ROLE OF REMOTE SENSING (RS) AND GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN BIODIVERSITY STUDIES
Remote sensing and GIS are the modern tools which have emerged as an outcome of the remarkable developments in science and technology. Space Remote sensing which can provide synoptic and repetitive high resolution images over large areas including inaccessible areas has now become a powerful tool for inventory, mapping and monitoring of natural resources including forests. The repetitive coverage of the satellite data provides an excellent opportunity to monitor the temporal changes in land use/land cover, deforestation and afforestation, wildlife habitat modelling, forest fires, pest and diseases, biomass changes etc. Satellite remote sensing coupled with GIS has demonstrated the potential of providing comprehensive information on various aspects of forest vegetation (Roy & Ranganath, 1993, Ranganath et al., 2000, Madhavan Unni, 1990, Roy, 1999).

New direction has emerged in the development and application of comprehensive methods for assessment of biodiversity at landscape level and its relationship to ecosystem diversity and heterogeneity. Remote sensing has become an important observation and measurement tool for analysis of landscape ecological relationships. Remote sensing offers the capability to collect data on landscape characteristics and interactions without disturbing the environment.

GIS is another principal technology available for investigation of landscapes. In addition to representing landscape features, GIS can be used in spatial statistical analysis of ecological distributions, assess disturbance levels, etc. It also helps to predict the consequences of a contemplated action, evaluate the results of actions that have been taken, and compare alternative actions.

Concept of remote sensing

Remote sensing is the process of obtaining measurements of an object from a distance. It is generally, defined as the science of collecting and interpreting information about a target without being in physical contact with the object. Remote sensing data has the advantages of providing synoptic view and large area coverage, which helps, in obtaining "birds eye-view" of the features. Cameras, spectroradiometers, multispectral scanners and the human eyes are all examples of remote sensing data collection systems. Remote sensing is a multidisciplinary activity, which deals with inventory, monitoring and assessment of natural resources through the analysis of data observed from a remote platform (George Joseph, 1993).
Remote sensing largely concerns the measurement of electromagnetic energy, which is reflected, scattered or emitted by objects receiving and then returning energy from the sun. Depending on the physical features and chemical properties, different objects on earth's surface reflect, reradiate or emit different amounts of electromagnetic energy in various wavelengths of electromagnetic spectrum. These unique reflectance patterns are called "Spectral signatures". Spectral reflectance is the ratio of reflected energy to incident radiation as a function of wavelength. The values of spectral reflectance/ emittance of objects averaged over different, well-defined wavelength intervals comprise the "Spectral Signature" of the objects or features (Navalgund, 2001). In remote sensing, detecting these differences enables identification of the earth surface features from the air or from the space. The measurement of reflected or reradiated or emitted electro-magnetic radiation forms the basis for understanding and identification of earth's surface features. Depending on the source of energy which illuminate the object under study, the remote sensing techniques are classified into two types namely Passive and Active remote sensing. In passive remote sensing system, the naturally radiated or reflected energy from the earth surface features is measured by the sensors operating in different selected spectral bands on board the air borne/space borne platforms (similar to photography in day time without flash). An active remote sensing system supplies its own source of energy to illuminate the objects and measures the reflected energy returned to the system (similar to photography in night with flash).

Electromagnetic spectrum

The Sun's energy commonly referred to as electromagnetic spectrum (EMS) is an electromagnetic radiation that moves with constant velocity of light characterized by wavelength or frequency. The EMS commonly ranges from cosmic rays to radio/television broadcast wavelengths. Remote sensing technology makes use of visible (0.4 to 0.7 μm), Infrared (0.7 to 3.0 μm), thermal Infrared (3 to 5 μm and 8 to 14 μm) and microwave (0.1 to 30 cm), regions of the EMS to collect information about various objects on the earth's surface.

Sensors and cameras are the instruments required for remote sensing data collection. Optical imaging system collects the data in visible and infrared portions of the EMS while Synthetic Aperture Radar (SAR) systems operate in the microwave regions. Optical sensors are incapable of providing useful data during cloud cover while microwave sensors has the ability to acquire data under virtually any weather
conditions. The wavelength of microwave signal is long enough to penetrate clouds, haze, rain and fog.

Earth observation satellites provide the vantage point and coverage necessary to study our planet as an integrated, interactive physical and biological system. Since, satellites orbit around the earth, with the rotation of the earth as added advantage, it is possible to obtain repetitive coverage at periodic intervals to monitor the features of the earth and evaluate the changes that occur over a period of time. Thus, satellite data provides opportunities to observe, measure, map and monitor the earth’s natural resources.

Image interpretation and analysis

The satellite data products are available in the form of photographic products such as films, diapositive, paper prints of various scales or digital data stored in the form of computer compatible tapes, cartridges, floppies and CD-ROM or through Internet. The desired information can be extracted from these data products through visual interpretation and/or digital image processing techniques. In practice, both visual interpretation and digital image processing techniques are complimentary to each other. For large areas and spectrally homogeneous scenes digital image processing method may provide a quick and cost effective means of image analysis. On contrary for smaller areas and spectrally heterogeneous scenes visual interpretation method may be more suitable because of the need for basic image characteristics, visual perception etc.

Visual interpretation techniques

Visual interpretation of remote sensing images, for extracting desired information could be achieved in an efficient and effective way by using several basic interpretation keys or elements (Sabins, 1997). The basic interpretation keys are (i) tone (ii) texture (iii) pattern (iv) shape (v) size and (vi) location or association. All these interpretation elements are qualitative attributes, and they are subjective depending on the experience and personal bias of an interpreter. The characteristics of each of the interpretation keys are given below:

- **Tone** refers to relative brightness of objects on the black and white image or refers to the combination of hue, saturation and intensity in colour images.
The tone in the black and white images is expressed as different shades or levels of grey. For example water, vegetation, soil etc. have distinct tonal variations. Without tonal differences, the shape, pattern and texture could not be discerned. Tonal variations depend upon the reflectance properties of surface materials, terrain slope, illumination condition, etc.

- **Texture** is the frequency of change and arrangement of tones on an image. It is produced by a spatial arrangement/aggregation of features that may be too small to discern individually on the image. The visual impression of roughness or smoothness created by some objects is a valuable clue in image interpretation. The texture is normally referred as fine, medium or coarse and also as stippled or mottled.

- **Pattern** on an image result from regular repetition of tonal variations and textures. The repetition of certain general forms or relationships is characteristic of many natural and man made objects. Arrangement of vegetation, topographic features, drainage networks, different rock types are typical examples of pattern. The most commonly used patterns are (i) the drainage networks, which have orderly association with geologic structure and (ii) rock types and outcrop patterns, which provide clues to geologic structures.

- **Shape** refers to the general form, configuration or outline of individual objects. The shape of some object is so distinctive that their image may be identified solely from this criterion. Forest plantations, R.F.boundaries, etc will have definite shape.

- **Size** of an object is one of the most useful clues to its identity and should be discussed in the context of the image scale. For example streams versus rivers can be differentiated based on the size as the criterion in their identification.

- **Location or association** of objects in relation to other features gives important clues on the identity of an object. Shola vegetation with grasslands, riparian vegetation along stream courses, irrigated crop near a tank; sand beaches along the coastline are the examples of association.
Among the above elements tone and texture are the functions of brightness, contrast and resolution of the image while size, shape and pattern are dependent on the scale of an image.

**Digital Image Processing Techniques**

Digital image processing involves interpretation / analysis of data in digital format with the help of computers. It enables speedy and accurate interpretation of the multispectral / multisensor / multidate data received from remote sensing satellites. The digital data can be treated with various algorithms for enhancing the ground features for better interpretability and analysis.

Remotely sensed data in digital format corresponds to the different earth features collected by the sensors and stored in computer compatible tape/cartridge/floppy/CD-ROM in the form of rasters or tiny equal areas or picture elements or pixels and are arranged in regular lines and columns. The pixels represent brightness value having a specific Digital Number (DN) value, which depends on the energy reflected by the earth surface in a specific wavelength or band or channel. Most of the sensors on-board the satellites operate in different discrete wavelengths. Therefore, each one of the earth features is sensed by the sensors simultaneously and provides a set of DN values. The DN value of each pixel is ranging from zero for black to some higher value for white, based on the radiometric resolution (eg: 6 bit data represents 0-63 grey level, 7 bit data represents 0-127 grey levels and so on). The availability of remotely sensed data in digital form helps in carrying out digital image processing with the aid of computers. Digital processing technique has certain advantages to carry out many of the functions which is not possible with hard copies. They are geometric and atmospheric corrections, data compression and resampling, image enhancement, multivariate analysis, multiscene registration, pixel level classification and theme area measurement, data base correlation, etc.

There are a number of procedures/methods available for image data manipulation (Jensen, 1986; Lillesand and Kiefer, 1994; Schowengerdt, 1997). However, they can be broadly grouped into three categories, viz., (i) Image rectification and restoration also called as pre-processing, (ii) Image enhancement, and (iii) Image classification.
Image rectification and restoration/pre-processing operations are intended to eliminate or correct the distortions or errors caused due to geometric distortions, radiometric distortions, presence of noise in the data, etc. The standard products made available to the interpreters are pre-processed. Therefore, generally data can be directly used for image enhancement and classification.

Image enhancement operations (Contrast stretching, Band Subtraction, Brightness Index, Vegetation Index, Band Ratioing, Principal Component Analysis, Decorrelation Stretching, Filtering, Intensity-Hue-Saturation (IHS) etc) are being implemented to image data to get the enhanced output for subsequent visual interpretations. The image enhancement techniques increases the amount of information / highlight features which can be visually interpreted from the image data by improving the apparent contrast between features in the scene. The enhanced outputs can be seen in the display monitor or can be recorded in the pictorial form as B&W and/or colour composite images.

Image classification techniques are essentially meant to substitute visual analysis of the remotely sensed data with quantitative assessment. Image classification is a quantitative method that classifies or identifies objects or patterns on the basis of their multispectral values. The classification of the remotely sensed data can be carried out either without a priori knowledge about the features present in the scene (unsupervised classification) or with a priori knowledge about the terrain features (supervised classification)

**Concept of GIS**

GIS is a new technology, which is becoming an essential tool for analyzing great diversity of data (spatial and non-spatial) in a short time. As a technology, GIS has evolved through the following three broad application domains.

- **As an information database** - a means of coordinating and accessing geographic datasets.
- **As an analytical tool** - a means of specifying logical and mathematical relationships among map layers (modeling) to yield new derivative maps.
- **As decision support system** - a means for deciding how to act upon the analysis produced and simulation of after effects.

GIS is a computer based integrated data base management system in which large volumes of geo-referenced spatial data derived from a variety of sources, are efficiently stored, organized, manipulated, retrieved, analyzed and displayed/presented according to the user defined specifications. The data of various parameters is synthesized in different layers and analyzed in conjunctions with related parameters. This capability to automatically synthesize and update spatial entries of the database is the key for functional success of GIS.

The distinguishing factor which separates GIS from other information storage and retrieval systems is the use of the location of features in a co-ordinate space as the fundamental referencing principle and as important variables in quantitative analysis. There are essentially two kinds of data bases viz., the spatial data in the form of maps which could be topography, soil types, geology, forests etc, and are stored as layers in digital form in the computer. Where as non-spatial data pertains to attribute information in the form of statistics, tables, lists etc, which could be demography, rainfall, wildlife census etc.. New maps can be generated precisely by easily integrating innumerable layers of data. Thus a GIS has a database of multiple information layers that can be manipulated to evaluate relationships among the chosen elements in the different layers under consideration. The data analysis in GIS is supported by computer aided mapping and data base management. Johnson (1990) has reviewed several applications of GIS in ecology and natural resources.

GIS are being increasingly applied to conservation problems for the following reasons:
- It provides the way to overlay different layers of data: the ecological conditions, vegetation physiognomy and biotic interference etc.
- It helps to assess disturbance levels; the spatial distribution of several species in order to determine the biodiversity hotspots; past and present maps for monitoring land cover and land use changes.
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- It provides a database structure for efficiently storing and managing ecosystem related over large regions. It enables aggregation and disaggregation of data between regional, landscape and plot scales.
- It also supports spatial statistical analysis of ecological distributions and modelling.
- It gives graphic and easily understood answers to complex questions in conservation planning.

Relevance of RS and GIS in biodiversity studies

For proper assessment of biodiversity, its rate of extinction and driving forces leading to extinction, periodic data on number of species, their habitats, human interventions and ultimately impact on landscape vis-à-vis biorich characteristics are required. Remote sensing technology has the potential to provide spatial representation of different types of bioresources, characterize their association and habitats. GIS allow the use of landscape ecology and spatial analysis approach to characterize the phytodiversity pattern. Biorich sites can be modeled using different landscape ecological parameters, environmental complexities and data on species inventory in different vegetation stratum / habitats. Thus, Remote sensing and GIS technologies provides opportunity to incorporate biological, ecological and cultural landscape heterogeneity for phytodiversity assessment and conservation strategy.

Note worthy contributions

The contributions and various work carried out in the field biodiversity using remote sensing, GIS and landscape ecology are highlighted here. Inventorying and analyzing vegetation cover is the most practical way of tracking biodiversity. Satellite images have been an important basis for vegetation mapping and monitoring and understanding of ecosystem functions, primarily through relationships between reflectance and vegetation structure and composition. Earlier studies have demonstrated substantial contribution of remote sensing and GIS techniques to map spatial distributions of important habitats (Fuller et al., 1998; Madhavan Unni, 1990, Roy & Ranganath 1993). Alan and James (1997), proposed structured, spatially explicit approach for describing, analysing and evaluating the distribution of vegetation, species composition of heath and mire in Northern Ireland based on multivariate land classification and field sampling. Application of Remote Sensing in the field of forestry including biodiversity has been reviewed (Ranganath et al., 2000). A review of GIS and databases for vegetation mapping and monitoring is given by
Recent approaches to study forest ecosystem emphasize on spatial characterization and vertical analysis together using landscape ecological principles (Roy et al., 1997, Raven & Roy, 1995). Field surveys of plants and animals were combined with satellite remote sensing of broad vegetation types to map biodiversity and thereby helped plan conservation in Sango Bay area in Uganda (Fuller et al., 1998). Debinski et al., (1999) had used remotely sensed data and GIS to categorise habitats, then determined the relationship between remotely sensed habitat categorizations and species distribution patterns. Roy & Tomar (2000) used geospatial modeling technique for characterizing biodiversity at landscape level. They have followed the three-tier approach of field observation, remote sensing and landscape analysis. A remote sensing agenda for mapping and monitoring was proposed by Stoms & Estes (1993). Davis et al., (1990) presented an approach to integrate existing data on species distribution and habitat characteristics in biodiversity assessments using GIS technology supported by remote sensing inputs.

Patterns of species richness in biogeographical, ecological or habitat space have long been a central theme in biology (Pinaka, 1966; Richerson & Lum, 1980; Rohde, 1992). The patterns of distributions of these species are exceedingly complex in space and time (Nagendra & Gadgil, 1999). Relationships between richness patterns and various ecological, geographical or other factors have been dealt in by many workers (Currie, 1993). Besides their key position in descriptive ecology and ecological theory, patterns of biological diversity also attract much interest. The accuracy and validity of modeling geographical patterns of species richness are critical factors in distinguishing and understanding the so called hotspots of biodiversity (Roy et al., 1993).

The landscape ecology provides insight into both landscape diversity and species diversity and suggests a theoretical and practical basis for conservation planning. Three landscape characteristics that are especially useful to consider are structure, function and change which affects diversity (Forman & Godron, 1986). An overview of many types of applications using remote sensing to landscape studies is given by Quattrochi & Pelletier (1991) and highlighted the capability of remote sensing to measure the state and dynamics of ecological variables and processes that derive these variables. Hobbs (1997) reviewed the present and future status of landscape ecology and also explored the extent to which landscape ecology has developed conceptual constructs and techniques, which are useful in an applied sense. Fragmentation is one of the severe processes which affects biodiversity (Farina,
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The patch is the basic unit of landscape structure; the characteristics of patches and spatial relationships among patches are important components of the landscape. The spatial arrangement of patches, their different quality, the juxtaposition and the proportion of different habitat types are elements that influence and modify the behavior of species populations and communities (Lidicker, 1995). Measurements of landscape diversity are analogous to common measurements of species diversity (Whittaker, 1977, 1995). Different patch types provide different habitats and species composition, thus one might expect that the total number of species in a landscape would increase as landscape richness increases (Burnett et al., 1988).

Godron (1991) has documented that remote sensing gives a perspective horizontal view and helps in delineating different landscape elements and their spatial characteristics. A horizontal relationship between the various spatial units at different spatial scale to study the homogeneity, heterogeneity and causative mechanisms have been established by Ravan & Roy (1995) during their landscape dynamics study of Madhav National Park (M.P.). Grossman (1991) approached the complexity of landscapes following a system analysis perspective that considers landscape as three layered hierarchical systems. Briefly, the bottom layers consist of a template defined by data such as topography, proper boundaries or soil type distribution and other spatial details usually incorporated into GIS. The intermediate layer and layer of complex dynamics includes structure and their dynamics. Finally the highest or strategic layer describes process that modify the structure. In the current pace of technological development, remote sensing and GIS plays vital role to evaluate the role of intermediate layers.

The impact of fragmentation on biodiversity is significant and its study is crucial for the maintenance of biodiversity. Because of increased fragmentation, patch size and the edge effect is reduced, which in turn has reduced the species richness of the district. A few studies have been done in India towards establishing the relationship between disturbance and the biodiversity of the landscape (Roy et al., 1997; Pandey & Shukla, 1999; Roy & Tomar, 2000). Menon & Bawa (1997) have discussed the role of remote sensing, GIS and landscape analysis for biodiversity conservation in western ghats using land cover modeling approach. The approach has modeled land cover/land use changes for habitat fragmentation. However, the study did not use quantitative landscape parameters like fragmentation, patchiness, interspersion, porosity, juxtaposition, disturbance index etc., to characterize biodiversity at
landscape level. Ramesh et al., (1997) have attempted a vegetation-based approach for biodiversity gap analysis. This landscape-based approach takes into account the extent of deforestation, distribution of forest/vegetation types, patchiness, and species diversity for each forest/vegetation type and uniqueness of the habitats. However, the study did not consider disturbance regimes operative in the area. Nagendra & Gadgil (1999) identified various landscape elements based on field observations and found that the landscape elements significantly support distinctive sets of species of flowering plants. However, the study did not analyse landscape ecological parameters. They have also not integrated the field data with satellite-derived vegetation map so as to demonstrate the use of satellite imagery for monitoring species diversity. Roy & Tomar (2000) have used geospatial techniques to characterize biodiversity at landscape level in Meghalaya state wherein the juxtaposition calculation was based on subjective judgement. Pushpangadan & Nair (2001) suggests to evolve a national mechanism to coordinate all on going and future research in systematics and taxonomy and to integrate it to meet the national goals of inventory, conservation, prospecting and sustainable use of biodiversity resources of our country.

**Literature available for the study area**

Vegetation of the western ghats in the form of regional floristic inventories and flora were published as early as 19th century (Beddome, 1869-1873). These were supplemented by remarkable works at the beginning of the century which are of fundamental importance even today. A few of them among them are the works of Cooke(1901-1908) in the form of Flora of presidency of Bombay, Gamble (1916-1935) in the form of Flora of Presidency of Madras, Fischer(1922) & Fyson (1932). After second world war, the inventories focussed at the district level or at the local level. Ecologically oriented studies on western ghats are also available: Aiyar(1932), Ahuja & Singh(1963), Chandrashekharan (1962), Legris (1963); Champion & Seth (1968) whole of India; Pascal (1984, 1988) for the evergreen formations of low & medium elevations. These works describe associations between species and analyze relationships between vegetation types and their natural environmental conditions. These relationships are also depicted on the vegetation maps, which cover at different scales, the whole or parts of western ghats (Gaussen et al., 1961, 1965). Subramanyam & Nayar (1974) described the vegetation and phytogeography of the western ghats. The vegetation type maps of French Institute of Pondycherry in
collaboration with forest departments of Karnataka, TamilNadu, & Kerala have been published (Pascal 1982, 1986, 1992, Pascal & Ramesh, 1995).

Study of plants in Karnataka has attracted the attention of workers from the earliest days of scientific floristic work. Buchanan Hamilton's (1807) is perhaps the pioneer account of the plants of Mysore noticed during his journey in the country. Some of the Cameron's early collections (1887-89) from all over the state were identified by Lawson who was a systematic botanist and the collections were deposited in the Mysore Govt. Museum. The first attempt to document the wealth of forests of Karnataka was done by Rao in 1920's in the book "Forest Wealth of the Mysore State". Then emerged one of the most important study on the ecology of forests and sylviculture of trees of western ghats by Kadambi (1929- 1969). Perhaps the best contribution to the floristic studies of Karnataka, is the publication of "The flora of Hassan" and "The flora of Karnataka" along with floristic details documented by Saldana & Nicholson(1976) and Saldana( 1984, 2000) respectively. The work of Ramaswamy & Razi (1973), and Rao & Razi on (1974) on the flora of Mysore district is noteworthy. The botanical exploration in Chikmagalur district are very meager except a few stray collections by Lawson, Eners (1988), Meabold (1911) & Rottler (1836) around Bababudans. Their collections have been included in Gamble under deposited in BSI. The flora of Chikmagalur district partakes mostly of the "Malabar province" as described by J.D. Hooker (1904) in "A Sketch of the flora of British India". A Comprehensive study on the floristics of Chikmagalur was carried out intensively and documented in "flora of Chikmagalur" by yoganarashiman (1981). A few biodiversity sample plots have been established by FORTI under western ghats forestry project and has been assessed tree bio-diversity and a wide range of associated variables (Ramesh & Swaminath, 1999).

So far, different methodologies have been adopted for characterizing biodiversity and mapping bio-rich areas in the study area. In the present study, satellite remote sensing and GIS techniques have been used for phytodiversity characterization at landscape level integrating economical, ecological and taxonomic importance of the biodiversity. This Study is first of its kind in Chikmagalur district, Western ghats of Karnataka.