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Component-I (B) - Description of Module

Items	Description of Module
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Keywords	

Application of RS/GIS in Forestry

- Role of Forests.
- Role of Remote Sensing for Assessment of Biomass/Carbon
- Forestry Information needs and Remote Sensing
- Timber Volume Estimation
- Major applications of remote sensing in forest studies.
- Damage assessment

1. Introduction

To meet the various information requirements in forest management different data sources, like field survey, aerial photography and satellite imagery is used, depending on the level of detail required and the extension of the area under study. Before aerial photography was used for forest management purposes, information was generally obtained by means of field surveys, identifying and measuring forest types and stands. This is still by far the most accurate and detailed way of measurement, although the lack of geographical positioning systems did not allow accurate location of the forests classified. The method is, however very elaborate, time consuming and expensive, and it is nowadays used predominantly for research purposes and for intensive sustainable production purposes. The traditional aerial photograph resulting from different film types was and still is an important remote sensing tool. Knowledge of photogrammetry and photography is essential for its proper use. For many decades the use of aerial photographic data has been accepted by many forest institutions as a tool in various forest activities, such as planning, mapping, inventory, harvesting, area determination, road lay-out, and registration of declined and dead trees etc. on a local, regional or national scale. For the purpose of consistently and repeatedly monitor forests over larger areas, it is preferable to use remote sensing data and automated image analysis techniques. Several types of remote sensing data, including aerial photography, multi-spectral scanner (MSS), radar (Radio Detection and Ranging), Lidar (Light Detection and Ranging) laser and videography data have been used by forest agencies to detect, identify, classify, evaluate and measure various forest.

Cover types and their changes. Over the past decades tremendous progress has been made in demonstrating the potentials and limitations for identifying and mapping various earth surface features using optical remote sensing data. For large areas, satellite imagery has been shown effective for forest classification, and consequently mapping. It is emphasized that one of the advantages of the use of remote sensing in forest survey is the relative short time in which most of the required information can be obtained. Gradually other types of remote sensing tools were developed with which forest object properties were registered from the air or from space. The new technologies, integrating satellite imagery, analytical photogrammetry and geoinformation systems (GIS) offer new possibilities, especially for general interpretation and mapping and will be a challenge for future research and application. The analogue photographic data of aerial photographs as well as the satellite scanning data can be digitized and used for multi-spectral or multi-temporal classification and corrections, geometrical or radiometrical. Scanning techniques are also applicable in airplanes. Nowadays the products of this aerospace technology are considered to be superior to and a replacement of the old fashioned analogue aerial photography. However, this technology is additional and complementary to the aerial photography. Sometimes the products are used alone, but in most cases a combination with aerial photographs is applied. Also fieldwork remains essential when applying remote sensing techniques. Various factors can be mentioned to explain why in managed forests the operational application of remote sensing in the estimation of a number of stand parameters, is relatively low. Foresters are in general conservative, in the beginning they were reserved in applying aerial photography and nowadays other remote sensing techniques are not embraced whole-heartily. There is a hesitation to take risks when departing from traditional data sources. Lack of knowledge of access to data of the specialized technology is and other reason for the limited application.

The Earth's atmosphere contains carbon dioxide (CO_2) and other greenhouse gases (GHGs) that act as a protective layer, causing the planet to be warmer than it would otherwise be. This heat retention is critical in maintaining habitable temperatures. If there were significantly less CO_2 in the atmosphere, global temperatures would drop below levels to which ecosystems and human society have adapted. As CO_2 levels rise, mean global temperatures are also expected to rise as increasing amounts of solar radiation are trapped inside the greenhouse. The concentration of CO_2 in the atmosphere is determined by a continuous flow among the stores of carbon in the atmosphere, the ocean, the earth's biological systems, and its geological materials (Fig. 1). As long as the amount of carbon flowing into the atmosphere as CO_2 and out (in the form of plant material and dissolved carbon) are in balance, the level of carbon in the atmosphere remains constant.

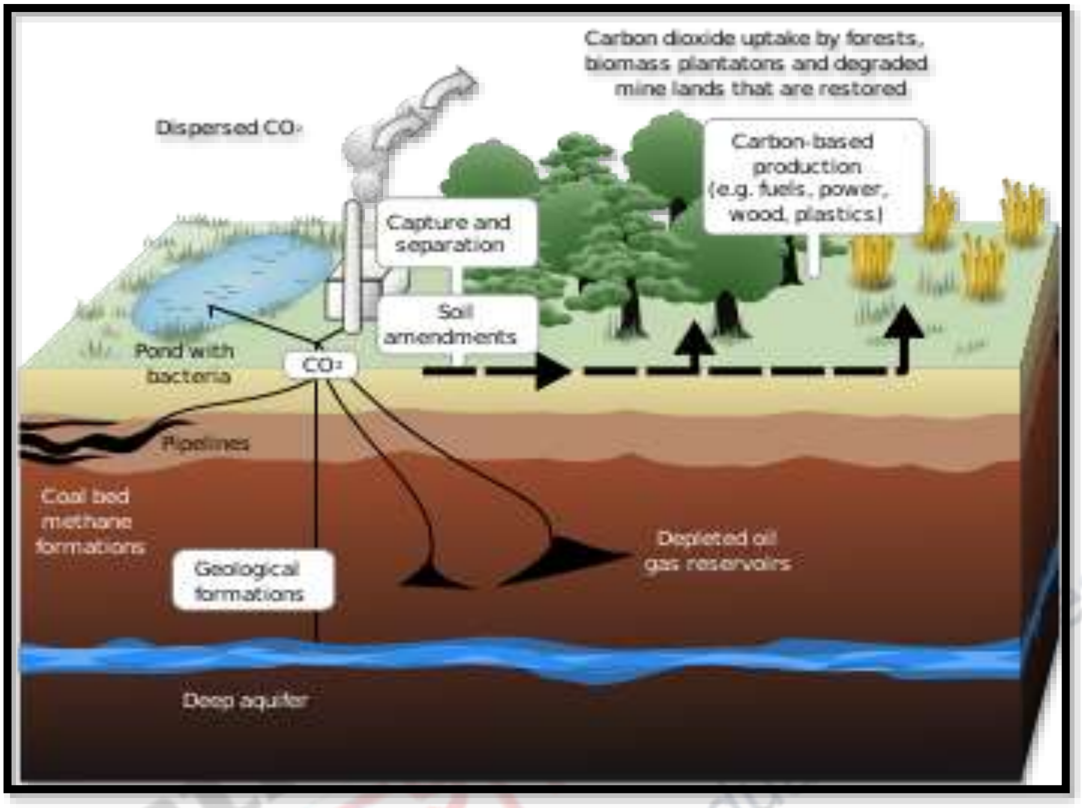

Fig 1. Terrestrial and geological sequestration of carbon dioxide

Source: http://en.wikipedia.org/wiki

Photosynthesis leads to the conversion of carbon dioxide into organic carbon in growing plants, and some of the carbon thus sequestered as plant biomass is subsequently lost through respiration. A large net flux of carbon from atmosphere to tree accompanies early tree growth. Over time, the net rate of exchange decreases due to increasing carbon loss through respiration or the loss and subsequent decomposition of plant material as litter and woody debris. A large amount of carbon is released to the atmosphere as trees die and decompose (Fig. 2). Other mechanism of carbon loss from forest systems includes physical removal of organic matter or rapid loss through natural disturbance, such as fire. A significant form of removal in the United States is harvest of wood, but carbon can also be removed through runoff or leaching through soil. Subsequent forest regeneration and growth can then re establish the section of forest as a sink of atmospheric carbon dioxide.

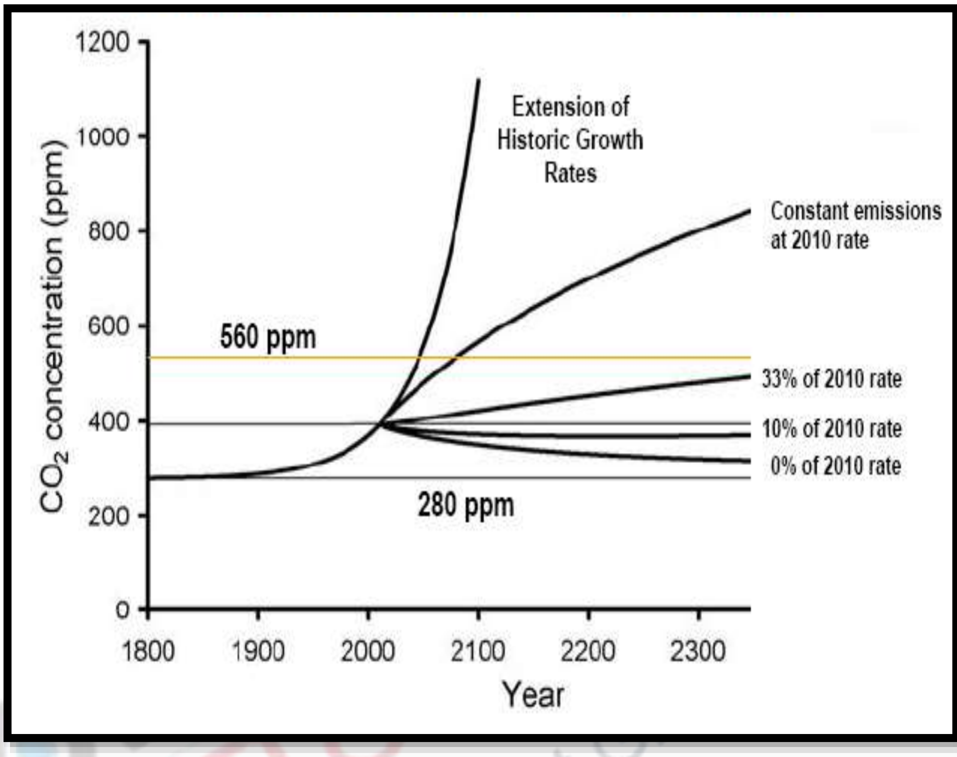

Fig 2. Holding the stock of CO_2 concentration

(Source: Klaus S. Lackner, 2007)

Forests are influenced by natural and human causes, including harvesting, over harvesting and degradation, large scale occurrence of wildfire, fire control, pest and disease outbreaks, and conversion to non forest use, particularly agriculture and pastures. These disturbances often cause forests to become sources of CO_2 because the rate of net primary productivity is exceeded by total respiration or oxidation of plants, soil, dead organic matter and net ecosystem production (NEP < 0). At the same time however, some areas of harvested and degraded forests or agricultural and pasture lands are abandoned and revert naturally to forests or are converted to plantations, thus becoming carbon sinks, i.e. the rate of respiration from plants, soil and dead organic matter is exceeded by net primary productivity (NEP > 0).The current role of forests in the global carbon cycle is not only a function of present forest land use, but also of past use and disturbance. Prior to this century CO_2 emissions from changes in forest land use, mainly caused by agricultural expansion in mid and high latitude countries, were higher than emissions from the combustion of fossil fuels (Houghton and Skole, 1990). From the turn of the century until about the 1930s, global CO_2 emissions from changes in forest land use were similar in magnitude to those from fossil fuel combustion (Fig. 3). After about the 1940s, CO_2 emissions from the changes in forest land use in the tropics dominated the flux from the biota to the atmosphere. Since then, worldwide fossil fuel use has soared, biotic emissions from the mid and high latitude regions has declined greatly as forests expanded into abandoned agricultural lands and as logged stands redrew, and deforestation in the tropics has accelerated (Houghton *et al.*, 1987).

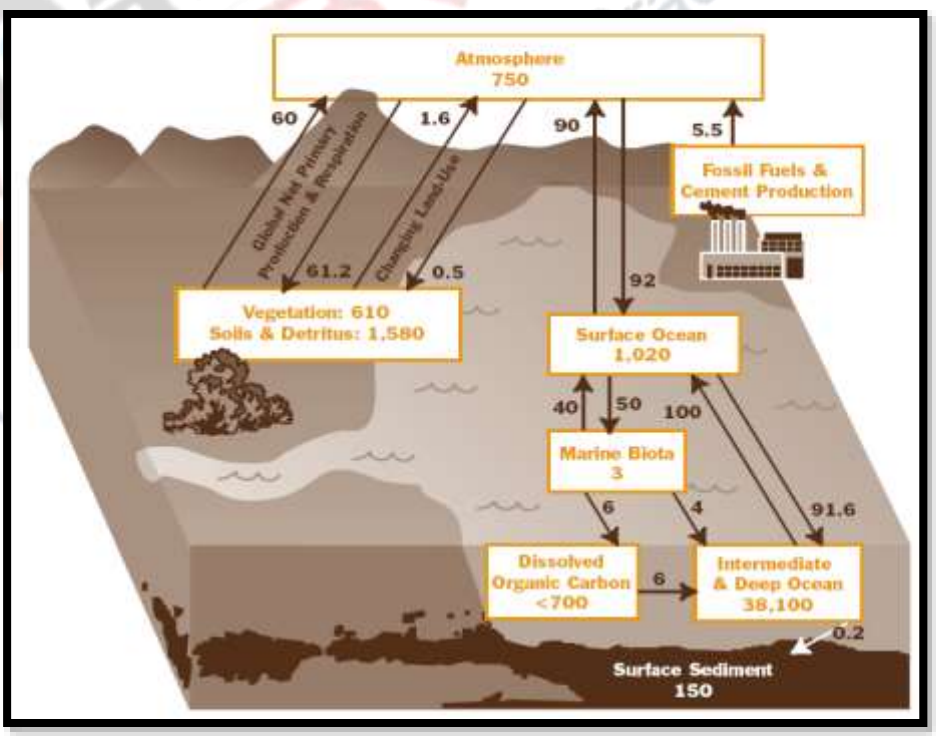

Fig 3**.** Global carbon cycle

(Source: www.metoffice.gov.uk)

2. Role of Forests

Forests play an important role in global carbon cycles. Policies that influence the rate of Conversion of forest to other land use or encourage afforestation and reforestation of deforested lands have the potential to have a large impact on concentrations of atmospheric CO_2 (IPCC, 2001). Forest conversion is the second largest global source of anthropogenic carbon dioxide emissions and is likely responsible for 10-25% of carbon dioxide emissions worldwide (Houghton 2003; Santilli *et al*., 2005).Within the U.S. forests are net carbon sinks, sequestering approximately 780 Tg/yr CO_2 Eq. (latest data for 2004), which is approximately 11% of U.S. greenhouse gas emissions. A number of existing and proposed policy instruments specifically include the use of forests to capture CO_2.

Global climate change is increasingly recognized as the greatest global threat facing humanity. For the majority of the world's population, the persistent problems of food insecurity, rural poverty, the struggle to develop, sustain new sources of economic growth must now be considered against a backdrop of uncertainty and change in historical climatic patterns. Separately and together, governments, and both international and domestic organizations not only need to continue responding to the immediate concerns of extreme poverty, environmental degradation and social unrest but in addition must now begin to prepare communities and entire regions to adopt to uncertain future climatic regimes as well as to make tangible contributions in first slowing, and ultimately reestablishing a balance in greenhouse gas exchanges at a planetary scale.

Under mounting time pressures, there is an urgent need to evolve win-win solutions that address both these immediate local and long term global threats. When the concentration of greenhouse gasses in the atmosphere increased, temperature at the Earth's surface is also expected to increase. Climate models developed in the 90's have shown that global surface air temperature may increase by 1.4^{o}C to 5.8^{o}C at the end of the century (IPCC, 2001; Rahmstorf and Ganopolski, 1999). Recent (IPCC,2007) report predicted increase in temperature with more precision at 1.8^{o}C to 4^{o}C at the end of the century (Petit *et al*., 1999) has link temperature increase to increase in the concentration of CO_2 in the atmosphere.

3. Role of Remote Sensing for Assessment of Biomass/Carbon

A variety of approaches and data sources have been used to estimate forest above ground biomass. A comprehensive review of remote sensing based estimates of AGB has been completed, categorized by data source: (i) field measurement; (ii) remotely sensed data; or (iii) ancillary data used in GIS based modeling. Estimation from field measurements may entail destructive sampling (Miksys *et al*., 2007) or direct measurement and the application of algometric equations Above ground biomass is necessary for studying productivity, carbon cycles, nutrient allocation and fuel accumulation in terrestrial ecosystems (Alban *et al*., 1978; Brown *et al*., 1999; Crow, 1978).Remote sensing techniques allow scientists to examine properties and processes of ecosystems and their interannual variability at multiple scales because satellite observations can be obtained over large areas of interest with high revalidation frequencies. Many studies have demonstrated that indices such as Spectral Vegetation index (SVI), Simple Ratio (SR), Normalized Difference Vegetation Index (NDVI), and Corrected Normalized Difference Vegetation Index (NDVIc) obtained from satellite data are useful predictors of Leaf Area Index (LAI), biomass and productivity in grasslands and forests (Cheng & Zhao, 1990; Diallo *et al*., 1991). Stand level biomass is frequently calculated from linear and non linear regression models established by species with field measurements (Crow & Schlaegel, 1988). Although estimates of AGB vary with species composition, tree height, basal area and stand structure, bole diameter at breast height (DBH) is the most commonly used and widely available variable for calculating AGB (Crow & Schlaegel,1988). Numerous regression models have been developed to estimate AGB in the Great Lakes Region, while these models are accurate at tree, plot and stand levels, they are limited when considering spatial pattern analysis of AGB across the landscape. In order to scale AGB estimates to the landscape level, the estimates have to be linked with various vegetation indices derived by remote sensing data. Past studies have shown varying degrees of success in estimating forest biomass and primary production from remote sensing data in temperate and tropical forests worldwide (Brown *et al*., 1999; Gower *et al*., 1999). Recent studies suggest that such relationships very temporally and spatially; however, biomass estimates at the landscape level are necessary for understanding processes of the target landscapes and provide baseline data for future studies (Foody *et al*., 2003; Woodcock *et al*., 2001).Models derived from remote sensing need further calibration with ground data before they can be used appropriately to predict AGB for a given landscape.

1. Forestry Information needs and Remote Sensing

In practice, researchers choose one or several types of remotely sensed data according to their information needs. The information needs are converted to specific properties of remotely sensed data, such as spatial resolution, spectral resolution, temporal resolution, etc.

Tables 1 list commonly used sensors on Earth observation satellite that are still operational. These sensors provide diverse remotely sensed data with a unique configuration of image resolutions, such as spatial resolution, spectral resolution and temporal resolution (Fig. 5).

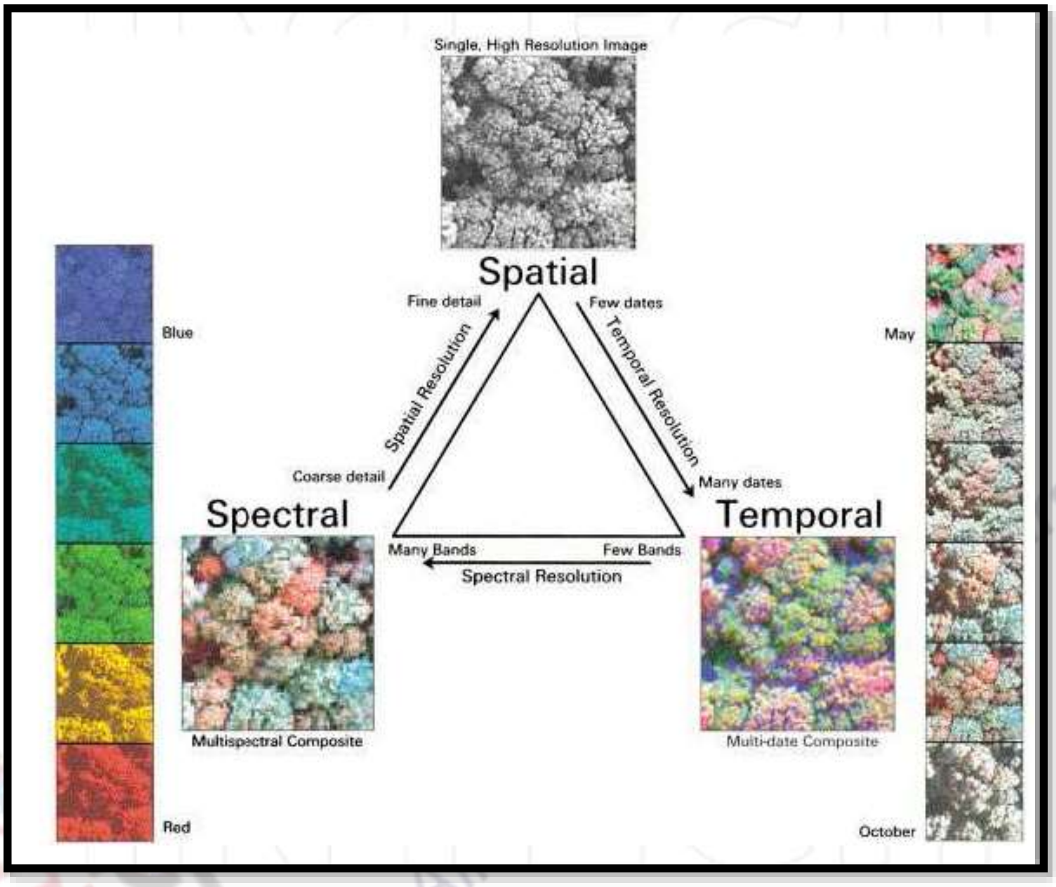

Fig 4. Given a limited bandwidth, trade-offs have to be made between spectral, temporal, and spatial properties of the imagery acquired.

Source: T., T.A. Warner, J.B McGraw, and M.A. Fajvan. 2001. *Remote Sensing of Environment 75: 100-112*

Jensen (2007) defined spatial resolution as “a measure of the smallest angular or linear separation between two objects that can be resolved by the remote sensing system”. In other words, the spatial resolution stands for how detailed information the remotely sensed data could provide. Temporal resolution can be defined as “how often the sensor records imagery of a particular area” (Jensen, 2007). For example, the well-known Landsat TM has 16-day temporal resolution. Another key property of a remote sensing system is spectral resolution, which is defined as "the number and dimension (size) of specific wavelength intervals (referred to as bands or channels) in the electromagnetic spectrum to which a remote sensing instrument is sensitive". Likewise, take the Landsat TM as an example. The Landsat TM imagery has 7 bands (6 optical bands plus 1 thermal band). It is noteworthy that the spectral resolution is mainly applied to describe optical imagery, and it cannot be used for Radar or Lidar remotely sensed data. In fact, the aforementioned data collection can be described as selecting the unique configuration of image resolutions (or properties), which can be used to meet certain research needs. Wulder et al. (2009) endeavored to clearly demonstrate the relationship of information needs and the selection of appropriate data and processing methods in remote sensing for studies of vegetation condition. The issues need to be taken into account, including "the scale at which the target must be measured (e.g. landscape-level or tree level information); the attributes of interest (change, condition, spatial extent); cost; timeliness; and, repeatability" (Wulder et al., 2009).

Table 1. The Current Commonly-used Optical and Radar Sensors

Satellite Program	Satellite Platform	Sensor	Data Operator
Data Operator Optical Remote Sensing			
POES (Polar Orbiting Environmental Satellites)	NOAA 18		
EOS (Earth Observing System)	TERRA/AQUA	MODIS	NASA/USGS

Landsat	LANDSAT 5	TM	NASA/USGS
SPOT (Satellite Pour l' Observation de la Terre)	SPOT 4	HRVIR VEGETATION	Spot Image
	SPOT 5	HRG VEGETATION	Spot Image
IRS (Indian Remote Sensing Satellites)	IRS P6 (ResourceSat-1)	LISS III LISS IV AWiFS	ISRO (India Space Research Organization)
DMC (Disaster Monitoring Constellation)	Beijing-1	SLIM-6 DMC	International Imaging Ltd
CBERS (China-Brazil Earth Resources Satellite)	CBERS-2B	CCD HRC IRMSS WFI	CAST (China)/INPE (Brazil)
Digital Globe Constellation	World View 2	WV110	DigitalGlobe Corporate
	Quick Bird 2	BGIS 2000	DigitalGlobe Corporate
Geo Eye	GeoEye-1 GIS MS Geo Eye Inc.		
RADARSAT Constellation			

Under remote sensing technologies in forest studies optical sensors have been commonly used in forestry studies. However, the use of hyperspectral sensors, Radar and Lidar is still relatively underdeveloped. It is worth paying more attention to the application of hyperspectral sensors, Radar and Lidar in forestry studies.

7. 1 Hyperspectral Sensors

Optical sensors mentioned above, which are divided from the dimension of spatial resolution, are categorized into multispectral sensors. By contrast, there is a group of sensors called hyperspectral sensors, which accordingly generate hyperspectral data. Wang et al. (2010) stated that "hyperspectral data have the ability to collect ample spectral information across a continuous spectrum generally with 100 or more contiguous spectral bands". Shippert (2004) listed the existing hyperspectral sensors acquiring imagery from space, including the Hyperion sensor on NASA's EO-1 (National Aeronautics and Space Administration's Earth Observing-1), the CHRIS (Compact High Resolution Imaging Spectrometer) sensor on the European Space Agency's PROBA (Project for On-Board Autonomy) satellite, and the FTHSI (Fourier Transform Hyperspectral Imager) sensor on the U.S. Air Force Research Lab's MightySat II satellite.

7.2 Radar and Lidar

Besides optical sensors, Radar and Lidar play more and more important roles in remote sensing of forest studies. Radar, the acronym of radio detection and ranging, is based on the transmission of long-wavelength microwaves (e.g., 3–25 cm) through the atmosphere and then recording the amount of energy backscattered from the terrain (Jensen, 2007). Wang et al. (2009) briefly introduced the Phased Array type L-band Synthetic Aperture Radar (PALSAR) on board Advanced Land Observing Satellite (ALOS), and RADARSAT- 2 operated by the Canadian Space Agency (CSA) and MacDonald Dettwiler and Associates Ltd (MDA). Both could provide fully polarized SAR data to support PolSAR (Polarimetric SAR) technology (i.e., PolSAR decomposition), which has achieved promising results in many environmental researches (e.g., Lee et al., 2001; McNairn et al., 2009; Shimoni et al., 2009). Light detection and ranging (Lidar), also called Laser altimetry, is an active remote sensing technology that utilizes a laser to illuminate a target object and a photodiode to register the backscatter radiation (Lim et al., 2003; Hyyppa et al., 2009). It has been widely accepted that Lidar is capable of accurate (or even precise) vertical information (Wang et al., 2010). Therefore, it is believed that Lidar will bring forestry studies into an unprecedented age.

8. Specific applications of remote sensing in Forest studies

Young and Giese (2003) summarized forest science and management into three categories: A. forest biology and ecology (e.g. forest biomes of the world, forest ecophysiology, forest soils, forest ecosystem ecology, landscape ecology, and forest trees: disease and insect interactions); B. forest management and multiple uses (e.g. forest management and stewardship, nonindustrial private forests, measuring and monitoring forest resources, silviculture and ecosystem management, forest-wildlife management, forest and rangeland management, forest and watershed management, forest and recreation behavior, behavior and management of forest fires, timber harvesting, wood products, and economics and the management of forests for wood and amenity values); and C. forests and society (e.g. urban forest, and social forstry: the community-based management of natural resources). As a matter of fact, remote sensing has more or less served all the three categories. Several examples in remote sensing of forestry studies are provided as follows. The selected examples were included in the papers that were either highly cited or newly published Science Citation Index (SCI) papers.

8.1 Timber Volume Estimation

Timber volume is simply function of Tree height (ht) and diameter of tree at breast height (DBH). There are some adopted techniques to calculate the volume of standing trees .i.e. volume table, volume equation. These techniques also depend upon the species in the forest stand and the region where the stand is located. Thus the timber volume can be calculated by using any of the above technique depending upon desired accuracy, money, time and labour. In Malili-Celebes (Indinesia), before estimating timber volume from aerial photographs, the relationship between dbh and crown diameter of upper canopy of trees was first investigated. As species identification was impossible on 1:10,000 scale photographs, all species were included in the test.

The regression equation was found to be:

$$d= 3.5C+12.3$$

where, d=dbh and C= crown diameter

8.2 Species Composition (biodiversity)

Turner et al. (2003) stated that the recent advances in remote sensing, such as the availability of remotely sensed data with high spatial and spectral resolutions, make it possible to detect key environmental parameters, which can be applied to determine the distribution and abundance of species across landscapes via ecological models. This approach, in general referred to as indirect remote sensing of biodiversity, plays a major role in this research area. For example, Defries et al. (2000) applied the 1km Advanced Very High Resolution Radiometer (AVHRR) to estimate and map percentage tree cover and associated proportions of trees with different leaf longevity (evergreen and deciduous) and leaf type (broadleaf and needle leaf).

8.3 Forest Ecophysiology

Kokaly and Clark (1999) developed an approach to estimate the concentrations of nitrogen, lignin, and cellulose in dried and ground leaves using ban-depth analysis of absorption features (centered at 1.73 μm, 2.10 μm, and 2.30 μm) and stepwise multiple linear regression. As mentioned above, hyperspectral remote sensing was used to estimate the leaf pigment of sugar maple (Acer saccharum) in the Algoma Region, Canada, and promising results were obtained (Zarco-Tejada et al., 2001).

8.4 Forest Ecosystem

Jin et al. (2011) developed an algorithm based on a semi-empirical Priestley-Taylor approach to estimate continental-scale evapotranspiration (ET) using MODIS satellite observations. The seasonal variation in ET has been indicated as a key factor to the soil moisture and net ecosystem CO2 exchange through water loss from an ecosystem. Lefsky et al. (2002) reviewed Lidar remote sensing for ecosystem studies. Lidar is capable of accurately measuring vertical information besides the horizontal dimension, such as the three dimensional distribution of plant canopies and subcanopy topography (Lefsky et al., 2002). More specifically, Lidar can provide accurate estimates vegetation height, cover, canopy structure, leaf area index (LAI), aboveground biomass, etc (Lefsky et al., 2002).

8.5 Measuring and Monitoring Forest Resources

Cohen et al. (1995) stated that "remote sensing can play a major part in locating mature and old-growth forests", and applied a number of remote sensing techniques to estimate forest age and structure. Over a 1,237,482 ha area was investigated and an accuracy of 82 per cent was obtained. Maps of species richness have been recognized as a useful tool for biodiversity conservation and management due to its capability of explicitly describing information on the spatial distribution and composition of biological communities (Hernandez-Stefanoni et al., 2011). Hernandez-Stefanoni et al. (2011) tested remotely sensed data with regression kriging estimates for improving the accuracy of tree species richness maps, and concluded that this research will make a great step forward in conservation and management of highly diverse tropical forests.

8.6 Damage Assessment

The use of remote sensing in the detection of the effects of damaging agents on a forest precedes most other remote sensing forestry uses. Forset damage is defined as any type and intensity of an effect, on one or more trees, produced by an external agent, that temporarily or permanently reduces the financial value, or impairs or removes the biological ability of growth and reproduction. In the United States, insects and diseases account for a timber loss equal to our annual growth and this loss exceeds that from fire by seven times. Because the damaging agents are dynamic forces, entomologists and pathologists find that remote sensing techniques are most valuable when they are used at critical periods of stress. One damage causing agent may produce a number of damage syndromes conversely syndrome may have been caused by any number of agents.

8.6.1 Insects

Forest insects cause symptoms of tree and forest injury which are more easily recognized than those caused by forest diseases or air pollution. For example defoliators of coniferous or hardwood trees frequently cause the foliage to change color from a normal green-yellow to yellow or dark yellow-red. These changes are readily visible, occur over large areas, and can be mapped by direct observation. When many trees are attacked at one time and begin showing signs of stress by changes in foliage color, they can be differentiated from healthy trees by remote sensing methods.

8.6.2 Disease

Most visible symptoms of forest disease are evident only when the disease is far advanced in the host tree. As with insect damage, manifestations of disease show as discolorations and thinness of foliage. Oak was affected by fungus which occludes the water conducting tissues of oak. The symtoms show up as dying back of the top and discoloration of wilting oaks. Damages caused by cronartium ribicola Fischer on Pinus strobes are easy to detect on medium scale color and color infrared photos.

8.6.3 Deforestation

Since deforestation is a continuing process, efforts to inventory and monitor changes are very closely related. There are many uncertainties about actual rates of deforestation (Sader et al.1990), hence the need for accurate, up-to-date monitoring schemes. Techniques used to inventory these areas also can be applied in their systematic monitoring to create a time-serie sof data describing rates and magnitudes of deforestation. In Rondonia Brazil, for example, Landsat MSS (1980) and TM (1986) imagery were used to define the area and deforestation rates for a study area of approximately 30,000 square kilometers (Stone et al. 1991). The researchers found that 3168 square kilometers (528 squarekm/year) of new clearing occurred between 1980 and 1986. Earlier research (Woodwell et al.1987) had revealed a rate of clearing of 14 square km/year from 1972 - 1978 and 79 square km/year from 1978 - 1980. Historical records have also been used in GIS to identify changes in forest cover. Between 1979and 1984, a land resource inventory project was completed in the Jhikhu Khola watershed in Nepal (see Schreier et al. 1989). Land use information was digitized using 1:50,000 scale topographic maps as the base for information collected by surveying 1980. Land use data that had been divided into three broad categories in the original 1950 topographic map were also digitized. The area of each land use type was calculated in the GIS and then the two layers were subtracted. "Although somewhat crude, this information was found to be very useful in producing a land use change overview map" (Schreier et al. 1989). The thirty-year interval revealed that about 50 percent of the forestland has been lost to shrub and agriculture. A second three-year project was initiated in 1988 to "examine processes relating to soil erosion, sediment transport, soil fertility changes and land use changes in a quantitative way" in the Jhikhu Khola watershed (Schmidt and Schreier 1991). Forest and agricultural land uses were mapped and digitized using 1:20,000 scale and aerial photographs taken in 1972 and 1989. Changes in the area of four land uses were calculated for each date: forest, grassland, irrigated agriculture and sloping terraces. In this case, using a larger scale and a different land cover scheme, the researchers found that the forest area had not decreased substantially (only 1 percent) during these 17 years.

8.6.4 Forest Fires

Fire is one of the disasters causing threats to the forests and the ecosystem throughout the world. Fires have adverse effects on soil, forests and humans. During the process of burning, the soil nutrients are reduced and the soil is left bare making it more susceptible to both soil and water erosion. The forest cover is drastically reduced through the death of fire intolerant tree species. Fire also leads to an increase in green house gas emissions (Fig. 6). Air pollution due to smoke causes prolonged effects on human health such as respiratory and cardiovascular problems. Mongolia has a serious increase in forest fires.

Fig 5. Forest fire in California (sep,2008)

Source: https://en.wikipedia.org/wiki/Wildfire

Giglio et al. (2003) presented an enhanced contextual fire detection algorithm in order to identify smaller, cooler fires with a significantly lower false alarm rate, and promising results were obtained. Lentile et al. (2006) reviewed “current and potential remote sensing methods used to assess fire behavior and effects and ecological responses to fire”. Urban forest Jensen et al. (2003) investigated the relationship between urban forest leaf area index (LAI) and household energy usage in a mid-size city, and concluded that the increase of LAI resulted in the less energy usage. Zhang et al. (2007) applied remote sensing to map the distribution, classification and ecological significance of urban forest in Jinan city.