INTRODUCTION

1.0. Forest Resource:

Forest - A forest is a naturally occurring biological community dominated by trees. Biologists define *community* as a group of interacting species. In natural forest communities, man has not planted the trees, and all the life stages of the trees are present: seeds, seedlings, mature trees, injured trees, infected trees, dead standing trees, and dead and down trees. Defining what constitutes a forest is not easy. According to the CDM (Clean Development Mechanism) of the Kyoto Protocol, a "forest" is an area of more than 0.5–1.0 ha with a minimum "tree" crown cover of 10–30%, with "tree" defined as a plant with the capability of growing to be more than 2–5 m tall (UNFCCC 2002, Sasaki and Putz, 2009). Forest also includes young natural stands and all plantations, which have yet to reach a crown density of 10-30 per cent or tree height of 2-5 meters.

Forests cover slightly less than one-third of the total land area of the Asia and the Pacific region. The world's total forest (**Plate 1**) area is just over four billion hectares or 31 percent of the total land area. They are the largest carbon pool and act as both carbon source and sink according to their management. In India, Forest comprises of 21.0 % (**Plate 2**) of the geographic area (i.e. 69.1 M ha) (FSI, 2009) and forestry represents the second major land use in the country after agriculture and it has been estimated that nearly 41% of the country's forest cover has been degraded to some degree (MoEF, 2002).

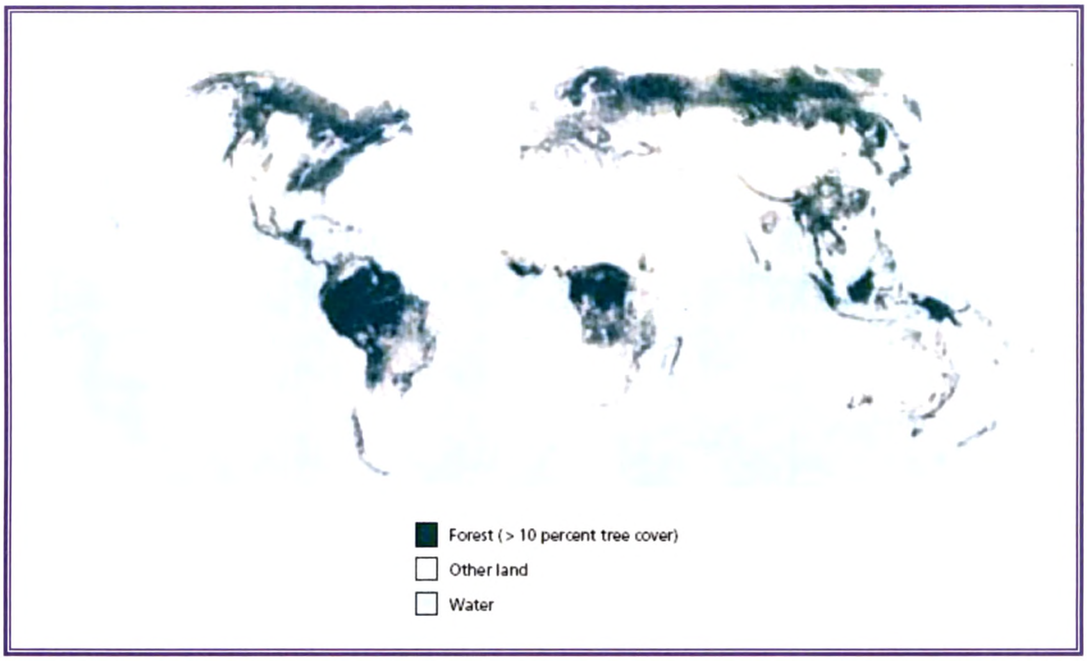
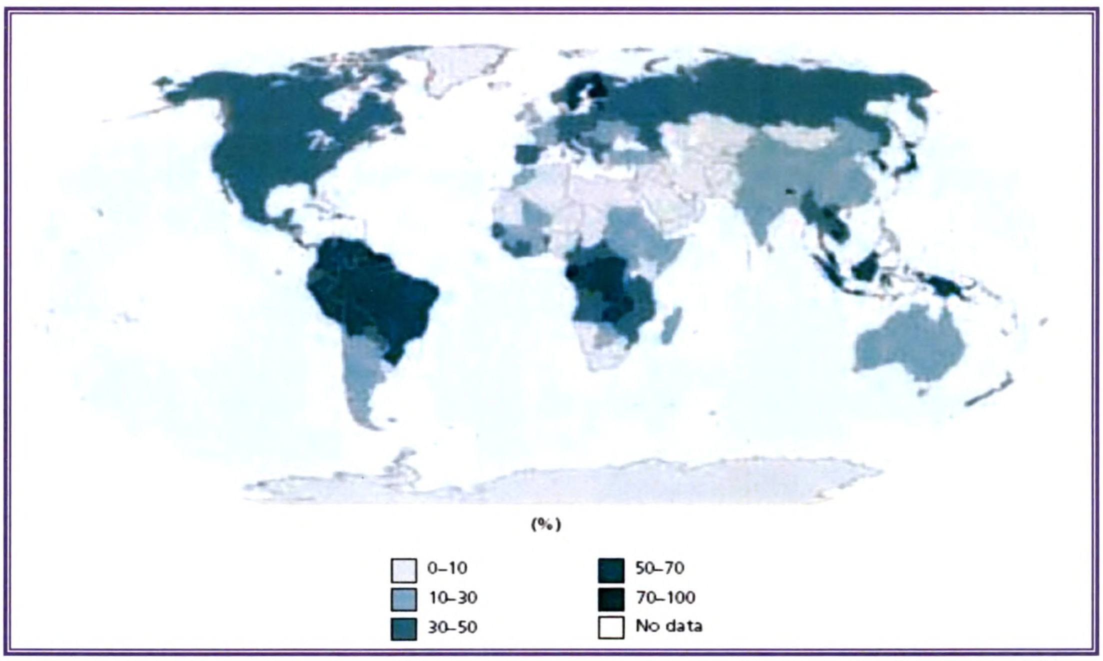


Plate 1: The world's forests



Source: FAO report, 2010

Plate 2: Forest area as a percentage of total land area by country, 2010

1.1. Present vital problems and emerging issues:

Forests play an important role in the conservation of environmental quality by preserving soil and water resources and biological diversity. The shrinking natural resource base, rapidly increasing human and livestock populations, and poverty are all responsible for the tremendous degradation and pressure on existing forest resources (Kumar et al., 2000). Degradation also occurs because forest subjected to a variety of disturbances that are themselves strongly influenced by climate. Disturbances such as fire, drought, landslides, species invasions, insect, and disease outbreaks, and climatic events such as hurricanes, windstorms, and ice storms influence the composition, structure and functions of forests (Dale et al., 2001). In addition climate change not only affects forests' susceptibility to disturbances, but also the frequency, intensity, duration and timing of such disturbances. It also brings changes in disturbance dynamics, in addition to the direct impacts on trees. This can have devastating effects and can increase forests' susceptibility to other disturbances. All of these impacts on trees and forests inevitably, have widespread effects on the forest sector. As observed in recent years global forest area is declining. The forest cover is taken over by other land cover. These forests are under tremendous pressure and are continuously declining. The degradation of tropical forest is proceeding at an unprecedented rate that is destroying the biodiversity and natural resource of the region. India is also facing the similar problem of deforestation due to increase pressure on the forest to meet biomass demand. This generates a need to monitor and quantitatively measure the changes occurring in the forest area. Considering the above facts in the present work the forest status of Dediapada region has been assessed, measured and monitored

1.2. Measuring a forest:

Measurement of things is a fundamental part of any scientifically based discipline. The measurement of trees and forests is fundamental to the practice of forestry and forest science throughout the world. Measurements are used to understand how forests grow and develop? To determine how much they contain the products man wants from them, and to ensure that they are managed appropriately. Many of the things which one need to know about trees or forests are that they are difficult to measure directly. For example, it is not easy to determine the amount of wood in the stem of a tree standing in a forest, simply because the tree is so tall and large. To deal with such problems, techniques have been developed to estimate those difficult things from simple measurements, which can be taken from the ground. This measurement obtained from the ground survey are known as the forest inventory.

1.3. Forest Inventory:

Inventory of trees involves collection of data and its analysis to establish the current condition and to generate baseline information of forest (Mc Lean, 2002; Nowak et al., 2002, Christensen *et al.*, 1996). It may be defined as the systematic collection, evaluation, and presentation of specific information about forest areas. Generally, detailed observations are made only of a small part of the area and reliable techniques are applied to extrapolate from these limited observations of the whole area of interest. Such inventories are done similarly in earlier times using different tree inventories.

1.4. History of Forest Inventories:

The main method used in inventories in the 19th century was complete enumeration, but it was soon noted that there was a possibility to reduce costs by using representative samples. Sampling-based methods were used in forestry a century before the mathematical foundations of sampling techniques were described (Doig, 1976, Honer and Hegyi, 1990, Gregoire, 1992, Van Hooser et al., 1992, Schreuder et al., 1993, Frayer and Furnival, 1999). According to Loetsch et al. (1973), visual estimation was used until the 1940's in Germany, where learning this method was part of a good training program for a forester in those days. Visual estimation was often used, as it was cheap and fast. In North America, for instance, these inventory surveys were carried out at the beginning of the 20th century by "timber lookers," whose years of field experience allowed them to develop the ability to assess timber volumes by eye without the benefit of any measurements. In the Nordic countries, especially in Finland, these visual estimates are still used for acquiring data for management planning at the stand level. In early inventories visual estimates were combined with statistical estimates in order to reduce bias (Ilvessalo, 1923). Statistical knowledge was gradually introduced into the forestry literature between 1900 and 1920, primarily in Scandinavia where the first small-scale forest inventories using systematic strip sampling had been carried out in Sweden in the 1830's by Israel af Ström (**Israel af Ström** (1778-1856) was a Swedish forest researcher and founder of Sweden's National Forestry Institute). An auxiliary purpose in conducting an inventory was that of developing a map showing the distribution of timber, forest types, access, and topographic detail. The method of cruising with continuous strips of fixed width covering a known percentage of the land area was the most popular in the 1930s because it served both purposes, inventory and mapping. The most important scientific work in this field in Finland was the inventory carried out in Sahalahti and Kuhmalahti by Werner Cajanus in 1912 (Seppälä 1985). Ilvessalo carried out the first four National Forest Inventories between 1921 and 1963 (1927, 1942, 1956, 1962). National inventories in the other Nordic countries started at almost the same time. Since these first inventories were systematic, estimators for the variance in systematic sampling have been intensively developed in these countries. Tree inventories are the primary methods for determining the composition of trees.

India started the regular program for forest inventory with the use of the remote sensing technology way back in early 1980s. Forest Survey of India (FSI) has conducted national assessments of forest resources since 1965 as it was mandated for this activity. The National Forest Policy of India, since 1952 has set a goal of bringing one-third area of the country under forest cover. The policy goal has given direction to the efforts of conservation, afforestation, and tree planting outside the traditional forest areas. Realizing the need for a closer and scientific monitoring of forest cover, the use of remote sensing was introduced. The first report on forest cover monitoring was published as "State of Forest Report" (SFR, 1987). Since then, biennial monitoring of the country's forest cover is being done regularly. India is among the few countries in the world to start such a unique system of monitoring of forest cover at National level.

In recent years, the need of assessing forest structure along with monitoring of forest cover has become essential for the forest management.

Forest structure is an integrated composite of individual tree structure, quantity, and arrangement in the landscape in both the horizontal and vertical dimensions and it should be studied from both these dimensions. The understanding of such structure along with different parameters such as tree size, stem density, growth is a prerequisite. Tree inventory, which involves the generation of comprehensive measurement of population of trees through ground surveys (Kenney and Puric-Mladenovic, 2002) is needed for the forest management. Tree inventory during a forest survey is basically carried out in three steps. First step is to understand the species composition of the forest, second is to observe the different phenological pattern in all the trees of forest and third is to, recognize the trees present in that composition and examine the different tree structures including the Diameter at Breast Height (DBH), Total tree Height (TH), Tree Canopy cover (CC), and the tree Basal area (BA).

Forest Inventory can be attempted in two ways either through conventional (ground survey) or through non-conventional method (Optical and Microwave remote sensing data).

1.5. Conventional /Ground Survey method:

It involves identification of the composition and phenology of the species present in an area. It also involves assessment of tree damage and different structural variables like DBH, basal area, total tree height, and the crown cover essential for understanding the tree health. Such assessment is done through primary analysis.

1.5.1. Primary Analysis

1.5.1.1. **Species Composition-** Understanding of species is essential for identification of native vegetation (or even weed species) as it is an indicative of site characteristics.

1.5.1.2. **Phenology-** It is the study of the timing of periodic biological events in the animal and plant world as influenced by the environment (Schwartz, 2003).

Records of long-term phenological observations on trees, such as the dates of leaf unfolding, flowering, leaf discoloration and leaf fall, provide historical information to indicate how plants have responded to variations in climatic conditions. Plant phenological studies are fundamental in understanding of forest as a resource base for other dependent populations or communities.

1.5.1.3. **Tree damage** -Tree damage involves the evaluation of Physical damage of the trees that occurs during pest outbreak or any other reason, affecting the overall tree health of the forest.

1.5.2. Tree structure

1.5.2.1. **DBH-** is the Diameter at Breast Height (DBH). DBH is an important predictive variable. (Leboeuf et al., 2007) It alone explains more than 95% variation in biomass (Gibbs et al., 2007). The actual location of DBH varies slightly around some countries. In continental Europe, Australia, U.K, Canada, and some former members of the British Commonwealth DBH of a tree is taken at 1.3 m above ground. According to the policy developed by USA, New Zealand, India, and South Africa and for other countries the DBH of a tree is measured at a height of 1.4 m (or 4' 6") above ground (Russell and Honkala, 1990)

1.5.2.2. **Crown Cover** is the percentage of the ground covered by a vertical projection of the outermost perimeter of the crowns in a stand (Spurr, 1960). Only the crowns that form part of the upper canopy level (dominant / codominant stratum) are used to determine closure in uneven-aged or stands with multiple canopy layers.

1.5.2.3. **Height-** In forestry, tree height is defined as the vertical distance from ground level to the highest green point on the tree (which will be referred to here as the tip of the tree). (West, 2009) The height of trees is important to forestry particularly because it is a part of the calculation of the total amount of wood contained within it and an important measure used in forestry to assess site productive capacity.

1.5.2.4. **Basal Area (BA)** is defined as the cross-sectional area of a stem of a tree at its breast height assuming cylindrical stem (Helms, 1998). This is an indicator of growing stock and biomass production in a forest area.

Along with the assessment of above forest parameters, ecological diversity is also one of the guiding principles for forestry management and planning. This diversity is often quantified with measurable indices, such as Shannon–Weaver index, Margalef,
Mc Intosh and Brillouin Index.

1.5.3. Secondary analysis

1.5.3.1. **Shannon-Wiener Diversity index-** which takes into account the number of individuals as well as number of taxa. It is commonly used to characterize species diversity in a community. It accounts both abundance and evenness of the species present.

1.5.3.2. Margalef Index- This index denoted as D was given by Margalef in 1957. The higher the index the greater is the diversity. It has no limit value and it shows a variation depending upon the number of species. Thus, it's used for comparison between the sites.

1.5.3.3. McIntosh Index- It was suggested by McIntosh in 1967. The values ranged between 0 – 1. When the values are getting closer to 1, it indicates organisms in a community are homogeneously distributed.

1.5.3.4. Brillouin index: This index measures the diversity of a collection, as opposed to the Shannon index, which measures a sample. Pielou (1975) recommended this index in all situations where the sampling is carried out in non-random, or where the full composition of the community is known. The value obtained rarely exceeds 4.5 and both the Brillouin and Shannon Indices tend to give similar comparative measurements.

1.6. Non-Conventional /RS-GIS Method of forest Inventory:

1.6.1. Remote sensing in forest Inventory- This method takes advantage of the fact that vegetation canopy structure through their inventory has significant impact on Earth Observation (EO) signal in both optical and microwave range of EMR. This fact has already been proved by various workers (Ross, 1981; Imhoff, 1995; Knyazikhin *et al.*, 1998a, b; Panferov *et al.*, 2001; Widlowski *et* *al*., 2004). These structural characteristics of a forest and the correlative relationships with canopy reflectance support the utility of remote sensing as a useful tool for assessing forest condition and forest disturbances, which are often patchily distributed across a landscape both spatially and temporally. Thus, such non-conventional techniques are cost-effective, precise providing near real-time data for larger area at an instant *i.e.* when compared to field survey methods, which are labor intensive, and costly, resulting in low sample coverage and frequency. Forest assessment using optical remote sensing till date has been attempted by several workers (Howard, 1991; Solberg, 1999; Robert, 2005; Pearson, 2007). It has been used for timely information regarding their stocking levels, health, and species diversity which is required for effective treatment decisions. Assessment of forest structure by optical remote sensing becomes difficult during cloud cover, when the terrain is not flat and the measurements are to be made in both vertical and horizontal directions. Microwave remote sensing data solve this difficulty as it is not affected by cloud cover and terrain. It has the ability to penetrate into the forest canopy due to its longer wavelength. Different wavelengths of microwave data help in understanding different forest features because the backscatter strength from the canopy is a function of different tree features as explained and shown below (Figure 1).

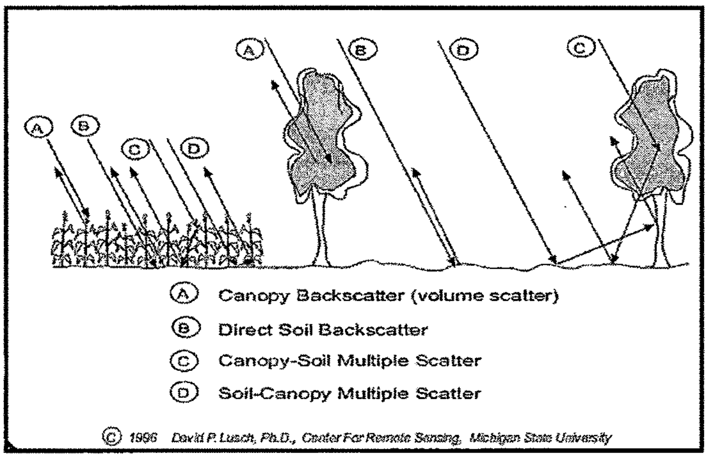


Figure 1: Types of canopy Backscatter

1.6.2. GIS in Forest Inventory:

The voluminous information on forest parameters is required to be updated, monitored, and assessed continuously. This can be done easily with Geographic Information Systems (GIS), which are computer-based methodologies conceived for spatial data collection, storage, retrieval, transformation, display and analysis (Kitanidis, 1996). The forest variable data can be integrated to produce a resource map, which can be compiled, manipulated, modeled, and analyzed using different statistical algorithm present in the system. e.g., Geostatistical methods using auxiliary data provide a variety of spatial estimation procedures, which are known as Kriging. Prediction accuracy can also be increased by incorporating large volumes of auxiliary data (i.e. Remote sensing data) for forest research with the help of Kriging, co-Kriging etc (Meng, 2006) .

In the present study, potential of both conventional and non-conventional methods has been exploited to understand the species composition, phenological status of forest trees, levels of tree damage to the forest area and for the assessment of different tree structural parameters essential for forest inventory. To recognize the levels of damage of forest tree, these trees can be further analyzed to understand their biochemical and biophysical parameters. These parameter forms an indicator to detect the tree health status.

2.0. Estimation of Biochemical and Biophysical parameters of Forest:

Changes in forest and forest ecosystem are also due to continuous and long-term succession. Discontinuous, occasional, and sudden natural or human-induced disturbances also contribute towards the changes in the forest (Wulder and Franklin, 2007). Different biotic and abiotic factors such as extreme weather conditions, pathogens like fungi or insects and anthropogenic pollution (Wild et al., 1996; Tausz et al., 1999) results into the decline of the forest. Decline in forest is therefore called as complex disease. To take protective measures against this disease bio-indicator parameter should be utilized as given by Ulrich 1991. Such indicators help in deducing information about the different physiological processes that is performed in living systems, to enable responses about plant vitality.

These indicators may be observed visually and through biochemical and biophysical parameters. The visual parameters can be like the foliage loss, leaf discoloration, necrosis, etc. A biochemical parameter can be understood through different photosynthetic components like chlorophyll, nitrogen, antioxidant, and phenolic etc and biophysical through relative water content, leaf area index and Biomass. The biochemical and biophysical parameters provide necessary supplementary information about plant vitality that may lead to an early risk assessment.

In the case of understanding, the forest health status, biochemical parameter like chlorophyll and biophysical parameters such as water, LAI, and biomass becomes significant because these parameters comprises the spectral feature of the plant and can be picked up through satellite images for understanding forest functionality.

Understanding of biochemical parameter through conventional and biophysical parameters through both conventional and non-conventional techniques will help in identifying the tree health status in the forest. It is also necessary for any forester or forest manger to monitor the forest cover.

3.0. Forest cover:

Tropical forests, although covering less than 10% of the land areas, represent the largest terrestrial reservoir of biological diversity, from the gene to the habitat level. For example, more than 50% of known plant species grow in the tropical forests. Forests are an important natural resource base, requiring action for their informed utilization, management and protection at spatial scales from the local to the global. In India according to the State of Forest Report 2003, forest cover is 67.83 M ha covering 20.64% of the geographic area. In the last two years, Gujarat has lost close to 100 square kilometers (sq. km) of forest area due to human activity. This is a 13 per cent of the national loss (728 sq. km) of forest area (Sulaimani, 2008). The FSI report also emphasized that the loss of green cover is due to human activity. In other words, increasing population pressures are taking a toll on the state's forest cover.

Utilization of satellite imagery can substantially improve the knowledge on changes in forest area as a result of deforestation, afforestation and natural forest expansion. Remote sensing data in combination with additional data sources has been recognized as an important source of information for detecting forest cover and its changes.

3.1. Optical remote sensing in forest mapping

In non-conventional method, the data of optical remote sensing satellites such as LISS-III, LISS-IV and Landsat-ETM$^+$ are used due to its resolution, both radiometric and spatial. Optical remote sensing methods have successfully been utilized in the inventory of forest species. The incorporation of ancillary data with remotely sensed data for digital data analysis in determining forest species distribution have further increased the classification accuracy. One of the most common applications of remote sensing in forestry is the production of thematic maps, depicting tree species or stand age, by means of image classification.

The only disadvantage of the optical data is that it is cloud affected. It is important to establish forest cover map in the cloud covered areas for continuous monitoring of these areas. Ulaby et al. (1982) suggested that, in order to achieve high correct classification rates, it is necessary to have uninterrupted (cloud free) coverage of the area under investigation for successive passes of the satellite.

3.2. Microwave Remote Sensing in forest mapping

Tropical forest cover and its depletion due to natural and anthropogenic factors have been studied previously using various remote sensing data. Generally high or coarse optical data are used to assess forest cover. Forest cover classification using optical data mainly depends on weather conditions and it is very difficult to get cloud-free optical data in the rainy season. Nonetheless, the utility of optical data is highly affected by atmospheric conditions. Synthetic Aperture Radar (SAR) provides an alternative to obtain the information. Microwave data in this context give a continual data, which gives the opportunity for continuous monitoring of forest. One more advantage can be attributed to microwave data is that its surface interaction is found to be different from the optical sensors, thus providing unique information about ground features. Due to the active nature of radar, whether or not the sensor detects any surface response it is a function of incident angles, landscape geometry, material dielectric constant, and surface roughness, which collectively constitute the amount of energy returned to the sensor (i.e. backscatter). Along with single polarization datasets, dual or fully polarimetric SAR images have been used. Disturbances in forested areas can be detected or mapped through fully polarimetric SAR.

Polarimetric SAR data can be utilized to detect or map disturbances in forest areas. VanZyl (1998), aimed at using a priori knowledge of a specific class of scattering properties to classify multi-polarization imagery without training areas. Radar Vegetation Index (RVI), was introduced which generally has a similar background of rating methods of reflective bands in optical datasets such as the NDVI. The RVI employed cross-polarized backscattering cross section in comparison with total backscatter in order to characterize designated objects. Woody vegetation, which retains a strong cross polarization component, has high RVI value. Nonetheless, this technique was confirmed to have faster saturation than other polarimetric features; hence, the application has been limited.

3.2.1. Polarimetric decomposition:

Polarimetric Decomposition techniques provide a new insight on polarimetric SAR data analysis. They offer a thorough and meaningful way to exploit fully polarimetric datasets. Various decomposition techniques have been presented; however, many researchers have favored the model based (for example Freeman-Durden decomposition algorithm) and eigen-based (such as Cloude-Pottier algorithms). The purpose of this study is to evaluate polarimetric SAR to assess different levels of forest stress with the help of the Cloude-Pottier decomposition theorem.

Cloude (1986) introduced the use of the characteristic decomposition of target covariance and coherency matrix for incoherent target decomposition. Cloude's decomposition was found to be unique and, in the monostatic case, breaks the average covariance matrix up to the weighted sum of three covariance matrices representing three different single scatterers. Cloude applied his decomposition on the target coherency matrix on the basis formed by the Pauli spin matrices. The classification technique used here is based upon polarimetric decomposition classification parameters: Entropy (H), Anisotropy (A) and Alpha (a). This classification procedure is based on decomposition theorem. The H/A/a set of parameters is derived from an eigen value decomposition of the coherency matrix. The entropy provides information on the scattering degree of randomness. The alpha parameter indicates the nature of the scattering: single or double bounce reflection or scattering over anisotropic media. The anisotropy provides information on the relative importance of secondary mechanisms.

Utilizing the above advantages of individual datasets in optical and microwave region the present study was undertaken to monitor and map the forest area of Dediapada Taluka. The combination of these data was further used to understand the explicit of both these data sets by fusion techniques.

4.0. Fusion of satellite data for further classification:

Data fusion is a process dealing with data information from multiple sources to achieve refined/improved information for decision-making (Hall, 1992). On the other hand, image fusion is the combination of two or more different images to form a new image by using a certain algorithm (Genderen and Pohl, 1994). Data fusion takes the advantage of the strengths of a particular data for improvement of visual interpretation and quantitative analysis. Due to the availability of multiple types of sensors, more and more data have become available for scientific researches. Such type of voluminous data for specific variable when gathered from different sources and combined can aid in extracting most useful information regarding the variable. (Figure-2)

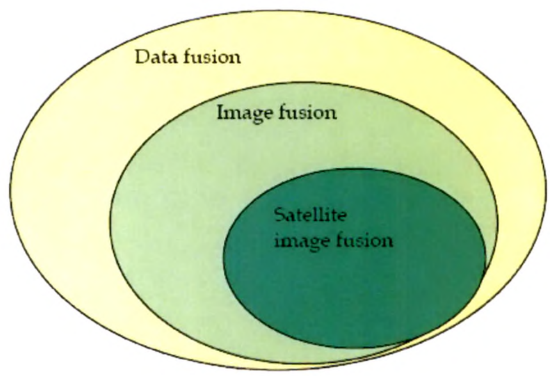


Figure 2 Illustration of relationship of data fusion and image fusion

Generally, the visible and infrared wavelength systems are recognized as being superior to radar data, due to their multispectral information content (Brisco and Brown, 1999). Based on this, strong argument for the utility of sensor fusion multispectral systems are based, where the fusion is carried out using of several individual bandwidths. The problem involved in such type of fusion is the sensitivity of optical and infrared wavelength to differential scattering and absorption caused by chlorophyll, green leaf area, and leaf structure, and leaving some vegetation types that cannot be separated, due to the similarity of their spectral responses (Raghavswamy et al., 1996). Microwave data on the other hand responds differently to varied terrain and dielectric factors such as plant canopy roughness and structure, plant moisture content, and subcanopy conditions. As such, a combined sensor analysis could contribute to information regarding both the leaf composition and the surface geometry, thereby greatly increasing the potential information content (Henderson et al., 2002).

There are distinct advantages of fusing radar with optical data, as the end product has the advantage of textural information from radar image, and spectral information from the optical and infrared bands. Hence, by fusing multiple datasets, an analyst has a single and more informative image (Pal et al., 2007). With its origin in military applications, image fusion has provided a framework to the civil sector which helps to integrate different sensor platforms for a variety of uses. One of the reasons for this increase in multisensory fusion is due to the complementary information about the various different datasets (Chavez et al., 1991). It is crucial for the scientific community to harness this potential useful technique, as it will immensely improve the geographical knowledge and application for remote regions across the world. To achieve an accurate classification of ground, an image of a suitable resolution of the forest to be acquired first, and then the characteristics of each small segment of the image must be classified accurately. Therefore, the present study has been undertaken involving different Fusion Techniques for accurate classification.

5.0. Need of the study:

This study addresses the status of one of the forest's most visible resources: the trees. Many of the world's ecosystems depend on trees for vital functions, such as sustaining soil structure and fertility and preventing soil erosion and floods. Trees provide human society with sources for industrial products, construction materials, food, and fuel-wood. The forest ecosystems can be optimally managed if timely information on their structure and function is available. There is a requirement of quantitative information on forest health, and how it varies in space and time. Therefore, Forest study is essential in order to monitor the forest.

6.0. Objectives

- To collect different information on tree attributes such as crown cover, tree height, DBH.
- To estimate biochemical parameter such as chlorophyll content and biophysical characteristics such as biomass, leaf area index (LAI), leaf Relative water content (LRWC) and vegetation indices
- To conduct forest mapping with the help of optical and microwave remote sensing to understand changes going in forest.