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Remote sensing: A tool for sustainable environment

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Abstract
Remote sensing is an important method of earth observation from out of space using satellites. Satellite sensors can constantly observe the earth's surface and with the development of remote sensing science, it has become an important mechanism to determine spatial and temporal land surface information quantitatively based on the principle of electromagnetic spectrum. It records the electromagnetic energy reflected or emitted by the earth's surface. The amount of radiation from an object (called radiance) is influenced by both the properties of the object and the radiation hitting the object (irradiance). High level remote sensing products are urgently needed to meet global changes and for many other applications. Generating these high level products is challenging, however and has become a hot research topic. Remote sensing imagery has many applications in mapping land-use and cover, agriculture, soils mapping, forestry, city planning, land degradation, archaeological investigations, military observation, land cover changes, deforestation, vegetation dynamics, water quality dynamics, droughts, floods, urban growth, forest fires, etc. This paper overview the use of remote sensing as tool to can get frequent and sustained information of the earth surface which can further utilized for the sustainability of the ecosystem services provided by the earth.

Keywords: Remote sensing, sustainability, environment health

Introduction

Global research poses significant challenges to the scientific community. Scientists have struggled with the challenges of data requirements for a decade or more and have identified the utility of satellite remote sensors as major sources of consistent, continuous data for many ecological services at a variety of spatial and temporal scales. So this satellite remote sensing technique can be an essential tool for the documentation of these environmental attributes and monitor physical and biological processes relevant to global scientific research.

Remote sensing has played a potential role atmospheric and ocean sciences communities. While in social sciences and human health, there is little involvement of this worthy technique. But has always played a significant role as in many areas such as "The use of satellites to monitor global transmission of microbes", Simmer and Volz (1993) [12] address the effects of atmospheric dispersion of disease on human health by discussing the use of satellite sensors for monitoring terrestrial and atmospheric parameters relevant to microbial spread and transmission. Similarly according to Epstein, Ford and Colwell (1993) [5] discussed the human health implications associated with the degradation of marine ecosystems due to pollution and global warming. Ultimately the main focus is to determine the integrated linkages between the scientific community and this very essential tool "Remote sensing" for welfare of ecosystem services, specifically organisms health.

Remote sensing is the science (and to some extent, art) of acquiring information about the earth's surface without actually being in contact with the objects or area under investigation. Information is acquired by measuring the interaction of electromagnetic radiation with the earth's surface which is usually stored as image data in the form of aerial photographs or satellite images (Pujar *et al.,* 2017) [11].

In much of remote sensing, the process involves an interaction between incident radiation and the targets of interest. This is exemplified by the use of imaging systems where the following seven elements are involved in remote sensing:

1. **Energy Source or Illumination (A):** The first requirement for remote sensing is to have an energy source which illuminates or provides electromagnetic energy to the target of interest.
2. **Radiation and the Atmosphere (B):** As the energy travels from its source to the target, it will come in contact and interact with the atmosphere it passes through. This interaction may take place a second time as the energy travels from the target to the sensor.

3. **Interaction with the Target (C):** Once the energy makes its way to the target through the atmosphere, it interacts with the target depending on the properties of both the target and the radiation.
4. **Recording of Energy by the Sensor (D):** After the energy has been scattered by, or emitted from the target, we require a sensor (remote - not in contact with the target) to collect and record the electromagnetic radiation.
5. **Transmission, Reception and Processing (E):** The energy recorded by the sensor has to be transmitted, often in electronic form, to a receiving and processing station where the data is processed into an image.
6. **Interpretation and Analysis (F):** The processed image is interpreted, visually and/or digitally or electronically, to extract information about the target which was illuminated.
7. **Application (G):** The final element of the remote sensing process is achieved when we apply the information we have been able to extract from the imagery about the target in order to better understand it, reveal some new information or assist in solving a particular problem.

Principle of Remote Sensing

In remote sensing, reflected energy from the object is recorded by remote sensors. The information about the object is obtained through the analysis of reflected rays. As mainly three energy interactions occur when electromagnetic energy falls on any surface feature i.e. reflection, absorption and transmittance (Navalgund and Kasturirangan, 1983) [10].

The interrelationship between these three energy interactions is given below:

$$E_I(\lambda) = E_R(\lambda) + E_A(\lambda) + E_T(\lambda)$$

Where E_I : Incident Energy
E_R : Reflected Energy
E_A : Absorbed Energy
E_T : Transmitted Energy

The proportions of energy reflected, absorbed and transmitted will vary for different earth features, depending on their material type and condition. Secondly, the proportion of reflected, absorbed and transmitted energy will vary at different wavelengths. Thus, two features may be indistinguishable in one spectral range and be very different in another wavelength band.

Function of Remote Sensing

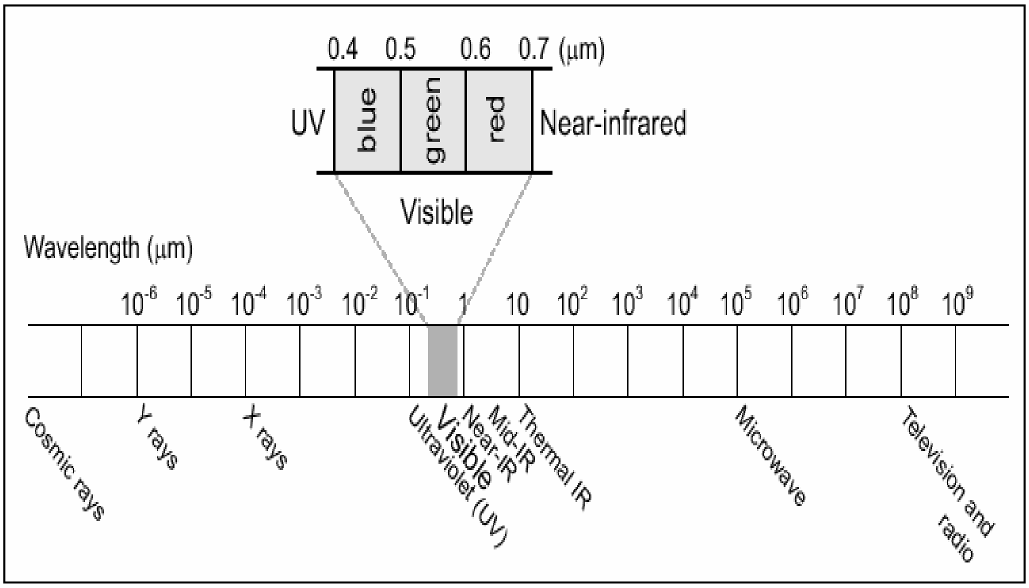
A Source of EMR

Before discussing the source of EMR used for Remote Sensing purpose, we should know what EMR or electro-magnetic radiation is the dynamic form of radiated energy that propagates as wave motion equal to the velocity of light. The EMR is classified into different types on the basis of their wavelength as follows:

Kind of waves in micron

Cosmic Rays	<.0000001
Gamma Rays	.0000001 to .0001
X-rays	.001 to .01
Ultraviolet Light	.01 to .4
Visible Light	.4 to .7
Infra-red Light	.7 to 1000
Microwaves	1000 to 10^6
Radiowaves more than	10^6

Out of these above types of EMR, Remote Sensing mostly uses the visible (0.4 to 0.7 microns), the reflected IR and thermal IR (.7 to 14 microns) and the microwave regions (1000 to 3000 microns).



Electromagnetic Spectrum

Remote Sensors

These are the device that receive electromagnetic radiation and converts it into signal that can be recorded or displaced as their numerical data or an image (Joseph, 1996) [6].

Classification of Sensors

Remote sensors can be classified in different ways as follows.

1. On the Basis of Source of Energy Used: On the basis of source of energy used by the sensors, they can be classified into two types – Active sensors and Passive sensors.

a. Active Sensors: Active sensors use their own source of energy and earth surface is illuminated by this energy. Then a part of this energy is reflected back which is received by the sensor to gather information about the earth's surface. When photographic camera uses its flash, it acts as an active sensor. Radar and laser altimeter are active sensors.

b. Passive Sensors: Passive sensors do not have their own source of energy. The earth surface is illuminated by sun/solar energy. The reflected solar energy from the earth surface or the emitted electromagnetic energy by the earth surface itself is received by the sensor. Photographic camera is a passive sensor when it is used in sun light, without using its flash.

2. On the Basis of Function of Sensors: On the basis of function of sensors, they are divided into two main types - Framing System and Scanning System.

a. Framing system: In framing system, two dimensional images are formed at one single instant. Here, a lens is used to gather the light which is passed through various filters and then focused on a flat photosensitive target.

b. Scanning System: In scanning system, a single detector / a number of detectors with specific field of view, is used which sweeps across a scene in a series of parallel lines and collect data for continuous cells to produce an image. Multi Spectral Scanner, Microwave Radiometer, Microwave Radar, Optical Scanners are few examples of scanning system sensors.

3. On the Basis of Technical Components of the System: On the basis of technical components of the system and the capability of the detection. These are: 1) Multispectral imaging sensor systems, 2) Thermal remote sensing systems, and 3) Microwave radar sensing systems. The multispectral or multiband imaging systems may use conventional type cameras or may use a combination of both cameras and scanners for various bands of electromagnetic energy.

Some known satellites used for remote sensing
1. GNSS: Global Navigation Satellite System
2. Landsat
3. SPOT (Satellite Pour I' Obervation de la Terre)
4. TRMM (Tropical Rainfall Measuring Mission)
5. GOES (Geostationary Operational Environmental Satellite): Known for forecasting our planet's weather.
6. NOAA (National Oceanic and Atmospheric Administration Satellite): Enable us to get complete views of weather and environmental conditions around the world each day.
7. Sentinel: Known to understand earth's climate.
8. SMOS (Soil Moisture and Oceanic Salinity): Enable us to enhance our knowledge of the land and ocean processes.
9. IKONOS
10. Quickbird
11. Resource SAT
12. Aqua: Multipurpose satellite taps into Earth's water cycle by measuring relative humidity, cloud height and energy flux.
13. DMC: Disaster Monitoring Constellation
14. POES (Polar-orbiting Operational Environmental Satellites): NOAA's polar orbiting meteorological satellite has taken some of the mystery out of atmospheric phenomenon with high spatial and temporal resolution images.
15. Geo Eye: Google's high-resolution imaging satellite is so sharp that ecologists have used it to track animal population.

Software's used in Remote Sensing
1. ILWIS (Integrated Land and Water Information System)
2. ArcGIS
3. ERDAS Imagine (1999)
4. ENVI
5. Geomatica, PCI Geomatics
6. IDRIS
7. Google Earth
8. GRASS GIS (Geographic Resources Analysis Support System)
9. ECognition
10. RemoteView
11. CLASLITE: Software designed specifically for images of forest.
12. OPTICKS
13. SAGA GIS
14. QGIS
15. INTEGRAPH

Applications of remote sensing
The use of satellite remotely sensed data for environmental monitoring has various advantages. Remote sensing provides a continuous monitoring and mapping, at both spatial and temporal scale. Therefore, the process of environmental decision making where environmental changes and impacts are being monitored at a regular basis can be enhanced by using remote sensing data and its various techniques at a great level (Cohen and Goward, 2004) [4].

Table 1: Application of Remote Sensing in Environmental Studies

Meteorology	Hydrology	Natural and Manmade Hazards	Landuse Planning	Environmental Studies
▪ Weather Forecast ▪ Climate studies ▪ Global change	▪ Water balance ▪ Energy balance ▪ Soil moisture ▪ Agro-hydrology ▪ Sea surface temperature	▪ Floods ▪ Tsunami ▪ Earthquakes ▪ Landslides Mapping and Risk ▪ Assessment ▪ Droughts ▪ Epidemic Mapping ▪ Forest Fires	▪ Landuse / land cover changes ▪ Urban planning ▪ Urban heat Islands ▪ Agriculture	▪ Sources/Effects pollution ▪ Water quality ▪ Climate change ▪ Environmental Impact Assessment
Soil Science	**Biology/Nature Conservation**	**Forestry**	**Atmospheric parameters**	**Agriculture Engineering**
▪ Land evaluation ▪ Soil mapping	▪ Vegetation mapping / monitoring ▪ Vegetation condition and assessment	▪ Forest inventorization ▪ Mapping of de-/re-forestation ▪ Forest fires detection	▪ Aerosol ▪ Fog ▪ Black Carbon ▪ Dust Storm ▪ Ozone and other trace gases	▪ Landuse development ▪ Erosion management ▪ Water management

Advantages of remote sensing technology

1. Remote sensing allows coverage of very large areas which enables regional surveys on a variety of themes and identification of extremely large features.
2. Remote sensing allows for easy collection of data over a variety of scales and resolutions.
3. A single image captured through remote sensing can be analyzed and interpreted for use in various applications and purposes. There is no limitation on the extent of information that can be gathered from a single remotely sensed image.
4. Remotely sensed data can easily be processed and analyzed fast by using a computer and the data utilized for various purposes.
5. Remote sensing allows for map revision at a small to medium scale which makes it a bit cheaper and faster.
6. Colour composite can be obtained or produced from three separate band images which ensure the details of the area are far much more defined than when only a single band image or aerial photograph is being reproduced.
7. It is easier to locate floods or forest fire that has spread over a large region which makes it easier to plan a rescue mission easily and fast.
8. Remote sensing is a relatively constructive method reconstructing a base map in the absence of detailed land survey methods.

Disadvantages of remote sensing

1. Remote sensing requires a special kind of training to analyze the images. It is therefore expensive in the long run to use remote sensing technology since extra training must be accorded to the users of the technology.
2. It is expensive to analyze repetitive photographs if there is need to analyze different aspects of the photography features.
3. It is humans who select what sensor needs to be used to collect the data, specify the resolution of the data and calibration of the sensor, select the platform that will carry the sensor and determine when the data will be collected. Due to which, there is introduction of human error in this kind of analysis.
4. Powerful active remote sensing systems such as radars that emit their own electromagnetic radiation can be interfering and affect the phenomenon being investigated.
5. The instruments used in remote sensing may sometimes be un-calibrated which may lead to false remote sensing data.
6. Sometimes different phenomena being analyzed may look the same during measurement which may lead to classification error.
7. The image being analyzed may sometimes be interfered by other phenomena that are not being measured and this should also be accounted for during analysis.

Role of remote sensing in land degradation mapping

Degraded land includes erosion by water and wind, stonied land, saline lands, alkaline lands, marshy lands and others. These different lands exhibit unique spectral reflectance in satellite image. The texture of satellite image is helpful in differentiating the land degradation with in a particular type. Hence mapping of land degradation involves many elements as many land degradation types occurs in one region (Agbu, 1994) [1].

Satellite remote sensing when combined with ground justification makes a potential means for land degradation monitoring. Capability of the remote sensing tool to survey land areas and good spatial-temporal resolutions are the major advantages of remote sensing technique compared to the land based surveys.

Land degradation mapping involves comparison of multi-seasonal satellite imageries. This is essential, as different land degradation exhibits different spectral signatures in different season. For example, saline lands are white and brighter in tone during summer, whereas its looks like soil colour in monsoon season. Minimum of three season imagery *viz.*, summer, monsoon and post monsoon is needed for this mapping. The interpretation is little more complex in this mapping. Initially the three season images are visually judged for changes in reflection pattern. The eroded lands give dull reflection in summer season. The rill erosion shows typical wavy texture in image. This is further confirmed by referring the contours in the toposheets (Codjoe, 2007) [4].

Land degradation mapping by SLUSI

Soil and Land Use Survey of India (SLUSI) under the Ministry of Agriculture, Govt. India has been using the remote sensing data to generate scientific information on degraded lands at district level, at 1:50,000 scale. A four-tier approach including the kind of degradation, severity of degradation, degradation under major land use and major landforms has been adopted by the SLUSI.

Multi-temporal images from the IRS LISS-II sensor have been used for the analysis. Classification of the satellite images has been attained using the standard procedures i.e., recognition, identification, analysis and inferences have been followed for mapping purposes. Further, a post classification approach of change detection has been adopted to identify the difference in the land characteristics over a time period and hence to identify the degraded land areas.

Role of remote sensing in soil resource inventory

Remote sensing is also widely used as a tool for preparing landform / physiographic maps which help in preparing soil resource maps as physiography and soils are known to be well related and the approach has been developed since 1970's. Remotely sensed data became an important tool in soil surveys at medium (1:100,000 to 1:250,000 scale) and small (1:250,000 to 1: l m scale). Recently, digital processing has been successfully applied in soil resource mapping, evaluation of crop condition, erosion processes, etc. In the present venture of preparing a charter of soil resources, the National Bureau of Soil Survey and Land Use Planning (NESS & LUP) initiated a enormous task of preparing soil resource maps of different states (on 1:250,000 scale) by undertaking visual interpretations of the remotely sensed data. A 370-sheets soil resource map (SRM) of India (state-wise) were prepared and databases about each mapped unit generated for use by different organisations. The basic mapping unit is the "association of soil families" which is most important category determining plant growth.

The soil maps are required on different scales varying from 1:1 million to 1:4000 to meet the requirements of planning at various scales. Though conventional surveys provided information related to soils for their subjective, time consuming and laborious nature. Remote sensing techniques have reduced field work to a considerable extent and soil boundaries are more precisely delineated than in conventional methods. Soil mapping using remote sensing technique needs identification of number of elements such as land type, vegetation, land use, slope, elevation, relief which control soil variability. Numbers of studies have been carried out in India on multi-scales (small, medium and large) soil mapping in different soils following visual interpretation of various satellite data.

Role of remote sensing in landuse / land cover mapping

Land use refers to the purpose the land serves, for example, recreation, wildlife habitat or agriculture. Land use applications involve both baseline mapping and subsequent monitoring, since timely information is required to know what current quantity of land is in what type of use and to identify the land use changes from year to year.

Land cover refers to the surface cover on the ground, whether vegetation, urban infrastructure, water, bare soil or other. Identifying, delineating and mapping land cover is important for global monitoring studies, resource management and planning activities. Identification of land cover establishes the baseline from which monitoring activities (change detection) can be performed and provides the ground cover information for baseline thematic maps.

Land use applications of remote sensing include the following

- Natural resource management
- Wildlife habitat protection
- Baseline mapping for GIS input
- Urban expansion / encroachment
- Routing and logistics planning for seismic / exploration / resource extraction activities
- Damage delineation (tornadoes, flooding, volcanic, seismic, fire)
- Legal boundaries for tax and property evaluation
- Target detection - identification of landing strips, roads, clearings, bridges, land/water interface

Land Use Change (Rural / Urban)

As the Earth's population increases and national economies continue to move away from agriculture based systems, cities will grow and spread. The urban sprawl often infringes upon viable agricultural or productive forest land, neither of which can resist nor deflect the overwhelming momentum of urbanization. City growth is an indicator of development and generally has a negative impact on the environmental health of a region.

With multi-temporal analyses, remote sensing gives a unique perspective of how cities evolve. The key element for mapping rural to urban landuse change is the ability to discriminate between rural use (farming, pasture forests) and urban use (residential, commercial and recreational). Remote sensing methods can be employed to classify types of land use in a practical, economical and repetitive fashion, over large areas.

Role of remote sensing in assessment of change in forest cover

The change in forest cover and area is assessed by comparing two sets of satellite data taken from particular area in two time interval. Forest cover change assessment is usually carried out once in 5 or 10 year. Initially both satellite imageries are subjected to forest cover mapping process. Then the two maps obtained are overlaid to identify the changes happened. It will clearly indicate the increase or decrease of forest area in a particular region. The change analysis study is helpful in locating the vulnerable areas where extensive deforestation occurs. Accordingly management measures are diverted to these regions.

Few precautions are necessary in this study. The scale of satellite imagery and its resolution is most important. Both imageries should be of same scale and resolution. Otherwise errors will happen in image interpretation and area calculation. Usually coarser resolution imageries lead to over estimation of forest areas.

Role of remote sensing in habitat evaluation

Habitat is the sum total of environmental conditions of a specific place occupied by a wildlife species. Each species have specific habitat requirements, which can be described by habitat factors. Habitat elements include vegetation, terrain, altitude, soil, weather and other biotic factors. Habitat management is the most crucial concern in protected areas. The habitat assessment and evaluation should be based on sound ecological principles and reliable techniques considering all relevant criteria.

Habitat analysis is important for introduction, rehabilitation and ex-situ conservation of species and their habitat. Habitat models relates animal and its environment and are mostly animal centric. Multi criteria analysis facilitates selection of site, land suitability analysis, resource evaluation, land allocation and making fine management plans.

Role of remote sensing in drought studies

The detection, monitoring and mitigation of disasters require gathering of rapid and continuous relevant information that is not effectively collected by traditional methods, but remote sensing technique make it possible to obtain and distribute continuous information rapidly over large areas by means of sensors operating in several spectral bands, mounted on aircraft or satellites. A satellite, which orbits the Earth, is able to explore the whole surface in a very less time and repeat the survey of the same area at regular intervals. The spectral bands used by these sensors cover the whole range between visible and microwaves. The remote sensing monitoring of drought can get frequent and sustained information on the surface characteristics of planar with full using information of ground surface spectrum of time, space and direction. It can provide macro, dynamic and real-time monitor data sources of drought. For the last three decades, advancements in the fields remote sensing have greatly facilitated the operation of drought risk assessment. Most data required for drought risk assessment have a spatial component and also change over time.

Traditional methods of drought assessment and monitoring rely on rainfall data, which are limited in the region, often inaccurate and most importantly, difficult to obtain in near-real time. In contrast, the satellite sensed data is consistently available and can be used to detect the onset of drought, its duration and magnitude. Even crop yields can be predicted 5 to 13 weeks prior to harvests using remote sensing technique. Vegetative conditions over the world are reported occasionally by National Environmental Satellite Data and Information System (NESDIS) using the Advanced Very High Resolution Radiometer (AVHRR) data.

Therefore, the use of remote sensing has become essential. It is evident that remote sensing has a great role to play in drought risk assessment because natural hazards are multi-dimensional. The main advantage of using remote sensing for drought risk assessment is that it not only generates a visualization of hazard but also relates potential to further analyze this product to estimate probable damage due to drought hazard (Melesse *et al.,* 2007) [8].

Role of remote sensing in tsunami hazard mapping

Tsunami causes huge human losses and damages extensively. Prevention of tsunami is not possible and hence preparedness is more useful. In this line, tsunami hazard mapping is getting more important now a day. Remote sensing data is more useful in providing essential data for tsunami hazard mapping (Melesse, 2004) [9].

Elevation data of higher resolution is needed for tsunami hazard mapping. Digital Elevation Model (DEM) of Shuttle Radar Topographic Mission (SRTM) is one such data is useful for this purpose. The base map of the area is prepared initially. The toposheets is used to demarcate different landform in the coastal land. Within a coastal landform, strip of land covering 2 km distance from the sea along the coastal line is considered for tsunami hazard mapping.

Role of remote sensing in flood risk mapping

Floods are a natural phenomenon. Floods of varying intensity have been occurring in all the flood plains since time immemorial. However, the ever increasing occupation of the floods results in huge loss of life and damages. There is no simple or fool-proof solution to the problem. Various measures or a combination thereof, have to be adopted depending on the situation. Satellite Remote Sensing technique has emerged as a powerful tool to deal with various aspects of flood management i.e. prevention, preparedness and relief management of flood disaster. Also, extensive use of this technique has great prospect in creating long term database on flood occurrence, risk assessment and relief management.

Flood prone maps show the extent of the areas liable to inundation at the time of flood. DEM data provided by NASA’s Shuttle Radar Topographic Mission (SRTM) is useful for this study. Dike failure or bank breach is considered as major cause of flood in rivers and its channel. Hence, considering elevation, landform and other local factors, the location of dike failure is marked. Now we have to assume the possible flood height for this point. This assumption should be based on the maximum rainfall possibility in that region. Theoretically all lands below this specified flood heights are liable to flood if it is continuously present from the failure point.

Role of remote sensing in forest fire mapping

Forest fire is the regular event year after year. Hence it needs frequent monitoring for restoring the fire damaged forest region. The easily available frequent remote sensing data is useful in mapping of forest fire. Forest fire usually occurs during dry summer months (April to May). The fire burnt areas look black due to ash deposition in soil. This reduces reflection pattern drastically. This helps identification of fire burnt areas easily inside the forest. Contrary to this, in monsoon season trees are full of leaves and greener in colour. In summer season most of the tree species shed their leaves and becomes leafless. Thus the colour of aerial view of forest is changed. In addition the canopy texture becomes coarse due to leaflessness. This also creates sudden change in colour of forest imageries. Hence, differentiation of fire burnt areas and this deciduous forest is important.

The above principle is applied for detecting the fire burnt area. For this purpose satellite imagery of monsoon and summer season is utilized. Initially the two images are visually compared for drastic reduction in reflection pattern for the particular forest. The regions having drastic reuction in reflection are demarcated. Dry deciduous forest also gives reduction in reflection pattern as it is leafless during summer. So these regions are deleted from the previous demarcation. The remaining areas usually fall under forest fire. This is verified in ground on sample basis and final forest fire map is prepared. Satellite imageries such as Landsat-MSS, MODIS AND AVHRR are useful for forest fire mapping purposes.

Forest fire risk assessment

The satellite images on 1: 50,000 scale is visually interpreted to obtain different map layers *viz.,* forest cover type, forest density, etc. The contour map, road network, settlement etc. have been extracted from toposheets. These layers are converted into index map *viz.,* fuel type index, slope index, aspect index and the distance/accessibility index. Then weightage is assigned to different factors based on its relevance to forest fire. Fuel type gets maximum weightage, followed by aspects and others. All these weightage is summed up together by using weighted overlay analysis. Finally, fire risk is assigned based on the cumulative index value. The fire risk map is verified through ground truth verification in selected strips. Based on this, corrections will be made and final fire risk map is depicted either in gradation of single colour or by various colour.

One fire risk model is given below:

Fire Risk Index (FRI): $FI \times 4 + AI \times 3 + SI \times 2 + AI + EI \times 1$

Where FI, AI, SI, AI and EI are the fuel type, aspect index, slope index, accessibility index and elevation index.

Conclusion

Remote sensing is a valuable tool for frequent monitoring and gathering information concerning the environment services at high spatial resolution which allow site specific economically favourable management strategies. Helps in reducing monitoring costs, enhances resource use efficiency and gives accurate information about earth’s surface including its components like forests, landscape, water resources, etc; which will help the scientists and researchers to gain information for their research activities about the environment services concerning its sustainable management and conservation.

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