ENVIRONMENTAL MONITORING AND NATURAL RESOURCE MANAGEMENT IN INDIAN ARID REGION USING SPACE INFORMATICS

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ABSTRACT

The advancement of space informatic technology in India since 1980s in general and establishment of Regional Remote Sensing Research Centres of Department of Space in particular have already had a significant contribution on desert monitoring and natural resource management in Indian Arid Region. The communication revolution initiated through INSAT of satellites are now providing climatic and meteorological information over the India enabling scientists to provide more accurate weather forecasting which is very essential for disaster prone arid regions. Subsequently, the satellite remote sensing data generated by IRS-1B LISS-II and IRS-1C LISS-III series of satellites has been assisting to promote sustainable resource development strategies at the micro-levels. Such initiatives are based on continuous environmental monitoring of land and water resources including meteorological parameters using space informatic technology.

INTRODUCTION

In recent years, environmental degradation has attracted attention to policy makers at global and national levels. This has become an issue for further regional and international negotiations as it cuts across political boundaries, Recognising the integral and interdependent nature of the earth, our home, the Earth summit held at Rio in 1992 identified 27 principles on general rights and obligations for environmental protection. The rapid increase in anthropogenic activities combined with the poor management of natural resources are posing severe threat to vulnerable arid geosystem in India. Largely it is true that ecologically marginal regions of India are also economically and socially marginal. For development of such regions like arid and semi-arid areas require multidimensional and integrated resource management strategies in order to promote sustainable development by ensuring livelihood security, capacity building and involvement of indigenous knowledge initiatives.

Environmental diversity in arid and semi-arid regions (Fig.1) is reflected by geographical environment, socio-economic conditions, traditional culture, population growth and poverty. Environmental degradation particularly land and water constitutes a major threat to the livelihood of millions of people in marginal areas. For tackling such complex issues, it is necessary to promote effective environmental monitoring and forecasting by making a state-of-the-art inventory of existing space informatic technology, natural resources information and data base and make them accessible to researchers willing to undertake scientific studies. It is necessary to establish Geographic Information System including remote sensing as Decision Support System for short and long term studies to improve our understanding of environmental processes (Singh, 1994)..

STATE OF ENVIRONMENTAL MONITORING IN ARID REGION

Desertification is a major problem which threatens the food supply and is a cause of human sufferings in the arid areas of India. The region is facing the severe problem and manifested in the overcultivation, overgrazing, deforestation and mismanagement of the irrigated farming. Sand dune encroachment and falling productivity of the land is a major cause of concern. Poor land use is presently crippling the ecological balance of the region. Biotic resources are severely pressurised by increasing livestock population. The biological characteristics of plants is adversely changing. The soil erosion and removal of vegetation are the two main physical characteristics of desertification. Water-table lowering is progressing at an alarming rate and farmers require deepening of wells each year. At some sites, the farmers are on the verge of abandoning the cultivation altogether. Excessive exploitation of the groundwater and poor or no replenishment year round to the aquifer, is threatening the entire local ecosystem (Singh, 1994)..

Dryland farming in the study area, inherently posses serious threat to land conservation. The plant growth, being less, varies from year to year in response to the fluctuations in the rainfall. Soil is bare and prone to wind and water erosion during five to six months each year. The choice of crop is restricted to drought-tolerant crops and the rotation of food crops with leguminous crops and vegetation is found to be uneconomic. Soil erosion is the prominent problem, being most extensive in areal coverage. Expansion of cultivated land and excessive grazing of village common lands and grazing lands are the two main cause of soil erosion in the district. Dust storms are a common feature of summers. Consistent overgrazing and expansion of net sown area has appeared in the form of extinction of some grasses and shrubs. The land use changes that are happening play a crucial role in the aggravation of the ecological problems. Land, which was earlier left abandoned for eco-friendly purposes such as regaining the depleted nutrients and fertility, is facing tough utilization competition. Farmers are not more interested in fallow system as they require more and more land for cultivation and, therefore, take the fallow lands for perpetual cultivation. Grazing lands and pastures are also experiencing decrease in areas. It resulted into intensive exploitation of those lands. Cash crop cultivation on the expanded land demand the most intensive use. Nutrient and fertility depletion occurred immediately. Secondly, the bare surface became prone to soil erosion which again resulted into fertility depletion. Sand dunes without vegetation are reactivated by repeated human interferences in the form of cultivation and grazing. Movement of sand dunes threatens the cultivated lands as sand dunes encroach upon the surrounding fields (Fig. 2).

In recent year, environmental degradation particularly land and water problems have attained worst proportions. Out of total country soil degraded area of 187.7 mha (57.1 per cent of the geographical area), 149 mha is due to water erosion and 13.5 mha attributable to wind erosion. The area affected is being concentrated in semi-arid and arid regions which occupy 95.7 and 31.7 mha or 30 and 10 per cent of the country's area respectively (Singh and Chauhan, 1994).. In the Indira Gandhi Canal Command Area, the increasing anthropogenic activities are responsible for the massive sand drifting and deposition problem resulting in the formation of barchan dunes of 1.5 to 6.5 m height, sand ridges of 0.9 to 2.9 m height and sand sheets of 150 to 450 cm thickness on the adjoining agricultural lands and engineering structures. The rate of sand movement in these areas varies from 4 to 40 m/year and the soil loss ranges between 2525 to 3452 t/ha/year. The soil loss by water generally varies from 5 to 25 tones per ha and sand transport from one field to another in sandy desert averages between 120 to 450 tones/ha. It has been estimated that 0.16 to 1545 t/sq km soil is annually lost from the Bandi river. The accelerated water erosion has removed 0.2 to 53.5 g/1 sediments in the hilly terrain of the Aravallis and 1.0 to 453.6 g/1 in the lower reaches of the Luni river basin. The Aravallis are facing severe problems of deforestation and environmental degradation. The forest cover of in the Aravalli hill region continuously declined and reached a level as low as 6.34 per cent as per the satellite imagery of 1990-92 in the Aravalli region of Rajasthan which constitutes more than 84 per cent of the total hill part. The recent data shows that of the 237 development blocks in the Rajasthan state, 198 are facing alarming decline of water table. Rajasthan being second state so far as the mineral deposits are concerned, it ranks fifth in the production. Illegal mining is going upto 60 per cent in some of the areas, resulting environmental degradation as those involved in illegal mining have no obligations towards EIA procedure.

According to an estimate, western Rajasthan is expected to face drought every 2.5 years. Such frequent occurrence of droughts creates environment of desertification. During 1971-72, there was an increasing trends of dust storms. Whenever rainfall falls steeply, there is a sharp rise in the occurrence of dust storms. It has a considerable significance in the soil erosion and desertification process. It also speeds up the process of their formation. The process of desertification is further accelerated by overgrazing on the pasture lands due to lack of fodder during droughts. Ministry of Agriculture of Government of India has implemented drought - prone areas programme for drought management. (Singh, 1990) (Fig. 3). Such complex environmental situations require application of space informatics for continuous natural resource monitoring in order to promote sustainable development.

SPACE INFORMATICS AS DECISION SUPPORT SYSTEM

Environmental monitoring require to analyze phenomena, processes and their interactions throughout space and time. Information has to be considered in its attribute dimension (variables), spatial dimension (spatial units of measurement), temporal dimension (dynamic process and change). Geographic Information System are offering such capabilities as they integrated attribute, spatial and temporal dimensions. Geographic Information System should be developed as a decision support system which is a system designed to support :- the analysis of decision problems,
- determination and evaluation of alternative decisions,
- selection of a particular decision (or rejection in given conditions), and
- monitoring of the execution of selected decision and suggesting corrective actions.

In general, governmental Decision Support Systems (DSS) can be easily interlinked with Geographical Information System which required access to large data bases containing data from censuses, surveys, inventories of natural resources using space informatics (Table 1 and Fig. 4). The following data base problems should be resolved :
- which data are needed for the system (electronic documents, drawings, maps),
- which data can be obtained from existing sources,
- which data bases must be created and how to collect row data,

- access to external data base (on-line, off-line),
- conversion of data in paper documents to electronic format,
- unification of data formats and access methods,
- interfaces between data bases (DBMS) and other modules of DSS,
- data verification and data integrity control.

Table 1 Principles of Decision Support System

Major Issues	Attributes
Spatial Data	- Space/Geographic Data - Spatial Data Sources : Conventional & Remote Sensing - Global Positioning System (GPS) - Coordinate Systems and Map Projections
Non-spatial Data	- Demographic/Census Data - Socio-economic data - Other data
Digital Representation	- Low-level Data Structures - High-level Data Structures - Data Capture - Database management - Digital Terrain Modeling - Three Dimensional GIS
Functional Issues	- Cartographic Modeling & Thematic Mapping - Spatial & Non-spatial Data Integration - Spatial Analysis Methods : Overlay etc. - Spatial Query Language (SQL) - GIS & Spatial DSS - Knowledge-based Approaches
Display Issues	- Visualization - Generalization of Spatial Databases - Object Oriented GIS
Operational Issues	- Evaluation & Implementation - Distributed Heterogeneous Spatial Databases - Spatial Data Exchange and Standardization - Inter-operability of Spatial & Attribute Data - Legal Aspects

The generic and specific characteristics of software architecture are very important for developing decisions support system which is an assembly of cooperating software modules. The components of a DSS are developed using many software technologies (RDBMS, GIS, Expert Systems, Natural Language Processing, Multimedia, etc. The major components of a DSS are : data base management, document repository management, embedded expert systems, simulation models base and user interface modules.

NEW OPPORTUNITIES IN APPLICATION OF SPACE INFORMATICS

With launching operational remote sensing satellites IRS-1A (1988) and 1B (1991) and setting up of information systems like NNRMS, NRIS, RRSSCs and NRDMS, about 350 national/regional level remote sensing application projects (Fig. 5) have been conducted in India. The successful launch of second generation and indigenously built IRS-1C satellite on 28th December, 1995 in India has provided tremendous opportunities for applying space informatics in areas of environmental monitoring and natural resources management in arid and semi-arid regions. Browse data for PAN and LISS - III are being generated for users. The IRS-1C marks a major milestone in the India's satellite remote sensing programme by contributing to National Natural Resources Management System with better resolution, coverage and revisit in order to provide invaluable data on environmental resources. The IRS-1C surveys the whole earth surface in just 24 days. The IRS-1C satellite has three types of advanced imaging sensors. The Panchromatic Camera (PAN) provide very high spatial resolution data of 5.8 m and a ground swath of 70 km. The PAN camera can be steered to ± 26 degrees which in turn increases revisit capability to 5 days . Linear Imaging and Self Scanning (LISS-III) Sensor provides multispectral data collected in four bands. The Wide Field Sensor (WiFS) collects data in two spectral bands (Table 2). All the three cameras are operating in real time over Indian ground station visibility circle two or three times a day (NRSA, 1995)

Table 2 Characteristics of IRS-1C Sensors

Sensors	Spatial Resolution (M)	Grand Swath (Km)	Bands/Regions (Microns)
PAN	5.8	70	Visible Region 0.50 - 0.75
LISS-III			
Visible and Infra-red	23.5	141	0.52 - 0.59 0.62 - 0.68
Shortwave Infra-red	70.5	148	1.55 - 1.70
WiFS	188	810	Visible Region 0.62 - 0.86 Near Infra-red 0.77- 0.86

Space informatic technology is being increasingly used mainly to improve data acquisition, storage and presentation; enhance precision and quality; accelerate pace of survey, interpretation and presentation of data; incorporate comparability over time and space. Local-specific action plans for sustainable development thus generated for priority watersheds/blocks (the size of about 10,000 ha) are essentially recommended for optimum management of land and water resources. The contents of the action plans to illustrate, involve identification of sites for :

- water harvesting through ponds and check dams, and soil conservation,
- afforestation, agro-forestry and agro-horticulture,
- fuelwood and fodder development,
- mining and necessary conservation measures.

CONSTRAINTS IN DEVELOPMENT OF SPACE INFORMATICS

The space informatic technology is very expensive in India. There is lack of digitized data and trained personnel. There is little GIS infrastructure at the micro-level. The GIS maps do not have large enough scale. Traditional data gathering agencies follow different systems, and do not provide digitized data. Thus, both duplication and expensive, data conversion are unavoidable. Largely GIS projects have been carried out for the project report and demonstration stage. There is a lack of an umbrella organisation which looks after related projects in holistic perspective at arid region. There is little understanding among decision makers in the management of the space informatics for government programmes.

CONCLUSIONS

The restoration of ecological balance in arid regions requires check on desert extension, intensification of desertification, degradation of natural resources such as forests, grazing lands, soil water aquifers, incidence of floods and droughts etc. There is an urgent need for regenerating arid regions particularly the Aravalli hill region by introducing Joint Forest management programme which is becoming key sustainable forest management strategy in India. Satellite photograph has facilitated mapping and distribution of dunal, inselberg and pediment areas. The geological and related environmental studies have been carried out from block and white and coloured satellite imageries. The emerging application of GIS provides further help in monitoring environmental issues and planning sustainable development strategies in arid region of India. The appropriate space informatic technology and its hardware and software requirements should be identified on the bases of experiences of several institutions. The establishment of space information database as a multi-disciplinary project at one place involving relevant organisations in order to promote technology transfer and exchange of Arid Information System at national level is an urgent requirement. At micro-level, existing data base available at various institutions should be taken into consideration for standardization identifying key sectors like meteorological, hydrological, geographical, paleoclimatic, geological, biospheric, land uses, anthropogenic and socio-cultural aspects. Subsequently satellite and geo-spatial data of low cost as well as user friendly format should be provided to various micro-levels resource monitoring projects. High resolution satellite data and low resolution satellite data should complied and integrated in a multi-temporal data base to support regional and local projects in arid regions.

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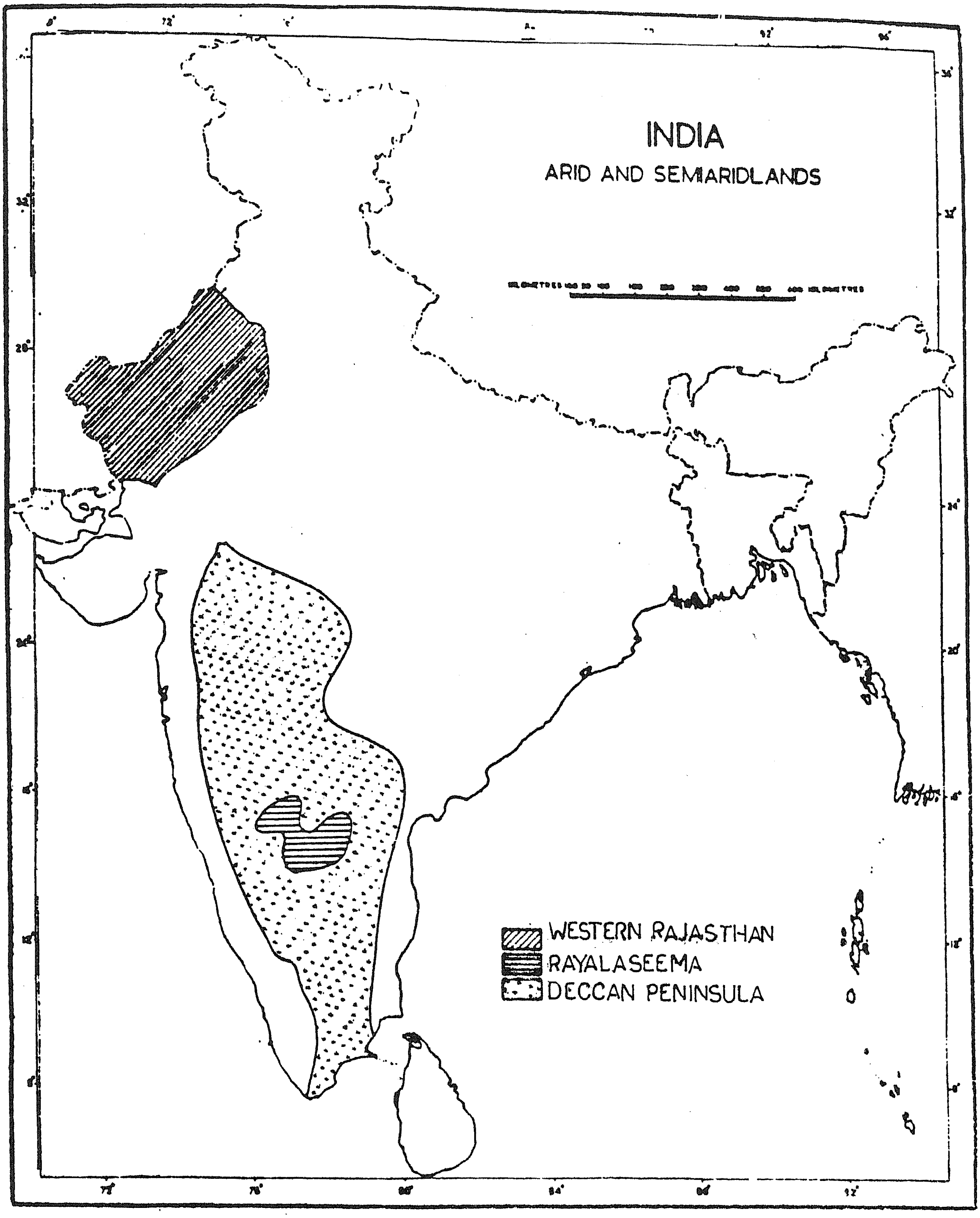
INDIA
ARID AND SEMIARIDLANDS
WESTERN RAJASTHAN
RAYALASEEMA
DECCAN PENINSULA

FIG.1

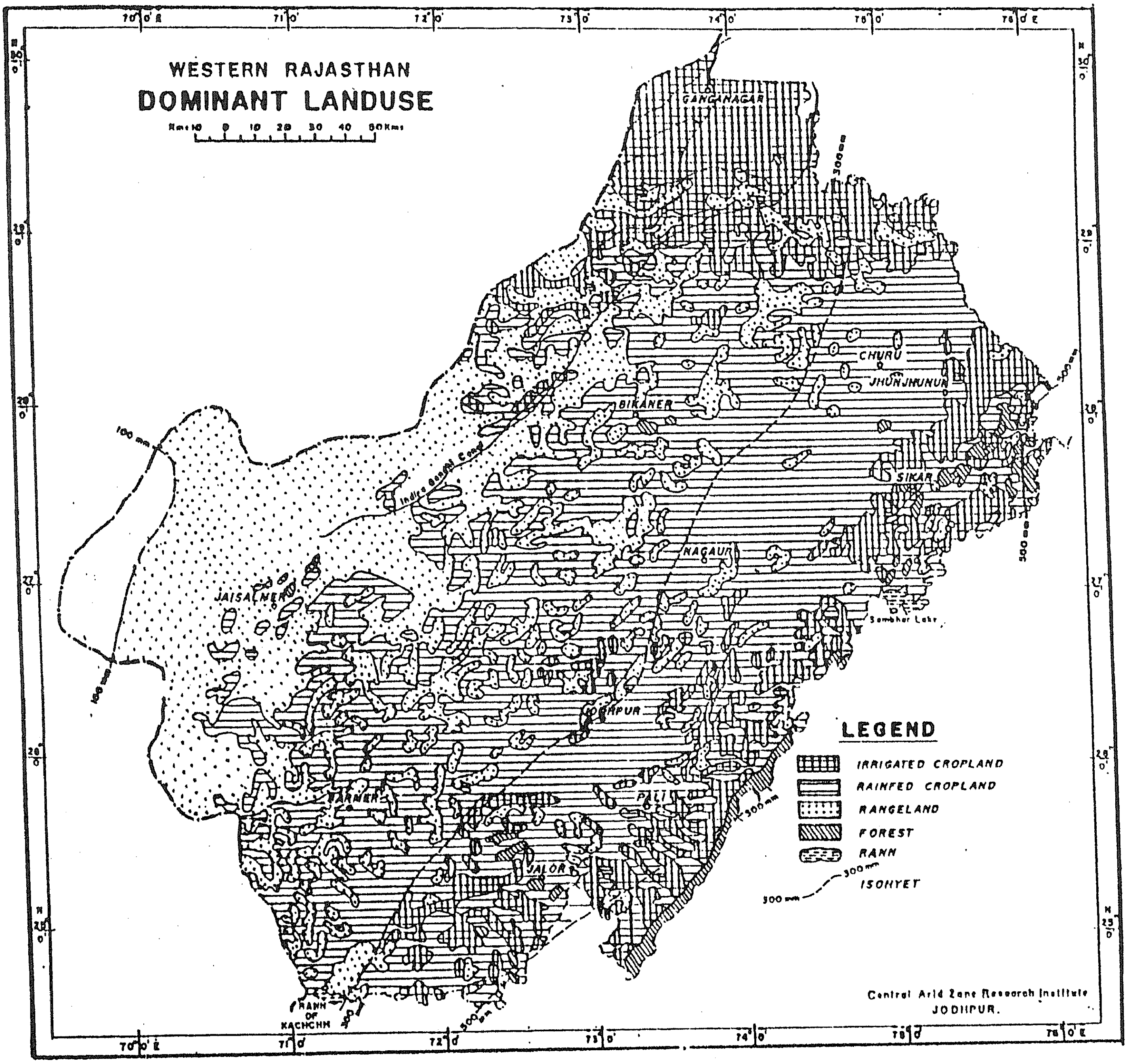
WESTERN RAJASTHAN
DOMINANT LANDUSE
GANGANAGAR
CHURU
JHUNJHUNU
BIKANER
SIKAR
NAGAUR
JAISALMER
BARMER
PALI
JALOR
Sambhar Lake
RANN OF KACHCHH
Indira Gandhi Canal
LEGEND
IRRIGATED CROPLAND
RAINFED CROPLAND
RANGELAND
FOREST
RANN
ISOHYET
Central Arid Zone Research Institute
JODHPUR.

FIG. 2

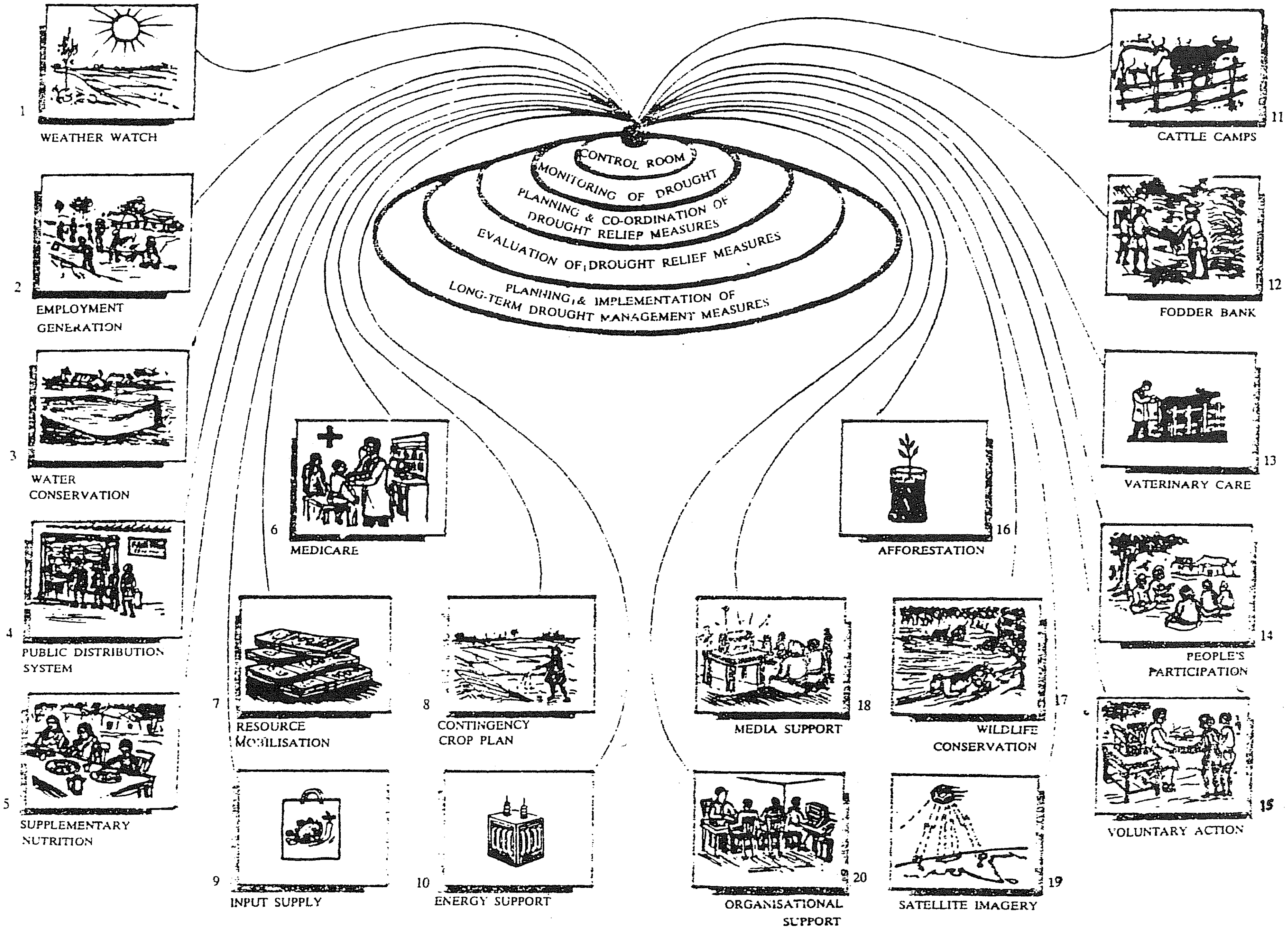

Figure 3 : A Conceptual Model of Drought Management

INFORMATION PROCESSING STEPS

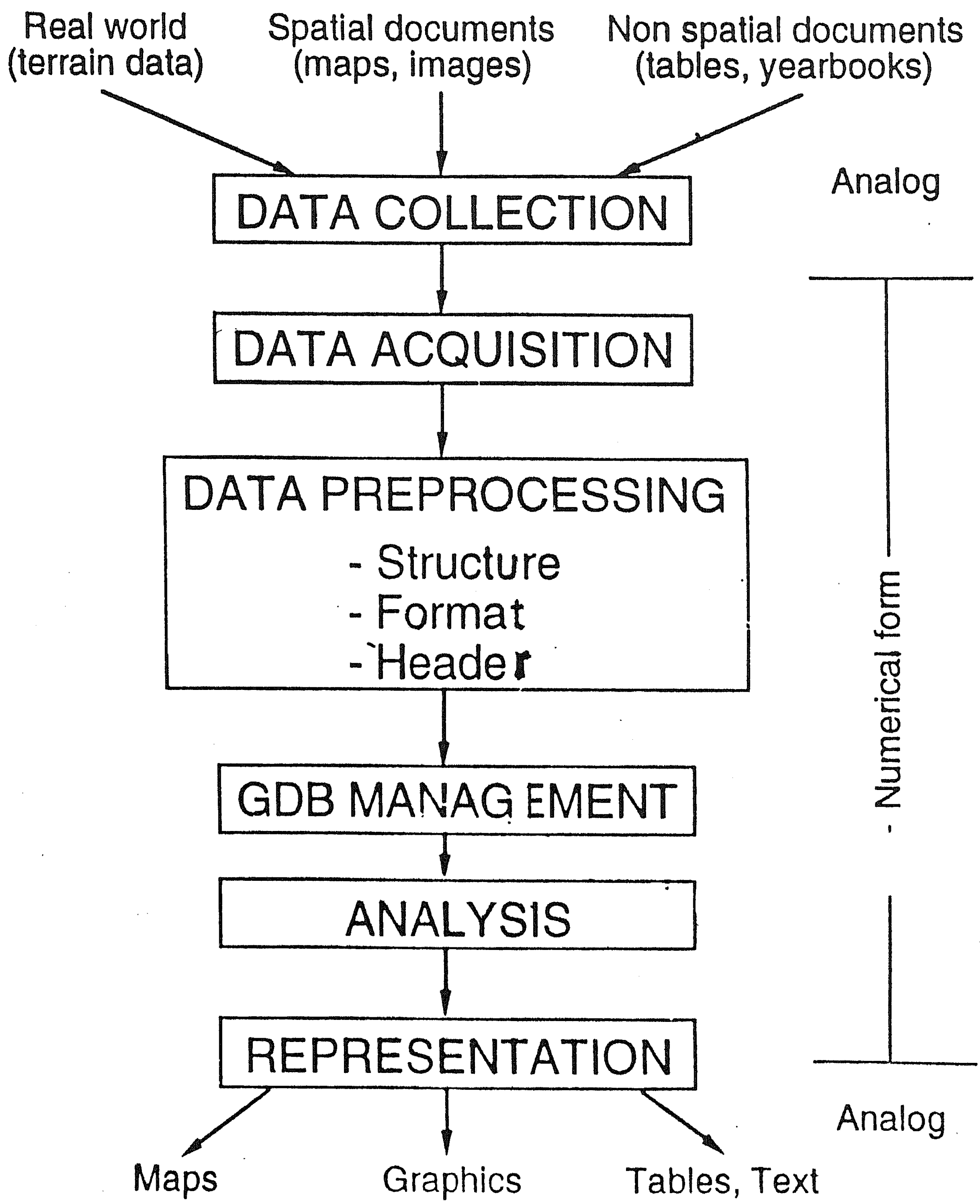

FIG.4

FLOW CHART SHOWING METHODOLOGY FOR MAPPING LAND USE/LAND COVER THROUGH VISUAL INTERPRETATION TECHNIQUES

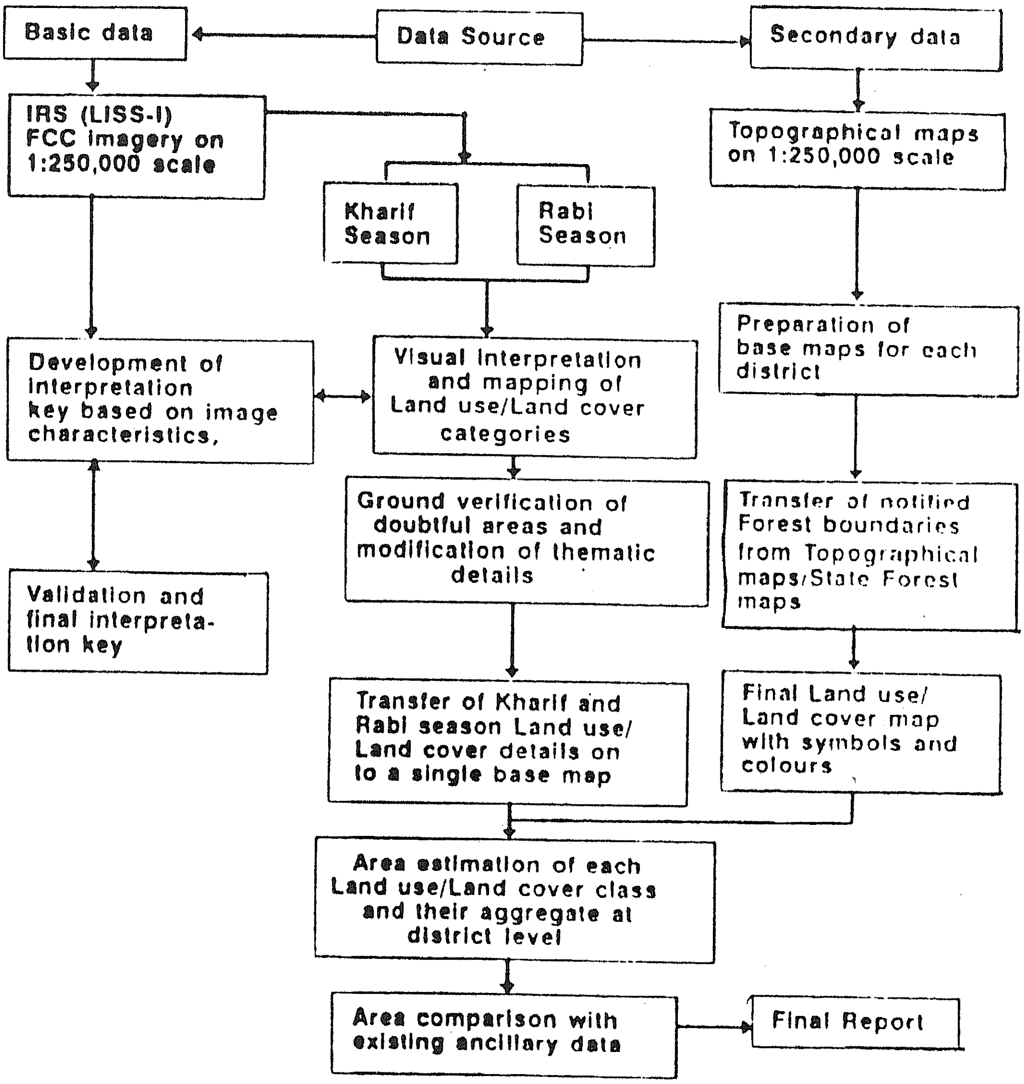

FIGURE 5