Spatial Decision Support System for Land Use Planning

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Sustainable natural resource management is a key issue for preserving the earth's resources. It plays a vital role in the sustainability and stability of ecosystems. Land use analysis through Remote Sensing (RS) and Geographic Information System (GIS) is very useful in generating scientifically-based statistical data for understanding ecosystem characterization and ecological diversity. The primary objective of this paper is to highlight the functionality of Geographic Resources Decision Support System (GRDSS) and discuss the land use pattern of Kolar district in Karnataka, India. GRDSS is based on GRASS that aids in decisions related to land use and land cover changes. This spatial decision support system aids the policy makers and planners to visualize the decision outcome. GRASS and GRDSS are freeware (and work on Linux), which could be widely implemented with less economical implications. LISS III MSS data of Kolar district was classified using Gaussian maximum likelihood classifier with an overall accuracy of 94.67%. This analysis shows that wasteland constitutes 38.88%, indicating a lack of holistic approaches in land use planning that has led to the loss of top productive soil due to removal of vegetation cover during the last four decades leading to unproductive waste lands.

Key Words: Spatial Decision Support System, GRDSS, Remote Sensing, GIS, Spatial analysis, Land Use, Natural Resource Management

Introduction

Spatial Decision Support System (SDSS) aids decision makers and planners to capture, store, process, display, organize, prioritize and visualize the decisions with spatial and temporal dimensions. This interactive, computer-based information system is designed to support users in achieving effective decision making by solving unstructured or semi-structured spatial problems (Jayashankar, 1991). The focus of SDSS is on providing flexible and adaptable tools for policy analysis and quick response rather than providing models to answer structured problems (Parker and Ul-Ataibi, 1986). Modeling tools are also a part of SDSS, which comprises three component subsystems: the database management system for managing integrated database to drive modules; the model management for creating, cataloguing, editing, interrelating models by links through the databases; and the dialogue management that is guided by various methodological considerations such as scenario approach, integrated environment planning, flexibility and user friendliness (Ramachandra *et al.*, 2001). The conceptual design of GRDSS is shown in Figure 1. GRDSS is based on Geographic Resources Analysis Support System (GRASS) and aids in decisions

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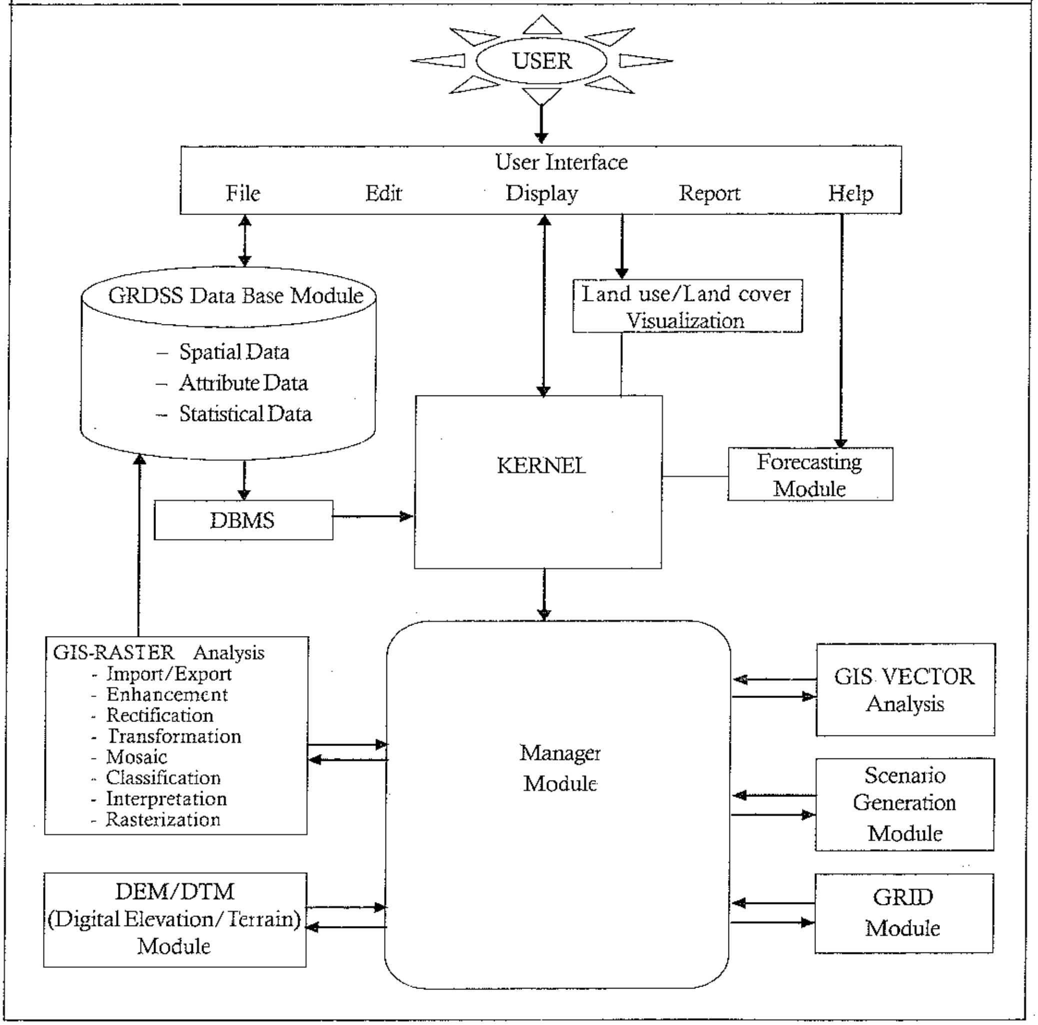
related to land use and land cover changes. This helps in sustainable resources management by analyzing the likely impacts associated with the decision related to land use changes.

GRASS released under General Public License (GPL) is an open source GIS under Linux platform (http://www.grass.itc.it/). It has vector analysis, image processing, data management, statistical analysis and spatial modeling capabilities along with graphics production functionality that helps in visualizing the data. It can also operate on various platforms through a Graphical User Interface (GUI) and shell in X-Windows. GRASS has evolved into a powerful utility with a wide range of applications during the last decade (http://ces iisc ernet in/grass). It contains programs (in C) for displaying maps and images, managing existing data, manipulating raster and vector data, etc. GRASS uses both intuitive windows interface and also command line syntax for ease of operations.

Figure 1: The GRDSS Design and Conceptual Diagram



A remote sensing and GIS-based decision support system for local land use officials developed by Arnold *et al.* (2000) shows that decision support system, when integrated with applications and outreach to form remote sensing information, becomes a powerful force in assisting local officials to plan better the growth of their communities. A simple DSS for town-level land use decisions could work well over municipalities in Connecticut, USA. The project analyses and information were incorporated into several regional and state plans. A watershed framework for local land-use planning with focus on Eightmile River Watershed (having 100 square kilometers in area and involves three towns) was made to demonstrate the utility of geospatial data and analysis in assisting local land-use decision makers. Based on the above two case studies, a framework to develop specific metrics and tools with emphasis on suburban/urban sprawl and its impacts on water and forest resources was made. These were applied by local use decision makers and officials to community planning.

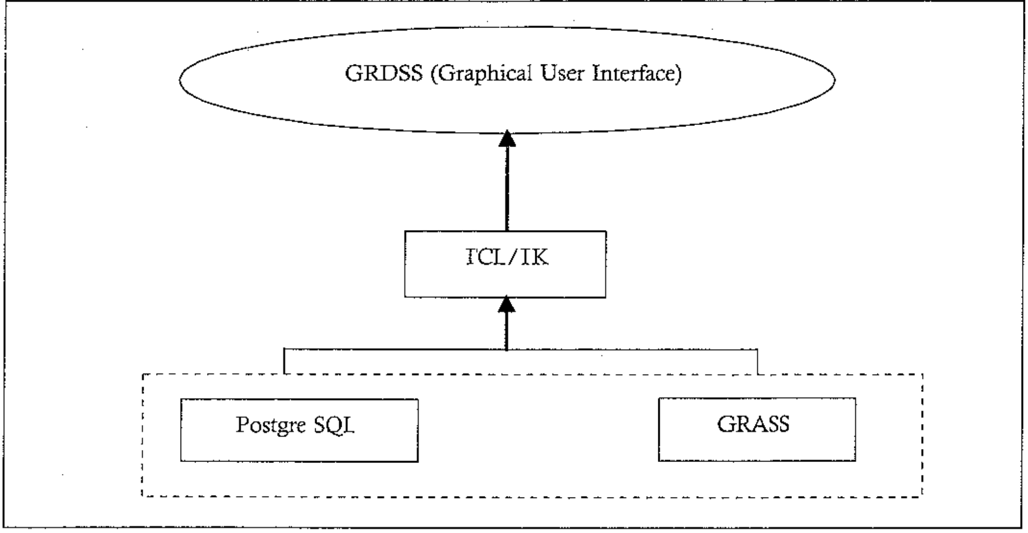
A geospatial semi-expert system for landscape analysis developed by Jeganathan and Roy (1999) attempts to analyze and prioritize different ecosystems for conservation by using the existing knowledge and assessing the disturbance impacts/regimes by way of investigating and inventorying biological richness of the areas. A mask of 0.5 x 0.5 km area was chosen and all the landscape parameters were calculated and integrated to yield the final models. The results for Meghalaya, one of the northeastern states of India, proved successful in putting the thematics expert in driving seat, and it was concluded that the presence of semi-expert system has made the end users and resources managers operationalize their views by integrating GIS software capabilities.

Land cover refers to the physical characteristics of earth's surface, captured in the distribution of vegetation, water, soil and other physical features of the land, including those created solely by human activities such as settlements. Land use refers to the way land has been used by humans and their habitat, usually with accent on the functional role of land for economic activities. It is the intended employment of and management strategy placed on and cover type by human agents and/or managers (Xavier and Gerard, 1997). Land use categories include built up (buildings, roads, industries, etc.), agricultural (crop lands, orchards), plantation, forest (areas with tree-crown areal density), wetland (water bodies, marshy areas), barren land (dry salt flats), etc.

Land cover and land use analysis is done to understand the dynamics of land use changes and the drivers responsible for changes. These changes often lead to serious ecological and environmental impacts. Moreover, insights in land use/land cover are needed to identify the likely points where human communities can intervene to change the trajectories of land use (and thereby environmental change) according to the changing needs and values (Fresco *et al.*, 1996).

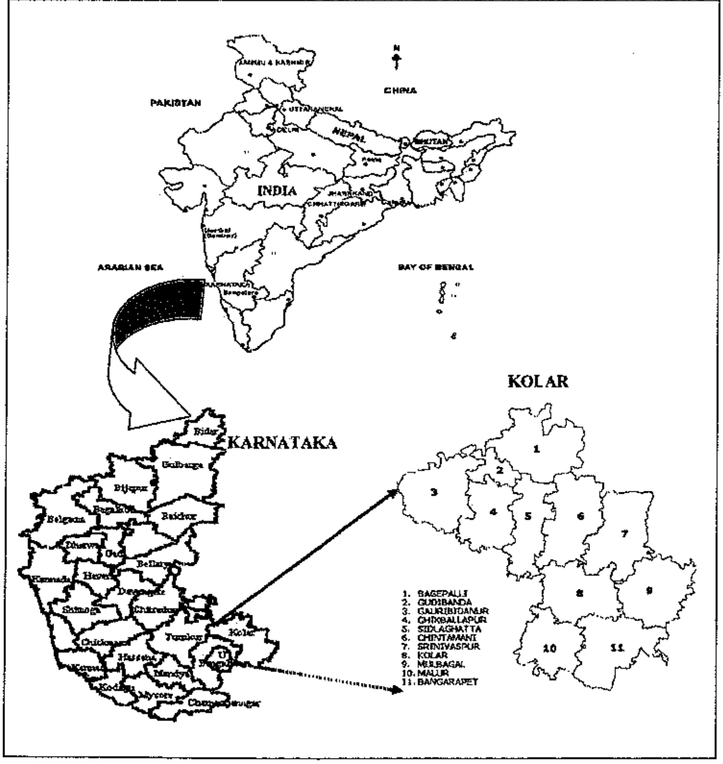
Land use and other natural resource management including environmental impact assessment can be visualized by GRASS-GIS. Since GRASS is in command line syntax, a GUI was developed to aid users with the menu driven functions in a graphical format. The structural diagram of GRDSS-GUI developed in the scripting language TCL/TK is shown in Figure 2.

Figure 2: GRDSS – GUI Structural Diagram



GRDSS can be invoked within GRASS with the 'tcltkgrass&' command and the interface allows to use the GRASS modules with a mouse. GRDSS uses postgre SQL (a freeware) as a database for data storage, data retrieval, query and manipulation of both spatial and attribute information. Postgre SQL has comprehensive SQL support, referential integrity, Multi-Version Concurrency Control (MVCC) to avoid unnecessary locking that increases the reliability of the database by logging changes before they are written to the database

Figure 3: Study Area – Kolar District with Taluk Boundaries



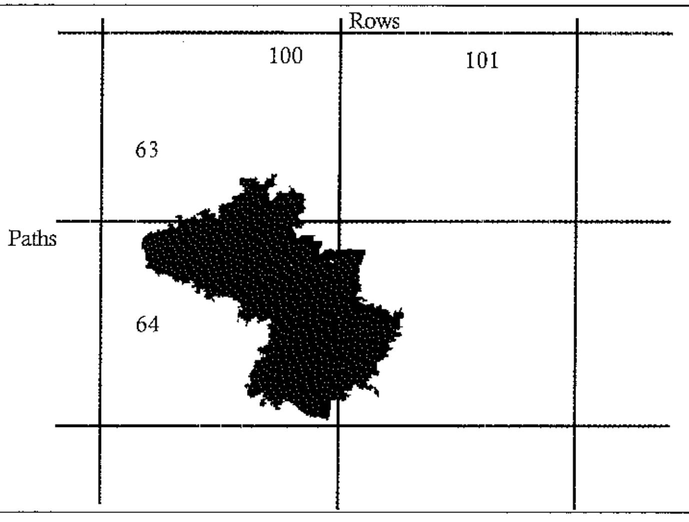
Study Area

GRDSS is tested using the data for the Kolar district, Karnataka State, India for land use analyses. Kolar is located in the southern plain regions (semi arid agro-climatic zone) extending over an area of 8238.47 sq. km between 77° 21' to 78° 35' E longitude and 12° 46' to 13° 58' N latitude (Figure 3) It is divided into 11 taluks for administrative purposes—Bagepalli, Bangarpet, Chikballapur, Chintamani, Gauribidanur, Gudibanda, Kolar, Malur, Mulbagal, Sidlaghatta, and Srinivaspur. The distribution of rainfall is during southwest and northeast monsoon seasons The average population density of the district is about 2.09 persons/hectare

Materials and Methods

The data collection was done from both primary and secondary sources The main sources of primary data (for image analyses, training data) were from the field (using GPS), the Survey of India (SOI) toposheets of 1:50,000 scale and the Multi Spectral Sensors (MSS) data of the Indian Remote Sensing satellite (IRS 1C). The secondary data were collected from the government agencies (Directorate of census operations, agriculture department, forest department, and horticulture department). LISS- III MSS data devoid of radiometric errors corresponding to the district as given in Figure 4, for the paths-rows (100, 63), (100, 64) and (101, 64), was procured from the National Remote Sensing Agency (http://www.nrsa gov.in)

Figure 4: IRS -1C Paths and Rows for Kolar District in Karnataka



The IRS-1C rectified (geo corrected) scenes for Kolar corresponding to paths-rows (100, 63), (100, 64) and (101, 64) for band 4 (near infrared) with district boundary is given in Figure 5

This includes the development of GRDSS and testing considering the Kolar district data for land use analyses

Development of GRDSS Entailed

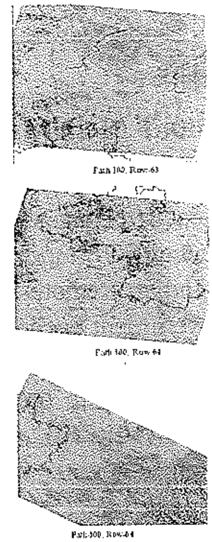
- Development of GUI in TCL/TK incorporating functionality of display, raster analysis (import/export, enhancement, rectification, transformation, mosaic, classification, interpretation, rasterization, etc), vector analyses, DEM/DTM;

- Development of GIS analysis and visualization module;
- Development of database module;
- Database integration to drive modules;
- Dialogue management; and
- Design of a decision support system

Land use/land cover analyses involve:

- Creation of base layers like district boundary, district with taluk and village boundaries, road network, drainage network, mapping of waterbodies, etc , from the SOI toposheets;
- Extraction of bands from the data procured from NRSA;
- Identification of ground control points and geo-correction of bands through re-sampling;
- Generation of FCC (False Color Composite) and identification of training sites on FCC;
- Collection of attribute information from field corresponding to the chosen training sites using GPS;
- Classification of remote sensing data; and
- Generation of confusion matrix and accuracy assessment

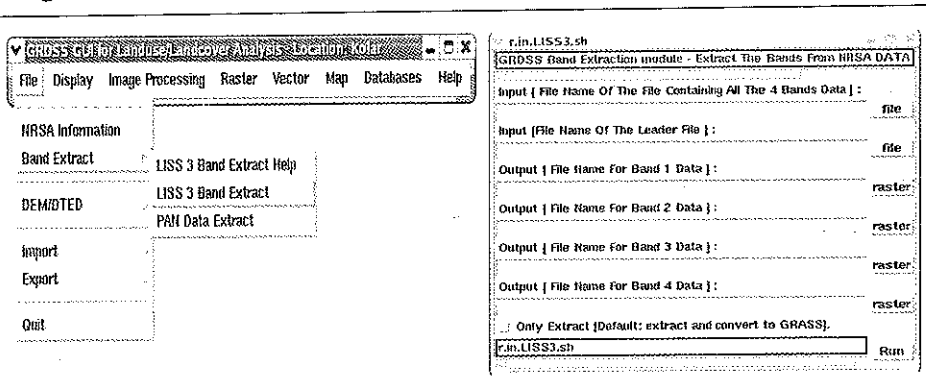
Figure 5: IRS-IC Rectified Scenes for Scenes Corresponding to (100, 63), (100, 64) and (101, 64)



Results and Discussion

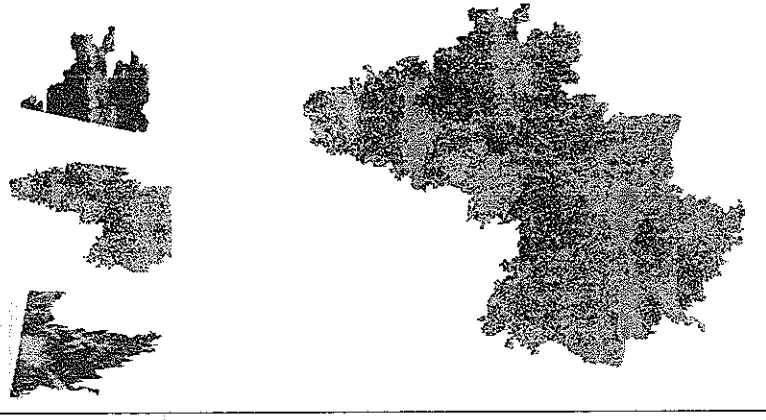
The SOI toposheets (scale 1:50,000 and 1:250,000) were digitized using GRASS 5 0 0. Separate base layers were created for boundary, road network, drainage network, forest land, built-up land, and water bodies. The multispectral LISS-III satellite imagery procured from NRSA, Hyderabad, India was extracted using the band extraction module of GRDSS, which is given in Figure 6

Figure 6: Main Menu and the LISS 3 Band Extraction Module of GRDSS



The respective band images were rectified using nearest neighbor re-sampling algorithm (geometric correction) considering field data collected Ground Control Points (GCPs) using GPS and by vector layer obtained by digitization of toposheets When mutually identified on the ground and on a satellite image, GCPs were marked precisely to establish the exact spatial position and orientation of the satellite imagery relative to the ground at that instance. (Dwivedi *et al.*, 2001). A new MAPSET and LOCATION were created in GRDSS database. The latitude-longitude coordinate system and the polyconic projection were assigned and the images were transformed by the first order polynomial transformation. The respective band images corresponding to the district were cropped from the scenes For this purpose, vector layer of district boundary was rasterized and each cell was assigned with a value of 1 for the region within the boundary and 0 elsewhere. Multiplication of this layer with the scene (100, 63, 100, 64 and 101, 64) crops the information for the district. These scenes were allied to obtain the entire scene for the district as depicted in Figure 7.

Figure 7: Three Different Scenes of IRS-IC (NIR Band) & Cropped and Allied Scene for the District



FCC was generated with the help of the composite module of GRDSS (Figure 8) using MSS data corresponding to band-2 (green), band-3 (red) and band-4 (near infrared) with a spatial resolution of 23.5 m (Figure 9). FCC helps in selection of training sites Chosen training sites were uniformly distributed all over the district image covering all heterogeneous patches. The overall objective of the training process is to assemble a set of statistics that describe the spectral response pattern for each land cover type to be classified in an image. Attribute information corresponding to these heterogeneous patches was collected in the field using GPS

The vector layer of field data is rasterized and overlaid on MSS data to obtain the spectral signatures corresponding to the training sites (Figures 10 and 11). With this information, image was classified for major land use categories.

Supervized classification using Gaussian Maximum Likelihood Classifier (GMLC) of the remote sensing data was done (Figure 12) to classify the data into categories—agriculture, forest, plantation, built up and waste land, and the classified image for the district is depicted in Figure 13. Further, by overlaying taluk boundaries, talukwise land use data was extracted.

Figure 8: GRDSS Module for Generating FCC Image

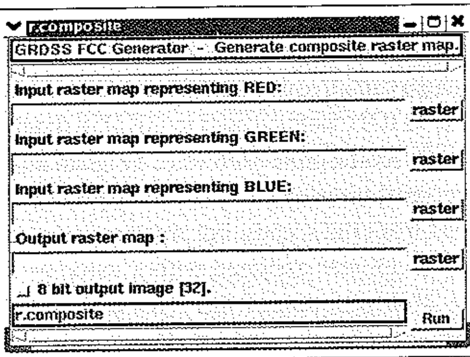


Figure 9: A False Color Composite

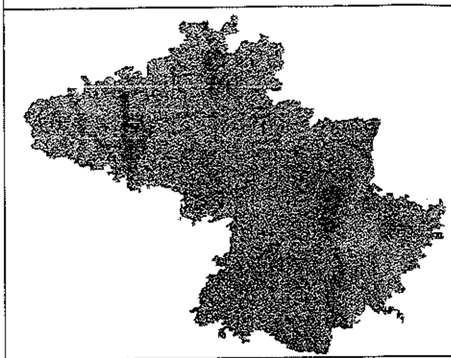


Figure 10: GRDSS Module to Generate Signature File

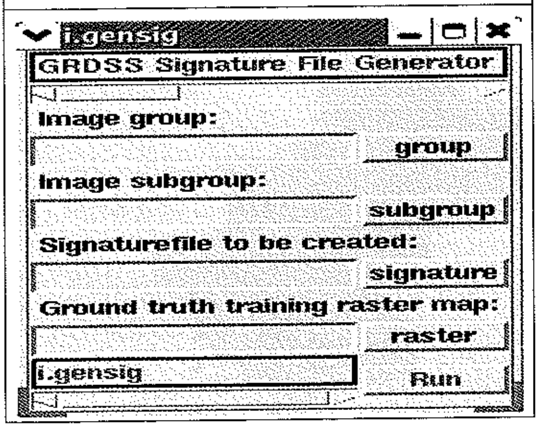


Figure 11: Kolar District with Training Data Sets

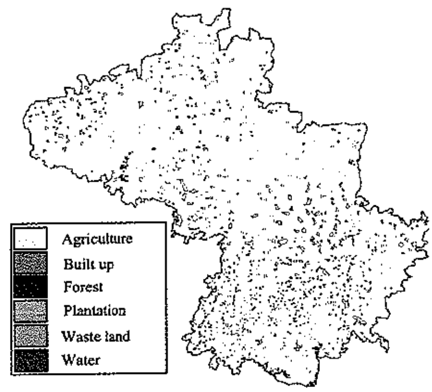


Figure 12: Classification Module of GRDSS

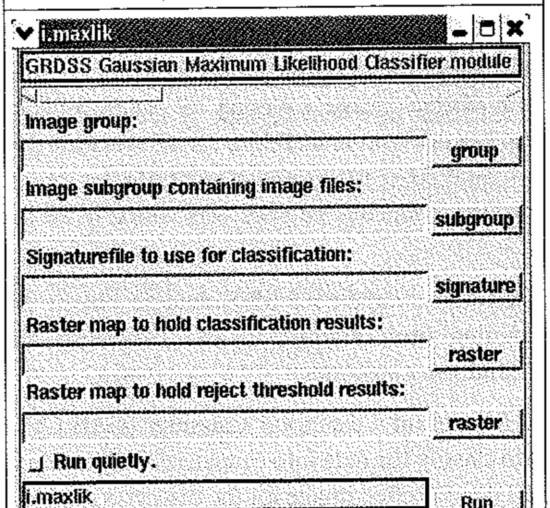


Figure 13: Supervized Classified Image of Kolar District

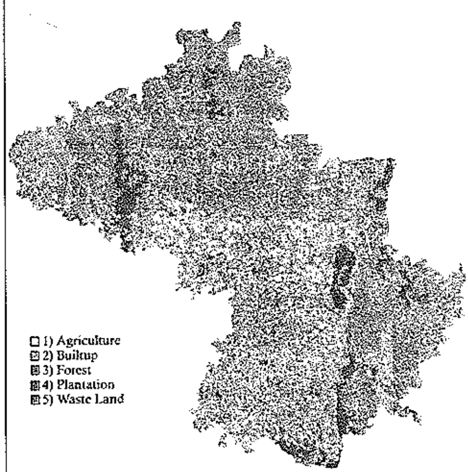
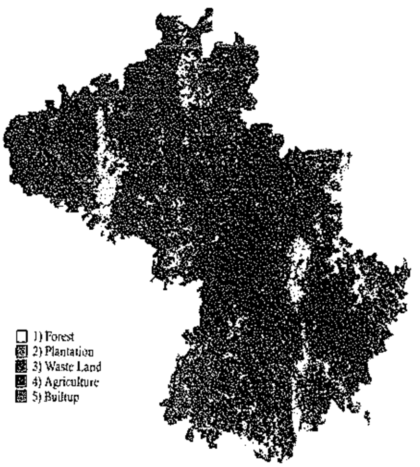


Figure 14: Unsupervized Classified Image of Kolar District



Talukwise land use details as per supervized classification are listed in Table 1. The data for March month was used for the analysis that corresponds to dry season, hence in the classified image there are no traces of water bodies.

Unsupervized classification of the data was done to assess the relative merits of the two techniques namely supervised vs. unsupervized. The histogram of the image was generated for deciding the initial number of classes and for choosing the number of clusters. The clustering algorithm was used and the image was classified into five categories using GMLC as shown in Figure 14.

Composition of land use (in hectares) for Kolar as per supervized and unsupervized classification is given in Table 2. Talukwise land use analyses details (in percentages) are listed in Table 3.

Table 1: Talukwise Land Use Area in Hectares (ha)

Taluk	Agriculture	Built up	Forest	Plantation	Waste land
Bagepalli	14630.94	20860.56	8605.97	3386.52	45403.27
Bangarpet	23811.91	13737.54	13848.42	12129.90	23276.26
Chikballapur	19536.17	6741.79	11675.26	5209.00	20654.69
Chintamani	26613.58	12081.67	1729.25	4909.80	43569.25
Gauribidanur	20219.60	19645.75	5779.35	2316.74	40897.11
Gudibanda	3541.23	2509.48	1015.18	580.02	15081.40
Kolar	26515.32	10371.38	4515.33	6074.55	31741.17
Malur	26411.55	5493.04	1952.50	12654.54	17988.50
Mulbagal	18726.92	17317.44	5119.21	7670.02	33134.76
Sidlaghatta	21769.99	9357.40	2195.49	7206.88	26527.31
Srinivaspur	31507.06	13232.16	11777.19	8058.65	21702.79
District	233284.27	131348.21	68213.15	70196.62	319976.51

Table 2: Land Use Details of Kolar District

	Supervised		Unsupervised	
Categories	Area (in ha)	Area (%)	Area (in ha)	Area (%)
Agriculture	233519	28.34	222416	27.00
Built up	131468	15.96	70970	8.62
Forest	68300	8.29	85295	10.35
Plantation	70276	8.53	84716	10.28
Waste land	320284	38 88	360450	43.75

Table 3: Talukwise Land Use in Percentage					
Taluk	Agriculture (%)	Built up (%)	Forest (%)	Plantation (%)	Waste Land(%)
Bagepalli	15.75	22.46	9.26	3.65	48.88
Bangarpet	27.43	15.83	15.95	13.97	26.82
Chikballapur	30.61	10.56	18.30	8.16	32.37
Chintamani	29.94	13.59	1.95	5.52	49.00
Gauribidanur	22.75	22.11	6.50	2.61	46.03
Gudibanda	15.58	11.04	4.47	2.55	66.36
Kolar	33.47	13.09	5.70	7.67	40.07
Malur	40.95	8.52	3.03	19.62	27.88
Mulbagal	22.85	21.13	6.25	9.35	40.42
Sidlaghatta	32.47	13.95	3.27	10.75	39.56
Srinivaspur	36.52	15.34	13.65	9.34	25.15
District	28 35	15 96	8 29	8.53	38.87

Accuracy Estimation

Accuracy assessment is done to measure the agreement between a standard assumed to be correct and a classified image of unknown quality (Campbell, 2002) An adequate number of sample points representing different land use categories were identified $\hat{k}$ on the training data sets for accuracy estimation. A one-to-one comparison of the categories mapped from all the training datasets and the classified image was made and is listed in Table 4 Accuracy estimation in terms of producer's $\hat{k}$ accuracy, user's accuracy, overall accuracy and Kappa coefficient were subsequently made after generating confusion matrix (Dwivedi *et al.*, 2001).

Table 4: Error Matrix Resulting from Classifying Training Set Pixels						
Classification Data	Agriculture	Built up	Forest	Plantation	Waste land	Row Total
Agriculture	42	1	0	0	0	43
Built up	0	16	0	0	0	16
Forest	0	0	20	3	0	23
Plantation	0	0	2	34	0	36
Waste land	2	0	0	0	30	32
Column Total	44	17	22	37	30	150

The statistic is a measure of the difference between the actual agreement between reference data and an automated classifier and the chance agreement between the reference data and the random classifier as shown in Equation 1 and Equation 2. This statistics serves as an indicator of the extent to which the percentage correct values of an error matrix are due to 'true' agreement versus 'chance' agreement (Table 5). It incorporates the non-diagonal elements of the error matrix as a product of the row and column diagonal. (Lillesand and Kiefer *et al.*, 2000).

$$\hat{k} = \frac{Observedaccuracy - chanceagreemen}{1 - chanceagreement} \quad (1)$$

$$\hat{k} = \frac{N\sum_{i=1}^{r} X_{ii} - \sum_{i=1}^{r} X_{i+} . X_{+i}}{N^2 - \sum_{i=1}^{r} (X_{i+} . X_{+i})} \quad (2)$$

where, r = Number of rows in the error matrix;

X_{ii} = The number of observations in row i and column i (on the major diagonal);

X_{i+} = Total of observations in row i;

X_{+i} = Total of observations in column i, and

N = Total number of observations included in matrix

The producer's accuracy, user's accuracy corresponding to the various categories and overall accuracy were calculated and the results obtained are summarized in Table 6

Table 5: Error Matrix for Unsupervized Classification

Classification Data	Agriculture	Built up	Forest	Plantation	Waste Land	Row Total
Agriculture	33	0	0	0	1	34
Built up	0	17	0	0	4	21
Forest	0	0	38	13	0	51
Plantation	0	0	0	28	0	28
Waste land	8	8	5	2	30	53
Column Total	41	25	43	43	35	187

Table 6: Producer's Accuracy, User's Accuracy and Overall Accuracy

Category	Supervized Classification			Unsupervized Classification		
	Producer's Accuracy (%)	User's Accuracy (%)	Overall Accuracy (%)	Producer's Accuracy (%)	User's Accuracy (%)	Overall Accuracy (%)
Agriculture	95.45	97.67	94 67	80.49	97.06	78.07
Built up	94.11	100.00		68.00	80.95	
Forest	90.90	86.96		88.37	74.51	
Plantation	91.89	94.44		65.16	100.00	
Waste land	100.00	93.75		85.71	56.60	

$\hat{k}$ computation for supervised classification matrix:

$$\sum_{i=1}^{r} X_{ii} = 42+16+20+34+30 = 142$$

$$\sum_{i=1}^{r} (Xi+ . X+i) = (43*44) + (16*17) + (23*22) + (36*37) + (32*30)$$

$$= 1892 + 272 + 506 + 1332 + 960$$

$$= 4962$$

$$\hat{k} = (150*142 - 4962)/(150*150 - 4962)$$

$$= 0.931577$$

A $\hat{k}$ value of 0.931577 is as an indication that an observed classification is 93% better than one resulting from a chance

Conclusion

GRDSS has demonstrated the potential to capture, process, display and analyze spatial and geographical information by applying Remote Sensing and GIS technology through a case study of Kolar district. The DSS has been designed to embrace the major functions: data input, information creation, query, map production and organizing the multiple integration into a unified form to allow resource managers and decision makers to interactively utilize the system resources to perform the analysis. It also indicates that geospatial techniques consist of powerful tools to assist the resource managers in operating and analyzing volumes of environmental data and information for decision making with ease. The land cover analyses show that Kolar district has a vegetation area (that includes forest, agriculture and plantation) of 45.16% and the non-vegetation area (built up and wasteland) is 54.84%. The land use analyses show that the overall agricultural land is 28.34%, built up (15.96%), forest (8.29%), plantation (8.53%) and the remaining area is wasteland. The producer's accuracy evaluation for wasteland was estimated 100%, while vegetation ranging from 90.90% to 95.45% and built up was 94.11% as against the user's accuracy estimation which shows that built up was 100%, vegetation ranging from 86.96% to 97.67% and wasteland was 93.75%. The Kappa value was found to be 0.93. The overall accuracy of the classification was found to be 94.67%.

Talukwise land use analyses show that among 11 taluks, Malur has maximum agricultural land (40.95%), followed by Srinivaspur (36.52%) and Sidlaghatta (32.47%). Chikballapur has maximum forest area (18.30%), followed by Bangarpet (15.95%) and Srinivaspur (13.65%). The talukwise assessment of wasteland share shows that wasteland ranges from 66.36% (Gudibanda) to 25.15% (Srinivaspur). This necessitates the decision makers to take immediate appropriate policy interventions to improve the quality of the land and prevent desertification.

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