and availability. It is manifested at the surface, mainly by geology, geomorphology, structure and recharge conditions. All

Table 2: Various geomorphic units in Zaheerabad.

S.No.	Map Unit	Geomorphic Unit	Litho Unit	Structure	Description
1	FV	Filled-in-Valley (FV)	Laterrite	Concretionery detrital laterite resting over the lithomargic clays.	Broad valleys formed due to removal of hard crust of laterite consisting of detrital/concretionary laterite.
2	MDP	Highly Dissected Plateau (MDP)	Deccan Trap (Volcanic Flows)	Flat to gently dipping volcanic flows (10-20 m thick each). Individual flows are hard and massive at bottom grading to vesicular or tuffaceous at top. Thin clay/grey earth beds mark the contacts between the flows.	Upland areas dissected by 5-15 m deep narrow valleys.
3	P1	Pediment Inselberg Complex (PI)	Peninsular Gneiss and Granite	Massive granite and foliated gneiss, traversed by joints, fractures and faults.	Gently undulating rock cut plain with small hills and rock out crops.

the four parameters were studied and integrated to arrive at the groundwater prospects under each geomorphic cum lithologic unit, designated as hydrogeomorphic unit. The following geomorphic units, mapped in the Zaheerabad mandal at 1:50,000 scale, are listed in Table 2.

Groundwater potential map: Groundwater potential maps were prepared by integrating information on geomorphology, slope lithology, structural features and the precipitation. Groundwater recharge depends on favourable slope, permeability and degree of compactness of the rocks. The movement and occurrence of groundwater is controlled mainly by geology, geomorphology and recharge conditions of the area. The geology and geomorphology of the study area have been studied by combining the individual litholo-landform units and the geomorphology map was prepared. These geomorphic units have been evaluated for their groundwater prospects based on the hydrogeological characteristics of the geological and geomorphological parameters. Salient features of various ground water potential zone units, delineated in the Zaheerabad mandal are given below.

Zone I: It consists of geomorphologic units like filled in valley. The groundwater potential is good in this zone. The material in filled in valley is made up of flat to gently dipping volcanic flows of 10-20 cm thickness each. The individual flows are hard and massive at bottom grading to vescuilar at the top. Thin clay earth beds mark the contact between the flows. These are gently undulating wide valley floors with good recharge from MDP2, HDP2 and SDP2. The groundwater potential in the weathered zones and also along faults/fractures is suitable for dug wells and bore wells respectively. The contact zones between trap and granitic basement often form good aquifers. The filled in valley is made up of concretionary detrital literate resting over the lithomargic clays. These are broad valleys formed due to removal of hard crust of laterite consisting of detrital laterite. It is suitable for good yields for dug, bore wells and tube wells. The potential will be better along faults and fractures.

Zone II: It consists of geomorphologic units like moderately dissected plateau (MDP2). The groundwater potential in this zone is moderate.

The lithographic unit is Deccan Trap (volcanic flow). These are upland areas, which are dissected by greater than 5 metre deep narrow valleys. These are flat to gently dipping volcanic flows with a depth of 10-20 m thickness each. Individual flows are hard and massive at bottom grading to vesicular at top. The clay earth bed marks the contacts between the flows. It has limited to moderate potential in the weathered zones along narrow valleys. It has moderate to good potential suitable for deep bore wells along the fault and fracture zones.

Zone III: It consists of geomorphologic units Pediment Inselberg Complex (PL4). The groundwater potential in this zone is moderate to poor.

The lithographic unit is peninsular gneiss and granite. These are gently undulating rock cut plains with small hills and rock outcrops. These are made up of massive granite and foliated gneiss, which are traversed by joints, fractures and faults. They have moderate potential along faults and fractures, which are suitable for bore wells subject to recharge.

The areal extent of the various geomorphic units with the groundwater potential for the Zaheerabad mandal is given in Table 3 and Figs. 3 and 4.

Soils

The district exhibits a variety of soils. Black cotton soil ranging in thickness from 0.3 to 0.75m occurs in Zaheerabad, Tumkund, Kotur and Didgi villages. Red soil ranges in thickness from 0.75 to 2 m. It possesses high water retention capacity. Major part of the district is arable unirrigated land around Zaheerabad. Around 17 soil series were mapped for

Table 3: Areal extent of geomorphic units of Zaheerabad Mandal.

Geomorphic Units	Ground water Potential	Area in sq.km	Area in %
Moderately Thick Lateritic Plateau	Moderate	84.05	21.43
Moderately Thick Lateritic Valley	Moderate to Good	141.80	36.17
Thick Lateritic Plateau	Moderate to Poor	166.28	42.40
Total		392.13	100.00

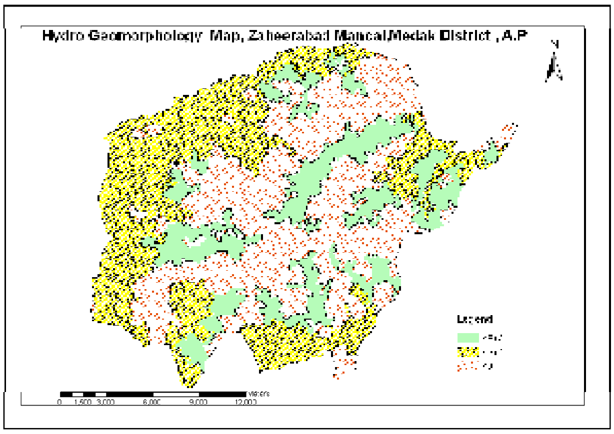

Fig. 3: Hydrogeomorphology map of Zheerabad mandal.

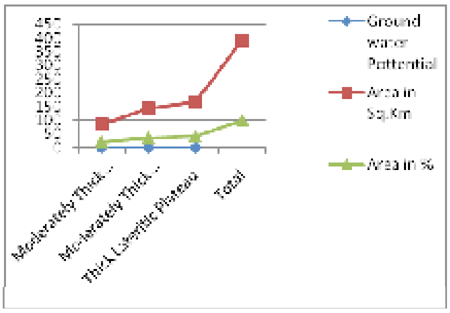

Fig. 4: Areal extent of geomorphic units of Zaheerabad mandal.

the entire mandal using the satellite imageries and field survey at 1:50,000 (Fig. 5).

Derived Soil Parameters

Soil-site and other land characteristics studied and recorded during field data collection and mapping have been interpreted and the soil map units grouped with respect to the major soil attributes such as soil depth (effective rooting depth), surface soil texture, gravelliness and stoniness, soil drainage, soil available-water capacity, soil slope, soil erosion, calcareousness, etc. Such interpretative grouping of soil and land characteristics help in identifying areas that have specific problems like shallow rooting depth, severe erosion,

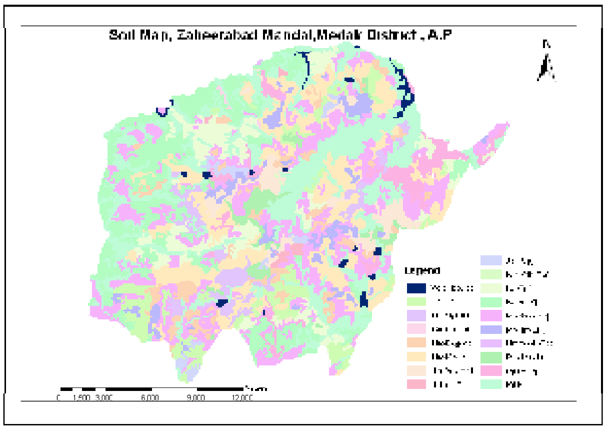

Fig. 5: Soil map of Zheerabad mandal.

poorly drained areas, sandy areas, steeply sloping lands, salt affected lands, etc., and areas that have high potential like very deep soils, non-gravelly soils, nonsaline or level areas etc. for sustained agricultural and non-agricultural uses.

Soil depth: Soil depth determines to a great extent the rooting system of plants, which is ultimately reflected in crop growth and crop yield. It determines the capacity of the soil column to hold water and supply plant nutrients in relation to soil texture, mineralogy and gravel content. The extent of area under each depth-class association for the study area is given in Table 4 and Figs. 6 and 7.

Table 4: Areal extent of soil depth units.

Mapping Unit	Description	Area in sq. km	Area in %
2	Extremely Shallow	98.99	25.24
3	Shallow	79.52	20.28
4	Moderately Shallow	17.36	4.43
7	Very Deep	192.10	48.99
	Water Bodies	4.16	1.06
	Total	392.13	

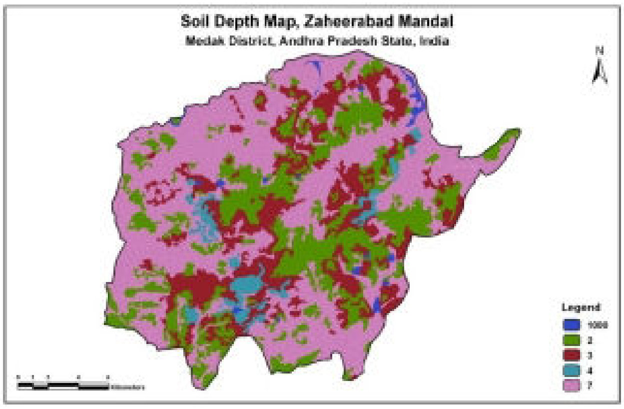

Fig. 6: Soil depth map of Zheerabad mandal.

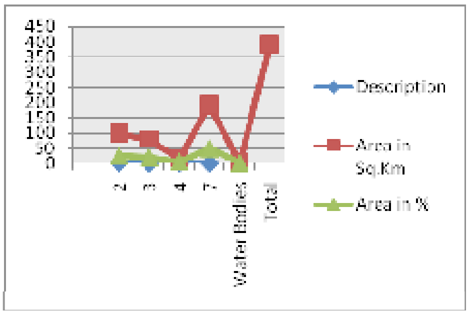

Fig. 7: Areal extent of soil depth units.

Soil erosion: Soil erosion refers to the wearing away of the earth's surface by the forces of water, wind and ice. It is both destructive and constructive. It is responsible for causing variations in topography by eroding elevated land surfaces and at the same time depositing the eroded material in the plains, basins and valleys. It is further aggravated by human intervention through indiscriminate felling of trees, overgrazing, mining, and cultivation on steep slopes and degraded lands, thus affecting the natural ecosystems. Based on the intensity of erosion as observed visually during field survey and mapping, and also the amount of soil (loss of A or B horizons) removed in the soil profiles examined, the soils of study area have been classified under three erosion classes viz., e1-nil or slight erosion, e2-moderate erosion and e3-severe erosion.

Soil calcareousness: Calcareousness (lime content) is the term used to indicate the content of calcium carbonate in the soil. In the field, it is estimated by observation of the effervescence given by the soil when it is moistened with dilute hydrochloric acid. Soil calcareousness classes used were 0-nil effervescence (non-calcareous), 1-slight effervescence (slightly calcareous), 2-strong effervescence (strongly calcareous). Calcareousness influences soil pH and the availability of macronutrients and micronutrients. Physical conditions of soils are also greatly influenced by the quantity and size of lime nodules and concretions. The extent of area under each calcareousness class association for the study area is given in Table 5 and Figs 8 and 9.

Soil available-water capacity: Available-water capacity (AWC) of soils is mainly dependent on the amount, intensity and distribution of rainfall, infiltration, permeability, drainage and texture, type of clay minerals, soil depth and content of coarse fragments. Classes of soil available-water capacity are based on the ability of soil column to retain water between the tensions of 0.33 kPa and 15 kPa in a depth of 100 cm soil or the entire column if the soil is shallow. The AWC of soils of the study area estimated from soil depth, gravel and stone and mineralogy can help in determining the length of crop growing period which helps in land use planning. The AWC classes used for grouping the soils of the district were (1) very low (< 50mm m^{-1}), (2) low (50-100 mm m^{-1}), (3) medium (100- 150 mm m^{-1}), (4) high (150-200 mm m^{-1}), and (5) very high (>200 mm m^{-1}). The extent of area under each AWC class association for the study area is given in Table 6 and Figs. 10 and 11.

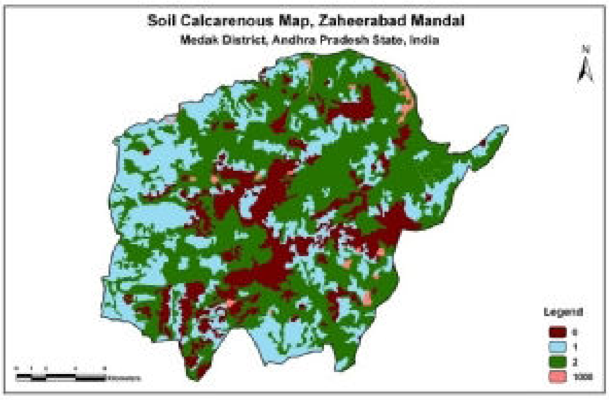

Fig. 8: Soil calcareousness map of Zheerabad mandal.

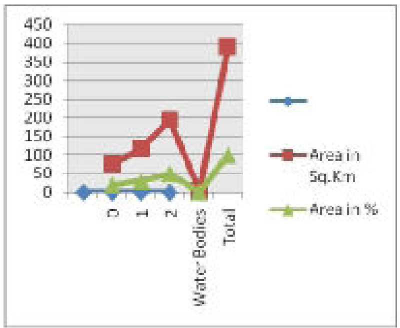

Fig. 9: Areal extent of soil calcareousness units.

Table 5: Areal extent of soil calcareousness units.

Mapping Unit	Description	Area in sq. km	Area in %
0	0- 15% Non gravelly	76.04	19.39
1	15-35 % Slightly gravelly	117.365	29.93
2	35 -60 % Gravelly	194.58	49.62
	Water Bodies	4.16	1.06
	Total	392.13	100.00

Table 6: Areal extent of soil water capacity units.

Mapping Unit	Description	Area in sq. km	Area in %
1	Very Low	189.17	48.24
2	Low	44.28	11.29
5	Very High	154.52	39.41
	Water Bodies	4.16	1.06
	Total	392.13	100.00

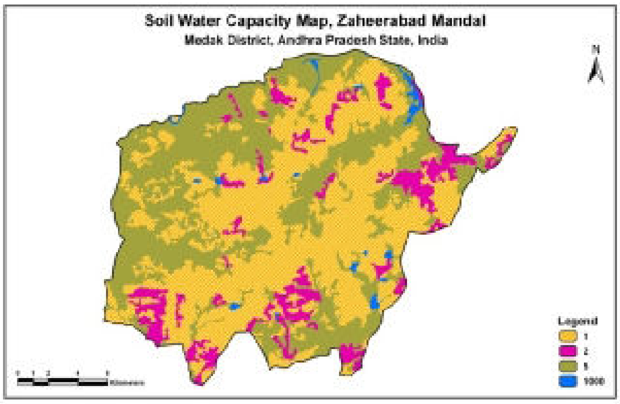

Fig. 10: Soil water capacity map of Zheerabad mandal.

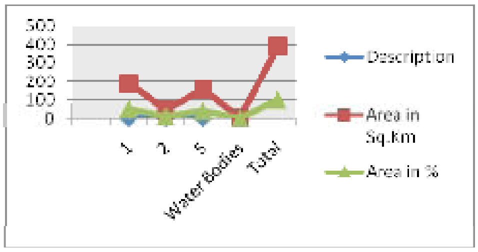

Fig. 11: Areal extent of soil water capacity units.

Graveliness and stoniness: Gravel is the term used for describing coarse fragments between 2 mm and 7.5 cm diameter, and stones between 7.5 cm to 25 cm. The presence of gravel and stones in soils reduces the volume of soil that affects moisture storage, drainage, infiltration and runoff, and hinders plant growth by impeding root growth and seedling emergence, intercultural operations and farm mechanization. The gravel and stone content by volume for each of the soil horizon, as well as on the surface recorded during soil survey were used for grouping the soils into different gravelly or stony classes. The gravelly and stony classes used were (1) g0-non-gravelly (0-15% gravel), (2) g1-slightly gravelly (15-35% gravel), (3) g2-moderately gravelly (35-60% gravel), (4) g3-strongly gravelly (60-90% gravel), and (5) st5-strongly stony (> 90% stones). The extent of area under each gravelliness/stoniness class association for the study area is given in Table 7 and Figs. 12 and 13.

Slope

Slope refers to the inclination of the surface of the land. It is defined by gradient, shape and length, and is an integral part of any soil as a natural body. The length and gradient of slope influences soil formation and soil depth, which in turn affects land development and land use. Around 97 sq.km of area under mandal is level to nearly level slope, 220 sq.km of area is under very gently sloping lands, and 72 sq.km is covered under gently sloping land. The areal extent of various slope categories in given in Table 8 and Figs. 14 and 15.

Table 7: Areal extent of soil texture units.

Mapping Unit	Description	Area in sq. km	Area in %
C	Clay	189.17	48.24
GC	Low	44.28	11.29
GSC	Very High	154.52	39.41
	Water Bodies	4.16	1.06
	Total	392.13	100.00

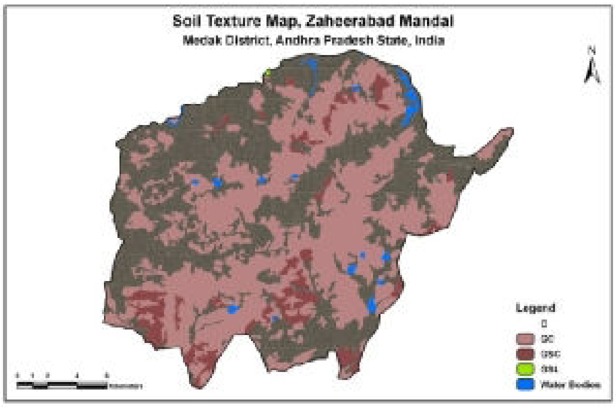

Fig. 12: Soil water capacity map of Zheerabad mandal.

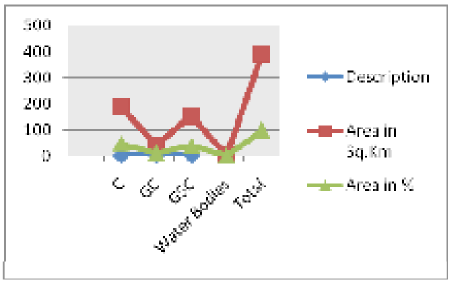

Fig. 13: Areal extent of soil texture units.

Table 8: Areal extent of slope units.

Slope Categories	Description	Area in sq. km	Area in %
A (0-1%)	Level to Nearly Level	97.07	24.76
B (1- 3%)	Very Gently Sloping	219.20	55.90
C (3 – 8%)	Gently Sloping	71.70	18.28
	Water Bodies	4.16	1.06
	Total	392.13	100.00

Land Evaluation Methods

Soil map provides the user with information about the soil and land form conditions at any site of interest (Young 1976). Soil maps are produced to suit the needs of users with widely different problems because they contain considerable detail

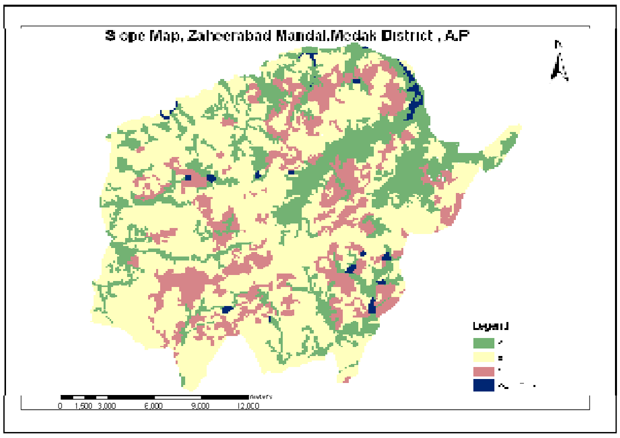

Fig. 14: Slope map of Zheerabad mandal.

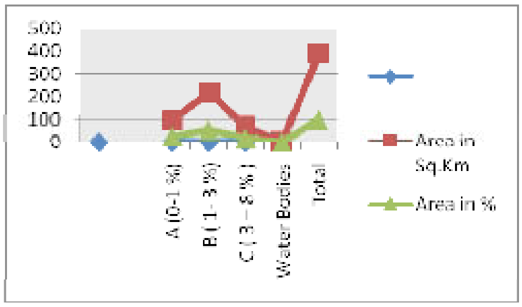

Fig. 15: Areal extent of slope units.

to show basic soil differences (Klingebiel 1966). Land evaluation is a tool for strategic land-use planning. It predicts land performance, both in terms expected benefits from and constraints to productive land use, as well as the expected environmental degradation due to these uses (Rossiter 1996). There are various land evaluation methods used for assessing the potential and productivity of soil for agricultural purposes. Some of them can be listed as below: 1. Land capability classification, 2. Soil and land irrigability classification.

Land capability classification: Land capability classification is an interpretative grouping of soils to show the capability of different soils to produce field crops or to be put to other alternative uses such as pasture, forestry, as habitat for wildlife, recreation, etc. on a sustained basis. It is based on inherent soil characteristics, external land features and other environmental factors that limit use of the land (IARI 1970). Eight land capability classes were identified. Soils suitable for agriculture are grouped under Classes I to IV according their limitations for sustained agricultural production. Soils not suitable for agriculture are grouped under Classes V to VIII for use for pasture, forestry, recreation purposes, quarrying and mining, and as habitat for wildlife. The land capability classes have subclasses to indicate the dominant limitation for agricultural use. Four kinds of limitations are recognized at the subclass level and denoted by 'e' for problems caused by water and wind erosion, 'w' for problems of drainage, wetness or overflow, 's' for soil limitations affecting plant growth like soil depth, heavy clay or sandy texture, gravelliness and stoniness, salinity or sodicity etc., and 'c' for climate limitation. The areal extents are given in Table 9 and Figs. 16 and 17.

Table 9: Areal extent of land capability units.

Land Capability Units	Area in Sq. km	Area in %
II ES	98.25	25.05
III ES	90.46	23.07
III WS	94.96	24.31
IV ES	104.3	26.60
Water Bodies	4.16	1.06
Total	392.13	100.00

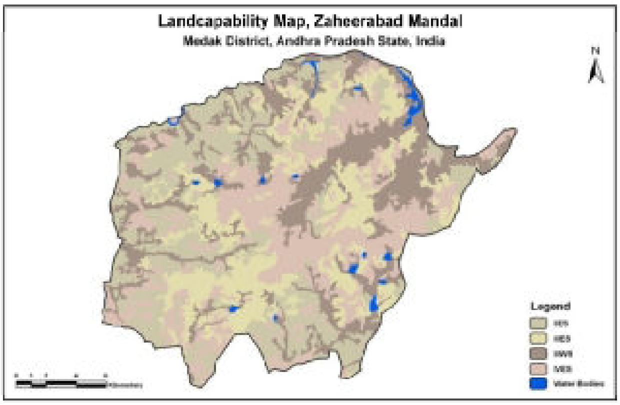

Fig. 16: Land capability map of Zheerabad mandal.

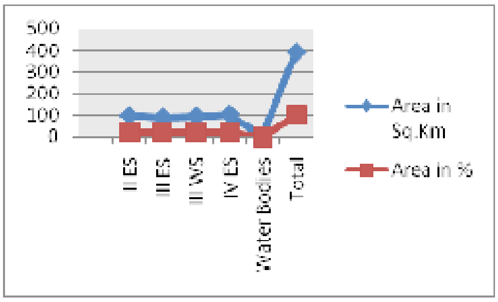

Fig. 17: Areal extent of land capability units.

Land irrigability: Land irrigability classification is primarily concerned with predicting the behaviour of soils under the greatly altered water regime brought about by introduction of irrigation. Land irrigability classification is an interpretative grouping of soil map units into soil irrigability classes based on the degree of limitations for sustained use under irrigation and on physical and socio-economic factors (IARI 1970). Soil irrigability classes are assigned without regard to the availability of irrigation water, water quality, land preparation costs, availability of drainage outfalls and other non soil related factors. Five soil irrigability classes are recognized. They are Class A (none to slight soil limitations), Class B (moderate soil limitations), Class C (severe soil limitations), Class D (very severe soil limitations) and Class E (not suited for irrigation).

The suitability of land for irrigation depends on the quality and quantity of water, drainage requirements and other economic considerations in addition to the soil irrigability class. Lands suitable for irrigation are grouped under classes 1 to 4 according to their limitations. Lands not suitable for irrigation are grouped under class 5 (temporarily classed as not suitable pending further investigations) and class 6 (permanently not suitable). Land irrigability classes have subclasses to indicate the dominant limitations for sustained use under irrigation. Three subclasses based on limitations are recognized and denoted by 's' for soil limitations such as heavy clay or sandy texture, soil depth, gravelliness and stoniness, 'd' for drainage problems and 't' for limitations of topography. The areal extents of various land irrigability are mentioned in the Table 10 and Figs. 18 and 19.

Table 10: Areal extent of land irrigability units.

Land Irrigability Units	Area in sq. km	Area in %
2ST	31.44	8.02
3DS	165.16	42.12
3ST	20 .36	5.20
4ST	94.06	23.98
6ST	76.95	19.62
Water Bodies	4.16	1.06
Total	392.13	100.00

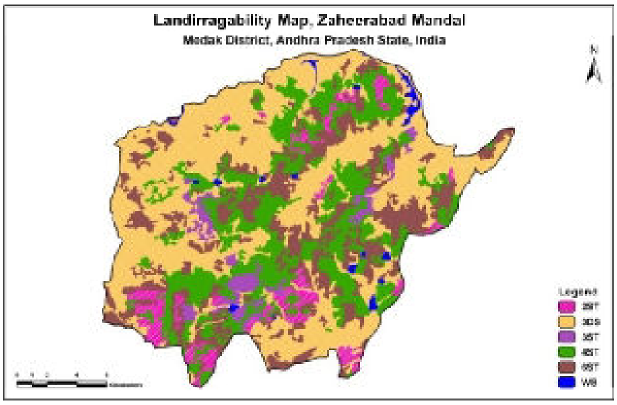

Fig. 18: Land irrigability map of Zheerabad mandal.

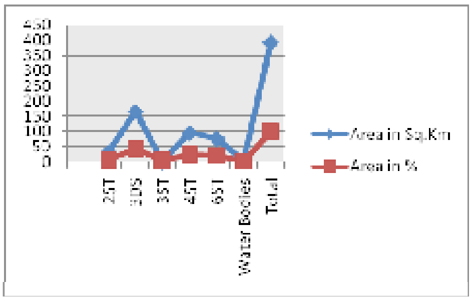

Fig. 19: Areal extent of land irrigability units.

Finalization of Action Plan

To analyse and integrate spatial data using GIS, the thematic maps were digitized, coded and stored using GIS software packages. Intersection of various theme maps was done progressively overlaying one layer over the other, and by applying suitable decision criteria developed for that area. The final composite units bring out various types of homogeneous units/polygons. These would fit into the decision rules/recommendation arrived at. The draft action plan is discussed with the department officials, district administration, local research centres, NGOs working in the area and some progressive farmers for their feedback. Such feedback is critically evaluated considering the concept of sustainability for suitable modifications/improvements. Subsequently, the draft action plan is validated on the ground before being finalized.

CONCLUSIONS AND RECOMMENDATIONS

The soil and land resource units of Zaheerabad mandal were assessed and evaluated for their suitability for growing rice, sorghum, maize, sugarcane, cotton, green gram, black gram, bengal gram, red gram, groundnut, sunflower, soybean, safflower, castor and guava, which are the major crops grown in different parts of the mandal. The parametric approach of Sys (1985), which is a modified version of the FAO Framework for Land Evaluation (1976) was used for evaluating the land suitability. The Framework for Land Evaluation has recognized two orders, namely, order S - suitable for agriculture and order N - not suitable for agriculture. These orders are further subdivided into classes, subclasses and units. Order S has three classes, highly suitable - S1, moderately suitable - S2, and marginally suitable - S3. Order N has two classes, N1 - currently not suitable and N2 - permanently not suitable for agriculture. The criteria assumed for differentiating into - e classes are that, under a given management level specified to obtain optimum yield from a highly suitable land (Sl), the maximum reduction in yield successively may be in the order of about 25% for S2 and 50% for S3 classes. The suitability subclass reflects the kinds of limitations and indicates the kind of land improvements required within a class. The subclasses are indicated by the symbol using-lower case letters following the arabic numeral (c-climate, e-erosion hazard, f-flood hazard, g-gravelliness, k-workability, i-topography, m-moisture availability, n-nutrient availability, p-crusting, r-rooting condition, t-texture, w-

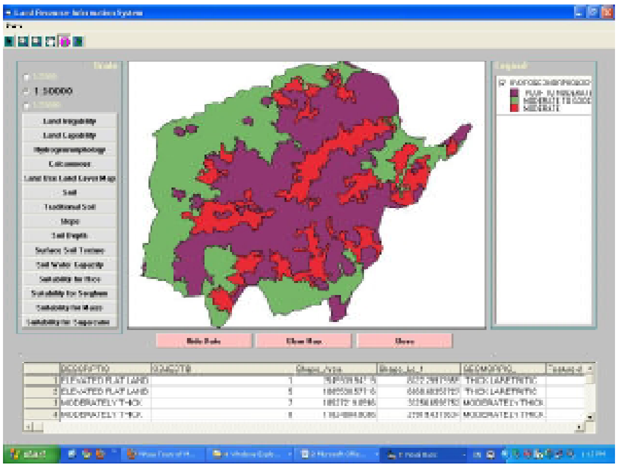

Fig. 20: Snap shots of LRIS for thematic layers.

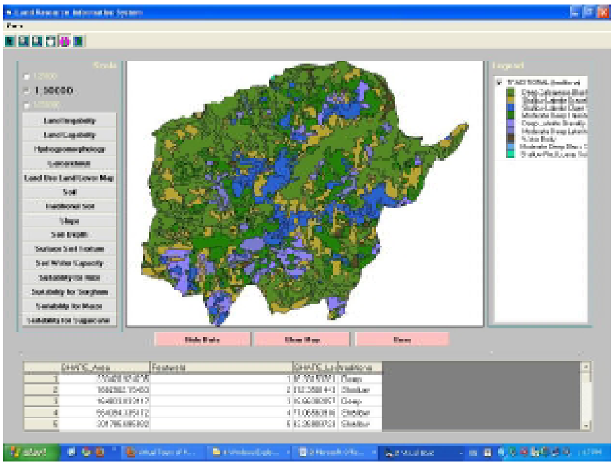

Fig. 21: Snap shots of LRIS for thematic layers.

drainage, z-excess of salts/calcareousness). The suitability evaluation shows the areas that are highly suitable (class S1), moderately suitable (subclasses of S2), marginally suitable (subclasses of S3), currently not suitable (class N1), and permanently not suitable (class N2) for each crop.

Land suitability for rice: The land suitability assessment revealed that there are 4 suitability classes, 5 subclasses and 14 subclass associations with different kinds and degree of limitations. About 13358 ha (27.79 %) area has been rated as moderately suitable in the mandal, 21614 ha (46.31 %) area as marginally, and 14186 ha (43.60 %) area as unsuitable (N2) for growing rice crop.

Land suitability for sorghum: The land suitability evaluation showed that there are 4 suitability classes, 5 subclasses and 17 subclass associations with different kinds and degree of limitations.

Land suitability for maize: The suitability evaluation indicated that there are 4 suitability classes, 6 subclasses and 16 associations of subclasses with different kinds and degree of limitations. About 10498 ha (21.01%) area has been rated as highly suitable (S1) in the mandal, 22940 ha (46.31%) area as moderately suitable (S2), 2862 (5.79 %) area as marginally suitable (S3), and 13322 (26.89%) area as unsuitable (N2) for growing maize crop.

Land suitability for sugarcane: The land suitability evaluation showed that there are 4 suitability classes, 5 subclasses and 15 subclass associations with different kinds and degree of limitations. About 10246 ha (20.64 % TGA) area has been rated as highly suitable (S1) in the mandal, 15646 ha (31.53 %) area as moderately suitable (S2), 16745 ha (33.75 %) area as marginally suitable (S3), and 6985ha (14.07%) area as unsuitable (N2) for growing sugarcane crop.

The LRIS was designed for all the thematic layers generated in order to enable the users to work without help of traditional costly software. The LRIS is a customized application which can be loaded in any system free of cost and be used by any person without formal training in GIS software. It has some limited GIS query and analysis functions. The snap shots of the LRIS for few thematic layers are shown in Figs. 20 and 21.

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