1.1 GENERAL

World’s population is increasing at a progressively faster rate with attendant changes in land use and land cover. Agricultural areas are being converted into urban uses; forest lands are being stripped for timber or conversion to agriculture. Although many of these changes are detrimental to the overall environment, it is highly unlikely that the process will halt. The alternative is to plan and regulate the changes to minimize negative impacts on the environment. Planning requires an accurate inventory of existing patterns of land use and land cover.

Land use describes how a parcel of land is used (such as for agriculture, residence or industry), whereas land cover describes the materials (such as vegetation, rocks or buildings) that are present on the surface. The land cover of an area may be evergreen forest, but the land use may be lumbering, recreation, oil extraction or various combination of activities. Accurate, current information on land use and land cover pattern is essential for many planning activities. The land use and land cover of an area is largely dependent on the natural resource potential of that area. Similarly, by optimizing the natural resource potential, the land use and land cover pattern of an area can be regulated to obtain desired land use outcomes.

Management of natural resources is of paramount importance in the present context. Anything, which is used by man to satisfy his needs and aspirations, is called a resource. Zimmermann (1951) defines resource as means of attaining ends, the ends being the satisfaction of individual wants and attainment of social objectives. Natural resources are properties of the physical environment that are considered useful for satisfying human wants (Jonston et. al, 1994 Ed.). Ramade (1984) define resource, as any form of energy or matter essential for the fulfillment of physiological, socio-economic and cultural needs both at the individual and community level.

Thus, any material, which can be transformed in a way that it becomes more valuable and useful, can be termed as a resource. In other words, it is possible to obtain valuable articles from any resource. Thus, land, water, livestock, forests, minerals as well as
human beings are resources. Any material can be termed as a resource provided an appropriate technology is available for its transformation into more valuable goods. The development of technology is closely related with the scientific knowledge and technical skills of the people. Natural resources are subdivided into non-renewable and renewable. The former are substances, which have evolved over geological periods of time and therefore effectively cannot be replaced. These include substances such as metal ores, coal, oil, and natural gas. Renewable resources are those, which are capable of regenerating themselves continually from input. These include animals, plants, soil, rain, wind, and tidal energy. Solar energy is not renewable but may be regarded as infinite.

Proper management of the natural resources is especially important in developing countries that cannot afford the consequences of irreversible losses of natural resources and ecological degradation. Nor can they afford high cost efforts to remedy environmental damages. Our objective should be to create an economic environment in which it is more rewarding to conserve resources than to destroy them, because growth derived from rapid resource depletion is neither ecologically nor economically sustainable.

The main objective of natural resource management should be identified as the extent to which resource exploitation can be done to achieve socio-economic benefits without any serious perturbation of nature. Resource management on the basis of ecological principles to achieve socio-economic development of human society through purposive and judicious utilization of natural resources and to maintain simultaneously the environmental quality is in fact an inter-disciplinary field. It is worth mentioning that the management of such resources should be ecologically viable, economically rewarding and socially acceptable (Singh, 1999).

In the given circumstances where the greatest dilemma is the population growth and the economic development vis-à-vis protection of our depleting resource base, the developmental planning based on the philosophy of sustainable development can only be a viable option. Such development philosophy meets the needs of the present without
compromising the ability of future generations to meet their own needs (UNEP, 1989). It also implies the maintenance, rational use and enhancement of the natural resource base that underpins ecological resilience and economic growth (UNEP, 1989).

1.2 TRADITIONAL APPROACH TO NATURAL RESOURCE MANAGEMENT AND ITS SHORTCOMINGS

Natural resource management involves manipulation of the resource to preserve or supply products on a sustained basis (Knight and Bates, 1995). It revolves around, but is not limited to the manipulation and analysis of many different types of spatial data. Spatial data is that which has physical dimensions and geographic location. Traditionally most of this data is stored in separate and unrelated databases. This makes its use in decision making complicated as spatial relationships are interpreted through visual observation of several different resources maps, unrelated in terms of scale and projection. The limiting factor in decision making is not the amount of data available to resource managers; rather it is the ability to mentally organise and compare these large quantities of information. This can be frustrating, time consuming and expensive. Many hours of manual processing are often necessary to get the data into suitable format. Consequently, managers may find themselves in a difficult position in which they cannot use all of the available information but are still required to provide solutions.

1.3 ROLE OF REMOTE SENSING AND GIS

It is in this context, Remote Sensing and Geographical Information System (GIS) techniques become highly relevant. Remote Sensing is defined as the science of deriving information about an object from measurements made at a distance from the object and without the sensor actually coming into contact with it (Barret and Curtis, 1982; Sabins, 1997). Remote Sensing technique by virtue of synoptic coverage, repetitive data acquisition capability, spatial information, real time data collection and computer compatibility offers an effective first hand tool in mapping and monitoring of natural resources within a reasonable short time frame (Drury, 1986; Sabins, 1997; Wirdum, 1993). GIS, on the other hand, can facilitate a multi criteria evaluation through the
overlay of maps. It's a powerful decision making tool as it provides facility for analysis of various spatial and non-spatial data and helps in decision making processes (Aronoff, 1989; Worrel, 1990; Morain, 1999). Thus, GIS enables us to process the data in terms of the people’s need as well as physical realities, hence play very significant role in management of natural resources.

1.3.1 GIS in Natural Resource Management

GIS is a vital tool in natural resources management. The various aspects of resource management it supports include storage and retrieval of data, interpretation and analysis of the resource data, and development of the Resource Management Plans (RMP's). Resource use alternatives are formulated, and the GIS is used to evaluate each in terms of environmental impact, economic implications, acreage, and potential use conflict. One important function of GIS is to assist in recognizing underlying patterns in data. These patterns may be areas of forestland suitable for timber harvest or potential shifts in population distribution. GIS simulations can be used to understand the direct and indirect effects of human activities over long periods of time and over large areas.

Due to its multi-applications characteristics, GIS is of interest to a wide and increased range of users such as land and resources managers, planners, administrators and policy makers. For the successful application of GIS, a Geo-data base has to be generated tailored to needs of user. This Geo-data base (GDB) contains cartographic, resources, socio-economic and climatic information about a geographic area. In order to handle such data efficiently and to extract meaningful information required for decision making process, the data for the GDB are to be acquired, processed and stored in an organised manner so that these can be retrieved, manipulated, analysed, formatted and if required documents/reports prepared which can be used for taking correct decisions. Such module is called Data Base Management System (DBMS), as shown in Fig. 1.1

By using the database integration capabilities of GIS, planners and resource managers gain a better understanding of the complex interrelationship between physical, biological, cultural, economical, and demographic considerations around a specific resource. Access
GEOGRAPHIC INFORMATION SYSTEM AND DATA BASE MANAGEMENT SYSTEM

DATA ELEMENTS OF AN AREA

TOPOGRAPHIC DATA
CLIMATIC DATA
SOCIO-ECONOMIC DATA
CADASTRAL DATA
LANDUSE DATA
VEGETATION DATA
SOIL DATA (MAPS)
HYDROLOGICAL DATA
GEOMORPHOLOGICAL DATA
GEOLOGICAL DATA
GEOPHYSICAL DATA (MAPS)
GENERATION OF DATA BASE
DIGITISATION OF MAPS ETC.
AND StORING OF DATA

UPDATING/ MERGING OF THESE DATA WITH THE SATELLITE, AERIAL AND OTHER CURRENT REFERENCED INFORMATION

DATA INPUT AND THEME ORIENTED DATA EXTRACTION

DATA MANIPULATION, STANDARDISATION AND ANALYSIS

CHANGE DETECTION STUDY

RESULT GENERATION

THEMATIC MAPS REPORT MAPS TEXT TABLES

GIS SOFTWARE PACKAGE

RESOURCE SPECIFIC ANALYSIS MODULES

DECISION MAKING SYSTEM

Fig. 1.1 Flow diagram showing various steps in GIS and DBMS.
to this information and its understanding makes it essential in making sound resource-use decisions. This ensures balanced management and use of the resources.

With the application of computers in handling of spatially referenced data it has become possible to store and update geographical information, conducting various spatial analysis never feasible manually, and presenting the map on easily obtainable maps. So GIS in a broader sense now encompasses the application of computer through special software Geographic Information System Software (GISS) in handling data referenced to the spatial domain with the capability to interrelate data set to carry out spatial analysis and to present results (Shrivastava, 1992).

1.3.2 Remote Sensing in Natural Resource Management

Remote sensing provides an opportunity to view or analyze natural resources in inaccessible areas. It can be generated in accurate unbiased form; acquired at minimal costs at a known point in real-time; geographically referenced; prepared in useful and storable format; and produced in volumes never attainable before. When remote sensing was first envisaged and activated in 1960's it was viewed as the science of obtaining the image of an object in space. The image had a number of uses that were primarily concerned with identification, area estimation etc. The number of usable images was limited by technical processing limitations, resolutions problem and cloud cover. Today, with the developments in sensor technologies, satellite images having high spatial, spectral and temporal resolutions are obtained from all weather remote-sensing satellites with cloud penetrating capacity. Remote sensing now includes photography, radar, lasers, and sonar and thus provides information with unique and valuable characteristics. The computational speed has also been increased manifold, enabling the users to process higher volume of digital satellite data in lesser times (Tounshend, et. al., 1981).

So far, data used as geo-data base for GIS lack adequate spatial information and is static (Tomlison, 1972), but the availability of various kinds of remotely sensed data in multi-temporal and multispectral modes, has given new dimension to data generation. When
these Remote Sensing data are integrated with other spatial and statistical information the GIS becomes valuable tool in the hand of managers and planners.

Aerial photography has been used for a long time by resource managers to assess the direction and magnitude of changes in important natural resource parameters. Simple aerial photographic techniques have been used to establish baselines for comparative environmental analysis, to develop an awareness of subtle long-term environmental effects, to identify indicators of environmental change, and to provide a new source of data for environmental planning and management.

1.3.3 Integration of GIS and Remote Sensing

GIS and Remote Sensing have a degree of mutuality; GIS provides a means for increasing the utility of remote sensed data. New information can be regularly updated. GIS makes it possible to improve the interpretation and analysis of remote sensed images. This is achieved by combining reference data from special sources. A GIS, integrated with image processing capabilities is a powerful tool for computer assisted resource mapping.

Single image or map data are not sufficient enough which can provide complete information for proper resource planning. Therefore remote sensing images taken at different points in time and often with different sensor configurations provide means to analyse, and produce results which can be combined with information obtained from existing maps and tabular data. This combinational process often involved secondary analysis. Though remote sensing constitutes an important data source but it does not normally provide the statistical, spatial, analytical and combinational capabilities required for multidisciplinary decisions in a timely fashion.

Further, sometimes it becomes necessary to update information regarding dynamic themes of land resources such as vegetation, land use and general environmental data. It is here that remote sensing proves to be the most economical source of information for updating and augmenting databases for Geographic Information Systems. Thus it
becomes necessary not only to extract the needed information from image data, but also to cast it into a form acceptable as input to the GIS. Remotely sensed images provide a coherent view of the Landscape that is not available from a GIS.

So, one can see that the combination of remote sensing image data with GIS makes an effective tool in the hand of resources managers and planners. Today, it's probably more accurate to describe the remote sensor data as "ancillary" since the GIS can contain a great many data layers, only one or a few of which are derived from remote sensing. Remote sensing is able to capture a wide range of images through the use of more varied sensors and increase effectiveness in data extraction. This has enabled the two disciplines to complement each other, broadening their utility (Meaden and Kapetsky, 1991).

1.4 NATURAL RESOURCE MANAGEMENT PROGRAMMES IN INDIA

With launching of operational Remote Sensing satellites IRS-1A (1988) and 1B (1991) and setting up of various information systems, about 350 national/regional level Remote Sensing application projects have been conducted in India. The successful launch of second generation and indigenously built IRS-1C satellite on 28th December 1995 and IRS-1D satellite on 29th September 1997 have provided tremendous opportunities for applying space informatics in areas of disaster monitoring and natural resource management. The IRS-1C/1D mark 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.

1.4.1 National Natural Resources Management System (NNRMS)

In 1983, the Department of Space (DOS) realized that to promote the wide use of the technology of remote sensing it would be necessary to integrate the technology into the existing information systems, which were in day-to-day use by resource managers and planners. With this in view a major programme called the National Natural Resources Management System (NNRMS) was launched under the aegis of the Planning
Commission of the Government of India in order to achieve optimum utilization of natural resources through a proper and systematic inventory of resource availability. Taking into account the recommendations and suggestions by the task forces, six standing committees have been set up to cover the following sectors: (i) Agriculture and soils, (ii) Bio-resources and the Environment, (iii) Geology and Mineral Resources, (iv) Ocean Resources (v) Water Resources and (vi) Remote Sensing Technology and Training sectors. The various ongoing projects include crop acreage and production estimation, soil moisture estimation using ERS-I, SAR, marine fisheries, coastal zone mapping, brackish water aquaculture, water-land mapping, grasslands of the Banni area in Kachchha, watershed prioritisation, environmental impact studies for the Narmada and Tehri projects, land use/land cover mapping for agro-climatic regional planning, drought monitoring, flooded area mapping and damage assessment, wasteland mapping and snow-melt run-off forecasting (Chandrasekhar, 1992).

1.4.2 National (Natural) Resources Information System (NRIS)

Since a comprehensive system is essential for policy makers to ensure the optimum utilization of natural resources, development of a NRIS has been conceived as a major component under NNRMS (NNRMS, 1988). The integrated system would provide updated and systematic information on natural resources related to land, water, forest, minerals, soils, and oceans etc., which are, in turn, being integrated with the socio-economic data. A computer system based on a Geographic Information System (GIS) is being developed with capabilities for data integration and easy retrieval. The NRIS has advanced capability and is proposed as an integrated information system with linkages with the other existing systems. Such an integrated information system of spatial (maps) and non-spatial (socio-economic) data at the districts, states and country level, provides an efficient and powerful tool for resource managers and policy makers.

1.4.3 Natural Resources Data Management Systems (NRDMS)

Natural Resources Data Management System (NRDMS) - a multi-disciplinary programme of the Department of Science & Technology, Government of India aims at developing scientific data based approach for operationalising the concept of
decentralised planning. Launched in 1982, the programme is a major initiative of the Government to promote research and development cum demonstration in the field of Geographical Information System (GIS) technology and its application to the problems of natural resources management. During the VIII Plan, the focus has been on preparation of spatial district resource profiles, upgradation of the low cost GRAM GIS package, area specific application studies and training of users. Academic institution, IITs and R & D Laboratories provide technical back up. Priority areas have been identified for research and development. Land system classification, watershed modelling, energy planning, groundwater budgeting, large scale resource mapping and landslide studies have the areas of research over the last few years. NRDMS is now poised towards further consolidating these efforts by upgrading the GRAM package to suit the data processing requirements of local level planning. Building up decision support modules in selected sectors like land use planning, water conservation, energy management, and infrastructure development is in the research agenda. Concerted efforts are being made to develop kits and tutorials for the training of potential users so that the methodology strikes roots in the resource management practices at different levels of the planning hierarchy, UNDP is supporting NRDMS in this endeavour.

1.4.4 Integrated Mission for Sustainable Development (IMSD)

IMSD is another national level project, which is based on GIS methodology. But in this case the project is multi-dimensional. “Sustainable development of natural resources is based on maintaining the fragile balance between productivity functions and conservation practices through monitoring and identification of problem areas which requires application of alternate agricultural practices, crop rotation, use of bio-fertilizers, energy efficient farming methods and reclamation of under-utilized lands” (ISRO, 1995). This model has local and global objectives. The solutions at the local level, similar to NRIS, are aimed to arrive through the effective use of space-based remote sensing data merged with collateral socio-economic data. This project has been launched in the 157 problematic districts of the country, which cover about 45 per cent area.
As per the approved methodology, this study involved generation of thematic maps showing current land use/land cover, types of wastelands, forest cover/types, surface water resources, drainage pattern, potential groundwater zones, landforms (geomorphology), geology (rock types, structural features, mineral occurrence), soil types etc. using data from IRS. Slope maps from topographical sheets were also used. With the help of above mentioned information, derived maps showing land capability, land irrigability, status of soil erosion, run-off potential, priority watersheds needing immediate treatment etc. are to be prepared. All this information is to be used to identify land units, which are unique in terms of their resource potentials and problems. Specific development plans with the help of the concerned departments have to be initiated. National level institutions like National Remote Sensing Agency (NRSA), Space Application Center (SAC), Regional Remote Sensing Service Centers (RRSSCs) and state level remote sensing centers are participating in this project (Nag, 1998).

1.5 SCHEME FOR NATURAL RESOURCE MANAGEMENT

In the present study an integrated approach to the natural resource management in the coastal district of Raigad, Maharashtra has been attempted taking into account the elements of natural resources as shown in the schematic diagram (Fig. 1.2). Initially, the study was started to assess and monitor the natural resource base of a part of coastal Maharashtra covering parts of Mumbai, Thane, Raigad and Ratnagiri districts, but later the study was confined to the Raigad district only, due to the ease in data generation and compilation. Major part of the study has been undertaken as per the guidelines prescribed by the Department of Space for NNRMS programme to make detailed inventory of resource availability.

As mentioned in Fig. 1.2, the parameters considered in the present study for natural resource management include (i) hydrology or water resources, (ii) land use/land cover pattern, (iii) geology and geomorphology, (iv) demography or human resources, (v) bio resources, (vi) climate, (vii) soil and (viii) topography. Though some other parameters are also discussed at different places but the study is confined only to the parameters mentioned above.
Fig. 1.2 Schematic diagram showing the approach to the Natural Resource Management.
1.6 A BRIEF LITERATURE REVIEW

It is believed that water is the most important and vital resource on the earth. This was the first resource to be harnessed by human beings as the early civilizations evolved on the banks of rivers. It is the water resource that influences the value of many other natural resources. Hence water resources, both surface and sub-surface, have been given maximum importance in the present study. A number of studies pertaining to groundwater exploration reveal that groundwater resource is scanty and is fast depleting by over-exploitation due to rapid urbanization and industrialization as well as improper land use practices (Bhattacharya et al., 1991; Kulkarni, 1992; Singh et al., 1993; Chi and Lee, 1994; Krishnamurty et al., 1995; Reddy et al., 1996; Pal et al., 1997; Ravindran et al., 1997; Saraf et al., 1998; Pratap et al., 2000; Reddy et al., 2000; Raj, 2001; and Sarkar et al., 2001). Similarly the groundwater prospects have also been studied by many, through surface drainage characteristics (Horton, 1945; Miller, 1953; Strahler, 1964; Nautiyal, 1994; Srivastava, 1997; Agarwal, 1998; Chaudhary, 1998; Singh, 1998; Biswas et al., 1999; Das and Mukherjee, 2002b). These studies indicate that the study of drainage characteristics in terms of morphometric analysis (quantitative description of the drainage basin geometry) of different watersheds in a region gives much information regarding the denudational history, subsurface material, geological structure, soil type and vegetation status of that region, which plays a crucial role in formulating a plan for watershed management.

Groundwater quality plays an important role in public health as well as in irrigation management, so as to achieve an optimal level of production, particularly in situations where resources are scanty. Hydro-geochemical characterization is a very important aspect of groundwater management. An understanding of chemical quality of groundwater is essential in determining its usefulness for domestic and agricultural purposes. A number of studies have been carried out to assess the groundwater quality in different areas (Choubisa et al. 1995; Nawlakhe et al. 1995; Jain et al. 1996; Mukherjee, 1996; Singh et al. 1996; Jain et al. 1997; Ballukraya et al. 1999; Mukherjee et al. 1999; Mohan et al. 2000; Das and Mukherjee, 2002a; Singh, 2002; Singh et al. 2002).
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The land use and land cover of an area is largely dependent on the natural resource potential of that area. Similarly, by optimizing the natural resource potential, the land use and land cover pattern of an area can be regulated to obtain desired land use outcomes. Anderson and others (1976) have developed a multi-level land use/land cover classification system for USA. In this classification scheme, broad land use/land cover classes are categorized under level-I and are applied to the regional level, similarly detailed land use/land cover classes of level-II are applied to local level classification. This multi-level classification system has been used for a detailed land use and land cover analysis of the study area using IRS-1B LISS II and IRS-1C LISS III images (Rao et al., 1991; Dhinwa et al., 1992; McCreary, 1992; Pathan, 1992; Aspinall, 1993).

The land use and land cover pattern analysis is an important part of natural resource management as it helps formulating an accurate inventory of existing patterns of land use and land cover. Land use/land cover studies have been carried out using remote sensing techniques by many researchers (Gautam and Narayan, 1983; Saxena et al., 1983; Singh et al., 1983; Thampi, 1983; Sharma and Garg, 1986; Porwar and Roy, 1992; Jagtap et al., 1994; Chauvaud et al., 1998; Samant and Subramanyan, 1998; Brahmabhatt et al., 2000). In the present study land use/land cover pattern has been analysed in order to evaluate the land for various economic activities. Land evaluation is concerned with the assessment of land performance when used for specified purposes. It involves the execution and interpretation of basic surveys of climate, soils, vegetation and other aspects of land in terms of the requirements of alternative forms of land use. To be of value in planning, the range of land uses considered has to be limited to those, which are relevant within the physical, economic and social context of the area considered, and the comparisons must incorporate economic considerations (Raghavswamy, 1982; Kumar et al. 1983; Babu et al., 1999).

Geology and geomorphology play a key role in the evaluation of natural resources. The geological and geomorphological studies using remote sensing techniques have been conducted by many workers (Thiagarajan, 1980; Goetz and Rowan, 1981; Krishnanunni, 1983; Subramanya, 1987, 1994 and 1996; Gupta, 1988; Sahni, 1991; Hayes, 1992;
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Radhakrishna, 1993; Tripathy, 1996; Subramanya et al., 1997; Nagarajan, 1998). The land forms, type of rocks and their weathering and erosional status, structural features like lineaments, dykes and faults, occurrence of minerals etc. in an area determine the land suitability of the area for a specific purpose (Gupta, 1989; Das, 1999; Das and Mukherjee, 2002c). The study area being a coastal district is characterised by hills, valleys, undulating plains, sea cliffs, coastal landforms, estuaries and creeks (Wagle, 1989; Powar, 1993; Nagarajan, 1995; Mukherjee, 1997; Sahasrabudhe, 1999; Tiwari et al., 1999; Srinivasan, 2002).

Study of structural features such as lineament fabric, lineament density and alignment, dykes and faults has been carried out by many researchers. Among these, the studies pertaining to the Konkan coastal belt show that the coast is highly fractured with majority of lineaments and faults are NNE – SSW and N – S trending (Das and Ray, 1973; Wagle, 1982; Kanungo et al., 1995; Mukherjee et al., 1997; Raj et al., 2001; Das and Mukherjee, 2002c). The lineament pattern is also studied to explore groundwater potential of an area apart from assessing micro-seismic activities (if any) in that area. Remote sensing technology was found to be a very useful tool for such studies.

The occurrence of mineral resource in the study area has been assessed by Muthuraman (1981) and Nagarajan (1998). The study revealed that apart from few low-grade bauxites the district is almost devoid of any mineral of economic importance. Remote sensing is found to be a powerful tool in mineral exploration (Smith, 1974). Apart from this the other resources like the human resources, bio-resources, soil resources etc have also been assessed and mapped in the present study to formulate a comprehensive natural resource management plan.
1.7 OBJECTIVES AND SCOPE

The main objectives of the present study are as follows:

- To assess water resources of the area and their management.
- To assess the quality of groundwater for domestic as well as irrigational use.
- To generate thematic maps on the themes of geology, geomorphology, demography, soil, topography, drainage etc. of the study area with the help of satellite imagery and other collateral data.
- To prepare broad land use/land cover map of the study area and to study its pattern using visual interpretation as well as digital image processing of satellite data.
- To undertake land capability/potential analysis for sustainable development.
- To integrate the thematic information in GIS environment to draw locale-specific resource development action plans as well as socio-economic development plans.
- To demonstrate the potentiality of GIS and Remote Sensing in natural resource management.

The present piece of work has been intended to be used by the resource planners and managers in the Raigad district of Maharashtra. The work will indeed throw some light on the intricacy of an integrated and comprehensive natural resource management plan. The outcome of the study will draw attention of the resource planners to take remedial and conservational measures at few environmentally vulnerable sites. As in the present study water resources have been assessed and evaluated intrinsically hence the study will leave behind a greater scope for water resource management in the district. Thematic maps prepared will serve as first hand information about the resource base for the district. Last but not the least the study will advocate the utility of GIS and Remote Sensing for such studies among the natural resource planners and managers. The study will also leave a vast scope for more detailed study of the natural resources pertinent to other areas using higher resolution satellite data.