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LAND USE MODELING FOR SUSTAINABLE RURAL DEVELOPMENT

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Abstract: The developmental activities during the past few decades have focused on exploitation of land and water, the most precious natural resources with total disregard to proper management and ecological impacts. As a result the land is losing its resilience at an alarming rate threatening the livelihood of millions of people and constraining the ability to develop a healthy natural/ agricultural resource base. Therefore sustainable land development and land management are among the greatest challenges posed to the administrators and planners and require comprehensive action programmes aimed at optimal utilization of available resource potential. The comprehensive action plans call for optimal land use models to entail harmonious development of physical and biotic resources of an area. The present study is an attempt to develop an optimal land use model for Amadalavalasa a typical rural mandal in Srikakulam district of Andhra Pradesh. Spatial information of geology & lineaments, geomorphology, surface water resources, soils, slope and land use/land cover are the major inputs required for developing the optimal land use model. Image processing techniques in conjunction with GIS techniques have been appropriately used to delineate, vectorise and integrate the thematic layers to derive a composite map. The Composite map is further generalized to derive optimal land use model with seven land use categories viz. intensive agriculture, irrigated dry crops, dry crops, horticulture, silvipasture, social forestry and quarrying. Based on the analysis of all input factors conservation measures have been suggested.
Key words: Sustainable development, Natural resources, Land use Modeling, Resource conservation.

Introduction

Land and water, the most pristine natural resources and the basic elements of life support system have been subjected to a variety of pressures for the past few decades. Increasing population and the associated developmental activities focused on exploitation of these natural resources with total disregard to proper management and ecological impacts have resulted in environmental degradation. Consequently the land is losing its resilience at an alarming rate threatening the livelihood as well as food security of millions of people and constraining the ability to develop a healthy natural/agricultural resource base. This situation calls upon scientific appraisal and sustainable measures to increase the efficiency of limited natural resources at the disposal and optimizing the use without any adverse consequences. Sustainable land development ensures and enhances better resource conservation and promotes long-term sustainability which is basic to future food production and to the economic welfare of rural communities. Managing and developing the land resources without endangering the environment is a crucial issue the world is facing today (Kachhwaha (1985), Khorram & John (1991), and Sharma& Bohra (1989). Any systematic attempt to address sustainable development planning should include a comprehensive action programme aimed at optimal utilization of available resource potential. Comprehensive plans have become common because development is complex, decisions are interrelated and the development process necessitates careful analysis, foresight and planning. Comprehensive land use modeling involves harmonious development of physical and biotic resources of an area. It is therefore imperative to exploit all the available technologies and sciences for improving the sustainability of rural areas. Krishna Murthy et al (1994), Singh & Gajbhiye (2004) and Suneetha & Tata Babu (2007) have effectively used remote sensing & GIS techniques for developing appropriate methodologies and models for developing pragmatic development plans consistent with resource potential and problems. The objective of the present study is to develop an optimal land use model, suitable for rural development planning at micro level and Amadalavalasa a typical rural mandal in Srikakulam district of Andhra Pradesh has been chosen for the study.

Study Area

Amadalavalasa mandal lies in the central part of Srikakulam district between $18^0 20' 46''$ – $18^0 27' 20''$ latitudes and $83^0 49'5''$ – $83^0 56'26''$ longitudes. The study area is a plain region and the economy is predominantly agricultural. Agriculture is characterized by both rain fed and canal farming. As the source of canals being seasonal river, it is true that irrigational crops too depend on monsoon rains.

Data and Methodology

The IRS-P6 LISS III image of February 2006 and survey of India topographic map (No. 65 N/15 on 1:50,000 scale) are the primary input for classification and mapping the resources. ERDAS imagine has been used for image processing operations. Techniques like stratification, directional filtering, layered approach, composition, aggregation and refinements are applied wherever necessary to improve the quality of mapping. Thematic maps of geomorphology, geology, lineaments, soils, land use/land cover, drainage and slope have been extracted from satellite image and topographic map as well, incorporating the ground truth. The integration of spatial data, manipulation and analysis are carried out using Arc GIS software. The vectorised thematic maps from the corresponding map files have been overlaid and integrated to derive the composite map. Based on the analysis of the Composite Map Units (CMUs) which consists of multilayered information and with due consideration of field observations, the composite map is further generalized and the optimal land use model has been generated.

Data Analysis and Discussion

The thematic maps of hydro-geomorphology (Fig1-A), slope (Fig.1-B), soil (Fig.2-A) and land use/land cover (Fig. 2-B) are derived, interpreted and integrated for generating land use model for sustainable development of the study area.

Hydrogeomorphology:

Hydrogeomorphology deals with the ground water occurrence and its distribution. Ground water potential of any area depends on its geology (rock type) geological structure (lineaments, fractures etc.) geomorphic features (land forms) and their hydrological characters. Variations in availability of water in time, quantity and quality can cause significant fluctuations in the economic well being of a country especially agrarian economy. The ever increasing pressure of growing population on water resources for both drinking and irrigation calls for exploration and optimal utilization of water resources. Identification and mapping of these elements is thus imperative for ground water exploration and optimal management of this precious resource.

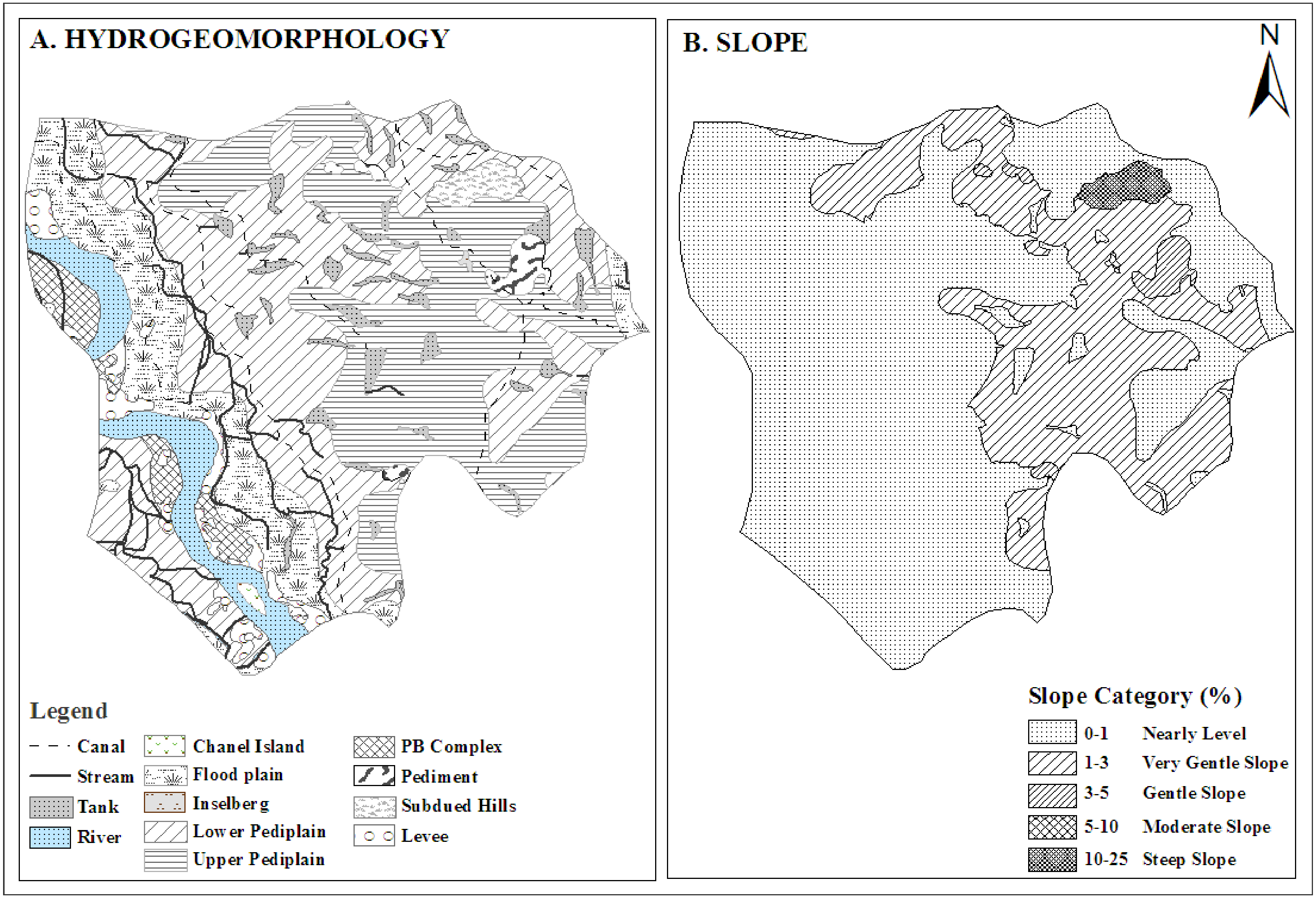

Fig-1. (A) Hydrogeomorphology and (B) Slope Maps of the study Area

Thematic maps of geomorphology, geology, lineaments have been generated from visual interpretation of satellite image. The drainage and surface water bodies have been digitized from both satellite and SOI topographic map. The vectorised thematic maps from the corresponding map files have been integrated to generate the composite hydro geomorphology map. The map is further generalized considering the field information. Fig-1-A shows the hydrogeomorphic features of the study area. Based on landform, genesis, geology, soils etc. nine hydrogeomorphic units viz. Flood Plain (FP), Inselberg (I), Lower Pediplain (LP), Upper Pediplain (UP), PB Complex (PB), Pediment (Pd), Structural hill (SH) and Levee have been identified. In general most of the study area has good ground water potential. A small pocket in the north-eastern part alone is graded as poor with respect to ground water potential essentially due to its structure.

Slope

Slope is a very significant factor from the view point of land utilization as its aspect and altitude are the major controlling attributes in land use planning. Slope is the degree of inclination of the surface from the horizontal expressed in percent of degrees. Slope map has been derived from the contour values on the topographical map following the guidelines of soil survey manual (1971) and five slope categories have been demarcated as represented in figure 1.B. Most of the study area has nearly level and very gentle slope categories. The entire western half, a few of the northeast and southeast parts is covered by nearly level slopes. The eastern part is dominantly covered by very gentle slope. A few patches of gentle slope and steep slopes are observed in the eastern part of the study area.

Soils

Soils differ greatly in their morphological, physical, chemical and mineralogical properties. These differences affect the response of the soils to agricultural inputs. For appraising the productivity of the soils and also for preparation of perspective land use plan for sustainable development a thorough knowledge of the distribution of different types of soils is essential. False colour composite has been visually interpreted with the help of topographical map to extract the soil map and presented in figure 2-A. Soil series information and field information were also incorporated to establish the soil taxonomy. Four map units have been identified in the mandal and their taxonomy and characteristics are presented in table 1. Soils in the study area are mostly clayey and are associated with loamy soils at few places.

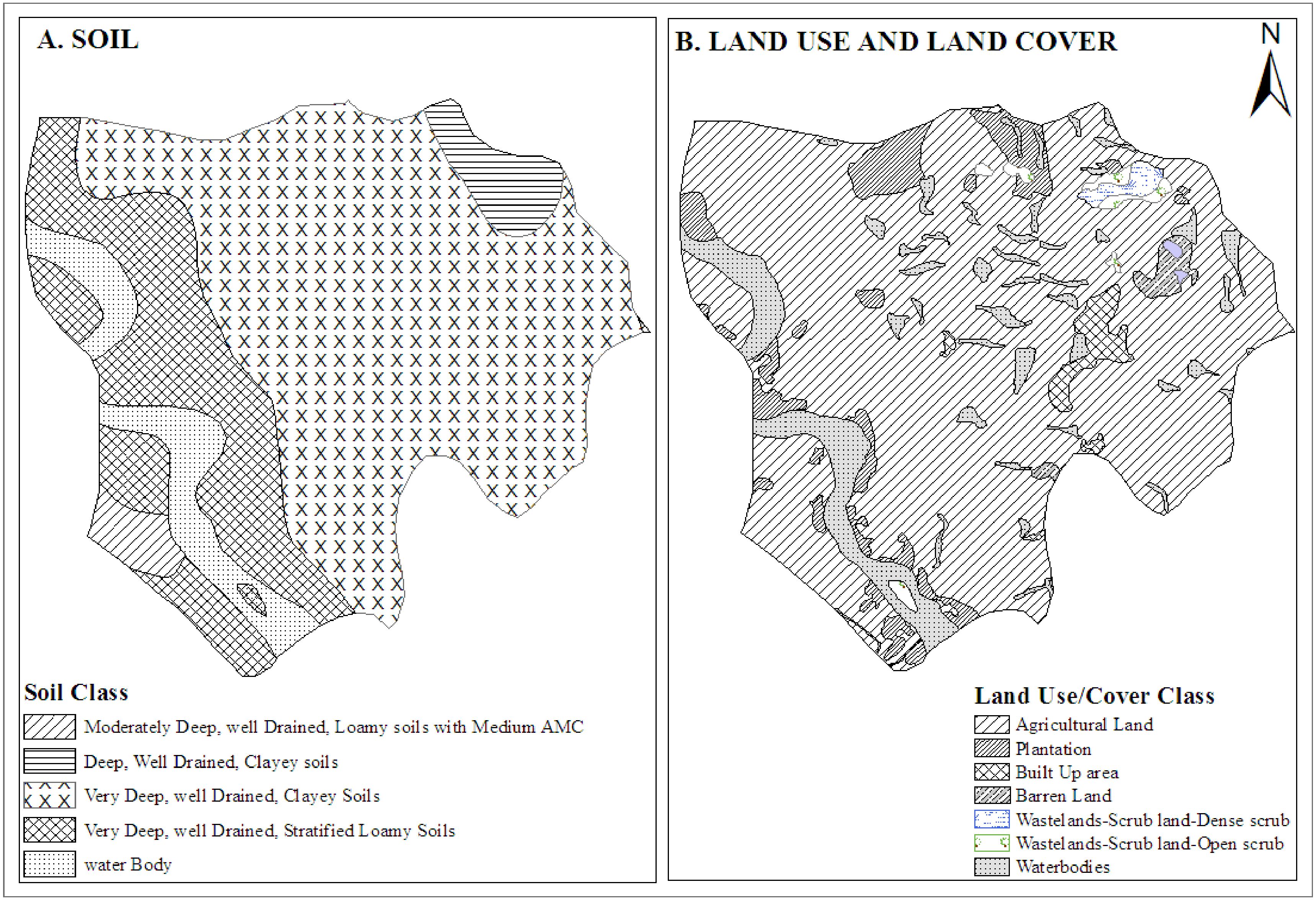

Fig-2. (A) Soil & (B) Land Use and Cover Maps of the Study Area

Table.1 Soil Taxonomy & Characteristics

Mapping unit	Description	Soil Taxonomy
1	Very Deep, Well Drained, Clayey soils with surface crusting and medium AWE, on gently sloping lands, moderately eroded; Associated with: Deep, well Drained, Clayey soils	Fine, Mixed, Rhodic Paleustalts
2	Deep, Well Drained, Loamy Soils with high AWC, on gently sloping lands, Moderately eroded; Associated with: Moderately deep, well drained, loamy soils with medium AMC	Fine loamy, mixed, Typic Haplustalfs Fine loamy, Mixed, Typic Ustropepts
3	Deep, well Drained, Clayey Soils with AWC, on very gently sloping plains, slightly eroded, Associated with: very deep, well drained, clayey soils.	Fine, Mixed, Typic Ustropepts Fine, Mixed, Typic Haplustalts
4	Deep, Moderately well drained, clayey soils with high AWC, on low lands, slightly flooded; Associated with: very deep, well drained, stratified loamy soils	Fine, Mixed, Typic Ustropepts Fine loamy, Mixed, Fluventic Ustropepts

Table-2 Land use / Land cover Classes

Land use Class	Land use Sub-class	Area in Sq.Km	Percent To Total Geographic Area
Agriculture	Agricultural Land (AL)	77.85	75.88
	Plantation (PL)	6.85	6.67
Built up	Built Up Area	4.40	4.2
Waste Lands	Barren Land (BL)	1.01	0.98
	Wastelands-Scrub land-Dense scrub (DS)	0.72	0.70
	Wastelands-Scrub land-Open scrub (OS)	0.97	0.94
Water Body	River	6.16	6.00
	Tank	4.64	4.52
Grand Total		**102.59**	

They have deep to very deep profiles and are well drained. Therefore the characteristics and distribution of the soils indicate that the whole area is well suited for cultivation of crops provided appropriate crop management practices to sustain soil fertility.

Land Use and Land Cover

Land use is defined as man's activities on land which are related to the land directly. Land cover refers to natural vegetation, water bodies, rock/soil, artificial cover and other resulting due to land transformations. IRS P6 LISS-III image of February, 2006 was visually interpreted for the identification and mapping of land use/land cover categories (Fig-2-B) using standard false colour composites classification system and interpretation key developed by NRSA (2006). The interpretation was made in conjunction with the topographic map and adequately supported with field information. The areal extent of Land use/land cover polygons comprise both classes and subclasses such as built up lands, agricultural lands, wastelands, water bodies etc. have been extracted from the attribute table and presented in table 2. Total geographical area of the mandal is 102.59 Sq. Km. It is evident from the statistics that agriculture is the most dominant land use covering 76% (77.85Sq.Km) of the total geographical area and most of which are under the command areas of tanks and canals. Plantations cover 6.85 Sq. Km, built up land 4.40 Sq. Km, waste lands 2.7 Sq. Km and water bodies accounts for 10.8 Sq. Km of area. Though there are many small and a few large tanks spread throughout the plains, only a very few of them hold sufficient amount of water for a full crop season. Waste lands are limited to only 2.7 Sq. Km of extent indicating the limitation for further development.

Land Use Modeling

The integrated approach developed by Andhra Pradesh State Remote Sensing Application Centre (1997) has been adopted to derive an optimal land use model for the study area. The vectorised thematic maps of hydrogeomorphology, slope, soil and land use/land cover from the corresponding map files have been integrated using overlay technique to derive the composite map which comprises 63 unique composite map units (CMUs). A CMU is a multi dimensional landscape unit, homogeneous in respect of characteristics such as quality of land, water, vegetation and separated from other dissimilar units by distinct boundaries. Analyzing the existing status of the natural resources and the suitability for various uses, the composite map units are further subjected to cartographic generalization and an optimal land use model (fig.3) has been

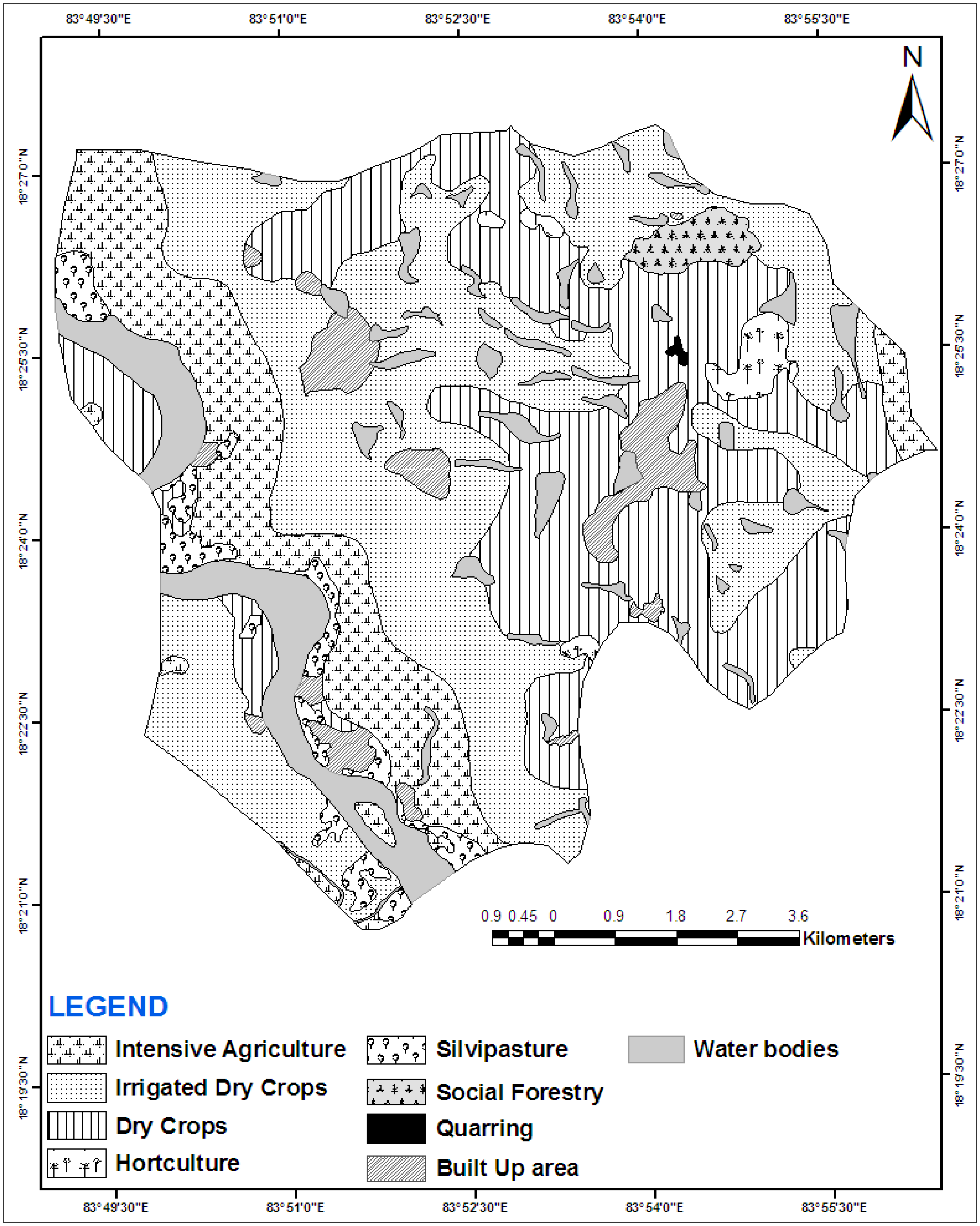

Fig-3. Optimal Land use Map

generated. It suggests seven alternative land use practices (query) viz. intensive agriculture, irrigated dry crops, dry crops, horticulture, silvipasture, social forestry and quarrying. Tables 3 depict the attributes of each optimal land use.

Table -3 Attributes of the Optimal Land Use Model

QUERY-1: INTENSIVE AGRICULTURE: (([hgeo_Id] = FP) and ([soil_Id] = 3) and ([slope_Id] =1) and ([Landuse] =AL)) or (([hgeo_Id] = C) and ([soil_Id] = 4) and ([slope_Id] =1) and ([Landuse] =PL))
QUERY-2: IRRIGATED DRY CROPS: (([hgeo_Id] = PPS) and ([soil_Id] = 1) or ([soil_Id] = 2) or ([soil_Id] = 3) or ([soil_Id] = 4) and ([slope_Id] =1) and ([Landuse] =AL) or ([Landuse] =PL))
QUERY-3: DRY CROPS: (([hgeo_Id] = Pb) or ([hgeo_Id] = PPM) and ([soil_Id] = 1) or ([soil_Id] = 3) or ([soil_Id] = 4) and ([slope_Id] =1) or ([slope_Id] =2) and ([Landuse] =AL) or ([Landuse] =PL))
QUERY-4: HORTICULTURE: (([hgeo_Id] = Pd) and ([soil_Id] = 3) and ([slope_Id] =3) and ([Landuse] =BL) or ([Landuse] =OS))
QUERY-5: SILVIPASTURE: (([hgeo_Id] = Levee) and ([soil_Id] = 4) and ([slope_Id] =1) and ([Landuse] =PL))
QUERY-6: SOCIAL FORESTRY: (([hgeo_Id] = SH) and ([soil_Id] = 1) and ([slope_Id] =5) and ([Landuse] =DS))
QUERY-7: QUARRYING: (([hgeo_Id] = I) and ([soil_Id] = 3) and ([slope_Id] =4) and ([Landuse] =OS))

After observing the attribute information of each optimal land use unit in conjunction with the field observation conservation measures for each query has been suggested and presented in table.4. The following heads briefly explain the seven optimal land uses suggested for the study area.

Query-1 - Intensive Agriculture: Intensive agriculture has been suggested for an area of 14.59 Sq.Km. These are the areas with excellent ground water availability, gently sloping terrain and soils with good land capability. Presently these areas are under double crops. Crops during kharif are cultivated with irrigation facilities. The area comprises a linear stretch along the river nagavali through Kottavalasa, Chittarupuram, Togaram, Gandredu, Belamam and Dallavalasa villages. As the soils are clayey, de-siltation of tanks and canals has to be taken up on a regular basis both to increase the volume of storage as well as to restore ground water recharge.

Table-4 Soil and Water Conservation Measures

Query	Optimal Land Use	Soil and Water Conservation Measures	Area (Sq. Km)	Villages
1.	Intensive Agriculture	Irrigation and water management – check dams, rock fill dams, de-siltation of tanks	14.59	Nelliparti, Marrikottavalasa, Duse, Chittarupuram, Kottavalasa, Togaram, Gandredu, Singuru, Kanugulavalasa, Belamam, Dallavalsa.
2.	Irrigated dry crops	Irrigation and water management-check dams, rock fill dams, sprinklers, drip irrigation	38.08	Nelliparti, Marrikottavalasa, Naira, Dondevalasa, Vedullavalasa, Totada, Katiychayulapeta, Korlakota, Rogulu, Chemalavalasa, Akkulapeta, Singuru, Sailada, Hanumantupuram, Togaram, Bobbilapeta, Bodellapallipeta, Talavalasa, Jaggushastrulupeta, Venkayyapeta, Ravikantipeta, Kuddiram, Duse, Kanugulavalasa, Vanjangipeta, Bavajipeta, Chintada, Kasimvalasa, Akkivalasa, Ponnam, singivalasa, Belamam, Tadivalasa, Gandredu, Dallavalasa.

3.	Dry crops	Soil erosion control measures-contour trenching, bunding and gully plugging etc.	28.80	Chittarupuram, Panasapeta, Belamam, Totada, Kuddiram, Kanugulavalasa, Korlakota, Chintada, Lankam, Sangivalasa, Bhairavanipeta, Akkivalasa, Amadalavalasa, Ravikantipeta, Bodellapallipeta, Kasimvalasa, Ponnam, Parvatiswarunipuram, Krishanapuram, Timmapuram, Sallada, Jaggushastrulupeta, Akkulapeta, Vedullavalasa, Bobbilapeta, Hanumantupuram, Venkayypeta, Togaram.
4.	Horticulture	Irrigation water management-sprinklers, drip irrigation	1.38	Kanugulavalasa, Kasimvalasa, Amadalavalasa, Krishanapuram, Jaggushastrulupeta.

As water is the controlling factor of agriculture in the study area as it is rainfall dependent, water conservation measures should be given top priority to increase the intensity as well as productivity of agriculture.

Query-2 - Irrigated Dry Cops: Very large extent of 38.08 Sq. Km spread over as many as 35 villages are suitable for irrigated dry crops. Deep Clayey soils with good to medium capability on gentle soles are well suitable for crop production. Presently these areas are under double crop, with irrigation facilities during kharif season. With the suggested conservation measures and adopting micro irrigation practices agricultural productivity can be assured.

Query-3 - Dry crops: An area of 28.80 Sq. Km has been suggested for dry crops. A large extent of 28.80 Sq. Km of land has been suggested for dry crops. The area is widely spread in as many as 28 villages. The areal extent as well as spatial distribution is extensive and next only to the irrigated dry crops. Erosion control measures and efficient water management practices are essential for assured production.

***Query-4 - Horticulture*:** An extent of 1.38 sq.km of land only has been suggested for horticultural crops. Clayey soils slightly eroded, low capability on gentle slopes, associated with very deep well drained clayey soils. Ground water conditions are generally poor to moderate owing to geological structure. Present land category is barren land. With appropriate land management practices the land is suitable horticultural crops.

***Query-5 - Silvipasture*:** An extent of 3.23 Sq. Km is suggested for silvipasture. Soils very deep well drained and stratified loamy soils. The existing land use comprises plantations of cashew and casuarinas.

Query-6 - Social Forestry: An area of 1.25 Sq. Km. in few villages is suggested for Social forestry. The soils are coarse with poor water potential. The present land use comprises wastelands, scrub, dense scrub etc. on steep slopes and structural hills. Slope of the terrain, erosion and availability of water are the limiting factors and therefore are suitable for social forestry.

Query – 7 - Quarrying: This is a very small area of 0.06 sq.km located in Krishnapuram village in the northeast region of the study area. The existing use is barren rocky area and the suggested use is quarrying essentially with environment conservational measures.

Conclusion

The composite map derived by integrating various basic and derived thematic layers shows 63 composite map units. The optimal land use model generated from the manipulation/analysis of this multilayered information suggests seven alternative land use practices (query) such as intensive agriculture, irrigated dry crops, dry crops, horticulture, silvipasture, social forestry and quarrying with conservation measures for each use. Though the soil and slope conditions are favourable for agriculture, availability of water is the limiting factor in the study area which is typical of a dry sub humid climate. Adoption of appropriate conservation measures like modern water management techniques (sprinklers, drip irrigation, construction of check dams, desiltation of tanks, clearing of weeds etc.,) and soil erosion control measures (contour trenches, bunding, gully plugging etc.,) would reasonably enhance the potential of water and land resources. Overlaying administrative layer on the optimal land use model will further help farmers in identifying problems, limitations and potential of their fields and thus formulating an appropriate site specific action plan.

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