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LAND USE/VEGETAL COVER MAPPING USING SATELLITE DATA

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SUMMARY

Land use and vegetal cover characteristics of a watershed has a significant influence on the quality and quantity of runoff available from it. Various hydrologic processes such as infiltration, evapotranspiration, soil moisture status etc. are influenced by land use/vegetal cover characteristics of a watershed. Thus, it may form an important input to hydrologic models. Hydrologic phenomenon is highly dynamic in nature and as such land use/vegetal cover information may be required at frequent intervals for making hydrologic inferences.

Conventional methods of land use/vegetal cover mapping may not serve the purpose because of limitations of cost, time and the data collection procedure itself. Remote sensing methods especially after the advent of satellites, proved to be advantageous because of the capability to obtain synoptic and repetitive view of the area in the various bands of electro-magnetic spectrum. The efficiency in terms of cost, time and opportunity of integrating existing information into an updated monitoring system is also quite encouraging when remote sensing techniques are resorted to for land use/vegetal cover mapping.

In this report an attempt has been made to review technological advancements in data collection systems and analysis of remotely sensed data for the preparation of land use mapping. Visual interpretation methods of satellite imagery based on tone-texture analysis are time consuming and less accurate. Computer aided analysis of satellite data is faster and more accurate. It is possible to employ various image enhancement techniques and to use various synthetic variables when one uses computer aided analysis.

Since many hydrologic parameters may be expressed in terms of land use and vegetal cover, the need to evolve a hydrologic land use classification scheme on regional basis has also been emphasised. Land use/vegetal cover maps prepared on the basis of such classification scheme could be suitably used for various hydrologic studies like runoff modelling, drought monitoring & estimation of soil erosion.

1.0 INTRODUCTION

Land and water resources are intimately interconnected and provide us with food and fibre. Movement and storage of Water resources in the land phase of hydrologic cycle vary with space and time. Prevailing land use and vegetal cover exerts considerable influence in determining the various hydrologic phenomena like infiltration, overland flow, evaporation, interception etc. As such, the knowledge of land use and vegetal cover is not only essential for planning and management of land resources but also is equally important for study of problems related to water resources.

Various aspects of hydrologic studies could be undertaken if information on land use and vegetal cover including their temporal changes are available for the watershed area as a totality. Quality of runoff from a watershed is greatly affected by land use and vegetal cover of the watershed. Thus by expressing hydrologic parameters as a function of land use and vegetal cover characteristics of watershed, it becomes possible to rationally predict the impact which present and future land use and vegetal cover changes will have on the quality and quantity of runoff. Vegetal cover mapping at regular intervals could provide valuable information about crop condition and stressed vegetation. Reduction in forest cover due to increased demand for agricultural and other human activities could lead to acceleration of soil erosion process. Monitoring of land use and vegetal cover could be helpful in identifying potential areas for soil erosion and assessing soil erosion in quantitative terms. Drought is a phenomenon which manifests itself in the ecosystem by depletion of soil moisture, degradation of vegetation and gradual extinction of soil and vegetal cover. Thus land use and vegetal cover mapping could be used as a tool for drought monitoring.

Since land use and vegetal cover are dynamic features over space and time, it is difficult to get real time information through conventional means. Also, these methods are time consuming,laborious and with high costs. Spatial variations of land use and vegetal cover generate uncertainties about the point data collected by conventional methods. As such, spatial repetitive and synoptic data from satellites collected over a wide range of electromagnetic spectrum admirably suit the requirements of land use and vegetal cover monitoring. These spatial data indicate the distribution of various land use and vegetal cover categories in an area. Due to the availability of repetitive data, it is possible to update existing data base and base maps for use in various hydrologic purpose. Monitoring of changes in vegetation, surface water storage and similar dynamic features are possible by this repetitive data. Synoptic coverage of the data helps in studying the integrated effects of various aspects of ecosystem and it is often possible to correlate the cause and effect of changes which are being monitored. The data collected by various sensors over various regions of electromagnetic spectrum help in differentiating one feature from the other and identify the features which could not otherwise be deciphered from a single band image. Figure-1 shows typical spectral reflectance curves for three basic types of earth features: healty green vegetation, dry bare soil, and clear lake water. From the figure it may be asserted that certain features such as healty green vegetation have considerably different reflectance characteristics in visible and near infrared regions of the spectrum whereas, dry bare soil has a relatively stable reflectance in both the regions. Water shows

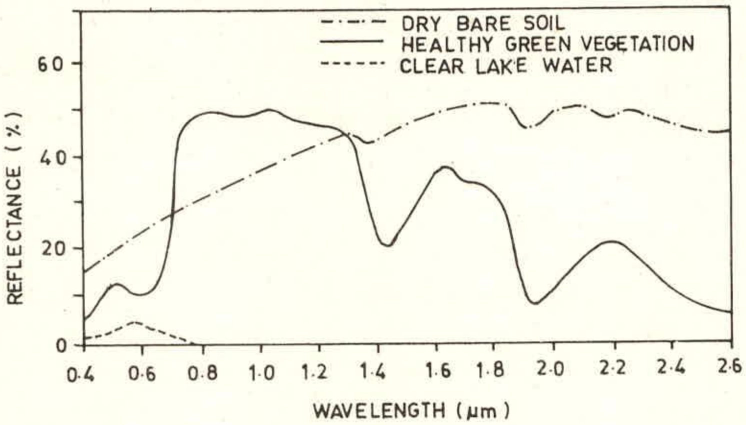

FIGURE 1-TYPICAL SPECTRAL REFLECTANCE CURVES FOR VEGETATION, SOIL, AND WATER.

very low reflectance in visible part of the spectrum and almost no reflection in infrared part of the spectrum. Thus by using multispectral data suitably, different ground features could be differentiated from each other and thematic maps depicting land use and vegetal cover could be prepared with satellite data .

So, with the advantages of remote sensing data, it is evident that these could effectively be used to prepare land use and vegetal cover mapping and to monitor changes time and cost effectively. These in turn are used to extract various hydrological information. These information are being attempted to use in various hydrological models for hydrologic forecastings.

2.0 REVIEW

Aerial photographs have been in use since the beginning of 19th century for land use and vegetal cover mapping. Development of colour and colour infrared films during 1940's further enhanced the capabilities of photo-interpretation for such mapping. As a result of technological advancements, concepts of multiband, multidate and multistage photography came into existence which resulted in a variety of data products and interpretation procedures. At later stages, it was realised that land use/vegetal cover information extracted from various types of data products using different interpretation procedures were entirely different from each other and hence had limited scope for its use in decision making and planning purposes.

In an effort to improve this situation, the U.S. Geological Survey proposed a scheme of classifying land use data by means of remote sensing techniques(Anderson,1971). The classification scheme was aimed to provide a logical framework for presenting land use and land cover information that could be derived from remote sensing techniques. The classification scheme consists of four levels of caegorization. Levels I and II of the system are to be used for land use mapping on a regional basis(table 1). The level I categories can be identified using space imagery at scales of 1:1,000,000 to 1:250,000 with very little supplementary information. Level II can be most efficiently and economically acquired by high altitude aerial photography(at 1:80,000 scale). Level II and IV are to be developed and utilized by local planners to meet their own specific requirements.

Study of earth's resources using satellite data has been a matter of great interest since the launching of first weather satellite

Table 1 : U.S.GEOLOGICAL SURVEY LAND USE CLASSIFICATION SYSTEM FOR USE WITH REMOTELY SENSED DATA

Level I		Level II
1. Urban Or Built-up Land	11	Residential
	12	Commercial and Services
	13	Industrial
	14	Transportation, Communications and Utilities
	15	Industrial and Commercial Complexes
	16	Mixed Urban or Built-up Land
	17	Other Urban or Built-up Land
2. Agricultural Land	21	Cropland and Pasture
	22	Orchards, Greves, Vineyards, Nurseries, and Ornamental Horticulture Areas.
	23	Confined Feeding Operations
	24	Other Agricultural Land
3. Range Land	31	Herbaceous Rangeland
	32	Shrub and Brush Range Land
	33	Mixed Range Land
4. Forest Land	41	Deciduous Forest Land
	42	Evergreen Forest Land
	43	Mixed Forest Land
5. Water	51	Streams and Canals
	52	Lakes
	53	Reservoirs
	54	Bays and Estuaries
6. Wet Land	61	Forest Wetland
	62	Nonforested Wetland
7. Barren Land	71	Dry Salt Flats
	72	Beaches
	73	Sandy Areas Other than Beaches
	74	Bare Exposed Rock
	75	Strip Mines, Quarries and Gravel Pits
	76	Transitional Areas
	77	Mixed Barrenland

8.	Tundra	81	Shrub and Brush Tundra
		82	Herbaceous Tundra
		83	Bare Ground Tundra
		84	Wet Tundra
		85	Mixed Tundra
9.	Perennial Snow or Ice	91	Perennial Snow fields
		92	Glaciers

like Nimbus series in 1958. Since then there had been substantial contribution to this field from various parts of the world. Probably systematic efforts towards the use of satellite data for study of earth's resources began with the availability of orbital photographs from Gemini satellite series. By the end of the Gemini program, some 1100 usable colour photographs had been obtained. These pictures produced a number of interesting and unexpected discoveries.

The Apollo program was further step forward in orbital photography. It was realised during the Apollo program that only one film filter combination may not be sufficient if space photography has to be used effciently. The need for multiband photography was greatly emphasized by Lowman in 1969. Apollo-9 carried a multiband camera with four film filter combinations: panchromatic film with red and green filters, black-and white infrared film and colour infrared film. The bands covered were approximately those planned for the NASA Earth Resources Technology Satellite i.e. Landsat. Colwell and his coworkers found that Apollo-9 pictures were suitable for Crop identification. Infrared colour pictures were found to be useful in estiamting timber volume distribution (Aldrich, 1971). However, the discrimination capability has greatly enhanced after the introduction of multiband photography.

Landsat series of satellite was first launched in July 23, 1972 and so far five satellites have been launched. First three Landsat satellites have collected over 1 million images of earth's surfaces. Landsat-4 and 5 have improved sensors, resolution and more sensitive ranges of band width. Table 2 furnishes the Multispectral Scanner and the Thematic Mapper spectral bands and their application.

Landsat data are available in two forms, analog and digital. The first is an imagery on film or paper, the second is on computer compatible

Table 2 : SPECTRAL RANGES OF BANDS IN LANDSAT-4 and 5

Sensor	Band Number	Spectral range(μm)	Application
Multi-Spectral Scanner	1	0.5 to 0.6 Visible green	Water penetration, sediment, turbidity studies.
Resolution =79 m	2	0.6 to 0.7 Visible red	Vegetation discrimination
	3	0.7 to 0.8 Near infrared	Land cover discrimination
	4	0.8 to 0.11 Near infrared	Water discrimination
Thematic Mapper	1	0.45 to 0.52	Water penetration
	2	0.52 to 0.60	Measurement of visible green reflectance
	3	0.63 to 0.69	Vegetation discrimination
Resolution	4	0.76 to 0.90	Delineation of water bodies
= 30 m = 120 m	5	1.55 to 1.75	Deifferentiation of snow and cloud
for Band-6	6	10.40 to 12.50	Thermal mapping
	7	2.08 to 2.35	Geological mapping

tape. Both the forms can be used for interpreting land use and vegetal cover.

2.1 Visual Interpretation of Satellite Imagery

Early experiments on the use of Landsat data for land use/vegetal cover mapping were mostly based on visual interpretation methods.variations in tone, texture and shape form the basis for visual interpretation. Interpretater draws the boundaries of the features which appear similar in tone and texture on imagery. Names of the categories are assigned after interpretation using the available ground truth. In this process aerial photographs on black and white and colour Infrared films are frequently consulted.

Selection of most appropriate band or combination of bands of Landsat imagery depends on the interpretive use. MSS 1 (0.5-0.6 μm) and MSS 2(0.6 - 0.7 μm) are usually best for detecting cultural features. MSS 3 (0.7 - 0.8 μm) and MSS 4 (0.8 - 1.1 μm) are best for delineating water features. Anderson(1973) reports that in a study conducted in Alaska,band 7 imagery alone could be succuessfully used in discriminating the various vegetation types.

Krebs(1977) demonstrated advantages of false colour composites over single band black and white imagery. However, he suggested use of black and white imagery of some other date to detect the changes and improve classification accuracy. By this way he was able to achieve an accuracy of 90 percent in land cover mapping of Denali project area in Alaska,USA. A comparison of minimum mapping unit, level of information detail, accuracy and cost of mapping from various data products is given in table 3.

Table 3 : COMPARISON OF SIZE OF MINIMUM MAPPING UNIT, INFORMATION DETAIL, ACCURACY AND COST

Data Source	Minimum mapping unit (acre)	Information detail	Accuracy (± 10%)	Cost per Acre (cents)
Colour infrared aerial photographs scale 1:30,000	5-10	Level III	89	30
Landsat imagery(FCC), scale 1:250,000	160-600	Level II-III	91	0.1

In land use mapping of Massachuetts, Rhode Island and Connecticut it was possible to identify land use categores derived on the basis of classification scheme suggested by U.S.Department of Interior(Anderson et al.1972). It was found that woodlands were delineated most easily. Built-up categories as a whole could be differentiated from non built-up categories with relative ease. Agricultural areas could be effectively mapped using seasonal coverage. Marsh land, and rock outcrops were very easily interpreted on colour composite(Leonard,1975).

A low cost visual interpretation technique based on the use of diazo films has been recommended by Naik et al.(1978), various image enhancement procedures such as contrast stretching, band ratioing etc. can be employed using this technique. He suggested that by exposing a combination of diapositive of one band and negative of another band, a band ratioed image is produced. This ratioed image is helpful in delineating vegetation. A colour composite obtained with ratioed images of band 7^+/band 5^- in yellow, band 5 in maganta and band 7^+/band 5^- in cyan may be used for enhancing relief of the terrain.

Limitations of the application of satellite data to extract detailed information like species identification in forested areas, forest density determination etc. has been discussed by Madhavan Unni(1978). He was able to decipher, the differences in colour tones on false colour composites of two different seasons of the year and show the phenological changes that have occurred. The areas where January imagery has red tone but in March imagery has reduced or negligible red tone, are deciduous forests which shed their leaves. Such comparisons not only help in understanding the phenological behaviour of forests over large areas but also help in differentiatior and delineation of different broad types of forests such as evergreen from deciduous etc.(Madhavan Unni & Roy,1979). To estimaste the extent of forest cover and monitor the reduction in forested area, NRSA carried out visual interpretation of false colour composites and supporting material for the periods 1972-75 and 1980-82. It was found that in the 1972-75 total area under forest was 16.89% of the total geographical area which reduced to 14.10% in the period 1980-82. This reduction in forest cover amounts to a loss of more than 1 lakh sq.km. forest area in the country during the period.

Land use survey of Iddukki in Kerala has indicated that visual interpretation of false colour composites can be successfully used in mapping of Level II categories of USGS classification scheme. However, some difficulties were countered in forested areas due to shadow effects caused by undulating terrain.(SAC and KSLUB, 1980). Visual interpretation of black and white imagery and false colour composite have been successfully used for prepatration of land use and vegetal cover maps at 1:250,000 scale with 10 categories of land use and vegetal cover in drought monitoring study of Dharwar, Belgaum and Bijapur districts of Karnataka. These maps were used to delineate irrigable and non-irrigated areas(NRSA,1980). Sahai et al.(1983) also report the similar observation in land use mapping of Punchmahals district of Gujarat. They found that the crop inventory for major crops and their acrage estimates could be done in a shorter time than through conventional methods with fair accuracy.

Gautam(1983) points out that on false colour composite forested and cultivated areas are easily delineated due to their characteristic red to dark red and pink to light red tone and their patterns respectively. Sahai (1983) reported that Landsat imagery can be successfully used in the mapping of wet land and coastal saline land.

Experimental studies have revealed that the pre-processing of raw Landsat digital data using image enhancement techniques like stretching, band ratioing etc. before generation of both B & W and colour composite imagery brings out the contrast between the vegetation types better and hence has a great promise in making visual interpretation easier and more accurate (Madhavan Unni,1983).

2.2 Computer Aided Analysis of Satellite Data

Computer aided interpretation of the digital data has the added capability of examining a large quantity of data and objectively classifying it quickly according to guidelines established by pattern recognition algorithms and by analyst. The land use/vegetal cover information derived from this analysis can directly be used in Geographic Information System(GIS) in combination with the data on slope, climate and other associated factors. The output of such a system gives the full picture and status of land and water resources to managers and this enables them to take a quick and rational decision.

Computer aided interpretations of spectral data based on pattern recognition technique either utilize unsupervised (clustering) method of classification or the supervised (training sample) method of classification. The unsupervised method works on clustring algorithms to automatically sort data into spectrally similar classes or clusters. These clusters represent the ranges of digital values which may be related to terrain features either through field observations or by comparing with aerial phtographs. This method is useful for classifying images where the analyst has no independent information about the same. Supervised classification method classifies data according to training statistics that have been generated through the training samples. This is the most widely used classification method.

Computer aided interpretation is now widely accepted as a tool for land cover mapping. Erb(1974a,1974b) used a variety of digital methods to classify the Landsat data for the land cover mapping of Houston and surroundings. In this study Landsat classifications were found to be fairly accurate when compared with classification made from high altitude photographs. Accuracy of Landsat digital classification is shown in table 4.

Butera(1977) was able to map the marsh salinity zones in Lake Borgne area and Terre Bonne area in Louisiana Coastal region of U.S.A., with an accuracy of 83 and 85 percent respectively using supervised classification of Landsat MSS data. Further in 1979, he was able to map wetland vegetation in Florida with an overall accuracy of 74%. Based on his experience of mapping a 1500 sq.km. of mangrove area, he worked out that the mapping cost was 3 cents per hectare using Landsat data against a cost figure of $ 46.50 per hectare for

Table 4 : ACCURACY OF LANDSAT CLASSIFICATION HOUSTON, TEXAS

Land use from aerial phtographs	Classes of land use and land cover (from Landsat digital classification)					
	Commercial Industrial & transportation	Residential	Mixed urban	Forest land	Range land	Water
Commercial Industrial and Transportation	94.2	5.5	-	-	-	0.3
Residential	2.6	66.8	23.0	4.5	3.2	-
Mixed urban	1.0	20.8	51.1	3.8	23.5	-
Forest land	-	0.7	0.2	95.1	4.0	-
Range land	1.1	12.1	25.7	4.8	56.2	-
Water	3.9	3.0	1.9	2.2	1.5	87.7

Note : Values are expressed as a percentage of total area.

mapping of similar area by conventional means. Only limitation in the method using remote sensing was that mapping of an area smaller than 80 hectares was not possible.

It has been observed that computer aided classification gives fairly accurate results where ground features are spectrally well separable. When there is a mixing of spectral responses, the accuracy of computer aided analysis detoriates. In land over mapping program of Imperial Valley,California, it was found that bare soil which was well separable from other cover types was classified with an accuracy of 100%. Erroneous results were obtained in case of Alpha-alpha because of mixing of spectrtal response with hay etc.(Barret and Curtis,1976).

Apart from the analysis of original digital data, efforts have been made to investigate classification techniques using synthetic variables. Efficiency of Landsat MSS band ratioing has been greatly emphasized by Vincent(1972) to provide additional information not recorded within the standard Landsat MSS image. The ratio of the near infrared and visible bands(e.g.MSS 7/MSS 5) improves the discrimination between green vegetation and all other objects. Tucker(1979) and others found that band difference(e.g.MSS 7-MSS 5) and normalized differences (e.g. MSS 7 - MASS 5 / MSS 7 + MSS 5) are valuable in vegetation monitoring. Technique of image differencing which makes use of multidate data has been tested by many researchers(Weismueller et al.,1977,Toll et al.,1980) for change detection with accuracy of more than 85%. This involves subtracting one date of imagery flrom a second date that has been precisely registered to the first. The subtraction of one digital image from the other results in an image in which positive and negative values represent areas of change and

and zero values represent no change. The method of principal component analysis has shown to be an effective method for data reduction by removing highly correlated components. This analysis has been found superior to simple ratio techniques (Friedman,1978).

In India, computer aided analysis of Landsat data has been attempted in many studies carried out by individuals and several agencies. In an experimental project Satellite Remote Sensing Survey of Nagaland, supervised classification approach was successfully used for forest cover mapping and identification of shifting cultivation(NRSA, 1977).

In Southern part of Tamilnadu,15 hydrologically significant land use categories were derived from the digital analysis of multispectral data which was supplemented by field visits and visual interpretation of satellite imagery in black and white and false colour mode in 1:10,00,000 and 1:250,000 scale. The informationcontained in such land use maps could be used for effective planning and management of surface and ground water resources (NRSA,1979).

Singh and Shankaranarayan(1982) report that results obtained from supervised classification of contrast stretched data are fairly accurate when compared with air photo-interpretation.

Kachhwaha et al.(1983) analysed line printer output of digital data manually utilizing ground truth information. They made an attempt to correlate forest density with the band 5 digital data. High density forest and low density forest were classified with accuracies of 89.2 and 98.5 percent respectively. However, classification accuracy was comparatively low for other cover types which could be improved by supervised pattern recognition techniques.

3.0 REMARKS

Satellite data provides fairly accurate information on land use and vegetal cover. Many researchers have reported that the accuracy with which land use/vegetal cover mapping can be done, varies between 70-80%. The data is essentially spatial unlike conventional data which is a point measurement. Hydrologic parameters of an area can be conveniently expressed as a function of land use of that area. Thus land use/vegetal cover classification made by use of remotely sensed data could be suitably used as an input to hydrologic models.

Considering the potential use of satellite derived land use and vegetal cover data in hydrologic studies, it may be necessary to evolve a hydrologic land use/vegetal cover classification system. Theoretically this system should provide a classification scheme which is applicable in many situations through out the country. However, due to large variations in vegetal cover and terrain conditions it may not be possible to have an unique classification scheme. Therefore, it may be recommended to develop land use classification scheme on regional basis.

Effects of terrain conditions and environmental factors greatly affect the spectral response of ground features, in which case visual interpretation may not provide adequate information. Digital techniques such as filtering or ratioing are capable of reducing these effects to some extents.

Apart from the visual and near infrared part of the electromagnetic spectrum, it may be required to utilize thermal I.R. and active and passive microwave bands. Since water has the highest specific heat, by sensing emitted thermal energy, it is possible to identify surface water bodies or moist areas. Water has distinct characteristics in the microwave part of the spectrum. In the case of active microwave wet areas show higher coefficients of emissibity. This itself speaks of its utility in hydrologic monitoring.

With the availability of Thematic Mapper data having finer resolution and improved channel structure, it is possible to get information which was not available with previous sensors. SPOT data with stereoscopic coverage and with high cartographic fidelity will further enhance the capability of remote sensing in land use and vegetal cover mapping.

Indian Remote Sensing Satellite(IRS-I) is planned to be launched in early 1987. This satellite is specifically tailored to the needs of water resources studies and related fields. A comprehensive utilisation programme, known as IRS-utilisation program has been drawn up for the effective utilisation of the huge amount of data which is likely to be available from this satellite. Most application projects of IRS-utilization program have been launched keeping in view the characterristics of remotely sensed data, their potential in providing reliable, timely and comprehensive data base for National Resources Management System(NNRMS). These efforts will go a long way in providing valuable experience in water resources studies using remotely sensed data.

At present, land use/vegetal cover mapping is categoriesed as Quasi Operational Application. Task Force on Water Resources set up by Planning Commission has recommended data requirement for an effective land use and vegetal cover monitoring using remotely sensed data. These are given in table 5.

Table 5 : OBSERVATIONAL REQUIREMENTS FOR LAND USE MONITORING

Parameter and its definition	Requirements Scale	Resolution	Frequency	Accuracy	Available from Satellites Expected 1980s	Remarks
Land cover type: natural vegetation or soil or artificial surface, expressed as a percentage of watershed area	A,B,C	100 m	(Every year)	($\pm$ 1% of watershed area)	Possible	Can be met on a limited area basis at present. Requires large-scale digital processing

A - less than 100 km^2

B - between 100 to 1000 km^2

C - more than 1000 km^2

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